CANADA

DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER; R. W. BROCK, DEPUTY MINISTER.

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR.

Petroleum and Natural Gas Resources of Canada

IN TWO VOLUMES

VOL. I.

TECHNOLOGY AND EXPLOITATION

BY

Frederick G. Clapp,
and Others

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PREFACE.

Arrangements were made with Mr. F. G. Clapp, of Pittsburgh, Pa., in April, 1912, to prepare this monograph on Petroleum and Natural Gas with special reference to Canada. It was proposed that the monograph should contain a general summary of all the information that was available with respect to the present or prospective Petroleum or Natural Gas fields in all the provinces of the Dominion. In addition, chapters on special subjects, such as the Technology of the Natural Hydrocarbons; Methods of Prospecting for Oil and Gas; Drilling Equipment; Development of Petroleum and Natural Gas fields; and related matters, were to be included in the monograph.

Mr. Clapp, and his assistant—Mr. L. G. Huntley—each spent about three months during the seasons of 1912 and 1913 on field work in connexion with this report. In November, 1913, before the manuscript was complete, Mr. Clapp accepted private contracts which necessitated his leaving for China. With the consent of the Director of the Mines Branch, he made personal arrangements with certain gentlemen, named below, to prepare special chapters of this report. He also arranged with Dr. David T. Day, of the United States Geological Survey, to assemble the whole report, and to forward it to this office when completed.

Under the arrangements made by Mr. Clapp, the following gentlemen have contributed chapters or sections of this report:—

1. Marius R. Campbell, of the United States Geological Survey, chapter IV, vol. I, on Theories as to the Origin of Petroleum and Natural Gas and their Migration in the Rocks of the Earth's Crust.

2. James H. Gardner, Lexington, Ky., contributed the sections of chapter VI, vol. I, dealing with the Surface Indications Useful in Exploration for Petroleum and Natural Gas.

3. Ralph Arnold and V. R. Garfias contributed the sections of chapter VI, vol. I, dealing with the subject of Casing of Oil Wells and the Exclusion of Water from Oil Wells.

4. Forrest M. Towl contributed chapter VIII, vol. I, on the Transportation of Oil and Gas.

5. T. T. Gray contributed chapter IX, vol. I, on the Utilization of Petroleum and Its Products.

6. Roswell H. Johnson contributed the sections in chapter X, vol. I, discussing Efficiency in the Extraction of Oil and Gas.

7. Mr. L. G. Huntley was associated with Mr. Clapp in much of the field work and is largely responsible for work in Ontario and on the lower Athabaska river. He also assisted in much of the office work.

The completed report was assembled by Dr. David T. Day in Washington, and reached this office in December, 1913. An examination of the text by several qualified officers of this Department indicated that there were a number of places where changes and corrections in matters relating to Canadian geology and geography were desirable. Since Mr. Clapp was absent in China, to return the report was impossible, as there is a pressing need for its publication, and the return would have involved too great a delay. The only alternative seemed to be to place the revision in the hands of a qualified engineer within the Department, and accordingly, Dr. Alfred W. G. Wilson, of the Mines Branch staff, was assigned the task of making whatever revision seemed necessary.

Dr. Wilson was placed in entire charge of the report, and in addition to the revision mentioned below, has supervised the preparation and assembling for publication of all the maps, sections, and drawings, which accompany this report. All the introductory sections in chapter V which deal with the geology of the various provinces have been revised and most of them have been re-written. Such changes as were necessary in matters of geological nomenclature, and Canadian geography, have also been made in the text. No changes, beyond minor editorial corrections, have been made in any of the chapters dealing with theories, or the technology of the subject. The geological nomenclature has been made to conform with that of the Canadian Geological Survey; while the geographic names and boundaries are those having official sanction. Three geological maps have been reprinted by the Geological Survey branch of the Department, for issue with this report. The three other maps which accompany it were compiled by the Chief Draughtsman of the Mines Branch—under the general supervision of Dr. Wilson—from data obtained from publications of the Geological Survey, and other sources, also from data supplied from Mr. Clapp's office. The numerous plates showing well logs were compiled in Mr. Clapp's office from various sources, and were transmitted to this office in the form of blue prints. These have all been re-drawn as accurately as possible; but the original geological nomenclature has been retained, because, in the majority of cases, it is that which was used on many of the original sections prepared by officers of the Geological Survey and others many years ago. In the text, however, particularly with reference to the geology of the Ontario peninsula, the nomenclature used is that officially adopted by the Geological Survey, on the basis of recent work by officers of the Survey, and others. The principal changes, so far as nomenclature is concerned, are the use of Beekmantown instead of Calciferous; Lorraine for Hudson River; and Onondaga for the Corniferous of the older geologists, together with the recognition of the occurrence of the Munroe formation above the Salina.

Since it has been impossible to submit the revised portions of the text to Mr. Clapp, before publication, all essential changes or additions which have been made by Dr. Wilson, or under his supervision, have been signed by him, or have been indicated by footnotes. All the proofs have also been read by Dr. Wilson as well as by the staff of the editor's division of the Department of Mines.

It has been found necessary to publish this report in two volumes, the first being devoted chiefly to the technology of petroleum and natural gas and to the methods of exploitation, the second dealing with the occurrences of petroleum and natural gas throughout the provinces of Canada. This latter volume is further divided, for convenience of distribution, into Part I. Eastern Canada, and Part II, Western Canada.

(*Signed*) **Eugene Haanel,**
Director Mines Branch,
Department of Mines.

Ottawa, Aug. 1, 1914.

Letter of Transmittal.

Dr. Eugene Haanel,
Director Mines Branch,
Department of Mines,
Ottawa,
Canada.

Sir,—I have the honour to transmit, herewith, the manuscript—consisting of text and illustrations—of a report on the Petroleum and Natural Gas Resources of Canada, to be published by the Mines Branch. This is a broad discussion, prepared during the past few months, of the subject as it pertains to the Dominion as a whole, with such general chapters added as are important to give a general understanding of the Petroleum and Natural Gas industry, and of its various phases. The report is not intended to enter into exhaustive discussions of individual fields, or to solve all the complicated problems regarding petroleum and natural gas in various parts of the Dominion, since such an undertaking would be a matter of years of study and work, but as much detail is included as has been possible in the time allotted, I trust that the publication may be of some value in the development of the Dominion's resources.

Very respectfully,

(*Signed*) **Frederick G. Clapp.**

Pittsburgh, Pa., U.S.A., March 1, 1914.

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TABLES.

ILLUSTRATIONS

Photographs.

Drawings.

Note.—The author is indebted to his students, Mr. G. W. Meyers for figures 16, 18, 19, and 20; Mr. F. A. Johnson for figure 17; and Mr. W. E. Bernard for figures 21, 22, 23, and 24, which are taken from their note-books in the Oil and Gas Laboratory of the University of Pittsburgh.

Map

Petroleum and Natural Gas Resources of Canada
Vol. I.

ERRATA

On page 136 is a copy of *The Petroleum Bounty Act, 1904:* this should have been supplemented by the amending Act assented to 4th May, 1910; which specifically defines the conditions controlling the bounty on the production of crude petroleum, not only from wells, but also from "shales and other substances" mined in Canada.

A copy of The Petroleum Bounty Act, 1909, will be found as an appendix to Volume II, p. 367.

On page	iii—line	18	from	bottom,	read	Monroe, not "Munroe."
"	v— "	6	"	" ,	"	period, " "comma."
"	ix— "	5	"	" ,	"	Geanticlinal, not "Geoanticlinal."
"	5— "	8	"	" ,	"	Petrolia, not "Petrolea."
"	63— "	8	"	" ,	"	ethane, not "ephane."
"	72— "	6	"	" ,	"	hydrolyzed, not "hycrolyzed."
"	94— "	8	"	" ,	"	geanticlinal, not "geoanticlinal."
"	100— "	3	"	" ,	"	" " "
"	100— "	2	"	" ,	"	geanticline, " "geoanticline."
"	104—Figure 7 is inverted.					
"	106—line	1	from	bottom,	read	artificially, " "artifically."
"	109— "	5	"	" ,	"	trachyte, not "trachite."
"	111— "	6	"	top ,	"	carburetted, not "carburretted."
"	133— "	9	"	bottom,	"	two, not "three years."
"	181— "	15	"	top ,	"	gauge, not "guage."
"	269— "	4	"	bottom,	"	Mariotte's, not "Mariott's."
"	286— "	15	"	" ,	"	Jan. 25th., not "15th."
"	286— "	13	"	" ,	"	1903, not "1893"
"	287— "	17	"	" ,	"	£3 not "£1 3s."
"	291— "	12	"	top,	"	reverberatories, not "reverboratories."
"	339— "	6	"	" ,	"	integration, not "intergration."
"	340— "	3	"	bottom,	"	carbureter, not "carboreter."
"	342— "	16	"	" ,	"	mantle, not "mantel."
"	346— "	7	"	top ,	"	Abitibi, not "Abittibi."
"	357— "	1	"	bottom,	"	Vermilion, not "Vermillion."
"	359— "	10	"	top,	"	" " "
"	364— "	6	"	" ,	"	hydrocarbon, not "hydrocarbons."
"	372— "	10	"	bottom,	"	mantle, not "mantel."
"	375— "	26	"	" ,	"	Herzegovina, not "Herzegovnia."

PETROLEUM AND NATURAL GAS RESOURCES OF CANADA

IN TWO VOLUMES

VOL. I.

HISTORY, GEOLOGICAL OCCURRENCE, TECHNOLOGY, AND EXPLOITATION

PETROLEUM AND NATURAL GAS RESOURCES OF CANADA.

VOL I.

CHAPTER I.

HISTORY AND DISTRIBUTION OF PETROLEUM AND NATURAL GAS.

INTRODUCTION.

IMPORTANCE OF PETROLEUM AND NATURAL GAS.

Petroleum is the most important of the bitumens, and, next to coal, the most important of all carbon compounds. Although the first commercial development of significance took place barely half a century ago, the production has increased by tremendous strides until to-day the output has reached enormous proportions. There is no sea whose waters are not churned by the propellers of oil-burning steamships, no country whose roads have not seen the petrol-driven motor car, and no village in the civilized world in which the flame of kerosene or other form of petroleum does not illuminate some house. Thousands of miles of highways are kept free from dust or otherwise improved by the use of petroleum oil.

Wherever petroleum occurs in nature, there also, as a rule, natural gas is likewise found. But gas is less restricted in distribution than oil, and hundreds if not thousands of good gas wells are found where no petroleum occurs. Although its physical character makes it somewhat inadapted to transportation and limits to a certain extent the range of its use, it is, nevertheless, conducted by a vast number of pipe-lines—some of which are hundreds of miles in length—to a great number of towns and cities, as well as to numerous glass and iron works and scores of other classes of industrial plants. It furnishes the cheapest and most convenient fuel and illuminant to many thousands of people in the different countries in which it occurs.

Both petroleum and natural gas are among the great industrial resources of the world and the countries possessing them in large quantities are fortunate indeed. The fact that they have not yet been developed in a locality is rarely a proof of their absence. No year passes without the discovery of some new and often unsuspected field. No stratified rock is so young, and scarcely any so old that the occurrence of oil in it is impossible.

The production of petroleum has advanced steadily in recent years, even in long settled regions, and there is no reason to believe that the maximum output has been reached. The new fields that are discovered each year and the old fields which are extended into new territory more than counterbalance, up to the present time, the losses due to exhaustion of older territory. Any country in which the geological conditions are favourable is, therefore, warranted in exerting every effort to investigate and determine its resources in petroleum and natural gas.

FORMS OF BITUMENS.

Petroleum (from the Latin meaning rock-oil) is the best known of the various natural hydrocarbons of the bitumen series. It is the *erdöl* or *steinöl* of the Germans and the *pétrole* of the French and other nations of southern Europe. The relation of petroleum and natural gas to allied bitumens is indicated in the following classification:—

Classification of Bitumens.

NAMES.

FORM	English	German	French	Spanish
Solid	Asphaltum	Asphalt Erdharz	Asphalte	Brea Chapapote
Semi-fluid	Maltha		Goudron minéral	Brea
Fluid	Petroleum Naphtha	Erdöl or Steinöl	Pétrole	Aciete
Gaseous	Natural gas	Natur gas	Gaz natural	Gas natural

EARLY KNOWLEDGE OF THE BITUMENS.

The bitumens were not only known but were probably fairly familiar to mankind before the beginning of the historic period. "The vale of Siddim was full of slime pits" (Genesis, XIV, 10). "Slime had they for mortar" (Genesis, IX, 3) in the building of the tower of Babel. "Oil out of the flinty rock" is mentioned in Deut., XXXII, 13, and in Job, XXIX, 6, "the rock poured me out rivers of oil."

Maccabees, II, 18-22, gives an account of the hiding of the fires from the altar in a deep pit with water by the Priests of the Sun, where, when Nehemiah was sent to investigate in later years, "they found no fire, but thick water." On placing this upon sacrifices and wood on the altar, the sun appeared from behind a cloud and "there was a great fire kindled, so that every man marvelled."

The pits dug for the collection of the oil were called by the Jews *nephtar* or *nephtoj* (nafta of the Persians), from which is derived the word naphtha of to-day.

Bitumen was used in ancient Nineveh and Babylon to cement the bricks and tiles of the temples, and in their grand mosiac pavements, the material probably coming from the Springs of Hit on the Euphrates. These later became famous as the springs of Oyum Hit or Fountains of Hit of the Arabs or the Cheshmeh Kir or Fountains of Pitch of the Persians. To the Turks the pitch was known as Hara saker.

Another important use of the bitumen or pitch in early times was in making tight the seams of vessels. Noah was commanded (Genesis, VI, 14): "Make thee an ark of gopher wood, rooms shalt thou make in the ark, and shalt pitch it within and without." Its use in boats on the Euphrates and in Egypt continues to this day.

Semi-fluid bitumen was also used by the ancients for lining cisterns and granaries, as is indicated by ruins still existing in Mesopotamia, Syria, and Egypt. In the latter country, bitumen was also extensively used in embalming, and to it we owe to a considerable extent the high state of preservation of the mummies.

At a very early period the Persians made pilgrimages to the "fire-temple" at Baku, the flames in which were fed with petroleum and natural gas from the vicinity. Practically down to the present day, it has been similarly visited by the followers of Zoroaster in India. A similar temple, known as Jawalàmŭhki, is said to exist near Kangra in the Punjab.

A more practical use of petroleum by the Persians was for domestic purposes. Long strips of dried dung were dipped in the oil and burned both for illumination and for heating and cooking. Special chimneys were required to remove the intolerable fumes. A light coloured, transparent oil was used for medicinal purposes (Ritter, Erdkunde, II, 578).

The manner of collecting the petroleum at the close of the fifth century before Christ is thus described by Heroditus, a contemporary Greek historian:—

At Ardericca is a well which produces three different substances, for asphalt, salt, and oil are drawn up from it in the following manner: It is pumped up by means of a sweep, and, instead of a bucket, half a wine skin is attached to it. Having dipped down with this, a man draws it up, and then pours the contents into a reservoir, and being poured from this into another, it assumes three different forms; the asphalt and the salt immediately become solid, but the oil they collect . . . It is black and emits a strong odor.

Another reference to the knowledge of petroleum by the ancients is found in Sir Thomas North's translation of Plutarch's Lives (1631, p. 702), where there is reprinted a tradition of a Macedonian in charge of Alexander's effects in the wars of the fourth century before Christ, who dug for water on the banks of the Oxus. "There came out, which differed nothing from natural oile, having the glosse and fatness so like there could be discovered no difference between them."

Plutarch also described the strong impression made upon Alexander when in the district of Ecbatana (Kerkuk) he looked on a "gulf of fire, which streamed continually as from an inexhaustible source. He admired also a flood of naphtha not far from the gulf, which flowed in such abundance that it formed a lake. The naphtha in many respects resembles the bitumen, but it is much more inflammable. Before any fire reaches it, it catches fire from a flame at some distance, and often kindles all the immediate air. The barbarians, to show the king its force and the subtilty of its nature, scattered some drops of it in the street that led to his lodgings, and standing at one end applied their torches to some of the first drops, for it was night. The flame communicated itself quicker than thought, and the street was instantly all on fire."

In the days of the Roman Empire the occurrence of both semi-fluid and liquid bitumen were well-known. The Greek historian Dioscorides Pedanius described the use of petroleum in lamps before the birth of Christ, and Pliny mentions the use of oil for lighting in Agrigentum in Sicily. Stabo writing in the same period, describes the rise of pitchy substances to the surface of the waters of the Dead Sea, where they formed floating masses resembling islands.

The same writer (Strabo) also refers to asphalt deposits near Selenitza, which are to-day still unexhausted.

In the confusion attending the later days of the Roman Empire, and accompanying the rise of Mohammedanism, comparatively little was written of petroleum by Europeans, although the oil pits and springs of the Caspian region and of Persia were well known to the Arabs. Many of the travellers to India in the days before the development of the Cape of Good Hope route, however, brought back accounts of the oil or pitch encountered in the overland journey. Of these, the best known is that by Marco Polo, who travelled extensively in the region in the thirteenth century. To him we are indebted for an account of one of the early conflagrations of oil upon the surface of the ground near Baku, of streams of flaming oil, and of great explosions of natural gas.

The nature of the geographical names of many localities shows more clearly even than the references in literature the general prevalence of the bitumens. Besides the well known Oil City and Petrolea of America, there are several Pitchfords in England. In Germany, Pitchelbronn near Hagenau is named for pitch. Neft and Neftiano, referring to oil, are similarly used in Russia, while the Spanish colonial names Brea, La Brea, and Breaita again refer to pitch. In Persia, Kir (pitch) is used as a part of many place names, and in Burma, Yenang (earth oil creek) is the root of Yenangyaung and Yenangyat (earth oil place), the names of important oil districts.

FOREIGN DEVELOPMENTS OF PETROLEUM AND NATURAL GAS.

So general is the distribution of petroleum and natural gas that comparatively few countries are entirely lacking in signs of their existence. Such indications have long been known to the inhabitants in their vicinity and many references to them are found in literature. Petroleum, because of the more conspicuous character of its "shows" and its greater ease of utilization, has more frequently attracted attention than has natural gas, and search for it has been more vigorous.

Since the introduction of modern methods of drilling, about 1860, prospecting has been conducted in almost every part of the world, and although much of it has been misdirected, petroleum in paying quantities has been developed in scores of places, including localities in every continent, in the East and West Indies, and Oceania. Natural gas is of even more widespread occurrence, but owing to the lack of available markets in the vicinity of many of the fields, has been comparatively neglected outside of America. Here, however, its production is an industry of very great importance.

In the following summary of the petroleum and natural gas industries in foreign countries the number of scattering references made use of is so great as to make it impracticable to quote all authorities. The chief sources of information are the report of S. F. Peckham on "The Production, Technology, and Uses of Petroleum and its Products," in volume 10 of the 10th Census of the United States, pp. 1-319; "Petroleum, its History, etc.," translated from the German of Wilhelm T. Brannt, 1895, 715 pp.; "Petroleum," by Boverton Redwood, 1896, 2 vols.; "Petroleum Mining and Oil Field Development," by Arthur Beebe Thompson, London, 1910, 362 pp.; and the annual statistical reports in the Mineral Resources series of the U. S. Geological Survey, by S. H. Shotwell, Joseph D. Weeks, F. H. Oliphant, W. T. Griswold, and David T. Day.

Europe.

GREAT BRITAIN.

As early as 1667 Thomas Shirley described (Phil. Trans., II, 482) gas from a spring near Wigan, in Lancashire, some of which he successfully collected and burned. In 1739 Rev. John Clayton described (Phil. Trans., XLI, 59) a ditch in the same locality, "the water in which would seemingly burn like brandy, the flame being so fierce that several strangers boiled eggs over it." Noticing coal in the vicinity, he distilled considerable gas from it. This is apparently the pioneer attempt at distillation and was the forerunner of the commercial processes of to-day.

In 1864, naphtha or liquid bitumen was described as collecting on the surface of the water of a spring near Pitchford, in Shropshire, by Dr. Plot (Phil. Trans., XIV, 806). The petroleum of this locality later became well known and was used for medicinal purposes.

In later years petroleum has been reported from numerous other localities. In Scotland, petroleum is reported from Orkney mainland, from the Carboniferous at Dysart (Fife), Broxburn (Linlithgowshire), and Liberton (Edinburgshire). In Wales, it has been noted in the Permian, at Ruabon (Denbighshire).

In England, the greater part of the petroleum indications have been found in the Coal Measures, or limestones of the Carboniferous. The localities include Whitehaven (Cumberland), Clowne and Alfreton (Derbyshire), Worsley (Lancashire), Langton (North Staffordshire), and Coalbrookdale, Coalport, and Pitchford (Shropshire). From 70 to 100 gallons a day are pumped with the water from a depth of 960 feet in the Southgate colliery, Clowne. Other petroleum bearing formations are the Upper Devonian shales at Barnstaple (North Devonshire), and the Liassic in the Bristol district (Gloucestershire-Somersetshire). At Ashwick (Somersetshire) several barrels of petroleum entered a well following a slight earthquake in 1892.

Notwithstanding the general distribution of petroleum indications, oil has not yet been discovered in commercial quantities at any point in Great Britain. The $5,000,000 worth of petroleum produced annually all comes from the distillation of bituminous shales, the greater part coming from Scotland, with a little from Wales, but practically nothing from England.

Natural gas has been reported from the Weald clays, near Petworth, West Sussex, from mines in the Lower Silurian in Montgomeryshire, and from the Triassic salt beds of Cheshire. Sufficient quantities to cause an explosion were encountered in the construction of the Thames tunnel. In 1893 considerable amounts were struck in a well in the Jurassic at Heathfield, and in 1896 the South Coast Railway Company secured in the same locality a larger supply under a pressure of 150 pounds per square inch, from a depth of 377 feet. This is utilized for illuminating and heating purposes at a rate of 1000 cubic feet daily. Later wells have secured still larger quantities, most of which are utilized.

NORWAY AND SWEDEN.

No petroleum or natural gas in appreciable quantities is known in Norway. In Sweden natural gas is of somewhat widespread occurrence at a number of horizons, especially in Silurian, Liassic, and Miocene rocks, but the volume is usually small. Petroleum indications are less common, but oil-filled fossil cavities have long been known in the Silurian, and led in 1867-1869 to the sinking of several borings on the flanks of Mt. Osmund, of Delarne, 35 miles north of Falun. Although drilling was carried to 900 feet, only traces of oil were found. Later drilling at Nullaberg and elsewhere has been equally unsuccessful. Petroleum resulting from the decomposition of sea weed is found in small quantities along the coast near Lund.

NETHERLANDS AND BELGIUM.

Practically no indications of petroleum have been noted in the Netherlands, although an oily liquid is reported from a well in chalk near Maestricht. In Belgium, traces of petroleum are found at a number of points in the coal fields, especially in iron concretions and in fossil cavities. Oil shows are also reported in the Eocene (?) at Bourlers, near Chimai, and in the Liassic shales of Jamoigne.

FRANCE.

Indications of oil, gas, or other bitumens have long been known in France. The natural gas of the "burning fountain," at La Gua, near Grenoble, Department of Isère, was described as early as 1618. At this date, or even earlier, petroleum was collected from the surface of a spring at Gabian, Department of Hérault, on the Gulf of Lyons, and used for medicinal purposes. A recent boring sunk to a depth of 1350 feet at this point in the Miocene or Triassic beds was, however, without result. Small oil seeps are reported from grey Miocene marls, limestones, and sandstones at depths of from 125 to 425 feet at Clermont-Ferrand, Puy de la Poix, Malintrat and Coeur in the plain of Limagne, Puy de Dôme, between the ranges of Puy de Dôme and Forests in southeastern France, and at Châtillon on the flanks of the Alps in Savoy. A deep boring at Macholle, near Riom, found, in 1896, a few gallons of oil mixed with brine at a depth of nearly 3500 feet. Other borings have been equally unsuccessful.

SWITZERLAND.

Traces of petroleum have been found in the bituminous Miocene limestones near Mathod, Orbe, and Chavornay, Vaud, while natural gas has been encountered in the Liassic rock salt of Bex and at Montreux, Vaud.

SPAIN AND PORTUGAL.

Petroleum indications are apparently limited in Portugal to certain calcitic amygdules in basalt at Sicario, near Cintra. In Spain, on the other hand, surface indications are found at a number of points, and small quantities have been collected in tunnels at Huidsbro, 30 miles north of Burgos. Although wells were drilled to a depth of over 1500 feet, only traces of oil were encountered. A few gallons were found in a mine shaft in the Eocene shales at Conil near Cadiz, but drilling was unsuccessful, as was likewise a boring sunk in similar beds near Algar, 38 miles E.N.E. of Cadiz. Other localities which have afforded petroleum indications, but which have not yielded oil in commercial quantities, are Cueva de la Pez near Bayarque, Liguenza and Molina in Guadaljara, Soria Girona, and San Lorenzo de la Muga and Pont de Molins lying to the west and north of Figueras.

ITALY.

The use of petroleum under the name of "Sicilian Oil" for illuminating purposes at Agrigentum, Sicily, before the beginning of the Christian Era was, as has been noted, described by Strabo and Pliny. The burning gas springs of northern Italy led in 1226 to the adoption by the town of Salsomaaggiore of a salamander surrounded by flames as its official emblem. In 1400 a concession for the collection of petroleum in Miano di Medesano was granted by the Ducal Chamber. The petroleum of Modena, used for lighting, medicinal, and other purposes, was discovered in 1640. Oil was collected early in the 18th century from Monta Chiaro near Piacenza and at Montechino. Genoa was lighted in 1802 by petroleum from the wells of Amiano.

Petroleum and gas indications are too numerous for enumeration. Oil in commercial quantities has been developed in Eocene, Miocene, and Pliocene beds of complicated structure in the Emilian provinces northeast of the Gulf of Genoa, in Eocene beds in the valley of Pescara, in the province of Chieti, in Central Italy, and in Eocene shales in the valley of the Liri near San Giovanni Incarico, midway between Rome and Naples. The Emilia production, after fluctuating between 2 and 30 metric tons annually for 20 years began to increase in 1880, reaching a maximum of 3532 metric tons in 1895. The yield of the Pescara district has been highly irregular, varying from nothing to 363 metric tons. The San Giovanni Incarico field reached a maximum of 600 metric tons in 1878, but was practically exhausted by 1890. Recent years have witnessed renewed activity in Italy and the production is increasing. In 1910 the yield was 7,069 metric tons for the country as a whole.

GERMANY.

The oil springs near Walsbron, Lorraine, were famous in the middle ages, and were even known to the Romans, whose coins have been found in the vicinity. Petroleum was medicinally used in Germany as early as 1436 under the name "St. Quirinus Oil," the supply coming from the Tegernsee district of Bavaria. Oil was discovered at Pechelbronn in Elsass in 1498, and shafts were early dug for its collection. Later, petroleum indications were found in Hanover, Prussia, Hildesheim, Luneburg, and elsewhere,

The commercial developments, which date back less than half a century, include the following districts: (1) North German field, (2) Elsass, (3) Bavaria (Tegernsee district). The North German or Prussian field is described as a belt lying between the Wesser and Elbe rivers north of the Hartz mountains and including the Wietz, Steinförde, Oelheim, and other pools of Hanover, etc. The petroleum, the production of which on a commercial scale dates from 1889, is said to come chiefly from limestones and sandstones of the Upper Jurassic or from transitional beds between the Jurassic and Cretaceous.

Elsass became a producer of petroleum in 1745, the oil being distilled from Tertiary sandstone mined by shafts near Pechelbronn. The production continued negligible until the introduction of machine drilling in 1881. Petroleum is also found at Lobsann and Schivabweiler near Strassburg in Lower Elsass, at Olhungen and Woerth, and at Altkirch near Basle in Upper Elsass.

The petroleum of the Bavarian field is from the Eocene marls and sandstones. The production is very light.

The total production of Germany in 1910 was 1,032,522 barrels, of which four-fifths came from the Prussian field with most of the balance from Elsass.

AUSTRIA-HUNGARY.

Galicia or Austrian Poland is the most important of the various provinces from the standpoint of petroleum indications and production. The "earth-balsam" was used medicinally in

1506. In 1810 oil from the Drohobycz district was distilled on a small scale and used for lighting the Alstetterung at Prague. Refining on a commercial scale dates from 1852. In 1853 petroleum was substituted for candles in the stations of Emperor Ferdinand's North Railroad, and in 1854, five years before the drilling of the Drake well of Pennsylvania, it was an article of commerce in Vienna.

The first systematic development in Galicia was in the Bobrka field in 1854, at which time considerable quantities were collected from trenches and shallow wells. The introduction of drilling in 1885 was accompanied by a rapid increase in production. The development of other fields followed in quick succession, more than a dozen distinct districts being recognized. Many of the wells were remarkable producers, yields of from 1,000 to 3,000 barrels per day not being uncommon. The "Jacob well" in the Boryslaw district is reported to have afforded between 6,000 and 7,000 barrels a day. The record spouter, however, appears to have been the "Oil City Well," struck July 4, 1908, at Tustanowicz in the same field.

The Galician oil field forms a belt 50 miles wide and 200 miles long, lying on the north flank of the Carpathian mountains. The geology is complex, the rocks being characterized by sharply compressed, irregular overthrust folds. The petroleum bearing formations are nearly destitute of fossils, but appear to include Lower and Upper Cretaceous, Eocene, Oligocene, and Miocene. The Eocene, which is very persistent, produces the largest quantities. Lithologically, the rocks are largely shales and sandstones, with some conglomerate and more rarely limestone. Beds of identical character occur at different horizons, adding greatly to the complexity of the geological problems.

The production of the province of Galicia increased from 4,300 barrels in 1878 to 15,000,000 barrels in 1909, but the following year saw the beginning of a marked decline and in 1911 the production was only 10,500,000 barrels.

In the Croatia-Slavonia district oil springs have been noted in the Pliocene shales at Ludbreg, 60 km. northeast, and at Lepavina, 15 km. south of Agram. Borings have obtained small yields at Ribejak, while natural gas has been found near Ivanich. A thick tarry oil exudes from the Miocene marls near Kutina in the Moslalvina Hills, at Bacindol, and at Petrovoszelo.

A strike of oil-gas has been made at Kalusz, in East Galicia. At the depth of 600 meters a strong flow of natural gas was encountered, which Dr. Zuber thinks is a favourable indication of deeper-lying oil sand. The Kalusz Petroleum Gesellschaft was founded with Dr. Zuber at the head of it, the object being to deepen the bore hole to 1,000 meters and develop the oil resources, if any. At a depth of 870 meters strong gas was struck. The rush was so violent that the water in the bore hole, sand, and stones were hurled over the derrick top. At first the volume of the gas escaping was measured as 200,000 cubic feet per hour. After some weeks a second gage showed a volume of 160,000 cubic feet per hour. Boring was continued, and at 890 meters a bituminous shale was met with which was recognized as the Menilite, so closely associated, as all Galician oil operators are aware, with the petroleum formations of that country. The boring is proceeding.

In Hungary, oil has been found in small amounts in Pliocene shales in the hills near Styria and Zala, from both Miocene and Pliocene at Szelnica and Peklenica on the Murakoz peninsula, in ryolite tuffs at Recsk, Heves, and in complexly folded Cretaceous, Eocene, and Oligocene beds at various points in the Carpathian mountains. In Transylvania, natural gas is given off from the Miocene salt-marls of Vizakna and Thorda, and from the Eocene beds in the valley of the Greater Kobel, and there are prospects of important developments in the near future. Petroleum is reported from the Eocene at Kovacs and Monostor, and from the Neocomian (Lower Cretaceous) along the Roumanian frontier. Producing wells have been secured in the Oligocene or Cretaceous at Sösmezö in the Ojtoz.

In Bukowina, oil has been found along the three major anticlines of the Cretaceous series, as well as in several minor folds in the same district. Traces are also reported in Silesia, Moravia, Bohemia, and the Tyrol.

GREECE.

In addition to the oil springs described by the ancients as emerging from the Tertiary deposits on the island of Zante, petroleum has been reported from the Miocene on the island of Antipaxos, in springs from Cretaceous limestone at Dremisou Maurolithari, in the Parnassid and at Galaxidi near Delphi, in seeps from lignitic Miocene strata near Lintzi (the ancient Cyllene) and from several localities on the island of Milo. Some of the earthquakes have been accompanied by discharges of oil, and petroleum and natural gas are known to rise in small quantities from beneath the sea.

RUSSIA.

The great rival of America in the production of petroleum is Russia. The oil and gas of Baku have been known from the earliest times, and up to the date of the Saracenic conquest in A.D. 636, the city was the principal point of pilgrimage of the Persian and Hindoo fire-worshippers and was visited by thousands of devotees annually. As late as 1880, according to a U.S. consular report, the Temple of Surakhani, for centuries the seat of the Sacred Fire, was still attended by priests from India.

Marco Polo, writing in the 13th century, says of the Baku springs: "There is a fountain from which oil springs in great abundance, inasmuch as a hundred shiploads might be taken from it at one time. . . People come from vast distances to fetch it, for in all the countries round there is no other oil." (The Book of Ser Marco Polo the Venetian, Ed. by Col. Yule, London, 1871, I, 4).

An inscription on a stone in an old pit indicates that the oil was worked as early as 1600. Olearius, who accompanied a German embassy to Persia in 1656, saw over 30 petroleum springs near the modern Schemakha, west of Baku. John Hanway, in his "Historical Account of the British Trade over the Caspian Sea" (London, 1754, K, 263 and 381), says of the region of the fire temples: "The earth around the place, for about two miles, has the surprising property that, by taking up two or three inches of the surface and applying a live coal, the part which is so uncovered immediately takes fire, almost before the coal touches the earth." The natural gas, to the ignition of which the flame was due, has been used for burning lime and brick from that day to this.

Speaking of the petroleum on the island of Wetoy (Sviatoi), the same writer says: "The Persians load it in bulk in their wretched vessels; so that the sea is covered with it for leagues together. When the weather is thick and hazy (low barometric pressure) the springs boil up the higher, and the naphtha often takes fire on the surface of the earth, and runs in a flame into the sea in great quantities, to a distance almost incredible. In clear weather the springs do not boil up above 2 or 3 feet. . . The people carry the naphtha by troughs into pits or reservoirs, drawing it from one to another, leaving in the first reservoir the water or heavier part."

Peter the Great, realizing the value of its petroleum, seized the Baku district from Persia in 1723, but later restored it. It was reannexed by Russia, however, in 1806. The monopoly of working the springs was sold to the highest bidder in 1820, the contract extending to 1834. From 1834 to 1850 the Government itself worked the springs, but from 1850 to 1870 they were again leased to private parties.

The collection of oil first took on business proportions in 1832, but as the Government refused to permit the use of tools and as its charges for the privilege of collecting the petroleum were exorbitant, the industry was effectively throttled. Only about 400 pits and dug wells were in existence in 1872 when the fields were put into the hands of a Government Commission. This commission divided the field into lots of 25 acres each, which were sold by sealed bids. High prices were realized. Machine drilling was introduced in 1871, but high taxes, however, prevented profitable exploitation until 1878 when they were removed. From this date the production advanced by leaps and bounds. Many gushers, some with jets from 200 to 400 feet in height, were struck. A single well yielded nearly 7,000 bbls. per day. Immense quantities were wasted, large volumes flowing off over the surface. The oil spray from certain wells was blown as much as 8 miles through the air. The maximum production in the field was reached in 1901 when an output of 80,637,300 barrels was derived from the several thousand producing wells then existing. From this quantity the yield declined to 49,791,336 bbls. in 1905, then rose again to 59,764,971 barrels in 1910, at which time a second decline set in.

The wells were originally from 400 to 800 feet in depth, but many have subsequently been deepened. The Russian developments are remarkable in being confined to small areas. The gas pressure behind the Baku wells is as great as the greatest pressures recorded in the Pennsylvanian fields. The Baku field lies on the Apscheron peninsula and has an area of 9 square miles. The oil is derived chiefly from the Oligocene series, here consisting of alternating beds of shaly marls and fine-grained calcareous sands or sandstone. Their upturned edges are covered with Pliocene or later deposits, also somewhat disturbed, and sometimes containing oil derived from the underlying Oligocene.

Other producing districts of importance are the Grosny and Maikop fields. The Grosny field lies on a sharp anticline of Miocene beds about 500 miles N.W. of Baku and north of the Caucasus range. (Lat. 43° 30′ North, Long. 44° 45′ East). It was worked by pits as early as 1823, but its modern development begins with the first drilled well in 1893. Several immense wells were obtained, one being a lake deep enough to float a steamboat. The yield of the field at one time reached nearly 300,000 barrels daily. The production has increased fairly steadily to a total of 75,189,591 barrels in 1911.

The Maikop field lies on the north flank of the Caucasus mountains in Kuban province, N.W. of the Black sea. The rocks are Miocene, the oil bearing series, about 1,000 feet in thickness, consisting of dolomitic limestone grading downward into shales and sandstone. The dip is commonly 45°—60° to the N.E. but considerable variation exists in the eastern part. Oil in large quantities was first produced in 1910 when the output was 156,640 barrels. The following year, however, the yield jumped to 952,453 barrels.

Oil shows exist in a large number of localities in Russia, Permian indications being noted in Finland, Vologda province, Central and Southern provinces, in Caucasia, Crimea, Taman peninsula, Terek, and Daghestan territories, Kutais, Tifles, etc. Several of the districts are commercially productive, the aggregate yield of the scattered localities being 4,066,782 barrels in 1911.

Notwithstanding the increasing yield of the Grosny, Maikop and scattering fields the production of Russia as a whole has declined since 1910. This is in part due to the retarding of developments in new territory resulting from the lack of transportation facilities, and in part to the Government ownership of some of the most promising territory. Its resources, however, are by no means approaching exhaustion.

The Russian gas fields are co-extensive with its oilfields, but practically none of the gas is utilized and little is known of its volume and pressure beyond the fact that the yield is great and the pressure high. At present nearly the whole is allowed to go to waste.

ROUMANIA.

Petroleum has long been known in Roumania, as is indicated by the frequent occurrence of the village name Pacureti, derived from the Wallachian word *pacura*, meaning petroleum. As early as 1750, travellers reported its use in treating diseases of cattle, lighting courtyards, and as wagon grease.

Modern activity in the development of petroleum began after the redistribution of lands by the government in 1866, but for 15 years the wells were dug by hand. The years 1880-1887 witnessed the first successful drilling. Thereafter progress was steadily forward.

The Roumanian oil district is continuous with that of Galicia, and lies along the south and southeast flanks of the Carpathian mountains, the principal centres of production being Prahova, Dimbovitza, Bacau, and Buzeu districts. The oil is chiefly from the Miocene and Pliocene, with subordinate quantities from the Eocene and Oligocene and possibly from the Cretaceous. The rocks are mainly shales occurring in alternations with sands and sandy clays, with some limestone, gypsum and salt, the whole compressed into a succession of sharp, narrow, and irregular folds associated with some faulting.

The increase in yield has been fairly steady from small beginnings to 11,101,878 barrels in 1911. Of this 90 per cent came from Prahova, 4 per cent each from Dimbovitza and Buzen, and 2 per cent from Bacau.

BOSNIA AND HERZEGOVINA.

No petroleum has yet been found in these districts, although asphaltic indications have been noted at a number of points.

MONTENEGRO.

Petroleum, associated with salt water and gas, has been reported as seeping from the Triassic shales at Bukowik, southwest of the head of Scutari lake.

EUROPEAN TURKEY.

Oil has been found in the sandy Miocene deposits bordering the sea of Marmora west of Gamos, and on the island of Koraka, opposite Salagora in the gulf of Arta. There are also more or less indefinite reports of its occurrence in the Miocene near Feredzik on the Maritza, and in the Jewish quarter of Constantinople.

Asia.

CHINA.

Oil occurs chiefly in Shensi province, China, and has been obtained in small quantities there for centuries. At present small amounts are obtained by antiquated methods and used locally. Kerosene is also found in small quantities in Shansi, Szechuan, and Kansu provinces. At Yenchang, in eastern

Shensi, are oil wells worked with rudimentary machinery under Japanese supervision. The yield of the wells now operated is small, owing to the methods in use. Petroleum, natural gas, and salt brine deposits are reported by travellers in the vast interior of the Chinese empire. However, this great empire will, for many years to come, depend upon the petroleum developed by other countries for its supply.

For many centuries in the province of Szecheun, wells have been drilled by a most primitive and laborious method from 2,500 to 3,000 feet in depth that have produced large quantities of salt brine, and natural gas and petroleum in limited quantities, the natural gas being used extensively as fuel to evaporate the salt brine. The petroleum obtained from the wells is of four different qualities. The first is of a very light colour, and is used in its natural state for burning with refined petroleum in special lamps; the second is of a very greenish colour, and is less valuable than the first; the third is of a yellow colour; and the last is black, very thick and viscous. The oil first mentioned is also employed by the Chinese for medical purposes for various diseases, especially for skin diseases and rheumatism. The temperature of the petroleum and salt water, as they come from the wells, is about 250°C., while the temperature of the atmosphere is only about 40°C.

The presence of petroleum in the salt wells and its use as fuel in obtaining the salt, makes it impossible to separate the two subjects in writing of them. In general, petroleum occupies second place. Salt production is ancient—it is a developed industry. Petroleum production is only of recent date and only exists as a side issue of the salt industry. It belongs to the future. The few wells drilled solely for petroleum may be considered the first efforts toward this new industry. The refining processes are rudimentary where they exist at all, and the oil is not sold commercially for illuminating purposes.

Many of the wells are on the side of a hill, which permit of the utilizing of the natural fall, whether it be for running off the salt water into the reservoir and pans for the evaporation of the salt by solar evaporation, or whether for conducting the gas which is given off from the salt wells, which serves like petroleum for fuel. All the conduits for water, gas, and oil are bamboo. The work of drilling the wells is conducted in the following manner: An ordinary pit is dug until it reaches hard clay, which is usually found at a depth of about 200 to 300 feet. In this a wall is built cone-shaped at the top and with an opening large enough to admit the passage of the cable of a drill. Starting with the first hard layer, the drilling is carried on with a drill the width of a section 5 inches by 2½ inches and 20 feet long and weighing a little over 130 pounds. The strikes are 30 blows to a minute, falling each time 16 inches. The last layer before reaching the salt water stratum is granite and very hard. In some mines the salt water is thrown high in the air when the last layer is pierced, but only for a short time. Any natural gas found with the water is separated and sent by a main pipe to be divided to various salt pans for heating. Certain wells strike rock salt—then a second well is drilled alongside and sweet water sent down to dissolve the salt.

The largest, and one of the oldest of the springs of natural gas is that at Tse-liu-tsin, close to the mountain of the same name; while that of Chu-pai-ching has been in operation day and night for forty years. As much as 400 or 500 pounds of fetid oil, which burns on water, may be obtained from a well in a single day. When a well produces petroleum alone, the oil is conveyed to special reservoirs, but where it is found mingled with the brine it floats on the top of the liquid amd is skimmed off. Where gas is the chief product of a brine-well, all the others are neglected. The gas appears to come from two separate horizons—one comparatively near the surface and the other at a depth of about 720 yards.

According to mining regulations established in March, 1904, the Chinese government reserves for itself 25 per cent of the profits of all mines.

JAPAN.

The main supply of petroleum thus far developed in the Empire of Japan is found on the island of Nippon, in the province of Echigo, on the northwestern coast, about 200 miles northwest of the city of Tokyo. There are other localities on this island where some petroleum has been produced, namely, in the province of Ugo, in the extreme northern portion, and in the province of Totomi, about 150 miles southwest of Tokyo.

The island of Hokkaido, or Ezo, has produced some superior grades of crude petroleum, in a limited way, near the western flank of the foothills of the great mountain chain running to the north, in the provinces of Mikawa and Ishikari. During 1903 and 1904 several wells were drilled in the Ishikari district which indicated the presence of petroleum in quantity; later tests, however, have given rather discouraging results. There are indications of petroleum scattered over a large portion of this northern island of Japan, and there are also indications of petroleum on the island of Formosa, and some small production in a primitive way. Oil was recently struck on this island at a depth of 810 ft.

The production in Echigo and the indications elsewhere are usually in the middle and newer Tertiary formation. Their individual occurrence is invariably on the flanks or along the crest of well-marked anticlinals. Generally these anticlinals are of comparatively short extent, as they suddenly burst out of the level newer formations, run their course, with slight undulations for from half a mile to 2 or 3 miles, and then suddenly plunge under the level surface of the plain. There are other cases where the ridge of an anticlinal can be traced 10 or 15 miles continuously.

There are usually steep dipping flanks on both sides of the anticlinals, which soon carry the oil-bearing strata to depths too great to be reached by the drill, or at which the strata are saturated with water. The depth of the wells is from 750 to 1,800 feet, and probably 80 per cent of the production comes from drilled wells. The remainder is from dug wells or shafts which range in depth from 200 to 500 feet.

The present production is maintained by the deepening of many of the wells that have exhausted the upper pay.

The formation holding the crude petroleum is generally a loosely cemented sandstone of a bluish cast, with more or less small crystals of pure silica, and in some cases with pebbles interspersed; the formation varies from 5 to 40 feet in thickness.

There are usually beds of blue shale or clay capping the sandstone, and in many wells they follow each other in succession.

The life of the average well is not long—it requires the constant drilling of new wells and the deepening of others where lower productive strata have been developed to keep up the production in most of the fields.

During the last six or eight years, the greater portion of the production has been secured by regularly cable-drilled wells, and some wells were drilled by the Canadian rod system. In 1912 and 1913 the California modifications of the rotary system were adopted with great advantage and the prospect that considerably increased production would result. It is rather surprising that the workmen of Japan should so soon have acquired the knowledge that enables them to drill wells where there are serious difficulties encountered, and a very large amount of skill is required to accomplish the end. In several of the fields, the improved methods of pumping wells in clusters by wire rope and solid connexions is used.

Natural Gas.—The banks of Lake Suwa are said to contain a large amount of natural gas, and the use of this supply for various purposes has been greatly extended with the advance of knowledge among the people there. The present consumers number more than 100, and certain villages there have been developing this industry systematically since 1911 with good results. The present output comes from four wells.

INDIA.

Almost the entire production of India is in Burma.

There are in Burma, as a matter of fact, two quite distinct oilfields, which are in process of being worked, for besides the main field in Upper Burma, there is a small field near the Aracan coast, on the islands of Ramree and Cheduba, but the output from that region per annum is only about 55,000 gallons. There appeared to be little probability of an enhanced production from this field, which seems to be of no commercial importance.

The Burma oilfield proper is situated in four sections on opposite sides of the Irrawaddy, about midway between Rangoon and Mandalay. It begins at Minbu, on the west bank of the river, just above the twentieth parallel of latitude, and about eighty miles above the old military station of Thayetmyo, and ceases for practical purposes, so far as at present known, a few miles north of Yenangyat, on the same bank, about seventy miles farther up and a few miles below Pagan, the famous old capital of Burma. Far the greater part of it, however, lies on the east bank, that portion being divided into the Yenangyaung field, twenty-six miles above Minbu, and that at Singu, about twenty miles higher up.

Petroleum is found in Assam in coal-bearing strata of Eocene age. These are exposed near the foot of the Naga hills to the southwest of the river Bramapootra. There is a line of outcrops on the northwestern slopes of the Tipham hills, a low range running from north-northeast to south-southwest and intersected by Dihing river near Jaipur and farther to the southwest by the Disang. Another line of outcrops, known as the Makum coal field, is met with farther to the east; running east-northeast and west-southwest, roughly parallel to and south of the Dihing river. It is intersected by the Tirap, Namdang Makum, and Dirah rivers, all tributaries of the Dihing, and then sinks below the alluvium near the Tipham hills. Some 40 miles farther to the southwest the coal and oil bearing strata reappear and are exposed in the beds of the Dikhu, Tanji, and Disa rivers.

Oil-bearing strata in Punjab are found among the Eocene rocks. There are two lines of outcrop running roughly east and west, one near Rawal Pindi, the other north of Shahpur. The only locality that has been worked to any extent is Gunda or Sudkal, about 23 miles west of Rawal Pindi. Oil wells were first dug in 1861. The principal well yielded at first only 5 gallons a day; on deepening the amount was increased, but it never yielded more than 50 gallons in one day, and in one hundred and ninety-eight days in 1870 only 1,963 gallons were obtained. About 1880 the total annual yield was rather more than 2,000 gallons. In March, 1888, a concession was granted to an American oil refiner, who does not appear, however, to have been very successful. In 1889 the yield was only

2,873 gallons, which appears to be the maximum amount obtained in any one year. A limited supply of oil is yet obtained. It appears to be employed in gas-making at Rawal Pindi.

PERSIA.

The Persian petroliferous region extends along a line northeast and southwest, starting at Shanku, on the Turco-Persian frontier, and ending on the eastern side of the Persian gulf.

The northern part of this basin has its center at Kasharashirin, near Shahku. Around this village are numerous pits of a depth of about 32 feet. This deposit is situated on an Eocene axis of sand and marl, and the Kurds exploit it in a most primitive manner, contenting themselves with collecting the oil from the pits every four or five days. An average output of 10 barrels is collected each time. The petroleum is very fluid and of a greenish colour and is refined on the spot. In the center of the Persian basin, parallel to the Bakhtiari mountains, there is the petroliferous district of Lauriston. This district, like that of Kasharashirin, is characterized by the same blue clays which are found in Galicia. The petroleum deposits are in the neighbourhood of important salt and sulphur deposits.

The existence of petroleum is also shown in a most conspicuous manner at Chouster, where the inhabitants collect it on the surface. The Chouster oil is of a special quality, being of a yellow colour, very clear and almost transparent, and having a specific gravity of 0·773.

South of this station and a few kilometers from Ram-Armuz are the natural springs of Chardin, one of which has a regular output of about 22 gallons per day.

Natural petroleum springs also exist near the Persian convent of Nuanzady at Haf-Cheide. These springs, which have an output of about 1 barrel per day, produce an oil of a greenish colour and of a specific gravity of 0·927.

Pacific Islands.

PHILIPPINE ISLANDS.

Oil indications are found at many points in the Philippines, especially in Luzon (southern part), Panay, Negros, Cebu, Bohol, where small amounts have been collected for nearly fifty years. Productive wells, presumably in the Tertiary, have existed for some years at Toledo on the west coast of Cebu. The belt in which these occur is probably represented on Panay, Guimaras, and Negros islands on the west and on Leyte on the east. Oil indications are also reported on Mindanao.

BORNEO, JAVA, AND SUMATRA.

Oil shows are numerous in the Tertiary coal-bearing series from the northwest part of the island of Borneo southwestward through the British possessions to Sarawak and on the adjacent islands of Labuan and Mengalon, but although some wells have been drilled, no developments of importance have resulted. In the Dutch possessions on the southeast coast, on the other hand, borings have been more successful. Since the beginning of drilling, about 1896, several hundred wells have been sunk and production has risen gradually to over five and one-half million barrels (1911). The oil is found mainly in Miocene sandstones along long narrow anticlines, and is associated with heavy gas pressures. Most of the wells are gushers. In recent years kerosene has been discovered in large quantities in Sumatra. The oil of Sumatra is of a better quality than that of Borneo, and this island produces a much larger quantity than the other two islands of the group. In Java petroleum is found at a depth of from 150 to 600 meters. There are no springs, but there are a few flowing wells, though the majority must be pumped.

Africa.

EGYPT.

Petroleum indications along the borders of the Red Sea have been known since ancient times, the Romans giving the name Mons Petrolius (Oil Mountain) to the elevation near which it was found at Jebel Zeit near the mouth of the Gulf of Suez. Pronounced oil indications have also been noted at Gemsah, 13 miles south of the first locality, but although borings were carried in 1885 to a depth of over 2,000 feet only small seeps were obtained. The rocks consist of Upper Miocene limestones, clays and gypsum, which form a belt extending from Ras El Gharib on the north to Abu Shaar on the south. Oil indications also occur in the Upper Cretaceous sandstones and limestones along a ridge parallel to the coast and lying west of the Miocene series. Oil under heavy gas pressure was found in a boring at Zafarana, while surface seeps have been noted on the Jebel Atakah, southwest of Suez. Oil indications are also reported at El Hamman (Mokattam) in the Eocene in the hills 20 miles inland from Suakin, and on the upper Nile. Although there has been considerable activity in prospecting, the production so far has been negligible. Considerable natural gas was encountered in a number of the wells, but is not utilized.

TUNIS AND ALGERIA.

Seeps of heavy asphaltic oil are reported from supposed Cretaceous limestones and shales near Testour, about 70 kilometres southwest of the capital of Tunis. In Algeria the presence of petroleum has been known since the time of the Romans, the principal occurrences being on the south flank of the Dahra range, in the Department of Oran. An attempt to collect the oil by tunnelling was made in 1877, and in 1892 test wells were drilled without much result. In 1895, however, small quantities were obtained in wells in a series of alternating Miocene marls, clays, gypsum, and limestone in the same province. Oil indications have also been reported from Cape Ivi, near La Stidia, at

Bel Hacel, on the Oued Kalaa, from Port-aux-Poules near Arzeu, in the valley of Oued-Ouarizane in the province of Constantine. Elsewhere no material production has been anywhere developed in Algeria.

EAST COAST.

Traces of petroleum are said to occur near the juncture of the Umzingwani and Limpopo rivers in Matabeleland, and Livingston reported seeps of a paraffin oil on the shores of Lake Nyanza. Cretaceous shales with shows of oil occur in Gasa Land. In Madagascar oil is reported from the Eocene on the west side in Mesozoic rocks in the valley of the Ranobe and Mananubolo rivers, and in the Jurassic coal fields of Ambavatoby on the northeast coast.

SOUTH AFRICA.

Traces of petroleum are associated with igneous intrusions in bituminous Triassic beds at several points, and gas has been reported from Upper Silurian and Devonian rocks in the Bokkeveldt (Ceres district), 90 miles northeast of Cape Town, and at Mossel bay. In Orange River Colony petroleum indications are again associated with igneous intrusions in bituminous shales. In Transvaal oil shows are reported in the hills 20 miles inland from Suakim, and on the upper Nile. Also 60 miles northwest of Potchefstroom and in Lower Mesozoic shales in a belt extending across the Wakkerstroom, Piet Retief, and Ermelo districts, mostly in association with or exuding from igneous intrusions. No commercial developments are reported.

WEST AFRICA.

Oil rises from the sea bottom off the Cape de Verde island. On the mainland the principal occurrences are in the local Cretaceous areas along the western flanks of the crystalline highlands. Among the localities from which it has been specifically reported are Portuguese Guinea, Gold Coast, island of St. Thomas, Cameroons, French Congo, and Angola. Some drilling has been done, but has not resulted in commercial production.

Australia and New Zealand.

WEST AUSTRALIA.

Petroleum seeps are reported near the mouths of Warren and Donnelly rivers on the southwestern coast. Inland, oil shows are found in the Permo-Carboniferous shales and sandstones near Fly brook and Lake Jasper. No developments have been made.

SOUTH AUSTRALIA.

Petroleum indications are reported in the Miocene shales on Leighs creek (Lat. 31° S.) and in the Gawler between Kapunda and Adelaide. Small quantities have also been noted in boring on Salt creek near Meningie and at Bordertown. Oil springs occur near Yorktown. There have been no commercial developments.

VICTORIA.

Traces of solid bitumens occur at numerous points and oil seeps have been found near Bridgewater, 100 miles northwest of Melbourne, but no occurrences of economic value have been discovered as yet.

NEW SOUTH WALES.

Tertiary lignites saturated with oil occur on the coast north of Cape Horne, at Twofold bay and Bonda, and at Kiandra in the interior, while oil-bearing shales are extensively mined at various points along the borders of the productive coal measure basin. There is no commercial production of petroleum other than derived from the distillation of the shales. Natural gas has been found in considerable quantities in Triassic rocks at Grafton in the northeastern part of the State.

QUEENSLAND.

Oil shales occur in the Tertiary basin of Dawson river and on the north flank of the McPherson range near the border of New South Wales; natural gas has also been found in the Triassic. No natural petroleum is produced.

TASMANIA.

Oil shales are found in the Carboniferous strata south of Table cape in the northern part of the island, and in a belt extending from the Don valley past the Mersey Run to the Tamar estuary. Some petroleum is secured from the distillation of the shales, but there is no natural production.

NEW ZEALAND.

Oil and gas indications have long been known in the North Island of New Zealand, especially at New Plymouth and on adjacent islands on the west coast, and in a belt extending from the vicinity of East Cape Waiapu to the Okahuatin block, 30 miles west of Gisborne on Poverty bay. The first drilled wells were sunk in 1865 near New Plymouth, but only a few gallons were secured. Later wells sunk near New Plymouth, at Poverty bay and on the Waiapu river, have found a little oil, but have not produced in commercial quantities.

Small showings of oil have been found in borings near Brunner, 21 miles east of Greymouth on the west coast, South Island.

Central America.

In recent years there has been an extensive search in Mexico and adjacent countries and in the West Indies, and in South America, for fuel oil, with special regard to the possible future supply of fuel for the great navies of the world. The occurrence of petroleum in these countries is therefore of special interest in considering the resources of these great powers.

MEXICO.

The coast states bordering on the Gulf of Mexico, Tamaulipas, Vera Cruz, and Tabasco, have been known for many years to contain very large deposits of bitumen, sometimes in the form of asphalt of sufficient purity to be mined and used as such, in other cases, bituminous limestone or sandstone, occasionally used for road purposes, etc. One deposit near the Tuxpan river, about 80 miles from its mouth, was worked for many years and probably thousands of tons were dug out, hauled to the head of navigation and shipped down the Tuxpan river.

When Capt. A. F. Lucas developed asphaltic oil at Spindle Top in Texas in 1901, Mr. E. L. Doheny, an oil operator in Los Angeles, California, conceived the idea that these large deposits of asphalt in Mexico represented old dried up oil seepages, and he drilled for oil at Ebano, about 50 miles from Tampico on the railroad line leading to San Luis Potosi. Wells were very successful and production from them still continues.

Soon after this S. Pearson and Son bought a small oil development in Tabasco, and also developed oil near Minatitlan, in southern Vera Cruz. They developed a refinery at this place and organized a general campaign for oil throughout Vera Cruz. This resulted in the development, first, of the wells at San Cristobal, then the great gusher at Dos Bocas, and finally a well with the largest daily capacity that has ever been recorded was developed at Potrero del Llano, about 40 miles north of the Tuxpan river in Vera Cruz.

The Pearson interest, now known as the Mexican Eagle Company, have developed several other fields and have pipe lines to Tuxpan bar and to Tampico. Meanwhile the Doheny interest, known as the Mexican Oil Company, have also developed a large field at Juan Casiana, north of Potrero del Llano, and other pools have been developed at Panuco and Topila on the Panuco river, not far from Tampico. Production is developing rapidly from the two large companies, and many other small companies. Refineries are being built and a large fleet of about forty of the largest sized tank steamers is being developed for the export trade in the crude oil and its products. At this time production amounts to about 20 to 25 million barrels a year.

HONDURAS.

In the republic of Honduras, indications of petroleum are reported in limestone (presumably of Neocomian age) near Comayagua, in the Guare mountains.

PANAMA.

Oil fields have been reported in the Province of Chiriqui, in the republic of Panama. No survey or drilling work has yet been done, so that the extent of the fields is uncertain.

GUATEMALA.

Oil seepages have been found in the northwestern part of Guatemala and on the Atlantic coast side of that republic.

COSTA RICA.

Indications of oil have been found on the Altantic side of the republic of Costa Rica, not far from the port of Limon.

West Indies.

CUBA.

There are numerous indications of petroleum in Cuba, with a range in gravity from that of naphtha to solid bitumen, but as yet there has been no commercial development. There are numerous deposits of asphaltum, and shales highly charged with hydrocarbons are found scattered over nearly all of the provinces in the island. There seems to be a peculiar condition brought about by the volcanic heat that has partially distilled the bitumens, whose lighter products have been condensed in the crevices of the higher and cooler portions of the strata where they are now found. However, there seems to have been little real work done in a systematic manner by persons who understand how to make a thorough test of the many localities where there are surface indications of both petroleum and natural gas.

PORTO RICO.

Exudations of petroleum are said to occur at several points on this island, possibly derived from the beds of bituminous lignite which are found in the Tertiary beds at the southwest corner of the island.

SANTO DOMINGO.

Recent explorations have, it is reported, confirmed the existence of crude petroleum on this island. The petroleum was found in pits and along the dry beds of streams near the old town of Azua, 4 miles from the harbor of Tortugerre.

BARBADOS.

The petroleum deposits of Barbados are almost entirely confined to the Scotland district, on the eastern side of the island, the petroliferous rocks being a series of Miocene sandstones and shales, known locally as the Scotland beds. The most northerly occurrence is that of the Morgan-Lewis estate, about 1½ miles north of St. Andrews, shallow wells have yielded a small quantity of petroleum, as is the case on the Turner's Hall Wood estate, about 3 miles to the southwest. Tarry Gully, a short distance south of the latter, derives its name from the quantities of petroleum-saturated earth found here. Oil is also produced in the Baxters district from shallow wells, and on the Friendship and Groves estates, a short distance to the southwest. On the latter, a large quantity of "manjak" or desiccated tar occurs at or about 4 feet from the surface. A little heavy oil has been obtained on Barrow Gully, about three-quarters of a mile farther south, while manjak and oil occur at Springfield, in the Lloyd wells on the coast, and at St. Joseph farther inland. Manjak is also found at Burnt Hill on Conset bay, some distance to the south, outside the Scotland district, in shales of like age.

The deposits which yield this tar occur in the Scotland district, which includes the parishes of St. Joseph and St. Andrew. The rocks in the district consist of thick-bedded sandstones, coarse grits, bituminous sandstones and shales, and dark grey and mottled clays. The strata are much disturbed, and are broken by many faults, being in some instances vertical, while close by they may be seen at an angle of 13° to 15°.

TRINIDAD.

The oil fields of Trinidad are situated mainly in the southern part of the island, and are now being energetically worked. It is as yet impossible, however, to foresee what will be their ultimate extent and importance.

Oil has been known to exist in Trinidad for a number of years, but it is only of late that it has been produced in commercial quantities, and the production now is not large. The oil is of very low specific gravity and has an asphalt base.

The formation here is somewhat similar to that of the Gulf Coast country. The surface is a rich alluvium, running off into a red sandy clay for some thirty feet, when a soft blue shale, which is a little harder than the clay, is struck. The shale, geologically speaking, seems to be young, and is streaked with seams of sand, in which the oil is found at various depths of from 300 to 700 feet. The pay sands do not lie in regular strata and there is no certainty of a well from one location to another, only a few feet distant. All the wells have some gas, but not sufficient for fuel purposes.

South America.

ARGENTINE.

There can be distinguished to-day in Argentine four different oil-bearing regions, namely: (1) The eastern border of the Andes in the provinces of Salta, Jujuy and Tucuman, (2) the limited deposit of Cacheuta near Mendoza, (3) a long zone of seepages on the eastern border of the Andes in the Province of Mendoza and in the territory of Neuguen, and (4) the deposit of Comodoro Rivadavia on the Atlantic coast. Almost always the oil or its derivatives, often in the form of asphalt (albertite), occurs in Mesozoic deposits. At a few places where one finds it in Tertiary formations, the deposits are secondary.

BOLIVIA.

Seepages of petroleum have long been known in Bolivia in a belt of country traversing diagonally the eastern provinces of Santa Cruz, Sucre, and Tarija and extending to the Argentine boundary at Yacuiva.

BRAZIL.

Thus far no deposit of petroleum is known to exist in Brazil, though very extensive deposits of hydrocarbon shales, containing 33 per cent of volatile matter, are known to exist.

CHILE.

Official confirmation has been given to the report that petroleum deposits have been discovered on the island of Chile. The governor of the colony there has reported that oil in quantity has been found in a shallow well. Arrangements are being made to investigate the mineral resources of this island.

COLOMBIA.

Known deposits of oil exist in many parts of Colombia and are found on the plains near the seacoast of the Atlantic, in the river valleys, along the foothills of the mountains, and at various points in the western chain of mountains (beyond the Magdalena river), where the beds overlying the cretaceous system are also found.

From the Magdalena river to the Atrato river there are indications of oil along the Atlantic seaboard. Many springs of natural gas and oil seepages are among the indications. For some distance up the Atrato river oil is found on the surface at many points.

ECUADOR.

The oil fields of Santa Elena lie between 50 and 80 miles westward of the port of Guayaquil. The principal surface indications occur at San Raimondo, on the coast; at Santa Paula, about 3 miles inland, and at Achaigan, 2 miles northeast of Santa Paula; but traces exist for 30 miles eastward of Point Santa Elena, and southward to Puna island. Oil is said to exude from dioritic rocks, a days' journey northward of Quito, and on the east flank of the Andes an oilspring is reported as found on the southern side of the Pastazza river, about 130 miles east-by-north of Guayaquil. Asphalt is raised on the Cojitambo hill, some 13 miles northeastward of Cuenca.

PERU.

The chief producing district for Peru is at Negritos, the port of shipment being Talara, a few miles distant.

The second district in importance is the Lobitos field, situated at Lobitos, a little north of Talara. The third producing district is at Zorritos. Another district, situated near Lake Titicaca, is being developed, and although some good wells have been struck no large sales or export of oil have been undertaken. These fields, with the exception of that near Lake Titicaca, have increased in production steadily for the last decade.

VENEZUELA.

There are five petroleum districts in or bordering on Venezuela as follows: Mara, where seepages of petroleum were found near the Limon River asphalt lake; Bella Vista, near Maracaibo; the district of Sucre, where seepages are found over a large area, together with asphalt deposits; Sardinate, on Sardinate river in Colombia, near the Venezuelan frontier, where the oil is used locally; Colon, in the state of Zulia, south of Lake Maracaibo.

United States.

In the United States, the greatest producer of oil during the last few years has been California, Oklahoma ranking second among the states in 1912, Illinois coming third, West Virginia fourth, Texas fifth, and Louisiana sixth. The production of California has been enormous, having produced more oil than any entire nation outside the United States. If Russia and the United States be omitted, California has produced more oil than all the rest of the world put together.

Canada.

As in America generally, references to the occurrence of oil, asphalt, and natural gas date back to the earliest history of Canada. Thus Sir Alexander Mackenzie noted the tar springs of the Athabaska region in the "Voyages through North America to the Frozen and Pacific Oceans," 1789, 1793. From that time until the present these tar springs have been commented upon by all the explorers of that region. Meanwhile, as far back as 1830, the settlers in the neighbourhood of Enniskillen in Lambton county, in the extreme western part of Ontario, noted the presence of oil in the swamps of that region. The presence of "gum oil" as the material in these swamps was called, was sufficient to seriously detract from the value of the land. Oil was developed from these swamps in 1857, when Mr. Shaw dug a shallow well near Enniskillen, at a place which became known as Oil Springs. In fact, not only does the actual use of oil in Canada antedate the drilling of the Drake well in Titusville, Pennsylvania, in 1859, but in 1857, a Mr. Williams drilled a deep well in Ontario with successful results.

Drake's lucky find caused great excitement in the Oil Springs region in Ontario. This caused careful search to be made for oil indications. By 1860 hundreds of derricks had been erected at Black creek in the township of Enniskillen. The wells were all shallow, the oil being obtained at 100 feet more or less. The first flowing well was struck in 1862 by Mr. Shaw at Oil Springs, at a depth of 160 feet, described by Mr. J. T. Henry in the "Early and Later History of Petroleum." This well was struck on January 11, 1862, and before October not less than 35 wells were producing. In spite of the better known development of western Pennsylvania, there is probably no quarter of the world where the production developed so rapidly in these early days as on Black creek, Ontario, in 1862, on account of the shallow depth at which large gushers were obtained. Several yielded as high as 3,000 barrels per day, three produced 6,000 barrels per day, and the Black and Matthewson wells flowed 7,500 barrels per day, according to Henry.

Shortly after the excitement of Oil Springs, another large oil deposit was struck at Bothwell in Kent county, about 30 miles to the southeast, and in 1865 Petrolia, 7 miles north of Oil Springs, developed a larger field, which led to the desertion of Oil Springs, in 1867, and has been a principal contributor to the Canadian oil industry ever since.

As far back as 1844, Sir William Logan noted the presence of several petroleum springs near the extremity of Gaspé in the Province of Quebec.

The history of the development of the Canadian oil and gas deposits has been given quite fully in the various reports of the Geological Survey of Canada.[1] In this report the further description of the development of Canadian oil and gas resources will be given in connexion with the description of each Province.

Statistics of Production.

PETROLEUM.

In addition to the historical review which has been given in the preceding sections, of the development of the world's oil industry, the following pages will present in condensed, tabular form the actual amount of crude petroleum produced by each nation. The unit used will be the barrel of 35 imperial gallons, which is the unit of measurement adopted in Canada. The imperial gallon contains 277·27 cubic inches. In the United States, the unit of measurement is the barrel of 42 American gallons, each of 231 cubic inches. The imperial gallon, therefore, is about one-fifth larger than the American gallon, but 35 imperial gallons, constituting the Canadian barrel, is the same in capacity as the American barrel of 42 American gallons—that is, to within

[1] Summary Reports of the Geological Survey of Canada for the years 1888 and 1889 (Montreal, 1890); in the "Report for 1889 of the Division of Mineral Statistics and Mines of the Geological Survey of Canada," (Montreal, 1890), and "Report for 1898," (Montreal, 1899), by E. D. Ingall; in "Report on Natural Gas and Petroleum in Ontario prior to 1891," (Ottawa, 1892), by H. P. Brumell; in "Report on the Mineral Resources of the Province of Quebec," 1890, by R. W. Ells.

less than one-tenth of one per cent. Therefore, the American barrel and the Canadian barrel can be used interchangeably.

Up to the close of the year 1912, the world's production of petroleum had amounted to 4,804,715,214 barrels, or 647,483,340 metric tons, and at this time, March 1914, the total production of the world has passed five billion barrels, three-fifths of which has been contributed by the United States. Canada, meanwhile, has also contributed over 23,000,000 barrels, as shown in the following table, in which the petroleum producing countries of the world are grouped by seniority, beginning with Roumania where production began in 1857, and ending with Mexico where production on a considerable commercial scale only dates back to 1907.

The world's total production has increased annually since 1906, and there is every prospect that the total production for the next few years to come must show an annual increase of which Canada bids fair to show a greater percentage of increase than most other countries, with the possible exception of Mexico, on account of the energy with which petroleum exploitation is being carried on in Alberta. It is interesting to note that the production of Canada dates back to 1862, in fact, that—leaving out Italy as one of the minor producers—there are only two countries, Roumania and the United States, which have been petroleum producers for a greater period of time. Canada produced petroleum before there is any record of a Russian production.

The figures in this table are taken in great part from the various reports of the Mineral Resources of the United States Geological Survey, where the foreign figures are obtained chiefly by direct correspondence with the officials of the governments concerned, and also from the Moniteur du Petrole Roumain, the Petroleum Review of London, the Petroleum of Berlin, the Petroleum World of London, and the Rivista del Servizio Minerario of Italy.

The following table gives the world's production of petroleum for the years 1857-1912 inclusive, by countries, in barrels of 35 imperial gallons:—

TABLE I.

World's production of Petroleum for the years 1857-1912, inclusive, by countries, in barrels of 35 Imperial gallons.

YEAR.	Roumania.	United States.	Italy.	Canada.	Russia.	Gallicia.	Japan.	Germany.	India.	Dutch East Indies.	Peru.	Mexico.	Other.	Total.
1857	1,977													1,977
1858	3,560													3,560
1859	4,349	2,000												6,349
1860	8,542	500,000	36											508,578
1861	17,279	2,113,609	29											2,130,917
1862	23,198	3,056,690	29	11,775										3,091,692
1863	27,943	2,611,309	58	82,814	40,816									2,762,940
1864	33,013	2,116,109	72	90,000	64,586									2,303,780
1865	39,017	2,497,700	2,265	110,000	66,542									2,715,524
1866	42,534	3,597,700	992	175,000	83,052									3,899,278
1867	50,838	3,347,300	791	190,000	119,917									3,708,846
1868	55,369	3,646,117	367	200,000	88,327									3,990,180
1869	58,533	4,215,000	144	220,000	202,308									4,695,985
1870	83,765	5,260,745	86	250,000	204,618									5,799,214
1871	90,030	5,205,234	273	269,397	165,129									5,730,063
1872	91,251	6,293,194	331	308,100	184,391									6,877,267
1873	104,036	9,893,786	467	365,052	474,379									10,837,720
1874	103,177	10,926,945	604	168,807	583,751	149,837								11,933,121
1875	108,569	8,787,514	813	220,000	697,364	158,522	4,566							9,977,348
1876	111,314	9,132,669	2,891	312,000	1,320,528	164,157	7,708							11,051,267
1877	108,569	13,350,363	2,934	312,000	1,800,720	169,792	9,560							15,753,938
1878	109,300	15,396,868	4,329	312,000	2,400,960	175,420	17,884							18,416,761
1879	110,007	19,914,146	2,891	575,000	2,761,104	214,800	23,457							23,601,405
1880	114,321	26,286,123	2,035	350,000	3,001,200	229,120	25,497	9,310						30,017,606
1881	121,511	27,661,238	1,237	275,000	3,601,441	286,400	16,751	29,219						31,992,797
1882	136,610	30,349,897	1,316	275,000	4,537,815	330,076	15,549	58,025						35,704,288
1883	139,486	23,449,633	1,618	250,000	6,002,401	365,160	20,473	26,708						30,255,479
1884	210,667	24,218,438	2,855	250,000	10,804,577	408,120	27,923	46,161						35,968,741
1885	193,411	21,858,785	1,941	250,000	13,924,596	465,400	29,237	41,360						36,764,730
1886	168,606	28,064,841	1,575	584,000	18,006,407	305,884	37,916	73,864						47,243,154
1887	181,907	28,283,483	1,496	525,655	18,367,781	343,832	28,645	74,284						47,807,083
1888	218,576	27,612,025	1,251	695,203	23,048,787	466,537	37,436	84,782						52,164,597
1889	297,666	35,163,513	1,273	704,690	24,609,407	515,268	52,811	68,217	94,250					61,507,095
1890	383,227	45,823,572	2,998	795,030	28,691,218	659,012	51,420	108,296	118,065					76,632,838
1891	488,201	54,292,655	8,305	755,298	34,573,181	630,730	52,917	108,929	190,131	*a*150,000				91,250,347
1892	593,175	50,514,657	18,321	779,753	35,774,504	646,220	68,901	101,404	242,284	*a*400,000				89,139,219
1893	535,655	48,431,066	19,069	798,406	40,456,519	692,669	106,384	99,390	298,969	600,000				92,038,127
1894	507,255	49,344,516	20,552	829,104	36,375,428	949,146	171,744	122,564	327,218	688,170				89,335,697
1895	575,200	52,892,276	25,843	726,138	46,140,174	1,452,999	141,310	121,277	371,536	1,215,757				103,662,510
1896	543,348	60,960,361	18,149	726,822	47,220,633	2,443,080	197,082	145,061	429,979	1,427,132	47,536			114,159,183
1897	570,836	60,475,516	13,892	709,857	54,399,568	2,226,368	218,559	165,745	545,704	2,551,649	70,831			121,948,575
1898	776,238	55,364,233	14,489	758,391	61,609,357	2,376,108	265,389	183,427	542,110	2,964,035	70,905			124,924,682
1899	1,425,777	57,070,850	16,121	808,570	65,954,968	2,313,047	536,079	192,232	940,971	1,795,961	89,166			131,143,742
1900	1,628,535	63,620,529	12,102	913,498	75,779,417	2,346,505	866,814	358,297	1,078,264	2,253,355	274,800			149,132,116
1901	1,678,320	69,389,194	16,150	756,679	85,168,556	3,251,544	1,110,790	313,630	1,430,716	4,013,710	274,800		*a*20,000	167,424,089
1902	2,059,935	88,766,916	18,933	530,624	80,540,044	4,142,159	1,193,038	353,674	1,617,363	2,430,465	286,725		*a*26,000	181,965,876
1903	2,763,117	100,461,337	17,876	486,637	75,591,256	5,234,475	1,209,371	445,818	2,510,259	5,770,056	278,092		*a*36,000	194,804,294
1904	3,599,026	117,080,960	25,476	552,575	78,536,655	5,947,383	1,419,473	637,431	3,385,468	6,508,485	345,834		*a*40,000	218,078,766
1905	4,420,987	134,717,580	44,027	634,095	54,960,270	5,765,317	1,472,804	560,963	4,137,098	7,849,896	447,880		*a*30,000	215,040,917
1906	6,378,184	126,493,936	53,577	569,753	58,897,311	5,467,967	1,710,768	578,610	4,015,803	8,180,657	536,294		*a*30,000	212,912,860
1907	8,118,207	166,095,335	59,875	788,872	61,850,734	8,455,841	2,001,838	756,631	4,344,162	9,982,597	756,226	1,000,000	*a*30,000	264,240,318
1908	8,252,157	178,527,355	50,966	527,987	62,186,447	12,612,295	2,070,145	1,009,278	5,047,038	10,283,357	1,011,180	3,481,610	*a*30,000	285,089,815
1909	9,327,278	183,170,874	42,388	420,755	65,970,350	14,932,799	1,889,563	1,018,837	6,676,517	11,041,852	1,316,118	2,488,742	*a*30,000	298,326,073
1910	9,723,806	209,557,248	50,830	315,895	70,336,574	12,673,688	1,930,661	1,032,522	6,137,990	11,030,620	1,330,105	3,332,807	*a*30,000	327,482,746
1911	11,107,450	220,449,391	74,709	291,096	66,183,691	10,519,270	1,658,903	1,017,045	6,451,203	12,172,949	1,368,274	14,051,643	*a*200,000	345,545,624
1912	12,991,913	222,113,218	*a*86,286	243,614	68,019,208	8,535,174	1,671,405	1,031,048	7,116,672	10,845,624	1,751,143	16,558,215	*a*250,000	351,213,520
Total	91,616,808	2,820,426,549	747,933	23,051,003	1,492,378,967	119,022,121	22,370,771	10,974,039	58,049,770	119,106,327	10,255,909	40,913,017	752,000	4,804,715,214

a Estimated.

NOTE: In Canada the unit for measuring oil is one barrel of 35 Imperial gallons; the gallon contains 277.27 cubic inches, while in the United States the barrel consists of 42 gallons, and 231 cubic inches to the gallon. The Imperial gallon is therefore about 1-5 larger than the American gallon, although the barrel at either place has the same capacity within less than 1-10 per cent.

TABLE II.

Production of Petroleum in the United States, 1859-1912, by years and by states, in Barrels of 42 gallons.

Year.	Pennsylvania and New York.	Ohio.	West Virginia.	California.	Kentucky and Tennessee.	Colorado.	Indiana.	Illinois.	Kansas.	Texas.	Missouri.	Oklahoma.	Wyoming.	Louisiana.	United States.	Total value.
1859	2,000														2,000	$32,000
1860	500,000														500,000	4,800,000
1861	2,113,609														2,113,609	1,035,668
1862	3,056,690														3,056,690	3,209,525
1863	2,611,309														2,611,309	8,225,663
1864	2,116,109														2,116,109	20,896,576
1865	2,497,700														2,497,700	16,459,853
1866	3,597,700														3,597,700	13,455,398
1867	3,347,300														3,347,300	8,066,993
1868	3,646,117														3,646,117	13,217,174
1869	4,215,000														4,215,000	23,730,450
1870	5,260,745														5,260,745	20,503,754
1871	5,205,234														5,205,234	22,591,180
1872	6,293,194														6,293,194	21,440,503
1873	9,893,786														9,893,786	18,100,464
1874	10,926,945														10,926,945	12,647,527
1875	8,787,514														8,787,514	7,368,133
1876	8,968,906	31,763	120,000	12,000											9,132,669	22,982,822
1877	13,135,475	29,888	172,000	13,000											13,350,363	31,788,566
1878	15,163,462	38,179	180,000	15,227											15,396,868	18,044,520
1879	19,685,176	29,112	180,000	19,858											19,914,146	17,210,708
1880	26,027,631	38,940	179,000	40,552											26,286,123	24,600,638
1881	27,376,509	33,867	151,000	99,862											27,661,238	23,512,051
1882	30,053,500	39,761	128,000	128,636											30,349,897	23,631,165
1883	23,128,389	47,632	126,000	142,857	4,755										23,449,633	25,740,252
1884	23,772,209	90,081	90,000	262,000	4,148										24,218,438	20,476,924
1885	20,776,041	661,580	91,000	325,000	5,164										21,858,785	19,193,694
1886	25,798,000	1,782,970	102,000	377,145	4,726										28,064,841	20,028,457
1887	22,356,193	5,022,632	145,000	678,572	4,791	76,295									28,283,483	18,856,606
1888	16,488,668	10,010,868	119,448	690,333	5,096	297,612									27,612,025	17,950,353
1889	21,487,435	12,471,466	544,113	303,220	5,400	316,476	33,375	1,460	500	48	20				35,163,513	26,963,340
1890	28,458,208	16,124,656	492,578	307,360	6,000	368,842	63,496	900	1.200	54	278				45,823,572	35,365,105
1891	33,009,236	17,740,301	2,406,218	323,600	9,000	665,482	136,634	675	1,400	54	25	30			54,292,655	30,526,553
1892	28,422,377	16,362,921	3,810,086	385,049	6,500	824,000	698,068	521	5,000	45	10	80			50,514,657	25,906,463
1893	20,314,513	16,249,769	8,445,412	470,179	3,000	594,390	2,335,293	400	18,000	50	50	10			48,431,066	28,950,326
1894	19,019,990	16,792,154	8,577,624	705,969	1,500	515,746	3,688,666	300	40,000	60	8	130	2,369		49,344,516	35,522,095
1895	19,144,390	19,545,233	8,120,125	1,208,482	1,500	438,232	4,386,132	200	44,430	50	10	37	3,455		52,892,276	57,632,296
1896	20,584,421	23,941,169	10,019,770	1,252,777	1,680	361,450	4,680,732	250	113,571	1,450	43	170	2,878		60,960,361	58,518,709
1897	19,262,066	21,560,515	13,090,045	1,903,411	322	384,934	4,122,356	500	81,098	65,975	19	625	3,650		60,475,516	40,874,072
1898	15,948,464	18,738,708	13,615,101	2,257,207	5,568	444,383	3,730,907	360	71,980	546,070	10		5,475		55,364,233	44,193,359
1899	14,374,512	21,142,108	13,910,630	2,642,095	18,280	390,278	3,848,182	360	69,700	669,013	132		5,560		57,070,850	64,603,904
1900	14,559,127	22,362,730	16,195,675	4,324,484	62,259	317,385	4,874,392	200	74,714	836,039	a1,602	6,472	5,450		63,620,529	75,752,691
1901	13,831,996	21,648,083	14,177,126	8,786,330	137,259	460,520	5,757,086	250	179,151	4,393,658	a2,335	10,000	5,400		69,389,194	66,417,334
1902	13,183,610	21,014,231	13,513,345	13,984,268	185,331	396,901	7,480,896	200	331,749	18,083,658	a757	37,100	6,253	548,617	88,766,916	71,178,910
1903	12,518,134	20,480,286	12,899,395	24,382,472	554,286	483,925	9,186,411		932,214	17,955,572	a3,000	138,911	8,960	917,771	100,461,337	94,694,050
1904	12,239,026	18,876,631	12,644,686	29,649,434	998,284	501,763	11,339,124		4,250,779	22,241,413	a2,572	1,366,748	11,542	2,958,958	117,080,960	101,175,455
1905	11,554,777	16,346,660	11,578,110	33,427,473	1,217,337	376,238	10,964,247	181,084	b12,013,495	28,136,189	a3,100	(c)	8,454	8,910,416	134,717,580	84,157,399
1906	11,500,410	14,787,763	10,120,935	33,098,598	1,213,548	327,582	7,673,477	4,397,050	b21,718,648	12,567,897	a3,500	(c)	d7,000	9,077,528	126,493,936	92,444,735
1907	11,211,606	12,207,448	9,095,296	39,748,375	820,844	331,851	5,128,037	24,281,973	2,409,521	12,322,696	a4,000	43,524,128	e9,339	5,000,221	166,095,335	120,106,749
1908	10,584,453	10,858,797	9,523,176	44,854,737	f727,767	379,653	3,283,629	33,686,238	1,801,781	11,206,464	a15,246	45,798,765	e17,775	5,788,874	178,527,355	129,079,184
1909	10,434,300	10,632,793	10,745,092	55,471,601	f639,016	310,861	2,296,086	30,898,339	1,263,764	9,534,467	a5,750	47,859,218	e20,056	3,059,531	183,170,874	128,328,487
1910	9,848,500	9,916,370	11,753,071	73,010,560	f468,774	239,794	2,159,725	33,143,262	1,128,668	8,899,266	a3,615	52,028,718	e115,430	6,841,395	209,557,248	127,899,688
1911	9,200,673	8,817,112	9,795,464	81,134,391	f472,458	226,926	1,695,289	31,317,038	1,278,819	9,526,474	a7,995	56,069,637	e186,695	10,720,420	220,449,391	134,044,752
1912	8,712,076	g8,969,007	12,128,962	86,450,767	f484,368	206,052	970,009	28,601,308	1,592,796	11,735,057	(h)	51,427,071	e1,572,306	9,263,439	222,113,218	163,802,334
Total.	736,205,411	415,444,184	238,985,483	542,887,881	8,068,961	10,237,571	100,532,249	186,512,968	49,422,978	168,721,719	54,077	298,267,850	1,998,047	63,087,170	2,820,426,549	2,337,934,607

a Includes the production of Michigan.
b Includes production of Oklahoma.
c Included with Kansas.
d Estimated.
e Includes the production of Utah.
f No production in Tennessee recorded.
g Includes production of Michigan.
h No production in Missouri.

There are no reliable statistics of production in Canada prior to 1886, but the following are the estimates of parties intimately connected with the industry:

TABLE III.

Production of Crude Petroleum in Canada from 1862 to 1885.[1]

Years	*Barrels*	*Years*	*Barrels*
1862	11,775	1874	168,807
1863	82,814	1875	220,000
1864	90,000	1876	312,000
1865	110,000	1877	312,000
1866	175,000	1878	312,000
1867	190,000	1879	575,000
1868	200,000	1880	350,000
1869	220,000	1881	275,000
1870	250,000	1882	275,000
1871	269,397	1883	250,000
1872	308,100	1884	250,000
1873	365,052	1885	250,000

Min. Rev. U. S. 1887, pp. 456–8.
" " U. S. 1907, p. 86.
" " U. S. 1909, pp. 88–90.
Geol. Survey, Canada.

The following figures of production of the entire province are given in reports of the Geological Survey of Canada prior to 1908, and in the reports of the Mines Branch, Department of Mines, since 1908: –

TABLE IV.

Production, Value, and Average Price Per Barrel of Petroleum in Canada, from 1886 to 1912, inclusive.

Year	*Quantity-Barrels*[1]	*Value*	*Average Price Per Barrel.*
1886	584,061	$525,655	$ 0.90
1887	525,655	556,708	0.78
1888	695,203	713,695	$1.02\frac{2}{3}$
1889	704,690	653,600	$0.92\frac{3}{4}$

[1] Barrels of 35 imperial gallons.

Year	*Quantity-Barrels*[1]	*Value*	*Average Price Per Barrel.*
1890	795,030	902,734	1.18
1891	755,298	1,010,211	1.33¾
1892	779,753	984,438	1.26¼
1893	798,406	874,255	1.09½
1894	829,104	835,322	1.00¾
1895	726,138	1,086,738	1.49⅔
1896	726,822	1,155,647	1.59
1897	709,857	1,011,546	1.42½
1898	758,391	1,202,020	1.40
1899	808,570	1,151,007	1.48⅔
1900	913,498	1,479,867	1.62
1901	756,679	1,225,820	1.62
1902	530,624	951,190	1.79¼
1903	486,637	1,048,974	2.15½
1904	552,575	984,310	1.78
1905	634,095	856,028	1.35
1906	569,753	761,760	1.337
1907	788,872	1,057,088	1.34
1908	527,987	747,102	1.41½
1909	420,755	559,604	1.33
1910	315,895	388,550	1.23
1911	291,096	357,073	1.23
1912	243,614	345,930	1.42

[1] Barrels of 35 imperial gallons.

The production prior to 1895 was sold at prices established by the Petrolia Oil Exchange—now the producers make sales direct to the refiners.

In the following table will be found a statement of the production of petroleum from each producing state of the United States from the year 1859 to and including the production of the year 1912:—

TABLE V.

Producers of Natural Gas in Canada.

ARRANGED ACCORDING TO PROVINCES AND COUNTIES

(From lists in the office of the Division of Mineral Resources and Statistics, Mines Branch, Ottawa)

Name of Company	*Address*	*Location of Wells*	*No. of Producing Wells as on Dec. 31, 1913*	*Representative or Manager*
Maritime Oil Fields, Ltd.	Moncton, Box 196	Albert co., N.B., Stony Ck. Dist.	31	A. Crichton.
The Canadian Natural Gas Co.	St. Hyacinthe, Que.	St. Hyacinthe co., Que., St. Barnabé	1	
The Provincial Natural Gas and Fuel Co. of Ontario, Ltd.	Niagara Falls	Welland co., Ont	212	D. A. Coste, Supt.
Bertie Natural Gas Co., Ltd.	Ridgeway	" " Bertie tp.	11	A. H. Kilman, Secy.
Empire Limestone Co.	Buffalo, 4th and Virginia	" " Humberstone tp.	17	J. N. Morris, Asst. Treas.
Niagara Nat. Gas and Fuel Co., Ltd.	Sherkston	" " " " II, 4, 5	3	B. F. Mathews, Pres.
Humberstone Mutual Nat. Gas and Fuel Co.	Humberstone	" " " "	2	L. R. Snyder, Secy.-Treas.
Miner and Mekelenbacker	"	" " " "	1	O. P. Miner.
Industrial Natural Gas Co.	Port Robinson	" " " and Crowland	43	Thos. Coulter, Mgr.
The United Gas Companies, Ltd.	St. Catharines, 45 King	" " Wainfleet tp.	39	P. I. Price.
J. A. Coleman	Wellandport	" " "	4	
Welland County Lime Works, Ltd.	Port Colborne	" " " and Humberstone tp.	32	D. Alair, Secy.
Sterling Gas Co., Ltd.	"	" and Haldimand co.	45	C. E. Steele, Mgr.
The Dominion Natural Gas Company.	Buffalo, 842 Marine Bk. Bldg.	Haldimand, Norfolk, Elgin, Lincoln, and Wentworth cos.	406	Art. J. Devlin.
F. R. Lalor	Dunnville	Haldimand co., Moulton tp.	5	H. E. Arderlay, Secy.
J. J. Lawson	Stromness	" "	3	
Buffalo and Dunnville Oil and Gas Co.	Dunnville	" "	5	Jesse Kittinger, Pres.
Canboro Nat. Gas Co., Ltd.	Canboro	" Canboro tp.	1	N. R. Teeft, Secy.-Treas.
Chippewa Oil and Gas Co.	Tavistock	" "	2	A. E. Ratz, Secy.
Moote, Melick and Lymburner	Canboro	" "	10	Robt. J. Melick.
Aikens and Kohler	Dunnville	" "	17	W. J. Aikens.
Lint and Emmerson	Attercliffe Sta.	" "	4	Jno. W. Lint.
Melvin G. Hart and Co.	"	" "	2	
Aikens, Beck and Lalor	Dunnville	" Cayuga South	21	W. J. Aikins.
F. L. Snively	" Box 232	" Cayuga South and Rainham	27	
The Waines and Root Gas Co., Ltd.[1]	"	" Cayuga S., Rainham, Dunn, Canboro, Walpole	71	
The Midfield Nat. Gas Co.	Hamilton, 32 Stinson	" Cayuga North	7	Walter Armstrong, G. Mgr.
Canfield Natural Gas Co., Ltd.	Canfield	" " "	3	W. M. Thompson, Secy.
Azoff Gas Co., Ltd.	"	" " "	1	Wm. Thompson.
Sundy Gas Well Co.	Dunnville	"	2	Jas. Ralton and Bennett.
Port Maitland Nat. Gas Co.	Port Maitland	" Dunn tp.	1	Ed. Martin.
The Dunn Nat. Gas Co., Ltd.	Dunnville	" "	16	W. J. Aikins.
The Eastside Gas Co.	Port Maitland	" "		
Jas. S. Jones	"	" "	4	
Lalor, Aikins and Smith	Dunnville	" " and Sherbrooke	16	W. J. Aikins.
The Home Natural Gas Co., Ltd.	Hamilton, 18 Cottage Ave.	" Oneida tp.	4	Robt. H. Foster.
The Aldrich Gas and Oil Co., Ltd.	"	" Rainham tp.	10	W. Aldrich, Mgr.
David E. Hoover	Selkirk	" "	8	J. A. Norrington.
D. E. and A. E. and M. Hoover	Rainham Centre	" "	7	
D. Kindy and Sons	Selkirk	" "	7	
Kindy Gas Company	Rainham	" "	3	Josiah Kindy.
North Shore Gas Co., Ltd.	Hamilton, Bk. of Hamilton Bldg.	" "	14	S. C. Macdonald, Sec.-Treas.
Fisherville Gas Co.	Fisherville	" "	2	Chris. Held.
National Gas Co., Ltd.	Rainham Centre	" " and Seneca tps.	72	R. F. Miller, Gen. Mgr.
The Producers Natural Gas Co., Ltd.	Buffalo, 842 Marine Bank Bldg.	" " and Walpole tps.	80	Art. J. Devlin, Agent.
The Holmes Gas Co., Ltd.	Selkirk	" " "	30	W. C. Holmes, Secy.
Port Colborne—Welland Natural Gas Co.	Port Colborne	" Seneca tp.; also Brant co., Onondaga tp.	25	Geo. H. Smith, Secy.-Treas.
Lime and Cement Works	Hamilton	" Seneca tp.	24	Jas. Marshall, Hamilton.
J. E. Hoover	Selkirk, Box 18	" Walpole tp.	6	
Lalor and Vokes	Dunnville	" "	11	H. E. Arderlay, Secy.
Nanticoke Natural Gas Co., Ltd.	Cheapside	" "	2	S. A. Thompson.
M. Wederick	"	" "	1	
Regal Natural Gas Company	Hagersville	" "	4	Howard Hager.
Cheapside Natural Gas Co., Ltd.	Cheapside	" "	3	Geo. E. Pond.
Alfred Lamb	Selkirk	" "	14	
Walter B. Lamb	Nanticoke	" "	11	
Enterprise Gas Co., Ltd.	Buffalo, 842 Marine Bank Bldg.	Norfolk co., Middleton tp. (Delhi)	9	Art. J. Devlin, Agent.
The Norfolk Gas Co., Ltd.	" " "	" Woodhouse tp. (Pt. Dover)	11	Art. J. Devlin, Secy.-Treas.
Port Rowan Natural Gas Co.	" " "	" Walsingham tp. (Pt. Rowan and St. Williams)	10	"
North Western Gas Co., Ltd.	Erie, Pa., 611 Masonic Temple	Brant co.	4	J. S. Owen, Secy.-Treas.
Standard Natural Gas Co., Ltd.	Dunnville	" Onondaga tp.	30	W. J. Aikins.
The Onondaga Oil and Gas Co.	Brantford	" "	12	Jas. C. Spence, Secy.-Treas.
Telephone City Oil and Gas Co., Ltd.	"	" "	4	B. Forsayerth, Secy.-Treas.
Commonwealth Oil and Gas Co.	Hamilton, 165 Bay N.	" "	2	Geo. Schuabel, Pres.
The Crystal Oil and Gas Co., Ltd.	Paris, River St.	" "	4	Jas. R. Inksater.
Grand River Oil and Gas Co., Ltd.	Brantford, 116 Dalhousie	" "	5	Alf. J. Wilkes, Secy.
D. Danskin	Cainsville	" "	1	
A. W. VanSickle	Onondaga	" "	3	
Wentworth Natural Gas Co., Ltd.	Hamilton	" "	2	M. Westcott.
Thomas Walker	Caledonia, R.R. No. 2	" Tuscarora tp.	1	
Oxford Oil and Gas Co., Ltd.	Brantford, 17 Albion	Oxford co., East Zorra tp.	3	J. J. Howey.
The Medina Natural Gas Co., Ltd.	Chatham, 40 Fifth St.	Elgin co., Bayham tp.	18	W. C. Ryan, Mgr.
The Union Natural Gas Co. of Canada, Ltd.	Niagara Falls	Kent co., Romney, Raleigh, and Tilbury E.	88	D. A. Coste, Secy.
The Canadian Gas Co., Ltd.	Detroit, Mich., 1426 Dime Bk Bldg.	Kent and Essex co., Romney, Mersea, and Gosfield S.	20	W. H. Beamer, Pres.
The Beaver Oil and Gas Co., Ltd.*	Brantford, 66½ Market	Kent co., Romney	14	
The Maple City Oil and Gas Co., Ltd.	Buffalo, 842 Marine Bank Bldg.	" Romney and Tilbury tps.	3	F. M. Lowry, Gen. Mgr.
Glenwood Natural Gas Co., Ltd.	" " "	" Raleigh tp.		" " "
Oil Springs Oil and Gas Co., Ltd.	Oil Springs	Lambton co., Euphemia tp.	2	A. W. Parks, Pres.
William Hawkin	Warwick	" Warwick tp., Egremont Rd., III. 7		
Corporation City of Medicine Hat	Medicine Hat, Alta.	Medicine Hat, Alta., Tp. 12	11	J. W. Craft, Supt., Box 265.
Canadian Pacific Railway	" "	" " (2) Carlstadt. (1). Tp. 15 Suffield (1) Tp. 14	4	R. S. Winter, Gas Inspector
Medicine Hat Brick Co., Ltd.	" "	Medicine Hat	1	A. P. Pashouse, Secy.
The Alberta Rolling Mills Co., Ltd.	" "	" "	1	J. L. Pollock, Pres.
Redcliff Brick and Coal Co., Ltd.	Redcliff, Alta.	Redcliff, Alta., Tp. 13	2	E. R. Sellhorn.
The Redcliff Light and Power Co., Ltd.	" "	" " "	4	H. O. Wheeler, Secy.
Dominion Glass Co., Ltd.	" "	" " "	1	Geo. Lydiatt.
Redcliff Rolling Mills and Bolt Co., Ltd.	" "	" " "	1	John Husband, Mgr.
Canada Cement Co.	Montreal, Herald Bldg.	Medicine Hat, Alta., (6 mi. south). Tp. 12	(Drilling)	H. L. Doble, Comptroller.
Dunmore Dev. Company, Limited	Medicine Hat, Alta.	Dunmore, Alta.	1	W. T. Black.
The Can. Western Nat. Gas L. H. and P. Co., Ltd.	Calgary, Alta.	Bow Id. (16) Tp. 10, Brooks (2) Tp. 18, Dunmore Tp. 12	19	Eug. Coste, Man. Dir.
Town of Bow Island	Bow Island, Alta.	Bow Island, Alta.	(Drilling)	W. A. Bateman, Secy.
Irvine Light and Power Co.	Irvine, Alta.	Irvine, Tp. 11, R. 2	"	S. W. Arbuckle.
High River Oil and Gas Co., Ltd.	Calgary, Box 18	High River, Alta. Tp. 19, R. 28	1	Geo. E. Mack.
The Calgary Pet. Producer Co., Ltd.	Calgary, Alta.		2	A. W. Dingman.
Lacombe Brick and Tile Co.	Lacombe, Alta.	Lacombe, Alta. Tp. 40. R. 27		W. L. Crane, City Eng.
City of Wetaskiwin	Wetaskiwin, Alta.	Wetaskiwin, Alta. Tp. 46. R. 24	1	L. B. Browne, Secy.
Municipality of Castor	Castor, Alta.	Castor, Alta. Tp. 37. R. 13	1	L. P. Browne, Secy.
Municipality of Tofield	Tofield, Alta.	Tofield, Alta. Tp. 50. R. 19	(Drilling)	J. W. McMullen, Sec.
Municipality of Vegreville	Vegreville, Alta.	Vegreville, Alta. Tp. 52. R. 14	1	H. R. Pozer, Secy.
Athabasca Natural Gas Co., Ltd.	Athabaska, Alta.	Athabaska, Alta. Tp. 66	(Drilling)	A. A. Greer, Pres.

[1]Present address, 842 Marine Bank Bldg., Buffalo, N.Y.

NATURAL GAS.

Canada.

The preliminary report on the mineral production of Canada for 1912, published by the Mines Branch, Department of Mines, states:—

"While the production of petroleum has been declining, the output and use of natural gas has been steadily increasing. The southern portion of Ontario has for many years been the principal source of gas, but the Albert County field in New Brunswick is now an important producer, while large developments are taking place in Alberta with such a rapid increase in output of gas that this Province may soon take first place as a producer.

"The total production of natural gas in Canada in 1912 was approximately 15,286,803,000 cubic feet, valued at $2,362,700, and includes 12,529,463,000 cubic feet in Ontario, valued at $2,036,245, and 2,583,437,000 cubic feet in Alberta, valued at $289,906. New Brunswick production was 173,903,000 cubic feet. The production in 1911 was reported at 11,644,000,000 cubic feet, valued at $1,917,678, including 10,864,000,000 cubic feet in Ontario, valued at $1,807,513, and 780,000,000 cubic feet in Alberta, valued at $110,165. These values represent as closely as can be ascertained the value received by the owners or operators of the wells for gas produced and sold or used. The values do not represent what consumers have to pay since in many cases the gas is resold once or twice by pipe-line companies before reaching the consumer."

The following table gives the value of natural gas produced in Canada each year since 1892, by Provinces:—

TABLE VI.

Value of Natural Gas produced in Canada, by Provinces, 1892-1912.

Year[1].	Alberta.	Ontario.	Total Canada.
1892	....	$150,000	$150,000
1893	....	238,200	238,200
1894	....	204,179	204,179
1895	....	282,986	282,986
1896	....	276,710	276,710
1897	....	308,448	308,448
1898	....	301,599	301,599
1899	....	440,904	440,904
1900	....	392,823	392,823
1901	....	342,183	342,183
1902	....	195,992	195,992
1903	*a*$5,675	196,535	202,210
1904	*a*74,852	253,524	328,376
1905	*a*63,085	316,476	379,561
1906	*a*50,077	533,446	583,523
1907	*a*68,533	746,499	815,032
1908	*a*24,044	988,616	1,012,660
1909	61,722	1,145,307	1,207,029
1910	75,168	1,271,303	1,346,471
1911	110,165	1,807,513	1,917,678
1912	*a*326,455	2,036,245	2,362,700

a Alberta and other.

[1] The first year in which records of natural gas were kept was 1892.

Italy.

The *Rivista Minerario* gives the production and value of natural gas in Italy from 1903 to 1912, as follows:—

TABLE VII.

Production and value of Natural Gas in Italy, 1903-1912.

Year	*Quantity (cubic meters)*	*Value*
1903	2,255,596	$15,024
1904	2,551,396	16,715
1905	3,092,000	19,310
1906	5,723,469	32,394
1907	5,710,000	32,279
1908	6,737,500	33,809
1909	8,268,000	42,287
1910	8,840,000	73,301
1911	9,021,000	74,174
1912	Not available	Not available

United Kingdom.

The annual report of the British home office gives the statistics of the production and value of natural gas in the United Kingdom for the years 1902 to 1912 as follows:

TABLE VIII.

Production and value of Natural Gas at Heathfield, (a) **England, 1902-1912.**

Year	*Quantity cubic feet*	*Value*
1902	150,000	$146
1903	972,460	944
1904	774,800	754
1905	(b)	(c)
1906	(b)	(c)
1907	(b)	(c)
1908	(b)	(c)
1909	236,800	(c)
1910	262,000	(c)
1911	221,400	(c)
1912	(d)	(c)

(a) Heathfield in Sussex county.

(b) None reported. The railway station at Heathfield, however, is lighted with it, but the quantity is not ascertained.

(c) Not stated.

(d) Not available.

TABLE IX.

Distribution of Gas consumed for industrial purposes in the United States.[1]

The following table gives the distribution of gas consumed for industrial purposes in 1912, by States.

STATE.	Industrial consumers.			Gas consumed.			Gas consumed.					
				Manufacturing.			Other industrial (power).			Total industrial.		
	Manufacturing	Other industrial	Total.	Quantity (M cubic feet).	Cents per M cubic feet.	Value	Quantity (M cubic feet).	Cents per M cubic feet.	Value.	Quantity (M cubic feet).	Cents per M cubic feet.	Value.
Pennsylvania	1,987	1,455	3,442	114,617,963	11.45	$13,127,440	9,706,948	12.42	$1,205,608	124,324,911	11.53	$14,333,048
Ohio	2,768	1,646	4,414	43,300,321	12.86	5,568,386	16,403,594	13.46	2,207,690	59,703,915	13.02	7,776,076
West Virginia	888	1,065	1,953	59,189,820	5.07	2,998,754	20,031,650	5.35	1,071,949	79,221,470	5.14	4,070,703
Kansas	959	145	1,104	32,353,405	6.94	2,246,186	3,143,299	8.19	257,309	35,496,704	7.05	2,503,495
Oklahoma	288	1,363	1,651	20,915,974	4.56	954,498	14,133,367	6.41	905,984	35,049,341	5.31	1,860,482
Louisiana	550	882	1,432	2,992,216	8.38	250,803	8,628,773	8.01	691,311	11,620,989	8.11	942,114
Alabama												
California	....	232	232	....	....	....	8,379,632	7.27	609,028	8,379,632	7.27	609,028
Texas	(a)	329	329	(a)		(a)	5,128,745	9.72	498,665	5,128,745	9.72	498,665
Illinois	26	186	212	948,415	10.00	95,088	3,418,791	6.71	229,392	4,367,206	7.43	324,480
New York	11	794	805	354,333	16.51	58,518	1,243,454	18.09	224,889	1,597,787	17.74	283,407
Kentucky	19	84	103	1,671,287	7.97	133,220	669,083	14.66	98,098	2,340,370	9.88	231,318
Indiana	20	120	140	223,547	18.19	40,675	404,882	15.16	61,368	628,429	16.24	102,043
Arkansas												
Colorado	(a)	103	103	(a)	....	(a)	870,751	6.93	60,315	870,751	6.95	60,315
Wyoming												
South Dakota	....	3	3	....	....	....	9,900	54.55	5,400	9,900	54.55	5,400
North Dakota												
Missouri	....	11	11	....	....	....	7,600	26.97	2,050	7,600	26.97	2,050
Michigan	....	2	2	....	....	....	900	50.00	450	900	50.00	450
Total	7,516	8,420	15,936	276,567,281	9.21	$25,473,568	92,181,369	8.82	8,129,506	368,748,650	9.11	33,603,074

a Included in other industrial.

[1] B. Hill. The Production of Natural Gas in 1912. Min. Res. of U.S. for 1912, pp. 9-10.

TABLE X.

Value of Natural Gas produced in the United States, 1882-1912, by States.

State.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.
Pennsylvania	$75,000	$200,000	$1,100,000	$4,500,000	$9,000,000	$13,749,500	$19,282,375	$11,593,989	$9,551,025	$7,834,016	$7,376,281
New York				196,000	210,000	333,000	332,500	530,026	552,000	280,000	216,000
Ohio				100,000	400,000	1,000,000	1,500,000	5,215,669	4,684,300	3,076,325	2,136,000
West Virginia				40,000	60,000	120,000	120,000	12,000	5,400	35,000	70,500
Illinois				1,200	4,000			10,615	6,000	6,000	12,988
Indiana					300,000	600,000	1,320,000	2,075,702	2,302,500	3,942,500	4,716,000
Kansas					6,000			15,873	12,000	5,500	40,795
Missouri								35,687	10,500	1,500	3,775
California								12,680	33,000	30,000	55,000
Kentucky								2,580	30,000	38,993	43,175
Tennessee											
Texas								1,728			100
Alabama											
Louisiana											
Arkansas								375		250	100
Wyoming											
Colorado											
Utah											
South Dakota											
North Dakota											
Indian Territory											
Oklahoma											
Oregon											
Iowa											
Michigan											
Other	140,000	275,000	360,000	20,000	32,000	15,000	75,000	1,600,175	1,606,000	250,000	200,000
	$215,000	$475,000	$1,460,000	$4,857,200	$10,012,000	$15,817,500	$22,629,875	$21,107,099	$18,792,725	$15,500,084	$14,870,714

State.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.
Pennsylvania	$6,488,000	$6,279,000	$5,852,000	$5,528,610	$6,242,543	$6,806,742	$8,337,210	$10,215,412	$12,688,161	$14,352,183
New York	210,000	249,000	241,530	256,000	200,076	229,078	294,593	335,367	293,232	346,471
Ohio	1,510,000	1,276,100	1,255,700	1,172,400	1,171,777	1,488,308	1,866,271	2,178,234	2,147,215	2,355,458
West Virginia	123,000	395,000	100,000	640,000	912,528	1,334,023	2,335,864	2,959,032	3,954,472	5,390,181
Illinois	14,000	15,000	7,500	6,375	5,000	2,498	2,067	1,700	1,825	1,844
Indiana	5,718,000	5,437,000	5,203,200	5,043,635	5,009,208	5,060,969	6,680,370	7,254,539	6,954,566	7,081,344
Kansas	50,000	86,600	112,400	124,750	105,700	174,640	332,592	356,900	659,173	824,431
Missouri	2,100	4,500	3,500	1,500	500	145	290	547	1,328	2,154
California	62,000	60,350	55,000	55,682	50,000	65,337	86,891	79,083	67,602	120,648
Kentucky	68,500	89,200	98,700	99,000	90,000	103,133	125,745	286,243	270,871	365,356
Tennessee										300
Texas	50	50	20			765	8,000	20,000	18,577	14,953
Alabama										
Louisiana										
Arkansas	100	100	100	60	40					
Wyoming										
Colorado		12,000	7,000	4,500	4,000	3,300	1,480	1,800	1,800	1,900
Utah	500	500	20,000	20,000	15,050	7,875				
South Dakota							3,500	9,817	7,255	10,280
North Dakota										
Indian Territory										360
Oklahoma										
Oregon										
Iowa										
Michigan										
Other	100,000	50,000	50,000	50,000	20,000	20,000				
	$14,346,250	$13,954,400	$13,006,650	$13,002,512	$13,826,422	$15,296,813	$20,074,873	$23,698,674	$27,066,077	$30,867,863

State.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.
Pennsylvania	$16,182,834	$18,139,914	$19,197,336	$18,558,245	$18,844,156	$19,104,944	$20,475,207	$21,057,211	$18,520,796	$18,539,672
New York	493,686	522,575	623,251	672,795	766,157	959,280	1,222,666	1,678,720	1,418,767	2,343,379
Ohio	4,479,040	5,315,564	5,721,462	7,145,809	8,718,562	8,244,835	9,966,938	8,626,954	9,367,347	11,891,299
West Virginia	6,882,359	8,114,249	10,075,804	13,735,343	16,670,962	14,837,130	17,538,565	23,816,553	28,435,907	33,349,021
Illinois	3,310	4,725	7,223	87,211	143,577	446,077	644,401	613,642	687,726	616,467
Indiana	6,098,364	4,342,409	3,094,134	1,750,715	1,572,605	1,312,507	1,616,903	1,473,403	1,192,418	1,014,295
Kansas	1,123,849	1,517,643	2,261,836	4,010,986	6,198,583	7,691,587	8,293,846	7,755,367	4,854,534	4,336,635
Missouri	7,070	6,285	7,390	7,210	17,010	22,592	10,025	12,611	10,496	11,576
California	104,521	114,195	133,696	134,560	168,397	307,652	446,933	476,697	800,714	1,134,456
Kentucky	390,301	322,104	237,290	287,501	380,176	424,271	485,192	456,293	407,689	497,909
Tennessee	300	300	300	300	300	350	350	300	300	375
Texas	13,851	14,082	14,409						1,014,945	1,405,077
Alabama				150,695	178,276	236,837	453,253	956,683	858,145	1,747,379
Louisiana			1,500							
Arkansas	2,460	6,515	21,135	34,500						
Wyoming					126,582	164,930	226,925	301,151	295,858	309,816
Colorado	14,140	14,300	20,752	22,800						
Utah										
South Dakota	10,775	12,215	15,200	15,400	19,500	24,400	16,164	31,999	16,984	30,412
North Dakota					235	2,480	3,025	7,010	5,738	
Indian Territory	1,000	49,665	130,137	259,862	417,221	860,159	1,806,193	3,490,704	6,731,770	7,334,599
Oklahoma					100	250	50			
Oregon						93	50	40	70	120
Iowa							255	820	1,330	1,470
Michigan										
Other										
	$35,807,860	$38,496,760	$41,562,855	$46,873,932	$54,222,399	$54,640,374	$63,206,941	$70,756,158	$74.621,534	$84,563,957

CHAPTER II.

PHYSICAL PROPERTIES OF PETROLEUM.

COLOUR.

The colour of a crude oil is usually taken by reflected light, although where the oil is translucent the colour by transmitted light is usually recorded also.

Colour by transmitted light: While most crude oils are opaque, except in very thin layers, when they are brown, many of the thinner grades of Pennsylvania oils and oils lately found in Alberta vary in colour from a pale straw to various shades of yellow, red, brown, and deepening shades of brown to black.

Colour by reflected light: Crude oils have usually a green cast by reflected light. Otherwise they vary in colour from yellow to black—the same as when seen by transmitted light. The greenish colour by reflected light is an important characteristic of crude oils. It is a case of dichroism, differing from the bluish florescence of refined oils. It is frequently a convenient means of distinguishing between crude oils and those which have been manufactured.

Dark crude oils can be deprived of their colour by filtration through Fuller's earth or clay. This is probably what happens in earth where white oils are found.

White oils are not common in America, but are sometimes found. Some cases have been noted in the Los Angeles field, California, which had a specific gravity of 0·810; some in the Placenta Canon district, California, which had a specific gravity of 0·740; some at Butler, Ohio, with a specific gravity of 0·7407.

There are black oils in Mexico, Wyoming, Texas, etc. One Wyoming oil had a specific gravity of 0·966.

The following is a table showing specific gravity, flashing point, and the colour of various Canadian oils, taken from Sir Boverton Redwood's Treatise on Petroleum, Volume One:

Physical Properties of Crude Petroleums in Canada.

Locality	Specific Gravity	Flashing Point (AbelTest.) F	Colour
Canada:			
Petrolia	0·858	....	Dark brown
New Field	0·840	Below 60°	Reddish brown
Gaspe—1	0·881	180°	Brown
2	0·856	65°	Brown
3 (2,057 feet)	0·853	54°	Dark brown
4 (906 feet)	0·877	90°	Dark brown
5	0·939	280°	Black
6	0·921	210°	Brown
7	0·948	....	Brown
8	0·871	104°	Brown
9	0·894	....	Brown
10 (2,361 feet)	0·847	46°	Brown
11	0·844	60°	Brown
12 (1,946 feet)	0·861	183°	Brown
13	0·795	20°	
14	0·828	Below 0°	
New Brunswick—1	0·857	40°	
2	0·852	Below 50°	Reddish brown
3	0·862	95°	
4	0·855	84°	
5	0·838	Below 60°	Dark reddish brown

ODOUR.

Oils from various regions are so well distinguished by odour, that it is frequently quite possible to note the origin of an oil in this way. Thus, the Pennsylvania oils have a peculiar odour described as gasoline odour. On the other hand, the oils of California, while having much less odour, have an aromatic smell somewhat like that of coal tar oils. The oils of Texas and Russia smell very much alike, and it is easy to detect an odour similar to oil of cedar in the petroleum from the East Indies. Frequently these characteristic odours are clouded by the strong disagreable odour of hydrogen sulphide. Other organic sulphur compounds give a peculiar, disagreeable character to the odour of much of the oil from Ontario which is like that of the oils of Ohio and Indiana.

In order to determine the characteristic odour of an oil, three samples should be prepared in narrow bottles, carefully stoppered, and half filled with the oil. The oil is shaken vigorously so as to impart its odour to the air above the oil in the bottle and, if this gives the odour of hydrogen sulphide, five cubic centimeters of a fairly strong solution of caustic potash should be added and the oil shaken until the odour of sulphide of hydrogen disappears. In the case of many of the California oils, the shaking with caustic potash solution will give an odour of pyrridine. In a second sample, the odour should be noted after similar treatment of five cubic centimeters of dilute sulphuric acid.

SPECIFIC GRAVITY.

All varieties of petroleum are lighter than water, except when contaminated with finely suspended mineral matter; therefore the specific gravity, *i.e.* its weight, compared with water as one, is expressed as a decimal ranging usually between 0·780 and 1·0. Petroleum lighter than 0·780 is rarely found. More commonly, the specific gravity of petroleum ranges between 0·85 and 0·94. It becomes denser on exposure to air.

On account of the inconvenience of using a decimal fraction as an expression of specific gravity, another system is used—the Baume scale which, while entirely arbitrary, is very convenient. The standard hydrometer scale is known as the specific gravity scale, and has as its initial point distilled water, which on the scale reads 1·000 or 1,000. It is divided decimally above this for liquids heavier than water and below for liquids lighter than water; all oils come under the latter. If an oil is 25 per cent lighter than water, it will therefore read 0·750 specific gravity; 15 per cent lighter than water 0·850 specific gravity, etc. This scale is used by the oil trade in England, France, Germany, Austria, and in fact nearly all of the continental countries. The oil industry in this country, however, has adopted and always used a scale known by its author's name, the Baume or Beaume, both spellings being extensively used.

Antoine Baume first published his table for liquids lighter than water about 1768. He derived his values from solutions of salt and water, and as his methods were what would now be known as crude, his errors were so large that an exact duplicate of his original solutions is impossible. Since the appearance of this first table there have been some fourteen different tables, all by good authorities, each known as the Baume table. Lately the United States Bureau of Standards has adopted the following relation of Baume scale to specific gravity: If 140 is divided by the specific gravity of the liquid taken at 60° and compared with water at 60° and 130 be subtracted, the result is the corresponding number of degrees Baume or

$$\text{Degrees Baume} = \frac{140}{\text{Specific Gravity}\frac{60^\circ}{60^\circ}\text{F.}} - 130.$$

The following table shows the specific gravity of the liquid and the pounds in a gallon for each degree Baume:—

Equivalents of the Baume Scale and Specific Gravity.

Baume	Spec. Gravity	Lbs. Per Gal.	Baume	Spec. Gravity	Lbs. Per Gal.
10	1·0000	8·33	61	0·7329	6·11
11	0·9929	8·27	62	0·7292	6·07
12	0·9859	8.21	63	0·7254	6·04
13	0·9790	8·16	64	0·7217	6·01
14	0·9722	8·10	65	0·7179	5·98
15	0·9655	8·04	66	0·7143	5·95
16	0·9589	7·99	67	0·7107	5·92
17	0·9524	7·93	68	0.7071	5·89
18	0·9459	7·88	69	0.7035	5.86
19	0·9396	7.83	70	0·7000	5.83
20	0·9333	7.78	71	0·6965	5·80
21	0.9272	7·72	72	0·6931	5·78
22	0·9211	7·67	73	0·6897	5·75
23	0·9150	7·62	74	0·6863	5·72
24	0·9091	7·57	75	0·6829	5·69
25	0·9032	7·53	76	0·6796	5·66
26	0·8974	7·48	77	0·6763	5·63
27	0·8917	7·43	78	0·6730	5·60
28	0·8861	7·38	79	0·6698	5·58
29	0·8805	7·34	80	0·6666	5·55
30	0·8750	7·29	81	0·6635	5·52
31	0·8696	7·24	82	0·6604	5·50
32	0·8642	7·20	83	0·6573	5·48
33	0·8589	7·15	84	0·6542	5·45
34	0·8537	7·11	85	0·6511	5·42
35	0·8485	7·07	86	0·6481	5·40
36	0·8433	7·03	87	0·6451	5·38
37	0·8383	6·98	88	0·6422	5·36
38	0·8333	6·94	89	0·6392	5·33
39	0·8285	6·90	90	0·6363	5·30
40	0·8235	6·86	91	0·6335	5·28
41	0·8187	6·82	92	0·6306	5·25
42	0·8139	6·78	93	0·6278	5·23
43	0·8092	6·74	94	0·6250	5·21
44	0·8046	6·70	95	0·6222	5·18
45	0·8000	6·66	96	0·6194	5·16
46	0·7955	6·63	97	0·6167	5·14
47	0·7909	6·59	98	0·6140	5·11
48	0·7865	6·55	99	0·6113	5·09
49	0·7821	6·52	100	0·6087	5·07
50	0·7777	6·48	101	0·6060	5·05
51	0·7735	6·44	102	0·6034	5·03
52	0·7692	6·41	103	0·6008	5·00
53	0·7650	6,37	104	0·5983	4·98
54	0·7609	6·34	105	0·5957	4·96
55	0·7568	6·30	106	0·5932	4·94
56	0·7527	6·27	107	0·5907	4·92
57	0·7487	6·24	108	0·5882	4·90
58	0·7447	6·20	109	0·5858	4·88
59	0·7407	6·17	110	0·5833	4·86
60	0·7368	6·14			

All densities taken at temperatures of 60°F and referred to distilled water at 60°F as standard.

The most practical instrument for testing the specific gravity of an oil is the hydrometer, which is undoubtedly familiar to all interested in the testing of oils. For the benefit of any who are interested in this subject and have not had actual use of the instruments, we will describe a hydrometer as an instrument composed of a long cylindrical body with tapering ends; on the upper end is mounted a stem, which stands at right angles to the diameter of the body; this stem contains the scale showing the gravity readings. At the lower extremity of the body is attached a small bulb or body, containing a weighted substance, usually mercury or lead shot, and adjusted so as to make the instrument float with the stem always perpendicular to the surface of the liquid. Hydrometers are nearly always made of glass, although there are a few metal forms on the market, and are made either with or without a thermometer placed inside the body, in the latter form enabling one to take the exact temperature of the oil at the time the gravity test is being made.

The important features in the handling and use of the hydrometer are: always have the instrument clean, as dirt will either weigh it down or buoy it up; see that the surface of the oil is free from dirt, dust, and air bubbles, and do not force the instrument down or allow it to sink more than an eighth or at the most a quarter of an inch over the point at which it will float, as the oil clinging to the stem will give it extra weight and cause inaccurate readings. With ordinary care in making the test, a hydrometer will give readings of the highest accuracy.

FRACTIONAL DISTILLATION.

While separation of oils into their individual constituent hydrocarbons is possible, it is never carried out, and the oil is separated merely into such portions as will best fill the requirements of trade, which in the past have been simple. These requirements depend chiefly upon the boiling point (volatility) of the products. Thus internal combustion engines require oils (grouped as naphtha, benzine, gasoline, motor spirit, etc.) which will easily vaporize and mixing with air explode easily in an automobile cylinder. Illuminating oils require that these explosive portions shall be removed so the oil will burn safely in lamps. Again, lubricating oils must be still more difficultly vaporized, so that by separating the oils into these three classes each one is better by being separated from the other.

The tables above show that oils with low specific gravity have correspondingly low boiling points, for members of the same series. When the crude oil is heated the most volatile oils are first to distil over. They are condensed by cooling and run into tanks by themselves as naphtha or crude gasoline until the gravity of the succeeding distillates shows that they are free from gasoline and safe for lamps. These are separated as "burning oil distillate," until the specific gravity becomes too heavy for the oils to rise freely in a wick, and the next products are set aside as gas oils because too thick for lamp oils and too thin for lubricants. The distillation continues at progressively high temperatures until various grades of lubricating oils have been distilled off and only a small percentage of coke is left in the still.

In examining a specimen of crude petroleum it is customary to distill 100 cubic centimeters in a glass flask of special dimensions, and at a specified rate heating prescribed by Engler and Ubbelohde and described in the rules offered by the International Petroleum Commission With American and Canadian, and most other petroleums, the distillate distilling over below 150° centigrade is taken as naphtha, and that between 150° and 300° as crude burning oil for lamps—with some Roumanian and other petroleums the burning oil fraction must be limited to 250°C. Higher products detract from the good quality of the oil.

By so distilling an oil a fair idea may be obtained as to what it will yield in a refinery, although by redistillation and the use of steam, much better separations can be made.

VISCOSITY.

The viscosity of oils increases as the specific gravity increases. It is measured by the time of flow of a given quantity through a small orifice in one of several types of viscosimeters. It is of value in determining the facility with which the oil can be pumped with or without heat through pipe lines. There is no dividing line between thick viscous oils and Maltha Brea and soft asphalt. The viscosity of paraffine oils usually increases quite rapidly with the lowering of temperature on account of amorphous wax contained.

The relation between Engler and Saybolt viscosimeters, which are frequently used in the examination of petroleum products, is thus given by Dr. S. W. Stratton, Director of the United States Bureau of Standards:

If E_t = time in secs. for outflow of 200cc with Engler
S_t = " " " " " 60cc " Saybolt
then $E_t = S_t F$
and $S_t = \frac{E_t}{F}$

where the conversion factors F have the values given in the following table:—

E_t *Secs.*	S_t *Secs.*	F *Conversion Factors*
65	37·8	1·72
70	41·7	1·68
80	50·0	1·60
90	58·1	1·55
100	66·2	1·51
125	86·2	1·45
150	106·4	1.41
175	125·9	1·39
200	146·0	1·37
2400	1765	1·36

Example 1. Suppose the observed time of outflow of 60cc with the Saybolt Universal viscosimeter was 1000 seconds. The conversion factor corresponding to $S_t = 1000$, taken from the above table, is about 1·365. Hence the corresponding Engler time is 1000 × 1·365 = 1365 seconds.

Example 2. Suppose the observed time of outflow of 200cc with the Engler viscosimeter was 185 seconds. The conversion factor corresponding to $E_t = 185$, taken from the above table, is about 1·38. Hence the corresponding Saybolt time is

$$\frac{185}{1\cdot 38} = 134 \text{ seconds.}$$

The above table was found to hold for all the oils tested ranging from light machinery to heavy cylinder oils, and at all temperatures, 70° to 210° F. The table must not be used below $E_t = 65$ seconds, as none of these viscosimeters are adapted to low viscous oils, as e.g. illuminating oils.

In the use of the Engler instrument, the so-called Engler numbers are very often used instead of the time in seconds. The Engler number is the time of outflow of 200cc of the oil at the test temperature divided by the time of outflow of 200cc of water at 20°C. With Engler instruments, having the standard dimensions specified for these instruments, and in which the variations do not exceed the specified limits, the time of outflow of 200cc of water at 20°C is between 50 and 52 seconds.

Example. Suppose the observed Engler time (for 200cc of oil at the test temperature) is 1000 seconds, and that the time of outflow of 200cc of water at 20° has been found to be 51 seconds. Then the corresponding Engler number is

$$\frac{100}{51} = 1\cdot 96$$

The above conversion table is given for the time of outflow of 200cc of oil, which is the standard method of using the Engler instrument. When viscous oils are tested at low temperatures, however, the time consumed for the outflow of 200cc is very long. The test can be very much abbreviated by observing the time of outflow of 50cc or of 100cc and multiplying by a suitable factor to reduce to the equivalent time for 200cc, in the way explained by Holde in his book on "Untersuchung der Mineralöle und Fette," 2nd ed. 1905, published by Julius Springer, Berlin.

A very complete investigation of the effect of small variations in the standard dimensions of the Engler viscosimeter is given by Meisener[1]. The same author has also published a paper in the same journal for January, 1912, giving the results of intercomparisons of one Universal Saybolt, one Redwood, and two Engler viscosimeters, with formulæ for reducing to absolute viscosities in dynes per square centimeter.

COEFFICIENT OF EXPANSION.

The coefficient of expansion of petroleum and its products varies not only with the density but with the locality from which oils are obtained. The following table, published by Dr. C. Engler[2] shows the coefficient of expansion of oils from various localities:—

Coefficients of Expansion of Crude Petroleum.

Origin	Coefficient of expansion × 1,000,000	Specific Gravity at ? °C × 1,000
Pennsylvania	840	816
Canada	843	828
Schwabweiler (Elsass)	843	829
Virginia	839	841
Schwabweiler (Elsass)	858	861
Wallachia	808	862
Eastern Galicia	813	870
Rangoon	774	875
Caucasus	817	882
Western Galicia	775	885
Ohio	748	887
Baku (Benkendorf property)	784	890
Oedesse (Hanover)	772	892
Pechelbronn—Pit oil	792	892
Wallachia	748	901
Oberg (Hanover)	662	944
Weitze (Hanover)	647	955

[1]Chemische Revue Uber die Fett-und Harz-Industrie, Heft 9, seite 202-209.

[2]Zeitangew. Chem. xxi, 1585-1597 (1908) Jour. Soc. Chem. Ind. xxvii, 643.

Höfer[1] gives the following co-officients of expansion for various oils:—

Relation of Coefficient of Expansion to Specific Gravity.

Origin	Density × 1,000 at 0° C.	Density × 1,000 at 50° C.	Coefficient of Expansion × 100,000.
West Virginia (White Oak)	873	853	46
(Burning Spring)	841	808	81
Pennsylvania (Oil Creek)	816	784	82
Canada	870	851	44
Burma (Rangoon)	892	861	72
Russia (Baku)	954	920	71
Eastern Gallicia	870	836	81
Western Gallicia	855	852	77
Rumania (Ploiesti) 1	862	829	80
(Ploiesti) 2	901	869	73
Italy (Parma, Neviano de Rossi)	809	772	96
Hanover (Oberg)	944	914	66
Elsass (Pechelbronn)	912	880	73
France (St. Gabian)	894	861	69
Zante	952	921	67

OPTICAL ACTIVITY.

The optical characteristics which are of value in connexion with the study of petroleum are:—

Index of Refraction; Petroleums from different fields vary in their refractive indices, and a study of this property is of frequent value in identifying the source of crude petroleums.

The following table, taken from Redwood, shows the relation of specific gravity to refractive index, in various petroleum derivatives from different localities:—

Refractive Indices of Petroleum Distillates.

	Fraction 140°–160°.		Fraction 190°–210°.		Fraction 240°–260°.		Fraction 290°–310°.	
	Sp. Gr.	Ref. Ind.	Sp. Gr.	Ref. Ind.	Sp. Gr.	Ref. Ind.	Sp. Gr.	Ref. Ind.
Tegernsee	0·7465	1·427	0·7840	1·437	0·8130	1·451	0·8370	1·465
Pechelbronn (Elsass)	0·7550	1·421	0·7900	1·440	0·8155	1·454	0·8320	1·462
Oelheim (Hanover)	0·7830	1·435	0·8155	1·450	0·8420	1·468	0·8620	1·480
Pennsylvania	0·7550	1·422	0·7860	1·439	0·8120	1·454	0·8325	1·463
Baku	0·7820	1·436	0·8195	1·454	0·8445	1·467	0·8640	1·475

[1] Das Erdöl, etc., 1888.

Optical Activity.—It has been found that many varieties of crude petroleum show double refraction. They usually rotate the plane of polarization to the right but many authorities have found a number of varieties of crude petroleum optically inactive while a few, particularly those in the East Indies, rotate the plane of polarization to the left. The optically inert petroleums are usually light paraffin oils from which various bodies known to be optically active have been removed by the natural process of diffusion and absorption. Just, as with the index of refraction, this variation in power to rotate the plane of polarization (polarized light) is useful in deciding upon the place of occurrence of crude petroleums.

THE CHEMICAL COMPOSITION OF PETROLEUM.

GENERAL COMPOSITION.

The varieties of petroleum found in different oil fields over the world are so different in their general composition as to present really almost continuous gradation from oils containing hydrocarbons of the paraffin series (with the general composition C_nH_{2n+2}) through the many series of hydrocarbons to oils which consist almost entirely of liquid asphaltum. Nevertheless, the predominance of one or another series of hydrocarbons in each field makes it possible to give a rough classification of the oils from different regions.

NATURE OF BASE.

The difficulty in refining oils which contain asphaltic bodies has led to a common division of petroleums into those which contain paraffin hydrocarbons alone—so-called "paraffin base" oils, and those which also contain asphaltic material—so-called "asphaltic base" oils.

HYDROCARBONS.

The oils which were first carefully studied were found in Pennsylvania and West Virginia, and were shown to consist chiefly of the members of the paraffin or methane series. Almost all the members from CH_4 (gaseous) to $C_{33}H_{68}$ (solid paraffin wax) were found. The study of Russian petroleum showed that this oil, while containing the paraffine series of hydrocarbons, also contains another series called napthenes which are hydrogen addition products of the benzol or aromatic series. An examination of the oils from the Gulf region of Texas and Louisiana showed the presence of small proportions of these same napthenes together with a considerable proportion of asphaltic bodies, but again containing a large proportion of paraffin hydrocarbons and even paraffin wax itself. A study of California oils showed that, while containing the same series of hydrocarbons found in Russian, Pennsylvanian, and Texas oils, also contain considerable proportions of the benzol or aromatic series. The examination of oils from Borneo and Sumatra brought to light still other hydrocarbons in addition to the ever-prevalent members of the paraffin series.

The following table gives a list of the individual hydrocarbons which have been found in petroleums in Canada:—

Canadian Hydrocarbons which have been identified.

Formula	Boiling Point	Specific Gravity at 20 ° C.
$C_{12}H_{24}$	216°	......
$C_{13}H_{26}$	228°–230°	0·8087
$C_{14}H_{28}$	141°–143° 50mm	0·8096
$C_{15}H_{30}$	159°–169° 50mm	0·8192

Individual Hydrocarbons known to exist in Petroleum.

Prof. Hans Hofer states that members of the following groups of hydrocarbons have been identified in petroleum:—

Hydrocarbons

C_nH_{2n+2}
C_nH_{2n}
C_nH_{2n-2}
C_nH_{2n-4}
C_nH_{2n-6}
C_nH_{2n-8}
C_nH_{2n-10}
C_nH_{2n-12}

Cn H_2n+_2 Hydrocarbons.

Composition	Spec. Gravity	Refractive Index	Boiling Point	Pressure	Melting Point	Authority
C_4H_{12}Iso.			0°	760 mm		Mabery
C_5H_{12}Nor.	0·6250 25/25°		36·3	"		Young
	0·6261 0/4°					"
	0·6454 "					"
" Iso.	0·6392 "		27·95	711 mm		"
C_6H_{14}Nor.	0·6771 "		68·95	"		"
" Iso.	0·6730 "		61·00	"		"
C_7H_{16}Nor.			98·40	"		"
" Iso.	0·6969 0/4°		90·30	"		"
C_8H_{18}Nor.	0·7188 20/20°		125·00	760 mm		"
" Iso.	0·7190 "		119·50	"		Mabery
C_8H_{20}Nor.			151·00	"		"
$C_{10}H_{22}$Nor.	0·7479 "		163–164	"		"
" Iso.	0·7467 "		173–174	"		"
$C_{11}H_{24}$	0·7581 "		196–197	"		"
$C_{12}H_{26}$Nor.	0·7676 "		214–216	"		"
$C_{13}H_{28}$	0·7834 "	1·451	226	"		"
$C_{14}H_{30}$	0·7814 "	1·436	236–238	"		"
$C_{15}H_{32}$	0·7896 "	1·4413	256–257	"		"
$C_{16}H_{34}$	0·7911 "	1·4413	274–275	"		"
$C_{17}H_{36}$	0·8000 "	1·4435	288–289	"	10	"
$C_{18}H_{38}$	0·8017 "	1·440	300–301	"	20	"
$C_{19}H_{40}$	0·8122 "	1·4522	210–212	50 mm	33—34	"
$C_{21}H_{44}$			230–231	"	40—41	"
$C_{22}H_{48}$	0·7796 15°		240–242	"	44	"
$C_{23}H_{48}$	0·7900 60°		258–261	"	45	"
$C_{24}H_{50}$	0·7902 "		272–274	"	48	"
$C_{25}H_{52}$	0·7941 "		280–282	"	53—54	"
$C_{26}H_{54}$	0·7977 "		292–294	"	58	"
$C_{31}H_{64}$	0.7992 70°		328–330	"	66	"
$C_{28}H_{58}$	0·7945 "		310–312	"	60	"
$C_{32}H_{66}$	0·8005 75°		342–345	"	68	"
$C_{34}H_{70}$	0·8009 80°		366–368	"	72	"
$C_{35}H_{72}$	0·80052 "		380-384	"	76	"

Monocyclic Polymethylenes—Cn H_2n.

Composition	Spec. Gravity	Boiling Point	Pressure	Authority
C_5H_{10} Penthamethylene	0·70000 04°	50°	760 mm	Young
C_6H_{12} Methylpentamethylene	0·7660 04°	72	"	"
C_6H_{12} Hexamethylene	0·7722 04°	80·6	"	"
C_7H_{14} Dimethylpentamethylene	0·7543 20/4°	94	"	"
C_7H_{14} Methylhexamethylene	0·7964 20/4°	102	"	"

Hydrocarbons Cn H_2n.

Composition	Spec. Gravity	Refractive Index	Boiling Point	Pressure	Authority
$C_{21}H_{42}$	0·8424 20/20°				
$C_{22}H_{44}$	0·8262 "	1·454	240-242°	50 mm	Mabery
$C_{23}H_{46}$	0·8569 "	1·4714	258-260	"	"
$C_{24}H_{48}$	0·8598 "	1·4726	272-274	"	"
$C_{26}H_{52}$	0·8580 "	1·4725	280–282	"	"

Hydrocarbons Cn H_2n-_2.

$C_{27}H_{52}$	0·8688 20/20°	1·4722	290–294°	50 mm	Mabery
$C_{28}H_{54}$	0·8694 "	1·4800	310-312	"	"

Napthenes from Petroleum.

Formula	Formation and Occurrence	Boiling Point °C.	Spec. Grav. $\frac{°C.}{°C.}$
C_6H_{12}	Hexahydrobenzene (Kijner) Russian petroleum	69°	0·7539
C_7H_{14}	Hexahydrotoluene (Lossen) Russian petroleum	97°	0·772
	From the products of dry dis-colophony (Renard)	95° to 98°	0·742 $\frac{20°}{20°}$
C_8H_{16}	Hexahydro-m-xylene (Wreden)	115° to 120°	0·777
	Russian petroleum (Wreden)	122° to 124°	0·7835
	From colophony	120° to 123°	
			0·764 $\frac{19°}{19°}$
C_9H_{18}	Hexahydromesitylene (Bayer)	135° to 138°	
	Hexahydro—X—cumene (Knowaloff)	135° to 138°	0·7812
	From petroleum	135° to 136°	0·7808
	Hexahydropropylbenzene (Tchitchibabin)	140° to 142°	0·7811
$C_{10}H_{20}$	Dodecahydroronaphthalene (Wreden)	153° to 158°	0·802
	From petroleum	160° to 162°	0·7808 $\frac{17·40°}{40°}$
	From petroleum	168° to 170°	0·8073 to 0·814 $\frac{15°}{15°}$

Napthenes from Petroleum (continued.)

Formula	Formation and Occurrence	Boiling Point °C.	Spec. Grav. $\frac{°C.}{°C.}$
	From menthene	168·5° to 170°	$0{\cdot}797\frac{15°}{15°}$
	From terpene hydrate	168·5° to 170°	0· "
	From camphor (Starodubsky)	167° to 169°	$0{\cdot}8114\frac{0°}{0°}$
	Tetrahydroterpene (Orloff)	162° to 167°	$0{\cdot}806\frac{0°}{0°}$
$C_{11}H_{22}$	From petroleum	179° to 181°	$0{\cdot}8019\frac{16{\cdot}2°}{40°}$
$C_{12}H_{24}$	From petroleum	197°	$0{\cdot}8120\frac{18{\cdot}4°}{40°}$
$C_{14}H_{28}$		240° to 241°	$0{\cdot}8215\frac{18{\cdot}6°}{40°}$
$C_{16}H_{30}$		246° to 248°	$0{\cdot}8210\frac{18{\cdot}8°}{40°}$

OCCASIONAL CONSTITUENTS OF PETROLEUM.

While petroleum, when pure, consists of various compounds of carbon and hydrogen, it frequently contains in solution other compounds of carbon, hydrogen and nitrogen, or carbon, hydrogen and oxygen, or carbon, hydrogen and sulphur, and besides it contains sometimes hydrogen sulphide or elementary sulphur in solution. The nitrogen present varies from 0·2 to more than one per cent. High percentages have been found in California oils. Of these oils, the nitrogen compounds are usually easily removable by sulphuric acid, and some of them have been isolated as alkaloidal bases. These alkaloidal bases are particularly evident in oils from shale where the distillation has been carried on in an atmosphere of hydrogen, and especially under pressure.

Sulphur exists in petroleum in the three forms already mentioned—these are hydrogen sulphide, free sulphur, and organic sulphur compounds. The oils of Mexico contain much sulphur in solution and in the form of hydrogen sulphide, and this is true of the oils in the Gulf region of Texas and Louisiana. Sulphur is comparatively easily removed by distillation, and this is true also with the smaller percentages of sulphur found in California oils. The sulphur in the oils of Lima, Ohio, and in the corresponding limestone oils in Ontario is present, however, in the form of organic sulphur compounds which distil over, particularly in the burning oil fraction, and are removed with great difficulty, the successful method consisting in exposing a large surface of copper oxide to the vapor of the oil during the distillation, by this means the sulphur compounds are broken up with the formation of copper sulphide from which copper oxide can easily be regenerated and used repeatedly. A considerable percentage of sulphur is a frequent characteristic of thicker asphaltic oils. Sometimes the sulphur is partly replaced by oxygen. The percentage of sulphur in the so-called sulphur oils usually varies between 0·5 and two per cent, but oils have been found in Mexico containing more than five per cent of sulphur. It is, however, more difficult to remove sulphur from Ohio oils containing not more than 0·6 per cent than from Mexican oils containing four per cent. The sulphur petroleums in Canada contain more sulphur than the Ohio oils. Maberry found 0·98 per cent of sulphur in addition to that present as hydrogen sulphide. Maberry and Quayle[1] separated the following sulphur compounds from Canadian petroleums:—

Sulphur Compounds	*Boiling Point*
$C_7H_{14}S$	71°— 73°
$C_8H_{16}S$	79°— 81°
$C_8H_{16}S$	97°— 98°
$C_9H_{18}S$	110°—112°
$C_{10}H_{20}S$	114°—116°
$C_{11}H_{22}S$	129°—131°
$C_{14}H_{28}S$	168°—170°
$C_{18}H_{36}S$	198°—200°

These boiling points are all at a pressure of 50 mm.

[1]Journal Society Chemical Industry 1900, p. 505.

The substances thus far mentioned as accompanying petroleum are such as will not settle on standing or can not be filtered from the petroleums. Ordinarily many of the varieties of petroleum contain mineral matter in suspension, and this increases as the oil increases in viscosity. The percentage of clay which can remain suspended or emulsified in an oil seems to depend on the proportion of water. If the water is removed, the clay will settle out—vice versa, if the clay is removed the water will likewise settle out.

ANALYSES.

It is unfortunate that so few analyses are existent of Canadian oils. In the early days some of the refineries and other companies had analyses made, but it was thought that they were of no particular value and the principle was largely discontinued. Few of the analyses are now available. Some of the old analyses are reported in the chemical dictionary published by Lippincott and referred to in the British Encyclopædia, 9th Edition.

In general the oils in Nova Scotia and New Brunswick are associated with thick beds of shale and consequently nearly free from sulphur and asphalt. They consist chiefly of paraffin hydrocarbons rich in gasoline, lamp oils, and paraffin wax and are associated with large supplies of natural gas which is likewise quite pure methane.

In Ontario, on the other hand, the oils are associated with limestones, and are characterized, as at Petrolia, by sulphur compounds including hydrogen sulphide which smells so strong that it can be recognized throughout the field. The crude petroleum contains less illuminating oil than Pennsylvania crude oil or than the Canadian oils farther east, or those near Calgary in Alberta. The Ontario oils are rich in lubricating oils and show good yields of paraffin wax. The Lambton county oil is dark brown in colour and has a gravity of 31 to 35 Baume. Its sulphur content is much higher than in the United States; the latter containing seldom more than 0·55 of sulphur, whereas the Canadian oil runs as high as 2½ per cent, making refining difficult except by the most modern methods.

The following table shows the yield of crude oils from various fields:—

TABLE XI.

Analyses of Petroleum from various fields.

	Location.	Depth of Well (feet).	Physical Properties. Gravity at 60° F. Specific.	Gravity at 60° F. Baumé.	Colour.	Odour.	Distillation by Engler's Method. Begins to boil at °C.	By volume. To 150° C. C. C.	To 150° C. Specific gravity.	150°–300°C. C. C.	150°–300°C. Specific gravity.	Residuum. C. C.	Residuum. Specific gravity.	Total. C. C.	Sulphur (per cent).	Paraffin (per cent).	Asphalt (per cent).	Water (per cent).	Unsaturated hydrocarbons (per cent). Crude.	Unsaturated hydrocarbons (per cent). 150°—300°	Remarks.
	Canada:																				
	Ontario, Lambton County—																				
1	Petrolia		.8580	33.0				2.50		57.50		*a*40.00		100.00							*a*Includes 4.08% coke.
2	Other							12.5	.7350	35.80	.8200	*a*48.70		97.00		3.00					*a*Includes 43.7% lubricating oil 5% coke and loss.
3	"							20.0	.7940	50.00	.8370	*a*30.00		100.00							*a*Includes 2.2% lubricating oil 8% tar, coke and loss.
	Quebec—																				
4	Gaspé No. 1.		.8470	35.0				8.75		48.00		*a*42.75		99.50							*a*Includes 2.75% coke.
5	" No. 2.		.7950	46.0				22.10		34.30		*a*42.80		99.20							*a*Includes .8% coke.
6	" No. 3.		.8280	39.0				15.90		41.30		*a*41.90		99.10							*a*Includes 1.4% coke.
	United States:																				
	Pennsylvania—																				
7	Perry County—Millerstown		0.7900	47.2				17.00	0.6930	43.00	0.7650	40.00		100.00							Percentages 17, 43, 40 are approximate.
8	Venango County		.8820	28.7	Dark brown			8.55		*a*42.78		*b*48.67		100.00							*a*150°–270° C.; *b*Includes loss and water.
	Kentucky—																				
9	Allen County—Petroleum	810	.8490	34.9	Brown	Like Pa. oil	71	12.50	.7373	41.00	.8144	45.30	0.9162	98.80		3.65	2.10	Trace.	18.8	7.0	
	West Virginia—																				
10	Ritchie County—Harrisville	1,850	.7977	45.5	Dark amber	"	93	17.00	.7265	42.00	.7770	40.90	.8485	99.90		5.32	.00		5.6	4.0	
11	Wood County—Parkersburg	350	.8750	30.0	Dark green	"	165			16.00	.8356	82.40	.8872	98.40			.00	Much.	21.6	5.0	
	Ohio—																				
12	Morgan County—Milner pool	325	.8046	44.0	"	"	74	14.50	.7137	38.50	.7815	43.60	.8669	96.60		5.36	.00		11.6	5.0	
13	Fairfield County—Bremen pool	2,462	.7848	48.4	Medium green	"	68	15.00	.7036	40.00	.7698	42.00	.8557	97.00		8.33	.00	None.	11.6	4.0	
14	Northwestern Ohio—Trenton limestone		.8284	39.0				15.00		33.00		51.46			.54						
	Illinois—																				
15	Lawrence County—Bridgeport Twp	1,700	.8289	38.9	Dark green	Sulphur	73	12.00	.7230	35.00	.7874	49.20	.9067	96.20		4.31		Trace.			
	Indiana—																				
16	Vigo County—Terre Haute		.8790	29.3						39.60	.8254	60.40		100.00	.72						300°–350° C., 14.8%; sp. gr., 0.867; 350°–390° C., 40.6%; sp. gr., 0.879.
	Kansas—																				
17	Allen County—Chanute pool	751	.8647	31.9	Dark green		109	5.00	.7350	36.00	.7993	57.80	.9223	98.80		4.25	1.23				
	Oklahoma—																				
18	Creek County—Glenn pool	1,500	.8459	35.5	Black		105	8.50	.7566	42.00	.8001	49.90	.9032	100.40		6.98	.45				
	Texas—																				
19	Hardin County—Sour Lake pool	1,020	.9352	19.7	Dark green	Sulphur	170			23.00	.8750	76.70	.9569	99.70		.00	.00		59.6	11.0	
	Louisiana—																				
20	Caddo Parish	1,620	.8723	30.5	Black		210			28.00	.8299	69.50	.8895	97.50			.14				
21	Marion County, Texas (Caddo pool)	±2,300	.8065	43.6	Brown	Like Pa. oil	100	6.00	.7305	50.50	.7646	42.90	.8739	99.40		7.02			12.8	5.0	
	California—																				
22	Fresno County—Coalinga		.9590	16.0						14.50		85.50		100.00			9.50				Flash point 120° C.
23	" "		.8459	35.5	Greenish			33.06	.7829	57.85	.8608	9.09		100.00	.21						Combustion gives carbon 86.24%, hydrogen 13.08%, bromine absorption 9.07%.
24	Kern County—Kern river		.9673	14.7	Black			1.00		*a*28.99		71.01		100.00	.95		21.25				*a*150°–350° C. 350° C. to asphalt, 48.13%. B. t. u. 10,471. Viscosity at 15.5° C.–274.35; at 85° C.–3.35.
25	Los Angeles Co.—Los Angeles city	1,060	.9706	14.2						26.30	.8852	73.70		100.00	1.18		25.30				Gravities at 15° C. 300° C. to asphalt, 44.2%. Calorific value per c. c., 10,073. Viscosity by Redwood viscometer over 1,800 at 150° C.
26	" Newhall district		.8107	42.7				51.00	.7830	43.00	.8333	6.00		100.00							150°–270° C.; above 270° C., 4%; loss 2%.
27	" "	662	.9474	17.8				1.20	.7790	40.20	.8723	58.60		100.00	.49		22.70				300° C. to asphalt, 34.8%. Gravities at 15° C. Calorific value per c. c., 9,911. Viscosity by Redwood viscometer 1,355 at 150° C.
28	" Whittier field		.9396	19.0				5.00		*a*20.00		75.00		100.00	.70		37.00				*a*150°–270° C; above 270° C 38%. Maumene No. 0.335. Nitrogen 0.669; oil at 19° C.
29	Santa Barbara Co.—Santa Maria field	1,600	.8882	27.6				25.90	.7460	30.60	.8469	44.50		101.00	1.56		12.00				Gravities at 15° C. 300° C. to asphalt; 29.7%. Calorific value per c.c., 9,364. Viscosity by Redwood viscometer, 90 at 15° C.
30	" "							12.00		12.00		76.00		100.00			16.00				No temperature given. Gas oil, 10%, lubricating oil, 50%.
	Colorado—																				
31	Mesa County	150	.8345	37.8	Yellow	Aromatic	145	1.00		42.00	.7188	56.50	.8427	99.50		19.65			12.4	4.0	
32	Fremont County—Florence	2,455	.8750	30.0			122	1.50		27.00	.7988	70.20	.9079	98.7		9.23					
	Wyoming—																				
33	Fremont County—Lander field	965	.9126	23.4	Dark brown		105	1.50		24.00	.8018	73.9	.9605	99.40		.90	11.04		58.0	4.0	
34	Natrona County—Salt creek		.8563	33.5	Dark green		126	1.00		36.00	.7854	62.4	.9032	99.40		5.63	.00		13.2	4.0	
	Utah—																				
35	San Juan County—Goodridge	225	.8363	37.4	Black		90	10.00	.7375	38.00	.7967	51.60	.8974	99.60		7.31		Trace.			
	New Mexico—																				
36	Eddy County—Dayton pool	914	.9109	23.7	Black	Sulphur	142	1.00		31.00	.8417	68.10	.9390	100.10	(*a*)	.00	3.91		25.6	14.0	*a*Not determined.
37	Trinidad No. 1.		*a*.9000	26.0				19.00		39.00		*b*42.00		100.00	.44						*a*Sp. gr. at about 28° C. *b*Includes 34% lubricating oil and 8% residue and loss.
38	No. 2.		*a*.8930	27.0				19.50		38.00		*b*42.50		100.00							*a*Sp. gr. at about 28° C. *b*Includes 36.5% lubricating oil and 6% residue and loss.
	Peru—																				
39	Zorritos		.8480	35.0	Dark brown			25.00		28.5 35.0		*a*17.00					31.00				*a*Lubricating oil.
	Russia—																				
40	Baku		.8800	29.0				.63	.7620	37.28		*a*62.09		100.00							*a*Includes 57.97% distillate above 300° and 4.12% residue and loss.
41	Roumania		.8460	35.0				10.00		81.88		5.89		97.77		2.23					
	Japan—																				
42	Formosa, Shinkkoko		.8284	39.0				10.00	.7880	80.00	.8350	*a*10.00	.8760	100.00							*a*Includes heavy oil and paraffin.
	New Zealand—																				
43	Gisborne district		.8642	32.0	Green	Aromatic	210			43.00	.7300	57.10	.8923	100.10		8.88		Trace.			
44	Tarauaki district		.8495	34.8	Brown	"	97	10.00	.7805	50.00	.8281	39.90	.8969	99.90		14.78		Trace.			
	Spain—																				
45	Province of Cadiz No. 1.		.7973	45.6	Amber	"	87	27.50	.7375	53.00	.8088	18.40	.8727	98.90		2.52	.00	0	5.6		
46	" " No. 2.		.8018	44.6	"	"	108	19.00	.7414	60.00	.8000	21.80	.8708	100.80		3.20	.00	0	7.6		

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TABLE XII.

Analyses of Natural Gases from various fields.

LOCALITY.	CONSTITUENTS.												REMARKS.	ANALYST.
	Methane.	Carbon Monoxide.	Carbon Dioxide.	Nitrogen.	Oxygen.	Hydrogen.	Ethylene Series.	Carbonic Acid.	Hydrogen Sulphide.	Inert Media.	Other Hydro-carbons.	Other Constitu-ents.		
CANADA.														
Ontario— Welland County	a96.57 (mostly methane)	...	...	2.69	...	...	...	...	.74	...	...	...	...	F. C. Phillips.
Kent County— New Tilbury and Romney	92.20 (mostly methane)	.21	1.40	5.59	trace	.40	...	...	.20	...	...	...	...	...
Alberta— Medicine Hat	99.49	...	...	...	...	...	...	...	.51	...	...	...	...	...
British Columbia— Vancouver	93.56	...	.14	6.30	...	...	...	...	...	...	...	...	...	F. C. Phillips.
UNITED STATES.														
California— Fresno County— Coalinga Field	88.00	...	11.10	.90	...	...	...	...	...	...	...	...	Collected by G. H. Salisbury, June 10, 1910.	G. A. Burrell.
King County— Sunset Field	87.70	...	10.50	1.80	...	...	...	...	...	...	...	...	Collected by I. C. Allen, July 16, 1909.	"
Los Angeles County— West Los Angeles	91.00	...	1.00	5.20	.10	...	...	...	...	...	2.70	...	Collected by I. C. Allen, July 23, 1909.	"
Santa Barbara Co.— Santa Maria Field	62.70	...	15.50	1.40	.20	...	...	...	...	...	20.20	...	Collected by I. C. Allen, Aug. 5, 1909.	"
Kansas— Allen County— Iola	94.50	...	...	5.08	.23	...	...	...	...	...	...	H–Trace. He–.18	Collected June 10, 1906.	Hamilton P. Cody and David F. McFarland.
Chase County— Elmdale	78.60	...	.15	12.13	.30	...	...	...	...	...	8.26	He–.56	Depth, 152 ft.; pressure 45 lbs.; collected Oct. 6, 1906.	"
Louisiana— Caddofield	95.00	...	2.34	2.56	...	...	...	...				.01	...	F. C. Phillips.
New York— Chautauqua Co.— Fredonia	90.05	...	.41	9.54	...	...	...	...	...	...	...	...	...	"
Pennsylvania— McKean County— Kane	90.38	...	.21	9.41	Tr.	...	...	...	...	...	...	...	...	"
Washington County— Houston	84.26	...	.44	15.30	Tr.	...	...	...	...	...	...	...	Contains also trace of ammonia.	"
Westmoreland Co.— Murrysville	97.70	...	.28	2.02	Tr.	...	...	...	...	...	...	...	...	"
West Virginia— Marion County— Fairmont	81.60	.40	.10	3.21	.20	.20	...	...	...	...	14.29	...	...	C. C. Howard.
AUSTRIA. Wels	97.10	...	1.30	1.00	.60	...	...	...	...	...	...	...	Specific gravity—(air=1.) 0.5667	...
GERMANY. Neuengamme near Hamburg	91.50	...	.30	4.60	1.50	...	...	...	...	...	2.10	...	...	...
HUNGARY	92.05	...	.65	7.30	...	...	...	...	...	...	...	...	...	...
RUSSIA. Samara	53.35	...	1.17	40.86	4.22	...	...	...	...	...	.40	...	...	...
Daghestan	65.84	...	12.82	...	...	...	...	...	...	...	...	Ethane 19.92	...	...
Tchelcken	77.30	3.50	3.60	8.90	1.80	...	...	...	...	...	...	Olefines 4.80	...	...
Caspian Region	93.07	...	2.18	.49	...	.98	...	...	...	...	...	Olefines 3.26	...	...
Baku (Peninsula of Apscheron)	92.89	...	.93	2.13	...	.34	...	...	...	...	...	Olefines 4.11	...	...
ENGLAND. Staffordshire— Charlemont	99.60	...	.30	.10	...	...	...	...	...	...	...	...	...	...
Sussex— Heathfield	93.16	1.00	...	2.90	...	...	...	...	...	...	...	Ethane 2.94	...	...

a Including minor amounts of other hydrocarbons.

CHAPTER III.

NATURAL GAS.

GENERAL COMPOSITION.

The gaseous members of the petroleum series are referred to as natural gas. Practically all oil pools contain the gaseous members dissolved in the liquid portion and usually under such high pressure that large quantities of gas are thus stored. In drilling into the deposit, if the highest point in the oil reservoir is tapped, the gas is liberated and a gas well is obtained whereas if the reservoir is tapped farther down the slope of the dome or anticline in which the oil is stored the pressure of the gas above presses out the oil inside, and an oil well is the result. It is this gas pressure which causes the oil to flow into wells, and produces flowing wells, and even the oils that are pumped owe their productivity to the pressure of dissolved gas which forces the oil slowly through the porous rock into the well cavity. Occasionally dry gas is obtained—that is gas which is not connected with any oil pool. Such gas can be distinguished from the gas from oil pools because it consists chiefly of methane, the first member of the series, and is comparatively free from the higher members such as ephane, propane, butane, pentane. The latter are vapours which are easily condensed under pressure and cold to produce a very volatile grade of gasoline known as natural gas gasoline. Natural gas is very commonly found issuing in sufficient quantities to be dangerous in coal mines and occasionally in mines of other minerals.

In composition, natural gas—from whatever source it is obtained—is to a large extent methane, the porportion of this frequently reaching 95 to 98 per cent, while the remainder is ethane, nitrogen, etc., as shown by the following analyses:—

Canadian Natural Gas.[1]

	Methane CH_4	Ethane C_2H_6	Carbon dioxide CO_2	Oxygen O_2	Nitrogen N_2	Other gases	Authority
Ontario..............	92·6	—	0·3	0·3	3·6	H_2 = 2·2, CO = 0·5, H_2S = 0·2 C_2H_4 = 0·3	Tassarts (*a*)
Vancouver, B.C.......	—	93·6	0·1	—	6·3		Phillips (*b*)
Sedgewick, Alberta.....	66·9	—	1·1	3·9	28·1		Stansfield (*c*)
Calgary, Alberta.......	91·6	—	0	0·2	8·2		Carter (*c*)
Mayton, Alberta.......	93·9	—	0·2	1·1	4·8		Carter (*c*)

(*a*) Exploit du petrol. 1908, 302.
(*b*) Amer. Chem. Jour. 16, 416, 1894.
(*c*) Fuel Testing Division, Mines Branch, Ottawa.

In the above analyses methane is not distinguished from its higher homologues ethane, propane, etc.; in the last three it was found that the amount of these homologues was small, certainly less than 1 per cent. That the higher hydrocarbons are not always so low is shown by Burrell and Seibert (Jour. Amer. Chem. Soc. 1914, 1538); they made a complete analysis of Pittsburgh natural gas by means of fractional distillation at the low temperatures attainable by the use of liquid air, and obtained the following results:—

Methane	=	84·7%
Ethane	=	9·4%
Propane	=	3·0%
Butane	=	1·3%
Nitrogen	=	1·6%

Stansfield and Carter have examined a Canadian natural gas from the Dingman well, Calgary, in which there were present considerable quantities of higher hydrocarbons; 1 litre of the gas at N.T.P. was found to contain 0·565 grams of carbon and

[1] This table and the following table of analyses of natural gas from foreign countries, and the accompanying notes were prepared by Dr. F. E. Carter, Mines Branch, Ottawa.

0·175 grams of hydrogen; if the gas were all methane the carbon hydrogen ratio would be 2·98, if it were all ethane the ratio would be 3·97. The actual ratio of this gas was 3·23, which shows that it was similar to that examined by Burrell and Seibert for which the ratio was 3·24 (calculated from above analysis). The so called "wet" natural gases contain higher percentages of ethane, propane, etc., and correspondingly less methane than the "dry" gases.

Some further analyses are given of natural gas in other countries:—

	Methane CH_4	Ethane C_2H_6	Carbon dioxide CO_2	Oxygen O_2	Nitrogen N_2	Other gases	Authority
United States:—							
Wyoming	81·7	17·4	0·2	0	0·7		Burrell (*d*)
Pennsylvania	92	·6	0·3	0	7·1		Phillips (*e*)
New York	90·1	—	0·4	trace	9·5		Phillips (*f*)
Cleveland, Ohio	93·5	—	0·2	0	6·3		Phillips
Indiana	77·4	14·2	0·7	0	6·6	C_2H_4=0·9, He=0·2	Cady and MacFarland (*g*)
Kansas	90·6	—	1·0	0·6	7·1	C_2H_4=0·2, Co=0·5	Cady and MacFarland (*g*)
California	83·7	0	6·7	2·8	6·3	C_2H_4=0·2, CO=0·3	Cady and MacFarland (*g*)
Russia:—							
Ssurachany	94·0	—	4·0	0·4	0·6	C_2H_4=1·0	V. Herr (*h*)
Bibi-Eibat	86·3	2·8	10·0	0·2	0·7		V. Herr (*h*)
Baku	91·2	1·3	1·8	1·2	4·5		V. Herr (*h*)
Galicia:—							
Tustanowice	86·5	—	—	1·0	3·8	heavy hydrocarbons=8·7	Grusciewicz and Hausmann (*i*)
Hungary:—							
Seibenburgen	91·0	—	0·2	0·3	1·4	heavy hydrocarbons =1·1 unstated 6·0	Zeller (*k*)
Kissarmas	99·0	—	—	0·4	0·2	H_2=0·4	Czako (*l*)

(*d*) Bureau of Mines, Tech. Paper 57.
(*e*) Amer. Chem. Jour. 16, 416, 1894.
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(*h*) Trudy, 1908.
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(*k*) Petroleum, 1906, 297.
(*l*) Jour. Für Gasbeleuchtung, Dec. 1911.

In Kansas a natural gas well has been found which consists largely of nitrogen while, on the other hand, many gas wells, especially those connected with a large petroleum supply, are largely made up of gasoline vapours—so as to be largely condensible into natural gas gasoline. Various methods have been given for the analysis of natural gas to ascertain the quantity of natural gas gasoline which can be extracted under pressure and cold. The simplest of these is to pass the gas through an absorbent, such as a heavy petroleum, and note the gain in weight, or to afterwards distil off the gasoline absorbed by the heavier material. More direct and, perhaps, more satisfactory methods consist in the actual condensation of the gasoline by means of pressure and cold. Where liquid air is accessible, condensation by this agent is most satisfactory.

SWAMP GAS.

In many stagnant pools, bubbles of gas are noticed frequently in considerable quantities. This gas, if collected, usually burns although sometimes the quantity of nitrogen and carbon dioxide prevents. In many places where large quantities of vegetable matter, trees, etc., are buried fifty or a hundred feet underground, as on the sea coast or any flood plain of a large river, wells drilled into this vegetable mass yield swamp gas under considerable pressure. Notable examples of this are on the west coast of Washington and Oregon and in Louisiana near the mouth of the Mississippi river. In the latter place, gas sufficient for lighting several houses has been obtained for years. This gas can be readily distinguished from the usual deep-seated natural gas by its odour of decaying vegetable matter whereas in some cases dry natural gas has no odour; however in the far greater number of cases it has the odour of gasoline or crude petroleum.

Frequently natural gas is largely contaminated by hydrogen sulphide, as in Mexico.

In the limited amount of gas which is found in the Petrolia field, Ontario, a considerable proportion of hydrogen sulphide is present; consequently, the government gas inspector has notified the company and consumers that gas must not be used for illuminating purposes in Petrolia, unless it be first purified. In Chatham and in some other localities purification is accomplished by the companies through the use of individual purifiers in each house.

CHAPTER IV.

Geological Occurrence of Petroleum and Natural Gas.

ORIGIN OF PETROLEUM.

By Marius R. Campbell.

Although petroleum or its residual products have been known from very early times, little progress has been made in determining its ultimate source and its mode of origin. It is true that many suggestions have been made and many hypotheses have been advanced with great zeal by their originators and ardently supported by their advocates, yet none of them has been universally accepted and they have never passed beyond the stage of theory pure and simple. Most of the theories are based on chemical evidence and so are difficult to prove or disprove, as Nature in her world-wide laboratory has been able, in the long eons of time since first the world began, to accomplish many things that are impossible to the limited facilities and the short space of time available to man.

Under such conditions the writer prefers to make a simple statement of the principal theories and of the strongest arguments that have been adduced in their support, and to leave the reader to select that which seems to him most reasonable or which appears to fit most of the facts in the field with which he is familiar.

Many students of petroleum have taken the position that the ultimate source of the oil and its mode of origin are unimportant to the practical geologist or oil operator, and that all that is necessary is to understand the forces which have caused the oil to move in the rocks and the conditions which have affected its accumulation. It is true that, from the standpoint of the man searching for oil, these are the important factors, but can he really be sure of finding an accumulation of oil without knowing something of the source from which it may have been derived and the extent of its migration? In many cases the geologist can, in advance of exploration with the drill, point out geologic structures favorable for the accumulation of oil, but unless there are some surface indications of the oil itself, he knows no more of its actual presence in the rocks below than the merest tyro. He must advise the oil man to test the ground with the drill to see if oil is present or not, and even then he has no idea, if the location is in entirely new territory, how deep he will have to go to make a thorough test. As the geologist does not know from whence the oil may come, he cannot set a limit beyond which it is fruitless to continue the search. In other words, the practice of exploration for oil to-day is largely governed by chance, but it is confidently believed that much which is now uncertain could be eliminated were the source of the oil well known and its mode of origin understood. The geologist cannot afford to ignore this phase of the question, for so long as he does he is obliged to confess that much of his work is unscientific and that the presence or absence of oil in any locality is, so far as he is concerned, a matter of accident about which he can only make a guess at the best. Let us hope that geologists and oil chemists the world over will be constantly on the watch for evidence upon which to settle this important question.

Although many theories have been proposed to account for the origin of petroleum, none have been well established and consequently public sentiment varies from time to time regarding them. At one time a certain theory may be generally accepted, but the discovery of new facts or the appearance of a new advocate may change the tide of public opinion and some other theory may be the one generally accepted. Such will naturally be the case until more positive proof can be obtained regarding the mode of origin that is at present available, and then it may be found that petroleum has been produced in various ways and that many of the theories advanced have an element of truth in them, but that no particular theory has universal application.

The theories of origin so far propounded may be separated broadly into two groups: (1) those ascribing to oil an inorganic origin, and (2) those ascribing to it an organic origin.

INORGANIC ORIGIN.

The theories ascribing to oil an inorganic origin have been propounded alone by chemists who necessarily know little of the geologic conditions under which oil occurs in various parts of the world. So far as the writer is aware, no geologist has yet publicly advocated such a theory. It would therefore seem that the geologic conditions do not favour such an hypothesis, else men familiar with them would rally to its support. This would seem to militate against such a theory, for the true explanation of the origin of oil must fit all the facts, both chemical and geologic, and neither set should be disregarded in attempting to solve the problem.

It seems to be unnecessary here to review all of the steps leading up to what may be considered the present accepted version of the theory of the inorganic origin of petroleum. It was extremely crude when first proposed, but has been modified from time to time as chemical knowledge increased.

The first suggestion that deserves the name of theory regarding the inorganic origin of petroleum was advanced by the distinguished French chemist, Berthelot, in 1866. He supposed that the alkali metals, potassium and sodium, exist uncombined and at high temperature in the interior of the earth. Whenever water carrying carbonic acid in solution finds access to these metals a series of hydrocarbon compounds would result. According to this theory the formation of oil and gas would take place deep in the earth without the intervention of organic matter of any kind, and the process, if not continuous, would be active whenever water penetrated to this part of the globe.

The theory of the inorganic origin of petroleum, in the minds of most people, is associated with the name Mendeljieff, the great Russian chemist, who in 1877 advanced the following theory. He supposed the interior of the earth to contain large masses of metallic iron and also metallic carbides all at a high temperature. The contact of water with these bodies would, according to his theory, generate metallic oxides and hydrocarbons and thus by these simple reactions petroleum would be produced. If this is accepted as the true mode of origin, it naturally follows that the process is continuous or intermittent and will continue in operation as long as the supply of metallic carbides exists. It is true that the rate of production is not known and it may be much slower than that of the removal of the oil by the hand of man, but the very fact that the process must be in a measure continuous would mean that the supplies of oil though exhausted to-day may be renewed to-morrow, and thus we are in little danger of a lack in our fuel supply. This is certainly a most consoling idea, much more so than the advocacy of a theory which provides only for a stored supply and little or no prospect of its replenishment, but despite this advantage the theory has not attracted many adherents, and few geologists familiar with field conditions have had the hardihood to advocate it or to apply it in the solution of the problems that confront them in the practical development of an oil field.

This feeling had grown so strong that seldom was any explanation of the origin of petroleum put forward, except the organic theory, until 1903 when an ardent advocate of the inorganic theory, Eugene Coste, appeared upon the scene and presented a fairly able defense of the theory. He claimed to have applied the principles of this theory in the practical development of several oil and gas fields, and he expressed full confidence that it applied to all occurrences of such hydrocarbons. Mr. Coste presented no new evidence and consequently made no addition to existing knowledge. He attempted to explain every phenomenon connected with an oil field by volcanic or solfataric action, but unfortunately most of his evidence was derived from the reports of others and he was apparently deceived by the term mud volcanoes, thinking them phenomena of true vulcanism.

If petroleum originated from inorganic material, then it should have been in the process of formation since the earliest geologic times and presumably it should permeate the oldest rather than the youngest formations, except as it has migrated through the rocky crust of the earth. It should also be found in igneous as well as sedimentary rocks; in fact, it seemingly should be more abundant in the former than it is in the latter. It should be most in evidence in regions of greater disturbance and faulting and least known in little disturbed and thick sedimentary formations. Its occurrence throughout the habitable globe is under conditions diametrically opposed to those which should prevail according to theory. It is true, however, that oil has been found in igneous rocks in many places, but the amount is small and its presence can be easily accounted for on the assumption that it has migrated from some sedimentary formation which is or has been in contact with the igneous rock.

Some of the phenomena encountered on the Gulf Coastal Plain in Mexico and the United States, such as the association of the oil with salt, sulphur, and hot water, and the presence in many places of dikes and plugs of igneous rock, are puzzling and may be interpreted as an argument for the inorganic origin of the oil, but even if this be granted it explains only its origin in a limited area and the arguments which may be good here do not apply in the great majority of fields throughout the world.

THEORIES OF ORGANIC ORIGIN.

Since 1803, when Leopold von Buch suggested that the bitumen of the Würtemberg Liassic shales was derived from animal remains in the rock, many theories to account for the vegetable or animal origin of petroleum have been advanced. As in the case of the inorganic origin, most of the theories have been put forward by chemists, and geologists have been backward in expressing views upon the subject. This may be accounted for largely by the conditions which prevail in most oil fields and which do not permit of a close examination of the oil-bearing strata, at least in the area in which the oil occurs. It may also be partly explained by the lack of knowledge regarding the laws that control the migration of hydro-carbons through the rocks, for until that question is settled it is extremely difficult to say where the oils have originated and what were the conditions surrounding them.

Most of the oil of the world occurs in formations having a marine origin, and hence it is commonly believed that marine organisms have supplied the material from which it was derived. This view has been greatly strengthened by the demonstration in 1865, by Warren and Storer, that fish oil on distillation would yield hydrocarbons similar to petroleum, and by similar though more elaborate experiments along the same line by Doctor Engler at a later date.

Many chemists and geologists have contributed to the literature on the subject, arguing for the origin from animal or vegetable remains, but the name that now stands out most prominently as having contributed materially to the knowledge of the origin of petroleum is that of Doctor Engler, although the names of Potonié, Orton, Pickham, Höfer, etc., are closely associated with this subject.

The details of the various advances that have been made, and the names of the scientists to whom credit should be given, are ably presented by Redwood in his latest edition ("A Treatise on Petroleum," London, 1913), and by Dalton in "Economic Geology" (Economic Geology, vol. IV, pp. 603-631, 1909), but it seems unnecessary here to do more than attempt to summarize the recent and most important conclusions of the men who have been most active in attempting the solution of the problem.

Engler's statement of the various stages in the process of the formation of petroleum from organic matter, as given by Dalton,[1] is as follows:—

(1) Putrefaction, or fermentation, by which albumen and cellulose, etc., are eliminated. Fatty matter (and waxes), with a small quantity of other durable material and possibly fatty acids from the albumen remain.

(2) Occurs partly during the first stage; saponification of the glycerides and production of free fatty acids, either from action of water or ferments, possibly both. The waxy esters are either wholly or partly hycrolyzed. The residues from many crude oils are probably due to lack of completion of these actions.

(3) CO_2 is eliminated from the acids and esters, water from the alcohols, oxy-acids, etc., leaving hydrocarbons of higher molecular weight containing oxy-compounds, c.f. the intermediate product like ozokerite of Krämer and of Zalo-

[1]Op. cit., p. 625.

ziecki, who also regarded that mineral as representing an early stage in the formation of oil.

(4) Formation of liquid hydrocarbons and violent reaction, with "cracking" into light or gaseous products = formations of petroleum.

He adds, in regard to all these stages, that he is assuming that time and temperature compensate one another, though pressure had no action beyond raising the temperature slightly, and it is in no way equivalent to it. He considers that with moderate temperatures and pressures oil of intermediate grade will be found, while increase of either tends to form light oils. Polymerization and addition products are formed after the completion of stage 4.

He further suggests that the various hydrocarbons are formed as under:—

Methanes—as direct products from the "bitumen," that is, the fats of stage 1 and heavy hydrocarbons of stage 3.

Olefines—directly formed by splitting up of saturated chains of hydro-carbons of the paraffin series.

$$C_{2n} H_{4n+2} = C_n H_{2n+2} + C_n H_{2n}.$$

These would afterwards polymerize to form simple methanes, etc., but they are probably partly reformed in distillation, especially at high temperatures as in the cracking process.

Naphthenes—perhaps from the decomposition of aromatic acids or esters, or from the isomeric olefines under the influence of heat and pressure.

Lubricants—formed directly from the original fats, at low temperatures.

Benzine, etc.—from the decomposition of the fats at comparatively high temperatures.

So far the evidence presented here has been almost entirely chemical. Geologists generally have favoured the theory of the organic origin of oil, probably because in most fields they found the oil contained in or associated with thick masses of sedimentary rock, fossils of which might easily have supplied the original material from which the oil was derived, but unfortunately the conditions have generally been such that no positive evidence could be obtained. The facts, so far as the geologists could observe them, were generally interpreted as favouring the organic as against the inorganic origin, but after all it was a matter of interpretation or personal bias and had little or no real foundation. Thus in the great Appalachian oil and gas fields, geologists have assumed that the great masses of Devonian shale in which the oil sands are imbedded were the source of the oil, but even on that assumption they were compelled to admit migration to its present resting place. The question then naturally arose, if the oil has migrated from the shale into the sandstones, what is to prevent its migration from underlying rocks, and if from underlying rocks, may it not have come from deep in the crust of the earth? It must be admitted that while such a migration is possible, it seems like carrying the movement to the extreme, and few geologists have been willing to admit even its possibility.

In probably every known field in the world there are fossiliferous rocks to appeal to as a source of origin, but the conditions are such that it is extremely difficult to prove such a source of origin. The writer is familiar with only one case in which the conditions are such as to offer almost positive proof not only of the particular formation in which the oil originated, but also the kind of organisms that furnished the raw material. This case is the oil fields of southern California as interpreted by Arnold and Anderson.[1] It would be impossible in this paper to review all of the evidence, but briefly summarized it is as follows:—

Several of the formations in this region are diatomaceous, in fact, one formation 2,500 feet thick (the Monterey shale) is made up almost exclusively of the casts of diatoms. The diatom-bearing formations do not as a rule contain oil to-day, but they bear inherent evidence of having contained it in times long past. The oil is now found in sandstone reservoirs, but only in those that are adjacent to the diatomaceous material either through faulting, through conformable disposition, or through unconformable deposition. This association of the oil-bearing rocks to the diatomaceous shale has been found to

[1]In various bulletins issued by the U.S. Geological Survey.

hold true throughout practically all of the fields of southern California and in case the Monterey or main diatom-bearing bed is barren of diatoms, as in certain parts of the field, the oil sands cease to follow it, but are associated with another diatomaceous shale lower in the series. The relationship is so constant that it has proved to be a reliable guide in new territory in determining whether or not the rocks contain oil.

The writer regards the assumption that the diatoms furnished the original material from which the oil has been found, so strong that it practically amounts to proof, and offers it as one case in which the geologic relations point unmistakably toward the origin of the oil. It seems probable also that in such fields as the oil shales of Utah and Colorado it may be possible by geologic studies to definitely determine the kind of material that furnished the supply of organic matter, and also to locate its position in the geologic section. It is to be hoped that similar proofs may be obtained in other fields so that the chemical results may be checked by geologic observations in order to completely establish the source and mode of formation of the oil.

Before concluding this brief resumé of the theories propounded and the generally accepted beliefs of to-day, it is important to consider the optical investigations and the light they throw on this important question.

Although it has been known since 1835 that the polarized ray was rotated by petroleum, it was not until 1904 that Rakusin suggested that this property of rotation was due to cholesterol, an element found only in animal fats. Later, Doctor Lewkowitsch pointed out that the rotation of the polarized ray could be produced not only by cholesterol from animal fats, but also by phytosterol from vegetable oils. On applying this optical test it was found that many crude petroleums possessed the rotary power, but that oil derived from inorganic materials was entirely inactive. On the basis of such tests Dalton[1] states: "There seems to be no reasonable room for doubt that the optical activity of petroleum is due to cholesterol and phytosterol...... Not only do they establish beyond question the organic origin of

[1]Op. cit.

petroleum, but also since the alcohols in question occur in the fatty parts of the animals and vegetables, it confirms Engler's hypothesis that these parts play the principal role in the formation of mineral oils." He also concludes his review with the following comprehensive statement: " One is led, therefore, to regard the great majority of oils as derived from the decomposition, during long ages, at comparatively low temperatures, of the fatty matters of plants and animals, the nitrogenous portions of both being eliminated by bacterial action soon after the death of the organism. The fats and oils from terrestrial fauna and flora may have taken part in petroleum formation, but the principal role must, from the nature of most petroliferous deposits, have been played by marine life."

In attempting to sum up the evidence presented herewith, and other evidence which the present paper affords no opportunity to present, three propositions seem to be established.

(1) The evidence available at the present time favours the animal origin of most petroleum.

(2) A certain amount has probably been derived from the fatty portions of plants.

(3) The optical and geologic evidence is decidedly against the inorganic origin of petroleum, but the association of oil and gas with volcanic features in certain fields suggests that there may have been a relationship of cause and effect in the associated phenomena.

MOVEMENT OF OIL THROUGH THE ROCKS AND CONDITIONS OF ACCUMULATION.

In considering the manner in which oil has moved through the rocks and the conditions that have led to its accumulation in the vast pools that have been found by the drill, it is immaterial what has been its source of origin or its mode of formation. Almost all geologists who have written upon the subject are agreed that, in general, oil has not been formed in the rocks in which it now occurs, but that it has migrated from its place of formation. Whether this movement has been from vents where volcanic emanations have come up through the strata, or from areas in which the oil has been produced from organic matter, is of little consequence. The fact of prime importance to the working geologist is that it *has migrated* from the place where it was formed and that it *has accumulated* where local conditions have been such as to interfere with its further movement. In most cases migration must be understood as preceding accumulation, but there are apparent exceptions which will be mentioned later. According to the generally accepted idea, there could have been no accumulation into pools without previous movement; therefore the first part of the problem to be considered is the migration of oil through the rocks, the cause of the movement, and the various geologic conditions that may have affected it and modified the results.

Migration.—There are three forces which, under certain conditions, tend to produce movement of oil in the rocks. These are (1) gravitation, (2) capillary attraction, and (3) difference in specific gravity of oil and water.

Gravitation.—Oil, in common with all other substances, is affected by gravitation, but as the attraction of gravitation is the weakest of the forces enumerated above, it operates only where the conditions are such that the others are inactive. This is when the rocks are dry and of an open porous character. As the pull of gravitation is towards the center of the earth the movement of the oil under such conditions is always downward, but its course is probably not direct and the movement is one of dispersion rather than concentration. This is due to the ready response of the moving oil to the inequalities and irregularities of the pore spaces in the rock and to the surface tension of the oil.

Owing to the vicissitudes encountered by the particles of oil moving alone under the influence of gravity, the movement is weak and probably has played only a small part in the great migration of oil from its point of origin to the pool in which it is found.

Capillary attraction.—The capillary attraction of oil is much more powerful than the pull of gravitation, but it is entirely overcome in the presence of water by the greater surface tension of the latter liquid. Therefore capillarity can produce movement of oil only in dry rocks, and as it operates in material having extremely small pores, it follows that it is not a factor of movement in open porous rocks but in fine-grained rocks. Day[1] has shown that petroleum will diffuse readily in all directions through dry clay and shale and that in the diffusion the oil will be separated into fractions of very different specific gravities. From this he concludes that most crude oil has been diffused through such material and that capillary attraction is the cause of much of the movement of oil in the crust of the earth. Day also proves that moist clay and shale are impervious to oil and hence that a cap rock of such material is the one best fitted to hold the oil after it has accumulated.

The diffusion of oil through dry shale or clay would seem to offer a plausible explanation of the manner in which the oil has migrated across the planes of stratification from its place of origin. If it originated from inorganic substances then the oil has migrated upward by capillarity with the porous strata in which it is now found, and if it originated from organic matter it passed from the shale in which it originated in all directions until it found a resting place in a more porous rock.

While this explanation seems plausible it is based solely upon the assumption that the rocks were dry, else the movement could not have taken place. As all of the sedimentary rocks were laid down by or in water it would mean that all of this original water must have departed before the migration occurred. Also if the oil diffused so readily through the dry clay or shale why should it accumulate in the open porous rocks? As the open rocks are bounded by fine-grained rocks, would not the oil continue to migrate rather than to accumulate? It is true that water could be appealed to as one agent for stopping the forward movement of the oil, but if water were present at any place in the rocks, why with its superior capillary attraction should it not have filled the rocks before the advent of the oil?

Although capillary attraction is doubtless an active force in the movement of oil under special conditions, it seems probable that the conditions have been neither sufficiently wide-

[1]Am. Phil. Soc. of Phil., Proc., vol. 36, No. 154, pp. 112-155, Jan. 1897; also Am. Inst. Min. Eng. Trans., vol. 41, pp. 219-224, March 1910.

spread, nor continuous in the past to make it an all-important factor in the problem of the broad migration of oil. The first step as stated above is the concentration of the oil in the porous strata, and in this movement capillarity may have played an important part. Its migration after it has reached such a stratum is almost entirely controlled by the water contained therein, and consequently the great movement of the oil is due to the next cause.

Difference in specific gravity of oil and water.—As both of the forces just mentioned presuppose the existence of special conditions, it is generally agreed that water has been and still is the great medium for the migration of oil through open porous rocks. As the latter substance is lighter than water it is forced upward by the pressure of the water toward the surface. This would cause movement up the rise of inclined porous beds that are saturated with water, but would not produce migration down the dip or in a horizontal direction.

Recently Munn has argued that movement was not produced by the difference in specific gravity of the oil and water, but by a definite circulation of the water itself. The particles of oil would, according to this hypothesis, be carried along by the moving water and the direction and extent of the movement would be controlled entirely by the movement of the interstitial water. This hypothesis, however ingenious, has not met with general acceptance and hence the theory attributing the movement to difference in specific gravity is regarded as having better standing and will be treated here as the one commonly accepted.

When the anticlinal theory was first propounded it seems to have been taken for granted that all rocks composing the outer crust of the earth are saturated with water, but recently deep drilling has shown that whereas such is generally the condition of the rocks for a few hundred feet below the surface, at great depths the rocks are generally dry, or at least in certain localities they are so dry that water must be pumped into the hole in order that the drilling may proceed.

Another factor, which undoubtedly has played an important part in this problem and which should be taken into account in attempting to explain the presence of oil in any particular locality, is the change of water level in the saturated rocks that may have taken place as a result of orogenic movements in the crust of the earth. If, therefore, such changes of level be postulated, it is evident that rocks which to-day are saturated may have been dry at some previous geologic epoch, and, conversely, rocks which to-day are dry may at some other time have been completely saturated. Knowledge regarding the circulation of water in the earth's crust and the factors which control its height at any particular point or any particular time is too meagre to warrant more than a reference, but evidence has accumulated that seems to prove that different conditioms have prevailed in the past and that these conditions must be considered in attempting to interpret the data available at the present time.

If, therefore, the extensive migration of oil through dry rocks is ruled out of the problem, the question again reverts to water as the medium for general migration. The rate of movement and the volume of oil depend upon the porosity of the rocks and the time during which the migration has been going on. The most porous of the clastic rocks are sandstone and conglomerate, hence these are generally the formations through which the oil has travelled, but in certain cases dolomitic limestone where formed largely of interlocking crystals, as is the condition of the Trenton limestone of the Ohio and Indiana fields, has afforded an open passage for the oil. It must not be assumed, however, that all beds of sandstone or all parts of any particular bed are permeable to oil. If the grains of sand are closely cemented the rocks may be practically impervious but if the grains have little cementing material between them the sandstone or conglomerate offers an easy passageway for the oil and also a reservoir for its accumulation if other conditions are favourable.

In a lesser degree joint cracks and fractures afford avenues for the movement of the oil, but such fractures are not formed until the rocks have received a certain degree of induration, which in all probability follows rather than precedes the main migration. Again, geologists and physicists generally maintain that open fissures are not possible at any great depth in the crust of the earth and therefore that they afford opportunity for movement only near the surface. With all due respect to the eminent authorities who have presented such an argument the writer maintains that it is based entirely on theoretical grounds which are not borne out by facts revealed by the drill, as will be noted on another page.

Dike walls and faults in many cases afford opportunity for the circulation of liquids in the earth's crust, but here again there may be great exceptions. In very much indurated rocks, fractures of any kind may constitute open avenues for the migration of oil, but in slightly indurated rocks, and especially those that contain an appreciable amount of argillaceous material, a fault may have the opposite effect, or act as a barrier to the movement of liquids or fluids. The reason why faults in such rocks form barriers is that in the slight movement back and forth that has undoubtedly occurred along most fault planes the clay contained in the sandstone has become plastered over its face, effectually sealing it to the further progress of gas and oil. Such barriers not only play an important part in preventing migration, but they also cause the oil to accumulate behind them and thus form pools, as will be explained later.

Persons in search of oil or gas should thoroughly understand the effect of faults and fractures on the movement and accumulation of oil, and when they understand it they will not look for large supplies of oil or gas in greatly disturbed rocks, especially if the rocks are geologically very old and greatly indurated, but where the opposite conditions of structure and character of rocks prevail they will find that such structures are no bar to the formation of large pools. These conditions are well illustrated by the different conditions which characterize the Appalachian and California oil fields. In the former, large accumulations occur in the great synclinal trough which coincides roughly with the coal fields. In this trough the rocks are gently flexed into a number of folds, but none are of such a magnitude as to have produced appreciable fractures in the rock. The belt of oil pools is abruptly terminated on the east by the line which marks the boundary between the gentle and the pronounced structures, and little or no oil or gas has been found east of that line. In California some of the largest pools are associated with the most pronounced folds and faults, and geologic structure and fractures cannot be said to be controlling factors in the case.

Accumulation.—The discussion so far has been confined to the migration of oil through the rocks and it has been shown that water is the medium by which this movement is largely effected. It now remains to consider the conditions which interfere with such a movement and which cause the oil to accumulate in the so-called pools.

Urged on by the difference in specific gravity the oil will rise through the interstitial pores in the rock. If the rock consists of a great mass of sandstone the oil will be forced to the top of the bed unless it has been arrested in transit by a barrier of impervious sand or a clay-sealed fault. After reaching the top of a particular "sand," be it thick or thin, the oil, if still forced by the water behind, will seek to escape into the overlying bed, but if this bed be composed of impervious clay or shale the oil will be confined to the one stratum. When so confined, its movement will depend almost entirely upon the attitude of the bed or, in other words, upon the geologic structure. If the bed lies nearly horizontal there is manifestly no place to which the oil can migrate and then it collects in the uppermost layers of the sand. Beds of rock, however, seldom retain their horizontality for any great distance. If they rise, the oil will tend to move in this direction, but whether this tendency develops into actual motion will depend largely upon the degree of inclination of the bed. If the dip is slight the pressure resulting from the difference in specific gravities of the water and oil may not be sufficient to drive the oil through the open sand, but in case the bed is sharply tilted the oil will move freely, provided that the sand maintains its open, porous character. This fact explains one of the conditions controlling accumulation of oil—a condition that is probably most marked in the case of the Ohio-Indiana pools in the Trenton limestone.

In the development of oil and gas in western Ohio and in Indiana, it was found that the oil occurred in pools on the flanks of a broad gentle dome in the Trenton limestone, not at its top, but on its sides and with little regularity regarding their positions on the dome. At first this was very puzzling as it seemed to be totally different from the conditions in other fields, but after considerable drilling had been done, and the position of the oil-bearing limestone determined, it was found that the pool marked a sort of structural shelf or terrace or area of arrested dip. In other words, the limestone rises gradually toward the centre of the dome, but in places this rise is not maintained and over a considerable area the rock is nearly flat. Beyond this flat the bed rises once more toward the axis of uplift.

The oil on being forced up through the interstitial spaces in the limestone finally arrived at the structural terrace and there the pressure was not sufficient to force it through the many miles of horizontal rock and it accumulated and was held in place by a large body of water behind it. Under such conditions the oil occurs near the outer edge of the terrace, because it is in that place that it is brought to a stop. If the oil had been moving down it would have accumulated at the inner edge of the terrace. The position, therefore, of the oil pool is a good indication of the direction in which the oil is moving.

Assuming again a single porous stratum thoroughly saturated with water, the oil would be forced to rise until it could go no farther. This arrest of motion might be due to (1) the oil reaching the limit of the bed of sand, (2) to a change in the character of the rock by which it becomes impervious, (3) to a barrier such as a clay-sealed fault, (4) to a change in the attitude of the sand (geologic structure), or (5) to the oil reaching the upper limit of the water. Conditions 1, 2 and 3 are simple and need no further explanation. Conditions 4 and 5 are those which control the locations of nine-tenths of the pools of the world and call for a more detailed discussion.

As the rock strata of the earth's crust are generally thrown into more or less strongly marked folds, it follows that in most cases where oil is migrating up a sloping bed of rock it will encounter a more or less well developed arch or anticline. If the fold is in an incipient stage it may take the form of an "arrested dip" or "structural terrace," as already described, or it may take a variety of irregular forms, almost all of which tend to produce pools of oil, for their effect is that of barriers and they make it impossible for the water to force the oil to a higher level. If the anticline is well developed and lies entirely below the level of ground water the oil will migrate to the crest where movement will be arrested by the dip of the bed in the opposite direction. In such folds, therefore, there is a tendency for the oil, or if gas be present, as it is in almost all cases, for the gas and oil to occupy the highest part of the crest of the fold floating on the water which had forced them and still holds them in this position.

This conception of the relation of gas, oil, and water to the crest of the anticline has been widely known as the anticlinal theory. Although the close association of the oil pools and anticlines has long been recognized and has been commented on by Hunt, Höfer and others, it was not until 1885 that it took the definite form of a theory. In that year it was first definitely stated by I. C. White[1] but since then if has been modified in many respects as knowledge has been acquired regarding the conditions below the surface of the ground. Many have combatted this theory, but to-day it stands as the theory most generally applicable to the oil fields of the world and most generally accepted by geologists familiar with oil conditions.

The case noted above as typical of the effect of anticlines on the accumulation of oil is simple in the extreme. In many places the structure, although generally anticlinal, may be so irregular that it bears little resemblance to the type, but in all cases of this kind each minor fold is controlled by the same conditions as the major fold and may be marked by small pools on the outskirts of the larger one.

Condition 4 also in many places tends to complicate the situation, for frequently the water line instead of being entirely above the anticline may cut it below the summit and at various angles to the axis of the fold. As there is no tendency for the oil to rise above the surface of the water it will accumulate in the rocks along the water line, and as the water line laps around a pitching fold so may the oil pools change in direction corresponding to the change in strike of the rocks.

[1]White, I. C., The geology of natural gas: Science, vol. 6, June 26, 1885.

If a pool is formed in the crest of an anticline or at the water line along the flanks of the fold and then the water level for this stratum is lowered, it is manifest that the oil would not remain at the point where it accumulated in the presence of water, but gradually under its own weight it will move downward, but it will lack the power of the water behind it as in its ascent, and also it will become more or less diffused through the porous stratum without a large quantity at any given point. Hence, under such conditions many small pools may be formed, but they will be so irregularly disposed and so widely scattered that their discovery will be largely a matter of accident. This is purely an assumed case, but the writer is familiar with areas in the Appalachian region which can be explained only on such an hypothesis. It seems probable that since conditions in the earth's crust have not remained constant throughout geologic time, that many changes in water level may have occurred throughout the crust of the earth and that similar results may be found in many oil fields.

As most of the oil has migrated up monoclinal slopes or up the limb of a syncline from the bottom of the basin, it follows that in any minor folds or wrinkles on these major structures, the oil will accumulate in the top of the fold if that is below water level, or if it projects above the surface of the water then the oil will tend to accumulate on that side of the anticline which is connected with the long slope down the monoclinal structure or into the centre of the basin. In other words, the large gathering ground of a long slope is more favourable for the formation of an oil pool of considerable magnitude than is the short slope on the other side connected with the slope above. Manifestly, the reverse would be true if the oil were moving in the opposite direction.

In regions of extremely complex geology, as in California, many modifications of the anticlinal theory are necessary, but the underlying principles of migration and accumulation, as outlined above, clearly fit in this region, as well as they do the Appalachian region. In California oil occurs in rocks of Cretaceous, Tertiary and Pleistocene age, but at the present time the great bulk of the product is derived from Tertiary formations.

These formations were laid down in a region where there were many and violent oscillations of level and corresponding changes in geographic conditions. As a result many formations overlie others unconformably and then the whole has been folded and faulted in a most confusing manner. The oil has migrated up saturated sands, but these, owing to the unconformable relations of many of the formations, come into contact with other sands along the line of unconformity. This allows the oil to pass readily from one formation to another lying above and complicates to a great extent the problem of tracing oil to its ultimate source. Again the plane of unconformity may be sealed by clay and thus it may in places serve as a barrier instead of an avenue of escape. Similarly faults in this region are sealed so that they prevent the movement of the oil and cause it to accumulate on the lower side of the fault plane.

In comparing the conditions in California with those in the Appalachian fields it is manifest that time is a large element in the oil problem. In the Palæozoic oil rocks the time since the oil migration has been so great that any avenue of escape however small has been sufficient to allow most of the oil to disappear, whereas in California the time since the rocks were deposited has been so short that even where the oil sands are tilted, eroded and exposed at the surface, the oil has only in part disappeared, but undoubtedly if the time were extended the oil would in a large measure pass off into the atmosphere. It must not be supposed, however, that this failure to escape through the eroded edges of the porous beds is due entirely to lack of time. That is probably the most important element in the problem, but the tendency of such thick asphaltic oils as those of California to part with their lighter constituents where exposed to the air and to clog the sands with the tarry residue, undoubtedly has played a prominent part in preventing the escape of much of the oil.

In some fields the oil finds a reservoir in cleavage joints and fissures in the rock. It matters not whether these occur in pervious or impervious rocks, they serve equally well in storing the oil. The most striking case of this kind with which the writer is familiar is the Florence field of Colorado. There is seemingly reliable evidence to show that in drilling many of the wells of this field the drill has struck open cavities in the shale even at depths of more than 1,000 feet and such cavities apparently contain the oil. The character of this reservoir is still further attested by the linear arrangement of the locations of the best wells and by the effect that the "bringing in" or exhaustion of one well has upon another. Pools of this character are not common, for the effect of fissures is generally to allow the escape of the oil from some reservoirs lower down than to retain the oil as a pool. In the Florence field the oil is apparently held in fissures in shale in a broad open syncline, and the impervious layer that prevents its escape until it is reached by the drill appears to be a zone of water-saturated shale which extends a certain distance below the surface. Day[1] has shown that oil will diffuse readily through dry Fullers earth, but that the moistened earth is absolutely impervious. From this it is seen that the impervious cover over an oil reservoir may be fine-grained rocks so cemented as to prevent the passage of the oil through it, or it may be fine material merely saturated with water.

One of the most striking occurrences of oil, and at the same time the most puzzling, is in the so-called salt domes of the Coastal Plain about the Gulf of Mexico. The salt domes are low mounds on the flat plain composed of enormous masses of salt or sulphur. In some mounds the salt appears at the surface, but in others erosion has not yet exposed the masses of salt which invariably form the cores of the mounds. The rock strata of the plain dip away from these masses in all directions and where not removed by erosion are found arching over its summit. In effect they are true structural domes or anticlines, with the oil occurring on the top or on the flanks of the fold. The occurrence of oil in these domes seems to conform to the anticlinal theory, but whether the pool exists in the bedded rocks near the top of the dome or whether it is derived from a reservoir lower down and merely finds its way upward around the core of salt has not yet been determined. Capt. A. F. Lucas, who first demonstrated the association of large bodies of oil with these salt domes by sinking the original well on Spindletop near Beaumont, Texas,

[1]Day, David T. The conditions of accumulation of petroleum in the earth. Am. Inst. Min. Eng. Trans. vol. 41, pp. 212-224, 1911.

sought to determine the source of the oil by deep drilling, but unfortunately the well had to be abandoned at a depth of about 3,400 feet, and thus the question of the composition of the core at great depth and the possibility of an oil reservoir below those already discovered remains unknown. The question of the origin and mode of accumulation of the oil in these domes is bound up with that of the origin of the domes themselves and the geologists who are most familiar with them do not agree in their explanations. Some have attributed the salt which forms the cores of practically all the mounds to have been deposited by currents of hot water ascending along lines of weakness caused by faults; others have attributed the dome structure itself to the power generated by the growing crystals of salt, while others are certain that the domes are but the surface expressions of laccoliths of igneous rock which do not reach the surface. Naturally, the latter explanation suggests the inorganic origin of the oil, but it is equally possible that the oil originated from inorganic material in the surrounding sedimentary rocks and has merely found reservoirs for its accumulation in the salt domes. The evidence available cannot be regarded as at all conclusive, but until such evidence is obtained it must be admitted that the theory of inorganic origin applies to this field as well as that of the organic origin and may prove to be the correct theory to apply to all fields showing such phenomena.

Although the limits of this paper will not permit of a full discussion of the movement of oil through the rocks and the effect of structure on its accumulation, no account would be complete without a word regarding the oil shales that have been found in many parts of the world. Most of these consist of masses of carbonaceous material, which yield upon distillation oil of various grades, but some are reported in which petroleum seems to exist as free oil that has been derived from the carbonaceous material held by the shale. Such apparently is the case in regard to the oil-shale of Colorado and Utah, and also, according to report, of that of Derbyshire, England. If this interpretation be correct the oil has migrated only a short distance if at all, and most of it is in the place in which it originated.

GEOLOGICAL OCCURRENCES OF PETROLEUM AND NATURAL GAS.

CONDITIONS NECESSARY FOR NATURAL GAS ACCUMULATION.

In any locality, no matter in what part of the world it occurs, at least three conditions are necessary to assure its accumulation at any particular locality. These are

(a) A porous formation to act as a reservoir.
(b) An impervious cover to prevent the gas from escaping.
(c) Some form of geological structure to concentrate it.

Reservoir.—Natural gas and oil occur in rocks of all geological ages. It is the character of the individual formations that is essential to assure a reservoir. The oil or gas rock must be porous; and it generally consists of sand, sandstone, limestone or dolomite, although there are a few known instances where gas exists in shale. The presence of gas in limestone may be due to the natural porosity of the rock, to simple solution, or to chemical changes which result in the formation of dolomite. The possibility of the Trenton limestone holding oil and gas is due to the fact that the limestone has been locally altered to a dolomite, which thereby becomes more porous than a sandstone. The exact point of occurrence may be controlled, therefore, not only by the structure of the rock, but also by its internal characteristics. Since its upper portions correspond with places of change from limestone to dolomite, the highest portion of the anticline is more commonly the region saturated with gas. In the case of sandstone, the occurrence of gas is due not only to structure, but is affected also by the continuity of the stratum. Not all sandstone contains gas, one essential feature being that the individual grains comprising the rock shall be rounded sufficiently to assure a porous bed which forms a reservoir. Well drillers recognize the internal variations when they speak of a sand being "open" or "close," "soft" or "hard," "good" or "poor" in character. An experienced driller can determine the porosity of a sand satisfactorily by an eye examination, but he is unable to determine whether it would be productive without knowing the geological structure of the locality in question. In order to illustrate the wide occurrence of natural gas and oil stratigraphically, the following summary is given of the various horizons at which they are known to exist in the principal fields of the United States and Canada.

Geological Structure of Typical Gas Fields.

Name of Gas Field	Locality	Age of Producing Sands	Type of Geological Structure
Bow island	Alberta	Cretaceous	Crest of geanticline or great arch in strata.
Leamington	Ontario	Ordovician	Northern end of Cincinnati geanticline.
Norfolk and Elgin County fields	Ontario	Ordovician	Pinching out of Clinton and Medina sands.
Central Ohio	Ohio	Ordovician	Pinching out of Clinton sand.
Lima	Northwestern Ohio and northern Indiana	Silurian	Crest of Cincinnati geanticline.
Majority of West Virginia and Pennsylvania fields		Carboniferous and Devonian	Crests of anticline.
Southeastern Ohio	Ohio	Carboniferous and Devonian	Structural terraces, small anticlines, and domes.
Kansas and Oklahoma fields		Carboniferous and Devonian	Crests of domes and pinching out of certain sands.
Caddo	Louisiana	Cretaceous	Crest of the Sabone uplift (geanticlinal).
Transylvania	Hungary	Tertiary	Crests of domes.

Formations Productive of Oil and Gas.

State	Formation	Age
New York	Guelph limestone Niagara limestone Medina sandstone Trenton sandstone	Silurian
	Potsdam sandstone	Cambrian
	Conemaugh Allegheny Pottsville	Carboniferous
Pennsylvania	Pocono	Sub-Carboniferous
	Catskill Chemung	Devonian
	Conemaugh Allegheny Pottsville	Carboniferous
West Virginia	Green Briar limestone Pocono	Sub-Carboniferous
	Catskill	Devonian
	Pottsville	Carboniferous
	Pocono	Sub-Carboniferous
	Corniferous	Devonian
	Niagara Clinton	Silurian
Kentucky	Hudson River Trenton limestone Calciferous	Ordovician
Alabama	Pottsville	Carboniferous
	Claiborne	Tertiary

State	Formation	Age
Louisiana	Nacatoch sand Annona chalk Eagle Ford Woodbine sand	Cretaceous
	Claiborne	Tertiary
Texas	Navarro	Cretaceous
	Permian series	Carboniferous
Colorado	Mesaverde Pierre Mancos Benton	Cretaceous
	Pierre	Upper Cretaceous
	Benton	Upper Cretaceous
Wyoming	Kootenai	Lower Cretaceous
	Embar	Carboniferous
	Fernando	Pliocene Tertiary
	McKittrick Monterey group	Miocene Tertiary
California	Tejon	Eocene Tertiary
	Chico Knoxville	Cretaceous
	Conemaugh Allegheny Pottsville	Carboniferous
Ohio	Ohio shales	Devonian
	"Clinton sand"	Silurian
	Trenton limestone	Ordovician

State	Formation	Age
Indiana	Huron sandstone	Sub-Carboniferous
	Corniferous limestone	Devonian
	Trenton limestone	Ordovician
	McLeansboro, Carbondale, Pottsville	Carboniferous
Illinois	Chester, St. Genevieve	Sub-Carboniferous
	Niagara limestone	Silurian
Kansas	Pleasonton shale, Cherokee shale	Carboniferous
	Trinity	Cretaceous
Oklahoma	Cisco, Cherokee, Atoka, Winslow	Carboniferous

Cap Rock.—Ordinarily the bed of impervious rock overlying a "sand "which holds oil or gas is known as the "cap rock." It is frequently very hard, though not always, and generally consists of limestone or shale. One of the most widespread formations overlying gas and oil sands is the Utica shale above the Trenton limestone in the Ohio-Indiana fields. The Clinton sand of central Ohio is overlain in a similar way by the Clinton shale. The numerous oil and gas sands of Pennsylvania and West Virginia are all overlain by impervious shales. In the Louisiana fields a very hard stratum of limestone acts as a cap-rock overlying a more pervious portion of the same formation. In fact cap rocks may consist of almost any material other than sandstone.

TYPES OF GEOLOGICAL STRUCTURE NECESSARY FOR OIL AND NATURAL GAS ACCUMULATION.

In order to consider the various geological structures in which oil and natural gas are known to exist, the writer has had occasion to classify them. The original classification was published in Economic Geology[1] and it referred to accumulations of oil as well as of gas.

CLASSIFICATION OF OIL AND GAS ACCUMULATIONS.

The structure of the productive stratum itself must be considered independently of the configuration of structure of any surface formation.

In order to illustrate the difference in geologic conditions, a tentative classification of fields has been made. There is no attempt made to distinguish oil structures from gas structures, nor between the different kinds or ages of productive formations.

The object of the tentative classification is to show that accumulations of oil and gas can be grouped into classes, each division of which follows a special rule of structure, and all of which have certain aspects in common.

The classification proposed is as follows:—

I. Where anticlinal structure exists.
   - (a) Strong anticlines standing alone.
   - (b) Well-defined anticlines alternating with synclines.
   - (c) Structural terraces.
   - (d) Accumulations on monoclines due to thinning out or change in texture of the sand as it rises toward the nearest anticline.
   - (e) Broad geoanticlinal folds.
   - (f) Overturned folds.

II. Quâquaversal structures.
   - (a) Anticlinal bulges.
   - (b) Stratigraphic domes.
   - (c) Saline domes.

III. Sealed faults.

IV. Oil and gas sealed in by asphaltic deposits.

[1]Econ. Geol., vol. IV, 1909, pp. 565-570.

V. Contact of sedimentary and crystalline rocks.
VI. In joint cracks.
VII. Surrounding volcanic vents.
VIII. Where there is no particular gas structure, but the gas is associated with adjacent oil pools.

Class I. *Where anticlinal and synclinal structure exists.*—This is the type of oil and gas accumulation with which we are most familiar. It includes a large majority of the known oil fields of the world. The Appalachian, Mid-Continent, Illinois, Indiana, Wyoming, Colorado, northern Louisiana, and northern Texas, and some of the California fields in this country, and the Russian, Austrian, Burma, and Borneo fields in the eastern hemisphere, all belong to this class. It is divided into five subclasses, in order to distinguish between various structural relations in which oil is found in connexion with anticlines and synclines.

Subclass (a). *Where strong anticlines exist standing alone.*—In this division I would include fields that bear a direct relation to *very pronounced* uplifts, easily recognizable, and which constitute a marked geologic feature of the region. The only prominent example in the eastern fields of the United States is the famous Eureka-Volcano Burning Springs anticline in West Virginia, which is 25 miles in length, ranging in direction from North 10 degrees West to North 20 degrees East, being from an eighth of a mile to half a mile broad on its flat crest, and having side-dips of from 20 to 60 degrees. This differs somewhat in direction from the main Appalachian folds, and was probably produced at a different time. It is one of the earliest recognized anticlines in the country, and probably has had as many wells drilled on it as any other anticline. It has been described by White[1], Andrews, and Evans. Some of the California fields having sharp anticlines probably belong to this class. Possibly the Baku field of Russia may also belong here.

Subclass (b). *Where well-defined alternating anticlines and synclines exist.*—This is really a composite of sub-class (a). With minor exceptions it includes the entire Appalachian field in

[1] I. C. White, Bull. Geol. Soc. Am., vol. 10, 1899, p. 29.

Pennsylvania, West Virginia, and eastern Kentucky, southern Indiana and Illinois, the Oklahoma fields and the Caddo field in Louisiana, the north Texas fields, and those of Colorado, Wyoming, and Montana.

The Caddo field has nothing in common with the Beaumont and Jennings fields and other fields of the Coastal Plain of Louisiana and Texas, but it is very similar in structure to the fields of Pennsylvania, West Virginia, and Illinois. The proper structure in northern Louisiana is afforded by the Sabine uplift. The final distribution of oil and gas in the Caddo field is presumably due to slight anticlines and synclines and differences in porosity of the Upper Cretaceous formations which exist there.

Several of the oil fields of California also belong in this class Examples are the Coaling field and the Los Angeles field, according to descriptions by Eldridge,[1] and by Arnold and Anderson.[2] In 1895 Noettling established the fact that the oil fields of the Irrawaddy, in Burma, correspond with the structural theory; and I believe they belong in this subclass. The oil and gas in those fields are directly related in their accumulation to anticlines and domes in the Miocene sandstone.

The rocks in the fields comprised in subclass (b) are folded into alternating anticlines and synclines, bounded by moderate dips, seldom more than 30 degrees from the horizontal. This is the subclass to which the anticlinal theory as originally propounded applies strictly; the gas occurs in the upper part of individual sands or "pay streaks," the oil occurs somewhere below the gas, while salt water, if it occurs at all, fills in the remaining space in the sand (if the latter is uniformly porous), or occurs in the separate "pays" (where the sand as a whole has not a high degree of porosity), all these deposits being controlled mainly by the force of gravity. Where oil or salt water occurs higher in the sand than gas, it is presumably due to sharp changes in the dip, or to a multiple nature of the "pay streaks."

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[1]Geo. H. Eldridge, Bull. 213, U.S. Geol. Survey, pp. 306-321, 1902.

[2]Ralph Arnold and Robert Anderson, Bull. 357, U.S Geol. Survey, pp 70-71, 1908.

Subclass (c). *Terrace structures are an exaggerated form of the flattenings of dip, included in subclass (d).*—As a rule where gas occurs, it is found on the outside of the terrace and

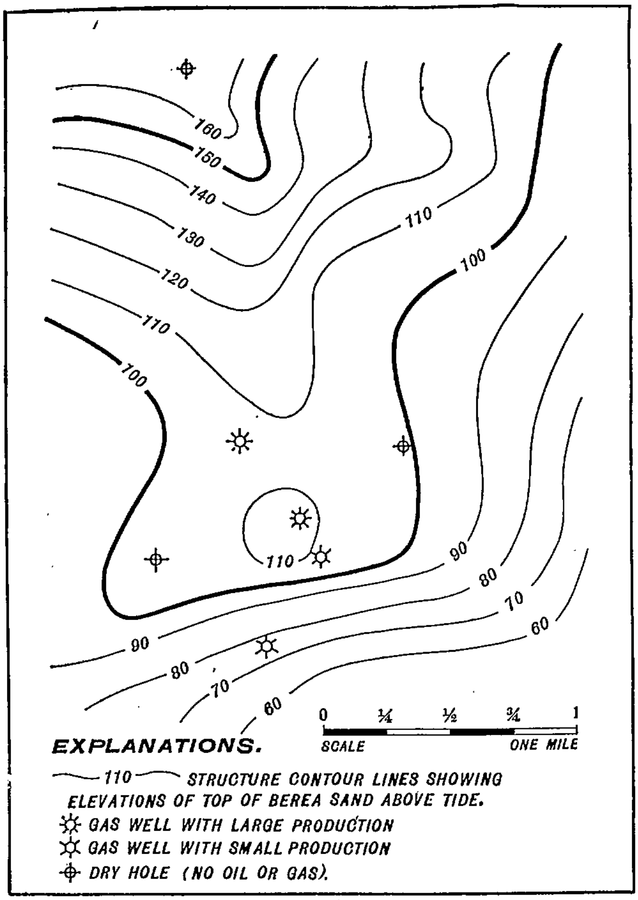

Fig. 1. Occurrence of natural gas on a structural terrace in Ohio.

oil on the inside, though this is not an infallible rule. The change in the rate of dip, forming a local interruption, seems to be the essential factor. An example of a structural terrace in southwestern Ohio is shown in Fig. 1.

The effect of terrace structure was first explained and illustrated by Edward Orton in 1886[1]. The terraces described by him were in the Trenton limestone fields of northwestern Ohio. In the Findlay field the oil and gas were found in two terraces, separated by a monoclinal dip. The upper terrace yielded dry gas, the lower terrace yielded oil and water.

Orton gave the name "arrested anticlines" to structural terraces, and cites the Macksburg field of southern Ohio as an example.[2] The terrace structure of the Macksburg field was first recognized and described by Newhall in the same volume.

During the past decade hundreds of similar terrace structures have been discovered throughout southeastern Ohio and to some extent in adjacent states, and most of them are available for oil and gas development. Generally, though not always, the structure can be determined from the geology of the surface without the need of borings until one is ready to make his test. Other good examples of terrace structures and relations of oil to them were shown by Griswold and Munn in Jefferson co., Ohio.[3]

Subclass (d). *Where there are monoclinal dips; i.e., where he rocks dip in one general direction throughout (although the dip may vary in steepness).*—The majority of the oil and gas pools in southeastern Ohio belong in this division. Definite anticlines are not so common in Ohio as in Pennsylvania and West Virginia, as the prevailing dip of the formations is all in one general direction (toward the southeast). However, the application of the structural theory, properly understood, is almost as certain of profitable results as it is in Pennsylvania, because the dip is not uniform, but varies from flat to over 5 degrees from the horizontal. Rounded or somewhat elongated semi-anticlines of subclass (b) are occasionally found.

Oil and gas can be predicted in subclass (c) through recognition of the principle that any change in the rate of dip is to be considered as a possible place of accumulation; and that such a

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[1]Science, vol. 7, p. 563.
[2]"Geology of Ohio," vol. 6, p. 94, 1888.
[3]Bull. 318, U.S. Geol. Survey, 1907.

place of accumulation once discovered, the pool can be easily extended (within structural limits) by following lines of horizontality in the sand.

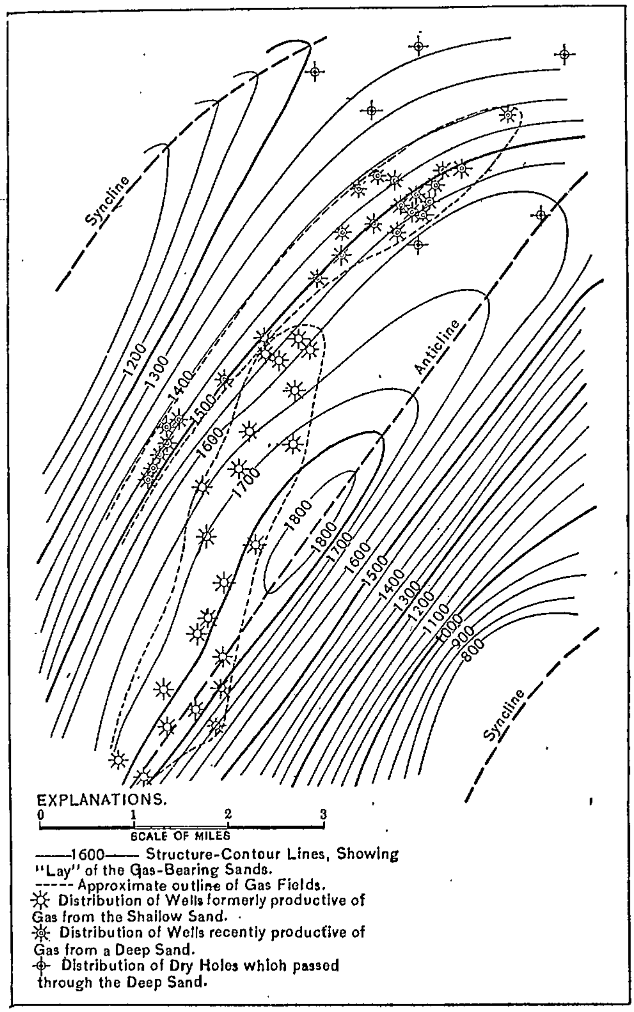

Fig. 2. Typical occurrence of natural gas fields on anticlines in Pennsylvania and West Virginia.

To this subclass may also belong (in part at least) the Florence oil-field in Colorado, where the oil exists in beds having a dip of less than 5 degrees, lying between dips as great as 20

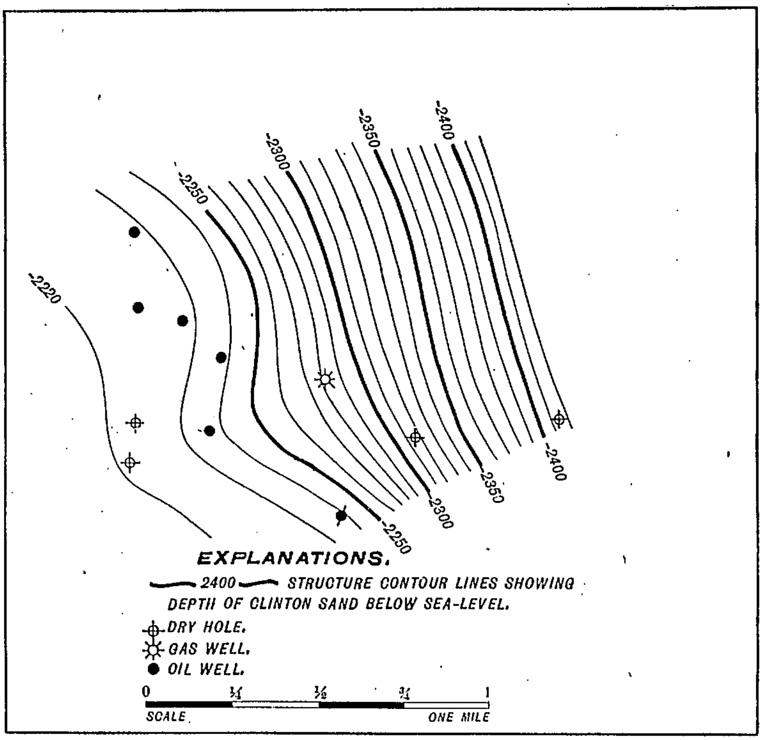

Fig. 3. Example of sub-class I (c.). An oil pool coincident with a change in monoclinal dip, in the Clinton sand of Southern Ohio. Structure map of the sand in a small area determined by the convergence method.

degrees (according to Fenneman), and occupying a portion of a structural slope where the sands locally are rather flat for a few miles, being a semi-terrace in the formation. In this field the beds carry little water.

Subclass (e). *Broad geoanticlinal folds.*—This is an extreme type of I(a). By a geoanticline is meant an anticline which is extremely long and broad, and constitutes more than

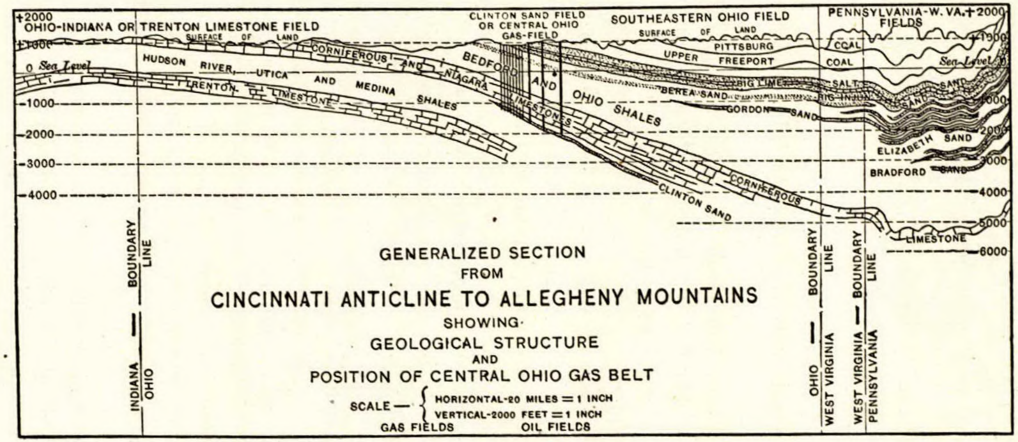

Fig. 4. Generalized cross-section from Cincinnati anticline to Allegheny mountains, showing relative positions and geological structure of the various Ohio and Pennsylvania gas fields.

a local feature, extending over thousands or tens of thousands of square miles. One of the best examples in this country is the Cincinnati anticline, in which immense reservoirs of oil and gas have been developed and exhausted, the oil and gas being contained mainly in the Trenton limestone. Owing to the broad areas under which oil and gas are found in the Cincinnati anticline the chances of success in drilling were originally much better than in other fields. The decline of the Trenton limestone fields was largely due to wastefulness of the gas before people in general understood that the fields were subject to exhaustion. Most of the pools in the Clinton sand in Ohio are situated along the eastern flank of the Cincinnati anticline, but these pools belong under subclasses (c) and (d), of the classification.

Subclass (f). *Overturned folds.*—Examples of oil and gas occurring in connexion with overthrust folds are not common but some such cases are conspicuous in California, as shown by Arnold and Johnson[1].

Class II. *Domes, or quaquaversal structures.*—Certain types of anticlines developed as well-marked domes might be classed here; but since they are included in subclasses (a) and (b) of Class I, the domes here considered will be limited to those which are not part of any well-developed anticline, and are thus susceptible of a different classification. The conspicuous examples of the occurrence in this country are in the fields of the Coastal Plain of Texas and Louisiana, described by Hayes and Kennedy[2], Fenneman[3], Harris[4] and others. Some of the best known instances are Spindletop, Sour lake, and Batson. The mounds in which gas and oil exist may not show as such at all on the surface. They do, however, appear *in some cases* as circular elevations, covering several hundred to several thousand acres and rising 50 to 100 feet above the surrounding plain, in which case they can, of course, be easily recognized. They are frequently

[1]Ralph Arnold and Harry R. Johnson, Bull. 406, U.S. Geol. Survey, 1901, p. 97.

[2]C. W. Hayes and Wm. Kennedy, Bull. 212, U.S. Geol. Survey, 1903.

[3]N. M. Fenneman, Bull. 282, U.S. Geol. Survey, 1906.

[4]G. D. Harris, Geol. Survey of La., Bull. No. 7, 1908.

known as "salines," on account of containing deposits of rock salt. Underneath the surface the whole body of strata have a mound-like shape, containing, in addition to the ordinary formations, limestone, salt, gypsum, and other minerals, all of

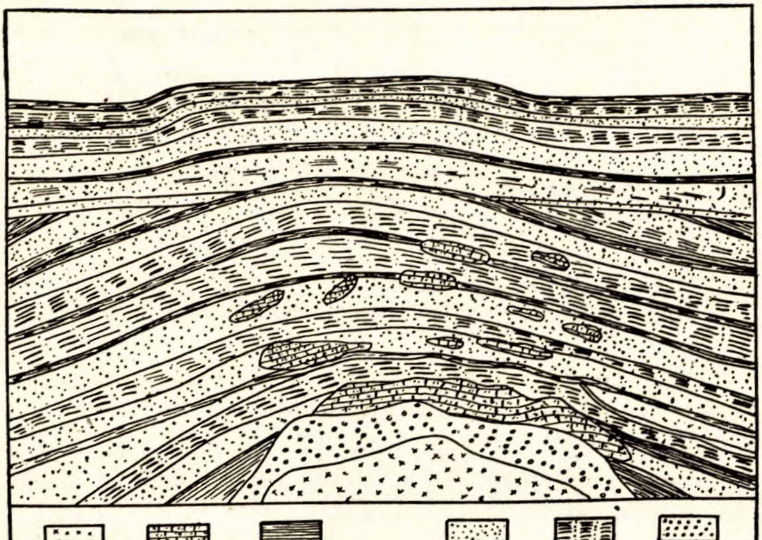

Fig. 5. Cross section of typical saline dome oil field, Texas (after Hager).

which have been passed upwards in approximately circular outlines. Fig. 5 shows a cross section of a typical saline according to the ideas of Harris.

Class III. *Along sealed faults.*—The known examples of this class consist of some of the pools in the Los Angeles field and some of those in the Lompoc field in California described by Arnold. In these cases the highly inclined oil sands are cut off abruptly below ground by a fault, thus sealing in the oil and gas and preventing their escape to the surface. Some of the other fields in California probably belong to this class. To show the probability that such cases are more frequent than known, it may be worth while to mention that oil springs frequently, and perhaps generally, occur along fault lines. Some of these instances exist in British Columbia and others in Gaspé, Quebec.

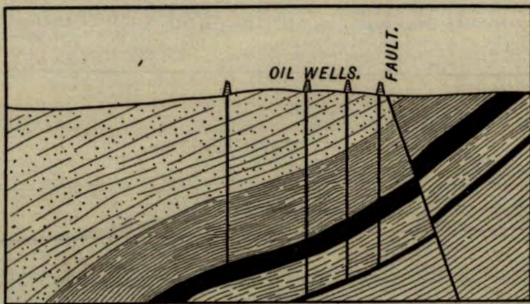

Fig. 6. Example of class III. An oil pool in California sealed in by a fault line. (After Arnold, Bull. 309, U.S. Geol. Survey, Plate 20, 1907.)

Class IV. *Oil and gas sealed in by asphaltic deposits.*—Certain examples of this class, like the last, are few, and not well known, but they may be exemplified by the Pitch lake of Trinidad, where small quantities of oil and gas are reported. Some of the oil found near the vein of grahamite at Ritchie mines,

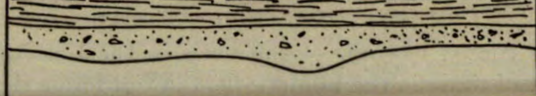

Fig. 7. Theoretical example of class V. A gas pool in the arkose zone between granite and Potsdam sandstone, in Province of Quebec.

West Virginia, described by White[1], may belong in this class, although these deposits are also dependent in their original accumulation upon anticlinal and synclinal structure, as in Class I.

[1]I. C. White, Bull. Geol. Soc. Am., vol. 10, 1899, pp. 277-284.

Class V. *At the contact of sedimentary and crystalline rocks.*—The principal known examples of this class are in the Provinces of Quebec and northern Ontario, and have not been much studied. It is probable that gas occurs at some places in northern New York state in this way. No records are at hand of *oil* occurring in such a position, but gas occurs in commercial quantities. It is held in the zone of the lower Potsdam sandstone, which is of arkose nature, and rests directly upon the underlying granite or gneiss. The deposits seem, so far as the writer has been able to learn from men who know the fields, to occur on top of prominent knobs of the granite. The occurrence may be somewhat as in Fig. 7.

Class VI. *In joint cracks.*—According to descriptions of Mr. H. S. Gale, some of the oil in the Florence field in Colorado occurs in joint cracks in shale. Other examples of this nature are believed to exist elsewhere.

Class VII. *Surrounding volcanic vents.*—This class seems to be illustrated by certain Mexican fields. It may be considered an exaggerated form of Class II.

Although most fields are susceptible of classification according to the foregoing plan, some of them do not fit in easily. It is believed that if all the causes and effects, and the internal character of the sands, were known in every case, the fields could be classified. Another factor of importance in the position and distribution of all types of oil and gas accumulations is the degree of saturation of the sand; although, as has been explained[1], the position of the water line is not so important as some persons have supposed. In the Berea grit, for instance, many pools have been found, and are still being tapped, where the oil lies below the water line in neighbouring pools in the same sand.

Some of the newer oil developments have taught lessons which operators and geologists took years to learn, but now that they have been learned, they are becoming productive of good results. For instance, in pools where the oil occurs in thin "pay-streaks," there are sometimes dry areas several square miles in extent, which lie directly "down-dip" from important pools of

[1]Econ. Geol. vol. IV, 1909, pp. 565-570.

oil or of water or of both. Near the corner of Brighton, Chippewa and South Beaver townships, in Beaver county, Pa., is a small pool in which the production of the wells is very light, which is bordered on the northeast, southeast, and south by a number of strong salt water wells. The "pay" here, as in the majority of pools in the Berea sand, is near the top of the sand. The salt water in close proximity to the pool occupies a definite structural position with reference to it, occurring on all sides of the pool except on the up-dip side. However, this water was not found to extend far down-dip from the oil-pool, several wells between there and the Ohio river, four miles southeast, having been dry of both water and oil. Similar occurrences are found repeatedly in the Berea sand in Beaver county, Pa., and in neighboring counties and the Pan-Handle of West Virginia and in Ohio, where dry areas of the sand occur on the down-dip sides of several pools of oil and salt water.

The point to be noted is that the lowest oil-pool in a stated group of pools in the Berea sand is successively higher above sea-level going from southwest to northeast parallel with the Ohio river. Near Steubenville and Mingo, in Jefferson county, Ohio, the lowermost elevation at which oil has as yet been discovered in this sand is 600 feet below sea-level; at Holidays Cove, West Va., it is about 400 feet below sea-level; on the West Virginia-Pennsylvania line near the southwestern corner of Beaver county it is 250 feet below; at Hookstown and Smiths Ferry, Beaver county, it is at sea-level; while near the corner of Brighton, Chippewa and South Beaver townships, in the pool first mentioned, it is 200 feet *above* sea-level. The progressive rise toward the northeast is explained in part by the greater general height of the anticlinal folds and the lesser depth of the adjacent synclinal depressions in the sand in that direction.

The fact that a so-called pay-streak lying down-dip from a known pool may be dry of both water and oil does not disprove the structural theory of the accumulation in its proper application; but the position of the dry area is due to the fact that whatever water and oil may once have occupied the pay-streak have been drained out, segregated elsewhere naturally or artifically, or the pay-streak is in reality not so porous as would seem from the size of the grains in the sand-pumpings. Moreover, many apparently dry areas are due to a change in the character of the sand, by which it becomes practically non-oil bearing or non-water bearing.

The fields in the deeper sands frequently do not correspond structurally with those in the shallow sands, even where the sands are parallel, and this is one reason why the deeper fields are not discovered more rapidly. As a rule, the shallows sands are productive of gas near the crests of anticlines, where anticlines occur, as in Classes I (a) and I (b), and are frequently confined to domes, in these crests, *while the deeper sands may be*, and frequently *are*, barren on the crests and productive of gas on the flanks of the anticline where it is dipping moderately steeply towards the adjacent syncline. This is generally due to the non-parallelism of the deeper sands. And since the size of pools is approximately inversely proportional to the steepness of the dips, these deep-sand pools commonly take the longest to be discovered by the drill.

THE GEOLOGICAL CONDITIONS GOVERNING THE OCCURRENCE OF PETROLEUM AND NATURAL GAS.

In applying the principles governing the accumulation of oil deposits which have been dwelt upon in the preceding pages, to the principal oil fields of Canada and the United States, it will be evident that in developing any new field, a thorough knowledge of the geological structure is necessary for any decision as to whether oil is likely to be found, and if so to locate the most profitable sites for drilling.

BASIS OF GEOLOGICAL KNOWLEDGE.

While it is true undoubtedly that the great majority of the oil fields of Canada, especially in Ontario, as in some other parts of the world, have been discovered by random drilling, it can be said on the other hand that many pools have been found on the basis of geological structure. For instance, in the Raleigh township field in Kent county, the logs of water wells, which have been drilled, showed the presence of an anticline, and Mr. A. T. Gurd, of Petrolia, who happened to be travelling through the region, became familiar with this fact, and with the presence of an oil scum on the water. In view of these facts the first well was drilled, which was known as the "Gurd gusher." After drilling operations had begun and more holes had been drilled for oil, additional information was available by which the anticline could be outlined accurately.

The following table shows the oil and gas formations in Canada in which oil and gas deposits have been found.

Table of Oil and Gas Producing Formations in Canada.

Period	*Formation*	*Productive Locality*
Devonian	Hamilton limestone	Upper showing at Petrolia and Oil Springs.
	Onondaga limestone	Oil Springs and Petrolia fields
	Oriskany sandstone	Euphemia, Lambton county.
Silurian	Guelph limestone	Three horizons in Essex and Welland counties.
	Niagara limestone	Not known to be productive in Ontario; locally productive in New York and Indiana.
	Clinton limestone	Welland county.
	Medina red sand	Welland county. Also in New York state.
	White Medina sands[1]	Welland and Brant counties. Also in New York state.
Cambro-Silurian	Trenton limestone	Showings of gas in Welland county. This is extensively productive in Ohio and Indiana.
	Beekmantown and Potsdam sandstone	St. Catharines, Ontario. Also reported[2] productive locally in New York state.
Cambrian	Quebec group	Reported productive in Newfoundland.

ASSOCIATION OF BITUMENS WITH OIL AND GAS.

The source of the grahamite dike in Richie county, West Virginia, is believed to have been the Cairo oil sand, at a depth of about 1,300 feet from the surface.

[1] The so-called Clinton sandstone of Ohio is probably equivalent to this sand.

[2] Reported by Eugene Coste.

Similarly, the source of the albertite dike in Albert county, New Brunswick, is believed to have been oil intruded from petroliferous strata in the Albert shales.[1] Albertite is a hydrocarbon filling a large vertical fissure and column, in a fine-grained dark grey to black shale of lower Carboniferous or Devonian age. The albertite fissure was as much as seventeen feet wide in some places, and was mined to a depth of 1,300 feet. It also fills many branch veins in the wall rock. Albertite is also reported in the pre-Cambrian metamorphic slates, in the overlying Coal Measures, and as veins in the gypsum at the Hillsboro quarries.

The uintaite (gilsonite) of Utah has been shown by Mr. Eldridge to occupy a fractured zone in the central Uinta synclinal basin. There are many parallel vertical veins of gilsonite from one-sixteenth of an inch to eighteen feet in width, and from a few hundred yards to eight or ten miles in length: paralleling the mountains which border the basin.

To illustrate the importance of such bitumen dikes as indications of oil and gas, it may be said that the grahamite dike of West Virginia is in the center of one of the greatest oil and gas regions in the world; that the albertite of New Brunswick is only a few miles from the Stony Creek oil and gas field; and that the uintaite dikes of Utah lead, in a general direction, toward the oil which is found over the boundary in Colorado.

THE OCCURRENCE OF OIL IN IGNEOUS ROCKS.

Petroleum and solid bitumen have often been noticed by various observers in traps, basalts, and other igneous rocks. An interesting instance was mentioned by Sir William Logan[2] in a greenstone dike at Tar Point, Gaspé, in the province of Quebec.

Another instance is reported by Rateau in trachite in Galicia.[3]

An instance from the United States was mentioned by Arthur Lakes[4] in the volcanic dike in Archeluta county, Colorado.

[1]Bailey, Geol. Survey Canada, 1876-77, p. 354 et seq.

[2]Geology of Canada, 1863, pp. 400-789.

[3]Annales des Mines, 8th series, Vol. XI, pp. 150, 152.

[4]Mineral Resources of the U. S., 1901, p. 561.

Another unpublished instance contributed by D. T. Day refers to a boulder of vesicular basalt from Colorado in which the vesicles were filled with oil. In order to prove whether the oil had filtered in from exterior sources, a fragment was boiled with benzol until no more oil could be extracted, and the basalt still contained much oil. It was shown, however, that the cavities had been sealed by a secondary deposit of carbonate of lime and that by removing this the oil could all be extracted and the basalt left intact. Thus the exterior origin of the oil was rendered probable.

In the vicinity of Binny Craig, Scotland, a volcanic neck or pipe was encountered in an oil shale working; this dike consisting of trap, and containing cavities in which mineral wax, pitch or paraffine were found.[1]

A still more radical instance was noticed by the undersigned in extensions of basalt cones in the coastal plain in the oil fields of Vera Cruz, Mexico, where a very viscous oil was seen running down the slope of the cone from a point perhaps about one hundred feet above its face. This and the other instances are not, however, in the opinion of the undersigned, due to the oil having had an igneous origin, but are accounted for by the fact that the volcanic rock was intruded from below into the sedimentary formation which contained oil, and consequently must have absorbed large quantities of bitumen in ascending to the surface. Moreover, in an instance like that in Mexico there are a great many crevices in the circumference of volcanic necks, and these are sufficient to allow oil to enter them from the surrounding Tertiary and Cretaceous formations, and to ascend to the surface in that way.

However, it is fair to say that no conclusive argument has ever been advanced, either for or against any theory of the origin of bitumen, except certain arguments which will apply in particular instances. As a rather convincing argument, Mr. Coste derives evidence from the eruption of Mt. Pelee in Martinque, where an immense quantity of gas swept down from the crater,

[1]Henry M. Cadell, oil-shale holdings of the Lothians, Transactions of the Inst. of Min. Eng., Vol. 22, Pt. 3, pp. 347-353.

killing many thousands of people and animals. It was inferred that the gas consisted mainly of hydrocarbons.

On the other hand, the opponents of the volcanic theory advocate the fact that the gas originating from volcanoes, wherever it has been collected and tested, consists mainly of carbonic acid, and the proportion of carburretted hydrogen is only from one to four per cent.

MUD VOLCANOS AS EVIDENCES OF NATURAL GAS.

One of the foremost localities in the world for mud volcanos is situated in Asia Minor at both extremities of the Caucasus mountains at Taman-Kertch, between the Black sea and the Sea of Azof, and also at Baku on the Caspian sea, in which mud volcanos have been known for centuries and having been associated with large quantities of natural gas and petroleum. The height of the mud volcanos from the Apcheron peninsula near Bakou is very great, sometimes being as much as 1,300 feet; while the mud volcanos of Hungary, on the other hand, are seldom over thirty feet in height.

EXUDATION OF OIL.

In past times rivers of oil have been known to boil out from beneath the Caspian sea, and natural explosions of burning oil have taken place, throwing masses of clay and stones into the air, uplifting the bottom of the sea locally and giving rise to small islands in the vicinity of Bakou.[1]

ASSOCIATION OF OIL AND GAS WITH SALT AND SULPHUR.

In a large number of American and foreign oil fields an association of salt and sulphur and hydro-carbons is found. This is true in Russia, Sumatra, Java, Japan, China, Roumania, Germany, and Hungary. Gypsum and zinc blend are also found associated with these deposits, and pyrites and galena are reported by at least one writer.

[1]A De Lapparent, Traite de Geologie, 1883, p. 490.

CHAPTER V.

PREPARATION FOR DEVELOPMENT.

CHOICE OF TERRITORY.

Whether the question is one of "wild-catting" for oil—prospecting for petroleum outside of all known oil pools—or whether it is the development of what is known as "proved" territory, it is possible at the present time to lessen the expense of the enterprise very greatly by giving careful geological study to the problem of selecting the sites for drilling.

More frequently than otherwise an incentive to drilling is given by the discovery of seepages of thick asphaltic oil or dried asphalt, or by the occurrence of a steady flow of gas from water. All of these bespeak the broken crest of an anticline from which oil is escaping, or similar escape from a fault or fissure. Care must then be taken to drill far enough away from the line of fracture so as to penetrate the oil-bearing stratum at a depth sufficient to secure a supply. The distance from the seepages depends very much upon the dip of the rocks; the greater the dip, the greater the depth at which the oil rock should be struck in order to secure a good supply. From a thousand to two thousand feet is the best range of depth at which to strike the oil-bearing stratum where the dip of the rocks is comparatively great. Where the beds have only a slight dip, the oil can be struck to advantage at 500 to 1000 feet below the surface.

Where the oil is sought in what has been known to be an unbroken anticline, or dome, the first well may be drilled to advantage as near the crest as possible, for while this well may develop nothing but gas, it gives valuable information for subsequent wells, and any enterprise must be prepared for drilling a number of holes in the development of a new field.

This subject, including a discussion of the best location for wells, spacing of wells, and the importance of geological examination of the territory, is given careful consideration in the chapter by Prof. Roswell H. Johnson.[1]

[1] Chapter x.

LAWS AND REGULATIONS FOR ACQUIRING PUBLIC OIL LANDS.

The policy of the different provinces of Canada with regard to the granting or reservation of minerals, both precious and base, in public lands when these were sold, has not been uniform. Under the regalian principle of the common law, although not expressly reserved in the grant, the right to the precious mineral was reserved if no mention was made of it.

The title to all the land, as well as all contained minerals, within the present Dominion of Canada was vested originally either in the King of France or in the English crown. As regards the part originally belonging to France, a grant of the land did not convey the right to the minerals without special words of conveyance regarding this right.

The common law of England, unless modified by statutes, is in force, however, in all the territories and provinces of Canada except Quebec, where the old French law is the basis of the legal system. By the theory of the common law in Canada, gold and silver mines belong to the crown in all land whatsoever, unless they have been expressly severed therefrom and granted by the crown.[1] By the British North American Act, under the provisions of which the Dominion of Canada came into existence, exclusive jurisdiction was given to the several provinces to make laws in relation to the management and sale of public lands within their boundaries. In general all the public lands within the different provinces had been granted by the crown to the provinces,[2] and this grant included the regalian right to gold and silver. The House of Lords has decided that in provinces such as British Columbia, which were not specially mentioned in said Act, but were admitted afterwards, the assignment of the regalian right to gold and silver to the provinces took effect upon their joining the Dominion.[3] In the case of British Columbia, however, this was only a recognition

[1]McPherson and Clark, "Law of Mines of Canada," p. 28.

[2]British North American Act of 1867, sec. 1904, Law Reps. 1867 (30-31 Vict.), ch. III, p. 5.

[3]Attorney-General of British Columbia vs. Attorney-General of Canada, 14 Appeal Cases, 295 (304).

of the rights which said province held in the lands, precious minerals, etc., previously. In this province the policy of late has been to reserve all minerals when public land is sold, together with right of entry for working it.

Acting under the powers conferred upon them by Sec. 97 of the British North American Act, 1867, the provinces of *Quebec, Nova Scotia, New Brunswick, Ontario and British Columbia* have by their Legislatures enacted laws dealing with mines and minerals, including, in most cases, specific provisions for the development of petroleum and natural gas deposits.

By the provisions of section 109 of this Act and subsequent Orders of Council, these provinces possess, subject to the administration and control of their several legislatures, the right to dispose of the public lands within their boundaries, excepting such portions as are reserved to the Dominion for public works and undertakings or are required for purposes of defence.

Although *Prince Edward Island* was admitted to the Dominion by authority of this Act it was not affected by the provisions of section 109 since at that time it embraced no public lands.

Public lands in *Manitoba, Alberta, Saskatchewan, Northwest Territory, and Yukon* are subject to administration by the Governor in Council by authority of the Acts admitting these provinces to the Dominion (Rupert's Land Act 1868 Imperial and Order of Her Majesty in Council, dated July 31, 1880), or by Acts of the Dominion Parliament establishing them (Manitoba Act, 1870), Alberta and Saskatchewan Acts assented to July 20, 1905, and Yukon Act, R.S.C. Ch. 63, 1906.

Unappropriated Dominion lands located in the above mentioned provinces and territories are open for petroleum prospecting by any individual or company under the following Petroleum Regulations approved by Order in Council dated March 11, 1911:

Regulations for the disposal of Petroleum and Natural Gas rights, the property of the Crown, in Manitoba, Saskatchewan, Alberta, the Northwest Territories, the Yukon Territory, the Railway Belt in the Province of British Columbia, and within the tract containing three and one-half (3½) million *acres of land acquired by the Dominion Government from the Province of British Columbia, and referred to in subsection (b) of section 3 of the Dominion Lands Act, approved by Orders in Council dated 11th day of March, 1910, (re-established by Order in Council 12th Aug., 1911), and Order in Council dated the 11th day of March, 1911.*

Minister shall mean the Minister of the Interior of Canada.

1. The petroleum and natural gas rights which are the property of the Crown, in Manitoba, Saskatchewan, Alberta, the Northwest Territories, the Yukon Territory, the Railway Belt in the Province of British Columbia, and within the tract containing three and one-half (3½) million acres of land acquired by the Dominion government from the Province of British Columbia, and referred to in subsection (b) of section 3, of the Dominion Lands Act, may be leased to applicants at a rental of twenty-five (25) cents an acre for the first year, and for each subsequent year a rental at the rate of fifty (50) cents an acre, payable yearly in advance. The term of the lease shall be twenty-one years, renewable for a further term of twenty-one years, provided the lessee can furnish evidence satisfactory to the Minister to show that during the term of the lease he has complied fully with the conditions of such lease and with the provisions of the regulations in force from time to time during the currency of the lease.

2. No applicant shall be allowed to lease the petroleum and natural gas rights under an area of more than 1,920 acres.

3. If the tract applied for is situated in surveyed territory, it shall consist of sections, or legal subdivisions of sections, but the several parcels comprising the tract shall be adjoining. the length of the tract not to exceed three times its breadth. In unsurveyed territory, if at least one of the lines bounding the section of part of section applied for has been surveyed, and such survey has been duly approved, an application for a lease of the petroleum and natural gas rights under such section or part of section may be considered under the provisions of this section of the regulations.

4. Application for a lease of the petroleum and natural gas rights on surveyed lands shall be filed by the applicant in person with the Agent of Dominion Lands for the district in which the rights applied for are situated, or with a sub-agent for such district, for transmission to the agent, but priority of application shall be based upon the date of the receipt of such application in the office of the Agent of Dominion Lands for the district.

5. In case the surface rights of the tract applied for have been patented, or have been disposed of by the Crown under any Act or Regulation which contemplates the earning of patent for such surface rights, the lease shall not authorize entry thereon except with the written consent of the owner or occupant being first had and obtained. In the case of a timber license, grazing or coal mining lease, mining claim or other form of terminable grant which does not contemplate the issue of patent, the permission of the Minister to enter upon the land must first be obtained, which permission will be made subject to such conditions for the protection of the rights of such lessee or licensee as it may be considered necessary to impose.

6. If the rights applied for are situated in unsurveyed territory, application for a lease shall be made by the applicant in person to the Agent of Dominion Lands for the district in which the rights applied for are situated, or to a sub-agent for such district, for transmission to the agent.

7. Applications for a location situated in unsurveyed territory shall contain a description by metes and bounds of the location applied for, and shall be accompanied by a plan showing the position of such location in its relation to some prominent topographical feature or other known point. The plan shall contain sufficient data to admit of the position of the location applied for being definitely shown in the records of the department. The location must be rectangular in form, except where a boundary of a previously located tract is adopted as common to both locations, the length not to exceed three times the breadth.

The application shall be accompanied by evidence, supported by affidavit of the locator, to show that the following requirements have been fully complied with:—

(a) That the location applied for has been defined on the ground by the locator in person by planting two wooden posts, at least four inches square, and standing not less than four feet above the ground—such posts being numbered '1' and '2' respectively. The distance between post No. '1' and post No. '2' shall not exceed 15,840 feet, and upon each post shall be inscribed the name of the locator and the date of the location. Upon post No. '1' there shall be written, in addition to the foregoing the words 'initial post,' the approximate compass bearing of post No. '2' and a statement of the number of feet lying to the right and to the left of the line between post No. '1' and post No. '2'. Thus—(initial post, direction of post No. '2' is...........feet lie to the right and...........feet to the left of the line between post No. '1' and post No. '2'). (O. in C., 11 March, 1911.)

When the tract which an applicant desires to lease has been located, he shall immediately mark the line between post No. '1' and post No. '2' so that it can be distinctly seen, in a timbered locality, by blazing trees and cutting underbrush, and in a locality where there is neither timber nor underbrush he shall set posts of the above dimensions or erect mounds of earth or rock not less than two feet high and two feet in diameter at the base in such a manner that the line may be distinctly seen.

(*b*) All the particulars required to be inscribed on posts No. '1' and No. '2' shall be set out in the application and shall be accompanied by a plan showing the position of the tract in its relation to some prominent topographical feature or other known point, such plan to contain sufficient data to admit of the location being shown definitely on the record of the Department.

(*c*) The locator shall post a written or printed notice on a conspicuous part of the location applied for, setting out his intention to apply within thirty days from the date of such notice for a lease of the petroleum and natural gas rights under the said location.

(*d*) The application shall be accompanied by evidence, supported by the affidavit of the locator, in due form, to show that the above requirements of the regulations have been fully complied with.

8. In case the tract applied for is located in unsurveyed territory on the margin of a river or lake, it shall not include more than one mile in direct distance along such water frontage, and shall extend back therefrom as far as may be necessary to include a total area of not more than 1,920 acres, the length of the location, however, not to exceed three miles. The tract shall be marked on the ground by two legal posts firmly fixed in the ground, one at each end of such front boundary. The posts shall be numbered '1' and '2' respectively. It shall not be lawful to move post No. '1', but post No. '2' may be moved by a Dominion Land Surveyor if the distance between the posts exceed the length prescribed by these regulations, but not otherwise. The side boundaries shall be parallel lines drawn from each end of the front boundary at right angles to the base line of such river or lake established or to be established, by the Department. In the event of the base line not being established, the side boundaries of the location shall be drawn at right angles to the general direction of the valley of the river, or the margin of the lake. The required notice of application shall be posted conspicuously on the location near the margin of the lake or river on which it fronts.

The boundaries of claims situated on the margin of a lake or river, and any disputes which may arise in connection therewith, shall be subject to final adjustment by the Minister. (O. in C., 11 March, 1911.)

9. Application for a lease of the petroleum and natural gas rights under lands situated in unsurveyed territory shall be made by the locator in person to the Agent of Dominion Lands for the district in which the tract applied for is situated, or to a sub-agent for such district, within thirty days from the date upon which the tract applied for was staked as above provided, if it is situated within one hundred miles of the office of the Agent or Sub-Agent, otherwise it will not be considered. One extra day, however, shall be allowed for every additional ten miles or fraction thereof that the location is distant more than one hundred miles from the office of the Agent or Sub-Agent.

10. Where two or more persons lay claim to the same location, or to portions of the same locations, situated in unsurveyed territory, the right to the lease shall be in him who can prove to the satisfaction of the Minister that he was the first to take possession of the tract in dispute by staking in the manner prescribed in these Regulations, and that he made application for a lease within the specified time.

11. As soon as the survey of a township has been confirmed, all petroleum and natural gas leases embracing any portion of such township so surveyed and confirmed, shall be made to conform to the Dominion Lands System of Survey if the Minister so decides, by the substitution of a new lease describing by sections, legal subdivisions of sections, or regular portions of legal subdivisions—as nearly as may be the tract embraced in the leasehold in so far as the township so surveyed is concerned. If any part of the leasehold is in territory which remains unsurveyed, it shall continue to be described as in the lease originally issued, until such portion is included in a confirmed survey.

12. As soon as the survey of a township has been confirmed, all petroleum and natural gas leaseholds embracing any portion of the township so surveyed and confirmed, shall be subject to the withdrawal forthwith from the lease, without compensation to the lessees, of any portions which, in accordance with such confirmed survey, are found to be the property of the Hudson's Bay Company.

13. The lease shall bear date from the day upon which the application is granted and the rental for the first year at the rate of twenty-five (25c.) cents an acre shall be paid within thirty

days from such date, otherwise the application shall absolutely lapse and the rights applied for shall become available for other disposition. If during the term of the lease the lessee shall fail to pay the rental in advance for each subsequent year, at the rate of fifty (50c.) cents an acre per annum, within thirty days after the date upon which the same becomes due, the lease shall be subject to cancellation in the discretion of the Minister and to the immediate forfeiture of all the rights which the lessee had in the said lease.

Provided that if the lessee, in consideration of the expenditure to be incurred by him in actual boring operations upon his leasehold, makes application, at or before the beginning of the second and third years, respectively, of the term of the lease, for an extension of time within which to pay the rental when due, or becoming due, the Minister may grant such extension of time in writing, and if the lessee, before the end of the year in respect of which application was made, submits evidence to the Land Agent, or Sub-land Agent, of the district in which the leasehold is situated, in the form of affidavits by himself and two reliable witnesses, that during such year actual boring operations have been prosecuted upon his leasehold, as required by Section 15 of these Regulations, the amount expended in such boring operations, exclusive of the cost of machinery and casing, may be deducted from the rental which became due at the beginning of the said year. The balance of rental due, if any, shall be paid at the same time as the evidence in regard to work done is submitted, as above required. Failure to submit such evidence, or to pay the balance of rental due, will render the lease liable to cancellation, as hereinbefore provided.

14. The lessee shall, within one year from the date of the lease, have upon the lands described therein such machinery and equipment suitable for carrying on prospecting operations as the Minister may consider necessary, and he shall within the same period furnish evidence, supported by affidavit, showing the character, quantity and value of the machinery so installed and the date of its installation. If the required machinery is not installed within the period specified, and if evidence of its installation is not furnished within the prescribed period, the lease shall be subject to cancellation in the discretion of the Minister. Provided, however, that the Minister shall not require that the value of the machinery so installed shall exceed the sum of five thousand ($5,000) dollars.

15. The lessee shall commence boring operations on his leasehold within fifteen months of the date of his lease, and he shall continue such boring operations with reasonable diligence, to the satisfaction of the Minister, with a view to the discovery of oil or natural gas. If the lessee does not commence boring operations within the time prescribed, or if having commenced such operations he does not prosecute the same with reasonable diligence, to the satisfaction of the Minister, or if he ceases to carry on the same for a period of more than three months, the lease shall be subject to cancellation, in the discretion of the Minister, upon three months' notice to this effect being given to the lessee. Provided, however, that if satisfactory evidence is furnished to show that the sum of at least two thousand ($2,000) dollars has been expended in actual boring operations, by recognized methods, upon the leasehold in any year, such expenditure shall be accepted as compliance with this provision for the year during which such expenditure was incurred.

16. The lease shall in all cases include only the oil and natural gas rights, which are the property of the Crown, but the lessee may, upon application, be granted a yearly lease at a rental of one ($1) dollar an acre per annum, payable yearly in advance, of whatever area of the available surface rights of the tract described in his petroleum and natural gas lease the Minister may consider necessary for the efficient and economical working of the rights granted him.

17. Should oil or natural gas in paying quantity be discovered on the leasehold, and should such discovery be established to the satisfaction of the Minister, the lessee will be permitted to purchase at the rate of ten ($10) dollars an acre whatever area of the available surface rights of the tract described in the lease the Minister may consider necessary for the efficient operation of the rights granted him.

18. If it is not established to the satisfaction of the Minister that oil or natural gas in paying quantity has been discovered on the leasehold, the lease shall be subject to termination upon two years' notice in writing being given to the lessee by the Minister.

19. The boundaries beneath the surface of a location shall be vertical planes or lines in which their surface boundaries lie.

20. A fee of five ($5) dollars shall accompany each application for a lease, which will be refunded if the rights applied for are not available, but not otherwise.

21. The lease shall be in such form as may be determined by the Minister of the Interior, in accordance with the provisions of these Regulations.

22. The lessee shall not assign, transfer or sublet the rights described in his lease, or any part thereof, without the consent in writing of the Minister being first had and obtained.

23. No royalty shall be charged upon the sales of the petroleum acquired from the Crown under the provisions of the Regulations up to the 1st day of January, 1930, but provision shall be made in the leases issued for such rights that after the above date the petroleum products

of the location shall be subject to whatever regulations in respect of the payment of royalty may then or thereafter be made.

24. A royalty at such rate as may from time to time be specified by Order in Council may be levied and collected on the natural gas products of the leasehold.

25. At the end of each year of the term of the lease the lessee shall furnish a statement supported by affidavit, showing the number of days during the year that operations were carried on upon the location; the number of men so employed; the character of the work done; the depth attained; the total expenditure incurred; a detailed statement setting out fully the purpose for which such expenditure was incurred; the quantity of crude oil or natural gas obtained, and the amount realized from the sale thereof. Failure to furnish such yearly return will render the lessee subject to a fine of ten ($10) dollars a day for each day's delay in furnishing the sworn statement, and after three months' delay the lease shall be subject to cancellation.

These regulations are extended and applied to lands included in the railway belt in the province of British Columbia. (Order in Council, 11th of March, 1911.)

Western Canada School Land Leases.—By ruling of the Dominion Government in 1913, school land reserves in the west can be leased for petroleum and natural gas purposes to applicants, at a rental of 25 cents per acre for the first year, and 50 cents per acre for each consecutive year. The leases are allowed to run twenty-one years, and are renewable at the end of that time. A condition is made, however, that not more than 640 acres will be leased to any one person.

LAWS CONCERNING INDIVIDUAL PROVINCES.

In addition to the laws and regulations quoted above various statutes and regulations apply to individual provinces and are quoted below.

Quebec.

Petroleum and natural gas mining rights in the Province of Quebec are acquired under the provision of the Quebec Mining Law (55-56 Victoria Ch. 20—1892). Specific mention of these minerals is not made in this enactment, but by regulation of the Lieutenant Governor in Council.

All such unwithdrawn public lands or private lands in which the minerals are reserved to the Crown containing them are subject to acquisition for development purposes.

Disposition of mineral lands and mineral rights is vested in the Commissioner of Colonization and Mines who is empowered to sell mining concessions not exceeding 200 acres each in extent at public auction or privately upon application accompanied by plan and field notes of official survey and cash payment at the rate of a certain amount an acre, if the land is more than 20 miles from a railway, which amount is doubled if the tract is less than 20 miles distant.

Lands may also be acquired for mining purposes by occupation and working under a mining license.

For a fee of $10 a miner's certificate good only for the current calendar year may be obtained from the Commissioner, conveying the right to prospect on all unoccupied unwithdrawn public lands and on private lands where minerals are reserved to the Crown in which latter case security is required to answer for any damage to the surface estate. When he makes a discovery the holder of a miner's certificate is allowed to stake and indicate on the ground in a prescribed manner an area not exceeding 200 acres in extent and after filing notice of his discovery is allowed four months in which to apply for a mining license. These are of two kinds (1) Private lands license, where minerals are reserved to the Crown, (2) Public lands license. Mining licenses are granted to holders of mining certificates upon application accompanied by a plan showing clearly the location of the desired claim, by an affidavit that the land sought is enterable and that the claim is properly marked on the ground, by payment of a fee of $10 and an annual ground rental of $1 an acre. Licenses are renewable from year to year upon payment of a renewal fee and an annual rental of $1 an acre subject at the discretion of the Lieutenant Governor to the requirement of a royalty in lieu of such renewal and rental fees. Private land licenses are qualified by provisions for indemnity to the owner of the surface estate for damages resulting from mining operations.

Ontario.

Search for and development of petroleum and natural gas deposits in Ontario is provided for in the Mining Act of Ontario (8 Edward VII, Ch. 21, 1908), amended at various times since its enactment.

Vacant crown lands and patented lands in which the mineral rights are reserved to the Crown are open for prospecting by individuals who hold valid miners' licenses from the Minister of Mines.[1]

Prospectors so qualified may stake in a prescribed manner a compact area not exceeding 640 acres, and by complying with certain regulations as to survey, indemnification for damages to owner of surface estate, etc., and payment of a fee of $100, obtain a boring permit granting exclusive right to prospect for petroleum and natural gas within the desired area for a period of one year.

Before the termination of this permit a sum amounting to not less than $2 an acre in actual development work for oil or gas must be spent in order to qualify the holder for a renewal of his permit, which, if the conditions are fulfilled, is renewable for one year at the same terms as to development work, for a fee of $100.

After a discovery of oil or gas is made the prospector is entitled to apply to the Minister of Mines for a lease of any or all the land involved upon the submission of satisfactory proof that he is the holder of the boring permit affecting the land and that he has discovered oil or gas in commercial quantities within the area. Leases are issued for a term of 10 years at an annual rental of $1 an acre payable in advance, and subject to the expenditure of not less than $2 an acre per annum in obtaining oil or gas, or in actual bona fide operations or works for the purpose of obtaining the same from the lands. The lessee has the right of renewal of his original lease for a second term of ten years at the same rental, and at the expiration of this term the right of a further renewal for twenty years on terms to be agreed upon at the time if not provided by statute or regulation. Every lease is issued subject to such other conditions, stipulations and provisos as the Lieutenant-Governor in Council may prescribe and are forfeitable for non-payment of rent and failure to comply with the prescribed terms.

[1] In the older parts of the province the mining rights have already been transferred from the Crown to the owner of the surface rights. See page 123.

The lease conveys to the lessee the right to enter upon the land described and dig, bore, sink, drive, or otherwise search for and obtain only petroleum, natural gas, coal, and salt. All other valuable minerals are reserved to the Crown and any holder of a miner's license is at liberty to enter the lands, prospect, stake claims and obtain limited patent thereto, provided the lessee is duly compensated for any resulting damage or injury to his interests.

FOREST RESERVES.

Lands embraced in Crown forest reserves in Ontario are open for prospecting by any holder of a miner's license, but are not subject to sale, although a lease permitting mining operations thereon may be granted for a period not exceeding ten years with the right of perpetual renewal for periods of not more than ten years each subject to such regulations as may be made by the Lieutenant-Governor in Council.

British Columbia.

Acquisition of petroleum and gas-bearing lands in the Province of British Columbia is under the Coal Mines Act, R.S. Ch., 137, and the procedure involved is, briefly, as follows:

Licenses to prospect for petroleum or natural gas over any compact area of public land in the province, not exceeding 640 acres, for a term not exceeding one year, may be granted to any person by the Chief Commissioner of Lands and Works upon the following conditions:—

Applicant must stake the desired area in a prescribed manner and post thereon a notice of his intention to apply for a license, must publish for 30 days a notice of his intention in the British Columbia Gazette and in some newspaper circulating in the local district; and at the expiration of this publication period must make duplicate application in writing, accompanied by a plan and description of the land and a fee of $100 to the local commissioner, for a prospector's license covering that area.

Licenses so granted are subject to two renewals upon payment of a fee of $100 for each renewal and satisfactory showing to the Chief Commissioner or Assistant Commissioner that the licensee has bona fide explored for coal or petroleum during the term of the lease. For purpose of prospecting, provision is made that license holders, not exceeding ten, on adjoining lands may unite in a partnership and proceed as a firm in prospecting one claim, which, if done satisfactorily to the Chief Commissioner, relieves the individual licensee of separate prospecting.

After discovery is made a lease is procurable by an individual or firm from the Lieutenant-Governor in Council, good for five years, subject to the payment of an annual ground rental of 15 cents an acre, and a royalty of 2½ cents a barrel for all crude petroleum obtained from the land, and further subject to continuous and vigorous prosecution of development work.

At the expiration of this lease if all conditions have been faithfully fulfilled the lessee is entitled to purchase the land together with the petroleum therein at the rate of $10 an acre, or in case the land has been alienated, he shall be entitled to obtain a grant of coal and petroleum underlying the land, upon payment at the rate of $5 an acre.

METHODS OF OBTAINING OIL AND GAS RIGHTS FROM PRIVATE LANDS.

In Ontario the surface owner has a title to the oil and gas rights and the companies lease the rights direct from the surface owner. The Canada Company has, however, some land on which the Government still holds the title. The courts have decided that oil is not a mineral. This decision was made in the test case of Farquharson vs. The Canada Land Co. In Northern and Western Ontario the government has reservations.

GAS LEASES.

As a rule the leases give a limited amount of free gas to the owner of the property; formerly it was the custom to give an unlimited amount of free gas. At present they seldom give over 200,000 cubic feet of free gas from the first paying gas well on the property. The rentals are 20 to 25c. per acre for every year after the first year. The companies never pay over 50c. an acre and they generally get one year free lease, They pay $50 for a gas well or give 200,000 cubic feet of free gas and only in a few cases do they do both. In a few instances they pay $100 for a well, but never over this. The leases provide a royalty of one-tenth to one-eighth of the oil to the owner of the surface; all the earlier leases giving one-tenth.

Form of Lease.

A lease form used by one of the prominent Canadian gas companies follows:—

THIS AGREEMENT made in duplicate this..................day of..................

A.D. 190....

BETWEEN..

....

of the Township of ....in the County of.............hereinafter called the Grantor, of the First Part; and

THE COMPANY

hereinafter called the Company of the Second Part.

WITNESSETH that in consideration of the sum of One Dollar, the receipt whereof is hereby acknowledged, and of the rents, royalties and agreements hereinafter contained, the Grantor ha granted and do........hereby grant unto the Company, for the purpose and with the exclusive right of searching for, producing and taking away petroleum and natural gas. All that certain tract of land situated in the Township of...................in the County of.....................................Province of Ontario, described as follows:..
....
....
....
....
....
....
....
....

together with all rights and privileges necessary or proper for these purposes, without restricting the generality of the foregoing, the Company shall be deemed to have the right of way over and across said lands; the right to transmit power and gas to and from said premises, for operating purposes and to have sufficient oil, water and gas from said lands to run all machinery necessary to operate the same; the right to bring upon, erect or remove from said lands, any piping, machinery or fixtures and the exclusive right to lay pipes for conveying oil and gas on and across said lands.

TO HAVE AND TO HOLD the said premises for the purposes and with the rights aforesaid, for the term of ten years from the date hereof and as much longer as said premises are operated for the production of oil or gas, or the rental paid thereon.

THE COMPANY AGREES:

1st. To give the Grantor the.............part of all oil produced and saved on the premises.

2nd. If gas is found in sufficient quantities to utilize, that the Grantor shall for the first paying gas well drilled have the privilege of using in his dwelling now on said premises....

...........feet of gas each year free of cost or a rental at the rate of.................. dollars a year, payable quarterly in advance so long as gas therefrom is sold off the premises: for all gas used in excess of that amount, the Grantor agrees to pay to the Company the sum of twenty cents per one thousand cubic feet payable on demand: for each subsequent paying gas well drilled the Company agrees to pay at the rate of......................dollars per annum, payable quarterly in advance so long as gas therefrom is being sold off the premises.

3rd. To compensate the Grantor at the rate of twenty dollars per acre for all damage to crops on said lands caused by operating thereon.

4th. To drill no well within two hundred feet of any house or barn now on said lands without the consent of the Grantor.

If no well is commenced within.........................from this date this grant shall become null and void unless the Company shall pay the Grantor a rental quarterly in advance at the rate of ....per year during the remainder of the said term, provided however that such rental shall not in any event be payable after surrender of this lease. Any moneys payable hereunder may be paid to the Grantor in person or by mailing the same in a postpaid envelope directed to him at.......................post office or by depositing the same to his credit in the..............................Bank at.......................................and may be made by cheque, Express Order, Post Office Order or the notes of a chartered bank.

THE COMPANY may at any time surrender this lease whereupon all liability of the Company shall forthwith cease and determine except for moneys due and unpaid at the time of such surrender: such surrender shall be in writing and the same, and any notice required to be given hereunder may be effectually given by delivering the same to the Grantor in person or by mailing the same in a postpaid envelope addressed to the Grantor at.......... ....Post Office.

THESE presents shall enure to the benefit of and be binding upon the parties hereto, their heirs, executors, administrators, successors and assigns respectively.

IN WITNESS WHEREOF the said parties have hereunto set their hands and seals the day and year first above written.

Signed, Sealed and delivered in the presence of

THE..................COMPANY, LIMITED.

..............................Pres.

......................Sec'y

The following is a form of lease quoted as a typical form used in Canada, by Mr. A. Beeby Thompson in "Petroleum Mining," p. 41.

THIS LEASE, made the.........................day of...................A.D., between..........................of..........................., in the County of ....and Province of Ontario, farmer, hereinafter called the lessor of the first part, and......................, hereinafter called the Lessee, of the second part. In consideration of the agreements herein contained, the lessor does hereby grant and lease unto the lessee, for the term of five years, and so long thereafter as oil or gas is produced from the land leased in paying quantities, the exclusive right to drill for and produce petroleum and natural gas, and the right to conduct all operations necessary for the production, storage, and transportation of oil or natural gas, with the right to use water and gas (if found) for the necessary engines, and to remove all machinery, fixtures, etc., placed by the lessee on the premises, namely:

....................................in the Township of............................ County of..............................Province of Ontario, being................ acres more or less. No wells to be drilled within..........................feet of buildings without lessor's consent. The lessee to deliver to the lessor on the premises, free of cost, the one-tenth part of all petroleum produced and saved from the premises, and to pay one hundred dollars ($100) per annum for each gas well from which the gas is marketed for lighting any village, town or city. If the lessor shall request it, the lessee shall bury all oil and gas lines below plough depth.

Lessee to pay compensation for any actual damage to crops or improvements caused by operations, to keep all gates closed and fences as found, and to pay all taxes rated on any property or effects he may place thereon.

This lease to be null and void and no longer binding on either party if operations for drilling are not commenced on the premises within.................days from this date, unless the lessee shall thereafter pay yearly to lessor twenty-five cents (25c.) per acre for delay.

It is understood between the parties to this agreement that all the conditions between the parties hereunto shall extend to their heirs, executors, administrators, and assigns.

Lessor to have free use of gas (if found) for household purposes on the premises during said terms.

SIGNED and sealed by.................................and.....................

A form of agreement entered into by individuals and the Dominion Government in leasing oil and gas lands follows, together with the latest regulations approved January 19, 1914, for the disposal of oil and gas rights in certain territories.

Petroleum and Natural Gas Lease No.......
File No..................................

THIS INDENTURE, made in duplicate, this day of in the year of our Lord one thousand nine hundred and BETWEEN HIS MAJESTY KING GEORGE THE FIFTH, represented herein by the Minister of the Interior of Canada, hereinafter called the Minister, of the first part, and hereinafter called the lessee, of the second part.

WHEREAS by Order of the Governor in Council, dated the nineteenth day of January, in the Year of our Lord, one thousand nine hundred and fourteen, regulations were made for the disposal of petroleum and natural gas rights, the property of the Crown in the Provinces of Manitoba, Saskatchewan and Alberta, the Yukon Territory, the Northwest Territories, the Railway Belt in the Province of British Columbia, and the three and one-half millions of acres of land acquired by the Dominion from the Province of British Columbia, and referred to in sub-section (b) of Section 3 of the Dominion Lands Act, Chapter 20, 7-8 Edward VII, a copy of which regulations is hereto appended.

AND WHEREAS the lessee having applied for a lease under the said Regulations of the petroleum and natural gas rights in the lands hereinafter described the Minister has granted such application upon the terms and conditions herein contained.

NOW THEREFORE THIS INDENTURE WITNESSETH that in consideration of the rents and royalties hereinafter reserved and subject to the provisos, conditions, restrictions and stipulations hereinafter expressed and contained, His Majesty doth grant and demise unto the lessee, for the sole and only purpose of mining and operating for petroleum and natural gas, and of laying pipe lines and of building tanks, stations and structures thereon necessary and convenient to take care of the said products.

ALL AND SINGULAR

TO HAVE AND TO HOLD the same unto the lessee for the term of twenty-one years, to be computed from the day of 19 , renewable for a further term of twenty-one years provided the lessee furnishes evidence satisfactory to the Minister of the Interior to show that during the term of the lease he has complied fully with the conditions of such lease and with the provisions of the regulations under which it was granted. Yielding and paying therefor during the first year of the said term unto His Majesty the clear yearly rent or sum of twenty-five cents of lawful money of Canada for each and every acre of land comprised within the said lands, and for each subsequent year of such term the rent or sum of fifty cents, such rent being payable yearly in advance on the day of in each year of the said term, the first of which payments has been made on or before the execution of these presents; and also rendering and paying therefor unto His Majesty a royalty at such rate as may from time to time be prescribed by Order of the Governor General of Canada in Council on natural gas products taken out of the said lands, and also such royalty on petroleum products taken out of the said lands from and after the first day of January in the year 1930 as the regulations then and thereafter in force may prescribe, and such rent and royalty to be free and clear of and from all rates and taxes and assessments and from all manner of deductions whatsoever except as hereinafter mentioned.

PROVIDED ALWAYS that this demise is granted upon and subject to the following provisos, conditions, restrictions and stipulations, that is to say:

1. That the lessee shall and will well and truly pay or cause to be paid to the Minister at Ottawa, the rent and royalty hereby reserved, and shall and will make all returns at the times and in the manner herein or in or under the said regulations prescribed.

2. That the lessee shall and will well, truly and faithfully observe, perform and abide by all the obligations, conditions, provisos and restrictions in or under the said regulations imposed upon lessees or upon the said lessee.

3. That the lessee shall and will keep correct books of such kind and in such form as may be prescribed by the Minister, showing the quantity of petroleum and natural gas taken out of the said lands, and whenever required so to do shall submit such books to the inspection of any officer or person appointed or authorized by the Minister to examine the same for the purpose of verifying the returns made by the lessee.

4. That the lessee shall and will, during the said term, make such provision for the disposal of the earth, rock, waste or refuse of the said lands that the same shall not be an inconvenience, nuisance or obstruction to any railway right of way, roadway, pass, passage, river, creek or place, or to any private, public or Crown lands, or conflict with or embarrass the operating of any other mines on the said lands, or in any manner whatsoever occasion any private or public damage, nuisance or inconvenience.

5. That the lessee shall and will, during the said term, make and deliver to the Minister or to any officer or agent appointed or instructed by him to collect, obtain or receive the same, all such true and proper information of the working and operations of any mines on the said lands (the truth and accuracy of which shall be verified by oath or solemn declaration of the lessee or his manager, agent or employee cognizant of the facts) as the Minister shall from time to time direct.

6. That the lessee shall also make proper and reasonable compensation to any railway company for any damage caused to the right of way or station grounds of the railway or other property of the Company upon the said lands.

7. That the lessee shall and will permit any inspector or other person duly authorized in that behalf, with all proper or necessary assistants, at all reasonable times during the said term, quietly to enter into and upon the said lands, mines and premises, and into all buildings erected thereon, and into any part thereof, and to survey and examine the state and condition thereof, so nevertheless that in so doing no unnecessary interference, is caused with the carrying on of the mining work, of the lessee; and shall and will by all means in his power aid and facilitate such inspector or other person in making such entry, survey and examination.

8. That the lessee shall and will during the said term, open, use and work any mines and works opened and carried on by him upon the said lands in such manner only as is usual and customary in skilful and proper mining operations of similar character when conducted by proprietors themselves on their own lands, and when working the same shall keep and preserve the said mines and works from all avoidable injury and damage, and also the roads, ways, works, erections and fixtures therein and thereon in good repair and condition, except such of the matters and things last aforesaid as shall from time to time be considered by any inspector or other person authorized by the Minister to inspect and report upon such matters and things to be unnecessary for the proper working of any such mine, but so that no casing placed in any mine shall be removed or impaired, and in such state and condition shall and will at the end or sooner determination of the said term deliver peaceable possession thereof and of the said lands to His Majesty.

9. That the lessee shall and will during the said term enclose and keep enclosed all abandoned openings or excavations made in connection with or for the purpose of mining operations on the said lands with fences or walls sufficient to prevent cattle and other animals falling thereinto, such fences or walls to be of a height and character satisfactory to the Minister or to the inspector or other person duly authorized by him as aforesaid, and to comply with any regulations or directions from time to time made or given by the Minister.

10. That no waiver on behalf of His Majesty of any breach of any or either of the provisos, conditions, restrictions and stipulations herein contained, whether negative or positive in form, shall take effect or be binding upon him, unless the same be expressed in writing under the authority of the Minister, and any waiver so expressed shall extend only to the particular breach so waived and shall not limit or affect His Majesty's rights with respect to any other or future breach.

11. That no implied covenant or liability of any kind on His Majesty's part is created by the use of the words "demise" or "lease" herein, or by the use of any other word or words herein, or shall otherwise arise by reason of these presents or anything therein contained.

12. That in case of default in payment of the said rent or royalty for 30 days after the ame should have been paid, or in case of breach or non-observance or non-performance on the part of the lessee of any proviso, condition, restriction or stipulation herein contained, and which ought to be observed or performed by the lessee and which has not been waived by the said Minister, the Minister may cancel these presents by written notice to the lessee, and thereupon the same and everything therein contained shall become and be absolutely null and void to all intents and purposes whatsoever, and it shall be lawful for His Majesty into and upon the said lands (or any part thereof in the name of the whole) to re-enter and the same to have again repossess and enjoy; anything herein contained to the contrary notwithstanding. Provided nevertheless that in case of such cancellation and re-entry the lessee shall continue to be liable to pay and His Majesty shall have the same remedies for the recovery of any rent or royalty then due or accruing due as if these presents had not been cancelled, but remained in full force and effect.

13. That within two months from the termination of this lease from any cause, if all rent and royalty due thereunder shall have been paid, and all provisos, conditions, restrictions and stipulations hereby imposed upon the lessee shall have been duly observed and performed, the lessee may remove from the said lands all tools and machinery, buildings and erections which he may have placed thereon, but shall not remove or impair any of the casing which is necessary to the use and maintenance of the shafts or wells in any mine on the said lands, or any article, matter or thing the removal of which might cause such mine to cave in or give way, and that in default of removal within such period of two months all such tools and machinery, buildings and erections shall be absolutely forfeited and shall become and be the property of His Majesty.

14. Provided that, if in consequence of insufficient survey or of any cause whatsoever the said demised premises are found to include a portion of the petroleum and natural gas rights demised to any other person under the regulations of any Order of the Governor General in Council, the lessee whose application was first recorded in accordance with the provisions of such regulations shall have priority.

15. That if in the opinion of the Minister the said petroleum or its products or any portion thereof should at any time during this demise be required for the use of His Majesty's Canadian Navy, the Minister shall have a right of pre-emption of all crude petroleum oil or its products gotten or won under this demise for such use as aforesaid, the price to be agreed on between the Minister and the lessee or in case of difference to be fixed by the Exchequer Court of Canada.

16. And provided further and it is hereby declared that this lease is subject in all respects to the regulations of the Governor in Council, relating to petroleum, and to any regulations that may be issued in amendment of and in substitution therefor.

Where the context permits the expression "lessee" herein includes the heirs, executors, administrators and assigns of the lessee; the expression "His Majesty" includes the successors and assigns of His Majesty; and the expression "Minister" includes the successors in office of the Minister of the Interior.

IN WITNESS WHEREOF the Deputy of the Minister of the Interior and the Lessee have hereunto set their hands and seals the day and year first above written.

SIGNED, SEALED AND DELIVERED

IN THE PRESENCE OF

....

....
Deputy of the Minister of the Interior.

And by the lessee in the presence of

....
Witness.

....
Lessee.

Regulations for the disposal of Petroleum and Natural Gas rights, the property of the Crown, in Manitoba, Saskatchewan, Alberta, the Northwest Territories, the Yukon Territory, the Railway Belt in the Province of British Columbia, and within the tract containing three and one-half (3½) million acres of land acquired by the Dominion Government from the Province of British Columbia, and referred to in subsection (b) of section 3 of the Dominion Lands Act, approved by Order in Council dated the 19th of January, 1914.

INTERPRETATION

"Minister" shall mean the Minister of the Interior of Canada.

"Adjoining" lands shall be those which are not separated by a section, or by any of the regular subdivisions into which a section may be divided.

"Location" shall mean the tract described in a petroleum and natural gas lease.

"Group" shall mean two or more of the locations described in petroleum and natural gas leases, consolidated for purposes of operation.

"Lessee" means any individual, company, corporation or municipality the holder of a petroleum and natural gas lease in good standing.

"River" shall mean a stream of water the bed of which is of an average width of 150 feet throughout the portion thereof on which the tract applied for fronts.

1. The petroleum and natural gas rights which are the property of the Crown, in Manitoba Saskatchewan, Alberta, the Northwest Territories, the Yukon Territory, the Railway belt in the Province of British Columbia, and within the tract containing three and one-half (3½) million acres of land acquired by the Dominion Government from the Province of British Columbia, and referred to in subsection (b) of section 3 of The Dominion Lands Act, may be leased to applicants at a rental of twenty-five (25) cents an acre for the first year, and for each subsequent year a rental at the rate of fifty (50) cents an acre, payable yearly in advance. The term of the lease shall be twenty-one years, renewable for a further term of twenty-one years, provided the lessee can furnish evidence satisfactory to the Minister to show that during the term of the lease he has complied fully with the conditions of such lease and with the provisions of the regulations in force from time to time during the currency of the lease.

2. The maximum area of a petroleum and natural gas location shall be 1,920 acres, and no person shall be permitted to acquire a greater area except by assignment.

Provided that a person who has been granted a lease for a location, and who subsequently abandons or assigns the same, may, after the expiration of twelve months from the date of the said lease, apply for an area not greater than that abandoned or assigned.

Provided further, however, that such rights shall not be granted unless all payments on account of rent or other liability to the Crown due by such person, have been fully made, up to the date of the registration by the Department of the assignment of his right to such lease, or up to the date upon which the notice of his abandonment of the same was received by the Department.

3. If the tract applied for is situated in surveyed territory, it shall consist of sections, or legal subdivisions of sections, but the several parcels comprising the tract shall be adjoining, the length of the tract not to exceed three times its breadth. In unsurveyed territory, if at least one of the lines bounding the tract applied for has been surveyed, and the returns of such survey have been duly received in the office of the Surveyor General, an application for a lease of the petroleum and natural gas rights under such tract may be considered under the provisions of this section of the regulations.

4. Applications for a lease of the petroleum and natural gas rights on surveyed lands shall be filed by the applicant in person with the agent of Dominion Lands for the district in which the rights applied for are situated, or with a sub-agent for such district, for transmission to the agent, but priority of application shall be based upon the date of the receipt of such application in the office of the Agent of Dominion Lands for the district.

5. If the rights applied for are situated in unsurveyed territory, application for a lease shall be made by the applicant in person to the Agent of Dominion Lands for the district in which the rights applied for are situated, or to a sub-agent for such district, for transmission o the agent.

6. Application for a location situated in unsurveyed territory shall contain a description by metes and bounds of the location applied for, and shall be accompanied by a plan showing the position of such location in its relation to some prominent topographical feature or other known point. The plan shall contain sufficient data to admit of the position of the location, applied for being definitely shown in the records of the Department. The location must be rectangular in form, except where a boundary of a previously located tract is adopted as common to both locations, the length not to exceed three times the breadth.

The application shall be accompanied by evidence, supported by affidavit of the locator, to show that the following requirements have been fully complied with:—

(a) That the location applied for has been defined on the ground by the locator in person by planting two wooden posts, at least four inches square, and standing not less than four feet above the ground—such posts being numbered "1" and "2" respectively. The distance between post No. "1" and post No. "2" shall not exceed 15,840 feet, and upon each post shall be inscribed the name of the locator and the date of the location. Upon post No. "1" there shall be written, in addition to the foregoing, the words "initial post," the approximating compass bearing of post No. "2" and a statement of the number of feet lying to the right and to the left of the line between post No. "1" and post No. "2." Thus—Initial post, direction of post No. "2" is..feet lie to the right and ....feet to the left of the line between post No. "1" and post No. "2."

When the tract which an applicant desires to lease has been located, he shall immediately mark the line between post No. "1" and post No. "2" so that it can be distinctly seen, in a timbered locality, by blazing trees and cutting underbrush, and in a locality where there is neither timber nor underbrush he shall set posts of the above dimensions or erect mounds of earth or rock not less than two feet high and two feet in diameter at the base in such a manner that the line may be distinctly seen.

(b) All the particulars required to be inscribed on posts No. "1" and No. "2" shall be sent out in the application and shall be accompanied by a plan showing the position of the tract in its relation to some prominent topographical feature or other known point, such plan to contain sufficient data to admit of the location being shown definitely on the records of the Department.

(c) The locator shall post a written or printed notice on a conspicuous part of the location applied for, setting out his intention to apply within thirty days from the date of such notice for a lease of the petroleum and natural gas rights under the said location.

(d) The application shall be accompanied by evidence, supported by the affidavit of the locator, in due form, to show that the above requirements of the regulations have been fully complied with.

7. In case the tract applied for is located in unsurveyed territory on the margin of a river or lake, it shall not include more than one mile in direct distance along such water frontage and shall extend back therefrom as far as may be necessary to include a total area of not more than 1,920 acres, the length of the location, however, not to exceed three miles. The tract shall be marked on the ground by two posts firmly fixed in the ground, one at each end of such front boundary. The posts shall be numbered "1" and "2" respectively. It shall not be lawful to move post No. "1", but post No. "2" may be moved by a Dominion Land Surveyor if the distance between the posts exceeds the length prescribed by these regulations, but not otherwise. The side boundaries shall be parallel lines drawn from each end of the front boundary at right angles to the base line of such river or lake, established or to be established by the Department. In the event of the base line not being established, the side boundaries of the location shall be drawn at right angles to the general direction of the valley of the river, or the margin of the lake. The required notice of application shall be posted conspicuously on the location near the margin of the lake or river on which it fronts.

The boundaries of claims situated on the margin of a lake or river, and any disputes which may arise in connection therewith, shall be subject to final adjustment by the Minister.

8. Application for a lease of the petroleum and natural gas rights under lands situated in unsurveyed territory shall be made by the locator in person to the Agent of Dominion Lands for the district in which the tract applied for is situated, or to a sub-agent for such district within thirty days from the date upon which the tract applied for was staked as above provided, if it is situated within one hundred miles of the office of the Agent or Sub-Agent, otherwise it will not be considered. One extra day, however, shall be allowed for every additional ten miles or fraction thereof that the location is distant more than one hundred miles from the office of the Agent or Sub-Agent.

9. Where two or more persons lay claim to the same location, or to portions of the same locations, situated in unsurveyed territory, the right to the lease shall be in him who can prove to the satisfaction of the Minister that he was the first to take possession of the tract in dispute by staking in the manner prescribed in these regulations, and that he made application for a lease within the specified time.

10. As soon as the survey of a township has been confirmed, all petroleum and natural gas leases embracing any portion, of such township so surveyed and confirmed, shall be made to conform to the Dominion Lands System of Survey if the Minister so decides, by the substitution of a new lease describing by sections, legal subdivisions of sections, or regular portions of legal subdivisions—as nearly as may be—the tract embraced in the leasehold in so far as the township so surveyed is concerned. If any part of the leasehold is in territory which remains unsurveyed, it shall continue to be described as in the lease originally issued, until such portion is included in a confirmed survey.

11. As soon as the survey of a township has been confirmed, all petroleum and natural gas leaseholds embracing any portion of the township so surveyed and confirmed, shall be subject to the withdrawal forthwith from the lease, without compensation to the lessees, of any portions which, in accordance with such confirmed survey, are found to be the property of the Hudson's Bay Company.

Provided, however, that upon such withdrawal being made from any location in good standing, the rental paid on the land so withdrawn, in whole or in part, may, in the discretion of the Minister, be refunded to the lessee.

12. The rental for the first year of the location applied for at the rate of twenty-five (25) cents an acre per annum, shall accompany the application filed in the office of the Agent of Dominion Lands for the district in which the rights applied for are situated, and no application for a lease of petroleum and natural gas rights shall be accepted or recorded unless it is accompanied by the full amount of the rental for the first year at the above rate. The lease, when issued, shall bear date from the day upon which the application was filed in the office of the Agent of Dominion Lands. If, during the term of the lease, the lessee shall fail to pay rental in advance for each subsequent year at the rate of fifty (50) cents an acre per annum within thirty days after the date upon which the same became due, the lease shall be subject to cancellation in the discretion of the Minister and to the immediate forfeiture of the rights which the lessee had in the said lease.

13. Provided, that if the lessee, in consideration of the expenditure to be incurred by him in actual boring operations upon his leasehold, makes application, at or before the beginning of the second and third years, respectively, of the term of the lease, for an extension of time within which to pay the rental when due, or becoming due, the Minister may grant such extension of time in writing, and if the lessee, before the end of the year in respect of which application was made, submits evidence to the Land Agent of the district in which the leasehold is situated, supported by affidavit, that during such year actual boring operations have been prosecuted upon his leasehold, as required by section 15 of these regulations, the amount expended in such boring operations, exclusive of the cost of machinery and casing, may be deducted from the rental which became due at the beginning of the said year. The balance of rental due, if any, shall be paid at the same time as the evidence in regard to work done is submitted, as above required. Failure to submit such evidence, or to pay the balance of rental due, with interest, will render the lease liable to cancellation, as hereinbefore provided.

14. The lessee shall, within one year from the date of the lease, have upon the lands described therein such machinery and equipment suitable for carrying on prospecting operations as the Minister may consider necessary, and he shall, within the same period, furnish evidence, supported by affidavit, showing the character, quantity and value of the machinery so installed, the date of its installation and the particular parcel of land upon which it was installed. If the required machinery is not installed within the period specified, and if evidence of its installation is not furnished within the prescribed period, the lease shall be subject to cancellation in the discretion of the Minister. Provided, however, that the Minister shall not require that the value of the machinery so installed on a location shall exceed the sum of five thousand dollars ($5,000).

15. The lessee shall commence boring operations on his leasehold within fifteen months of the date of his lease, and he shall continue such boring operations with reasonable diligence, to the satisfaction of the Minister, with a view to the discovery of oil or natural gas. If the lessee does not commence boring operations within the time prescribed, or if having commenced such operations he does not prosecute the same with reasonable diligence, to the satisfaction of the Minister, or if he ceases to carry on the same for a period of more than three months, the lease shall be subject to cancellation in the discretion of the Minister, upon three months' notice to this effect being given to the lessee. Provided, however, that if satisfactory evidence is furnished to show that the sum of at least two thousand ($2,000.00) has been expended in actual boring operations, by recognized methods upon the leasehold in any year, such expenditure shall be accepted as compliance with this provision for the year during which such expenditure shall have been incurred.

16. The Minister may permit a lessee, who has acquired by assignment or otherwise more than one petroleum and natural gas lease, to consolidate his operations and expenditure, and to install machinery and equipment on one or more of the locations described in the lease affected. Provided that such consolidation or grouping shall apply only to the second and third years of the term of the leases, and shall comprise only such leases as may at the time be included in such consolidation or grouping . Evidence of the installation of machinery on one or more of the locations included in a group shall be that prescribed by Section 14 of these regulations. If the required machinery is not installed on one or more of the locations included in a group within the period specified, and evidence of its installation furnished within the prescribed period, and if boring operations are not commenced and continued on such location or locations in the manner set out in Section 15 of these regulations, the leases included in the group shall be subject to cancellation in the discretion of the Minister.

17. The Minister may, in consideration of the expenditure to be incurred by a lessee in boring operations upon one or more of the locations included in a group, grant an extension of time within which to pay the rental for the second and third years of the term of the several leases so included, and upon receipt of the evidence required by Section 13 of these regulations, he may deduct from the rental which became due at the beginning of the year in respect of the several locations grouped, the amount expended in actual boring operations on one or more of the locations, exclusive of the cost of machinery and casing. The balance of the rental due, if any, shall be paid at the same time as the evidence in regard to work done is submitted, as above required. Failure to submit such evidence or to pay the balance of the rental due, with interest, will render the several leases included in the group liable to cancellation.

18. Provided, however, that the Minister shall not require that the value of the machinery to be installed on any group of locations shall exceed the sum of ten thousand dollars ($10,000) nor shall he require that the expenditure incurred in boring operations thereon in any one year shall exceed the sum of two thousand dollars ($2,000) for each location included in the group.

19. The maximum area of the locations which may be included in one consolidation or group shall not exceed twenty (20) squares miles, nor shall the locations so included be separated one from the other by a greater distance than two miles.

20. The Minister may, upon application, grant a lessee during the second and third years of the term of the lease an extension of time within which to pay the rental and to install the prescribed machinery and equipment, and within which to commence actual boring operations upon the location, or upon a group of locations consolidated under the provisions of these

regulations: Provided that evidence to the satisfaction of the Minister is furnished to show that an expenditure equal to that prescribed by these regulations in respect of boring operations is to be incurred in some other acceptable and necessary form of preliminary development, having for its object the discovery of petroleum or natural gas, by which the interests of the district in which the locations are situated might be materially benefited. Upon receipt of evidence on or before the termination of the year, supported by affidavit and duly corroborated, that such expenditure has been incurred, and that the work done was of a character beneficial to the district, the Minister may deduct the amount of such expenditure from the amount due on account of the rental of the location or locations affected, in the manner prescribed in section 13 of these regulations. In case evidence is not furnished, or, if furnished, is not acceptable to the Minister, the leases shall be subject to immediate cancellation in the discretion of the Minister.

In case an extension of time is granted during the second and third years of the term of a lease within which to install machinery and commence boring operations on any location under the grouping provisions of these regulations, then the provisions of sections 14 and 15 of the regulations shall apply to the fourth year of the term of the lease of such location.

21. In case the surface rights of a petroleum and natural gas location are covered by a timber license, grazing or coal mining lease, mining claim or other form of terminable grant, the lease shall not authorize entry thereon, without the permission of the Minister being first had and obtained, and such permission shall be given subject to such conditions for the protection of the rights of such lessee or licensee as it may be considered necessary to impose.

22. In case the surface rights of a petroleum and natural gas location have been patented, or have been disposed of by the Crown under any act or regulation which contemplates the earning of patent for such surface rights, and the lessee of the petroleum and natural gas rights cannot make an arrangement with the owner of such surface rights, or with his agent, or the occupant thereof, for entry upon the location, or for the acquisition of such interest in the surface rights as may be necessary for the efficient and economical operation of the rights acquired under his lease, he may, provided the mineral rights in the land affected with access thereto and the right to use and occupy such portion of the land as may be necessary for the effectual working of the minerals therein have been reserved to the Crown in the original grant of the surface rights, apply to the Minister for permission to submit the matter in dispute to arbitration. Upon receiving such permission in writing, it shall be lawful for the lessee to give notice to the owner, or his agent, or the occupant, to appoint an arbitrator within a period of sixty days from the date of such notice, to act with another arbitrator named by the lessee, in order to determine what portion of the surface rights the lessee may reasonably acquire:—

(a) For the efficient and economical operation of the rights and privileges granted him under his lease;

(b) The exact position thereof, and

(c) The amount of compensation to which the owner or occupant shall be entitled.

23. The notice mentioned in this section shall be according to a form to be obtained upon application to the Agent of Dominion Lands for the district in which the land in question is situated, and shall, when practicable, be personally served on the owner of such land, or his agent, if known, or the occupant thereof, and after reasonable efforts have been made to effect personal service without success, then such notice shall be served by leaving it at, or sending it by registered mail, to the last known place of abode or address of the owner, agent or occupant, and by posting a copy of the same in the office of the Agent of Dominion Lands for the district in which the land in question is situate. Such notice shall be ten days if the owner, or his agent, resides in the district in which the land is situate; if out of the district and if in the province or territory, twenty days, and if out of the province or territory, thirty days, before the expiration of the time limited in such notice. If the owner, or his agent, or the occupant of the land refuses or declines to appoint an arbitrator, or when, for any reason, no arbitrator is so appointed in the time limited therefor in the notice provided for by this section, the Agent of Dominion Lands for the District in which the land in question is situate shall forthwith, on being satisfied by affidavit that such notice has come to the knowledge of such owner, agent or occupant, or that such owner, agent or occupant, wilfully evades the service of such notice, or cannot be found, and that reasonable efforts have been made to effect such service, and that the notice was left at the last place of abode or known address of such owner, agent, or occupant as above provided, appoint an arbitrator on his behalf.

24. In case the two arbitrators cannot agree upon the award to be made, they may within a period of ten days from the date of the appointment of the second arbitrator select a third arbitrator, and when such two arbitrators cannot agree upon a third arbitrator, the Agent of Dominion Lands for the district in which the land in question is situate shall forthwith select such third arbitrator.

25. All the arbitrators appointed under the authority of these regulations shall be sworn before a justice of the peace to the impartial discharge of the duties assigned to them, and after due consideration of the rights of the owner and the needs of the lessee, they shall decide as to the particular portion of the surface rights which the latter may reasonably acquire for the

efficient and economical operation of the rights and privileges granted him under his lease the area thereof, and the amount of compensation therefor to which the owner or occupant shall be entitled.

26. In making such valuation the arbitrators shall determine the value of the land irrespective of any enhancement thereof from the existence of minerals thereunder.

27. The award of any two such arbitrators made in writing shall be final, and shall be filed with the Agent of Dominion Lands for the district in which the land is situate, within twenty days from the date of the appointment of the last arbitrator. Upon the order of the Minister the award of the arbitrator shall immediately be carried into effect.

28. The arbitrators shall be entitled to be paid a per diem allowance of $5 together with their necessary travelling and living expenses, while engaged in the arbitration, and the cost of such arbitration shall be in the discretion of the arbitrators.

29. The lessee shall at all times take reasonable measures to prevent the injurious access of water to the oil bearing formation. Upon a well proving to be unproductive, or ceasing to yield oil in paying quantity, or being abandoned for any cause, the lessee shall be at liberty to withdraw the casing from the said well, but in order to prevent water gaining access to the oil-bearing formation, the lessee shall immediately close the well by filling it with sand, clay or other material which may have the effect of preventing water from gaining access thereto.

In case natural gas is discovered through boring operations on a location, the lessee shall take all reasonable and proper precautions to prevent the waste of such natural gas, and his operations shall be so conducted as to enable him, immediately upon discovery, to control and prevent the escape of such gas.

Should salt water be encountered through operations upon the location, the lessee shall immediately and effectively, to the satisfaction of the Minister, close the well at such a depth as may prevent such water from gaining access to the oil-bearing formation.

The Minister may, from time to time, make such additional regulations as may appear to be necessary or expedient governing the manner in which boring operations shall be conducted and the manner in which the wells shall be operated.

Failure on the part of the lessee to comply with the above requirements, or to comply with such other requirements as the Minister may consider it necessary to impose in respect of boring and operating, will render the lease subject to cancellation in the discretion of the Minister.

30. The lessee may be permitted to relinquish at any time the whole or any portion of the location described in his lease, provided he has complied in every respect with the provisions of the regulations, and that all payments on account of rental or other liability to the Crown, due in connection with the lease, have been fully made, and provided the portion of the location which may be retained shall be of the prescribed shape, and shall not be of a less area than forty acres.

31. The lease shall in all cases include only the oil and natural gas rights, which are the property of the Crown, but the lessee may, upon application, be granted a yearly lease at a rental of one dollar ($1) an acre per annum, payable yearly in advance, of whatever area of the available surface rights of the tract described in his petroleum and natural gas lease the Minister may consider necessary for the efficient and economical working of the rights granted him.

32. Should oil or natural gas in paying quantity be discovered on the leasehold, and should such discovery be established to the satisfaction of the Minister, the lessee will be permitted to purchase at the rate of ten dollars ($10) an acre whatever area of the available surface rights of the tract described in the lease the Minister may consider necessary for the efficient operation of the rights granted him.

33. If it is not established to the satisfaction of the Minister that oil or natural gas in paying quantity has been discovered on the leasehold, the lease shall be subject to termination upon three years' notice in writing being given to the lessee by the Minister.

34. The boundaries beneath the surface of a location shall be vertical planes or lines in which their surface boundaries lie.

35. A fee of five dollars ($5) shall accompany each application for a lease, which will be refunded if the rights applied for are not available, but not otherwise.

36. The lease shall be in such form as may be determined by the Minister of the Interior in accordance with the provisions of these regulations.

37. The lessee shall not assign, transfer or sublet the rights described in his lease, or any part thereof, without the consent in writing of the Minister being first had and obtained.

38. No royalty shall be charged upon the sales of the petroleum acquired from the Crown under the provisions of the regulations up to the 1st day of January, 1930, but provision shall be made in the leases issued for such rights that after the above date the petroleum products of the location shall be subject to whatever regulations in respect of the payment of royalty may then or thereafter be made.

39. A royalty at such rate as may from time to time be specified by Order in Council may be levied and collected on the natural gas products of the leasehold.

40. Any company acquiring by assignment or otherwise a lease under the provisions of these regulations, shall at all times be and remain a British company, registered in Great Britain or Canada and having its principal place of business within His Majesty's Dominions and the chairman of the said company and a majority of the directors shall at all time be British subjects, and the company shall not at any time be or become directly or indirectly, controlled by foreigners or by a foreign corporation.

Any alteration in the memorandum of articles of association, or in the constitution of the company, or in the by-laws of the company shall be reported to the Minister, provided that two months' previous notice of the intention to make any alteration which might conceivably affect the British character of the company shall be given in writing to the Minister, and if, in the opinion of the Minister the said alteration shall be contrary to the cardinal principle that the lessee company shall be and remain a British company under British control, the Minister may refuse his consent to such alteration.

If the company which may acquire a location under these regulations shall at any time cease to be a British company, or shall become a corporation under foreign control, or shall assign any of the rights acquired under the lease without the consent in writing of the Minister being first had and obtained the lease shall be subject to immediate cancellation in the discretion of the Minister.

41. The Minister may at any time assume absolute possession and control of any location acquired under the provisions of these regulations, if in the opinion of the Government of Canada such action is considered necessary or advisable, together with all buildings, works, machinery and plant, upon the location, or used in connection with the operation thereof and he may cause the same to be operated and may retain the whole or any part of the output, in which event compensation shall be paid to the lessee for any loss or damage sustained by him by reason of the exercise of the powers conferred by this provision of the regulations, the amount of the compensation, in case of dispute, to be fixed by a Judge of the Exchequer Court of Canada, provided that the compensation in any such case shall not exceed the profit which the lessee would have earned in the working of the location and the disposal of the products thereof, had possession and control of the location and of the buildings, works, machinery and plant not been assumed.

42. If the location described in any lease issued under the provisions of these regulations, shall yield oil in paying quantity, the lessee shall pump and work the wells faithfully and uninterruptedly with due vigour and skill, with good and sufficient machinery and appliances in accordance with the provisions of the regulations and to the satisfaction of the Minister, so long as the said wells continue to yield oil in remunerative quantity.

43. At the end of each year of the term of the lease the lessee shall furnish a statement, supported by affidavit, showing the number of days during the year that operations were carried on upon the location; the number of men so employed; the character of the work done; the depth attained; the total expenditure incurred; a detailed statement setting out fully the purpose for which such expenditure was incurred; the quantity of crude oil or natural gas obtained; and the amount realized from the sale thereof. Failure to furnish such yearly return will render the lessee subject to a fine of ten dollars ($10) a day for each day's delay in furnishing the sworn statement, and after three months' delay the lease shall be subject to cancellation.

44. These regulations shall apply to all applications submitted on and after the first day of August, 1913, in accordance with the provisions of the regulations which were for the time in force.

And that if the rent hereby reserved or any part thereof shall be unpaid for thirty days after becoming payable (whether formally demanded or not), or if any covenant, proviso, stipulation or condition on the part of the lessee herein contained shall not be performed or observed, then and in any of the said cases it shall be lawful for the Minister by notice in writing under his hand to cancel these presents and terminate the estate or term hereby demised, and thereupon these presents and everything therein contained and the estate or term shall, from the time of the giving of such notice, absolutely cease, determine and be void without re-entry or any other act or any suit or legal proceedings to be brought or taken, provided that His Majesty shall nevertheless be entitled to recover from the lessee the rent then accrued or accruing, and moreover that any right of action of His Majesty against the lessee in respect of any antecedent breach of any of the said covenants, provisos, stipulations or conditions, shall not thereby be prejudiced.

And that any notice affecting the tenancy hereunder which the lessor may desire to serve upon the lessee shall be sufficiently served on the lessee if left addressed to him on the demised premises or posted to him addressed to his last known address, or if left at the said address. A notice sent by post shall be deemed to be given at the time when in due course of post it would be delivered at the address to which it is sent.

For purposes of comparison a form of lease used in the United States is given below:—

OIL AND GAS LEASE.

AGREEMENT OF LEASE, made this..........day of..........A.D. 19....between ....
....Lessor
and ....Lessee

WITNESSETH, that the Lessor in consideration of one dollar, the receipt of which is hereby acknowledged, does hereby grant unto the Lessee for the term of ....years (and so long thereafter as oil or gas is produced from the land leased, and royalty and rentals paid by Lessee therefor) the exclusive right to drill for and produce petroleum and natural gas from and the possession of so much of...
......................acres of land more or less in.................................
Township..................................County, State of Ohio as may be necessary therefor, with the right of way in and to said premises, the right to use water and gas (if found) for the necessary boilers and engines, and to remove, either during or after the term hereof, all machinery, fixtures, etc., placed by Lessee on the premises. Said land bounded:
North by Land of...
East by Land of..
South by Land of...
West by Land of..
....

No well to be drilled within................feet of the barn or dwelling house without the Lessor's consent.

The Lessee to deliver to Lessor in tanks or pipe line one eighth (⅛) of all petroleum produced and saved from the premises and to pay for each gas well from the time and while the gas is utilized an annual rental of..........................Dollars (......................) payable......................and to pay all damages to growing crops.

This lease to be null and void and no longer binding to either party if a well is not........ ....on the premises within..............................from this date, unless the Lessee shall thereafter pay....................................to Lessor ....dollars ($...................), per.................... for each...................delay in.........................said well. Each payment to extend the time for...........................and no longer. A deposit to the credit of the Lessor in..........................Bank at...........................on or before the date rentals fall due, shall be a good payment of any moneys on this lease.

It is mutually agreed by and between the first and second parties that if second party fails to pay the rental or drill a well, said second party shall have the right to surrender this lease, and all the terms shall cease, determine and become void, Lessor is to have free use of gas for domestic use if found on land covered by this lease, by making his own connections at well.

....

....

....

....

....

And that all conditions, terms and limitations between the parties hereto shall extend to their heirs, successors or assigns.

And for the consideration aforesaid...................of the said................. joined herein, hereby releases unto the Lessee, the right of dower in and to the granted and leased premises.

WITNESS the hand and seals of the parties hereto, the day and year above written.

Signed in the presence of:

....	................................[SEAL]
....	................................[SEAL]
....	................................[SEAL]
....	................................[SEAL]

DRILLING CONTRACTS.

All wells in Ontario are drilled by contract. The contractors get 90c per foot and pay for their own fuel in western Haldimand county. In eastern Haldimand county the price is less and in Elgin county it is more. The contractors provide their own fuel at $5 per day. Generally 40,000 to 60,000 cubic feet of gas per day is used for drilling. The company provides the casing and the contractor provides the rig and tools.

GOVERNMENT BOUNTY ON OIL.

In August, 1904, an Act was passed by the Dominion government providing for the payment of a bounty on all crude petroleum produced in Canada. The text of this Act, with its provisions, is given below:—

"An Act to provide for the payment of bounties on crude petroleum from Canadian wells."

(Assented to 10th August, 1904.)

His Majesty, by and with the consent of the Senate and the House of Commons of Canada, enacts as follows:

1. This Act may be cited as The Petroleum Bounty Act, 1904.

2. The Governor in Council may authorize the payment out of the Consolidated Revenue Fund of a bounty of one and one-half cent per imperial gallon on all crude petroleum produced from wells in Canada on and after the eighth day of June, one thousand nine hundred and four, the said bounty to be paid to the producer of the petroleum.

3. The Governor in Council may authorize the payment out of the Consolidated Revenue Fund of a bounty of one and one-half cent per imperial gallon on all crude petroleum produced from wells in Canada and held in storage tanks or other storage receptacles on the eighth day of June, one thousand nine hundred and four, the said bounty to be paid to the actual owner of the petroleum on that day.

4. The Minister of Trade and Commerce shall be charged with the administration of this Act, and may, subject to the approval of the Governor in Council, make such regulations as he deems necessary respecting the payment of the said bounties.

5. This Act shall be deemed to have come into force on the eighth day of June, one thousand nine hundred and four."

REGULATIONS.

Regulations under the provisions of the Petroleum Bounty Act, 1904, entitled—

"An act to provide for the payment of a bounty on Crude Petroleum from Canadian Wells."

1. The Minister of Trade and Commerce having been charged with the administration of the Act has, with the approval of the Governor in Council, made the following regulations respecting the payment of bounties.

2. All producers of crude petroleum from wells in Canada who desire to avail themselves of the provisions of the Act above quoted, and to be paid a bounty, before making claim for such bounty, shall notify the Minister of their intentions to claim under the provision of the

Act and shall for registration purposes, declare where or approximately where their wells are situated, the number thereof, their estimated monthly production, the place and names of the purchasers of the crude product, and in the case of a co-partnership the names of the individual partners, and in the case of an incorporated company the names of the President, Secretary and Manager, as well as the name and address of the official authorized to make the claim.

3. The books of the claimants and those of the refineries, tanking companies, gas companies, fuel oil companies and sundry purchasers, shall be at all times open to the examination of the supervising officer and of any officer of the Department of Trade and Commerce who may be detailed by the Minister for such purpose.

4. All claims shall be substantiated by the certificate of the receiving stations, tanking companies, refineries, gas companies, fuel oil companies, manufacturers of lubricating oil, or other purchasers as well as that of the supervising officer.

5. Samples must be taken at time of delivery of all crude oil sold by claimants and a record of same kept by the receivers and buyers.

6. The supervising officer may, at any time, make examination of samples or take samples at any of the receiving stations, fuel oil companies, tanking companies, refineries, gas companies, or at any purchasers or receivers of crude oil.

7. Claims for bounty may be made monthly when amounting to $25 or more per month, and quarterly, when for a less sum.

8. Claims when made and certified as above, shall be forwarded by the supervising officer to the Department of Trade and Commerce for payment.

9. No claim will be recognized or paid unless the claimant has conformed to the requirements of regulation 2, and unless claim is made and substantiated as per regulation 4 and in form hereto attached.

10. *All claims to be made in duplicate.*

Much oil and gas land is owned in fee. The advantages of this form of controlling oil land are mainly in cases where it is non-agricultural and non-mineral land, where this form of ownership may be cheaper in the long run. The disadvantages are that it is not applicable on land on which the government owns the mineral rights.

RENTALS AND ROYALTIES.

In the public lands of the Northwestern Provinces[1] there is a rental of 25 cents for the first year and 50 cents for each subsequent year, payable in advance, for a term of 21 years, and renewable upon fulfilment of certain conditions for a second term. For a tract of land covering more than the actual oil and gas rights, but considered necessary for proper development of the territory, a rental of $1 an acre a year is charged.

In this section of the Dominion of Canada there is no royalty on oil, but a gas royalty is levied, as specified from time to time, by Order in Council.

[1] Manitoba, Saskatchewan, Alberta, Northwest Territory and Yukon.

School lands in this part of the country rent for 25 cents an acre for the first year and 50 cents each succeeding year, the term of lease being 21 years.

In Quebec, a yearly rental of $1 an acre is charged for public oil and gas lands, renewable from year to year and subject to change by the Lieutenant Governor as to royalty at his discretion.

Public oil and gas lands in Ontario may be leased at $1 an acre each year for a term of 10 years, the lease being renewable upon the fulfilment of certain conditions.

In British Columbia a smaller yearly rental of 15 cents an acre is charged, the term of lease being only 5 years, and a royalty on oil is exacted in addition of 2½ cents a barrel.

Private gas lands are leased for 20 to 25 cents an acre after the first year, which is usually given free. A royalty of 10 to 12·5% is also provided. Ontario farmers usually receive 10 per cent royalty on their lands.

CHAPTER VI.

METHODS OF OBTAINING PETROLEUM AND NATURAL GAS.

SURFACE INDICATIONS USEFUL IN EXPLORATION FOR PETROLEUM AND NATURAL GAS.

By James H. Gardner.[1]

Surface indications useful in exploration for petroleum and natural gas may be divided into two general classes. One class includes all the different conditions by which actual signs are evident to the non-scientific or practical man while the other class covers all the various indirect data that enables the technical geologist to map the rock folds from various exposures on the surface. One may be called the "direct" and the other the "indirect" class. In the direct class are included "oil seeps," "oil springs," "outcrops of oil sands," "oil-filled fissures," "asphalt veins," "asphalt lakes," "oil in faults," "escapings of natural gas," etc. These are indications that have a direct bearing on the presence of oil and gas either in small or large quantities in any particular region. But it must be borne in mind that many of the large oil and gas fields of the globe have not shown any of these direct indications previous to drilling. But practically all oil and gas fields show the surface indications that are here classed as the "indirect," namely: The presence of folding in the rock strata.

The oil and gas bearing folds in the rocks of the earth are of several types; they bear oil and gas under various conditions of water saturation in the sands and under varying amounts of hydraulic and hydrostatic pressure. What is known as the "anticlinal occurrence of oil and gas" in its broad usage includes all the several conditions under which oil and gas are found related to the rock folding. An anticline is what might be termed the ideal condition wherein the strata are arched into

[1]Of Fohs and Gardner, oil geologists, Lexington, Ky., and Tulsa, Okla.

an elongated fold of the nature of an inverted canoe; the rocks dip downward from the main axis while the fold dies out toward the two ends; on such a structure gas, oil and water are separated according to their gravities leaving gas and oil at the crest, and slightly below, and water in the sand down the sides of the fold and in the neighbouring depressions. Gas is often held soluble in oil under pressure as well as usually being entirely separated above the oil on folds. If the upper limit of water is low on a fold, then the oil does not reach to the crest and this permits the volatilization of the lighter constituents of the oil

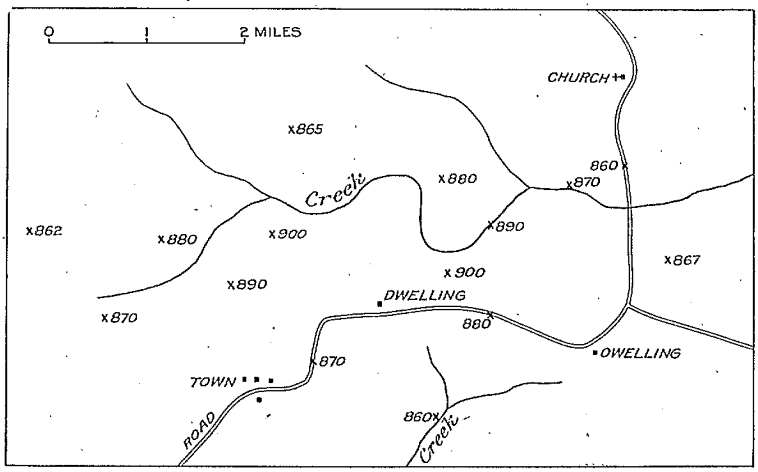

Fig. 8. Sketch map showing numbered elevations on the same outcropping stratum, at different points.

into gas at the crest. Then if later the rock pressure is increased by subsequent folding the oil and gas are put under pressure, in which case the oil absorbs the gas. But in case the salt water limit is near the top of a fold, then oil lies at the crest under pressure with no chance of volatilizing into gas, as in Lawrence county, Illinois, where oil lies at the top of the anticline with no gas of consequence. But where no water is present in the sands the occurrence of oil and gas is quite different, and in that case, as has often been demonstrated in developed fields, the oil lies in the depressions, or synclines, while gas is found along the sides or at the crests of neighbouring anticlines. Oil and gas are found also on monoclines (rises in the strata where normally they lie horizontal) or on terraces (flat places

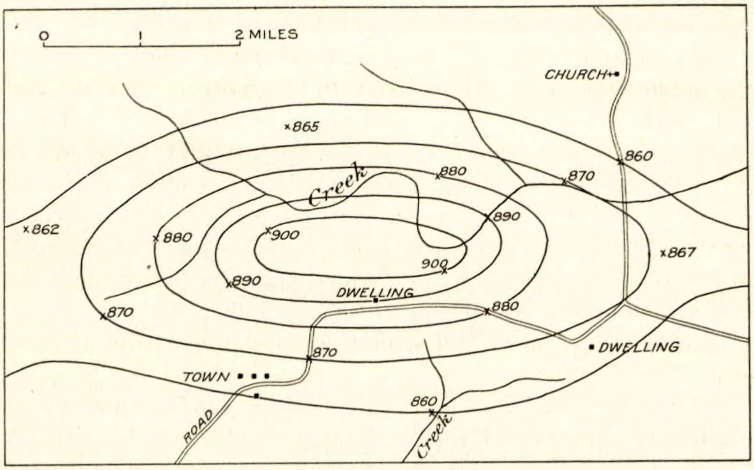

Fig. 9. Same map as Fig. 8, with structure contour lines connecting points of equal elevation, thus outlining an elongated dome or anticline.

in the strata where normally they lie on an inclination) or on domes which are practically circular anticlines. Oil and gas

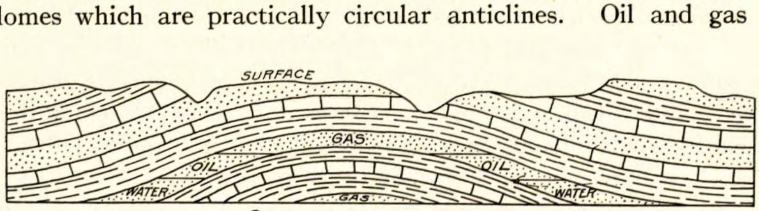

Fig. 10. Lengthwise section of the structure shown in Fig. 9.

accumulations are found on these different types of structure under different conditions that cannot be discussed under the subject of this chapter.

It is sufficient to say that all surface indications in the oil and gas exploration work belong to the domain of geologic science. The use of all surface observations in the selection of favourable territory for drilling belongs especially to that branch of geology known as "applied geology."

The practical oil and gas operator who happens not to be familiar with geology as related to his business is apt to ridicule the application of it. He is likely to be sceptical as to the usefulness of all surface indications in throwing light on what is to be expected at great depths, or else attempt to make use of some appearance of the surface hills and valleys that have no application to the subject. But the operator who has been taught the methods of modern geology in working out the folds in the rocks as shown on the surface, and who understands not only the value but also the limitations of such work is an ardent supporter of having careful structure maps prepared in advance of drilling.

It matters not how little the oil man may use his eyes in noting the outcrops of rocks in ledges, cliffs, etc., and in observing the dips and positions of the same, he will nevertheless find himself, on close analysis, making some slight use of geology. In some manner he feels that the search for oil and gas should not be wholly haphazard and without method. Manifestly every operator owes it to himself to investigate the claims of the oil and gas geologist. He should not be too prone, in his inherited disbeliefs of the old school, to place everyone in the class of "faker" who claims to be able to foretell in some measure what is to be expected in drilling a well. The science of geology is young. But it is evident to the most casual observer that vast sums of money are annually appropriated by legislative bodies all over the world for the purpose of carrying on geological surveys. The advance that has characterized all other sciences including chemistry, medicine, agriculture, etc., has been equally shown in geology. Broadly speaking, there is the scientific and the practical division of all the sciences. The use of surface data in oil and gas exploratory work is a practical division of science. Most of the large operating companies in all portions of the globe where oil and gas are found have their geologic corps of trained men which itself speaks in certain terms of the wisdom of studying the surface carefully in advance of development and along with development.

The search for oil and gas has difficulties peculiarly its own. These substances normally occur in such a manner that they are carefully sealed off from surface escape and for this reason the drill itself must, in every instance, tell the final story of what occurs in the depths that it penetrates. So that the surface indications must be looked upon as forerunners of the drill. They go in conjunction and as a part of the drilling operations. They tell where to place the drill and where not to place it. They point out many places where it would be folly to drill and permit the selection of places where it would be wise to drill. This means the saving of money, time, and labour.

With the foregoing paragraphs made clear at the outset, the writer will attempt in the following pages to outline some of the methods of obtaining information from surface studies. This will be done in terms, so far as possible, that are plain to the practical man.

Oil and gas are found in sedimentary rocks, which are those that have been deposited through the agency of water; in general terms these are limestone, sandstone, and shale. Consequently, in searching for new fields a long distance away from known oil and gas fields, and in areas where geological explorations have not been made, it is first necessary to learn whether sedimentary rocks occur there. In many large areas, the only rocks to be found are metamorphic and igneous rocks, including granite, gneiss, basalt, and related rocks. In such rocks oil and gas do not exist, and it is very exceptional that drilling is done in such areas. Now and then, however, a company is organized and several thousands of dollars are expended in drilling in some such place, in entire ignorance of this plain geological classification.

In a region of sedimentary rocks where suitable rocks do not occur, there are other classifications to be made between favourable and unfavourable territory for testing in search of new fields. This involves the working out of what is called the structural conditions. Areas of great disturbance where the rocks are turned up on edge or closely folded and faulted must be ruled out as being unfavourable, for in such cases all collecting ground has been broken up and any oil or gas that may have previously existed has been given avenues of escape to the surface. Now and then faults are found in near proximity to oil producing territory and in such cases it is very important to locate them as negative ground. But in the selection of favourable territory, there are certain types of rock folds that are known to carry oil and gas in other fields that have been developed. These include anticlines (elongated upward folds), synclines (elongated downward folds), monoclines (folds with only one direction of dip), terraces (flat places along the dip), and domes (upward circular folds as suggested by an inverted wash pan). Now to work out the positions and details of these different folds involves a thorough knowledge of field geology backed by good experience. There are many thorough geologists in the geological surveys and in private practice who are amply capable of working out the details of rock folding. But the practical oil man should exercise care in the investigation of the experience and standing of the men he employs in such work, for like all other professions there are a number of individuals in geologic work who, without ability, are continually thrusting themselves forward on the public only to the slander of the science.

The surface indications utilized in working out the structure of oil and gas fields consist of observations, carefully mapped and recorded, of the outcropping ledges of rock as they occur in place. In most of the oil countries of the globe, there are numerous places where the solid rocks can be found in outcrop, from point to point over the land; in most cases the ravines, gullies and creeks cut into rocks in their natural bedding, or exposures are found along roadways or in railway cuts. These are very valuable in working up data for a structure map. But the compiling of the map from observations at these different points is not so simple as may at first seem. Not only are accurate levels to these different exposures necessary but the intervals across the bedding from one layer of rock to another must be worked out, so as to calculate the levels from one place to another on the same bed. In some fields some certain bed can be picked out and different levels run to this bed over the district that is being worked. This is called the "key bed" or "key horizon" and the various levels on it above some datum plane (usually sea level) will show the points that lie high and those that lie low so that in this manner the details of the folding can be determined. In some areas some one coal bed can be used for this if the territory lies within a coal field. The idea in working out the different levels of some surface beds is to determine the underground variations which usually run parallel with it; the sedimentary rocks of the earth are bedded over one another in a laminated series like the leaves of a book, so that if the top layers are folded the lower ones conform with it. So while an oil sand may lie a thousand feet or more beneath the surface, its rises and depressions can be worked out by a study of the rises and depressions of some one ledge that outcrops over the surface a thousand feet or more above. To fully grasp this idea in all its simplicity is to understand the basic principles of geologic oil work. Now it must be clearly understood that the rises and depressions of the surface itself are not the same as the rises and depressions of the rocks that outcrop over the surface. This point is difficult for many men to grasp though it seems very simple to the student of geology.

It must be borne in mind that vast areas of rocks have been removed from the surface of the earth. Ledges match across valleys from one hill to another so that the mind must restore what erosion has taken away. In discussing this idea recently with an oil man he remarked that the surface of the earth so far as the rocks are concerned reminded him of a human head nearly bald with patches of hair left here and there showing that it once covered the entire scalp. This was a very good illustration.

One hears often some one speak of an anticline when he really means a valley. Ridges, valleys, and plains are the result of erosion and may or may not bear a relation to the folding; they frequently do not in the oil fields, and a ridge in the surface may be a depression in the rocks so that on both sides of the ridge the rocks dip in toward it, the ridge lying in the trough of the strata; or a ridge may be half in a syncline and half in an anticline, or in any conceivable relation to the surface configuration (topography).

In the preceding paragraphs, the writer has purposely omitted the usual notation of the nature of oil and gas origin and accumulation in order not to distract from these other points more in line with the subject matter under discussion.

The oil operators all over the globe have in past years been gathering data with the drill that has taught the nature of oil and gas occurrences. More is known now than ever before in this respect, and for this reason geological work is more valuable than ever before. Then too the methods of modern geological mapping are far in advance of former years. More detail is supplied, and the results are more accurate.

DRILLING FOR PETROLEUM AND NATURAL GAS WELLS.

HISTORY OF EARLY METHODS.

The earliest method of petroleum production appears to have been to skim it off the surface of pools of water, this having been done in many contries. In Galicia and Roumania, as well as in Ontario, wells were dug and timbered in the early days. In Roumania, however, hand-dug wells prevailed long after drilled wells were introduced in Galicia and elsewhere, and even at present many small land owners or leasers develop their properties by this means. Evidences of such workings can still be seen at some localities in America.

American.

Early oil wells in California were hand dug to a depth of 70 feet and curbed with planks.

In Johnson county, Kentucky, according to Prof. Lesley, oil was formerly collected from sands by making shallow canals 100 to 200 feet long, with an upright board and reservoir at one end, from which they obtained as much as 200 barrels per year by striking the sands with a pole. These are known as "stirring places." Similar spots at Burning Springs, West Virginia, were worked in the same way over 100 years ago.

Oriental Methods.

In 1868 a peculiar method of digging was in operation in Japan.[1] The work was done by two men in shifts of 3 hours each, one man working in the well, the other sending down fresh air to him by means of a large bellows, which is operated by walking back and forth along a board covering the bellows. The wells were timbered and cross pieces were attached for assistance in descending into it. The rock and earth was raised by means of rope-nets, pulled by several men. Wells were dug by this method to a depth of 900 feet, at a cost of only $1,000.

In China[2] early in the past century artesian wells for the production of brine were sunk by raising and lowering a rammer of 300 pounds or more in weight, by means of a man dancing on a lever which raised the rammer about two feet and let it fall. The rock was softened by occasionally throwing in bucketsful of water.

More recently the Chinese have devised a method of drilling for salt which parallels our American standard methods of oil drilling.[3] A pit several feet in diameter is first dug to a depth of about 100 feet. Then the well is walled by blocks of hard stone, giving it a mouth 6 to 9 inches in diameter, the cavity then being filled with earth between the stones and the sides.

The boring machinery consists of a large hoisting drum with wooden axle 7 or 8 feet in length, terminating in an iron pin, and surrounded with an iron framework, forming a skeleton drum, on which the cable winds. In place of the "walking beam" a plank lever, resting on a wooden frame, is used. The boring bits differ somewhat in shape for the upper and lower parts of the well, and are attached to the "sinker-bar" by bamboo strips, allowing for more or less play, as in the case of the "jars" used in American drilling. A safety cord is attached to the bit,

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[1]Lyman, Report on the Geological Survey of the Oil Lands of Japan, 1877, p. 17.

[2]Père Imbert, Ann. Assoc. Propag. Foi., Vol. 3, 1828, p. 369.

[3]Louis Coldre, Annals des Mines, 8th Ser., Vol. XIX, 1891, pp. 441 et seq.

to eliminate the danger of loss if the cable should be broken. The cable is attached to the working lever by means of a swivel, and the length of cable is adjusted so that the lever is horizontal when the bit rests on the bottom of the well. By the process of working the lever by the jumping workmen, 700 to 800 strokes per hour are obtained. The Chinese also have a primitive form of sand-bucket. The oil is raised by long bamboo tubes of much the same proportions as an American bailer.

When it is necessary to tube the well, this is done by means of bamboo stems or hollowed trunks of cypress trees. The tubes are coated first with a canvas wrapping saturated with boiling water. Naturally, fishing tools are used in China, as elsewhere, and some of them resemble American fishing tools, but are constructed of bamboo.

In Burma the modern drilling methods have improved little on those of a hundred years ago.[1] A square hole 5 or 6 feet in diameter is dug, lined with wooden casing of rough stones as the work proceeds. The digging tool in soft ground consists of an iron shoe in the shape of a chisel attached to a wooden handle, which is used like a shovel. In order to drill through hard sandstone beds, a lump of iron of angular shape weighing 150 pounds or more is hung by a rope in the mouth of the well, and then allowed to drop, fracturing the stone. Owing to the presence of oil vapours, a digger can only work in the well for a few minutes at a shift. The earth and rock are raised to the surface by a leather rope pulled by coolies and running over a drum at the well-mouth. Earthern pots are used for raising oil and for conveying it to the river.

European Methods.

The methods used in drilling in Europe are a decided improvement over those of Asia and are more or less similar to those in use in America. The principal European method is the Canadian system and its various modifications, as effected in Galicia and Russia. These methods will be hereinafter described.

[1]Fritz Noetling. Report on the Petroleum Industry in Upper Burma; Rangoon, 1891; and Mem. Geol. Sur. India, Vol. 27, pt. 2, 1897.

Methods in use in Canada.

In Canada, as in all countries, thousands of shallow wells have been sunk by digging by hand. This method has been confined mainly to water wells, but in the Petrolia fields in the early days many oil wells were sunk by hand. Driven, punched, and bored wells are also used to a certain extent for water. The abrasive methods are applied in drilling for coal, iron and sometimes other minerals, and a few diamond drill holes have been sunk in prospecting for oil. But the principal types of drilling used in Canada, as in American and European oil fields, are the percussion or churn drill methods. As yet, hydraulic drilling is little used in Canada; but there is no doubt that in some parts of the west it will prove desirable.

CHOICE OF METHODS.

The choice of drilling method to be used in any part of the country depends on several factors, among which may be mentioned the following:—

(a) Depth of well desired.....	whether 500 feet in Ontario or 5,000 feet in Alberta.
(b) Purpose of well desired....	oil. gas. water. salt. prospecting.
(c) Character of the materials.	hard or soft. sandy or clayey. porous or close. stratification flat or inclined. similar or changeable. consolidated or unconsolidated.

(d) Amount of water present.

(e) Custom in the particular field.

The advantage of knowing the kind of outfit necessary can be readily understood. In shallow water wells, in superficial deposits, driven or bored wells will generally suffice. In the 500 to 800 foot oil wells of Ontario, wells drilled by the percussion portable rig method are satisfactory and cheapest, while in 2,000 to 3,000 foot wells of New Brunswick or Alberta a heavy Standard drilling rig must be used. It is probable that in the future still deeper wells of Alberta, steel rigs must be used for going to depths of a mile or more; and in some cases rotaries should be procured. The character of the material is important, since this decides whether or not the rotary is necessary, and many other technical questions. The amount of water present is very important, since this has a great bearing on the question of casing. The custom of the field must be considered, since the drillers operating in any field are familiar with and prefer the methods ordinarily in use there, and disaster might be entailed by experimenting with a better, but less understood, method. No method can be said to be best under all conditions.

CLASSIFICATION OF DRILLING METHODS.

There are a great number of drilling methods employed in the oil business. For a full comprehension of drilling methods it is necessary to group them in several classes, as follows:—

1. Digging.
2. Driving.
5. Punching.
4. Boring.
5. Abrasion methods.......
   - a. Diamond drilling.
   - b. Calyx drilling.
   - c. Chilled-shot drilling.
6. Percussion methods.....
   - a. Standard American method.
   - b. Portable drilling machines.
   - c. Pole tool method.
   - d. Self cleaning method.
   - e. California method.
   - f. Canadian method.
7. Hydraulic rotary method.

1. *Dug wells.*—These wells are common in Canada as they are also in all countries, but they have chiefly been sunk for

water. In the Petrolia field in Ontario many of the wells sunk for oil in the early days were dug by hand. Since then this has not been done.

2. *Driven wells.*—Driven wells also are seldom sunk for oil or gas, but frequently for water. These commonly consist of a few feet of iron pipe and a driving point, the well being driven by hand. The pipe is generally one and one-quarter inch in diameter, although sometimes larger pipe is used. The point consists of a perforated gas pipe covered with brass wire cloth, generally from 60 to 100 mesh and protected by a perforated brass jacket. These wells are frequently shallow water wells, operated by a pitcher pump, and common in the United States. Driven wells are sometimes of large size, up to several inches in diameter and 100 feet or more in depth, driven by sledge or steam power, and sunk to the bottom of the unconsolidated deposits.

3. *Punched wells.*—In a few localities where the material is very clayey wells are sunk by a punch instead of an auger. Of this method and its use in Arkansas and Louisiana Veatch says:[1]

"In regions where there are uniform clay beds without rocks or boulders wells are often made with a well punch. This consists of a cylinder of steel or iron 1 to 2 feet long, split along one side and slightly spread. The lower portion is very slightly expanded, sharpened and tempered into a cutting edge. In use it is attached to a rope or wooden poles and lifted and dropped in the hole by means of a rope given a few turns around a windlass or drum. By this process the material is forced up into the bit, slightly springs it, and so is held. When the bit is filled it is raised to the surface and emptied. When working in very dry clay water is sometimes added to aid the bit in picking up the material. Thin sand layers are passed by throwing clay into the well and mixing it with the sand until the bit will take it up."

This process is not very extensively used in this region, and is not so practicable as the Arkansas clay auger.

[1]Veatch, A. C., Geology and underground water resources of a portion of northern Louisiana and southern Arkansas: Prof. Paper U. S. Geol. Survey No. 46, 1906, p. 97.

4. *Bored wells.*—These wells are also used mainly for water, and are bored with an auger, in unconsolidated deposits. A common size for bored wells is 8 inches. They are lined with iron tubing or with wood and the water is raised by a windlass and cylinder bucket having a valve at the bottom. Such methods are still in use in Arkansas and in Florida, in the United States, although this method was in common use in the United States between 1855 and 1885. The augers commonly range in size from 2 to 8 inches.

5. *Abrasive methods.*—The abrasive methods of drilling may be classified as follows:—

a. Diamond.

b. Calyx.

c. Chilled shot.

These are all known commonly as "core drill methods." They are used in prospecting for coal, copper, iron or other metals, and for testing foundations and dam and bridge sites. The advantage is that, in hard formations, a complete core can be preserved of the material penetrated. Core drilling is not employed in drilling for oil or gas; though in certain cases such holes have discovered these substances. In Hungary some cores have been taken of certain strata in gas wells which it was desired to examine for potash salts. Core drilling is accomplished by a circular shoe or bit set on the lower end of a hollow rod, which is rotated by machinery from above. Such holes range in size from one-half inch up to 6 inches or more.

These drills may be operated in all kinds of rock from the hardest trap to the softest shale; but in unconsolidated formations a hydraulic or other attachment must be used. The three classes of abrasive methods have their respective advantages in special instances. The diamond method was used first in 1863, being followed in 1873 by the calyx method. This method differs in the respect that the bit is of hardened tool steel, like the cutting shoe of a hydraulic rotary and has teeth instead of employing diamonds, for this purpose. There are also other minor differences, such as an arrangement for preserving fragments of the material which is ground out in boring. Calyx drill holes are sometimes as much as 15 inches in diameter. In the chilled shot method, the cutting is accomplished by revolving an iron or steel tube on shot poured down the hole. Distribution of the shot in the hole is aided by special shaping of the tube.

In all the abrasive methods a constant stream of water is pumped down the central tube, and, sweeping away the rock cuttings, it passes it to the outside of the pipe in a similar manner to that hereinafter described for hydraulic rotary boring.

6. *Percussion methods.*—The first deep well sunk by percussion methods, and for many years the deepest in the world, was the artesian water well at Grenelle, near Paris, France, completed in 1841 to a depth of 1,798 feet. It required seven years to drill it. One of the earliest wells of this type was the Passy well in Paris, which was completed in 1857 and curbed to a depth of 1,923 feet, having a diameter of $2\frac{1}{3}$ feet and being a flowing artesian water well. Another well, situated at La Chapelle, France, was 1,000 feet deep and $5\frac{1}{2}$ feet in diameter. It was sunk by a drill weighing four tons and operated by a powerful steam engine.

At about the same time deep wells were sunk in the United States at Charleston, South Carolina, Louisville, Kentucky, at St. Louis, Missouri, and in Pennsylvania. Within a few years wells 2,000 to 4,000 feet deep had been drilled in the oil fields of the latter state.

Percussion methods may be classified as follows:—

(a) Standard American.
(b) Portable drilling machine.
(c) Pole tool method.
(d) Self-cleaning method.
(e) California method.
(f) Canadian method.

Drilling Outfit.

Outfit necessary for drilling.—In order that a well may be drilled it is necessary to have an outfit which is frequently very complicated; but which, in all cases, consists of:—

(a) The rig or derrick.
(b) The machinery.
(c) The drilling tools.
(e) The casing.

The derrick or rigs.—By either of these terms is meant the structure with its foundation of heavy timbers, its wheels and reels and fully equipped frame, on which are hung the lines and cables to which the drilling tools are attached. Two kinds of rigs are in use, which are:—

(a) The stationary derrick.

(b) The portable drilling machine.

The first mentioned will be discussed first, and the drilling machine will be taken up in later paragraphs of this chapter.

The derricks or rigs are of various classes, namely:—

(a) The American Standard rig.

(b) The Canadian or Galician derrick.

(c) The pipe derrick.

(d) The structural steel derrick.

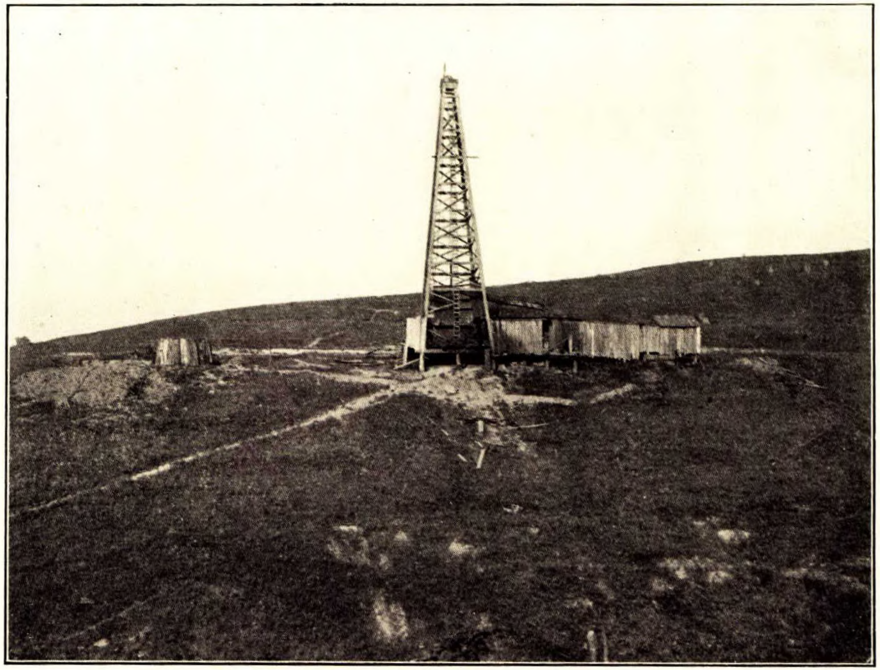
The type of derrick which must be used for drilling a well in any locality varies according to the character of the formation to the depth which must be drilled; the weight of the casing required; climatic conditions; and other features.

Material for the derrick.—As a rule, the timber and lumber required for a derrick are cut in the immediate vicinity of the hole, wherever such timber is available. The rig irons—which include the irons, nails and bolts and also the special parts for building the wheels and reels—are obtained through a supply company, costing from $50 to $275, according to the size and design. Their weight varies from 1,500 to 8,000 pounds. Where the timber and lumber for erecting a derrick are not available in the vicinity of a well, as is the case in the plains of Southern Alberta and Saskatchewan, it is possible to obtain the entire rig from a supply company ready to erect it; the prices ranging from $600 to $750, and having an average weight of perhaps 60,000 pounds.

AMERICAN STANDARD DRILLING METHOD.

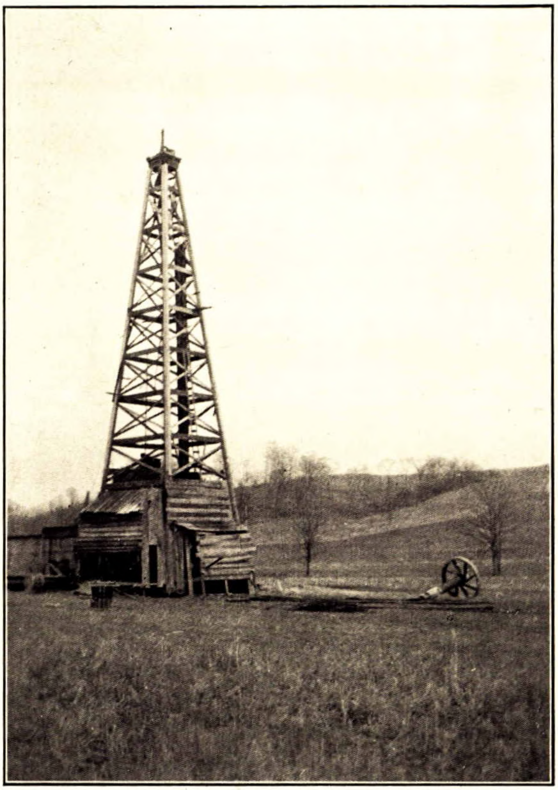
General Description.

The so-called "Standard" rig is that used throughout the American fields for practically all deep wells, with appropriate modifications to suit varying conditions in



Typical West Virginia (United States) well.

Plate II.



Typical Ohio (United States) well.

different fields. See Plate I. This outfit acquired its essential features during the early developments in Pennsylvania; but from time to time the tools have been enlarged and several features modified, until the rig has become a very modern and rapid working one. While standard rigs, when completed in any given field, are so nearly alike that a person unfamiliar with the business could hardly detect any difference in detail, the rigs nevertheless generally differ in some particulars to suit varying conditions or the preferences of the drillers. A photograph of a Standard drilling rig is given in Plate II.

Description of the rig.—The most conspicuous part of a drilling outfit is the derrick, which consists, in the Standard method, of a framework of timber, or sometimes steel, from 30 to 110 feet high, erected over the spot at which the well is to be sunk. In warm weather the derrick is generally left open except on one side, which is boarded in to form a shed for storing tools and clothing, and to protect the forge; but in winter the lower part of the derrick is often closed on all sides for protection of the workmen from the severe weather. The essential particulars of the Standard derrick, when completed for use, are shown in Fig. 12, p. 158. The common height of one of these derricks is 72 or 82 feet; but the writer has seen one 110 feet high in Mexico. It is very important that a Standard rig shall contain all of the parts necessary, and they should be of material up to the required specifications and strength.

The Standard derrick.—The derrick has four legs, extending from the ground to its full height, and steadied by girts and braces, and surmounted by what is known as the crown block, in which is set the crown pulley, over which the drilling cable passes. Access to the *crown block* is had by a *ladder* which extends the entire height of the derrick on one side. The derrick has a solid *floor* which rests upon its *foundation posts*, six in number, which are set deep in the ground to render the structure very firm. In some parts of the world, as in Louisiana and Texas, it is necessary to run guy wires from the top of the derrick to some firm object at a distance to act as wind braces. On the floor of the derrick and set even with one of its sides are the *bull wheels*, which consist of a large reel on which the drilling cable is wound; and at each end of which is a wheel which is usually built up of wooden arms and segments, fastened together with wooden pins, and known to the trade as *arms, cants* and *handles*. The entire bull wheel equipment is set firmly into *bull wheel posts*, and strenghthened by the *bull wheel post brace*.

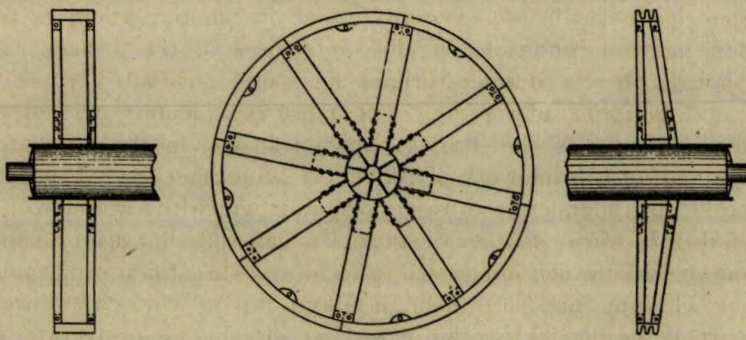


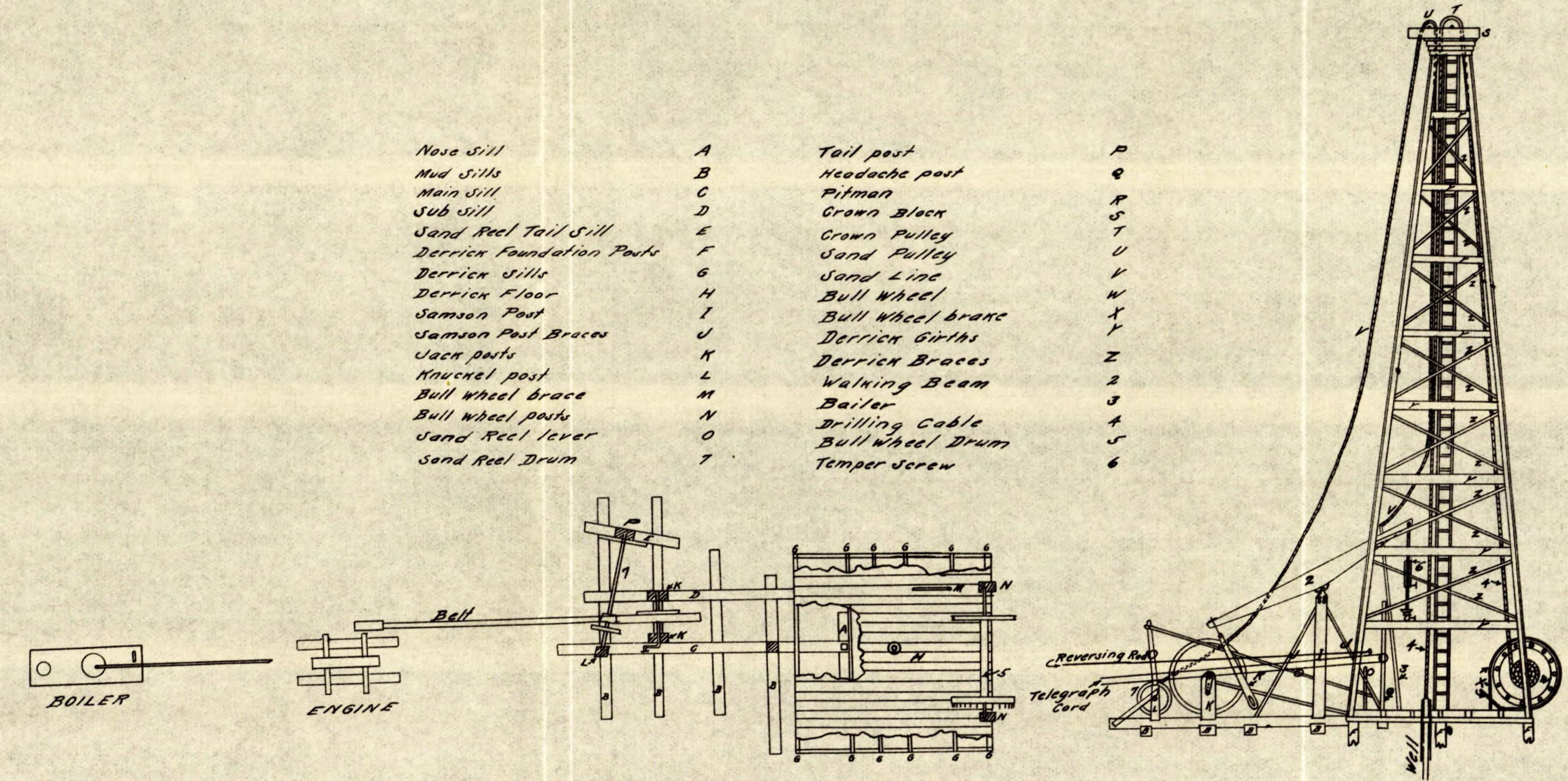
Fig. 11. Detailed drawing of steel bull wheels; consisting of a full side view of the grooved wheel in the centre; on the right, an edge view of the brake wheel, and on the left, an edge view of the tug rope wheel.

The bull wheel is grooved at one end of the reel, in order to hold the bull rope, which acts as a belt in operating the reel. In order to control the movement of the reel there is a brake, which passes over the wheel at the other end of the reel and is controlled by a lever. This brake consists in modern derricks of an iron brake band, although in early rigs rope or belting was used, which was less satisfactory. At the opposite side of the derrick from the bull wheel, and resting on four heavy *mud sills* is a still heavier main sill thirty feet in length, extending nearly that distance outside the derrick towards the engine. At the farther side of the derrick from the bull wheel is set the *samson post*, usually about fourteen feet in length, which rests firmly on the *main sill*, is strongly braced by the *samson post braces*, and supports the *walking beam*. The walking beam is commonly 26 feet in length, and carries the *pitman* at one end and the *temper screw* at the end inside the derrick to which the tools are fastened, which are used in drilling. The pitman is connected by a wrist pin with the crank of the jack or band wheel which is supported on *jack posts* and transmits the power to various parts of the rig. This *band wheel* is set at the farther end of the main sill from the derrick. The power is transmitted from the band wheel to the walking beam by means of crank and pitman and to the bull wheels through the tug wheel and bull rope.

Just behind the band wheel is set the *sand reel*, which is operated by the former through a friction pulley. The sand reel is mounted on a *knuckle post* and is controlled by the *sand-line pulley* from within the derrick and is used in handling the *sand bucket* or *bailer*, which is lowered into the well at necessary intervals to remove the drillings or sediment which accumulate. A modern derrick is not complete without the *headache post*, also called the *life preserver*, which is usually a piece of heavy timber set on the derrick end of the main sill directly under the walking beam, so that in case of accident the latter would only fall a few inches and save the driller from injury to the head. The headache post is also useful when repairs are necessary to the pitman or band wheel and crank, as in such cases a block may be placed between the headache post and the walking beam, enabling the pitman to be easily removed.

In the California type of Standard rig there is an additional reel which is known as the *California or "calf" reel*, which is set even with the side of the derrick opposite the bull wheels, and carries a cable which is used in lowering and pulling the casing, and saves considerable time in deep drilling operations. The *calf reel* is operated by the hand wheel through a tug and rope belt, and its operation is controlled by a lever and clutch. For supporting the various wheels and reels and the other parts of the rig, various Standard posts and sills are used which are given appropriate names by the drillers.

Extending from a convenient place on the derrick to the engine some distance away, is the *telegraph cord* used by the driller in controlling the throttle of his engine. This cord consists of a double line of telegraph wire passing over small wheels, Extending from the derrick to the engine is also a reverse lever which is used for reversing the engine. A derrick of the type described can be constructed by three or four skilled workmen in from three to five days; the time depending largely upon the accessibility of the lumber. Such a derrick is commonly put together by nailing and may sometimes be used for three or more wells, but can seldom be used longer for the reason that the timber and lumber become too badly worn to be set up again; hence the advantage of a bolted wooden or steel derrick which is described in a later paragraph.



12
Fig. [redacted] Side Elevation and Ground Plan of Standard Rig.

The parts needed, illustrated on the accompanying figure by appropriate letters, are as follows: (The references are to Fig. 12).

Specifications for Standard 82-foot Derrick.[1]

Pieces	Size Inches	Length Feet	Name	Illustration Marks
1	16×16	10	Nose sill	A
2	16×18	16	Mud sills	B
2	16×18	20	Mud sills	B
§1	18×18	31	Main sill	C
1	18×18	16	Sub sill	D
1	14×14	16	Sand reel tail sill	E
6	16×18	4	Derrick foundation posts	F
2	10×10	21	Derrick sills	G
20	12×12	20	Derrick floor	H
1	16×16	16	Samson post	I
2	6×8	14	Samson post braces	J
*1	16×18	16	Front and rear jack posts and knuckle post	K L
1	6×8	14	Bull wheel post brace	M
*1	14×14	22	Bull wheel posts	N
*1	9×10	14	Sand reel lever and dead block	O
*1	12×14	5	Tail post	P
1	6×8	14	Headache post	Q
†1	5×12	12	Pitman	R
*1	5×14	16	Crown block	S
1	....	....	Crown pulley	T
*1	3×14	10	Sand sheave pulley block	U
1	....	....	Sand line	V
1	Diam.	10	Bull wheel	W
1	....	....	Bull wheel brake	X
	....	....	Derrick girths	Y
80	1×6	16	Derrick braces and roof batting	Z
‡1	....	....	Walking beam	2
1	....	....	Bailer	3
1	....	....	Drilling cable	4
1	....	....	Bull wheel drum	5
1	....	....	Temper screw	6
1	....	....	Sand reel drum	7

If closed or winter rig is desired, add 500 feet, 1 inch by 18 foot boards.

* These pieces should be oak or other hard wood. If hard wood is not obtainable, sizes must be increased according to quality of material.

§ The main sill may be sawed in two pieces, 16 and 18 feet in length, with 2-foot splice.

† Pitman should be 5 inches square at top, and 5 x 12 inches at bottom.

‡ The walking beam should be 14 inches square at each end, the taper beginning 3 feet on each side from centre.

Estimated weight 67,000 pounds.

[1] Catalogue A. Oil Well Supply Co.

Labour Necessary in Drilling.

The rig is usually erected by carpenters known as rig builders. The rig builder takes entire charge of putting up the derrick and all wood work. He usually employs on the spot such help as he finds necessary. He may or may not install the boiler and engine depending upon whether the well is let by contract or not. If by contract, the boiler and engine may be installed by the contractor in charge of the drilling. The whole care of the drilling is now turned over to the drill crew under the charge of the contractor, or, if the well is drilled by day labour, to the field superintendent who provides for the board and lodging of the drillers, and furnishes all supplies. The actual drilling is in charge of a driller and his assistant, a tool dresser. The driller is in charge of the well and is responsible for the log during his turn of 12 hours, when he is relieved by the night crew, which is the exact duplicate of the day crew and goes on at 6 p.m. and works till 6 a.m. The driller's work requires him to stay in the derrick while the drilling is in actual progress. The tool dresser has charge of the machinery; he fires the boiler and runs the engine while the tools are being drawn from the holes. Many features of drilling are common to all systems and may therefore be stated in connexion with the Standard system.

Fuel.

Gas, crude oil, coal, and wood are the fuels in question, for power in drilling, pumping, and cleaning oil wells. They are mentioned in the order of their value. In developed fields gas from some neighbouring well is usually depended upon. It is piped from the well to the boiler at a safe distance from any gas which the drilling well may develop. Gas will undoubtedly be the fuel used in drilling in the western Canadian provinces. The ordinary charge is the flat rate of 5 cents per day per well for drilling purposes. Crude oil is burned under the boilers instead of gas in most drilling operations in California. The amount for drilling, pumping and other field work amounts to between 3 and 4 per cent of the total California product. In the

80 Foot Yorke Standard Derrick

and Drilling Rig

Last Patent Granted Jan. 18, 1910, No. 946,815

Scale 1/4 = 1 - 0

Fig. [redacted]
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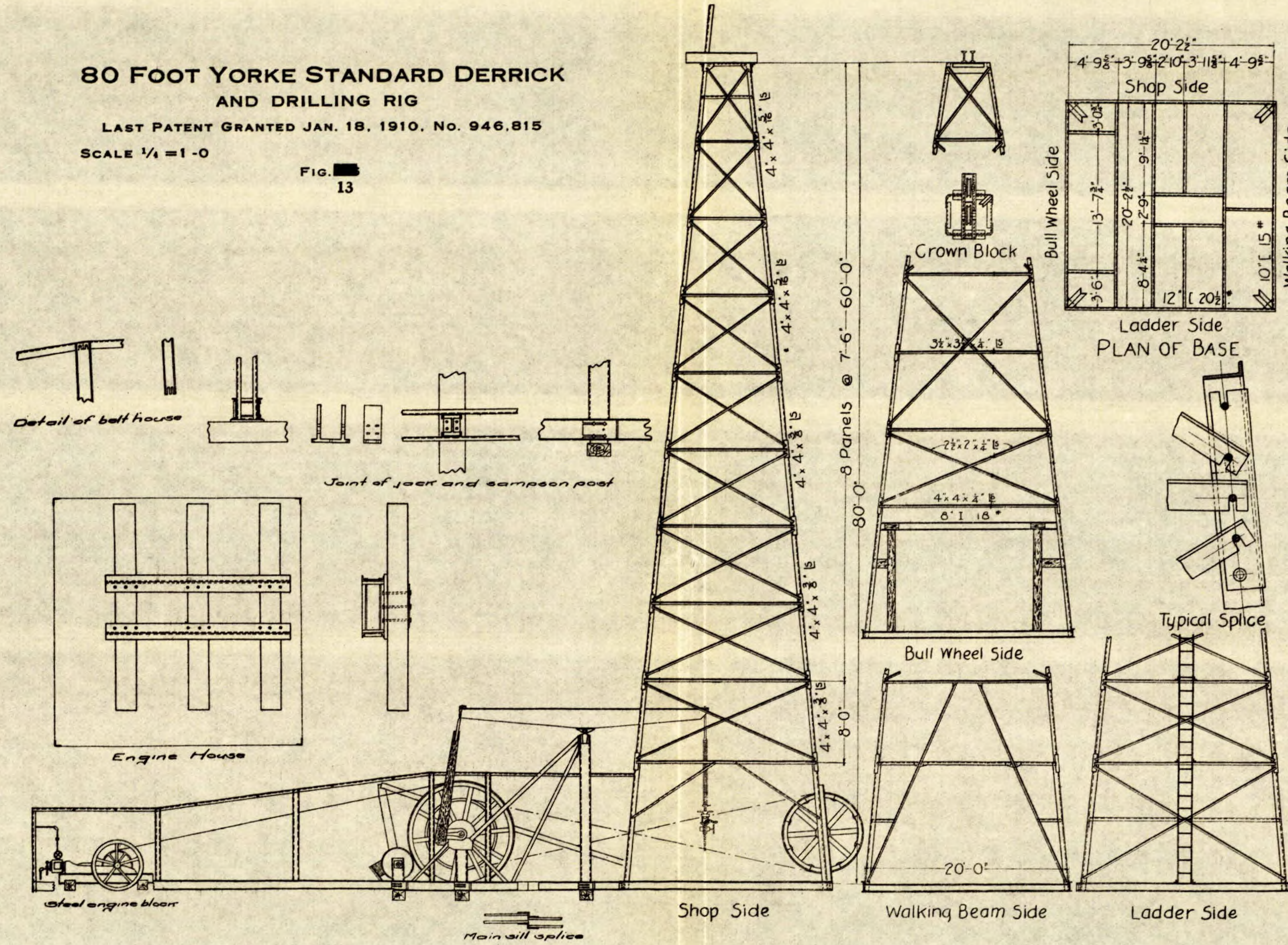


Midway district and where the gas is available it has promptly supplanted oil.

In wildcatting operations where gas or oil is not available coal is greatly preferred to wood. Relative cost is not nicely measured on account of the steadier, hotter fire which coal maintains.

In California the usual fuels have been supplanted to some extent by electric power even for drilling—this will be considered further on.

The consideration of a supply of water of fair quality for boiler purposes is of greatest importance. In fact drilling operations have been delayed and even totally stopped for important periods in the middle west by the droughts of the past two summers. Usually the wooden or steel tanks, provided for taking care of the first oil struck and located close to the well, are utilized for a considerable water supply.

Where water is so distant that it cannot be pumped economically to the tanks at the rig, and it becomes necessary to drill a water well, this is usually put down before the regular drilling operations are begun. The water well is usually put down under the walking beam about three feet back from the point where the oil well is to be drilled. The water is pumped by the walking beam.

Boiler and Engine.

The boiler used in drilling wells in cases where a stationary rig is erected, ranges from fifteen to forty horse-power, and the engine commonly is from twelve to thirty horse-power. The ordinary cost of this essential is from $500 to $1,000 and the weight is from 8,000 to 16,000 pounds.

Cost of the Drilling Outfit.

The cost of a drilling outfit varies so greatly in different types of wells and in different parts of the country, that it is almost impossible to give any features of the expense. In certain cases a suitable outfit might be obtained at a cost of

$500 or less, while under other conditions an expenditure of ten times that amount may be necessary.

The machinery used in drilling.—In a portable drilling machine which is described in later paragraphs of this report, the machinery is all carried on the portable outfit itself; consequently, it will be discussed later. A stationary rig, however, must be equipped with machinery before the well can be drilled. By machinery is understood, the boiler, engine and their equipment.

The drilling tools include all essential articles used in making the hole in the ground and cleaning out the detritus; and also all special appliances which may be necessary for removing broken tools, or tools which become fastened in the bore hole; also the drilling cable and the sand line with tools for handling the casing used in the wells. The character and type of the drilling tools are very variable, and will be discussed in further detail.

Drilling Tools.

The string of tools[1] used in deep drilling consists of several parts, all of which have certain definite functions and are the outgrowth of years of experience. A full string comprises *rope socket*, *sinker bar*, *jars*, *auger stem*, and *bit*. Whether or not the complete string is used depends on the conditions under which drilling is done.

The *socket* may be fastened to the drilling rope in several ways. It may have a tapered hole in which the rope is secured by knotting; the rope and socket may be riveted together, or the rope may be threaded back and forth through several holes in the socket secured by wedging.

The *sinker bar* is a long, heavy bar, which is used to add weight and length and thus aids in keeping the holes straight. It was formerly thought to be an essential part of the string, but it is now seldom used unless a wet hole (one partly filled with water) is being drilled. It then assists in sinking the cable

[1] Bowman, Isaiah. Well drilling methods. U. S. Geological Survey, water supply paper 257, pages 38-40.

rapidly. If it is placed between the jars and the bit, it adds force to the blow of the latter.

The *jars*, as previously stated, consist of a pair of linked steel bars. When drilling in rocks in which the bit is apt to stick they are necessary to jar the drill loose. The drill responds to the powerful upward blow of the jars as they are jerked violently together by the stroke of the walking beam when it will not yield to the slow and relatively steady pull of the rope. In ordinary brittle rock the jars are now almost universally discarded but they have a very important use in fishing for lost tools; those intended for this purpose are made longer than jars used in ordinary drilling.

The jars in no sense act as a maul to drive the drill into the rock, as many people suppose. In fact, a good driller so adjusts the cable that it is impossible for the upper jar to strike the lower one except when the cable is raised. The only weight which adds effectiveness to the blow of the drill is the weight of the lower jar, the auger stem, and the drill. The weight of these three parts, or of the two last-named parts, makes up three-fourths to seven-eighths of the total weight of the string of tools. This weight, falling through a distance of several feet, is all that the drill can bear. Some inexperienced drill men give the drill too much rope, so that the bottom of the upper jar strikes into the bottom of the slot of the lower jar at each downward stroke, and in a short time the links are seriously damaged. The stroke must be carefully adjusted to the play of the jars, taking into account the stretching of the rope.

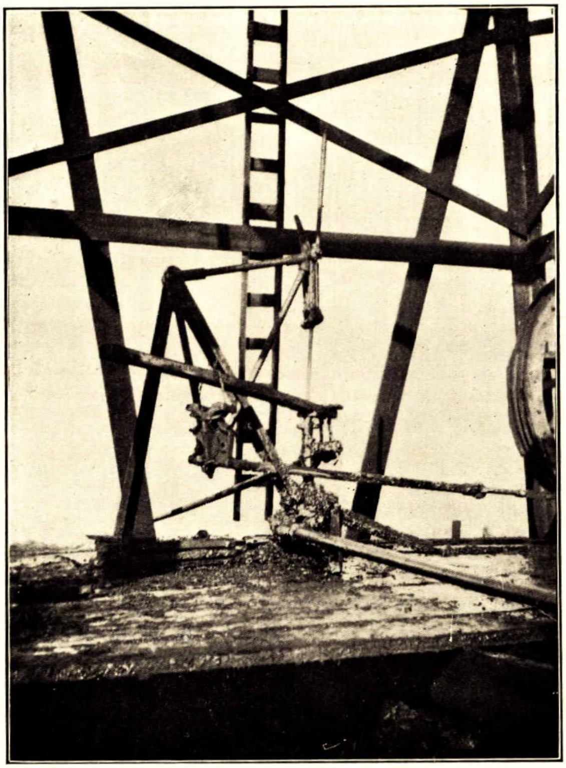
The *auger stem* gives additional weight to the blows that are struck, and also, by increasing the length of the drill, helps to maintain a straight hole. It is of the same shape as the sinker bar, but is considerably shorter.

Various patterns of *drilling bit* are used, according to the character of the rock that is being penetrated. The shape illustrated at the bottom of the string of tools in Plate VIII, is used in moderately hard rock; the "Mother Hubbard" pattern (Plate III) is a similar, but thicker drill that is used in hard, fissured rock; the California pattern, which is concave on the bottom, is much used in the shales of the oil districts in that state. A shorter, lighter bit is used in spudding at the beginning of drilling. Star bits are sometimes used in creviced rock that dips steeply, and more complex shapes are used in reaming and in other special operations.

Bits of good length are very desirable; in the event they are lost from the stem they are not so easily driven into the wall of the hole; when they stand in a perpendicular position they are more easily recovered. It is also desirable that they be so thick as to almost fill the hole which prevents the hole from going crooked in passing through crevices or fissures in the rock. A water course or flutes on the sides of the bit permits the water and drillings to pass up freely past the bit. The tool wrenches vary in weight to meet the judgment and ideas of the different contractors, the average weight being about 300 lbs. each. They are usually made to fit a 5-inch square, which is the size of the square on the larger tools, and by the use of a bushing called a Dutchman, the size of the wrench is made to fit the smaller tools. The wrenches are attached to a balancing weight in the derrick which permits one man to handle them with ease. They are operated by a powerful apparatus called a "jack", which consists of an arc circle of heavy iron which is fastened to the floor around the hole and far enough distant from the hole to catch the extreme end of the wrenches when they are placed in position on the joint. The jack travels on the circle, and while one wrench is firmly held by a wrench post pin, the other wrench is moved around the circle by a ratchet jack.

The *temper screw* consists of two steel reins about 6 feet in length, connected at the top to a steel rod $2\frac{1}{2}''$ in diameter and $16''$ in length, upon the top of which is a tee $2\frac{1}{2}''$ in diameter and $14''$ in length. On the bottom of the reins is a split box which, when closed, is $2''$ in diameter, supplied with a screw $1\frac{1}{2}$ threads to the inch. The temper screw proper is a steel screw $2''$ in diameter with $1\frac{1}{2}$ threads to the inch and 6 feet in length; to the bottom of which is attached a C (half circle) which holds the clamps which go around the cable, and which is attached to the screw with a ball-bearing attachment. When the screw is placed in the box on the reins, the box is tightened by a set screw which passes through a band or yoke. When the

PLATE III.



Type of Jack used in pumping oil wells
(Oklahoma fields, etc)

screw is to be raised or lowered, this set is gently loosened, which allows the screw to be turned.

All joints of the string of tools have taper screws, so that only a few turns are required to fasten them together. They are screwed up tightly by heavy wrenches on which great leverage is exerted by means of a ratchet floor circle and jack, or by a simpler arrangement in which the floor circle is an arc of band iron with holes punched in it every 2 or 3 inches. These holes give footing to a bar by which the upper wrench is forced around. The great stress that is thus brought on the screw binds the string of tools together. When first assembled and screwed together tightly each joint of the string may be marked by a cold chisel cut that extends across it, and each time a joint is put together care is taken to see that it is screwed up as far as or a little farther than it was before. If the two halves of the chisel mark fall short of coinciding, sand or mud in the threads may be the cause, and if this material is not removed and the joint screwed together tightly, the sand may work out, leave the joint loose, and cause loss of all tools below the joint.

Both hemp and steel wire ropes are now used for *drilling cables*, the steel wire having come into more general use during the last ten or fifteen years.

The best quality of hemp rope is that made of manila hemp (not common hemp nor sisal) and is hawser laid, that is, it consists of three ropes of three strands each, twisted together into a single rope. In its manufacture a "nap" is formed, of the ends of hemp fibres, nearly all of which point towards one end of the rope. The rock socket should be fastened to the end toward which the fibres point, for although when the tools are attached to this end the fibres spread out and retard the downward stroke in a hole that is partly filled with water, they protect the rope better from being frayed by rubbing against the casing on the upstroke.

Steel wire drilling cable is composed of several strands wound about a hemp core, each strand being formed of several wires. Rope consisting of six strands of seven wires each is a style commonly used.

The advisability of substituting steel wire cable for hemp cable in drilling deep wells has been much discussed, some maintaining that hemp can never be replaced by steel, and others that steel will shortly be used altogether. The importance of the substitution of steel for hemp is better appreciated when it is known that a hemp cable ordinarily cannot be used to drill more than one or two wells, but the hemp cable possesses certain qualities which are not found in the steel cables and which must be considered in dealing with the problem. The careful driller never allows his tools to fall as a dead weight on the rock which he is drilling, but so adjusts the rope that the tools will stretch it in reaching the bottom of the hole. The nature of this action may be illustrated by suspending a weight by a piece of rubber elastic a little above a table or other surface. It will be found that by giving a slight reciprocal motion to the rubber the weight may be made to strike the surface with considerable force. Manifestly, the force of the blow is diminished by this arrangement, but in drilling this loss of force is more than compensated by the springing blow that is struck; and if the rock is easily cut by the drill this rebound is essential, as otherwise the drill will be imbedded so firmly as to make it difficult to remove except by jarring.

In drilling a deep well the stretch of the rope is often underestimated, and it may happen that the tools are falling when the walking beam is rising, thus bringing a great strain on the cable and making the blows of the drill very ineffective. The operation of the tools is rendered still more difficult when the hole contains several hundred feet of water, which interferes with the free upward and downward motion of the cable.

Steel cable, with its smaller diameter and greater weight, has the advantage of passing comparatively freely through water which may stand in the drill hole, the water friction being much less than on a hemp cable, and the water also reduces the shock of the steel cable by acting as a deterrent to the rapid drop of the tools. On drilling through thick oil as in Mexico, hemp cable would frequently be impossible. On the other hand, steel cable has very little elasticity, and drilling by the stretch of the rope is hardly possible. Every blow that is struck by the drill is a dead blow, as there is no compensating rebound and the upward stroke causes severe strain, both on the derrick and on the cable itself where it is attached to the tools at its lower end and to the temper screw at its upper end. The difference in stretch of the two kinds of cable is shown by the fact that with a 5-foot temper screw 7 or 8 feet may be drilled with hemp cable, while at best a distance of only 5½ feet is possible with steel cable. Some drillers use 150 or 200 feet of hemp rope between the tools and the steel rope, and this gives some elasticity to the cable and rebound to the tools.

The use of the steel cable was considerably increased during the Spanish-American war by the fact that the price of hemp cable became so high that its use seriously increased the cost of a well.

In the last few years at least half of the oil wells put down in the California fields, where the wells are usually drilled "wet," have been drilled with steel cables. In other oil fields a very small proportion of the drilling is done with steel cables. For cleaning wells, however, it has largely supplanted hemp cable throughout the east, as in this work it is not necessary to use such a rapid stroke, and hence steel cable may be advantageously employed.

Experiments have been made by several supply companies looking toward the construction of some device that will give elasticity to a steel cable, but the thousands of dollars thus spent have had little practical result. Several experimenters, however, are continuing this investigation, working along the line of a spring fastened to the walking beam, the whole being adjusted in such a way that the spring, when given the proper tension, will take up the slack of the cable on the upward stroke and give it out again under the weight of the tools on the downward stroke. Experiments are also being made with a cushioned walking beam, looking toward the same result; and it is possible that a sufficient degree of efficiency may be reached in the construction of this device to permit the wider distribution of steel for hemp in future drilling operations.

The standard well-drilling outfit with steel wire drilling cable has been used to some extent in the Baku oil region of

Russia, where it was found that only a very limited amount of rotation could be imparted to a wire rope without damaging it, because of the untwisting and kinking of the strands. To overcome this disadvantage a special kind of wire rope was employed, consisting of left-hand and right-hand strands plaited together. It is said that this rope worked satisfactorily in the hands of a skilful attendant, but it had to be disconnected from the main drum at each change of operations.

As a general proposition it may be said that with wells which are drilled to any great depth a manila cable is used for the first 1,000 feet; after that it is the general practice to substitute a steel cable.

A complete outfit of cable drilling tools and machinery suitable to do testing or deep and difficult drilling consists of the following:—

1—25 h.p. boiler.

1—25 or 30 h.p. steam engine.

1—12″ 6-ply, 90 ft. rubber belt.

1—$2\frac{1}{4}$″ Manila hemp drilling cable; length governed by the depth of hole to be drilled, or equivalent in steel cable.

1—Wire sand line, $\frac{1}{2}$″ or 5-8″ in diameter, 2500 ft., in length.

2—Bull ropes, $2\frac{1}{2}$″ in diameter, 85 ft. in length.

1—Temper screw.

1—Jack.

1—Blower for heating bits.

1—300 lb. anvil.

1—Full equipment of miscellaneous small tools, such as sledges, hammers, hatchets, wrenches, blacksmith's tongs, saw, square, etc.

1—16″ all	crescent	steel	bit,	weight		1500 lbs.
2—13″ "	"	"	"	"		1300 lbs. each.
2—10″ "	"	"	"	"		1100 lbs. "
2—$8\frac{1}{4}$″ "	"	"	"	"		800 lbs. "

All of the above bits provided with taper pins $3\frac{1}{4} \times 4\frac{1}{2}$″; 7 flat threads per inch; outside diameter of collar $6\frac{1}{4}$″.

2—$6\frac{5}{8}''$ all crescent steel bits weight 500 lbs. each. Provided with taper pins $2\frac{3}{4} \times 3\frac{3}{4}''$; 7 flat threads per inch; outside diameter of collar $5\frac{1}{4}''$.

1—Crane and hoist for hanging or connecting bits to stem.

2—5″ cold rolled steel stems, 32 to 36 ft. in length; taper pins $2\frac{3}{4} \times 3\frac{3}{4}$; 7 flat threads per inch; outside diameter of collar $5\frac{1}{4}''$. Box $3\frac{1}{4} \times 4\frac{1}{4}''$; 7 flat threads per inch; outside diameter of box $6\frac{1}{2}''$.

2—4″ or $4\frac{1}{2}''$ cold rolled steel stems, 36 to 40 ft. in length; $2\frac{3}{4} \times 3\frac{3}{4}$ taper pins; 7 flat threads per inch; box of same size; outside diameter of box $5\frac{1}{2}''$.

2—Rope sockets; box $2\frac{3}{4} \times 3\frac{3}{4}''$; 7 flat threads to the inch.

2—Sets of drilling jars, with 6″ to 8″ stroke; box and pins $2\frac{3}{4} \times 3\frac{3}{4}''$; 7 flat threads per inch.

2—Sets of fishing jars, 18″ stroke; box and pins $2\frac{3}{4} \times 3\frac{3}{4}''$ 7 flat threads per inch.

1—Set tool wrenches.

1—Boiler tube, 11″ × 24 feet.

1—Boiler tube, 9″ × 24 feet.

1—Boiler tube, 7″ × 24 feet.

1—Boiler tube, $5\frac{1}{2} \times 30$ feet.

Drilling Operations.

FISHING.

If a bit is lost from the bottom of the stem and the driller does not detect the break instantly he is likely to drive the top of the bit into the wall of the hole, in which event the box of the stem goes by the top of the bit and sticks. When the stem sticks in this way, if there is sufficient cable in the hole to permit the beam to continue its motion on the stretch of the cable, the engine will instantly increase its speed; the tension in the cable pulling the beam down quickly, only to be pulled up again by the engine. This notifies the driller that something has gone wrong and (if he is awake) he investigates.

If the tools are drilling in sand and the bit is even slightly worn, when it passes through the sand, it will have too much wearing surface to run in slate formation, in which event it will stick with the same results as noted above. In either case, the driller will loosen the tools by switching. This is done by increasing the speed of the engine, which gives the walking beam a quick motion which usually jerks the tools loose. When this is done, the tools are pulled out. If the bit is off, the stem is taken down and sent to the shops for a new box. A spud is attached to a light stem and lowered into the hole.

The cable is then connected to the beam. The wrist pin is changed in the crank to give the beam a short stroke. The tools are then operated much the same as if drilling, with the result that the spud usually brings the bit into an upright position again. After this is accomplished, a friction socket is lowered over the bit and it is recovered.

When tools lost in a hole are so large as not to allow a fishing tool of sufficient strength to withstand great weight or jerking, to go over them, it then becomes necessary to turn off the outside of the broken part in the hole, leaving a core to which the fishing tool can be attached. This is called milling a pin, and is accomplished by attaching a mill of the desired size to two-inch tubing. The tubing is lowered into the well until the top of the lost tools is found. The upper end of the tubing is connected to a wheel in the derrick which turns it. The weight of the tubing is lifted off the mill to allow it to turn freely. In this way the pin is milled. The tubing is removed and the necessary tool is lowered, and the lost tools are recovered.

The various fishing tools are referred to on a later page under difficulties in drilling.

SPUDDING.

The term spudding is applied to drilling without the aid of the walking beam—the method nearly always used in sinking the first 75 or 100 feet of a well, as the string of tools is too long to be operated from the walking beam in beginning work. It is possible to attach the tools to the drilling cable before the hole has been drilled to this depth, but owing to the short length of cable between the tools and the walking beam there is very little spring in the rope, and the hole must be spudded to a sufficient depth to allow a considerable length of cable to come between; otherwise the blow of the drill will be dead and the rope will be likely to break.

For spudding a short cable is run through the crown pulley at the top of the derrick, one end being attached to the bull wheel shaft and the other to the rope socket, to which are usually screwed only the auger stem and spudding drill. The drill may be given an up-and-down motion in two ways: In the first method the rope is carried around the bull wheel shaft in two or three turns, its end being left free. A man standing in front of the bull wheels grasps this free end of the rope and gives a slight pull, causing the coils to tighten and grip the revolving shaft, and by this means raising the tools; when the rope is slackened the tools fall. By alternately tightening and slacking the rope the operator may rise and drop the drill. The second method has come into use comparatively recently and is much more effective than the other. In this method, which is self-adjusting, the drill rope is wound about the bull wheel shaft and passed through the crown pulley, and from its end the tools are suspended in the drill hole. A rope called the jerk line is attached to the wrist of the band-wheel crank, brought inside the derrick, and attached to the part of the drilling cable which extends from the crown pulley to the bull wheel shaft by a curved metal slide called a spudding shoe. By carefully adjusting the length of this rope each revolution of the band wheel results in a pull on the line and its subsequent release, and a corresponding rise and fall of the tools. As the hole deepens the cable is let out by giving the bull wheel shaft a partial revolution, and the spudding shoe is slipped farther and farther down, for this downward sliding of the spudding shoe increases the length of the pull on the drilling cable and hence the distance through which the drill drops. The sliding motion is imparted by the driller's assistant, between the jerks of the line, by means of a crooked stick long enough to reach the spudding shoe from the floor of the derrick.

Spudding is much harder on the derrick than is ordinary drilling as the strain is brought on the top of the derrick where there is the greatest leverage. In drilling with the walking beam the weight comes on the samson post, which is not directly connected with the derrick, and the strain comes on the derrick only when raising or lowering tools or casing and when using the sand bucket or the bailer.

DRILLING WITH THE WALKING BEAM.

As the hole is deepened the tools are lowered by releasing the brake and allowing the cable to gradually unwind from the bull wheel shaft. After a certain depth is reached in this way, the bull ropes are thrown on the bull wheel and the tools are pulled up into the derrick, and the larger bailer, attached to the sand line and operated by the sand reel, is brought into use to remove from the hole the drillings which have been mixed by the bit. When this is done, the tools are lowered into the hole again and the spudding continued.. The hole is usually spudded in this way to a depth of 150 feet, when the connexion is made to the walking beam by the use of the temper screw.

This is done by lowering the tools into the hole to the proper depth; the beam is elevated by putting the pitman on the wrist pin in the crank and a wrapper is securely wound around the cable at a point directly opposite the temper screw clamps.

This wrapper is tapered from the bottom upward, and when placed in the clamps, which form a kind of socket, the brake is released and the wrapper is allowed to settle into the clamps, which causes it to tighten on the cable. When this connexion is complete the bull wheels are released and some cable is taken from the shaft which will prevent the bull wheels from interfering with the motion of the beam. The beam is now put in operation by the driller standing near the hole in the derrick, who has control of his engine by means of a cord, called a telegraph line, which extends to and is wrapped around the engine throttle wheel. There is also a reverse pipe ½ inch in diameter connected to a reverse lever in the engine and of sufficient length to extend to the position in the derrick occupied by the driller. This connexion allows the driller to operate the engine at will.

In a shallow hole, the engine is usually run at a pretty rapid motion as the tools drop freely, but as the hole is deepened, the motion of the beam is slackened. The driller while drilling in a shallow hole, notes the working of the tools by a down jar as the tools strike the bottom. As the hole deepens this jar gradually works off and is changed to an up jar. While the tools are being operated, the driller usually stands near the hole with his hand on the cable, and by an unexplainable knowledge or intuition, gained only by experience, he is able to correctly note and determine the action of the tools. The labouring of the engine will also indicate to the driller whether or not the tools are working properly.

If the driller gets lost, or is not sure that his tools are a proper distance from the bottom of the hole to strike the most effective blow, by checking the motion of the engine, the tools, if working properly, will swing clear of the bottom and the jar is not noted on the cable. By increasing the motion of the beam again the tools will reach farther and again strike the bottom of the hole.

As the hole deepens the driller lets out the temper screw which lowers the tools, and this process is continued until the entire length of the screw is lowered, which deepens the hole approximately 6 feet.

The bull ropes are then thrown on the wheel, the tools are pulled out of the hole, the bailer is brought into action, by which the drillings are pumped out of the hole. Sufficient water is poured into the hole to mix another screw length; the tools are lowered again and the operation is repeated. As the hole is deepened and the soft cavey formation has been passed through, it is often necessary to keep the wall of the hole dry to prevent caving. This makes it necessary to lower the water in the bailer and dump it in the bottom of the hole.

Until within the last few years it was the custom to revolve the drill by inserting a stick in the rings below the temper screw and slowly turning the rope first in one direction and then in the other. This was thought to insure a round hole by causing the drill to strike each time in a different place. The drill, however, is jerked free from the rock unevenly, and the torsion of the drilling cable under the lifting strain has the effect of rotating the tools in one direction on the upstroke and in the other on the downstroke. This action, however, takes place to a notable degree only when there is a sufficient length of rope between the tools and the walking beam; until a considerable depth is reached it is often necessary to turn the cable by hand, otherwise the drill may strike successive blows in the same place, but it is now rightly considered that after the hole is 200 or 300 feet deep it is needless to turn the rope while drilling.

The skilled workman takes hold of the rope or swivel often, for by the feel of the rope he ascertains whether the string of tools is intact and the drill is cutting the rock. When the drilling bit strikes the bottom of the well, the cable is drawn taut and conveys the vibration to the driller's hand; by this means he soon learns when to adjust the temper screw. In the same way the operator learns whether or not the jars open and shut at each blow of the drill.

The proper tension of the cable can be determined only by practice. An old cable has more spring to it than a new one; and the weight of the drilling tools, the depth of the hole, and the speed at which the machine is running must also be taken into consideration. Ordinarily the engine should be speeded up until the cable tightens slightly in advance of the stroke of the drill, not so as to retard its fall, but so that when the drill touches bottom it will be instantly lifted, with no time either to settle or stick. This careful adjustment of the stroke is absolutely necessary for rapid and skilful work. If the drill touches bottom when at rest, there is too much rope out and it should be taken up with the temper screw, for the downward stroke of the drill will stretch the rope sufficiently to let the bit strike the bottom of the hole.

The motion of the drill will be greater than that described by the walking beam, unless too much cable is let out, in which event the stroke of the drill will be less than the stroke of the walking beam, the strain on the cable will be greatly increased, and little or no progress can be made. One of the hardest things for a beginner to learn is that he can not make the drill cut faster by letting out more cable. With a hemp cable, at a depth of about 50 feet, when the drilling tools are at the lowest point in the stroke, the point of the bit should hang 2 or 3 inches above the bottom of the hole. At 100 feet it should be 4 or 5 inches; at 200 feet it should be 6 to 12 inches; and at greater distances with greater depths. An unskilled driller will sometimes allow the full weight of the tools to fall on the drill rope, the drill actually being stopped in its descent a short distance above the rock in which it is supposed to be cutting. The likelihood of such an occurrence increases with the depth of the hole, for the increasing weight of the drill rope added to the weight of tools, often several tons in all, makes it difficult to detect by the feel of the rope whether or not the total weight is decreased at the end of the stroke by the weight of the tools below the jars.

As the drill cuts deeper it is necessary to let out the drill rope gradually, so that the drill will strike at each stroke. This is done by loosening the yoke clamp a little, and running out the temper screw a turn or two. At the end of from half an hour to several hours the temper screw has been run out its length of several feet and the drill has advanced an equal or greater distance. The tools are then withdrawn, the waste that has accumulated since the last bailing is removed with the sand bucket, and if necessary a sharpened bit is substituted.

The withdrawal of the tools is accomplished by first taking up the slack cable on the bull wheel shaft, thus transferring the weight of the tools to it through the crown pulley. The rope clamp is then loosened, the temper screw is disconnected, and the pitman is thrown off from the band-wheel crank pin, as in Plate V. By rotating the bull wheel brake shaft with the engine connexion, the tools may then be raised or lowered at will. This part of the work demands skill, for if the bull wheel brake should not be applied as the tools clear the hole and the tools are allowed to be raised to the crown pulley they would fall on the workmen beneath. After the tools are clear of the hole, they are swung to one side and caught in the loop of a $\frac{1}{4}''$ rope fastened to a leg of the derrick.

The operator is now ready to bucket the drillings from the well. The sand bucket, or bailer, consists of a section of tubing 15 to 60 feet long and somewhat smaller than the well. It has an iron valve at the bottom, either of the flat pattern, or the ball and tongue pattern. In some materials in which the drillings are thick and heavy and do not readily enter the bailer, a sand pump is used. In addition to the bottom valve this has a plunger which is worked like that of a water pump, and thus sucks the drillings into the tubing. The bucket or pump is suspended from a wire cable that is wound on the sand line reel and carried through the sand line pulley. The reel is operated from the derrick by a lever, which brings its friction pulley into contact with the band wheel. The sand bucket line is thus wound up and the sand bucket is swung over the hole. The friction bearing on the band wheel is then released and the bucket is lowered into the well at any desired speed. As the drillings form a thin mud, owing to the addition of water from time to time by the driller, they rise into the sand bucket, are retained by the valve in its bottom, and are then removed. The bucket is emptied by lowering it upon an upright stake or pin beside the well, thus opening the valve.

The liquid condition of the drillings often makes it possible to drill 5 or 6 feet without bucketing; otherwise the drill would become ineffective at the end of a very short time, by striking into its own cuttings, and the necessity for frequent bailings would greatly increase the work and cost of drilling. Water is usually added to the drillings by the bucketful at the well head. Sometimes it comes into the well from water-bearing strata that have been penetrated by the drill in a quantity sufficient to soften up the drillings, and yet not great enough to interfere with the work. It is then unnecessary to pour in water from the surface.

In many localities water is added to the drillings by means of a barrel set at one side of the derrick, from the lower end of which a pipe extends within 2 or 3 feet of the drill hole; to this pipe is fastened, by a loose joint, another piece of pipe as long, at least, as the height of the barrel and long enough also to reach from the end of the horizontal pipe to the mouth of the drill hole. When the short length is dropped to a horizontal position water flows from the barrel down into the hole; by raising the short pipe to a vertical position the flow is shut off.

TOOL DRESSING

While the tools are drilling in sand rock the bit wears out of gauge. It is usually taken off the stem after it has drilled five or six feet and another bit of the proper gauge, which is always in readiness, is put on the stem. While this bit is being run the tool dresser heats the bit taken off, which is done in a forge in the side of the derrick. When it is ready for dressing, the driller and tool dresser, each with a 15lb. sledge, upset and expand the face of the bit to a size larger than the hole being drilled. The bit is then turned on its edge and the corners are drawn forward and rounded to correspond to the circle of the hole, leaving the flutes or water course on the sides of the bit open. The bit is dressed with a double short bevel on its face and is otherwise shaped to do the most effective work in the formation it is required to drill.

To dress the bit the exact size of the hole, a steel gauge is used which is a complete circle the size of the hole.

When oil or gas is found the forge is removed from the derrick to a safe distance outside to guard against fire. The boiler is also moved for the same reason when necessary, and again connected to the engine by lengthening the steam lines.

HYDRAULIC ROTARY SYSTEM OF DRILLING.

This system is an improvement on the American Standard method, made to suit certain conditions, originally employed in Texas and Louisiana, but now extended to other parts of the world where very little, if any, solid rock formations are present; and, consequently, the ordinary churn drill or Standard method of percussion drilling will not apply.

This method of drilling was first successfully used in sinking oil wells in the Spindle Top field near Beaumont, Texas, where other methods of drilling had failed, and it has since been a great factor in the development of the Texas fields. Its successful use in that region and the consequent great improvement in the machinery employed has led to its increasing use where soft materials are encountered.

The Hydraulic Rotary system should be applicable to large areas in western Canada, where the formations are comparatively soft, but up to the present it has not been introduced.

Drilling with a rotary machine is not desirable where it can be avoided, inasmuch as the weight of water used to force the drillings out of the hole is greater than the rock pressure found in the producing sands. The sand formation is plastered with mud and often salivated to such an extent as to hide the value of the well.

Description.—A rotary drilling machine consists of heavy rollers placed in a revolving frame; the frame is supplied with cog gear, sprocket wheel and chain, which connect it to the engine which operates it. The drill stem, consisting of heavy four-inch pipe made especially for such work, passes through the rollers freely when being elevated or lowered. When the rotary is revolving, the rollers grip the drill stem and turn it; the bit made to resemble a fish-tail, is fastened to the bottom of the stem; a water pump is connected by a heavy two-inch rubber hose to the top of the stem with a swivel joint connexion; when in operation, the stem revolves quickly; the bit on the bottom of the stem cuts or loosens the formation, and at the same time the water is being forced down through the stem and escapes through holes in the bit, and coming up on the outside of the stem carries the drillings to the top of the hole.

With the hydraulic rotary outfit, a derrick similar to that of the standard rig is used, but the machinery and tools are unlike those of percussion outfits. The principal parts of the machinery are a revolving table or whirler, two hydraulic pumps, and boiler, engine, and line shaft to furnish power.

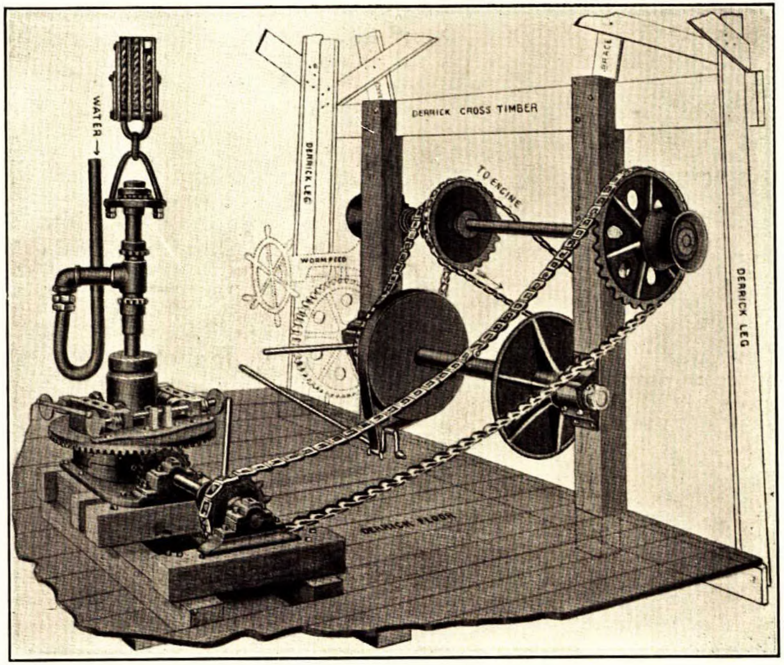
The revolving table is a heavy rotating device, set on heavy tool-steel rollers, that grips the casing firmly and permits it to be revolved and yet allows it to be gradually lowered as sinking progresses. The table is revolved by means of bevel gearing connected with the line shaft and controlled by a clutch and lever.

The hydraulic pumps, which supply water for drilling, are capable of developing pressure of from 125 to 175 pounds to the square inch. As the water used is very muddy, the pumps are made with but 6 to 10 valves, whereas if the water were clear

PLATE IV.

Rotary method of drilling, Caddo field, La., U.S.A.

PLATE V.



Rotary hydraulic ready for use.

20 to 24 valves would be used. The valves also fit more loosely than in ordinary pumps, so as to reduce the abrasion produced

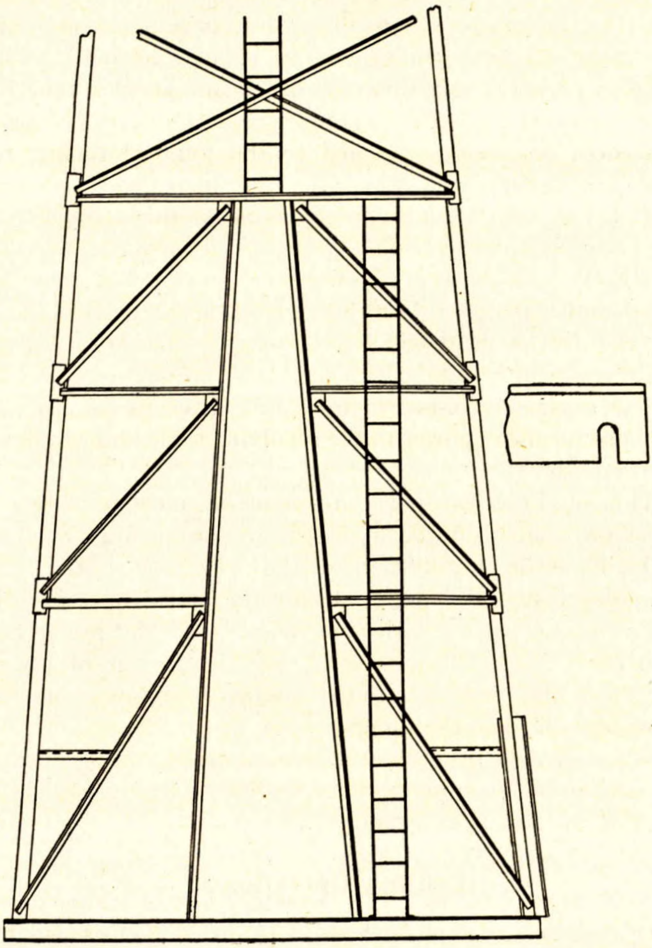


Fig. 14. Three sections of a rotary derrick; these derricks differ little from the ordinary standard derrick, only in the lower sections as shown here.

by the sediment. Only one pump at a time is in use, but to permit packing of the valves and to provide for accidents and emergencies two pumps are always installed. In many plants, two boilers are also installed for similar reasons. The pump that is in use is connected with the top of the casing through a hose line and water swivel similar to those in the self-cleaning outfit, but larger, so as to allow the continuous pumping of water into the casing while the latter is being rotated. A back-pressure valve is usually inserted in the gooseneck at the upper end of the swivel, to relieve pressure on the hose. Two swivels are needed, one being attached to the joint of casing, to be added next to the string, while the other is in use.

The drill stem is suspended from blocks through which lines pass up through and over pulleys on top of the derrick, returning to a wheel at the base of the derrick, where the reserve line is spooled and which is under the control of the driller, who can lower the drill stem at will by releasing a friction brake which holds the wheel.

The engine is connected by a link drive to the line shaft, which also furnishes power to the revolving table and to a hoisting drum and reel.

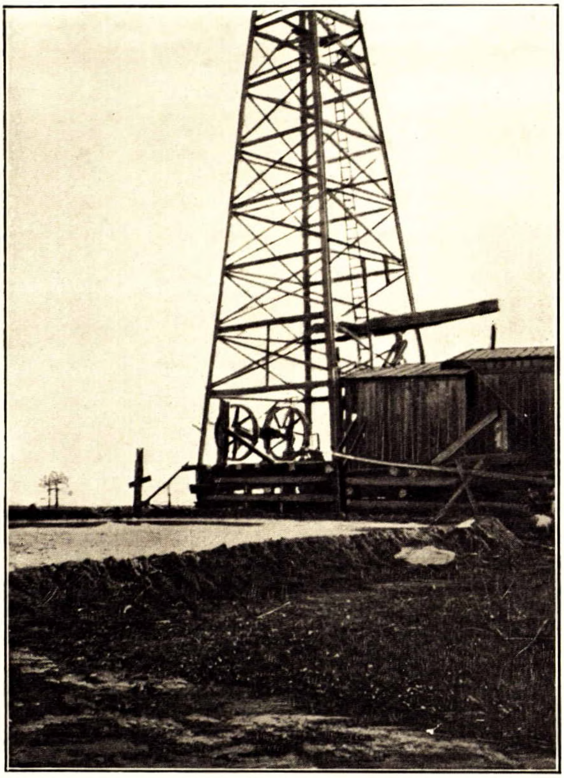
Thin mud or slush plays an important part in drilling, and a slush pit is an essential accessory to the outfit. This pit is usually dug near the derrick, on the same side as the pumps, and is about 40 feet long, 15 feet wide, and 3 or 4 feet deep, though the size varies with convenience and the preference of the driller. A ditch where sand may settle out of the mud is cut from the well circuitously to the slush pit, from which hose or pipes lead to the pumps.

The cost of a rotary outfit is somewhat variable, but may be placed in the neighbourhood of $3,000. The rig used is very similar to the American Standard rig.

Drilling Operations.

Drilling is accomplished by rotating the entire string of casing, on whose lower end is a fish-tailed bit. The rotation under heavy pressure breaks off and grinds up particles of the material that is being penetrated, and they are carried to the surface by water that is pumped down the casing under pressure and rises to the top on the outside between the casing and wall of the hole. Only one casing, that which is being revolved,

PLATE VI.



Raised derrick, showing "sludge pool," Oil City, Caddo field, La., U.S.A.

is used, for as the muddy water escapes upward it puddles the side of the well so that the material stands alone.

If a bed of clay is encountered, the water used in drilling is kept as clear as possible and is not drawn from the slush pit, for the clearer the water is when introduced the greater is its capacity to uphold and move particles of earth, and the clay is sufficiently compact to make a wall that will not cave. In penetrating sand and gravel layers, clay often has to be added to the slush pit, so as to make a thin mud that will plaster up these beds and prevent them from caving and also prevent the escape of drill water into them. In some oil fields, a trough with revolving paddles, called a mud mixer, is used to prepare the slush of proper consistency for plastering up sandy layers and also for closing gas pockets.

A pressure guage enables the driller to feed the casing into the hole with uniform pressure. The casing must be lowered with care, for if it is fed too fast the hole may become clogged by failure of the pumps to raise the outside column of water and carry up the drillings.

When the casing has been sunk so that its top is near the revolving table, another length of casing to whose upper end the second water swivel is attached, is elevated by means of the hoisting reel so that it can be screwed on to the last length used. The first water swivel is then unscrewed, the new length of pipe is coupled on, and the hose connected to the water swivel at its upper end. This operation requires only a few seconds of the skilful workmen's time, and drilling proceeds with scarcely any interruption. To prevent the drenching of the men during the attachment of the water swivel, the pipe couplings are sometimes fitted with back-pressure valves.

It is essential that the pump be kept going constantly otherwise the drillings will settle in the bottom of the hole and "freeze" the pipe fast. Should drilling cease at any time, the water circulation must be kept up if possible, as slight cavings of material will cause the pipe to become clogged.

Sharpe-Hughes Bit.—What is regarded as the greatest advance yet made toward the perfection of the rotary system of drilling oil, gas, and water wells has been accomplished by the invention of a practical and highly efficient mechanical bit, which successfully overcomes one of the weak spots in the rotary process—the difficulty of drilling through rock and other hard formations. Heretofore cable tools have had the best of the rotary in "making hole" in rock, but this new bit evens up the discrepancy in results in this respect as between the two methods, and removes the only valid objection to the rotary's claim of superiority over other systems of drilling in localities where soft formations predominate. It is the invention of Howard R. Hughes.

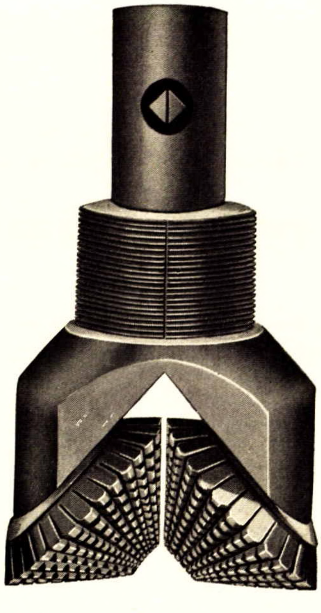
Briefly stated, it consists of two or more detachable, cone-shaped, hardened steel cutters, running on bronze bearings and lubricated with oil supplied by means of a small pipe carried inside the drill stem. The cutters, being detachable, may be removed and sharpened while duplicate sets are in use. The patent bit has sixty or seventy series of cutting edges as compared with the two cutting edges of the fish-tail bit.

For fishing operations, which are sometimes rendered necessary by the twisting off of the casing, tools are used that do not differ greatly from those employed for similar purposes in percussion drilling. If the twisted-off portion is short, however, it may be possible to pass it by using a diamond-shaped bit and side-tracking or drilling past it.

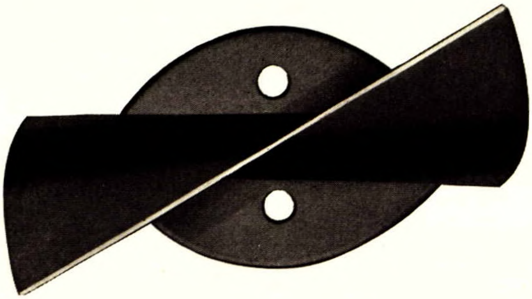
As in the percussion methods of oil well drilling, the drive shoe is usually set in the formation that is known from other wells in the same locality to overlie the oil-bearing sands. Drilling is then continued inside the casing for the remaining few feet or yards to the oil sands, and a smaller string of casing with a strainer at the bottom is lowered to the oil.

Packing is accomplished, as in other methods of drilling, by seed bags, cement, or special packers. A packer called a boot leg is also frequently used. This is a slightly tapering leather sleeve somewhat larger than the casing. If it is slipped over the casing and its lower (smaller) end is tied fast to the casing a short distance above the strainer, the mud remaining about the casing settles into the open upper end of the boot leg and thus fills and packs the space between the casing and the side of the hole.

Plate VII.



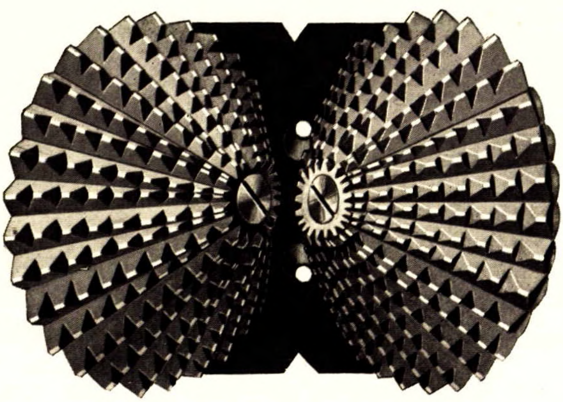
Sharp-Hughes patent cone-shaped cutter bit.



(*a*)

Standard Fish-Tail Bit

(Underside View)



(*b*)

Sharp-Hughes Patent Cone Bit

(Underside View)

Views showing the cutting edges of a Standard fiih-tail bit, as compared with sixty or more rows of cutting teeth of the S-H cone bit.

Many water wells sunk by the hydraulic rotary method are difficult to screen because of the depth at which the operation is conducted and the fineness of the material. A method in use is to puddle the wall of the well at the water bearing layer, set the screen, and draw the casing to the top of the screen. By pumping heavily for a few hours, the pores of the puddled water bearing sand are partly re-opened, but the method has the defect of leaving the water bearing layers more or less clogged by fine material. A more difficult but a better and more common way of screening is to sink the screen below the casing by forcing a hole down by a jet of water, the wash pipe being run ahead of it. A packer or lead seal is then inserted at the point where the top of the screen joins the well casing to prevent material from rising over the top of the screen and filling it.

Advantages and Disadvantages.

An objection to the hydraulic rotary method for drilling wells has been made by some engineers, who claim that the driller often seals oil off by puddling, and that the location of the oil bearing stratum must be known before drilling begins, otherwise it will be passed through without the driller being aware of its presence.

The hydraulic rotary is very rapid for drilling in loose material where the drill may descend continually. At Corsicana, Texas, 1,065 feet were drilled through clay and marl in thirty-two hours. Both method and machinery have been rapidly developed through extensive use in the Texas and California oil fields. The method will, however, never supplant the jetting and self-cleaning methods for shallow work where only a cheap, light rig is required, any more than the heavy standard oil well outfit will supplant portable rigs for drilling shallow wells.

THE COMBINATION METHOD OF DRILLING.

The combination method, used in localities where the formations are very soft and consequently suitable for the rotary; but where occasionally hard strata are encountered through which it is necessary to drill by the ordinary percussion method; in other words, the Combination rig is a combination of the American Standard rig and the Hydraulic Rotary rig. Such an outfit weighs about 47,000 pounds and costs approximately $5,000 in addition to the timber and lumber for the derrick. The combination method should be used in many parts of Alberta.

CALIFORNIA OR "STOVEPIPE" METHOD.

This form of well construction has been developed in California to meet local conditions, but it is equally well adaptable for use in many other parts of the country; particularly where a number of water-bearing beds are available in unconsolidated materials. This method has been described by Slichter.[1] The abundance of boulders and other heavy debris in the outwash in mountain valleys of southern California necessitated special devices. The sizes of these wells are 7 to 14 in. The well is started with a riveted steel starter, from 15 to 25 ft. long, made of two or three thicknesses of No. 10 sheet steel with a forged steel shoe at lower end. For ground containing large boulders still heavier starters are necessary. The rest of the casing consists of two thicknesses of No. 12 sheet steel in riveted length, each two feet long. One set of sections is made just enough smaller than the other to permit them to telescope together, and the outside section overlaps the inside section by about a foot; hence the name "stovepipe" method. The casing is sunk by ordinary heavy oil-well machinery, with a few modifications and the casing is forced down, length by length, by hydraulic jacks, which must be previously securely anchored. The material from inside the casing is loosened and removed with the sand pump, which must be large and heavy, generally weighing 1,100 to 1,400 pounds.

When the well has been drilled to the required depth a cutting knife is lowered into the well and vertical splits are cut in the casing opposite known water bearing beds, which have previously been determined by keeping an accurate log as the

[1] C. L. Slichter, Eng. News, Nov. 19, 1903, W. S. P., No. 110, U.S.G.S., pp. 32-36.

well progressed. Hence, by this method the screen may be made to occupy as much of the well as circumstances render desirable.

For splitting the stovepipe a special form of perforator is provided of which a number of forms are in use.

The advantages claimed by Slichter for the stovepipe method are as follows.[1]

1. The absence of screw joints liable to break and give out.

2. The flush outer surface of the casing, without couplings to catch on boulders or to hang in clay.

3. The elastic character of the casing, permitting it to adjust itself in direction and otherwise to dangerous stresses, to obstacles, etc.

4. The absence of screen or perforation in any part of the casing when first put down, permitting the easy use of sand pump and the penetration of quicksand, etc., without loss of well.

5. The cheapness of large size casings, because made of riveted sheet steel.

6. The advantage of short sections, permitting use of hydraulic jacks in forcing casing through the ground.

7. The ability to perforate the casing at any level at pleasure is a decided advantage over other construction. Deep wells with much screen may thus be heavily drawn upon with little loss of suction head.

8. The character of the perforations made by the cutting knife are the best possible for the delivery of water and avoidance of clogging. The large side of the perforation is inward, so that the casing is not likely to clog with silt and débris.

9. The large size of casing possible in thissystem permits a well to be put down in boulder wash where a common well could not possibly be driven.

10. The uniform pressure produced by the hydraulic jacks is a great advantage in safety and in convenience and speed over any system relying upon driving the casing by a weight or ram.

11. The cost of construction is kept at a minimum by the limited amount of labour required to man the rig, as well as by the good rate of progress possible in what would be considered in many places impossible material to drive in, and by the cheap form of casing.

The cost of constructing a 12 in. stovepipe well is given as generally 50c per foot for the first 100 ft. and 25c additional per foot for each succeeding 50 ft., casing to be furnished by owner. The cost of No. 12 gauge, double stovepipe casing averages $1.05 per foot, and a starter costs $40.

The style of rig varies with the driller, a common form being shown in Plate IX.

The stovepipe is devised to give the very maximum yield from every water-bearing formation penetrated by the well. Some of the best wells of this type in use are those of the Sea Side Water Co. at Long Beach, California.

[1] Ibid, pp. 34-35.

SINKING WELLS WITH PORTABLE DRILLING MACHINES.

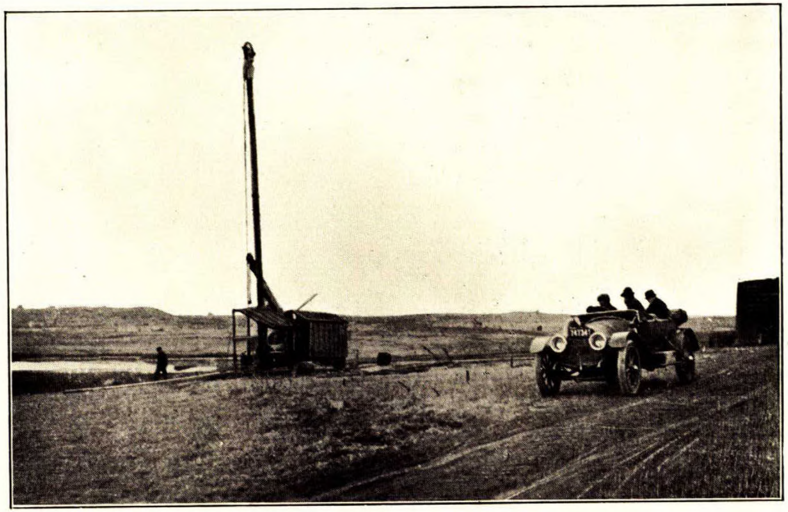
This method is preferable in all cases where the wells are of shallow depth; and, consequently, that the great weight and strength of a Standard derrick are not required to carry the weight of the tools. For shallow wells, a rig which can be moved about has many advantages. Various portable drilling machines are in the market, among which may be mentioned the Star, Columbia, Keystone and others; and it would not be in the province of this Report to discriminate between them, as they are all good, and, moreover, they all have their special uses in various fields. The wells at Puce and Belle river in Essex county were drilled by such machines.

CANADIAN POLE TOOL SYSTEM.

The Canadian Pole Tool system of boring is perhaps the most useful all-round prospecting rig which can be purchased, and it is especially suitable for those regions where excessive caving makes it necessary to have some positive method of rotating the bit. The Russian and Galician systems are only modified pole tool processes in which the original ash drilling poles have been replaced by iron rods.

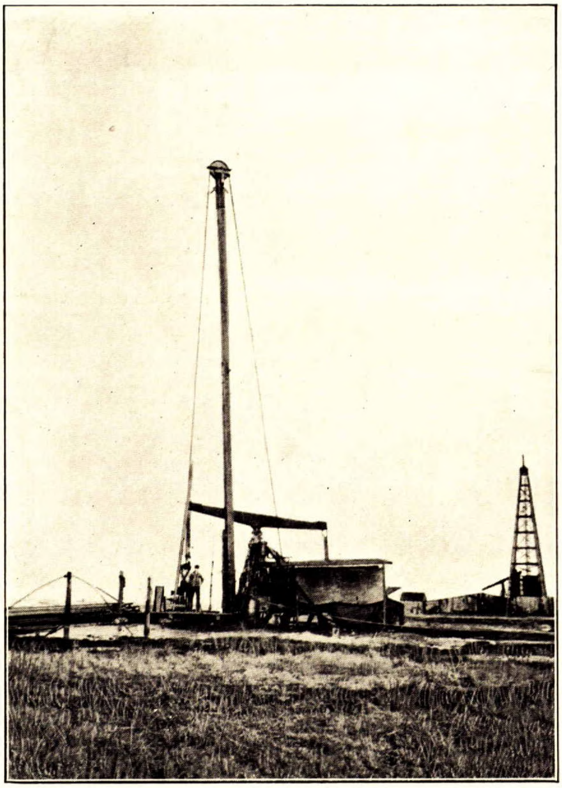
Rig.—The Canadian rig is a simple woodwork framing in which one shaft and two spools running in bearings transmit the various motions desired. The drive is taken by a pulley attached to the main shaft on which are also keyed two band pulleys which communicate by belting with two spools running immediately overhead in the upper part of the framework. The main shaft is also provided with a disc crank on one of its extremities which, through the medium of a pitman or connecting rod, transmits an oscillating movement to an overhead pivoted walking beam when the engine is run. The band and spool pulleys are flanged to prevent the driving belts which surround them from slipping off, as the belts are always left loosely in position, and the spools are put into action by jockey pulleys which are drawn firmly inwards by levers against the belts. One spool wheel operates the sand line when cleaning out the well, the other is used for raising and lowering the rods and tools as they are inserted or withdrawn from the well. To the walking beam is attached at the centre of oscillation a slipper out

PLATE IX.



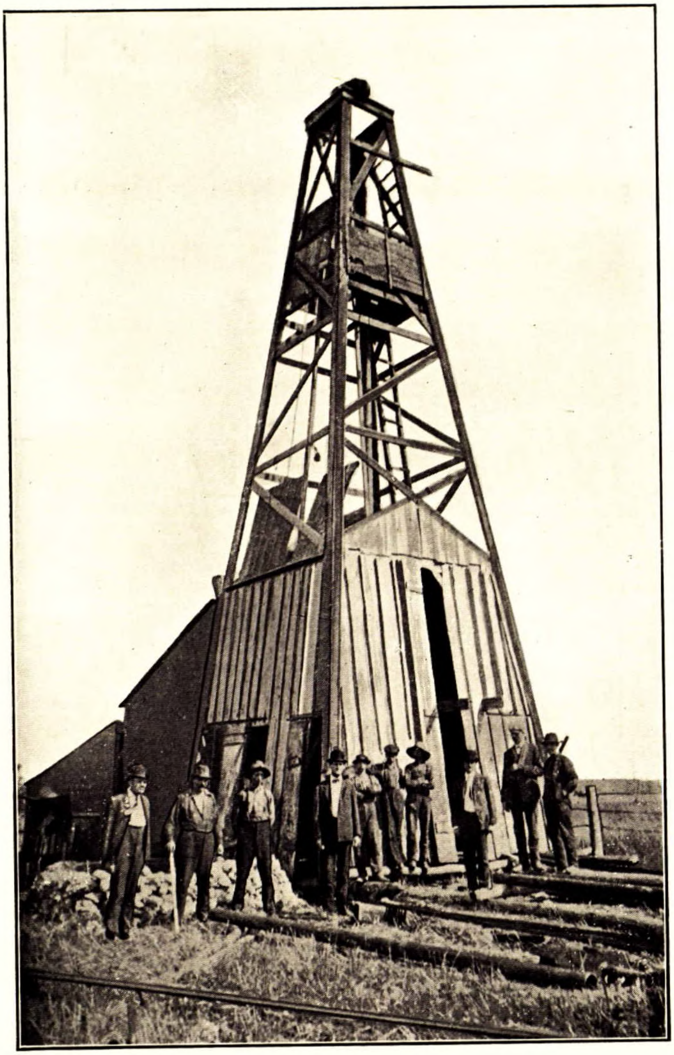
Drilling in Delaware Extension pool, Oklahoma, U.S.A.

PLATE X.



Cleaning well with Star No. 27 drilling machine,
Muskagee field, Okla., U.S.A.

PLATE XI.



Drilling rig, Petrolia, Ontario.

which is used for giving the feed during drilling, and is merely a clutch gear attached to a spindle upon which is coiled a chain leading to the spring pole overhanging the well. At the end of the beam the chain several times encircles a fitting so that when the tools are released by the clutch gearing, the greater part of the weight is taken by the beam and not by the clutch.

Plate XI shows the general arrangement of a Canadian standard rig.

Drilling tools.—The tools consist of chisels or bits, sinker bar or stem, jars, substitute and wooden ash drill poles to the surface. Sometimes wing guides are coupled to the stem to keep the tools straight in inclined strata, and an under-reamer is occasionally connected also. The tools are very similar to those used for the cable rig, the only important difference being the ash drill poles which are used instead of a rope. The bits are sometimes fluted and sometimes flat, with or without side wings, and not infrequently eccentric bits are employed to enlarge the hole sufficiently to allow the casing to follow. The pole tool system permits under-reaming much better than cable systems, as the action is positive and definite, the rotation of the rods at the surface assuring the twisting of the bit in the hole. The sinkers have diameters between $2\frac{1}{2}$ and 4 inches, and lengths from 10 to 30 feet, and the jars are similar to those already described under cable tools.

The poles are of 2 to $2\frac{1}{2}$ inches hexagonal or round trimmed ash, in lengths of about 18 feet, to the extremities of which are riveted iron straps which partially encircle the rod and have a screwed pin or a box joint. Sometimes two such rods are coupled together by means of two iron straps encircling the pole, making 36-foot lengths. The joints are always screwed taper to take up wear, and there are six to eight threads to the inch. The figures below give the Canadian standard sized joints for poles and other attachments:—

No.	Diam. at point	Diam. at Shoulder	Length	Threads per inch	Size of Wrenches	Diam. of Collar
	Inches	Inches	Inches		Inches	Inches
1	$1\frac{1}{2}$	$2\frac{1}{4}$	3	8	$2\frac{1}{4}$	$3\frac{1}{4}$
2	$1\frac{3}{4}$	$2\frac{3}{4}$	4	8	3	$4\frac{1}{8}$
3	2	3	4	8	3	$4\frac{3}{8}$
4	$2\frac{1}{2}$	$3\frac{1}{2}$	4	8	$3\frac{1}{2}$	$4\frac{7}{8}$

The rods are raised and lowered by a pole box and swivel on a $\frac{7}{8}$ inch steel wire rope worked by one of the spools, a suitable fork being pushed beneath the collar of each joint as it reaches the mouth of the well. The descent of the rope after a rod has been raised and placed aside in the derrick is brought about by a heavy weight coupled to the rope above the swivel-screwed joint by which they are lifted. When the tools and rods have been lowered to the bottom of the well, suitable short lengths of rods are attached to give the desired distance to couple up the feed chain on the walking beam by a drill swivel, the feed being adjusted by the slipper out clutch during work.

In addition to the ordinary sand pumps and bailers which can be operated by a steel wire line, augers can be lowered and rotated by the rods. The common fishing tools consist of horn sockets and slip sockets which can be guided over lost and broken rods by "bonnets," which are simply bell-mouthed guide pieces which can be attached to the tools.

SPECIFICATIONS OF CANADIAN RIG AND TOOL FOR DRILLING 2,000 FOOT WELL.

1 steam boiler capable of evaporating 1,000 lbs. of steam per hour at 100 lbs. pressure, with Colonial type fire-box, fusible plugs, feed pump, injector, and spares.

1 horizontal 12 by 14 inches single cylinder reversing stem engine, with pulley and flywheel, feed pump and feed-water heater, with means of operating steam admission and reversing gear from a distance.

1 derrick, 56 feet high, 18 feet square at base, $4\frac{1}{2}$ feet at top.

1 heavy drilling rig for 2,000 feet, including bolts, beams, husk-blocks, snatch post, spring pole, etc.

1	mud	pump,	12 in.	by 6	ft. long,	with hinged	bail and	drill pin.
1	sand	"	$10\frac{1}{4}$ "	18	"	"	"	"
1	"	"	$7\frac{1}{4}$ "	36	"	"	"	"
1	"	"	$5\frac{1}{4}$ "	36	"	"	"	"
1	"	"	$4\frac{1}{4}$ "	36	"	"	"	"

Fishing Tools.

1 fishing jar, $1\frac{3}{4}$ by $2\frac{3}{4}$ inch box and pin.
1 pole hook for 10-inch hole.
1 9-inch horn socket, with 3 dogs.
1 $6\frac{3}{4}$-inch two-legged socket, with two dogs and springs.
1 $5\frac{3}{4}$-inch " " " "
9 $4\frac{1}{4}$-inch " " " "
6 bonnets for sockets for 5-inch, 6-inch, 7-inch, $8\frac{1}{2}$-inch, 10-inch and 12-inch casing.
1 wire rope knife.
1 " spear.

Casing, Elevators, etc.

2 casing swivels for 12-inch casing.
2 " 10 "
2 " $8\frac{1}{2}$ "
2 " 7 "
2 " 6 "
2 " 5 "
6 sets wooden clamps for above casing.
4 2-inch casing clamp bolts, with heavy nuts.
2 casing chains, $\frac{1}{2}$ and $\frac{5}{8}$ inch ring and hook.
3 clevices and pins for casing swivels.
1 extra heavy quadrangle block, with 15-inch sheaves and swivel head.
1 extra heavy treble block, with 15-inch sheaves and shackle.
1 steel shoe for each size of casing.

Cables, Wire Ropes and Belts.

200 feet $1\frac{1}{4}$-inch manilla rope.
200 feet $\frac{3}{8}$-inch "
200 feet $\frac{3}{8}$-inch "
1 $\frac{7}{8}$-inch by 120 feet draw line, with 2 eyes.
1 $\frac{5}{8}$-inch by 650 feet block line, with 2 eyes.
1 $\frac{5}{8}$-inch by 2,500 feet sand line, with 2 eyes.
2 12-inch by 65 feet double leather draw belts.

½ gross belt laces.
1 12-inch by 42 feet drive belt.
1 pair belt clamps.

Drilling Tools.

2	13¼-inch bits,	250 lb. steel,	3 by 4 inch pin-joint.		
2	11¼	"	180	"	"	"
2	9½	"	150	"	"	"
2	8	"	110	"	2½ by 3½	"
2	6½	"	90	"	"	"
2	5½	"	75	"	1¾ by 2¾	"
2	4½	"	60	"	"	"

2 11¼-inch undercutting bits, 3 by 4 inch "
2 9½ " " " "
2 8 " " 2½ by 3½ "
2 6½ " " " "
2 5½ " " 1¾ by 2¾ "
2 4½ " " " "
1 7-inch by 15 feet long sinker, 3 by 4 inch joint.
2 5 " 15 " " 2½ by 3½ inch joint.
2 3½ " 12 " " 1¾ by 2¾ inch joint.
2 3 " 12 " " " "
1 6¼ " jar, 3 by 4 inch box, 2½ by 3½ inch pin.
1 5⅛ " " 2½ by 3½ inch box, 2½ by 3½ inch pin.
1 4⅛ " " 1¾ by 2¾ " 1¾ by 2½ "
1 substitute, 3 by 4 inch box, 2½ by 3½ inch pin.
1 " 3 by 4 inch pin, 2½ by 3½ inch box.
1 " 2½ by 3½ inch box, 1¾ by 2¾ inch pin.
1 " 2½ by 3½ " pin, 1¾ by 2½ inch box.
1 " 2½ by 3½ " box, pole pin.
1 " 1¾ by 2¾ " box, pole pin.
1 " 2½ by 3½-inch pin, pole box.
1 " 1¾ by 2¾ " "
2 heavy tool wrenches for 4½-inch square.
2 " " " 4 "
2 " " " 3 "
2 knock wrenches.
1 catch wrench.

1 key wrench for iron poles.
1 chain lever, heavy.
56 drill poles, 36 feet long.
4 tubular hand poles.
1 pole swivel, with chain.
1 drill swivel.
1 sand pump swivel.
1 sand pump hanger and chain.
1 pole hook.
1 3-inch clevice and pin for top of derrick.

HOLLOW-ROD METHOD.

Outfit.—The self-cleaning or hollow-rod method of wel sinking includes the essential features of the percussion methods, but differs in combining in one operation the breaking up and removal of the material.

The tools consist of a string of pipe with screwed couplings, usually of special manufacture to insure strength and durability, with a water swivel at the upper end and a drill bit at the lower end. Because of this use of joints of pipe instead of a drilling cable the machine is often called the hollow-rod outfit.

The water swivel is essentially a swiveled goose-neck that allows the water and drillings to be discharged from the pipe in a constant direction and still permits the drill pipe to be rotated. In the usual outfits of the class the pipe is $1\frac{1}{2}$ or 2 inches in diameter and the drill is $2\frac{1}{2}$ to 4 inches across, though the hole may be enlarged by using an expansion bit.

The drill has one or more holes at its upper end and a flap valve that allows water and drillings to enter the pipe and be lifted automatically to the surface. Blind valves are also usually placed at intervals within the pipe to relieve the lower valve of the weight of the entire column of water and drillings.

In drilling by the self-cleaning method water must occasionally be poured into the well until it is encountered in sufficient quantity for the needs of drilling. The drilling operation is continuous, for as the drill is alternately raised and let fall the jumping or pumping action forces water and drillings into the drill rods and upward to the surface. This action resembles that of a hydraulic ram, but in the drill the sudden compression required to open the valve is obtained by the drop of the tools instead of by the fall of a water column, as in the ram.

A properly tempered bit will be sharper when it is taken out of the hole than when put in, for the wear comes mainly on its edge and tends to reduce its gauge. When the approximate depth of the hole to be drilled is known, bits may be run long distances. So long as they are larger than the joints on the rods they will not stick as will cable bits when worn, for the vibration of the rods keeps them free. Many holes 100 to 150 feet in depth have been drilled with one bit without removing it from the hole. When a bit is used too long, however, the hole must be reamed when a bit of standard gauge is substituted for it.

JETTING METHOD.

Outfit.—In the jetting method of well sinking the material is both loosened and carried to the surface by water under pressure.

The principal parts of the outfit are a force pump and water swivel, drill pipe, nozzle or drill bit casing, and drive weight.

Hand-power jetting outfits are made in several styles which differ chiefly in the arrangement for driving the casing. One outfit uses a block and tackle for raising and letting drop a weight of 200 pounds or more; another uses a lighter weight which is lifted directly by hand. Some outfits require a light derrick and working platform; others are operated from the ground.

In the jetting method water is led into the well through a pipe of relatively small diameter and forced downward through the drill bit against the bottom of the hole. The stream of water loosens the material and the finer portion is carried upward and out of the hole by ascending water current, as in the hydraulic rotary method.

Casing is usually sunk as fast as drilling proceeds. In the softer materials, by using a paddy or expansion drill a hole may be made somewhat larger than the casing, which may be lowered a considerable distance by its own weight. Ordinarily, however, a drive weight is necessary to force it down.

CORE-DRILLING.

General Features.—Core drills are little used for sinking wells, though they have been tried from time to time in developing new oil fields, and diamond drills have been employed to some extent in South Africa for deep-water wells. The core-drill principle is, however, occasionally employed in connexion with the more common well-drilling outfits.

The advantage of core drills over all other types of boring machines is that they enable an accurate sample of the material penetrated to be obtained. They are therefore widely used in prospecting for coal and other economic deposits, for making borings for foundations for dams and similar structures, in preliminary tunnel investigations, and in excavation work. The importance of obtaining a true sample of the material penetrated is illustrated by the experience of a firm of contractors, who became bankrupt because at a certain depth they encountered hard conglomerate instead of the gravel indicated by the drilling of a percussion outfit.

Rotary core drills of the several classes are alike in employing a hollow rotary drill that by abrasion wears an annular hole, leaving a core in the centre. The drillings are removed continuously by water under pressure, and the core is broken off and removed from time to time.

Core drills are intended primarily for drilling holes of relatively small diameter in hard material. They resemble hydraulic rotary outfits in method of operation, but the formation of a core and the necessity for its occasional removal makes the drilling process intermittent instead of continuous.

Core drills may be used in all kinds of rock, from the hardest trap to the softest shale, but where a core is not especially desired drilling in the softer formations can usually be done more rapidly by means of percussion, hydraulic rotary, jetting, or some other method, and as a rule saving can also be effected in the cost of outfit.

DIAMOND DRILLING.

Outfit.—Diamond-drill machines to be worked by hand are made, but the larger outfits require a derrick, hoisting sheave, and hoisting drum similar to those employed in other methods of drilling. The drilling apparatus includes a force pump and water swivel, drill rods and rotating device for turning them, feed mechanism, and a cutting bit.

The derrick in most common use is a tripod 20 to 80 feet high, the height varying with the work to be done. Where timber is easily available the derrick may be constructed of poles, but for drilling to depths of 1,000 feet or more a strongly braced 4-pole tower or a steel derrick is usually employed. The drill rods are smaller and lighter than those used with the hydraulic rotary outfit, and the hoisting drum, force pump, and water swivel though similar, are correspondingly lighter and are of somewhat different design. Only one force pump is installed. The drill rods are of heavy lap-welded iron tubing or of seamless steel tubing, with screw joints, and are 5 to 10 feet long. The sections are added as sinking progresses.

The bit is made of a ring or sleeve of tough but ductile steel, three-eighths to five-eighths inch thick, whose upper end is threaded to screw into the drill rods and whose lower end is turned true and bored with eight holes to contain the diamonds. The diamonds are carefully set in the holes so that their lowest points lie in a plane, and are arranged alternately on the inner and outer faces of the bit, so that the outer edges of four project a little beyond the outer face and give it a clearance, while the edges of the inner four project slightly beyond the inner face and clear the drill of the core. The diamonds are calked in place by carefully swaging the steel firmly against them with light blows.

Two kinds of diamonds, known as carbons and borts, are used in diamond-drill work. Carbons are found as opaque, irregularly shaped nodules, black on the outside and shades of grey on broken surfaces. They have no cleavage planes, and it is this quality, together with their hardness, which especially fits them for drilling in hard rock. Borts are semi-transparent diamonds similar in appearance to the rough brilliant but differing in crystallization. They are usually nearly spherical in shape, are as hard as carbons but not as tough, and have a cleavage plane, so that when used in hard rock they may break whereas carbons wear away but seldom break. Carbons come mainly from Brazil; borts from both Brazil and South Africa. Borts are much cheaper than carbons and may be used in boring in soft rock. In some holes a toothed cutter bit similar to that of the hydraulic rotary outfit is used in penetrating soft rock. In moderately hard material a drill armed half with carbons and half with borts may be used, but for drilling in very hard rock only carbons are suitable.

CALYX DRILL.

The calyx drill was invented in Australia. It is now in use in many parts of the world.

The hoisting and driving machinery of the calyx drill is similar to that of the diamond drill, and feed water is supplied through a swivel and hollow drill rods. The bit of the calyx drill is made of hardened tool steel and consists of a toothed collar, somewhat like the cutting shoe of the hydraulic outfit, but having longer barrel and teeth, the teeth being so set as to provide clearance to the core and to the bit and rods.

Above the core barrel a cylindrical chamber or calyx, open at the top, encircles the drill rods. Into it the coarser rock fragments torn off by the drill bit are caught as they are dropped by the upward water current when its velocity decreases. They are removed when the rods are hoisted to remove the core, and furnish a second record, in inverted order, of the materials penetrated. This record is of especial value in material too soft to yield a good core.

The action of the toothed bit in cutting the rock seems to depend largely on the torsional power of the drill rods, for the drill bites into the rock and resists turning until the twist of the rods forces it to loosen and partly turn around to a new grip. It thus has a "chatter" motion, which chips off fragments of the rock. Its action has been compared to that of the stone mason's chisel, which chips off rock fragments at each blow of the hammer.

The calyx drill is not restricted in size by such considerations of cost as is the diamond drill, and machines are built capable of taking cores 15 inches in diameter.

CHILLED SHOT METHOD.

Experiments in drilling by the use of loose abrasives poured down the drill hole led to the adoption for this purpose of chilled steel shot, such as is used in sawing marble and other stone. Other parts of the shot outfit are similar to those of the diamond drill, but cutting is accomplished by revolving an iron or steel tube on the shot. A slot a few inches long and half an inch wide cut into the lower end of the tube or bit allows the shot to reach the cutting surface more readily and be more evenly distributed. Distribution is also aided by slightly beveling the edges of the tube so that the shot may get under it. Under the weight of the drill rods the shot bites into the rock and chips out or wears off small pieces of it, which are brought to the surface by the water current.

That the supposedly round and smooth shot can thus wear away rock may seem at first almost impossible, but close examination of the tiny steel balls shows that they are slightly irregular in shape, and because of this unevenness of form they sink into the softer bit tube and are held firmly by it, abrading the rock surface as sand-paper abrades wood. The shot does not develop a tendency to polish the hard rock—a tendency sometimes shown by the diamonds used in the diamond drill.

COMPARISON OF CORE-DRILLING METHODS.

The diamond drill is especially adapted to penetrating hard rock to great depths, and will bore a hole at any angle; hence it is especially useful in mineral-prospecting work. It is somewhat restricted by the character of the rock formation, however; for example, no diamond-drilling firm will send a drill into the lead and zinc districts near Joplin, Mo., for the limestone there contains many chert nodules, loosely embedded, which tear the diamond bits. In highly inclined and flinty rocks there is thus the danger of loss of the stones. The high cost of the diamonds limits the use of this drill to boring holes of smaller diameter, and hence to the higher classes of work, such as prospecting for ore deposits.

The calyx drill is commonly used to bore much larger holes than the diamond drill, and in soft or moderately hard material it is cheaper. In very hard rock it works more slowly, however, and it is not adapted to boring holes at an angle greater than about 45° from the vertical. It is largely employed in coal prospecting and in boring holes for testing foundations.

The shot method may also be used in obtaining cores of large diameter. In very hard material it is more efficient than the calyx cutter, but it is not adapted to soft material. It may be used for boring holes at any angle, provided the drill is rotated rapidly and the shot kept properly distributed by centrifugal force.

All rotary core drills are portable and, as they can be taken apart for transportation on pack animals, can be used in regions where more cumbersome outfits are debarred. Nearly any power can be used—electricity, compressed air, steam, gasoline, horse, or hand—but where its use is possible steam is usually the best.

The three methods of rotary coring are sometimes used in boring the same hole, the style of cutting bit employed depending on the character of the material that is being penetrated. The shot and calyx bits are frequently interchanged, and on one of the leading makes of core drill the outfit is expressly designed to use a toothed cutter bit in soft and moderately hard rock and shot in penetrating the hardest materials. For this purpose a double water swivel is used, through one neck of which the shot is fed into the rods.

The percussion core drill should prove valuable in sampling coal beds and in other work in comparatively soft formations in localities where a cable rig can be advantageously set up.

DIFFICULTIES IN DRILLING.

The contractor usually holds the driller responsible for accidents caused by losing tools in the well, but not for those due to geologic conditions, unless the formation is well known from previous borings.

Causes of Loss of Tools.

These are usually due to one or more of the following conditions or causes:—

1. A worn cable. The stretching and bending of the part of the cable immediately above the socket cause it to become thin and frayed after a few weeks' wear.

2. The imperfect attachment of the cable to the socket. The joint should be tested by putting a strain on the rope while the drilling tools are anchored at the surface.

3. Neglect in setting up the tools after each run. If the parts are not securely fastened together, they become unscrewed and fall into the drill hole.

4. Paying out too much or too little cable. If too much cable is paid out, the jars will batter and break; if too little, the whole weight of the tools will fall on the cable and strain it excessively.

5. Crystallization of the iron of the tools through successive jarrings. The screw pin of the auger stem may break from this cause.

To ascertain the nature of an accident one-half mile below the surface in a hole perhaps only 6 inches in diameter, by means of a cable having a very appreciable stretch, is clearly an operation requiring great skill. As the string of tools is usually more than 50 feet long, weighs over a ton, nearly fills the hole, and is wedged in so tight that the strongest cable could not pull it loose in a straight pull, the conditions involved in some fishing jobs is obviously unusual. Occasionally, the driller is compelled to break up the broken tool in the well, crushing it with the driller by repeated blows.

Locating Lost Tools.

The first step in recovering a lost tool is to learn the shape of its upper end and the position in which it lies in the well. This knowledge may be obtained by lowering over the tool a sheet iron vessel containing soap or other soft material, in which an impression is easily made. An examination of the mould then enables one to determine the position of the tool and to devise means for its recovery.

If the fallen object has been caught in the well wall above the oil or water or lies in a dry hole, its position may be determined by reflecting light into the well from a mirror. It was perhaps this operation which suggested the invention of a photographic device for determinations of this character. The device was invented by Mr. Loran, a Baku engineer, and both the instrument and process of photographing have been described by A. Beebe Thompson.

The device consists of a stereoscopic photographic apparatus, which is lowered to a point near the lost tool, light for the negative being furnished by an electric current carried by wires arranged in the camera. Concerning its construction, Mr. Thompson says:[1]

An internally blackened, bell-mouthed vessel, at the small upper end of which is fixed the stereoscopic camera, and at the sides of which are fixed two small electric lamps with shades reflecting the light downward, is attached to a sinker rod with guides. Incased in an air-tight chamber above the photographic device is an electric accumulator, which supplies the light, and interposed in the circuit is a small clock that can be regulated to produce contact at any desired time, switching on the light and opening the camera shutter at the same moment. Above this is placed a cylinder in which compressed air is stored, leading by minute tubes to the bell-mouthed photographic vessel beneath. By a clever device, a quick upward or downward motion of a few inches causes a disk, nearly equal in size to the well, working freely on the central spindle, to rise or fall and transmit a motion to a lever which actuates an air valve leading from the air vessel. The pressure of air must exceed the pressure due to the submergence of the apparatus in the liquid, and on the air valve being opened the fluid is displaced in the bell-mouthed vessel and an undisturbed view of the lost article is secured. After an exposure of one or two hours, the air is shut off by a repetition of the before-mentioned jerk and the apparatus raised.

Recovering Lost Tools.

Most of the instruments made for recovering lost tools are expensive and so many of them have been devised that one contractor can not afford to own a complete set. Usually he purchases first the ones he is most likely to need and others as he may require them.

Slip socket.—If the drill is lost in the well, but is not jammed tight, it may be possible to lower a spudding spear into the well and prod the top of the drill loose from the wall. The drill may then be grasped and removed by a slip socket which consists of a pair of slips inserted in a tube-like instrument and

[1]Thompson, A. Beebe, The Oil Fields of Russia, 1904, 2d ed., 1908, p. 164.

suspended by a light string. The teeth of the slips are bevelled upward, so that when the socket is lowered the slips readily move downward over the upper part of the lost tool. By quickly jerking the socket upward the string supporting the slips is broken, the teeth bite into the tool, and as the socket is raised the bevelled groove in which the slips work narrows the space and causes the grip to become more firm. In this operation, it is essential that jars be used to cause the teeth of the slips to bite as deep as possible into the drill, and also to jar the drill from the rock in which it is held. If it is impossible to lift the tool, the socket may be driven down again. The slips are thus raised and are automatically caught on the side of the socket. If a harder pull on the object is required, the socket should be brought to the surface and reset. If the jars should be broken and the string of tools fall into the well, the tools may be withdrawn by lowering a slip socket of special pattern over the sides of the broken jar.

The slip socket was invented in this country and has been adapted to many uses and is more employed than any other instrument for lost tools. If it is properly arranged before being lowered into the well, it will not fail to seize the lost object and it grips it with greater and greater force as stronger pull is applied to the drill rope, and if the driller is unable to bring enough force to bear on the cable to withdraw the tools, it may be easily released and raised.

If tools have fallen far, and have become firmly embedded in the rock at the bottom of the well, the fishing jars must be very long and the longest possible stroke must be given to the walking beam. The tools may usually be loosened by repeated blows and then removed.

Horn sockets.—If the tools have fallen only a short distance, they may be removed by a horn socket, a tube with two slits, cut on opposite sides, which when jammed down over the fallen tools expands slightly and obtains a friction grip. It is cheap, easy to operate, and is almost as much used as the slip socket.

Electric-magnet.—Another device used in fishing is a powerful electro-magnet, by which a lost tool may be drawn out of a niche in the drill hole and recovered. The electro-magnet has been used successfully by Mr. Phillips, of the firm of Phillips and Worthington, New York city, in drilling a well in New Jersey, but the rigging up of the apparatus is expensive and difficult.

Rope spear.—If the cable has broken near its connexion with the temper screw and has fallen into the well, it may perhaps be withdrawn by catching it with a rope spear, a rod armed with upward pointing barbs, which is lowered into the well by a rope. If the drill is wedged in so tight that the cable can not be withdrawn by the spear, a rope knife is lowered by which the cable is cut off as near as possible to the drill. The drill may then be withdrawn by a slip socket and the cable speared and removed.

Defective casing.—Two instruments that are frequently used in dealing with defective casing are illustrated in Plate XII. If the casing has been dropped to the bottom of the well from a considerable height, it may be bent, or even twisted like a corkscrew, so that it can be withdrawn only in short sections. To do this the casing cutter is inserted, the knives of which expand as the pipe on which it is screwed is rotated, and the casing is cut at any desired point. If the casing is only slightly bent, it may be straightened by the use of a pipe swedge dropped into it repeatedly in the manner in which the drill is operated from the walking beam.

Redrilling and enlarging.—If the methods just described are ineffective in removing the broken parts, the driller may shift the drilling tools a few inches to one side and re-drill and enlarge the hole. By drilling some distance below the level of the top of the lost tools and spearing them into the new hole, part of them may usually be grasped by a slip socket and withdrawn. If the drilling is done in relatively soft material, the tools may be pushed to one side and passed by thus drilling a second hole. This at first seems to be an almost impossible operation, but it is easily done, and is effective in disposing of even large broken instruments.

GEOLOGIC DIFFICULTIES.

Spalls.—Spalls of rock or loose stones may fall from the wall of the hole on top of the drill and wedge it in so tightly it can not be withdrawn by cable pull alone. This is a common accident in wells in highly creviced or fissured rock or in glacial till, without casing or drive pipe. The spalls or loose stones may usually be broken up by a smaller drill, and the tools can then be withdrawn.

In brittle sandstone and in shale the top of the string of tools may become jammed in a cavity in the wall of the well, made by the detachment of rock fragments. It is then necessary to bring the string of tools into their normal position in the drill hole by means of the spudding spear. They can seldom be loosened simply by playing on the cable.

Boulders.—An accident that shows the close dependence of drilling on geologic conditions is the mistaking of a boulder for bed rock. Ordinarily the driller determines whether the hard rock which the drill has struck is or is not a boulder by noticing whether it seems loose and rebounds under the stroke of the drill. If it does not seem to be solid rock, he endeavours to break it to pieces and remove it.

The boulder may be so large that the driller mistakes it for bed rock, and after drilling into it for 3 or 4 feet sets the casing in the boulder, substitutes a smaller drill, and proceeds as if he were in bed rock, but after drilling a few feet farther he again encounters sand or clay of the same character as that above the boulder. He must then draw the casing set in the boulder and ream out the hole to a size which will enable him to sink the proper casing through it.

The error of mistaking a boulder for bed rock may be avoided by observing the drillings brought up to the surface and noting whether they are of material like the bed rock in the vicinity. In northern Indiana, for example, a driller may be pretty certain that if the drillings indicate granite, or schist, or trap, the drill is in a boulder and not in the bed rock, which in that region is for the most part limestone. If the rock appears to be a boulder, he will of course expect to find soft material below it and will proceed accordingly.

In the glacial regions of North America the bed rock is overlain by a bed of till that ranges in thickness from a few feet to several hundred feet and contains many large boulders. The bed rock in most places is shale, sandstone, or limestone, but the boulders, having chiefly come from the north where the rocks are of different character, are chiefly of granite, schist, and other crystalline rocks; some boulders, however, as those derived from the country rock, are of limestone and sandstone.

If a boulder is especially hard, it may be blown to pieces by dynamite or rock powder tamped with a bushel or two of dry sand or clay. This may split the boulder so that the casing will pass down between the broken parts, or it may break it into pieces so small that they can be further reduced by the drill and removed by the bailer. If a boulder is to be broken by explosion, the casing should be drawn 3 or 4 feet above the charge so that it will not be injured.

Running Muds and Clays.—Mud produced from some shales hardens quickly when exposed to the air. If such mud runs into a well and fills the space between the drill and the well, it may solidify and interfere with the withdrawal of the drilling tools. A hole drilled through a stratum of such shale must be cased down and drilling must be pushed forward so rapidly that the mud will not have time to solidify. The drill may be freed from obstruction by this mud and withdrawn by slowly working it up and down so as to gain on the up-strokes, and the mud may be removed by small buckets or augers. If this method fails, $1\frac{1}{2}$ or 2 inch pipes may be lowered into the well and the hardened mud and sand may be flushed out by a powerful water jet. Such a layer of mud and clay can sometimes be passed by casing it off with a short length of pipe and using a smaller drill, but the driller usually prefers to work patiently past it rather than to reduce the size of the hole by casing it off.

Even if only a small quantity of water is present, clay will "crawl" and relieve pressure by squeezing through very small openings in threads or sheets. The slow but forcible movement of plastic clay into a drill hole may fill the hole during a single night when drilling is suspended. When drilling is resumed, the next morning, the drill will strike this soft plug of clay and ram it down until the compression of the air below prevents its further movement. The drill may continue to pound this elastic cushion for days, or even weeks, without making further progress while the clay slowly accumulates in the hole. The difficulty may be overcome by casing off the clay before it forms a plug or by jetting through the plug. Plastic clays are encountered in South Dakota and in the Atlantic coastal plain, but most of the glacial clays are so sandy that they yield readily to the drill even if the well does become clogged.

Caving of the formations.—One of the most important difficulties which drillers have to contend with in oilfields is a frequent caving of the strata into the wells from the sides. In many fields there are special beds which cave particularly and these are often given names by the drillers in recording the depth in the wells at which they are found. For instance, a certain caving shale of peculiar character in the West Virginia oil fields is known by the drillers as the "pencil caving", being generally situated between two prominent beds of limestone in the Lower Carboniferous formation. In Oklahoma caving also takes place in formations similar to those of eastern Canada.

This is one of the great difficulties encountered in drilling in New Brunswick, and wells have frequently been delayed for many weeks owing to its occurrence.

Quicksand.

Character of the material.—In drilling water wells in the soft coastal plain formations that stretch from Cape Cod westward and southward along the border of the continent the most serious difficulty encountered is caused by beds of quicksand, which are as a rule interstratified with beds of coarser sand and of clay. The quicksand comes into the drill hole and must be bailed out in large quantities before the casing can be driven further and drilling continued. Under ordinary conditions, quicksand will not yield its contained water, and therefore, if it has a tendency to rise in the pipe the difficulty can seldom be obviated by pumping alone. The whole mass is saturated, its water can not be separately withdrawn, and it exerts practically hydrostatic pressure.

A driller in the Northern States may find pockets or lenses of clay or coarser sand in a quicksand layer, and these cause him to think he has passed through the quicksand. Coarse sand, such as "bar" sand, will not rise if the velocity of the water through it is less than about $2\frac{1}{2}$ feet per minute. The drive pipe shuts off the water and quicksand above such a pocket of coarse sand or clay, but as soon as the drill penetrates the pocket the quicksand again flows in and may rise to the height of the top of the deposit. If the bed is 20 feet or more thick, the pipe can not be driven through it on account of the resistance of the compact sand; and if the water in it is under great head, so as to force the sand up to or above the point at which the bed was struck, further progress may be almost impossible. In some wells, quicksand has risen in the pipe 100 feet above the depth at which it was struck.

Pressure of material.—If the drill hole is not kept full of water, the pressure exerted by quicksand on well casing may be very great. Experiments have shown that quicksand saturated with water exerts a lateral pressure equal to one-half its vertical pressure. Beyond the point of saturation, the pressure is hydrostatic, the vertical and horizontal pressures being equal. Quicksand can be confined only by using water-tight casing, for it is commonly so fine that it will pass a standard 100 mesh sieve. Saturated material of this fineness will flow wherever water flows. The lateral pressure of quicksand is exceeded only by that of clay, and the clay moves much more slowly.

Withdrawing tools.—When quicksand is encountered not only does the material require laborious excavation, but unless the drill is withdrawn rapidly it gets jammed in the hole and is buried by the sand. The driller is then under the necessity not only of cleaning out the hole, but also of recovering the drill before he can resume drilling. In this event it is usual to bail out the quicksand to the point at which the drill is stuck and then introduce into the well a wash pipe an inch or two in diameter. With this the quicksand is agitated (or jetted) and washed up to the surface. This operation continues until the drill is partly free, when a slip socket is inserted over its upper end and, with the assistance of the fishing jars, it is jerked free from the quicksand.

In connexion with the up-and-down motion given to the drill while it is being removed from the quicksand, it must be raised with each stroke, and in this way gradually freed. The same method of procedure is required where quicksand comes into a well suddenly, the drill being moved up and down as if it were cutting into rock, while at the same time it is lightly raised at each upstroke. This operation must be carried on rapidly, otherwise the sand will pack about the drill and prevent its removal.

If the driller is working in sand of rather fine texture, he draws the drill at night, as otherwise the sand may creep up around the drill and set almost as hard as rock. The drill is seldom left in the well over night on account of the danger from sand or of malicious cutting of the rope, or, in a rock well, or having a boulder fall and become jammed between the drill and the well wall.

Penetration of quicksand.—If the layer of quicksand is only a few feet thick it may be penetrated by bailing out and then driving the casing. The pipe is driven as far as possible into the bed without bailing, and the quicksand may occasionally be passed through at one drive.

A thin bed of quicksand that lies near the surface may be shut off by driving sheet piling around the mouth of the well.

Difficulty caused by quicksand may be partly overcome by filling the bottom of the well with mortar or Portland cement, which sinks through the quicksand and sets. The hole may then be drilled through the mortar or cement, which forms a wall that prevents further inflow of quicksand. Stones, clay, and asphalt have also been dropped or poured into the hole to restrain the quicksand, with some success.

Water pressure.—The head of water which produces the pressure in quicksand is nearly always less than that due to the elevation at which the mouth of the well is located. Some drillers maintain that quicksand can always be penetrated by keeping the drill hole filled with water. If the quicksand lies at a depth of several hundred feet and its pressure head is 100 or

150 feet below the surface, a column of water in the well will exert a back pressure on the quick sand of 43·4 pounds per square inch for every 100 feet of drill hole, which will prevent it from rising in the pipe. The sand bailer may then be inserted and the well may be bailed through the column of water.

It sometimes happens that after bailing out large quantities of quicksand the pipe becomes bent, a fact that is explained by assuming that the quicksand bailed out is removed from beneath a higher layer of firmer material, such as till or clay, on only one side of the pipe, and that the pressure of this material against one side of the lower end of the pipe causes it to be thrown out of alignment. The remedy consists in keeping the hole full of water. This prevents the formation of such an artificial cave; or if the pipe has already become crooked, corrects the trouble by causing the pressure on the pipe to be equal on all sides.

If such cave is formed beneath a layer of till, boulders may fall down from its walls and become jammed against the pipe and prevent it from being driven ahead. The side pressure caused in this way may likewise be at least partly overcome by keeping the hole full of water. If the trouble is not remedied by this means, the process may be supplemented by drawing the pipe until the drive shoe is above the boulder. The boulder may then be crushed with the drill and the pipe driven ahead.

Pumping.—By keeping the shaft full of water, J. E. Bacon, in sinking a large open well at Charlotte, Mich., in 1904, removed quicksand by a powerful sand centrifugal pump. This method was also successfully employed at Millville, N. J., in sinking a well 8 feet in diameter, to a depth of 36 feet, the lower 16 feet being through fine, saturated sand.

Freezing.—Quicksand has been penetrated by shafts by means of freezing. This method was first employed in 1883 by F. H. Poetsch, a German mining engineer, who by using it sunk a shaft in a mine near Schneidlingen, Prussia, through a bed of quicksand about 18 feet thick, lying about 100 feet below the surface. As other methods had proved unsuccessful, Poetsch drove pipes into the quicksand and circulated through them a refrigerating brine which froze a wall of quicksand 5 feet thick around the proposed shaft. Excavation was continued within this wall, and the shaft was carried downward through and below the quicksand. The same engineer later excavated through 107 feet of quicksand by the same means. The process has also been used in this country in sinking a number of shafts, one of which is described by D. E. Moran.[1] The machinery used in freezing the quicksand consisted of the following essential parts:

1. An ammonia compressor or pump with suitable motive power.

2. Pipe coils surrounded by constantly changing cooling water. In these coils the compressed and heated gas coming from the ammonia compressor is cooled to such a temperature that, at the pressure existing in the coils, it condenses to the liquid form.

3. A valve, regulating the flow of the liquid ammonia from the above described coils into—

4. A second set of pipe coils, surrounded by brine or other vehicle. The liquefied ammonia passes from the regulating valve into these coils and immediately expands, absorbing the necessary heat from the surrounding brine. From the coils the gas is led back to the compressor, completing the cycle.

The brine used was a 60 per cent solution of the impure calcium chloride of commerce. The cold brine was pumped from the refrigerating tank through a system of distributing pipes and regulating valves to the ground pipes, and after circulating through these it returned to the refrigerating tank, the velocity of the brine in the downward flow pipes being about 2 feet a second. No protection was given to the connecting pipes above ground, so that these were soon covered over with a snow-like ice, the result of condensation from the atmosphere, and this served as a cheap and effective lagging.

Soon after the brine was started in circulation the ground began to freeze around each pipe, forming frozen cylinders, which increased in diameter until at the end of six days adjacent

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[1]Moran, D. E., The freezing process as applied at Iron Mountain, Mich., in sinking a shaft through quicksand: School of Mines Quart., vol. 2, 1890, pp. 237-254.

cylinders intersected and made a circular wall extending from the surface to the bottom of the drive pipe and thus formed a cofferdam inclosing the proposed shaft. Excavation was then begun inside this cofferdam, and no water came through the frozen wall at any time. The rate of freezing differed in different parts in the deposit, depending on the amount of water the parts contained. The smaller the amount of water the longer it required to effect freezing.

Some of the physical qualities of the frozen quicksand were noted.

Frozen quicksand may be regarded as a mortar in which the cementing material is ice, and, as in a cement mortar, the strength will probably be found to depend on the quality of the sand and the presence of sufficient cementing material, as well as on the strength of the cement.

Frozen quicksand looks like a fine-grained sandstone. It is perfectly homogeneous, breaks with a tendency to conchoidal fracture, and is hard to work as a stone of similar character. When mixed with gravel or boulders the mass resembles conglomerate or a concrete made with similar stone. The difficulty of working the material is more than doubled by the presence of gravel, which greatly increases its density and dulls the pick points or "moils" of the miners. The strength with which the quicksand adheres to the stone is shown by the line of fracture in such material. There seems to be no tendency for the rounded boulders to pull out of the quicksand, but rather for the break to follow the shortest line, whether through flint or quicksand.[1]

Quicksand beds that lie near the surface can be thus frozen without very great expense, but the expense of freezing beds that lie at depths of over 100 feet will probably be great and the process will be slow.

GENERAL DRILLING OPERATIONS.

Casing.

Primitive methods of casing.—As elsewhere stated, deep wells in the Orient are sometimes lined with bamboo or hollow tree trunks for casing.

[1] Op. cit., pp. 248-249.

Some bored water wells in Arkansas and Florida even, are lined with wood. This is ineffective as a means of preventing contamination; and besides has the disadvantage of decaying in time and adding organic matter to the water. A better casing for bored water wells is clay tiling, now frequently used.

Modern Methods—Conductor Box.—In many places the surface material consists of loose sandy clay, sand, and gravel, varying in thickness (in the Pennsylvania oil regions) from a few feet on the hills to several hundred feet in the valleys. To restrain this material, which would otherwise impede the work of drilling, a conductor box, made of plank, circular, square, or octagonal in shape, and 8 inches to 20 inches across, is sunk to the bed rock. If the rock lies only a few feet below the surface the necessary excavating is done by hand; if the soil is deep, a large drilling bit is used to spud down a hole, into which the conductor box or a section of large iron pipe may be sunk as fast as drilling proceeds.

Drive-pipe or conductor.—In starting a well it is the custom to extend what is known as a conductor or drive pipe from the surface to as great a depth as can be driven by ordinary driving methods, through the superficial formations to the solid rock. Years ago it was the custom to use a wooden conductor made of planks for this purpose; but at present the metal drive pipe is used almost exclusively. The ordinary sizes of the drive pipe are 10, 8, 6, and 4¼ inches in diameter. The length of the drive pipe varies very greatly; being in some parts of Ontario and elsewhere as much as 100 or 200 feet, while in other localities the solid rock comes to the surface and no pipe line is required.

The casing.—The casing of a well is not properly equipment used in its construction, but is rather part of the material which is used up in sinking the well; in other words, the rig machinery, rig and drilling tools can be used again in sinking some other well after the completion of the first, while a casing becomes a part of the well and is never used again, unless the well is a failure, in which instance it is pulled out and used in another well. The principal object of the casing is to shut off water which is encountered in the upper strata penetrated, but casing is also of service in preventing the caving of formations which are very soft. In most deep wells, casing of several different diameters is used; the larger sizes being put in the upper part of the well and smaller sizes used successively with depth.

The methods of casing vary somewhat according to the different methods of drilling; but the general principles are substantially the same, namely, that when a strong flow of water or dry caving formation is encountered, a casing should be inserted to line the well just as soon thereafter as a hard stratum can be reached in which the casing can be set. When once a casing has been set in a formation firmly to shut off the overlying water, it is then possible to drill deeper with a bit of smaller diameter until a deeper water vein be encountered, when a second string of casing is required, which will of necessity be of smaller diameter than the first.

Casing is of various types and the type used in any particular field must correspond with the local conditions. The sizes of casing in common use in the oil fields are as follows:—

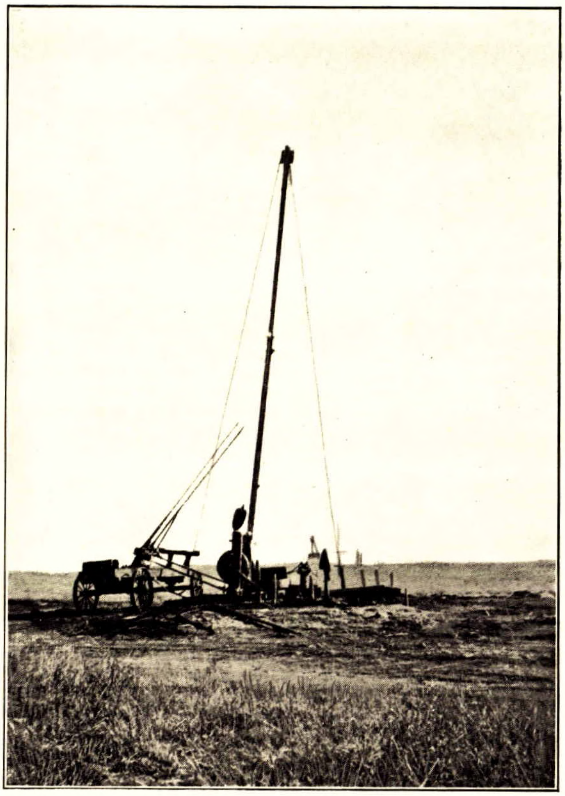
TABLE XIII.

Dimensions, etc., of Lapweld Casing.[1]

Diameter, Inches. Nominal.	Diameter, Inches. Internal.	Diameter, Inches. External.	Nominal weight per foot.	Thickness, inches.	No. of threads per inch.	Outside diameter of couplings, inches.
2	2·06	2 1/4	2·22	·095	14	2 3/4
2 1/4	2·282	2 1/2	2·82	·109	14	3
2 1/2	2·532	2 3/4	3·13	·109	14	3 1/4
2 3/4	2·782	3	3·45	·109	14	3 1/2
3	3·01	3 1/4	4·10	·120	14	3 25/32
3 1/4	3·26	3 1/2	4·45	·120	14	4
3 1/2	3·51	3 3/4	4·78	·120	14	4 1/4
3 3/4	3·732	4	5·56	·134	14	4 1/2
4	3·982	4 1/4	6·00	·134	14	4 3/4
4 1/4	4·218	4 1/2	6·36	·141	14	5
4 1/4	4·094	4 1/2	9·38	·203	14	5
4 1/2	4·468	4 3/4	6·73	·141	14	5 7/32
4 1/2	4·344	4 3/4	9·39	·203	14	5 7/32
4 3/4	4·704	5	7·80	·148	14	5 5/8
5	4·954	5 1/4	8·20	·148	14	5 13/16
5	4·867	5 1/4	9·86	·191	14	5 13/16
5	4·753	5 1/4	12·80	·248	11 1/2	5 13/16
5	4·65	5 1/4	15·88	·300	11 1/2	5 13/16
5 3/16	5·187	5 1/2	8·62	·156	14	6 1/16
5 3/16	5·042	5 1/2	12·49	·229	11 1/2	6 1/16
5 5/8	5·688	6	10·46	·156	14	6 5/8
5 5/8	5·594	6	12·04	·203	11 1/2	6 5/8
5 5/8	5·560	6	14·20	·220	11 1/2	6 5/8
5 5/8	5·457	6	16·70	·271	11 1/2	6 5/8
6 1/4	6·280	6 5/8	11·58	·172	14	7 9/32
6 1/4	6·219	6 5/8	13·32	·203	14–11 1/2	7 9/32
6 1/4	6·149	6 5/8	17·02	·238	11 1/2	7 9/32
6 5/8	6·640	7	12·34	·180	14	7 11/16
6 5/8	6·503	7	17·51	·248	11 1/2–10	7 11/16
7 1/4	7·265	7 5/8	13·55	·180	14	8 5/16
7 5/8	7·617	8	15·41	·191	11 1/2	8 23/32
7 5/8	7·482	8	20·17	·259	11 1/2	8 23/32
8 1/4	8·265	8 5/8	16·07	·180	11 1/2	9 3/8
8 1/4	8·167	8 5/8	20·10	·229	11 1/2	9 3/8
8 1/4	8·082	8 5/8	24·38	·271	11 1/2–8	9 3/8
8 5/8	8·640	9	17·60	·180	11 1/2	9 7/8
9 5/8	9·577	10	21·90	·211	11 1/2	10 29/32
10 5/8	10·594	11	26·72	·203	11 1/2	11 7/8
11 5/8	11·594	12	30·35	·203	11 1/2	12 7/8
12 1/2	12·457	13	33·78	·271	11 1/2	14
13 1/2	13·432	14	42·02	·284	11 1/2	15
14 1/2	14·416	15	47·66	·292	11 1/2	16 1/8
15 1/2	15·416	16	51·47	·292	11 1/2	17 1/8

[1]Catalogue of Oil Well Supply Co.

PLATE XII.



Machine set for pulling casing, Muskagee field, Okla., U.S.A.

Pulling Casing.

After casing has been in a well for a time the formation settles around it, sometimes making it difficult to remove it. If it cannot be pulled out in the ordinary way with blocks and lines, hydraulic jacks are used. If the bottom of the casing will not yield to the pressure of the jacks, it is usually parted. The upper part is pulled out. If a collar is left on the casing in the hole a steel die is attached to the collar and the casing is then pulled out. It is lowered again and the die firmly screwed into the casing below. If the collar is pulled off the casing left in the hole a steel collar with cutting dies is sent down and firmly screwed onto the casing. A casing cutter is then sent down on a string of tubing and the casing is cut off where it is thought the obstruction is holding it. If the first cut does not release it, it can be cut again and again each time higher up, until it is released.

Squibbing the casing with nitro-glycerine is the quicker and less expensive way to loosen it when there is no water in the casing to damage it by the explosion. This is done by filling a small tin tube with nitro-glycerine and attaching this tube to a wire line with a firing head attachment; on the bottom of the tube a piece of stiff V-shaped wire is attached, the points coming up on either side of the tube and extending to the casing. The points drag along the casing while the squib is being lowered. When the objective point is reached, the squib is pulled slowly until the points of the wire come to a collar, when they usually catch the bottom of the upper joint of casing and hold the squib; a piece of small pipe through which the wire has passed in lowering the squib is released; it drops upon the firing head. The explosion which follows separates the casing.

The size of the hole is always governed by the contemplated depth of the well, and the anticipated difficulties to be encountered.

In wild-cat wells, or wells drilled in undeveloped territory, sometimes an 18-inch hole is started which is drilled below the surface sands, which may contain water. Casing 16″ inside diameter is then placed in the hole and all water found to this level is shut off. The hole is then continued 16″ in diameter to other water sands and casing of $12\frac{1}{2}''$ inside diameter is inserted; the hole is again continued $12\frac{1}{2}''$ in diameter to another objective point, when casing $10''$ inside diameter, 45 pounds to the foot, is inserted; the $10''$ hole is then continued through the deeper water sands or cavey formation, when casing $8\frac{1}{4}''$ inside diameter, weighing 24 pounds to the foot, is inserted; the hole $8\frac{1}{4}''$ in diameter is then continued, usually to the top of the oil producing sand, when casing $6\frac{5}{8}''$ inside diameter 17 pounds per foot is put in, which shuts off all cave and water found above the oil-bearing sand. If, however, other difficulties arise and it is found necessary to use additional casing, casing $5\frac{3}{16}''$ inside diameter, weighing 13 pounds to the foot is put in.

In the event any of the strings of casing placed in the hole have not reached a sufficient depth to shut off water or caving as anticipated, the casing is pulled up eight or ten feet from the seat upon which it rests, and is suspended from clamps which securely hold it at the mouth of the hole; then a tool called an under-reamer is inserted and when it passes out of the lower end of the casing in the hole, it expands sufficiently to meet the wall of the larger hole and the shoulder or former seat of the casing is reamed so that the larger hole is carried to the point where it is desired the casing should be re-seated, in order to shut off water or cave which may have been encountered; the casing is then lowered on the shoulder or seat made by the under-reamer.

In proven territory, where conditions are well known and after a well has been fully completed and put in producing order, all of the larger sizes of casing are usually pulled out of the hole, leaving the inside string to shut off all water and cave from the oil-producing sand. The casing so removed can be used in additional wells, which greatly reduces the cost of operation.

Packing.—The importance of proper casing can not be over estimated. An important precaution with artesian wells is to make sure that no water escapes between the outside of the casing and the surrounding rock.

The usual method of preventing such an escape is to surround the casing just above the water-bearing stratum with a seed-bag, *i.e.*, a bag made of leather or rawhide and filled with dry flaxseed. The latter absorbs the water and by swelling it expands the bag so as to shut off all escape of water outside the pipe. The method of attaching the bag is shown in Plate XIII. Another method of shutting off the water is by means of rubber disks described later on.

In order to prevent water from entering an oil or gas well, the casing is set as tightly as possible on some tight rock below the point at which the water would enter. A small amount of water may enter at this point without doing serious damage, provided the pressure of the oil is strong and flushes invading water to the surface. Frequently, however, the amount of water which would thus enter is so great as to require special precautions known as packing. The water from casing wells should be packed in as completely as possible, otherwise it will accumulate in the well and frequently, by hydrostatic pressure, stop the flow of gas. In the early days of oil exploration, a bag of flax seed was sometimes inserted at the point where the casing was to be set. The seed swelled rapidly, closing the cracks between the end of the pipe and the rock. In other cases the bag of flax seed is placed around the casing where it is desired to fill the crack between the casing and the wall of the well.

Patent Packers.

While there are too many patent packers to be mentioned in detail, a device in most common use is made of two metal cylinders with rubber between, one or two inches thick and varying in length. Such a packer is lowered into the well by lengths of pipes to the position it is to occupy. A weight is then dropped into it which relieves a string, causing the two cylinders to approach and bulge the rubber out into the space to be filled. If the problem is to shut off water from the bottom of the hole, the packer consists of a rubber plug with a tapering hole. The top mandrel of wood or iron is driven into the block and expands the rubber to fit the wall of the well and shut off the water below.

Mr. Coste states that the wells at Bow Island are packed with a lead packer to keep out water from below. There are two of these wells which penetrated strata containing salt water and had to be packed.

The city of Iola, Kansas, is cleaning out the old gas wells by a simple method. The well is cased with 1½″ pipe. After it has been drained by the demands of the consumers and water has seeped into it until the gas no longer is forced upward, a smaller pipe is placed inside the first and connected at the top by a T shaped pipe, one side of which is connected with a drip reservoir and the other with the main gas line. From the drip-pan another pipe leads back into the well again.

When the smaller pipe is placed inside the large one, pressure is increased because of the smaller area of resistance. The water is forced up through the pipe even by the pressure of the old worn-out well and as the well cleans itself, the pressure grows stronger. The water is caught in the drip-pan, while the gas passes on through the pan, back into the pipe and is in turn forced back into the main, the T pipe being regulated by a valve which is operated to suit the conditions under which the well is being cleaned.

When medium size gas wells show water, it is best to use a ¾″ siphon or water line hanging from the top inside of the tubing and with a blow-off on the top end. The bottom of the siphon should be plugged and hung one foot from the bottom of the well. The joint of the pipe opposite the main gas sand is perforated with ¼ inch holes. Both sides of the pipe are drilled through and spaced one foot apart. If blown often, this method keeps the water out of the well. Where there is no floating sand in the well, the same method can be installed with a 1″ working barrel and anchorage on the bottom of the ¾″ pipe, using the ¾″ pipe as a sucker rod as well as a conductor for the water. The top of the ¾″ casing should work through a stuffing box on the top of the tubing with a small walking beam and gearing, using a horse for power, or a two to four h.p. gas engine.

In equipping gas wells with ¾″ water pumping outfits where the size of tubing is over 3″, a cast iron spider can be used on every second or third joint. The spider fits loosely in the tubing and is made to slip over the $\frac{3}{4}''$, but not large enough to slip by a $\frac{3}{4}''$ collar. This method prevents the $\frac{3}{4}''$ from weaving while pumping.

Screening.

Where wells are sunk in fine sand, etc., a screen must be used which will permit water or oil to enter, but not sand.

In Texas oil fields the screens or strainers are made of ordinary pipe, with perforations usually 2 to 6 inches apart. The pipe is then wrapped around with iron wire. If the sand is fine, the wire is wrapped close, if it is coarse, space is left between successive wrappings. This kind of strainer is supplied by machine shops throughout the oil fields, and can be made by any mechanic. Frequently the casing is perforated with slotted holes after being set.

Patented strainers are also used. Some makes, like the Layne strainer, differ from the shop-made ones in the shape of the wire used. In the Layne and similar streamers the wire has a triangular section and presents a narrow surface to the sand, and thus reduces the clogging of the screen and insures greater production and a longer life to the well.

Capping.

This operation merely consists of placing a gate on the tubing or casing and shutting in the well.

If in drilling a gas well a volume greater than 35,000,000 cubic feet daily capacity is anticipated, and the conditions of the well are favourable for casing to be used in place of tubing, a gate is screwed on the casing and the size of the drill or bit reduced just before drilling into the gas vein. If reducing the size of the bit is objectionable, a swedge nipple is used and a gate one size larger than the casing.

Torpedoing.

The torpedoing of oil wells with nitro-glycerine dates back almost to the very beginning of the oil industry, and there is no part of the construction and operation of oil wells which demands more careful attention. The very dangerous character of the high explosive is too well known to require comment here, but, regardless of danger, nitro-glycerine is freely used to stimulate the production of declining wells and is always used in torpedoing new wells when completed where the sand is found of a close hard texture.

Locating the glycerine in the pay sand is of the greatest importance. If the torpedo is allowed to extend above the pay sand, the barren formation shattered by the explosion will fall down and cover the pay sand, greatly interfering with the operation and production of the well.

A selfish competition among producers often prompts the use of large torpedoes, with the hope of shattering the pay sand to such an extent as to let the oil come more freely to the hole from a great surrounding area. Where large torpedoes are used in wells with limited pay sand, the barren formation is usually shattered to such an extent as to render the wells valueless.

The experienced and conservative producer will not ruin his property in this way. If he has a well with ten feet of pay sand, which he desires to torpedo, he will place 20 quarts or $66\frac{2}{3}$ lbs. of glycerine in a shell $5\frac{1}{2}''$ in diameter, and 4 feet, 4 inches in length. An anchor, consisting of a tin tube of sufficient strength to support the weight of the torpedo, and of sufficient length to elevate the top of the torpedo to within three and one-half or four feet of the top of the pay sand, is attached to the bottom of the shell. The shell is attached to a line with a hook which releases its hold of the shell when it reaches the bottom of the hole and after the torpedo is placed in this way, the careful operator, to guard against any possible error in calculation, or in danger of some obstruction preventing the torpedo from going to the objective point, will take a steel line measurement to determine the exact location of the torpedo before it is exploded. Should the torpedo be found misplaced, it is fished out of the hole; the obstruction is removed, or the anchor is shortened or lengthened, as the case may require, to bring the shell to the desired place in the pay sand.

When the explosion occurs, the fluid and much shattered sand is usually thrown out of the hole. Should the shattered sand settle into the hole made by the explosion, it is taken out by the use of tools made for this special purpose. When the hole is thoroughly cleaned, it is usually sufficiently large to admit several torpedoes of the size of the first one used, being placed in the same space in the pay sand.

When the shell of a subsequent torpedo is released from the line which carries it to the bottom of the hole, there being no wall to support it, it falls over in the hole; additional shells can be placed in the cavity, or shot hole, and in this way, the size of the torpedo greatly increased, and at the same time kept in the pay sand.

Shells used in subsequent torpedoes, or where the wall of the hole will not keep them in a perpendicular position, should be so constructed that the opening in the top of the shell through which it is filled, can be corked to prevent the glycerine from escaping from the shell.

The old style plan of exploding torpedoes in oil wells consisted of a small tin tube attached to the top of the torpedo shell and extending down on the inside into the glycerine. In this tube were several small steel pins fitted to percussion caps. A longer pin came up through the top of the tube and shell and connected to a flat cast iron disc, nearly the diameter of the top of the shell; this pin or rod made a connexion between the disc and the pins carrying the percussion caps.

When everything was in readiness to explode the torpedo, the "go-devil," a cone-shaped cast iron weight, was dropped from the top of the hole, which struck the disc on the top of the torpedo with the desired results.

Many premature explosions caused a change in this method of exploding torpedoes. The glycerine jack squib is now being generally used. This squib consists of a tin tube about $\frac{3}{4}''$ diameter, and two feet in length. A 3 minute fuse, with a fulminate cap attached to the lower end, is wound around the tube to the top and extends several inches above the tube. The tube and fuse are placed inside of a larger tin tube about $2''$ diameter, and slightly longer than the inner tube. Dry sand tamping fills the space between the two tubes. The top of the larger or outside tube is turned in and pressed down on top of the sand, keeping it in place. When everything is in readiness to explode the torpedo, the inner tube is filled with glycerine and corked; the fuse is then lighted and the jack is dropped into the hole. The explosion usually follows.

It is desirable to have fluid tamping on top of the torpedo. Where this cannot be done on account of the proximity of the casing to the top of the sand, large torpedoes cannot be used with success.

Electric Torpedo.

When it is found necessary to case a well near to the top of the pay sand, it cannot be given a large torpedo safely in the pay sand without great danger of damaging the casing. In cases of this kind the well is given an electric torpedo, as follows:—

The torpedo is placed in the proper location in the hole; a squib containing two or three quarts of glycerine attached to an insulated wire is then lowered to the top of the torpedo. The casing is pulled out of the hole over the wire and the squib is exploded by a battery and it in turn explodes the torpedo. The casing is again put into the well, the hole cleaned out and the well put in producing order.

This style of shooting should only be resorted to in newly developed territory where there is a good rock pressure. In old territory where the rock pressure is low and where much oil has been taken out of the sand when the casing is removed, the water and cavings which have been shut off by the casing are allowed to flood the sand. When the torpedo is exploded the column of water offers more resistance than the rock pressure of the sand, with the result that the mud and water is blown into the pay sand and the well greatly damaged, and in many cases totally destroyed.

There are times when wells flowing large quantities of oil can be improved by torpedoing. This is a dangerous proceeding which is usually accomplished in this way. If the well is flowing by heads, careful gauges of its production are taken, noting the time between flows and the quantity of oil produced at each flow. When the maximum flow is ascertained in this way, it is known almost to a certainty how much time will elapse before the well will flow again. The torpedo is prepared, the well is watched closely; when it flows the gauge is taken and if it has produced the maximum flow there will then be sufficient time to lower the torpedo safely before the well will flow again. If the well did not make its maximum flow it will come in again in less than the usual time and if the well should flow while the torpedo is being lowered, it will be thrown out of the hole with disastrous results.

When a torpedo is safely landed in the pay sand, it will not be thrown out by the flow. The torpedo shooter is usually waiting for the well to flow and while the hole is empty or the oil which has been left in the hole is held in suspension by the gas, the torpedo is exploded safely without damage to the casing.

If a well flows continuously and the production is large, "well enough should be left alone." Such wells should not be torpedoed. If, however, the wells are gassy, and do not produce much oil, and the owner desires to torpedo with the hope of increasing the production of oil, and in the event the gas pressure offers too much resistance to permit the torpedo to be lowered into the hole, a weight sufficient to overcome the gas pressure is attached to the bottom of the torpedo which carries it to the bottom of the hole.

The Petrolia wells were shot with 8 to 10 quarts of nitroglycerine, the charge being much smaller than in the Pennsylvania fields, where 80 to 90 quarts are frequently used.

Shooting has been tried at Brantford, but as it does no good, the wells are not now shot.

FLOWING WELLS.

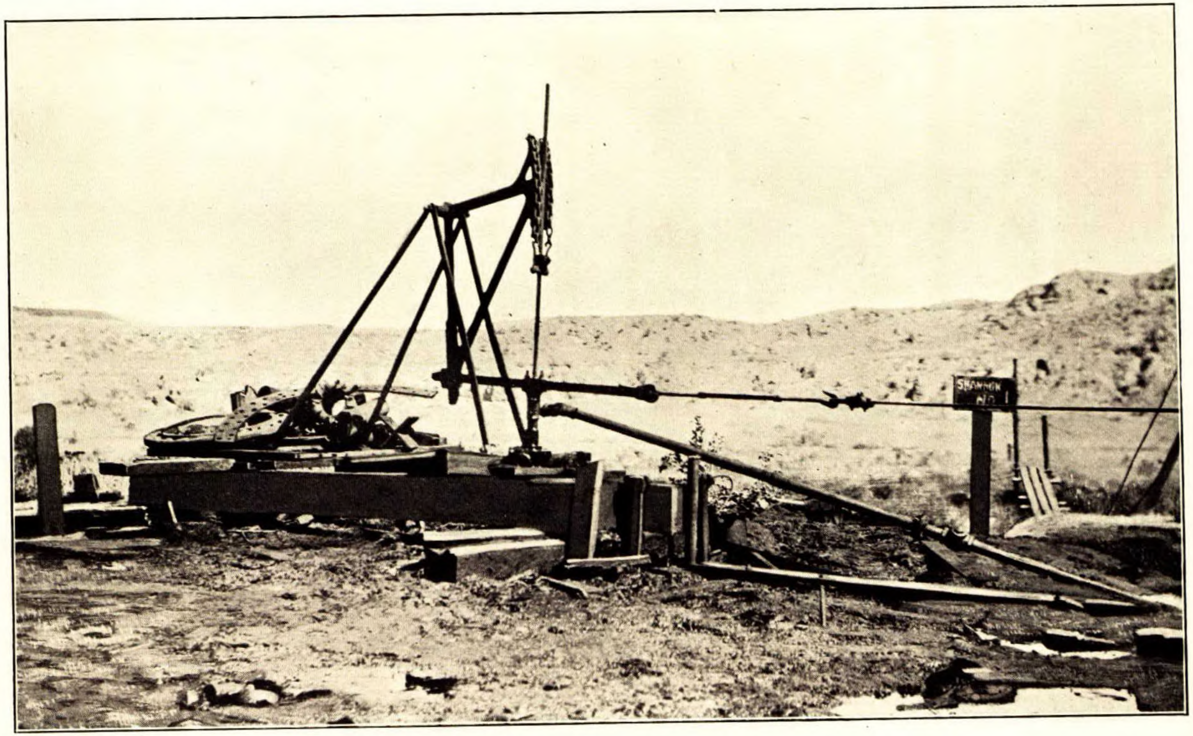
When wells are new, there is usually sufficient rock pressure to flow the production. Where the production is large and especially where there is much gas coming with the oil, the lead lines conducting the oil from the mouth of the hole to the receiving tank should be of sufficient capacity to relieve the well of all the back pressure. This, however, cannot be done in parts of Louisiana and Texas where some wells flow the sand out with the oil to such an extent as to wear out the heavy six-inch pipe used for lead lines within a short time. Such large wells in the districts referred to, when allowed to flow unrestrictedly, usually drill themselves into water; when the oil is greatly damaged by being cut or mixed with the water to such an extent as to make it difficult and expensive to refine it.

Where gas is found in large quantities above the oil producing sand and allowed to come in contact with it, it not only greatly interferes with the production of oil, but the oil which is produced is usually blown into the tank with much force and often much of it is lost, and the gas itself, a most valuable product, is lost entirely. This waste of oil and gas can be avoided in nearly every instance by the use of an extra string of casing. The bottom of the casing is supplied with a special gas packer to be lowered to a point below the gas, where the packer is set, which will prevent the gas going down by the bottom of the casing. An appliance called a stuffing box casing head is then attached to the top of the larger casing and the gas safely and securely confined between the two strings of casing. Suitable holes in the stuffing box head supplied with gate valves will control the gas and allow it to be utilized as needed. In this way, the production of oil and gas coming from the same well can be utilized.

The method by Pollard and Heggen for controlling great gas pressures so as to allow drilling to deeper oil sands, is referred to in the chapter on conservation.

PUMPING WELLS.

As the rock pressure of the oil sand or gas sand works off, the wells cease flowing and it becomes necessary to equip them for pumping. In good territory, where wells will pump a good production, each well is usually operated with an individual engine, which is used not only to pump it on the walking beam but also to pull the pumping equipment from the hole when necessary.



Pumping well, showing connexion with cam wheel.

As the production declines, a central pumping power plant is installed. All wells are connected by iron rod lines to cam wheels in the power plant, which is driven by a gas engine. As the power plant is always centrally located, the rods in the wells on one side of the plant are dropping, while the rods in the wells on the other side are being pulled up. This forms a kind of teeter, it balances the strain on the cam wheel and relieves the power.

The oil when it comes from the well is conducted through a system of gathering lines to storage tanks, where it is measured and sold to the pipe line, or purchasing companies.

Where wells produce salt water from the same sand which produces oil, a separator for separating the water from the oil should be used and the salt water should not be allowed to go into the storage tanks.

Where a well produces water with oil, and in the event the valves are not kept in perfect condition, the leaking of the oil and water back through the valves will cut the oil to such an extent as to render it unmerchantable. In order to reclaim such oil, it must be heated by steam to a temperature of 80°F. and allowed to stand for several days during which time the water usually settles to the bottom of the tank and is drawn off, leaving the oil of a gravity to meet the pipe line requirements.

Wooden tankage is generally used on producing properties, ranging in capacity from 100 bbls. to 1600 bbls. To avoid evaporation, wooden tanks should be securely decked and housed. The lead line carrying the oil from the wells to the tanks should be buried before reaching the tanks to guard against lightning following the lines into the tanks.

COST OF DRILLING.

Only for well developed oil fields is it possible to give any general statement of the costs of drilling, and even then the prices per foot are subject to great variations under exceptional conditions. The following table shows in some cases the usual total cost in established fields and in others the price per foot, while in newer regions the cost of individual wells is mentioned.

As a rule in the Ontario fields the thrift of the oil and gas industry is much more advanced than it is in similar fields of the United States. While wells in some of the large fields of the United States have been abandoned sometimes in cases where they produced as high as 10 or 20 barrels per day, wells in the old Ontario fields, on the other hand, are seldom abandoned until the production falls to a few gallons.

TABLE XIV.

Cost of Drilling Wells.

Locality.	Standard Method.	Canadian Method.
Brant county		
Brantford fields		$ 800.00
Onondaga "		
Ontario.		
Petrolia		160.00
Bothwell		500.00
Haldimand county.		
Carlow	$ 700.00	
Simcoe.	1.35 per ft.	
Port Rowan	2,900.00	
Caddo, La.	12,000.00	
Northern Alberta.		
Pelican		25,000.00
Central Alberta.		
No. 2 Tofield	9.50 per ft.	
No. 3 Tofield	7.50 per ft.	
Vegreville	9.00 per ft.	
Wetaskiwin	10.00 per ft.	
Southern Alberta.		
Medicine Hat		7.25 per ft. for 10″ hole. 6.50 per ft. for 6″ hole.
Brooks station		40,000.00
Lethbridge		10,000.00
Gaines, Pa.	.65 per ft.	
Summerland, Cal.	.85 per ft.	
Northern Mississippi valley	.75 per ft.	
Eastern Washington	2.50 per ft.	
Texas.		
Beaumont field	4.00 per ft.	

In Ontario in the early days it naturally took a long time to put down a well, as the methods were not improved as they are at present. In 1868 it sometimes took six months to drill a well. In 1890, however, a hole could be drilled in four or five days at a cost of $160 per well, the owner of the well furnishing the casing. After the well is finished the pump is inserted by the driller and the well is tested for a day.

In the Petrolia fields a drilling gang consists of six men, three working in the day shift and three in the night shift. Pole tools are used, consisting of a bit and an iron bar about 3½″ in diameter connected with the walking beam above by poles.

Owing to the decline in production and the abandonment of most of the oil wells in Ontario, it has been necessary for the men employed in the contracting and drilling business to seek employment elsewhere. The Canadian drillers, being very expert, have been in great demand, and have now moved to all parts of the world, including Germany, Austria, India, Burma, Mexico, Australia and some have even gone to Pennsylvania.

The cost of sinking an ordinary well in the Petrolia fields in the early days of development was about $1500. The cost in 1890 had dropped to $150 or $160, which is as cheap as wells can be drilled in almost any oil field in the world, with the exception of Oil Springs, where the depth is 100 feet less.

In the Petrolia field the plan was to drill one to ten oil wells to an acre, and it was supposed by the oil men that if less than four wells to the acre were drilled, the territory had not been thoroughly tested.

Wells in the Petrolia field are kept in good condition by occasionally cleaning them, which custom has been followed in recent years.

In the last few years wells have been rapidly abandoned in the old fields of Ontario.

In the Simcoe field, Ontario, American standard rigs are used in general, with 72 foot derricks, although there are several Canadian cable rigs in the field. Drilling as a rule, is done by contract at $1.35 per foot, the company furnishing water and charging 10 cents for gas, or a net price of $1.25 per foot for drilling alone. It costs from $2,900 to $3,200 to drill and equip a producing well in the Port Rowan district, the higher price being accounted for from the fact that American drillers use more iron in the well. Canadian rigs can drill better in a wet hole with a steel cable than the American; but the Americans can drill faster in a dry hole with a manilla cable. On this account the American drillers case off the water at from 600 to 700 feet, this accounting for the extra cost of such wells. Canadian rigs take from 24 to 28 days as a minimum, up to 60 days, to complete a well. The well on the Clemens farm was drilled in 24 days. But the average time to build the derrick, drill the well and tear down the derrick again is two months. The rock is sharp and hard on the bits. Pole tools could not be used with ash rods, although possibly solid iron rods could be used in this field. A new wire line is necessary for each well, on account of the hard drilling and the great amount of corrosive sulphur and mineral water. Farther east, in Selkirk, eight or nine 800-foot wells are drilled with one line.

The average cost of a 400-foot well in the Bothwell pool is about $500. Pole tools are used as a rule, and the derrick is removed upon completion of the well. A small three-pole or tripod derrick is then used for pulling the tubing and cleaning the wells. Most of the wells are pumped by iron or wooden shackle rods from a central steam plant, although several internal combustion oil engines are in use at present.

In the Petrolia field in Ontario wells were commonly $4\frac{5}{8}''$ in diameter, and where cased they are reamed to accommodate a casing of $5\frac{1}{8}''$ outside diameter. The wells were drilled in five or six days and the cost was $150 to $160. This was in 1890, but in the early days of the field the cost ranged from $1 to $3 per foot and the time occupied was from two to six months. Wooden rods were generally used instead of cables. The drilling was done in three shifts of three men each. The great majority of the drillers from the old Petrolia field have since gone to fields in Europe and Asia, being in great demand.

In the Vienna pool in Elgin county, both Canadian and American standard rigs are used, but the latter predominate.

In Ontario it is the custom to drill 10 feet through the White Medina, this giving a pocket in most wells below the pay stratum, of 113 to 125 feet. In one well the bottom of the Red

Medina was struck at 1,067 feet, and the well was drilled to 1,180 feet in depth.

In Haldimand county wells are largely drilled by contract. In the eastern part of the field they only cost from $1,000 to $1,200. In the Carlow field both cable rigs and drilling machines are used. One standard American rig with 64-foot derrick is in use and one steel derrick is giving good satisfaction. The average cost of drilling a gas well in the Carlow field is $700. Pockets of 50 to 100 ft. are drilled. In the Selkirk and South Cayuga fields gas wells are drilled with 50-foot pockets below the last producing stratum. By practice it has been found that this is necessary to keep the face of the sand clear, the pockets serving as a catchment for water and oil seepage, and also for the accumulation of sediments. One company, the Standard Natural Gas Company, has recently gone over all the wells and drilled all pockets deeper to 100 feet, claiming that they could be cleaned with greater facility.

The cost of drilling and equipping a producing well in the Onondaga pool of Brant county, including pump, tanks, etc., is about $900. Drillers contract for $800 to do the drilling alone, which is done with a standard Canadian rig, with a 55-foot derrick. Wells are cased to the top of the Clinton sand with $5\frac{5}{8}$ inch or $6\frac{1}{4}$ inch casing.

The spacing of wells in this pool would be considered too close in many fields in the United States, especially in the paraffin oil fields. However, while at one place there are 22 wells in ten acres, and in another as many have been drilled in a five acre space, yet they are all small producers, and experience in the Petrolia and Bothwell pools has been of such a nature as to indicate that where like underground conditions govern, the most efficient recovery is obtained by a large number of wells. However, as the oil in the Onondaga field contains a greater proportion of the heavy paraffin, there being more gas associated with the oil and the productive formation being of a different nature, the rapid decline of wells in this field would seem to indicate, that different handling was necessary from that of wells in the older oil fields of Ontario.

At Brantford they drilled a pocket for the oil, but not for the gas. It takes ten days or so to complete these wells. All the Brantford wells are small in volume. Most of the drillers in this field use standard rigs or petrolia rigs, but there are some Star drilling machines in the field; the Star drilling machine drills with a mast. Mr. Carmody has a 50-foot derrick, which he bolts together. It can be taken down in one day. He reports it good for drilling from 25 to 30 wells. He does not use a house over his engine in the summer time. The price paid for wells in the Brantford and Onondaga fields is $850. A contract is made at this price to drill 40 feet below the White Medina sand.

He states that all the wells have a pocket of 40 feet in the red shale below the sand, which gives room for the water to settle.

The machine wells at Brantford are drilled with masts. The Dominion Natural Gas Co. would drill one well to every 100 acres if they were let alone, but the other companies of course will not observe this rule.

The wells throughout the old Kent county field were drilled by the Canadian rig. When the wells were completed the rig was removed and a three pole rig erected for use during pumping of the wells. The power was transmitted by shackle rods operated by a gas engine at a central pumping station. In these fields the wells average 500 feet apart but are irregularly spaced.

The best time made in drilling a gas well in the Tilbury-Romney field is reported to be $17\frac{1}{2}$ days for a $5\frac{5}{8}''$ hole, which was drilled to a depth of 1,362 feet by the Beaver Oil and Gas Company. American standard rigs with 72-foot derricks are used.

The principal objection to the American standard drilling rigs is that the driller is obliged to pay a duty on the United States materials. This is essential in the case of the deep sand pools, such as the Tilbury-Romney gas field, for the reason that the Canadian pole tools cannot be used in the deep wells.

In the Delhi field Canadian standard rigs are used for drilling, all drilling being done by the Company, which is cheaper than contract drilling. No tubing is used at Delhi, cheapening the cost of the wells.

THE CASING OF OIL WELLS.

By Ralph Arnold and V. R. Garfias.

GENERAL STATEMENT.

Oil wells generally are lined with wrought iron or steel casing, the depth to which any column or "string" is carried depending on the nature of the formation, the location, number, and importance of water and oil-bearing strata penetrated, drilling method employed and the ability of the driller.

As the nature of the formations penetrated by the well varies, not only in different fields but in distinct areas in any one territory, it is out of question that uniform methods of casing wells should prevail. For instance, the strata overlying the oil beds in some of the Russian fields are so incoherent that only comparatively shallow depths can be attained before the casing is frozen. For this reason it is customary to start a well of large diameter, a 40-inch hole not being uncommon. The opposite conditions are encountered in certain fields in the Eastern United States where it is possible to drill 2,000 feet or more without the necessity of lining the well, except to exclude the water before tapping the oil-bearing beds. Somewhat similar conditions prevail in parts of the Mexican oil fields where the wells pass through about 2,000 feet of practically impervious shales. Conditions in California, and in some of the Gulf Coast fields represent in a general way an average between those existing in Russia and the Eastern United States, it being necessary to line the hole as drilling progresses, but with less difficulty than in Russia. Thus it is common practice to carry a 10-inch hole for over 2,000 feet.

In drilling for oil it is the aim of the operator to tap the oil-bearing beds with a well not smaller than four inches in diameter.

Wells finished with six or eight-inch casing are usually operated more satisfactorily than with the four inch.

Oil-well casing is manufactured in two general ways: (1) from plates two or three feet in length, lap-riveted to diameters from twelve to twenty inches, and (2) in lap-welded sections twenty to forty feet in length and from four to sixteen inches in diameter. This represents the average American practice; the Russian wells are lined with casings of considerably greater diameter.

RIVETED CASING.

Riveted or stovepipe casing is manufactured from No. 8 to No. 12 steel plates in two to three-foot lengths, from twelve to twenty inches in diameter. To build a string of these short tubes two separate columns are necessary, one fitting tightly inside the other so that the joints between the tubes of one column come in the middle of the tubes forming the other. These two columns are riveted together in lengths from ten to twenty feet before insertion in the hole, and in order to obtain a better bond between the pipes they are indented by hammering with a pointed sledge.

Stovepipe is used for lining the first few hundred feet of hole in order to hold in place the loose surface material. This casing, owing to its smooth outer surface, penetrates more readily the gravel and coarse sediments generally encountered near the surface, and its freedom from screw joints makes it adaptable to heavy driving. The absence of screw joints, however, precludes the easy removal of a complete string of stovepipe, and it is usually left in the well or only partially taken out.

SCREW CASING.

After the stovepipe has been landed, the wells are lined with wrought iron or steel, lap-welded casing. This is made in twenty to forty foot lengths, four to sixteen inches in diameter, threaded at both ends and coupled by a threaded collar, the California standard thread for screw casing being ten to the inch and from three to three and one-half inches in length. The collars have at either end a smooth recess which fits tightly around the casing, thus affording greater rigidity to the string. During the last two years the manufacturers have put on the market casings provided with extra long collars with a deep recess at each end, and when one considers that the most frequent casing trouble in incoherent formations results from weakness of the joints, it is easy to realize the importance of a rigid and strong bond between casing and collar.

At times it is necessary to employ screw casing that will stand heavy driving, in which case the couplings are made so as to allow the joints to abut. The use of this drive pipe is only resorted to when it is thought that its withdrawal is nonessential.

Every string of casing generally is provided with a shoe at its lower end to facilitate its insertion and prevent damage. The shoe is riveted to the stovepipe and screwed to the lapwelded casing, the toothed shoe being a great improvement over the plain type.

As before noted, casings are made of iron or steel, and although each operator may claim all merit for the particular type he favours, it is safe to state that both are equally well adapted to the requirements, the deciding factor being the prevailing price, which now favours steel.

THE EXCLUSION OF WATER FROM OIL WELLS.

By Ralph Arnold and V. R. Garfias.

One of the most important problems encountered in well drilling is the permanent exclusion of water from oil wells. The details of the operation vary according to the location of the water-bearing beds in relation to the oil zone, it being comparatively easy to case off water occurring a considerable distance away from the oil zone, and proportionately harder to exclude water immediately over, between or below the oil-bearing beds and these difficulties are greatly magnified with the increased depth of the wells. The porosity of the formations penetrating the different gravities of the oil and the varying gas and hydrostatic pressure affecting the oil or water are also important factors having a direct bearing on the problem of shutting out the water.

The number of water-bearing beds encountered before the oil-producing zone is reached varies, usually being from one to five. In some fields there exist two or more distinct oil zones and water sometimes occurs between them, in which case the operation becomes doubly important as the greatest care must be exercised in order to effect the recovery of the oil from the different sources without admitting the intervening water.

At one time it was considered sufficient, in order to exclude water, to land a string of casing on any tough sticky shale or flat surface of hard shell encountered between the water and oil-bearing beds, it being considered that sticky shale gave, as a rule, better results. Later, this method was proven to afford in many instances only temporary relief, and at present it is thought that the only permanent means of excluding water is to place cement in the space between the casing and the wall of the hole.

Although there are in use many processes of cementing which differ in minor details, the operation generally is accomplished in one of two ways: (1) by filling with water the space between the inner casing and a column of tubing and pumping the cement mixture through the tubing, whence, unable to flow back between the tubing and the casing owing to the water pressure, it is forced outside the casing; or (2) by lowering the cement mixture in a dump bailer and forcing it to the outside, either by means of a plunger driven down with the aid of water under pressure, or with a plug fitted to the end of the casing. The first method is known commonly as the pump method while the devices used in the latter are variously designated, according to detail, by the name of the inventor.

For a detailed description of the operation one is referred to Technical Paper 32—"The Cementing Process of Excluding Water from Oil Wells as Practiced in California"—prepared by the writers for the United States Bureau of Mines.

Before cementing, it is essential to place the well in good condition, this being particularly true as regards lost or side-tracked casing and tools in the well. If gas appears through the water it should be excluded, as the agitation of the cement by gas often prevents it from setting. It is also advisable to under-ream the lower 100 feet of the well so as to obtain a cavity surrounding the casing, and in order that the latter may not touch the wall. Some operators prefer not to under-ream the lower few feet, so that the casing will be held fast at the bottom, presumably in the centre of the larger under-reamed hole above. In shallower wells a toothed shoe eliminates considerable under-reaming and casing troubles.

Cement, if properly placed, not only permanently excludes water but protects the casing from the action of mineralized waters and reduces the water pressure on the casing. In a number of cases it is found economical to cement all the strings before reaching the oil, and some operators believe that the larger-sized water strings should be cemented as nearly as possible over their entire length as these usually are left in the hole during the life of the territory.

When all the water encountered is excluded by cementing one casing alone, the failure of this one string jeopardizes the life of the well, but additional cemented strings add new barriers between the water and the oil sources, much as the different watertight compartments protect the eventual flooding of a ship. In order to avoid the possible cracking of the cement or the stratum on which the casing rests, it is considered best to support the weight of the string on clamps at the surface.

After the operation is accomplished, should it become necessary to drill through the cement core inside the casing, this is best done with a rotary, as the jarring of the standard tools is very apt to cause the cracking of the cement on the outside. When the well begins to produce, the oil should be tested for water at least once a week in order to ascertain whether the water is permanently excluded.

In certain cases the following procedure may be employed as a substitute for cementing. The hole is filled with muddy water containing about 40 per cent solids, this being forced between the casing and the wall of the hole. The casing is then landed and the well left to stand for a considerable time. In this way the clay held in suspension in the water settles and packs tightly around the outside of the casing, thus providing a natural and efficient water-tight bond between it and the wall.

A very necessary factor in the successful exclusion of water, and, in fact, in the intelligent operation of a well throughout its economic life, is a carefully compiled log, based on the most reliable and minute information. The log should record any water indications and the nature of the formation penetrated; all accidents encountered in drilling, either to tools or casing; and a description of whatever tools or fragments of casing may have been left in the hole together with the exact location of the same. A careful watch on neighbouring wells should also be maintained in order to counteract the bad effects of any carelessness of operation. For example, if the water has not been excluded in a neighbouring well and this is abandoned before reaching the oil beds, any barren sands penetrated by it would be eventually flooded, thus ruining adjacent wells in which the same beds were not cased off. If the defective well has been drilled into the oil, the water thus admitted will eventually force the oil in the reservoir away from the well. In this case some operators consider that the best policy is to shut off the water in nearby wells by landing the water string as near as possible to the oil beds, the presence of water in the wells thus finished indicating that practically all of the oil between these and the flooded well has been removed.

THE PREVENTION OF FLOODING OF OIL WELLS BY WATER.

The following statement of the injury to oil wells by flooding is taken from the report of Isaiah Bowman.[1]

Irremediable injury is constantly being wrought in both old and new oil fields by "flooding"—the invasion of the oil or gas bearing stratum by water from some higher source[2].

As water is heavier than either oil or gas, it displaces these substances or becomes mixed with them, and not only damages

[1] Isaiah Bowman, Well Drilling Methods, Water Supply Papers, U. S. Geol. Surv.

[2] The term "flooding" is also used locally in another sense with reference to cleaning wells.

the well into which the water first enters, but also floods the contiguous sands and may result in the destruction of an oil district.

In some wells flooding produces a mixture or emulsion of oil and water, which in the rock can only very slowly separate again under the influence of gravity.

Oil usually rests on salt water, and in order to keep the well in good condition as long as possible the oil should be pumped off the water slowly. In a state of rest the oil and the water are separated by gravity. The flow of oil from a well producing 500 barrels a day is so slow that it does not disturb the water, but if the amount is as great as 5,000 barrels a day the oil is drawn over the water so rapidly that the two are to some extent disturbed and the water is drawn into the porous beds containing the oil.

An emulsion is also formed if the well has been put down too far into the oil-bearing strata and the water level has risen by reason of continued and rapid outflow of oil. Forced production is often practised, however, because it enables the owner of one well to draw oil from under his neighbour's property before his neighbour has had time to sink a well. In small fields this forced production is important, because the oil is soon exhausted, and each well owner tries to get as large a share of the supply as possible.

Rapid pumping may exhaust a well and cause water to rise in the area around its lower end so as to flood adjacent wells and render them useless, as was shown in the fields at Chanute, Kansas, at Humble, Tex., and some fields in Illinois.

Rapid pumping may have the further disadvantage of making it necessary to store large quantities of oil at the surface, where 25 per cent of it may be lost during a single summer by evaporation. The sand or rock originally holding the oil is its best reservoir, because it does not permit evaporation, and it furnishes the maximum yield.

Well owners have apparently not realized the importance of considering the durability of well casing in connexion with flooding, yet the decay of the casing is probably the chief cause of the trouble. A well to which water has had no access for a score of years may be suddenly rendered useless by flooding caused by decay or break in the casing. It is more probable that by action of minerals in the water, chiefly iron sulphate, the pipe has been corroded and water allowed to come into the well.

Another source of flooding may be an abandoned or dry well—one that does not yield oil or gas, but contains water. The hole may have been drilled into sands that yield oil at some near-by point, and unless the hole is properly plugged before it is abandoned water from it may enter the oil sand, find its way into neighbouring wells, and cause great damage.

Where the rock throughout an oil field is widely flooded, as from abandoned wells whose locations even are no longer known, there seems to be no remedy for the flooding, either by pumping or by drilling deeper.

PERMANENT EFFECTS.

The permanence of the effects of flooding may be judged from the results of experiments made by a number of well owners. Mr. L. C. Sands, secretary of the Oil Well Supply Company, attempted over twenty years ago to restore a flooded area at Elizabeth, W. Va. The wells of the locality produced oil before the civil war at the rate of 200 to 300 barrels a day, but when the war began they were abandoned and water accumulated in them. Mr. Sands purchased about 1,000 acres of oil-producing land and attempted to pump the water off the oil sand. The pumping was continued for a long time, but the yield of oil was increased only about a barrel a day, and the experiment was therefore abandoned.

Flooding is a serious matter. Again and again it is caused by the ignorance or carelessness of the drillers that first enter a field, who practically destroy all chance that it will ever be successfully exploited. Wild-cat drillers in a new field, who work rapidly and move from one place to another, frequently cause flooding, for they drive many wells that do not yield oil or gas, and abandon them without casing off the water or properly plugging the wells. Even the casing may be withdrawn. Water and oil may be found near by and after the oil well is pumped for some time it begins to show water, which has entered from the hole first drilled and flooded the sands—that is, has partly displaced the gas and oil.

The term wild-cat driller is applied to one who drills in a locality where oil or gas has not previously been found—that is to say, to a driller engaged in exploration.

STATE LAWS FOR PREVENTION OF FLOODING.

PLUGGING.

To guard against flooding, several states in which oil and gas are found have passed laws making it an offense to abandon a drill hole without first plugging it with a wooden plug of a specified length, to be driven down by the drilling tools. The wood swells under the influence of the water and presses against the inner surface of the casing, firmly sealing it at the bottom. Most of the laws prescribe the distance above or below the oil sands at which the plug is to be driven.

If water fills the well to a considerable depth it is difficult to lower through it a plug of the required size, hence the plug is made in the form of a hollow cylinder, which is lowered to the well bottom, and a pin or plug is firmly driven into it by the string of tools. Several feet of earth are then thrown on top of the plug to complete the sealing process. If oil and gas are found at several horizons plugs must be inserted below the lowermost and above the uppermost horizon, and if a water-bearing stratum lies between oil and gas bearing strata this must be plugged satisfactorily both at its top and bottom. In addition the top of the well must be closed by a plug.

A few of the statutes relating to the plugging of abandoned wells are quoted here, as they show the seriousness with which flooding is viewed.

In Pennsylvania a law passed June 10, 1881 (sec. 1, P. L. 110), prescribes that—

> Whenever any well shall have been put down for the purpose of exploring for any producing oil, upon abandoning or ceasing to operate the same, the owner or operator shall, for the purpose of excluding all fresh water from the oil-bearing rock, and before drawing the casing, fill up the well with sand or rock sediment to the depth of at least 20 feet above the third sand or oil-bearing rock, and drive a round, seasoned, wooden plug at least 2 feet in length, equal in diameter to the diameter of the well below the casing, to a point at least 5 feet below the bottom of the casing, and immediately after the drawing

of the casing shall drive a round wooden plug into the well, at the point just below where the lower end of the casing shall have rested, which plug shall be at least three feet in length, tapering in form, ahd to be of the same diameter at the distance of 18 inches from the smaller end as the diameter of the well below the point at which it is to be driven (and) after it has been properly driven, shall fill in on top of same with sand or rock sediment, to the depth of at least 5 feet.

Ohio has statutes equally specific, as follows:—

Sec. 306-4. It shall be the duty of the owner of any well drilled for gas or oil and which in drilling shall have passed through any vein of mineral coal, before abandoning, or ceasing to operate such well, and before drawing the casing therefrom to seal the same in the manner following: There shall be driven in such well to a depth of at least 10 feet below the floor of the lowest coal measure a round seasoned wooden plug at least 3 feet in length and equal in diameter to the well at that point, on the top of which plug shall be filled at least 7 feet of sediment or drillings, or cement and sand. Where any gas or oil well passes through any gas or oil bearing rock lying above the coal measures, the owner of said well or his agent shall, upon abandoning or ceasing to operate such well, drive a dry wooden plug not less than 2 feet in length, equal in diameter to the diameter of the hole, to a point as near as possible to the top of the coal vein, on the top of which plug there shall be filled at least 5 feet of sediment or drillings, or cement and sand, as the mine inspector shall direct.

In case such well is not plugged as aforesaid within ten days from the abandonment thereof, the chief inspector of mines or a district inspector of mines may cause the well to be plugged, and the costs and expenses of such plugging may be recovered of the person, firm or corporation whose duty it is to plug the same; in the manner provided for the recovery of penalties by section 303-5 of the Revised Statutes of Ohio.

Indiana well owners are protected by the following statute:—

Sec. 651. *Plugging abandoned wells.* 2. Whenever any well shall have been sunk for the purpose of obtaining natural gas or oil or exploring for the same, and shall have been abandoned or cease to be operated for utilizing the flow of gas or oil therefrom it shall be the duty of any person, firm, or corporation having the custody or control of such well at the time of such abandonment or cessation of use, and also of the owner or owners of the land wherein such well is situated to properly and securely stop and plug the same as follows: If such well has not been "shot" there shall be placed in the bottom of the hole thereof a plug of well-seasoned wood, the diameter of which shall be within one-half inch as great as the hole of such well, extend at least 3 feet above the salt water level, where salt water has been struck; where no salt water has been struck such plug shall extend at least 3 feet from the bottom of the well. In both cases such wooden plugs shall be thoroughly rammed down and made tight by the use of drilling tools. After such ramming and tightening the hole of such well shall be filled on top of such plug with finely broken stone or sand, which shall be well rammed to a point at least 4 feet above the Trenton limestone, or any other gas or oil bearing rock; on top of this stone or sand there shall be placed another wooden plug at least 5 feet long with diameter as aforesaid, which shall be thoroughly rammed and tightened. In case such well shall have been "shot" the bottom of the hole thereof shall be filled with a proper and sufficient mixture of sand, stone, and dry cement so as to form a concrete up to a point at least 8 feet above the top of the gas or oil bearing rock or rocks, and on top of this filling shall be placed a wooden plug at least 6 feet long, with diameter as aforesaid, which shall be properly rammed as aforesaid. The casing from the well shall then be pulled or withdrawn therefrom, and immediately thereafter a cast-iron ball 8 inches in diameter shall be dropped into the well and securely rammed into the shale by the driller or owner of the well, after which not less than 1 cubic yard of sand pumping or drilling taken from the well shall be put on top of said iron ball. (R. S., 1897, sec. 7888; R. S., sec. 7511.)

The following law also makes it possible for others besides the well owner to remedy the defect and recover the cost of the labour and material:—

Sec. 653. *Liability.* Whenever any person or corporation in possession or control of any well in which natural gas or oil has been found shall fail to comply with the provisions of this act, any person or corporation lawfully in possession of lands situated adjacent to or in the vicinity or neighbourhood of such well may enter upon the lands upon which such well is situated and take possession of such well from which gas or oil is allowed to escape in violation of the provisions of section 1 of this act, and pack and tube such well and shut in and secure the flow of gas or oil, and maintain a civil action in any court of competent jurisdiction in this State against the owner, lessee, agent, or manager of said well, and each of them jointly and severally, to recover the cost and expense of such tubing and packing, together with attorney's fees and cost of suit. This shall be in addition to the penalties provided by section 3 of this act. (R. S., 1897, sec. 7890; R. S., 1901, sec. 7513.)

NECESSITY FOR RECORDING WELL RECORDS.

A complete and accurate record or log of the well while drilling should be kept by either the contractor or the field man. All formations and known sands should be shown with their proper names, depth of finding oil, gas, or water, and a statement of the thickness of the sands, with an opinion of the quality of the sand, should be included in the report.

In the United States in Pennsylvania, West Virginia, and Ohio, where natural gas and oil occur in the same regions in which large coal mining operations are conducted, accidents have sometimes occurred, owing to the fact that mines were extended into regions in which wells had been sunk and abandoned years ago; the gas escaping into the mines and becoming ignited. In order to prevent such disasters, it is quite important that records of all holes drilled in the west should be filed by the Government, as recommended by the Commission of Conservation.

DRILLING LINE AGREEMENTS IN CALIFORNIA.

In order to overcome the great disadvantage of forcing each company to drill on the property line to offset the wells on contiguous leases, much progress has been made in California in agreements to limit drilling to a given number of feet from the line.

Kern River Field.

The old practice in this field was usually to drill 100 feet from the property line. In later years this has largely been modified to 150 feet. The Associated now drills 150 feet from the lines but is not always able to get the neighbour to agree to this. In general the larger companies agree to this readily while the smaller companies, whose holdings are limited, drill closer, usually 100 to 125 feet. Probably none drill closer than 100 feet. These agreements are binding contracts and have been in vogue since the early years of the field. The oil sands are fairly uniform over considerable distances in this field and a uniform system is possible.

Coalinga Field.

Here the usual practice is to drill 150 feet from the line. On Section 36 the Associated drills 300 feet from its lines and where adjacent to the Kern Trading and Oil Company, the same is done by the K. T. and O. No other company in the field uses the 300 foot distance.

McKittrick Field.

Here the field is narrow and irregular. No uniform practice is used, where conditions permit the wells are not less than 100 feet from the lines. In one instance near the southwest limit of the field, there is an agreement between the Reward, C.J. and K. T. and O. companies in which the companies to the south drill 50 feet from the line and those north drill 150 feet making the distance between wells 200 feet. No uniform rule has been made to fit the McKittrick field on account of the complicated nature of the geology.

Midway Field.

The Associated has not operated in this field previous to 1910. Most of the wells in the "25 Hill" area were drilled 150 feet from the lines. Many of the older wells in other parts of the field were drilled very close to the lines but this may have been due to uncertainty as to the exact location of the lines. On its property in what is considered gusher territory, the Associated is endeavouring to get agreements with its neighbours to drill not closer than 300 feet from the property lines. It is presumed that with deep drilling and comparatively light free flowing oil, 600 feet between wells will be the most economical distance.

LINE DRILLING AGREEMENT.

....

And

ASSOCIATED OIL COMPANY.

Dated:

This Agreement, made and entered into this......................day of............... 19...., by and between.. the party of the first part, and ASSOCIATED OIL COMPANY, a corporation, the party of the second part.

WITNESSETH:

That Whereas, The party of the first part is the...................................... of the following described lands situate in the County of................................ State of California, in what is known as the...Oil District, to wit:

and is engaged in the business of developing the same and producing crude petroleum therefrom: and

Whereas, Said party of the second part is the.................................... of the following described lands, situate in the County of................................ State of California, in what is known as the...Oil District, to wit:

and is engaged in the business of developing the same and producing crude petroleum therefrom.

All of which lands are specifically delineated on blueprint hereto attached, referred to and made a part hereof, which blue print shows the dividing lines between the respective properties of the parties hereto; and

Whereas, It is important that wells should not at any time be drilled or sunk nearer to said dividing line between said properties than as indicated on said map or plate hereunto attached; and

Whereas, Said first party has already drilled wells along said dividing line as delineated on said map or blueprint, as follows:

And Whereas, Said second party has drilled wells on its property along said dividing line, as follows:

Now, Therefore, In consideration of the premises and the sum of Ten (10) Dollars by the parties hereto interchangeably in hand paid, the receipt whereof is by each hereby acknowledged, said parties hereto do hereby contract and agree as follows, to wit:

Said....................................party shall have the right to drill ....wells on its property along said dividing line and....................................feet therefrom as an offset to the wells drilled by....................................party along said dividing line, as indicated on said blue print.

It is further understood and agreed between the parties hereto that except as hereinabove stated, neither of the parties hereto will drill any well or wells closer to...................... line between the lands hereinabove described than.................................... feet from said dividing line; said dividing line forming the.................................... boundary line of said properties of first party and the.................................... boundary line of the properties of said second party hereto.

It is further understood and agreed by and between the parties hereto that upon any violation of any of the conditions hereinabove stated, either of the parties hereto shall have the right to apply for and obtain an injunction or injunctions, as the case may be, against the other for such violation and shall also have the right to use all other proper laws or remedies at law as the case may require.

This contract shall be binding upon and shall run with the land hereinabove described, and all right, title and interest of each of said parties therein shall be and the same is hereby made security for the faithful performance of this agreement.

This agreement shall be binding upon the successors and assigns of the respective parties hereto.

In Witness Whereof, the parties hereto have caused these presents to be signed by their officers thereunto duly authorized and their respective corporate seals to be hereunto affixed this the day and year first above written,

....

By....................................

By....................................

OIL COMPANY,

By....................................
President.

By....................................
Secretary.

DEEP WELLS.

The general policy of the larger oil companies in exploring any large oil field is, at sometime during the development, to make such deep drilling tests as will determine the greatest depth at which oil wells should be sought.

This subject is further discussed in connexion with the chapter on the efficiency of oil well drilling by Mr. R. H. Johnson.

This work, however, has produced certain wells which are phenomenal from the standpoint of well-drilling results, and are tabulated below.

Lately the United States Government and the Carnegie Institute are uniting in a systematic study of such deep wells with a view to determine rate of increase in temperature with depth, and with the view of determining whether any special terminal temperature can be connected with the occurrence of oil.

Of most prominent interest, in connexion with this deep drilling work, is the well still in progress at Derrick City, near Bradford, McKean county, Pa. This well is being drilled to test the Medina sands for oil and gas.

The drilling was started with a diameter of 12 inches and has proceeded with remarkably few accidents, and has now reached a depth of 5,673 feet. It is hoped that this well will be continued to the utmost depth possible.

DEEPEST WELLS IN AMERICA.

The deepest well ever drilled in America was sunk by the Forest Oil Company at West Elizabeth, Pennsylvania, 12 miles from Pittsburgh, to a total depth of 5,575 feet. It was started about 100 feet below the Pittsburgh coal vein. Only one string of casing was used, it being 6¼ inches in diameter and 900 feet deep. At 2,285 feet below the surface a quantity of gas was struck, which was sufficient to make steam to drill the rest of the hole. At 5,500 feet the temperature was 129°F. At that depth the crown pulley broke, cut the rope and dropped the tools 100 feet, causing a suspension of operations, and causing the well to be a failure.

To drill the well extra heavy machinery was necessary. The total weight of cable from top to bottom used in drilling was 14,000 pounds, representing a value of $2,250. The approximate cost of the well was $40,000.

The deepest well in the Eastern States that ever produced oil is supposed to be situated on the G. Robinson farm in Wetzel county, W. Va., and it reached a depth of 3,555 feet.

CONTRACT DRILLING.

Drilling by contract is advisable, provided the operator conscientiously looks out for the best interests of the proprietor in actually finding oil rather than drilling for a speed limit or to reach an exceptional depth in a given time. An important duty of the driller is the exclusion of water from the well during the process of drilling and though he usually receives only a small amount of pay during the suspension of drilling for this purpose, this course is necessary for complete success in bringing in a productive well.

The form of contract varies in different localities. Certain parts of the machinery as well as fuel and water must usually be found by the contractor, though he is sometimes furnished everything by the proprietor. The following is a typical form of agreement used by one of the largest oil companies of the United States:—

This Agreement, made this ....day of ..................................A.D., 19......, between..............................of ....parties of the first part, and the............ ....Oil Company, party of the second part.

Witnesseth, That the said parties of the first part have covenanted and agreed with the said party of the second part, its successors and assigns, that said parties of the first part will drill for said party of the second part a certain well for the purpose of obtaining petroleum oil or natural gas, to be known as WELL No..............................on the farm of township..county.....................................

The material, machinery, and appliances necessary for drilling and completing said well shall be furnished, and the work of drilling the same shall be done in the manner hereinafter specified, viz.:—

A complete carpenter's rig of good quality (including wooden conductor) to be furnished by the party of the second part, and all repairs on same while well is being drilled shall be made by and at the expense of said parties of the first part.

All casing to be furnished by party of the second part.

Boiler, engine, belt, bullrope, steam and water pipe, and connections to be furnished at the well by party of second part.

The expense of fitting up and connecting same to be borne by parties of the first part.

Fuel to be furnished at expense of the parties of the first part.

Water to be furnished at the expense of the parties of the first part.

Oil saver and steel measuring line at expense of the party of the first part.

All machinery, material, and appliances furnished by said parties of the second part shall, at the completion or abandonment of said well, be returned to said party of the second part, in as good condition as when received by said parties of the first part, ordinary wear and the action of the elements alone excepted.

The said parties of the first part further agree to pay all expenses and furnish everything necessary to drill and complete said well, except the articles and appliances herein specifically mentioned to be furnished by the party of the second part.

The said well unless sooner abandoned by direction of the party of the second part, is to be drilled to 2,000 feet, the consideration for which shall be two dollars per foot.

All fresh water shall be cased off with a casing of a diameter of not less than.............. inches, and all salt water cased off with casing of a diameter of not less than...........inches.

TABLE XV.

List of Deep-Well Borings.

Data collected by B. L. Johnson.

Location.	Depth Feet	Diameter Inches	Object	Remarks
East of Rybnick, Up-Silesia, Germany	6,572	3·6 to 2·7	Coal	Cost $18,241—completed Aug., 1893, after 1½ years' work—deepest bore in the world.
McDonald, Washington co., Pa.	6,487		Oil or gas	Still drilling.
Schladeback, near Leipsic, Germany	5,735	11 to 1·3	Coal	Cost $53,076—completed about 1893. Average daily rate of drilling 4½ feet.
Derrick City, near Bradford, Pa.	5,673	12 to 6	Oil	Boring being continued.
Springs, 25 miles east of Johannesburg, So. Africa	5,582	2 to 1⅜		Completed 1905, after 9 months' work. Diamond drill hole.
Dornkloof, 16 miles east of Randfontein, So. Africa	5,560	2 to 1⅜		Completed December, 1904, after 14 months' actual work—diamond drill hole.
In Aleppo township, Greene county, Pa.	5,322	13 to 6⅝	Gas	Abandoned July, 1905.
2½ miles west of West Elizabeth, Pa	5,575	10 to 6¼	Oil	Cost $40,000—deepest well drilled with a cable—deepest well in the United States—third deepest well in the world.
Bimerah Run, Queensland	5,045		Water	Flow, 70,000 gallons a day.
Randfontein, South Africa	5,002			Diamond drill hole.
Slaughter creek, Kanawha co., W. Va.	5,000			
Spur, Dickens co., Texas	5,000			
Gaines, Pa.	5,000			
Bimerah, Queensland	4,860			
Turfontein Estate Johannesburg, So. Africa	4,845			Diamond drill hole.
Near Boksberg on the Rand, South Africa	4,800			
Pittsburgh, Pa.	4,618		Oil or gas	
Elderslie No. 2, Queensland	4,523		Water	Flow, 1,600,000 gallons a day, temperature 202° F.
Clarksburg district, South Africa.	4,500			
In the Black Reed series 12 miles south of the main reef series on the Rand	4,500			Diamond drill hole.
4 miles southeast of Wheeling, W. Va.	4,500	4⅞	Oil or gas	
In the city of Erie, Pa.	4,460		Oil or gas	Abandoned 1889.
One well in State of South Australia	4,420		Water	Flow 600,000 gallons a day.
Irwin, Westmoreland county, Pa.	4,380		Oil or gas	
Buchanan well, 6½ miles south of Burgettstown, Pa.	4,303		Oil or Gas	
Knurow, Upper Silesia	4,173	192 to 13		
Glenariffe, Queensland	4,140			
Warbreccan, Queensland	4,125			
Dolgelly bore, New South Wales	4,086		Water	Flow, 745,200 gallons a day.
Northampton, Mass.	4,022		Water	
Winton, Queensland	4,010			
In the Vlakfontein district, South Africa	4,003			
New Haven, Conn.	4,000	8	Water	
Renova, Pa.	4,000		Oil	
Darr River Downs, No. 4, Queensland	4,000			
Norris well, Findlay, Ohio	3,000			
Grubb well	2,470			

The diameter of the well when completed shall not be less than..................inches.
The outside strings of casing, viz., the..............................inch and ....inch, shall be pulled at the expense of the party of the second part.

When said well reaches the oil or gas-bearing sand, the method of drilling through the same shall be under the direction of said party of the second part, or its agent in charge of the farm or lease, and if oil or gas is found in sufficient quantities to endanger the rig and material by fire from the boiler, then said parties of the first part shall, without delay, and at second party's own expense, move the boiler to a safe distance from the well. All pipe fittings made necessary by such removal to be furnished by the said party of the second part.

When completed, unless prevented by too great a volume of gas or oil, the well shall be thoroughly "bailed" and "sand pumped" by the said parties of the first part, until all drillings and sediment are removed therefrom and the well thoroughly cleaned.

The parties of the first part shall carefully examine all machinery, casing, and other appliances to be furnished for said well by the party of the second part, and if any defect be found therein sufficient to make the use of such machinery, casing, or other appliance unsafe, shall immediately notify the party of the second part of such defect or defects, and the party of the second part shall at once replace the article so found defective with a good and safe one; but if the parties of the first part shall not make such examination, or shall not report any defects in said machinery, casing, or other appliance, they shall be deemed to have assumed all risks and all responsibility for any mishap which may occur in the drilling of said well by reason of a failure in such machinery, casing, or other appliance.

No part of the contract price mentioned shall in any event be paid until said well be completed to the depth above required, and delivered to the party of the second part in thorough good order, free and clear of all obstructions.

The parties of the first part agree to begin the drilling of said well within thirty days from..and prosecute the work actively and continuously (Sundays excepted) to completion.

It is Further Agreed, That time shall be of the essence of this contract, and that in case the parties of the first part shall neglect or discontinue the work of drilling said well for the space of ten days, such neglect or discontinuance shall of itself be a forfeiture of all rights and claims of the parties of the first part under this agreement without any notice or demand by the party of the second part. The party of the second part shall have the right at any time after such forfeiture to take possession of said well, discontinue the drilling thereof, and at its pleasure dismantle or abandon the same without liability to the parties of the first part for any portion of the contract price above mentioned. The party of the second part shall also have the right at any time after such forfeiture as above mentioned, if it so elects, to take possession of said well and all the ropes, tools, and appliances thereat of the parties of the first part, and drill said well to completion. In case it shall succeed in completing said well, the cost of such completion without any allowance to said parties of the first part for the use of the said ropes, tools, and appliances, shall be deducted from the contract price above mentioned, and the balance, if any, paid to the parties of the first part; but if said party of the second part should not succeed in completing said well, it shall not be liable to the parties of the first part in any sum whatever, and shall return said tools, ropes, and appliances to the parties of the first part in as good order as when received, natural wear and tear and accidental loss or breakage excepted.

In Witness Whereof, the parties of the first part have hereunto set their hands and seals, and the party of the second part has caused these presents to be signed by its representative the date first above written.

CHAPTER VII.

PUMPING, STORAGE, AND TRANSPORTATION OF OIL AND GAS.

PUMPING THE WELLS.

If wells are not "gushers," that is, if they do not flow of their own accord, they must be pumped. The preliminary pumping to determine the capacity and character of a new well is usually done directly from the walking beam of the drill rig. After more than one well has been brought in, however, the pumping is done from a central power plant by means of pull rods or pumping jacks, or in the Canadian fields by jerker rods, bell cranks and walking cranks. The pull rods are usually steel rods or wire cable mounted on supports at different heights, depending upon the topographic configuration of the land. An oscillating pull wheel or jerker in the central power house, by means of large double pull rods, which radiate from the power house, actuates a number of flat pumping discs, which rotate through about 50 or 60 degrees and from which further pull rods radiate to the pumping jacks over the individual wells. In this way a great number of wells may be pumped from a single power plant, and it becomes possible to profitably pump wells of small yield. The pumping jack consists of a right triangular framework suspended on a pivot at the right angle and connected up with the pump at the upper acute angle, and with the pull rod at the lower acute angle, so that when the pull rod brings the lower angle forward, the upper angle rises carrying up the pump rods. The weight of the sucker rods sinking back into the well takes the slack in the pull rods and brings them back into position for another pull. When the sucker rods are either too heavy or too light a weight on the appropriate arm of the triangle suffices to balance things.

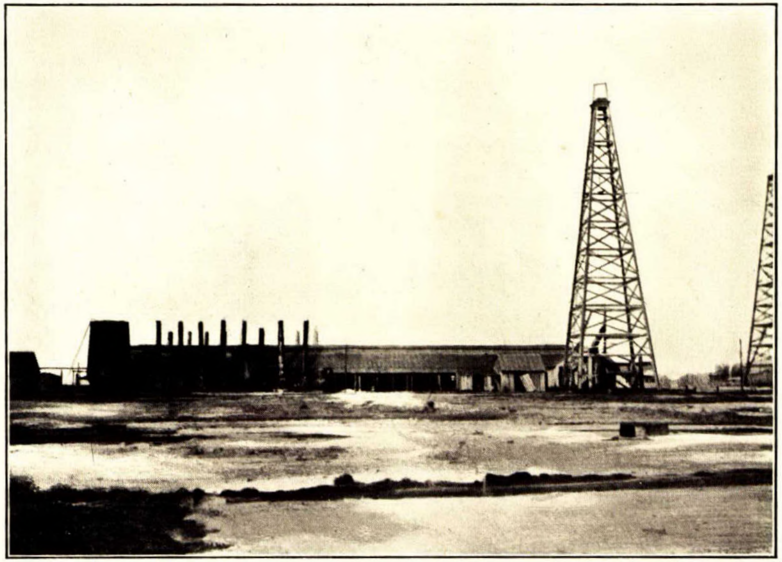
The pumping jacks are made of wood or steel. In the home-made form of pumping jack, the pivot angle is at the bottom, the pull angle at the top, and the pumping angle is connected with the pump by a rigid rod, by the thrust of which the pump is moved. In the Petrolia field wooden shackle rods, jerker lines, take the place of steel rods and cable, and are capable of transmitting the power many hundreds of feet, and in some cases as much as a mile. When the direction of the power must be changed horizontally, cranks are used, *e.g.*, where the pull is transmitted to the horizontal walking beam pump at the well. The jerker system of pumping was adopted in this field at an early date. Before that the wells had been worked by man power with spring poles.

The number of wells pumped from one power plant varies greatly. On the C. O. Fairbanks property at Oil Springs, 200 wells are pumped by one 40-horse power steam engine; and at one time there were 242 wells on this engine. The Canadian Oil Fields Co., Ltd., operates 240 wells from one power plant at Petrolia, and J. L. Englehart and Co. pull 226 pumps from one central power plant described in more detail below. In the Petrolia field a 12-horse power engine has driven as many as 90 pumps. A 50-horse power engine is generally regarded in the United States as capable of pumping 175 average wells. The cost of pumping in large series is so small that wells yielding but a few gallons daily are worked at a profit.

The following description of pumping arrangements on the J. L. Englehart and Co.'s land at Petrolia, is taken from the Canadian Department of Mines Report on the mining and metallurgical industries of Canada, 1907-8, page 435:—

"The pumping system which has been developed in the Petrolia oil fields is a somewhat interesting one, and differs in some particulars from that in vogue in Pennsylvania. A good example of this system is the plant operated by this Company. One central power plant pumps direct from 226 wells, scattered over an area of 400 acres. It is a balanced system, half of the dead load of rods and mechanism in the field being lifted, while the other half is descending, so that the power required is only that for overcoming inertia and friction, plus the weight of the oil lifted at each stroke. Counterweights are unnecessary, thus reducing the mass of material to be moved, and giving in consequence a higher efficiency. In the case of the Englehart plant, four engines, coupled in pairs, each of 40 indicated h.p., serve the entire group of 226 wells. These two pairs of engines are connected to two main, or master wheels, which, in addition to direct connexions to pumps, operate 22 secondary or local wheels, each controlling two jerker rods. These are large disks, set horizontally, cast with four lugs, at the ends of two diameters at right angles

Plate XIV.



Compressed air-pumping plant of Crowley Oil and Mineral Co., Crowley, La.

to each other. Each lug carries two wrist pins for connecting the jerker rods. The wheels have a reciprocating motion imparted to them, which causes them to swing through an arc sufficiently to give the jerker rods the necessary forward and backward motion to produce the proper length of stroke at the pumps, which is communicated to them in the ordinary way by walking-beam or triangle-arm connexions. The jerker rods are of wood, with spliced joints, suspended from posts by pin-connected hangers of iron, and serve, in conjunction with the pump rods, as the counterbalance in the system. The pump rods are of gas pipe, $\frac{3}{8}''$ pipe being used with a $1\frac{1}{4}''$ pump, and $\frac{1}{2}''$ pipe with a $1\frac{1}{2}''$ pump, the average length being 475 feet.

"The power plant consists of two tubular boilers of a total capacity of 200 h.p., heated partly by natural gas (derived from 7 wells), and partly by coal. There are 32 underground collecting tanks, each of 50 barrels capacity, distributed through the field, and two main collecting tanks, each of 700 barrels capacity, close to the power plant. A 2″ pipe line connects the main tanks with the receiving station of the Imperial Oil Company, on the 12th line. There is also a complete drilling outfit always in use in putting down new wells."

The power for pumping is usually furnished by a gas engine or by a steam engine. A boiler is generally erected near the power house for emergency use, and for steaming the oil to precipitate suspended sulphur. In fields where gas is not available oil is burned beneath the boiler.

In some fields the oil is raised with an air lift by forcing compressed air deeply in the well through a central tube, the oil rising between this and the outer casing. The chief advantages of the air method are that it is automatic and that there are no wearing parts to get out of order and require care. However, this method has not been extensively adopted and has not been used at all in the Canadian fields.

In some fields where the wells do not flow and where there is so much sand that ordinary pumps cannot be employed, the oil is raised by a bailer holding commonly about 50 gallons. This is a long bucket which will move freely inside the well casing, and which has a valve at the bottom. The bailer is raised and lowered by means of a steam winch. This method is employed extensively in the Baku field.

STORAGE OF OIL.

The first oil from the new well is put into emergency tanks which are low cylinders of wood holding from 100 to 1,600 barrels of oil, but commonly of about 250 barrels capacity and costing about $100. When the permanent tanks are built the oil goes directly from the well to these tanks. In case there be more oil than can be taken care of in the tanks, temporary earthen reservoirs are built by throwing a dam across a hollow, or by building a square embankment on level ground. But permanence of production presupposes some system of storage. The tanks may be wooden, steel or earthen. A group of tanks is known as a tank farm. So far as the topography permits, the tanks are located so that the oil will flow into them by gravity from the contributory wells. When the oil will not flow by gravity, a donkey pump is used to force the oil from the well to the tanks.

The larger steel storage tanks, having a capacity of 35,000 barrels, are 90 feet in diameter and 30 feet in height, the steel varying from 13·64 lbs. per square foot in the lower ring of plates to 8·15 lbs. in the 7th or upper ring. Each tank has a conical roof of sheet steel and is equipped with a windlass to raise the swing pipe.

All sizes of steel and wooden tanks between the 250 barrel wooden tank and the large steel tank are found. When several smaller wooden tanks are situated in a row, they are covered with a low inclined shed to prevent evaporation of the oil and drying and warping of the tanks.

The oil in the Petrolia fields of Canada is frequently stored in large underground tanks which are excavated in an impervious clay and are boarded over and covered with earth. These tanks ordinarily are 60 feet deep and 30 feet in diameter, holding 8,000 barrels of oil. From these tanks the oil is pumped to the refineries. The underground system of tanking was devised in the early days on account of a fire which destroyed a large amount of property in 1867. The advantage of these earthen tanks is that the clay formation makes a perfect reservoir if the hole is kept filled with oil or water, and moreover the earth-covered tanks are practically fire and lightning proof. The following notes on the use of these earthen tanks are taken from an article by James Kerr in the Toronto Mail, December 1, 1888.

One of the necessities from the want of which the early oil operator suffered was tankage in which to store his oil pending the season of the year in which the bulk of it would be required, or to tide over a plethora of production till the requirements of the market could overtake it. Naturally the Canadians erected in the first place great wooden tanks, which increased in time to enormous proportions, some of them being as large as 24 feet in diameter and 29 feet deep, set on the ground and bound with iron hoops. Large iron tanks were introduced in 1865, two of which of 3,000 barrels capacity still remain a memento of that period. These, however, were found very expensive and subjected the oil stored in them to many sources of danger, and a vast improvement was found practicable, and of such a nature as no other part of the world has been known to supply.

The Erie clay, before referred to, would almost appear to have been supplied for the express purpose of oil storage. This clay is of a solid tenacious quality, free from seams or flaws, and easily removed. When properly constructed the tanks sunk therein prove to be cool, perfectly free from danger or loss from leakage or evaporation or destruction by fire, whether caused by lightning or otherwise. The tank is formed by excavating a circular hole about 30 feet in diameter to a depth of about 15 feet through the top soil, the Saugeen clay, which is somewhat porous; a wooden crib is placed therein formed of double inch rings, five inches wide, outside of which boards are nailed and clay from the strata below is solidly packed between the curbing and the wall, making a solid "pudding" about five inches thick. The sinking of the tank is then proceeded with to a depth of 50 or 60 feet; the entire wall is lined with segments made of inch pine about five inches wide, forming a perfectly tight tank holding from 8,000 to 10,000 barrels of oil, which saturating the wood renders it exceedingly durable. Timbers are projected across the top, supported by a bolt from the arch over it; joists are laid thereon, covered with plank and clay and the contents rest in perfect safety till required.

A large number of these tanks (of which about one million barrels capacity exist in this locality,) are owned by companies, who receive the oil from the producers at the wells and convey it through their pipe lines, some of which are nine miles in length, storing it and issuing certificates to the owners thereof.

In the Petrolia field tanking is undertaken by the Tanking Company which has many miles of pipe throughout the field, in order to gather the crude from the producers into the central underground tanks. The prices charged by the Tanking Company are necessarily variable, but range from 2 to 37 cents a barrel, according to the distance from Petrolia. The tanks are at Petrolia, and there are 50 or more of these reservoirs with a storage capacity of 8,000 barrels each, or a total capacity of 400,000 barrels. An 8,000-barrel tank of this description can be completed in six weeks at a cost of $1,760.

Storage capacity must not only be provided on the lease, at the loading rack, at the pipe line pumping station, and at the refinery, but also at the seaport, if the oil is to be transported over sea in tank steamers, and at the seaport where the oil is delivered by the tank steamers. A 37,000 barrel tank of the latter sort was recently completed near the wharves of the

Grand Trunk Pacific railway at Prince Rupert, British Columbia. An inner steel shell is surrounded and reinforced by a concrete wall 3 feet thick at the base, but somewhat thinner at the top. Pipes are laid under the wharves through which the oil is pumped into the tank from tank steamers which bring the oil from California. The oil is to be used as fuel for oil-burning locomotives on the Grand Trunk Pacific railway.

TRANSPORTATION OF OIL.

Where an oil field has a small yield, as when a small output of oil is incidental to natural gas production, and the market is purely local and the oil is used in a crude state, the means of transportation and distribution are apt to be correspondingly simple and primitive. For instance, in the gas fields of New Brunswick some of the wells yield a few gallons of oil per day. This is piped to a loading tank by the roadside, from which it is transferred to tank wagons which distribute it.

Some heavy lubricating, or otherwise peculiarly valuable oils which do not occur, or are not purchased in quantity sufficient to make a separate run in a pipe line or even to justify shipping in a tank car, or which are destined to points away from railway or pipe line facilities, are shipped in wooden barrels, or more generally in steel drums. In the early days of the industry, of course, this was the customary method of shipping crude oil, but now on land the great bulk of the petroleum product is transported in pipe lines, with smaller quantities in tank cars, and, on the ocean, in tank steamers.

Tank barges, 130 feet long by 22 feet wide and 16 feet deep, holding 2200 barrels of oil, were used in the early days of the Pennsylvania oil industry to transport crude oil from the wells on the lower Alleghany and the Little Kanawha to the refineries on the Ohio river.

In transporting oil by rail, the first form of tank cars in use about 1865 or 1866 consisted of flat cars on which two wooden tub-like tanks, holding about 2,000 gallons each, were fastened. These were succeeded in 1871 by cars with tanks of the present horizontal cylindrical type $24\frac{1}{2}$ feet in length, $5\frac{1}{2}$ feet in diameter, and holding about 5,000 gallons. The tank cars now used are 32 feet long, 6 feet in diameter, and hold 8,000 gallons. A train of tank cars is filled simultaneously from a loading rack which consists of a long platform beside the track and about on a level with the top of the tanks. The oil feed pipe runs along this platform, and at intervals equal to the distance between domes of the tank cars is fitted with valves and T branches through which, with suitable extensions, the oil is conveyed into the tanks. Such loading racks are provided with facilities for measuring the oil put into the tank cars.

In the Kansas and Oklahoma oil fields of the United States, in 1913, there were in September, 1382 tank cars still in use among refiners and small shippers. In addition to the cars owned by the railway companies, the Standard Oil Company and the Texas and Gulf companies, certain refining companies also had a large number of tank cars in these States and they were used also in connexion with eastern plants. In 1904 the Union Tank Line Company, a subsidiary of the Standard Oil Company, had about 9,000 tank cars, and the Waters Pierce Company had about 1000 tank cars. The capacity of the tank cars in the Kansas and Oklahoma fields ranges from 4,000 to 10,000 United States gallons.

The first successful pipe line was laid in Pennsylvania in 1865, was four miles in length, and was put two feet underground. The sections of pipe were joined by carefully fitted screw-sockets, whereas previous pipe lines had failed because of leaky joints. From that time until the present the use of pipe lines has rapidly grown. Most of the oil produced in the United States, except in Texas, Louisiana, and California, is transported to the refineries by means of pipe lines. A network of small pipes gathers the oil from the wells and trunk lines, often of great length, and conveys it to the refining point. The oil of Texas and Louisiana is used chiefly for fuel, largely within the States themselves. It is, therefore, transported chiefly in tank cars, though there are several short pipe lines to the Gulf ports. California oil is also used mostly for fuel but pipe lines reach from the oil fields to tidewater at Port Richmond and to the refinery at Port Costa and other points.

The rifled pipe line, introduced in 1907, greatly facilitates the transportation of the heavy viscous grades of oil. This pipe is provided with spiral grooves about an eighth of an inch in depth, and making a complete revolution of the pipe every ten linear feet. Through these grooves a lubricating current of water is pumped with the oil. In California the heavy oils are heated with steam and sometimes mixed with lighter oil or water, before being admitted to the pipe line. Insulating the pipe with some non-conductive covering is also found to help.

The construction and operation of pipe lines is discussed with some fullness in the chapter by Mr. Towl in the following pages.

The pipe lines of the United States, comprising those of seventeen subsidiary companies of the Standard Oil Company, and eight independent lines, owned and operated pipe lines, were estimated by the United States Bureau of Corporations in 1907 to total more than 45,000 miles of pipe ranging from 2 to 12 inches in diameter. The majority of the lines are 6 or 8 inches in diameter. The largest continuous line reaches from Oklahoma to New York city.

Two of the chief producing oil fields of Canada, the Petrolia and Oil Springs fields, are located within eight or ten miles of the refinery of the Imperial Oil Company, Ltd., at Sarnia, on the St. Clair river. From six receiving stations in these fields the oil is carried through pipe lines of the Imperial Oil Company to the refinery at Sarnia. From a receiving station in the centre of the East Tilbury field, oil is delivered through a 4-inch pipe line owned by the Imperial Oil Company to a large receiving tank of 700 barrels capacity at Merlin station on the Père Marquette railway. From Merlin the oil is shipped in tank cars to the refinery at Sarnia. These several short lines, together with the feeders from the producing properties to the receiving stations of the Imperial Oil Company, comprise all the oil pipe line service of the Dominion.

By sea, crude petroleum is transported in tank steamers or tank barges. Fuel oil from the Texas and California fields is piped to the seaports as noted above, and distributed to the various markets by tank steamers. Mexican oil likewise goes to European refineries and markets in tank steamers. From the eastern seaboard of the United States some crude oil is shipped to Europe in tank steamers and in tank sailing vessels, but the main employment of tank steamers is for shipping in bulk, refined oil or kerosene. On the Caspian sea, early in 1913, there were 168 vessels engaged in the transport of oil to and from different parts of the Russian empire. The vessels fitted with Diesel engines, owing to their low consumption of fuel, are rapidly replacing the other forms of power boats. As has just been said, the bulk of the oil transported in tank steamers is refined oil, including kerosene. Since 1905 the Standard Oil Company has also used tank barges. The tank steamer carrying 400 tons of oil tows a tank barge carrying 6,000 tons of oil, by means of a 600 fathom steel-wire hawser, fitted with winding drums which automatically take in or pay out the hawser depending on the strain upon it and thus act as shock absorbers. Both steamers and barges are entirely of steel, divided into compartments by bulkheads and provided with means of escape for the oil gases, and with supply tanks to make up any loss of oil in the tanks by leakage or evaporation. The Imperial Oil Company operates three tank steamers of 6,000 barrels capacity each, and with its shipping docks near Sarnia on the St. Clair river has all facilities for shipping its products by steamer as far west as Port Arthur and as far east as Montreal.

Refined oil products, lubricating oil, kerosene, gasoline and the like when shipped by rail are transported in tank cars, in wooden barrels, in steel drums, or in tin cans. Towns on a railway and large enough to support a distributing wagon service, have receiving storage tanks adjacent to the railway switch and the oil is pumped into these tanks from the tank cars. Smaller towns, especially those without railway communication, are supplied with oil in wooden barrels usually. In the western part of the country considerable oil is shipped in tin cans in wooden cases, each container holding two cans, each of 5 gallons capacity. Much kerosene is shipped to foreign countries in such cans.

MEASUREMENT AND TRANSPORTATION OF NATURAL GAS.

The volume of natural gas yielded by some wells is enormous. The Tippecanoe well in the Findlay field of Ohio yielded 32 million cubic feet the first day, falling to 19 million cubic feet the third day. The open pressure was 38 lbs. the first day and 11 lbs. the second day. The Mellott well six miles north of Findlay yielded 28 million cubic feet with an open pressure of 28 lbs., and a well near Bairdstown furnished 33 million cubic feet daily at an open pressure of 45 lbs. The Wallace well at Fostoria yielded 50 million cubic feet daily but lasted only three days. In the Sunset-Midway district of California there are very large gas wells. The largest one, which was a shallow 18-inch well lasting only a few weeks, was reported to yield 65 million cubic feet daily. Several others were estimated at 30, 35 and 40 million cubic feet daily. The gas wells so far struck in Canada have not such large yields as those just mentioned, though a well in Essex county, Ontario, yielded 10 million cubic feet per day and several wells in the East Tilbury field yielded 1½ million cubic feet daily. The Tuna well at Medicine Hat, Alberta, yielded 6 million cubic feet, and the first wells at Bow island 7 or 8 million cubic feet daily. Well No. 4 at Bow island is reported to have had an original flow of 29 million cubic feet, as measured by Eugene Coste.

When a gas well is struck, and capped, the pressure of the confined gas rises to a maximum point known as the rock pressure. The time required for the pressure to reach this point depends upon the porosity of the gas reservoir. In porous or fissured rock it reaches the maximum very soon. In tight reservoirs some time may elapse before the rock pressure is reached. The rock pressure varies greatly in different fields. In New York rock pressures as high as 1,500 lbs. per square inch are known. Rock pressures in Pennsylvania vary from 300 to 800 lbs. per square inch; and in West Virginia, 1,000 to 1,250 pounds to the inch; the rock pressure in Ohio and Indiana ranged between 50 and 800 lbs. per square inch. The original rock pressure in the gas field of Kansas was 325 lbs. to the inch; and in Oklahoma about the same. In California the rock pressure is very great in some districts. In the Sunset-Midway district one well has been measured at 2,000 lbs. to the square inch, and this was not the maximum pressure, but only the limit of the gauging appliances. Other wells in the same district have pressures ranging from 500 lbs. up to 1,200 lbs. per square inch. In Canada according to Coste[1] the rock pressure varies with the geologic horizon of the gas reservoir as follows: "In every field where gas is found in several strata, the highest pressure is always recorded in the lowest or deepest strata; for instance, in the Welland county field the rock pressure of the gas was 300 lbs. in the Guelph dolomite; 400 lbs. in the Clinton; 525 lbs. in the Medina white sand; and 1,000 lbs. in the Trenton limestone." The rock pressure at Medicine Hat, Alberta, is 550 lbs., and at Bow island 810 lbs. per square inch."

The cause of rock pressure has been variously ascribed to hydrostatic pressure of the ground water, to pressure due to accumulation of gas by distillation from organic remains, and to pressure of gaseous emanations from beneath the sedimentary rocks. Prof. Edward Orton of Ohio maintained the hydrostatic pressure theory and apparently demonstrated its truth for the Ohio fields deriving their supply from the Trenton limestone, since in nearly every case the observed rock pressure agreed with the required pressure assuming it to be of artesian origin, taking the level of Lake Erie as the elevation of the outcrop of the Trenton limestone. However, the occurrence in New York of rock pressures of 1,500 lbs. at many hundred feet less than the hydrostatic theory would require casts doubt on this theory as a general explanation. There remains for those who believe in the organic origin of gas and oil, the theory of pressure due to gases distilled from the organic remains of the sedimentary rocks, and for those who believe in its inorganic origin, the suggestion of gaseous emanation from below.

The minute pressure of a gas well is used in one method of obtaining the open flow of the well; *i.e.*, the volume of gas which will escape from the well into the open air in one day. It yields an approximate, but conservative result, and is much in use for rough measurements. The minute pressure is obtained by allowing the well to blow into the air until its head is blown off; *i.e.*, until the open pressure becomes constant. The well is then closed very quickly, and the accumulated pressure read one minute after the closing of the well.

[1] Coste, Eugene, Jour. Can. Min. Inst. vol. III, p. 83.

The formula for determining the open flow of a well by means of the minute pressure is given by Weymouth,[1] as follows:—

"Q, the open flow capacity of the well in cubic feet per day on an atmospheric pressure base of 14.4 lbs, per square inch absolute, becomes

$$Q = 1440V \left\{ \frac{pm + Po}{Po} - \frac{Po}{Po} \right\} = 1440 \frac{Vpm}{Po} = 100Vpm$$

in which V = volume of well tubing in cubic feet

pm = minute pressure in pounds per square inch gauge.

Po = atmospheric pressure in pounds per square inch absolute.

The Pitot tube is also used in the open flow measurements of gas wells. This method, which is generally employed in accurate measurements, was devised by Prof. S. W. Robinson,[2] and is bound upon this formula:—

$$Q = 1{,}462{,}250\ d^2 \left\{ \left(\frac{P_1}{Po} \right)^{0\cdot 29} - 1 \right\}^{\frac{1}{2}}$$

in which

Po = absolute pressure of atmosphere, pounds per square inch.

P_1 = absolute pressure shown by Pitot tube, pounds per square inch.

d = internal diameter of well mouth in inches.

The Pitot tube consists of a short tube bent at a right angle and with one end drawn out into a nozzle. This tube is inserted into a horizontal pipe through which a liquid is flowing, with the nozzle pointing upstream. The height to which the liquid will rise in the vertical arm of the Pitot tube varies with the velocity of flow of the liquid and is a measure therefore of the volume of flow. The Pitot tube was adapted to the measurement of the flow of gases by bending twice the vertical arm of the tube to form an inverted U water manometer. An accurate

[1] Weymouth, Thos R., Measurement of Natural Gas, Trans. Am. Soc. Mech. Eng., vol. 34, 1912, pp. 1901-1104.

[2] Robinson, S. W., Van Nostrand's Eng. Mag. Aug. 1886; Ohio Geol. Surv., vol. 6, 1888.

TABLE XVI.

Discharge of gas 0·6 specific gravity from one inch opening corresponding to water pressure in inches.

Pressure in inches	Cubic feet per hour	Pressure in inches	Cubic feet per hour	Pressure in inches	Cubic feet per hour	Pressure in inches	Cubic feet per hour
0·10	495	0·90	1,485	3·50	2,928	10·00	4,950
·20	714	1·00	1,555	4·00	3,130	11·00	5,215
·30	857	1·25	1,738	4·50	3,321	12·00	5,422
·40	980	1·50	1,915	5·00	3,500	13·85	5,800
·50	1,106	1·75	2,070	6·00	3,834	20·77	7,110
·60	1,213	2·00	2,214	7·00	4,140	2·770	8,200
·70	1,310	2·50	2,475	8·00	4,428		
·80	1,401	3·00	2,712	9·00	4,694		

TABLE XVII.

Discharge of gas of 0·6 specific gravity from 1-inch opening corresponding to pressure of mercury column and of gauge pressure.

Mercury pressure in inches	Pounds gauge pressure per square inch	Cubic feet per hour	Mercury pressure in inches	Pounds gauge pressure per square inch	Cubic feet per hour	Mercury pressure in inches	Pounds gauge pressure per square inch	Cubic feet per hour
0·10	0·05	1,835	5·59	2·75	13,375	....	14·00	28,495
·20	·10	2,590	6·10	3·00	14,175	....	15·00	29,295
·30	·15	3,170	6·61	3·25	14,755	....	16·00	30,045
·40	·20	3,655	7·11	3·50	15,320	....	17·00	30,755
·50	·25	4,095	7·62	3·75	15,850	....	18·00	31,415
·60	·30	4,490	8·13	4·00	16,370	....	20·00	32,730
·70	·35	4,850	8·64	4·25	16,875	....	22·00	33,470
·80	·40	5,180	9·15	4·50	17,360	....	25·00	35,620
·90	·45	5,495	9·65	4·75	17,845	....	30·00	37,945
1·02	·50	5,790	10·16	5·00	18,330	....	35·00	40,040
1·52	·75	7,095	12·20	6·00	19,835	....	40·00	41,945
2·03	1·00	8,195	....	7·00	21,555	....	45·00	43,605
2·54	1·25	9,165	....	8·00	22,600	....	50·00	45,080
3·05	1·50	10,030	....	9·00	23,735	....	60·00	47,380
3·56	1·75	10,830	....	10·00	24,815	....	75·00	50,975
4·07	2·00	11,550	....	11·00	25,915	....	90·00	54,350
4·57	2·25	12,275	....	12·00	26,775	....	100·00	55,705
5·08	2·50	12,950	....	13·00	27,695	....	110·00	57,055

TABLE XVIII.

Multipliers for pipe of other diameters than 1 inch.

Size of opening diameter in inches	Multiplier	Size of opening diameter in inches	Multiplier	Size of opening diameter in inches	Multiplier	Size of opening diameter in inches	Multiplier
1/16	0·0038	1½	2·25	5	25·00	7	49·00
⅛	·0156	2	4·00	5 3/16	26·90	7¼	52·50
¼	·0625	2⅛	6·25	5⅝	31·60	8	64·00
½	·2500	3	9·00	6	36·00	8¼	68·00
¾	·5625	4	16·00	6¼	39·00	9	81·00
1	1·00	4¼	18·00	6⅝	43·90	10	100·00

pressure gauge should be substituted for the water manometer when the Pitot tube registers more than 5 lbs. pressure. Tables for the calculation of volume of open flow of gas wells based upon Pitot tube readings have been prepared by Prof. Robinson,[1] and by F. H. Oliphant.[2] Of these the latter are here given as being more compact in form.

Correction for foregoing table: For any specific gravity other than 0·6, multiply by $\sqrt{\frac{\cdot 6}{\text{given sp. gr. gas}}}$. For temperatures of gas over 60° F. deduct 1 per cent for each 5°, and add 1 per cent for each 5° less than 60° F. In practice these corrections are usually neglected and the calculation made directly from the values in the table. Weymouth[3] has criticised the formula and the tables as giving quantities slightly in excess with high pressures, and somewhat too small with low pressures. A thorough discussion of the Pitot tube is given by W. B. Gregory.[4]

Natural gas is transported in pipe lines, except in rare instances when, greatly compressed, it is carried in cylinders as noted on a later page. The construction of pipe lines has been very fully discussed in the chapter by Forrest M. Towl, which follows on a later page. So too the compressor stations, at intervals along the long gas mains, in which the pressure of the gas is raised to a point sufficient to force it to its destination, have been described by Mr. Towl, and likewise the different forms of meters by which the volume of the gas transported or delivered is measured.

Pipe lines for the transportation of natural gas in the United States, while not of as great length as oil pipe lines, being rarely more than a hundred miles or so in length, are nevertheless very numerous. So too in Canada there are many gas mains for carrying natural gas. Of these the principal ones are as follows:—

In New Brunswick, gas is piped from the Stony Creek field 9 miles to Moncton through a 10-inch main, and 4 miles to Hillsborough through a 4-inch line.

[1] Ohio Geol. Surv., vol. VI, 1888, pp. 572, 573.

[2] Oliphant, F. H., U. S. Geol. Surv., The production of Natural Gas in 1902, p. 26; reprinted in West Virginia Geol. Surv., vol. 1 (a), 1904, p. 39.

[3] *Op. cit.*, p. 1093.

[4] Gregory, W. B., Trans. Am. Soc. Mech. Eng., vol. 25, 1903-4, pp. 184-207; with supplemental note by Prof. S. W. Robinson, pp. 208-211.

In Quebec, the Three Rivers field furnished gas for Three Rivers, Yamachiche, St. Barnabé and Louiseville.

In Ontario the three gas fields have furnished much natural gas to the cities and towns of the province and much gas has been exported to the United States. The Essex county field furnished gas to Toledo, Ohio, by way of Detroit through an 8-inch main. Two mains laid across the bed of the river at Detroit furnish that city with gas from the same field, which also supplies Chatham. Leamington, Blenheim, and other towns. The Welland field gas is piped to St. Catharines, Niagara Falls, Bridgeburg and other places, and until 1898 was piped to Buffalo, N. Y. The Haldimand-Norfolk field furnishes gas to Hamilton, Dundas, Galt, Brantford, and elsewhere. These are by no means all of the towns supplied with natural gas in Ontario. Recently incorporated companies propose to pipe gas throughout western Ontario.

In Alberta the output of the Medicine Hat field is consumed in that city. The gas from the Bow Island field is piped in a 16-inch main 160 miles in length to Calgary, Lethbridge, and fourteen other towns. This is the only pipe line in that province at present, although others are planned.

DISPOSAL OF OIL PRODUCT.

In new fields where the yield of oil is small, with no gas, and there is much drilling, a considerable portion of the output of crude oil may be used as fuel in the drilling operations. So too when the field is close to an industrial market, the output of oil may be consumed as fuel. Large quantities of Beaumont, Texas, oil found a market in the field itself with the railway companies being used as fuel for oil-burning locomotives.

The great bulk of the oil, however, is sold to the pipe line companies, or to oil purchasing companies owning lines of tank cars. The methods pursued in the former case have been outlined in the chapter by Mr. Towl.

The refined kerosene, gasoline and lubricating oils are sold by the refinery company direct, or by subsidary wholesale dealers. As previously noted, these companies ship the kerosene and gasoline by tank cars to the local agents in the towns, where the oil is distributed from receiving storage tanks by means of tank wagons. Lubricating oils are sold in wooden barrels. Kerosene and gasoline are distributed to small country places without railway communication in barrels and tin cans, usually through wholesale grocery houses.

DISPOSAL OF NATURAL GAS PRODUCT.

More or less gas is produced in nearly every oil field. The local use of such gas as fuel in further drilling operations is comparable to the similar use of crude oil where gas is wanting. There is also more or less use of the gas in the field for domestic lighting and fuel purposes. When the field is near towns, the gas may be sold to local gas companies who distribute it, or if the supply be plentiful enough it may be piped to distant markets. Mention has been made of the pipe line from the Essex field of Ontario to Toledo, Ohio, and of the 160 mile main from Bow island to Calgary, Alberta.

While gas, struck without oil, will generally be closed off and utilized, it is nevertheless true that in new gas fields there is a great waste of gas in continuously burning flambeaux, and wild wells. On the other hand, it is the history of practically all oil fields, that in their earlier days the associated gas goes to waste. It has been true for Pennsylvania, Ohio and Indiana, Kansas and Oklahoma, and is now true for California in the United States, and was true of the oil fields of Ontario. There are, of course, reasons for this waste; among them, lack of markets, difficulty of controlling and closing off the flow; and the undesirability of stopping the flow of gas from an oil man's point of view because of his belief that if the gas be allowed to escape oil will usually follow it in the well; and finally, the lowering of the gas pressure to a point which makes it unprofitable to try to market it. Many states have enacted statutes compelling oil companies to close up and plug all gas wells, and to prevent the escape of gas from oil wells. A new provision that all reasonable precautions be taken to guard against the waste of natural gas was inserted in the Dominion petroleum and natural gas regulations, January 14, 1914. Such compulsory conservation is necessary and wise, though naturally repugnant to the oil prospector.

An economic use of natural gas which has been greatly developed within the last four or five years and which promises in time to do away with the waste of natural gas in most oil fields as well as gas fields, is the manufacture of gasoline from natural gas.

This subject is treated fully in Chapter IX.

CHAPTER VIII.

THE TRANSPORTATION OF OIL AND GAS.

By Forrest M. Towl.

When an oil well is completed, it either flows naturally or is pumped into a tank situated near the well. From this tank, the usual methods of transporting the oil to the refineries are by tank cars or through pipe lines. (Boat transportation is good and cheap if location of wells permits.) When tank cars are used, it is customary to gather the production from a number of wells through a system of pipe lines and to conduct it to some point located on a railroad. Before the production of a field reaches an amount sufficient to warrant the building of a pipe line, the oil is either collected in tanks and allowed to stand, or, if there is a railroad convenient, shipped by cars. After a field is developed enough to warrant a pipe line system for gathering the oil, there is run, from the producers' tanks at each individual well, a pipe line which connects with other similar lines leading to a point of concentration. The oil is either forced through these lines by a pump located at the well, run by gravity, or run into a system of lines having a suction pump at their terminus. The gravity system is to be preferred where it is possible to use it, even though it often requires larger lines. Where the oil is nearly as fluid as water, a pipe of about 2″ in diameter is used, but where the oil is viscous, larger pipes are necessary, the size, of course, depending on the amount of oil to be handled. With the same head, the more liquid oils flow about the same as water, but, when the oil becomes viscous and thick, the flow is very much reduced. The fluidity of the more viscous oils changes with the temperature. In general, the heavier oils are the most viscous, but there are many notable exceptions to this rule. The gravity of the oils is usually obtained by a Baumé hydrometer. The specific gravity of the oil can be obtained by substituting the Baumé gravity in the formula:—

$$\text{Sp. gr.} = \frac{144}{134 + \text{Baumé degrees}}$$

After the oil has been collected by the gathering system into the first concentration tank, it can be pumped through lines to some point of storage, or through a series of pump stations to the places where it is to be refined. There is a great difference in the crude oils, some of them being black, brown, or dark red; while others are amber or straw colored. As these lighter colored oils are often of more value than the darker, it is necessary to keep the different grades separate. This can only be done by pumping through separate lines, or handling the oil in large consignments. The history of the pipe lines dates back nearly to the discovery of oil in large quantities. The first successful pipe line in the United States was built in 1865 by Samuel Van Sickle. This line, between Pithole and Miller's Farm, was only four miles long, but they were able to pump 81 barrels of oil per day using three pumps. Since that time the pumping machinery has improved in line with other machinery being built. At first, high-pressure steam driven pumps were used, the steam being used but once. This was followed by the introduction of the compound pump, then the triple pump, which later gave place to the high-duty triple expansion condensing fly-wheel type of pumps. The first style of pumps required about 120 lbs. of water, converted into steam, per H.P. per hour. The last type of steam pumps require about 15 lbs. One pound of oil will evaporate about 15 lbs. of water, so that a pound of oil burned under a boiler with a good triple expansion pumping engine will furnish a H. P. for one hour. Recent developments in the oil engine have resulted in producing an oil engine driven pump which will furnish a H. P. per hour on less than 0·5 lb. of oil. In 1902 and 1903 the writer built a pipe line for handling the viscous California oil. The oil was heated by a surface heater using the exhaust steam from the pumping engines. This heating system is now in general use where viscous oils are to be handled

In the United States, the pipe lines take the oil from the producer's tank, gauging the tank before the oil is run into the pipe line system and after the run has been completed, care being taken to see that all of the water has been drawn from the tank before the run starts, and that the valves and connexions are all tight so that no water or oil can come into or leave the tank while the oil is being run into the pipe line. It is customary for the pipe lines to seal or lock their valves when oil is not being run from the producer's tanks. Where the oil is handled by a pipe line company not owning the production, the company furnishes the owner's representative at the well with a statement called a "Run Ticket", showing the level of the oil before starting to run, the level at the close of the run, and the number of barrels of oil taken from the tank as shown by the engineer's table. In the United States, the barrel contains 42 U.S. gallons of 231 cubic inches each. This is equivalent to 35 imperial gallons. There is generally some water and sediment in the oil coming from the wells and also considerable gas. For this reason, it is necessary for the oil to stand for some time before it is measured and run into the pipe lines. Even when this precaution is taken, it is found the lighter gravity oils, containing considerable gasoline, lose some in volume; for this reason, it has become a question to allow a certain percentage of difference between the gauge of the producer's tanks and the gauge in other tanks along the lines. With the light gravity oils, this loss amounts to about 2 per cent of the oil run which is the figure used in most of the fields producing light gravity oils. The heavier oils carry more water and sediment and hold them suspended for a long time. In handling the oils through pipe lines, it is necessary to be very careful around the pumping stations and keep fire or lights away from the oil or its fumes. Fires are often caused around the pumping stations and tankage fields by lightning. It has been found that a steel tank with a steel roof is not as liable to be struck by lightning as a steel tank with a wooden roof. Where there is a large tankage field, it is necessary to build banks around the tanks, or place them far enough apart so that when one is on fire it will not endanger others. Lightning rods have been used to prevent lightning striking the tanks, but it is generally considered that their value in preventing the loss by lightning does not warrant the additional expense. Where tanks are located near power plants having steam available, a steam pipe is connected into the top of the shell of the tank, so that, in case the tank is struck by lightning, steam can be turned in above the oil. If the roof of the tank is not blown off by the explosion, it is often possible to put out the fire in this manner. Care is to be taken to see that all of the openings in the tops of the tanks are closed to retain this steam. If water is available, it is the practice to play water on the adjacent tanks and sometimes on the tank which is on fire. This can be done with reasonable safety for a few hours after the tank has been struck. Oil is sometimes drawn off from the tanks by connecting pipe line systems and water forced in at the bottom to keep the burning oil as high as possible. By this means it is sometimes possible to save the bottom and lower ring of the tank, which is the most expensive part.

For the pipe lines, mild steel or wrought iron screw joint pipe is used. Bessemer steel also is used, but makes a cheaper and inferior grade of pipe.

In the collection of natural gas from the wells, there is often water or oil carried with the gas in such quantities that it will clog the lines. For this reason the wells are connected up with a trap to catch the liquid before it enters the lines. A number of wells are connected into a larger line and these larger lines converge to the trunk line which carries the gas to a point near to where it is to be consumed. At this point it is usual to reduce the pressure of the lines before distributing. The distribution is carried on in the same manner as when handling manufactured gas. When the pressure at the wells is not sufficient to deliver the gas to the market, compressor stations are put in and the pressure raised to a point sufficient to carry the gas through to the point of consumption. The following formula can be used in computing the amount of gas which will be delivered through a given line:

$$Q = C\sqrt{\frac{(P_1 + P_2)(P_1 - P_2)D^5}{L}}$$

TABLE XIX.

Chemical and Physical Properties of various forms of Fuel Oil.

No.	Description.	Specific gravity at 15° C.	Carbon.	Hydrogen.	Sulphur.	Oxygen and Nitrogen.	Net Calorific Value.	
			Per cent.	Per cent.	Per cent.	Per cent.	Calories.	British Thermal Units.
1	Fuel oil used on trial of a torpedo-boat destroyer..................	0.921	85.28	11.93	0.55	2.24	9,986	17,975
2	A petroleum product sold at a little over £2 per ton................	0.888 (at 18° C.)	86.20	12.57	0.31	0.92	10,097	18,175
3	An ordinary crude petroleum often used for Diesel engines...........	0.923	–	–	0.45	–	9,956 (Hydrogen assumed as 12% for correction.)	17,921
4	"Light fuel oil"....................	0.900 (at 18° C.)	88.58	10,81	0.43	0.18	10,114	18,205
5	"Admiralty fuel oil"................	0.928	86.40	11.55	0.34	1.71	9,961	17,930
6	"Residuum".........................	0.943 (at 18° C.)	86.44	11.23	0.30	2.03	10,065	18,117
7	"Black oil"........................	0.928	86.44	11.83	0.51	1.22	9,977	17,959
8	A refined oil specially adapted for Diesel engines..................	0.904 (at 18° C.)	85.05	12.15	0.37	2.43	9,998	17,996
9	A Roumanian crude oil.............	0.825	–	–	0.20	–	9,924 (Hydrogen assumed as 13.0%.)	17,863
10	A Roumanian crude oil.............	0.830	83.77	12,98	0.29	2.96	10,012	18,022
11	Solar oil (Texas)..................	0.862 (at 18° C.)	85.35	12.92	0.17	1.56	10,191	18,344
12	Scotch shale oil....................	0.855 (at 18° C.)	86.16	12.37	0.26	1.21	10,138	18,248
13	Scotch shale oil....................	0.8624	85.35	12.44	0.29	1.74	10,176	18,317
14	Scotch shale oil; works well on Diesel engines........................	0.867	–	–	0.33	–	9,961 (Hydrogen assumed as 12.5%.)	17,930
15	A coal-tar oil......................	0.958	86.16	9.05	0.80	3.99	9,422	16,960
16	A gas oil; gives trouble with Diesel engines.........................	1.067	87.62	5.98	0.67	5.73	8,974	16,153
17	A gas oil; a composite coal-tar product	1.004	83.72	7.29	0.82	8.17	8,876	15,977

Q = cubic feet per hour (15 lbs. absolute).

P_1 = absolute head or initial pressure in pounds per square inch.

P_2 = absolute delivery or terminal pressure in pounds per square inch.

D = diameter of the pipe in inches.

L = length of the pipe in miles.

C = a constant.

The onstant used for air computations is $C = 38 \cdot 28$.

The constant for any other gas is inversely in proportion to the square root of the specific gravity of the gas.

For a natural gas having a specific gravity of $0 \cdot 59$ the corresponding constant is $C = 50$.

These constants have been checked by many tests on pipe lines of various diameters and lengths.

With natural gas, it is seldom necessary to use gas holders to regulate the supply at the point of consumption as the line itself forms a reservoir and can be used to store a large amount of gas by what is known as "packing the line," which consists in permitting the pressure back of the regulator to increase until it approximates the pressure in the field. In Volume 34 of the Transactions of the American Society of Mechanical Engineers, page 185, is to be found a very interesting paper on problems in Natural Gas Engineering by Mr. Thomas R. Weymouth of Oil City, Pa. This includes a discussion of the properties and composition of natural gas, transmission of natural gas, pipe line storage capacity, the power required to compress natural gas, station designs, and general remarks on the subject. In the same volume on page 1091 is an article by the same author on the Measurement of Natural Gas. In the National Tube Company handbook of 1913, pages 320–325, there is an article on "Flow of Gas in Pipes—High Pressure," giving several coefficients and formulæ. The writer respectfully refers the student of these questions to the articles above cited.

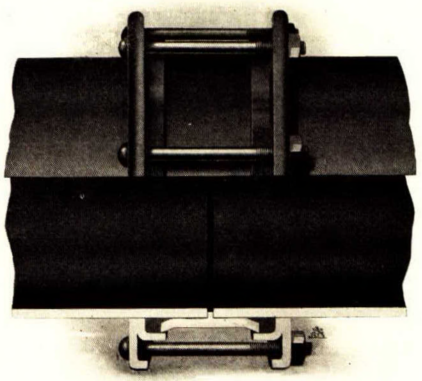
PIPE LINE REQUIREMENTS.

The transporting of gas requires a pipe line which shall be air tight. It is much more difficult to make a line to hold gas under pressure than it is to hold a liquid. Trouble has been experienced in almost all lines built for high pressures on account of the leaking of gas at the couplings. The first high pressure lines were laid with bell and spigot joints, caulked with lead. The lines might be tight when they were first laid, but the movement in expanding and contracting soon caused them to leak large amounts. The next lines used were of wrought iron or steel pipe, with screw joints. While these held much better than the bell and spigot pipe, there was still enough leakage to make it desirable to have a more perfect joint. The leakage on some of the earlier screw joint gas lines was such that by putting a rubber bag over the coupling, gas could often be collected at the rate of from 20 to 50 cubic feet per hour, or enough to run a good sized torch. This was true of lines up to 8 or 10 inches in diameter. When the lines became larger the leakage increased so much that it was practically impossible to use large size lines and get a large percentage of the product to the market. As the demand for natural gas increased it became necessary to use larger lines, and a rubber packed stuffing box was developed. The first successful joint of this kind in the market was the Dresser coupler, and it is due largely to this and other couplings that the natural gas industry has become so great.

The Dresser coupler consists of a sleeve into which the ends of the pipe are placed. There is a projection in the center of the sleeve so that the ends of the pipe will be each inserted into the sleeves the same distance. This sleeve acts as a follower to compress rubber in an annular space into the end rings which are drawn together by bolts. The rubber is surrounded on one side by the pipe, on another by the body of the coupling, and on the remaining sides by the end rings so that there is very little of the surface of the rubber exposed either to the gas on the inside or the air on the outside of the line. It is found that these joints will last for years. (Plate XV shows a cross section of the Dresser coupler).

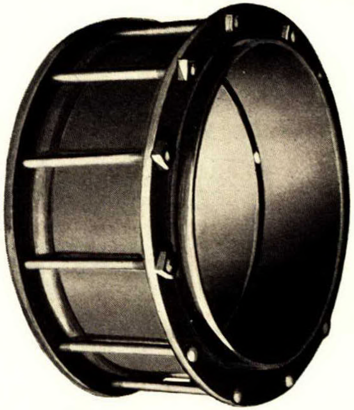
The Hammon coupler is a modification of the Dresser, one of the principal features of which is that the projection at the centre of the sleeve is made by lugs welded on to the sleeve. When it becomes necessary to take apart one of these couplers,

PLATE XV.



The Dresser coupler.

Plate XVI.



The Hammon coupler.

the lugs can be broken off and the coupler slipped back so as to allow of the pipe being easily removed. (Plate XVI shows the Hammon coupler).

Lines of pipe can be built in almost any kind of country, but it is necessary in some places to arrange to keep the line from acting as a Bourdon tube and expanding in one direction until the ends of the pipe may be pulled out of the coupling. To avoid this trouble it is customary in such places as river crossings to use screw pipe, and to place over the collar a clamp which is constructed to make a rubber joint between the ends of the collar and the pipe.

For power transmission lines or for temporary gas lines where the distances are short or the service temporary and it is not considered necessary to bury the pipe, it will be found that the screw joint pipe is satisfactory, but for other natural gas or air service, the rubber coupling has many things to recommend it, and when the capacity requires large pipe it is almost absolutely necessary to use this type of coupling. These couplings have been used for manufactured gas, but it is found that the condensation from the gas collects in the coupling and soon causes a leak in the rubber joint. Work is now in progress to perfect a material which will not be acted upon by the condensation in the gas and which will make a gas tight joint.

METERS.

When gas having a commercial value is to be transported, it becomes necessary to measure it with a considerable degree of accuracy, and, as the problem of the flow of gas must be based on some measurement of volume or weight of the gas, the first thing required is the establishment of a basis for measurement and an apparatus for measuring. The basis usually employed is the cubic foot at atmospheric pressure and at a stated temperature, although many engineers use one pound of air as the unit. By Mariott's law, it is a simple problem to change from one basis to the other.

On account of the change of volume of the gas, for differences in temperature and pressure, the actual accurate measurement of the gas becomes a very difficult problem. It is usually considered that a gas meter is accurate if it registers within 2 per cent of the standard. The commercial gas meter has been perfected so that, when it is in good condition and working under normal speed, it can be relied on to give results within that amount, provided the temperature and pressure remain practically constant.

The measurement of gas at high pressures in particular presents many difficulties.

The following types of meters are at present in use:

The displacement or regular type of meter.

The orifice.

The proportional, which is a combination of the first and second.

The anemometer.

The dynamic, and

The electric.

Each of these forms of apparatus has its special advantages and limitations when employed in measuring gases at high pressure. For measuring large volumes at high pressure, the proportional meter, the orifice, the dynamic and the electric seem to be the only ones available.

THE ORIFICE METER.

A number of meters have been made using the orifice to measure the gas. The meter is usually calibrated by gas or air flowing through the orifice into a gasometer under a constant difference in head. After the orifice has been calibrated, one or more orifices are placed in line and the pressure is noted each side of the opening. This requires constant watching and readings in order to compute the amount of gas flowing. The St. Johns meter of this type uses a variable orifice and on a chart records the position of a plug in an opening. There is no attempt in this meter to make corrections for variations in pressure. The charts are averaged by a planimeter. This plan of measurement is used largely by the New York Steam Heating Company.

THE PROPORTIONAL METER.

In the proportional meter, it is necessary to make corrections on account of change of pressure. This requires either an observer to note the readings of the meter and the pressure or a recording apparatus to show the readings and pressures simultaneously. Such an apparatus is manufactured by several of the companies, but it is difficult to make the computations from the charts.

THE DYNAMIC METER.

The principal representative of the dynamic class is the Pitot tube. The General Electric Company makes a recording Pitot tube which is automatically corrected for variation in pressure. The general practice in measuring gases with the Pitot tube is to take readings at stated intervals and make computations from these readings.

THE ELECTRIC METER.

The electric meter is a recent development in gas engineering resulting from work done by Prof. Carl C. Thomas of Johns Hopkins University. It is based on the principle that to increase the temperature of a given weight of a gas a given amount requires the addition of a corresponding amount of heat. The heat is supplied electrically and the amount of energy required is measured.

In 1901 an 8″ pipe line supplying gas from northern Pennsylvania to the city of Buffalo, New York, was tested under various conditions to obtain the coefficient for the flow of natural gas. Pressure gauges were carefully calibrated and installed at each end of the line and at five intermediate points. Observations were taken every fifteen minutes night and day for a period of one week. The amount of gas delivered from the line at Buffalo by a Pitot tube showed the delivery to be at the rate of 221,000 cubic feet per hour. The temperature was 32 degrees F. and the weight of the gas per 1,000 ft. was 51·61 lbs. when measured at an absolute pressure of 14·65 lbs. From this test, the coefficient of C–50 for gas having a specific gravity of 0·64 was obtained which corresponds to a coefficient of 40 for air.

A number of formulas have been suggested, based on data which seems to show that the number of cubic feet per hour varies as the square root of the 5·33 power of the diameter. Other formulas suggested have slight variations in reference to the diameter but the author does not consider that the evidence is at all conclusive and prefers the formula using the square root of the 5th power of the diameter as it gives results which are in all probabilities as accurate as the gas measuring apparatus in use at the present time.

CHAPTER IX.

UTILIZATION OF PETROLEUM AND ITS PRODUCTS.

By T. T. Gray.

UTILIZATION OF CRUDE PETROLEUM.

Petroleum is sometimes used in the crude state for fuel, for surfacing roads, or for dust prevention on roads, but ordinarily the first stage in the utilization of crude petroleum for any purpose is to subject it to some form of distillation which will reduce it to the most desirable consistency for the purpose in question. Petroleums used in the crude state as fuel are the more viscous varieties occurring on the Pacific Coast and in Mexico. Perhaps 30 per cent of the fuel oil burned in Mexico in the year 1913 was burned as crude oil, without any form of previous treatment. These viscous oils contain, as a rule, considerable asphalt and sufficient water to make it difficult to distill them, and are therefore used in the crude state. Similarly the oils used on roads are the heavier grades containing asphalt which in California sometimes reaches 60 per cent.

PETROLEUM PRODUCTS.

The nomenclature of petroleum and its products has never been clearly defined, and is therefore often confusing. As stated in Chapter II of this report three general kinds of crude petroleum are spoken of, namely: paraffin-base, which carries solid paraffin hydrocarbons and practically no asphalt; the asphalt-base, which contains asphalt and no paraffin; and paraffin-asphalt, which is a combination of the two. Generally speaking, the paraffin-base petroleum is of lighter gravity, and yields a greater variety of lubricating oils.

In the early days of the petroleum industry, when petroleum was refined for illuminating products only, at which time gasoline was a drug on the market, the residue from the distillation known as tar which contained the lubricating oils, was run to waste. Later this tar was distilled separately for the manufacture of lubricating oils, being processed in stills and distilled to coke. The distillation of tar was particularly hard on the stills, due to the formation of a large bed of coke. Tower stills, or stills of the dephlegmation type were finally adopted, and the crude oil distilled to coke in one operation, which process is the one in general use to-day.

Asphaltic base oils are distilled to asphalt and the distillates are cut according to gravity. As asphalt base oil does not yield steam refined cylinder stock or paraffin wax, it does not answer well for an illustration of the different refining methods.

REFINING.

In general, whatever use petroleum is to be put to, it is normally pumped and shipped in tank cars to a refinery, and the lighter products are distilled off. The simplest methods are those applied to oils which are essentially fuel oils and from which a slight amount of naphtha and burning oil is distilled off in order to yield a fuel oil which can be stored with entire safety. The oil is pumped into a horizontal, cylindrical still and ordinarily heated by external fire made by burning crude oil or some form of residuum in a jet burner by which the oil is sprayed into the fire box and thus burned in a long flame under the boiler. These methods of burning oil will be described under fuel oils. The practice is becoming very general at the present time of introducing steam into the still for all kinds of distillation, this causing the distillation to take place at slightly lower temperatures than would be the case without the steam, and also preventing overheating the residum left in the still so that a sweeter product is left. In practice the distillation is carried on until the distillate which is passed through a condensor and appears in the so-called still house, shows by its specific gravity that the oil remaining in the still will have a flash above a degree designated as safe—usually 150° Fahr. The oil is then pumped, while still warm, into the proper tanks for distribution to the points of use.

In the manufacture of road oils, the process is the same although the practice is becoming more frequent of carrying the distillation until the residuum left in the still is largely asphaltic oil that is almost solid when cold. Steam is used very generally in the reduction of crude oils for road purposes because the resulting oil is more elastic than would have been the case if steam had not been used. Without steam, the oil is cracked into a product which is more brittle.

General Refineries.

A refinery which is intended to furnish the usual list of products is much more complicated than that required simply for the production of road and fuel oils. It was the former practice to pump the crude oil into stills of from 500 to 1000 barrels capacity and carry the distillation to the stage when first naphtha, and then the oil suitable for illuminating purposes had been distilled off and sent to the appropriate tanks for crude naphtha and crude burning oil distillate. The residium was then called tar, and was pumped while warm—but not hot—into tanks or direct into the so-called tar sills where the distillation was continued to coke with a fraction first of low grade naphtha, low grade illuminating oils, gas oils as the next succeeding product, then light lubricating oils containing paraffin wax, then successively heavier oils also containing paraffin wax, and finally paraffin butter as the last semi-solid product, leaving the last product of coke in the still. The still was then steamed free from explosive gases, allowed to cool down, and the coke dug out, and the still made ready for another distillation. The recent progress in distillation has avoided the use of two of these stages of distillation, in the two different kinds of stills described, and the crude oil is distilled clear to coke in the first stills, which are modified by the introduction of towers on top of the still through which the vapors pass and are more thoroughly fractioned, portions—when desirable—being returned to the still for the purpose of cracking them to afford a greater yield of light products. By this means, the present day stills can be made to yield very different proportions of products according to the market demand. As a rule, the greatest possible yield of naphtha and burning oil is desired, and the proportion now obtained is considerably greater than the same variety of oil would have yielded in the past under the former systems of distillation.

The crude products obtained from the primary distillation of crude oils are next redistilled. The crude naphtha is pumped into large stills, heated entire by injected steam, the outside of the still being well insulated to prevent loss of heat. A modern improvement in naphtha steam stills is to install over the still a higher tower through which the naphtha vapour from the still ascends and meets the cold, crude naphtha which flows down fron the top of this tower. The heat exchange thus effected has proved a great economy in naphtha distillation. By this distillation, the crude naphtha is fractioned into a great variety of products ranging from gasoline with specific gravities between 80 and 90 degrees Baume to ordinary stove gasoline with specific gravities between 70 and 80 degrees Baume. Motor naphthas with specific gravities of from 56 to 60 degrees Baume and certain special heavier products designed as solvents are prepared from a certain variety of crudes, especially in Texas and California. A considerable proportion of heavier material corresponding in gravity and flash point to illuminating oil is left in the still. This is added to the tank containing crude burning oil distillate. This distillate is similarly distilled, partly by fire underneath and partly by steam slightly super-heated. The first products from this steam still are again heavy napthas which are mixed with the corresponding product from the naphtha stills, and the burning oil is then taken off, distilled—being gauged both by its gravity and colour, and the distillation continued until one or the other is unsatisfactory when the residuum is either added to gas oil or returned to lower grade stock. The gas oil distilled is usually sold for enriching water gas, that is this gas oil is sprayed into the top of the white hot column of coke which is being decomposed into gas by the injection of steam below. The oil is principally broken into gases of high illuminating power. Within the last few months, this gas oil has been applied to the production of so-called motor spirits by distillation under pressure, according to Burton and other systems, in one of which the hydrogen or fixed gases obtained in various cracking processes with the refineries are passed, together with vapor of the gas oil, through porous, catalytic agents by which the permanent gases are so combined with the cracked gasoline as to afford material with satisfactory colour and odour.

In the case of oils from the Petrolia, Sarnia regions, etc., in Lambton county, Ontario, the crude burning oil distillate is agitated with copper oxide during the operation for the purpose of removing the sulphur, according to the process invented by Dr. Herman Frasch.

In distilling petroleum of the Pennsylvania type, three methods are used, namely: The dry or destructive distillation, the steam distillation, and the vacuum distillation.

The dry or destructive distillation, which causes cracking or decomposition, is conducted by means of fire heat only and is usually carried to coke. The process is better adapted to petroleum which is unfit for the manufacture of cylinder stocks.

The steam distillation makes it possible to distil oil at lower temperature than by the dry distillation, and is therefore used to prevent decomposition. The stills are of the same type as those used in the dry distillation, except that they are well insulated in order to prevent the vapors from condensing on the sides and falling back into the superheated oil. Steam is introduced into the body of the oil in the still, and the distillation controlled by fires underneath the stills.

Vacuum distillation is sometimes used in conjunction with the process of steam distillation. A partial vacuum is created by means of a pump, thereby causing the hydro-carbons to distil at low temperatures. This method requires heavier stills, and although the results are said to be superior, the difference is not usually considered great enough to warrant the increased cost of installation and operation.

Where Pennsylvania crude petroleum is subjected to distillation, gasoline is the first product to pass over. The stream starts flowing at about 75° Baume gravity, but as the distillation continues the gravity becomes heavier. Gasoline is separated by the gravity of the stream at some pre-determined point, which varies in different plants but which is in the neighbourhood of 57° Baume gravity. The stream of distillate starts practically water white in colour but darkens slowly until the cracking point is reached, or at about 43° Baume gravity, at which time the colour changes very rapidly.

The cracking which ensues after the normal illuminating oil distillate has been separated, gives rise to the production of a gasoline of unsaturated character. The different fractions separated, namely: gasoline, normal burning oil distillate, and low test or cracked burning oil distillate, are redistributed in specially constructed apparatus heated by steam. The heavy end of the gasoline fraction finds its way into the normal burning oil distillate, and the light end of the normal burning oil distillate goes into the normal gasoline fraction.

PRODUCTS OF THE DESTRUCTIVE DISTILLATION OF PARAFFIN BASE CRUDE OIL OF THE PENNSYLVANIA TYPE.

Gasoline.—This name has been applied broadly to the lighter products derived from petroleum, ranging in gravity from 58° Baume to the very high gravity products, 90° Baume and over, which are extracted from the still gases by the compression method.

There are two general grades of gasoline; the normal gasoline which exists naturally in petroleum, and the cracked gasoline formed by the decomposition of the heavier products. The normal gasoline has a low iodine absorption, whereas the gasoline produced by the cracking process has a high iodine absorption.

The examination of gasoline should include gravity test, temperature distillation, with determination of initial and boiling points, and the iodine absorption.

Normal gasoline should be water white in colour, of sweet odour, should evaporate without leaving any stain or appreciable odour, and the iodine absorption should be below five per cent. Normal gasoline is used, or rather should be, in all dry cleaning establishments.

Cracked gasoline, as the name implies, is likely to fluctuate in properties. Speaking generally, and of its application to use in gas engines, it should show a low initial boiling point, and should have a final boiling point of not higher than 350° F. As long as these conditions are fulfilled, the lowest gravity is the best product.

Illuminating oils.—These oils are the products heavier than gasoline, ranging from 100° to 250° F. flashing point. Like gasoline, they are divided into two general classes, depending whether they are normal or cracked products. The usual tests applied to burning oils are, gravity, flash point, fire test, distillation, sulphur determination, viscosity, colour and burning tests.

There are several grades of illuminating oils, which may be classified roughly as follows:—

1. 45° to 47° Baume gravity, usually called Water White burning oil (normal product), fire test 150° F. or better.

2. 43° to 45° Baume gravity, usually called Standard White burning oil (cracked product), fire test 100° F. or better.

3. Below 43° Baume gravity, a cheaper product which may be either normal or cracked, fire test 110° F. or better.

4. 300° F. fire test, known as 300° Oil, Mineral Sperm, Mineral Colza or Mineral Seal.

The first three grades are ordinary kerosene lamp oils. 300° oil is used as an illuminating oil in cases where lower fire test oils are objectionable.

The most practical test to apply to illuminating oils is to make an actual burning test, taking into consideration the incrustation of the wick and diminution of the flame. These tests are merely comparable and require some practice in order to judge the quality of the oil. Provided the flash is satisfactory, the best burning oil is that with the lowest viscosity, lowest iodine absorption, highest gravity, lowest sulphur, and best colour.

Fuel oils.—In judging the quality of fuel oils, consideration must be given to the following points: Safety, transportation, storage, and method of application. Naturally the best fuel oil is the one which will do the work most satisfactorily at the lowest cost. It would not be practical to design a set of fuel oil specifications for one case that would fit every other case.

Fuel oils, from a refining standpoint, are usually the distillates heavier than burning oil and lighter than the lubricating oils, ranging from 25 to 30° Baume gravity.

A discussion of the uses of fuel oils will be found on a later page.

Paraffin oils—The lubricating oils made by the dry distillation method are generally known as paraffin oils. They range in gravity from 30° to 20° Baume, in flash from 300° to 450° F. by the Cleveland open cup, in viscosity from 40 to 600 seconds on the Saybolt viscosimeter at 70° F., in cold test from 0° to 40° F., in colour from pale-yellow, through red, to dark green.

Paraffin oils are usually decolorized by the sulphuric acid treatment.

In judging the quality of paraffin lubricating oils we face the same condition as with fuel oils, in other words, the oil that does the work most satisfactorily at the lowest cost is the best product from the consumers' standpoint. The ordinary physical tests should be determined, such as gravity, flash-fire test, cold test, viscosity, and colour, and the oil should show no trace of acid.

Uses.—These oils are suitable for all kinds of lubrication, except perhaps for steam engine cylinders.

Paraffin wax.—Refined paraffin wax should be practically water white when in the molten state, should be odourless, and should not darken rapidly when exposed to the sunlight.

Paraffin wax is derived from the paraffin distillate, which it will be remembered, is the heavier distillate separated at the crude stills after the fuel oil has been cut and until just before the coking period, at which point a very heavy, sticky, green, asphaltic like substance known as wax tailings, distils over.

The paraffin wax is separated from the paraffin distillate by cooling and filter pressing. The pressed distillate is used for the manufacture of the paraffin oils, and is reduced by the steam distillation method.

Uses: Paraffin wax is used to a large extent in the manufacture of candles; it is used also in making so called wax paper, for water proofing, for laundering, protecting preserves from fermentation, in admixture with asphaltic products for making insulating pitches for wires, for floors and a variety of other purposes.

Wax tailings.—This product of decomposition contains chrysene, picene and other compounds formed by destructive distillation. It is of dark green colour but darkens on exposure to light. It is asphaltic in nature and varies in melting point according to the care with which it is separated and later refined.

Uses: Used for weather and waterproofing compounds, in some cases as a flux in street paving mixtures, and as a filler in very cheap axle greases.

Coke.—Petroleum coke usually shows the following composition: volatile and combustible matter, 5 to 10 per cent; fixed carbon, 90 to 95 per cent; ash, from a trace to 0·3 per cent; sulphur, from 0·5 per cent to 1·0 per cent. On account of the purity of petroleum coke it has found wide application in metallurgical processes, in making of battery carbons and carbon pencils.

PRODUCTS OF THE STEAM DISTILLATION OF PARAFFIN BASE CRUDE OIL OF THE PENNSYLVANIA TYPE.

Normal gasoline.—Same as with the dry distillation.

Illuminating oils.—The yield by the steam distillation is much lower than by the dry distillation.

Fuel oils.—Lower yield than by the dry distillation.

Spindle oils.—The lubricating oils range in gravity from 26° to 35° Be., in flash from 320° to 450°F. (Cleveland open cup), in viscosity from 400 to 40 seconds—Saybolt at 70°F., in cold test from 10° to 40°F., and in colour from almost colourless to dark red.

Spindle oils are usually decolourized by filtration through Fullers earth or bone-black, they differ from paraffin oils in that for a given viscosity they are of higher Baume gravity. For illustration, a spindle oil and a paraffin oil of the same gravity may have the following tests:

	Spindle Oil.	*Paraffin Oil.*
Baume gravity @ 60°F	30·0	30·0
Flash, Cleveland open cup..........	420°F.	340°F.
Fire test, Cleveland open cup.....	475°F.	390°F.
Viscosity, Saybolt @ 70°F........	300 seconds.	60 seconds.

Spindle oils are used for all kinds of high grade lubrication except steam cylinders; as high grade engine oils; for spindles in textile mills from whence the name came, and on account of the fact that spindle oil does not make bad stains on fabrics whereas paraffin oils do. They find wide application as automobile oils, for which purpose they seem to be particularly well adapted. Specially purified oils of this class are being used in medicine with very successful results in treating cases of bowel auto-intoxication.

Steam cylinder stocks (oils).—These are the steam residues from high grade crude oil, they vary in gravity from 20° to 27° Baume, in flash from 650° to 475°F., in viscosity from 350 seconds to 100 seconds Saybolt universal viscosimeter at 210° F., in cold test from 30° to 60°F. They are dark green in colour and contain varying amounts of asphaltic matter, depending upon the quality of crude oil refined and the care exercised in refining. These oils are often further refined by filtration through Fullers earth or bone-black, which process raises the gravity and the cold test, but reduces the viscosity depending upon the degree of filtration. Filtered cylinder stocks may be recognized by their transparency.

Uses: The lubrication of steam cylinders, for which purpose they are often compounded with fatty oils.

Vaseline or Petroleum Jelly.—This is the steam residue from selected crude oil rich in amorphous paraffin wax, which has been refined and decolourized by filtration through Fullers earth or bone-black. The colour is dependent upon the extent of the filtration and varies from white to red.

Uses: Largely as a salve. It is also put on the market in medicated forms as an antiseptic salve.

Miscellaneous.

TURPENTINE SUBSTITUTES.

These products are usually intermediate between gasoline and illuminating oil. They vary in gravity from 40° to 58° Baume, and are more homogeneous than the burning oils. As they are designed for paint thinners and for admixture with turpentine, they should evaporate without leaving residues or stains. A representative sample found in the market gave the following tests:—

Baume gravity @ 60°F....................	48·2
Refractive index @ 60° F....................	1·4595
One drop evaporated from white paper.......	No stain.
15 drops in a watch glass evaporated in......	2 hrs., 23 mins.
15 drops of turpentine in watch glass evaporated in............................	2 hrs., 15 mins.
Initial boiling point.......................	282°F.
Final boiling point........................	426°F.

BLACK OILS.

These oils may be residues from crude oil or from distillates. They vary widely in tests and are cheap lubricants. They are used on car wheels and in other places where the higher refined oils are not necessary.

ASPHALTS.

The residues of asphalt-base oils are known as petroleum asphalt. They may be steam residues, dry or oxygenated residues. Asphalts are made also from the sludge acids resulting from the sulphuric acid treatment of paraffin oils, or they may be made by blowing distillates with air at high temperatures, which converts the low viscosity oils into asphalt by the abstraction of hydrogen and carbon and a reconstruction of the molecules.

Uses: Street paving, roofing pitches, water-proofing, and similar purposes.

Use for street oiling.—In the past few years various cities in Canada have taken up oil for oiling their streets instead of sprinkling with water, as heretofore. This has been done extensively in London, Ontario, and towns to follow suit are Windsor, St. Thomas, Aylmer, Tilsonburg, Parkhill, Otterville, Tilbury, Wheatley and Kincardine.

Conclusion.

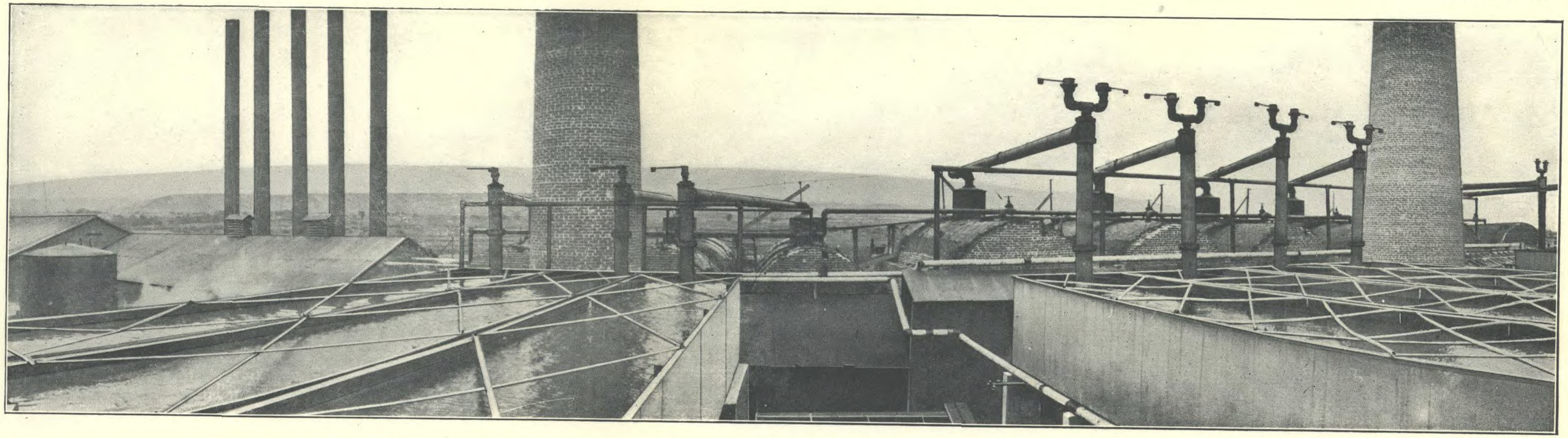
In addition to the uses given above for petroleum products, they are used in the manufacture of harness oils, leather and belt dressing, greases, wool oils, soluble oils and in many other products and other ways too numerous to mention.

Pressure distillation, which for a long time was avoided on account of the hazard involved, has finally come into practical use in the manufacture of gasoline from heavy fuel oils. Under the patent of Dr. Burton, the Standard Oil Company is now making this cracked product under the name of Motor Spirits. Dr. David T. Day took out a patent previous to Burton's, which combines pressure distillation with hydrogenation. By this process hydrogen or a hydrogen carrying compound is introduced at the time of cracking of the fuel oil and, mixed with the light gasoline vapours formed, it then passes over a contact or catalytic agent. These processes will no doubt have much to do with the future development of the gasoline industry, and it is perfectly safe to say, that as long as we have oil, we will be able to manufacture gasoline in large quantities.

FUEL OILS.

GENERAL CONDITIONS.

There are certain oil products which must, in the future of the Canadian oil trade, require especial consideration. Chief among these is fuel oil. At present the situation is one of finding a supply, especially for railroad locomotive use, sufficient for a demand which is now not filled at all and yet is increasing rapidly. In spite of importation from the United States it is safe to say that the fuel oil will not be filled from the present sources of supply. Even a large development of the oil shale



Stills at Casper, Wyoming, erected for the purpose of extracting gasoline from heavy oils by the cracking process.

industry, which would be most fortunate for the eastern provinces, would find its product absorbed without affording any considerable low grade oil for fuel purposes. On the other hand it is quite likely that a large addition to the supply of Canadian oil may be furnished from Alberta or Saskatchewan at any time, when the conditions would be reversed and a larger market than now exists would be required to dispose of the supply.

DEVELOPMENT OF OIL AS FUEL.

In a previous paragraph fuel oils have been defined, as regards the product furnished by refineries. But in all oil countries so many products have been utilized for fuel that a brief review is desirable of the history of fuel oil.

The use of large quantities of any oil as fuel began in Russia when the one product in general demand from crude was kerosene and it was obligatory to find a use for the residue "astatka," which was sold for whatever it would bring for fuel in place of coal for the steamers on the river Volga. This was no definite product, but simply whatever was left behind when first gasoline and then kerosene had been distilled away from the crude oil. From that time to this the practice of the oil men has extended of getting rid of waste products by selling them as fuel oil. The points of advantage of oil over coal became so evident that the amount which could be sold as fuel was practically unlimited provided the price was not so high as to be entirely out of proportion to solid fuel. These advantages caused the adoption of oil in place of coal in certain places at prices far above the coal equivalent; thus, in the United States, glass makers adopted this easily regulated fuel, obtaining the supply from eastern refineries.

In 1901 the unearthing of a flood of oil at Spindletop, Texas, quickly brought about its adoption by the Southern Pacific railway, which was already using crude oil in the same way in California not only because there was little use for California oil for usual refining purposes but also because coal fuel was so very high priced. This crude oil became fuel oil, as well as the surplus refinery products. This has always been an expedient for marketing a surplus until the development of refining methods suitable for the new oil. Then the fuel oil trade again was filled by the less valuable residues.

Only a few years ago Dr. Rudolph Diesel found that many heavy oils could be efficiently burned in internal combustion engines, in place of gasoline, by so increasing the compression as to heat the oil to the point of ignition. Not all oil residues are acceptable for this Diesel engine, chiefly because it is difficult to feed certain thick oils to the combustion chamber in good admixture with air. But for this it is claimed that any oil would be satisfactory; in fact it is claimed that vegetable nut oils are thus used in Africa, and that coal dust could be burned if it could be properly supplied to the cylinder. As a matter of fact very clean oils free from sediment and not so thick as to clog the feed are desired for the Diesel engine, and distillates are preferred. With the progress in converting one kind of oil product in almost any desired condition it is probable that less attention will be paid to the improvement of Diesel engines for using heavier crudes and more will be given to the furnishing any desired grade of fuel oil.

CHARACTERISTICS.

A valuable description of the characteristics of fuel oils in common use was given in a lecture by Mr. W. Hamilton Patterson, M.Sc., in the University in Liverpool in 1912, from which the following is extracted from the Petroleum Review of January 15, 1913.

"Since the report of the Royal Commission on Coal Supplies in 1893 there has been vast development in the world's oil resources; new oil fields are being continually tapped. There has also been a great increase in the production of tar oil obtained from coal, and there will probably be a larger increase in the near future. In line with this the internal combustion engine has made rapid strides, being constructed of ever-increasing size and higher efficiency. An epoch in the history of internal combustion engines was inaugurated by the advent in 1897 of the Diesel engine, which is adapted to burn almost any variety of liquid fuel, at the same time creating a record in efficiency, being able to transform 37 per cent or more of the heat energy of the fuel into available work. Of no less importance are the engines of the semi-Diesel type.

The chemical side of the question has scarcely kept pace with the mechanical, and there is much room for scientific research and investigation in the preparation and utilisation of fuels. There is also much overlapping and ambiguity in the nomenclature of the various technical products which are put on the market as liquid fuels. To begin with, there ought to be some distinction between oil fuels and fuel oils. In this paper the term fuel oil will be reserved for oils burnt in external combustion, *e.g.*, under a boiler for the purpose of raising steam; oil fuels, on the other hand, will mean oils utilised for the production of power in internal combustion engines. The term liquid fuel may be applied in either case. Athough many fuel oils may often be equally well utilized as fuels, there is a difference in the requirements. In oil fuels, volatility is of greater importance, and the obtaining of oils which will neither corrode nor give trouble in the cylinders of internal combustion engines on explosion or burning. In fuel oils more vital factors are: cheapness, a fairly high flash point, and high calorific value. The various liquid fuels and their allied products, derived either from petroleum or coal tars, are not definite compounds; it is therefore impossible to assign to these varying mixtures scientific names. It is, however, greatly to be deplored that, in technical usage, the same name is not applied in different parts of the world to denote what is essentially one and the same product and vice versa. What confusion occurs, for example, in the designation of the words paraffin, benzine, solar oil, naphtha, etc. To add still further to the chaos which already exists, we find specially coined trade names. Of oil fuels, the only variety widely used for certain kinds of motor engines is petrol, but alcohol might be used instead, provided it could be obtained cheaply enough, and also benzol, or better still, a mixture of the two. When, however, liquid fuels have to compete with coal for the production of power, only crude products, by-products or residues can be considered . The available sources of such liquid fuels may be divided as follows:—

(1.) Crude petroleum, or residues and products from petroleum;
(2.) Tar oils from coal distillation, coking, or producer plants, especially from bituminous coal producers;
(3.) Liquids or oils from vegetable or animal sources, including alcohol and nut oils, at the present time of little importance;
(4.) Oils from lignite, peat, wood, or shale.

The last class is not very important as far as this country is concerned, except as regards the Scottish oil production from shale, which amounts to about 70,000,000 gallons per annum. This figure includes, however, a large percentage of constituents too valuable to be utilised as ordinary liquid fuel. The following results have been obtained in the examination of various liquid fuels, most of which are available in this country, and obtainable at the cheapest price; the highest price in any case in this country is a little over £1–3s. per ton, most of them, however, being cheaper. They have been examined more particularly with reference to their use as oil fuels. The calorific values were determined by the Mahler Bomb Calorimeter, a method which gives absolutely reliable results when worked under proper conditions. The sulphur was determined by titration of the bomb liquid, allowance being made for nitric acid produced in each case. Carbon and hydrogen were determined by the ordinary combustion method of elementary organic analysis. Open tests were made of flashing and burning points, while viscosity was determined in a special viscometer. The main figures are here tabulated:[1]—

Of these, Nos. 3, 11, and 14 have been found to work well on Diesel engines, and there is good reason to suppose that Nos. 1, 2, 7, 8, 13, and 14 would work equally well. Nos. 16 and 17 have been found to give trouble with Diesel engines.

As fuel oils, probably all the oils tabulated would give an efficiency proportional to their net calorific value. It will further be seen that the sulphur content is in no case excessive. The much lower calorific values of oils

[1]See Table XIX.

Nos. 16 and 17 may account in some measure for the trouble they give in Diesel engines, but there are other factors which are brought out in the tables above. In combustion of fuels in the bomb calorimeter, the products of combustion are cooled to the ordinary temperature of the calorimeter, the hydrogen of the fuel is oxidised to water, which gives up its latent heat on condensation. There is also a small amount of sulphuric and nitric acid produced which must be allowed for. The heat value actually obtained in the bomb calorimeter is the gross value, while that corrected for hydrogen and acid formation is the net value, and corresponds to the maximum energy of the fuel which is available for the production of work in ordinary practice. It is astonishing how, in ordinary commercial practice, the two values are confused. To apply the right correction for the water condensed, it is necessary to know the hydrogen in the oil (also the free water if there is any). To ascertain the correction due to the former cause, the only absolutely reliable means is to determine the hydrogen by making an elementary analysis of the oil. This is, however, a tedious process, and in most cases, as will be shown below, the hydrogen content may be assumed with an accuracy sufficient for the purpose of applying this correction in technical work. In the table given above the figures are given for the open flash points, burning points, hydrogen contents, gross calorific value given by the bomb calorimeter determination, the water correction for the hydrogen, the acid correction in the order, nitric acid, sulphuric acid, and the corrected or net calorific value.

In low boiling fractions of petroleum products, the hydrogen content may reach 16 per cent. or more."

Oil burning locomotives have been in use hardly a dozen years, but at the present time oil engines are rapidly being installed in ocean steamships and in the navy. The progress of fuel oil consumption has been largely increased through the invention of the crude oil consuming gas engine, which has rendered oil the world's best fuel. The British Admiralty has recently decided that the use of oil as fuel is of such great advantage over coal as to warrant its adoption in the navy. The American navy also is well advanced in oil burning. All battleships—the construction of which has been started within the past half dozen years—are equipped for oil burning, either as an auxiliary to coal or in place of coal. Oil is used as an auxiliary fuel in seven battleships and is used exclusively in four, while thirty torpedo boats have exclusively oil fuel. The superiority of the ocean steamers driven by internal combustion engines was largely a matter of theory up to the year 1912, but in that year the fuel question was revolutionized by a Danish Company operating a line from Copenhagen to Singapore, which completed a 7,000 ton steamer, equipped with oil engines, which was the first large steamer ever to use oil fuel. The latter has proved to be eminently successful. Since that time several other large oil burning steamers have been launched in various countries.

Advantages of oil over coal as ocean fuel.—The advantages of internal combustion engines over engines driven by burning coal are numerous. In the case of the navy the removal of funnels increases the firing arc for a number of guns. The proportionate energy of fuel oil over coal is considerable. The oil occupies much less space than would the coal; hence, there is an increase in horse power. The reduction in the number of stokers employed results in economy, both from the sleeping space and from the salary and food question. Perhaps one of the greatest advantages of oil is its cleanliness and the absence of smoke.

The United States has equipped its latest submarines with internal combustion engines. Since the discovery that oil possesses great advantages over coal as a fuel in warships, Great Britain has energetically prosecuted a search for a large fuel oil field throughout her colonies; nothwithstanding these efforts, no large supplies have been found in any of them. Some oil has been discovered in Trinidad, but this is far from sufficient for the purposes required. There have been encouraging prospects in Malaysia and the East Indies, but neither in India, Australia, Japan, or Canada have fuel oil fields been developed of large size, and it will be necessary for Great Britain to purchase her fuel outside the empire unless supplies can be discovered in some other places mentioned.

The largest supplies of fuel oil in the world have been discovered in Mexico and Russia. When stating that the British empire has not yielded important deposits of fuel oil, however, we must make an exception of the Yenangyaung in Burma, midway between Rangoon and Mandalay; but even this field, which produces approximately 7,000,000 barrels per year, is not comparable to the American, European or Dutch India fields. Consequently, it would be a great boon, not only in Canada, but to the British empire, if a large supply of oil could be developed in western Canada.

USE OF OIL AS RAILWAY FUEL.

On the Great Northern railway in British Columbia, oil has been used as fuel on the locomotives for several years, and since the installation of oil burners, no fires have been reported starting from locomotive sparks, whereas previously the fires were numerous. The use of oil in the same respect is also reported on the main line of the Canadian Pacific railway, between Kamloops and Field, British Columbia. Similar results are reported in the Adirondack mountains in New York state. Oil is also used as fuel on the Esquimalt and Nanaimo R. R. The total mileage on which oil is burned is 587 miles, exclusive of the Grand Trunk Pacific railway, which proposes to adopt oil burning locomotives on its Pacific division.

USE OF OIL FUEL FOR SMELTING.

The use of fuel oil for generating steam and in internal combustion has been discussed quite generally in the technical press, compared to the meagre accounts of the use of oil in smelting. This practice, however, has been remarkably successful in the United States and elsewhere and justifies the following description by E. H. Hamilton in the New York "Engineering and Mining Journal."[1]

"In Pueblo, in 1896, I roasted ores and mattes, using oil for fuel in Brown-O'Hara roasters and by proper adjustment obtained a perfectly nodulized product which was in ideal condition for smelting in a blast furnace. In another plant fuel oil was used with great satisfaction in the retorting of zinc crusts, but the economy depended upon the whim of the sellers of the oil. I also ran three muffle furnaces containing two muffles, each muffle 13 × 21 × 7½ in., for assaying in a copper smeltery. We used 28 gallons of California crude oil per day of 6½ hours per furnace, with good results.

The greatest advance in reverberatory smelting of recent times was the large reverberatory furnaces which were developed in Anaconda by Mr. Mathewson while I was his assistant. These furnaces were enlarged from a 50-ft. hearth up to 118 ft. The average tonnage was brought up to approximately 300 tons per day on a coal consumption of 1 to 4½ of calcine.

In 1904 these furnaces were copied by Cyrus Robinson and built in Arizona with modifications to use California crude oil, and it became my lot to make them operate successfully. The ore was first roasted in Edwards roasters to which were attached oil jets. Whenever the heat began to get too low to do good work these jets were turned on for a few minutes. By this means the roasting was maintained in the furnace. At times when there was a shortage of sulphur the length of time for oil firing was increased considerably. Many difficulties were encountered, but the application of the oil as fuel was a great success.

[1] Eng. Ming. Jour., Jan. 28, 1911.

It seems strange that the smelteries did not adopt that system in various parts of the country, where the conditions of the ore, etc., afforded ideal conditions for the working of oil-fired reverberatories. The conditions which were forced upon me were such that the silica in the slags ranged from 45 per cent downward and the lime from 2 per cent up to 23 per cent. The physical and chemical conditions of the constituents varied widely during the time these oil-fired furnaces were run and I know from three years' experience on the coal-fired furnaces of the Anaconda plant, that it would have been impossible to smelt charges in Anaconda with coal which I smelted successfully with crude oil for fuel. From tests made I came to the conclusion that, given the Anaconda conditions of charge (both chemical and physical) we would have been able to smelt over 300 tons per day in oil-fired reverboratories.

My experience showed that about 19 per cent to 20 per cent of the heat was absorbed by the charge and about 50 per cent was taken up by the boilers. However, anyone who has been a close student of the reverberatory smelting will know what a great range of possibilities there are which tend to vary these proportions and the firing of the furnaces by oil affords especially good opportunities to study these. In our case we had to produce power from the waste heat to run mines situated 20 miles away and to furnish power for a concentrator and to run the whole smelting plant and sampling mill.

With a furnace hearth of over 100 feet in length, all at a white heat, it was possible to regulate the flames so as to obtain complete combustion, if desired, before reaching the throat, where there was practically no CO. All the combustible constituents of the oil were completely burned before reaching the boilers, and in this way an efficiency was obtained which could not be obtained in ordinary oil-fired boiler practice.

One barrel of 42 gallons of the California oils was about equal to one ton of best bituminous coal. However, it must not be lost sight of that the heavy California oils have to be kept warm in passing through the pipes, and that a considerable amount of the steam generated in the boilers is used to atomize the oil. A small amount of steam is also used (either directly or indirectly) to run the oil pumps. Steam was also used to heat the oil in various tanks. These losses of course are variable, depending on many conditions, but in our case it averaged very closely to 7 per cent of the steam produced in the boilers. A great number of factors enter into the loss, many of which can be avoided by proper construction and by the arrangement and balance of the plant, but others cannot be avoided, such as weather conditions, etc. A great deal is being written about reverberatory smelting which is misleading. It is only under certain conditions that reverberatory practice is profitable.

Much has been written about burners. The point to be borne in mind is to "atomize" the oil and burn it in the right part of the furnace.

I also dried and heated up converters by means of a small oil jet. This for a time gave trouble as each new converter was cold and damp. Finally it was successful and the converters were dried and heated more economically than by any other fuel.

On one occasion during a scarcity of coke it became quite evident that we would not have sufficient coke to keep the blast furnace running and, as a shutdown was objectionable, I resolved to use oil as an auxiliary to replace some coke. So far as I was able to find out, the principal difficulty previously had been that the thick oil failed to reach the fire zone and the fire went out; so I rigged up a temporary "hot blast" consisting of one straight pipe around which I built a temporary brick furnace and put a small oil jet under it. This gave a warm blast for the tuyere in which the oil was injected. This gave an optical illustration of the action of the blast in the furnace, because we could see the flames from the oil in two or three tuyeres on each side of the one in which the oil was introduced. In this way we kept the blast furnace running several days longer than we would have been able to do otherwise, until a supply of coke arrived.

This was what I set out to do and it was certainly not done at any monetary loss as between a full coke supply and the cost of oil which replaced it. The question then arose as to how much of the saving of coke might be due to warm blast and how much to the oil fired in the furnace. So I proceeded to try the warm blast alone, but my "stove" burned out and as the manager did not see any immediate profit to the company the stove was not rebuilt. The only difficulty experienced was the slagging of the furnace tuyère."

UTILIZATION OF NATURAL GAS AND ITS PRODUCTS.

The most important use of natural gas and the use for which it is most beneficial is in domestic heating, lighting, and cooking. In all countries where gas is found, however, a certain proportion of the product is used for industrial and manufacturing purposes, particularly for burning brick and lime and in glass, iron and sugar works, in generation of steam, cement manufacturing, zinc smelters, etc., because it is very difficult and very costly to store natural gas from wells of high pressure, and the gas must either be used or wasted. In industrial works the price of gas is generally a little over half the price charged to domestic consumers; consequently, the depletion of the supply is generally very rapid in cases where industrial works exist within the range of the pipe lines.

ADVANTAGES OF NATURAL GAS.

People who live in portions of the country where natural gas has never been found do not appreciate the great boon enjoyed by the inhabitants of more favoured communities where gas can be found by drilling or within the range of pipe lines constructed from distant fields. The consumers of artificial gas do not appreciate natural gas after having once enjoyed it, since natural gas can generally be sold at a fraction of the price of artificial gas. One of the cheapest supplies of artificial gas in the country, or perhaps in the whole world is in the city of Toronto, where the price is only 75 cents net per thousand cubic feet; but even this price is three times as much as the price which the people of Wallaceburg, Chatham, and many other towns pay for natural gas.

GASOLINE FROM NATURAL GAS.

Natural gas is divided by chemists into two classes; first, a so-called "dry gas" known and used for years as the natural gas of commerce; and second, a gas which contains easily liquifiable vapours, which is known in the vicinity of the oil fields as a "wet gas".

For many years it has been known that gases could be liquified to a certain extent. As long ago as the 70's J. J. Coleman[1] succeeded in liquifying gases which were obtained from Scotch shale oils. Since that time gas has been made by cracking oils in hot retorts by the processes of Blau, Pintsch, Gray, Hastings, Brink, Swiss Liquid Gas Company, Schneider, Williams, Wolf, Wolski and others.[2] Gases thus made are commonly washed and compressed into steel cylinders capable of withstanding the pressures developed, and some of the companies have been commercially successful. Natural gas has rather recently been bottled in a similar way and sold commercially.

HISTORY OF NATURAL GAS GASOLINE.

The first gasoline in commercial quantities from natural gas was procured in 1904 near Titusville, Pa., by Pasenmeyer and others.[3]

In 1905 the yield of gasoline was further increased by chilling the pipes with cold water, and from 1905 to 1909 by the establishment of small low pressure single stage compressing plants. Since then the industry has made remarkable strides. Previous to the latest improvements the gas was compressed

[1] Chem. News, Vol. 39, 1879, p. 87.

[2] Allen, J. C. and Burrell, G. A. Liquified products from natural gas, Technical Paper No. 10, U. S. Bureau of Mines, 1912, p. 4.

[3] Taylor, Frank H. Early History of Utilization of Gasoline from Natural Gas. Oil City Derrick, May 6, 1911, p. 9.

Oil and Gas Journal, Vol. 9, May 11, 1911, p. 20. The gasoline from natural gas industry; Oil and Gas Journal, Vol. 9, March 2, 1911, pp. 2–6. Petroleum, March 17, 1911, Vol. 6, p. 896.

in single-stage compressors under a pressure of 150 to 300 pounds per square inch. Then the production was run into a tank and weathered, which process consisted in allowing the lighter portions to volatilize and escape into the air until the liquid had practically ceased to boil away. In this process there was a loss of 25 to 50 per cent of the natural gasoline, which was an absolute waste.

PRACTICAL METHODS IN NATURAL GAS MANUFACTURE.

A good summary of the methods of obtaining natural gas gasoline from the gas is given by Allen and Burrell.[1]

A very complete bibliography accompanies the paper which will give a reader access to all the literature on the subject published up to that time.

Natural gas occurs very frequently so associated with oil as to exist really in solution in the oil, in a manner similar to the way carbonic acid is found in many natural springs, dissolved in water. Just as carbonic acid, issuing from such a spring contains all the water vapour it can carry (that is, is saturated with water vapour) so natural gas—issuing from oil deposit, contains all of the lighter gasoline vapours of the oil that it can carry for that temperature. The warmer the gas when it issues from the well, the larger proportion of gasoline vapours it can contain. Therefore if such gases, in being piped to the place where they are to be utilized, become cooled, they will deposit some of the gasoline vapours as liquid, and in fact in many cases it is necessary to provide drip cups for collecting this liquid.

By slightly cooling such natural gas or compressing it, the heavier part of the gasoline will condense, and the stronger the pressure applied and the lower the temperature to which the gas is cooled, the greater the extent to which the gasoline vapours can be condensed to natural gasoline, until finally under a pressure of from 600 to 700 pounds at the ordinary atmospheric temperature everything can be condensed from the gas leaving only the gas itself, that is methane.

[1] Allen, J. C. and Burrell, G. A. Liquified products from natural gas, Technical Paper No. 10, U. S. Bureau of Mines, 1912, 23 pages.

Up to the last two years the general practice in the manufacture of liquid natural gas was to make the product by compression of the gas in single-stage compressors operated at a pressure of 150 to 300 pounds per square inch.[1] The one product thus obtained, so-called natural gasoline was run into a tank and weathered. The weathering consisted in allowing the lighter portions to volatilize spontaneously and escape into the open air until such time as the boiling away of the liquid had practically ceased. Thus the process involved a loss of 25 to 50 per cent or even more. This loss was absolute waste, not only of power and of cost of operating the engines and compressors but of the product itself.

The next step in the industry was to pass the waste gases (of which only the small quantity used for power had been utilized) from the single-stage compressor through a higher-stage compressor, thereby getting a second and more volatile product—a "wilder" liquid—which was run back to the first tank and mixed with the first or heavier condensate. This mixture was then again weathered to a safe degree, whereby it lost the greater part of the more volatile product that had been condensed in the second stage.

Recently the process has been improved another step, in that the first stage compressor product is run into one tank and handled as ordinary gasoline; the second stage compressor product is run into a second tank and handled as lighter gasoline,[2] with which the heavy refinery napthas can be enriched or enlivened.

The last mentioned method of using the second stage compressor product should receive wide recognition, and a market for the product should develop that would be no mean factor in the industry. Blending in the proportions of say 1 part of the product to 4 or 5 parts of the refinery napthas makes these heavy napthas more volatile and of greater value as fuel for automobiles; it also greatly increases their usefulness. The

[1]Liquefied Products from Natural Gas, Tech. Paper 10, Bureau of Mines, p. 7, Irving C. Allen.

[2]Fithian, Dr. Edwin J. The fractionation of natural gas gasoline: Natural Gas Association, sixth annual meeting, at Pittsburgh, Pa., May 16, 1911. Natural Gas Journal, August, 1911, pp. 16-17.

proportions to be used in blending, however, must be determined more definitely by test.

The natural gas of this country frequently contains light products that do not condense in the second-stage compressor, and for which it is practicable and necessary to install, three, four, and even higher stage compressors. These light products—true gases at ordinary temperatures and pressures—can be compressed and liquefied, but the liquid gases so obtained must be handled as gases and not as oils. The mistake, heretofore, has been made in the natural gas gasoline industry, as some have recognised, of attempting to handle the light gaseous products as oils and not as gases. Until the manufacturers of this lightest third and fourth stage compressor product recognize its gaseous nature, the absolute necessity for insuring the safety[1] of the public involves certain restrictions in its transportation, and not until the realization that this extremely volatile liquid should be handled only in strong steel containers capable of withstanding high pressures will it be transported with safety.

A great deal of complaint has been made regarding the light and volatile natural gas gasoline which has been sold in some places near the oil fields in the United States for automobile gasoline; but this is presumably due in large measure to an unwise proportion in the blending of the two grades. It is necessary to handle the liquid gases as gases and not as oils, and the lack of this proceeding was one of the mistakes made in the early days of the natural gas gasoline industry.

QUALITY OF GASOLINE NATURAL GASES.

Natural gases that issue from old wells in which the rock pressure has diminished to a marked degree, contain higher members of the paraffin series such as propane and butane in larger quantities; and when a pressure below the atmospheric pressure is applied to the wells, still larger quantities

[1]Dunn, B. W. Gas gasoline safety standards, Oil and Gas Jour., vol. 10, June 22, 1911, pp. 16-18; Standards for gasoline safety, Oil City Derrick, June 19, 1911, p. 8; Proposed regulations of Bureau of the Safe Transportation of Explosives and other Dangerous Substances for the shipment of liquids flashing below 20°F., Nat. Petroleum News, vol. 2, February, 1911, pp. 10-11.

of the higher paraffins are obtainable. Gases which contain methane only will not yield gasoline or liquid gas because methane liquifies at pressures so high and temperatures so low as to be impracticable, and the product if obtained, could not be stored even as well as liquid air. Gases which contain no paraffin hydrocarbons higher than ethane require a pressure of 600 to 700 pounds per square inch at 35° C. to liquefy the ethane, but at lower temperatures less pressures are required. Propane and butane are on the dividing lines between liquids and gases and must be handled as such.

GASOLINE FROM GAS IN CANADA.

Charles Bisnett of Blenheim, and certain parties from Brantford and Chatham, have erected a plant in the Onondaga field, for the recovery of gasoline from the gas associated with the oil. At the time the field was visited in 1912 the plant was reported complete, but no test of the plant had been made.

The gas from the New Brunswick field has been tested and found to be too dry for extracting natural oil and gasoline.

COMPRESSED NATURAL GAS ON RAILWAY TRAINS.

Throughout the entire line of the Intercolonial railway of Canada, running from the Atlantic seaboard to Montreal, the passenger cars are lighted with gas from the New Brunswick natural gas fields, the product having been successfully used in place of the Pintsch gas, with which the lights were formerly charged.

Gas is used exclusively as fuel and for power generation in the car shops at Moncton, over 30,000,000 cubic feet being consumed in September, while in winter months some 50,000,000 cubic feet are used. The steady and reliable heat makes it an ideal fuel for forges, furnaces and gas engines, no time is wasted in firing up and there is a considerable saving in expenditure.

The gas from the Canadian Pacific railway well at Medicine Hat is bottled in steel flasks 8 inches in diameter and 50 feet in length, and is shipped for use in lighting the cars. The pressure of the bottled gas is 1,700 pounds, according to Mr. Winter. All the cars are restocked with gas at Medicine Hat.

PRODUCTION IN THE UNITED STATES.

Although gasoline has been produced in a small way in the oil fields of Pennsylvania for as many as 12 years, it was not until within the last few years that steps were taken to produce it on a larger scale by making use of the enormous quantities of waste or casinghead gas from the oil wells of the country. The low price of gasoline in the year 1911 was a great hindrance to the progress of this industry, but during the year 1912 the price continued to advance. The natural gas gasoline industry is assuming large proportions and is likely to expand until it will become a very important adjunct of the natural gas business. The use of casinghead gas for the production of gasoline is one of the most important means of conserving the natural gas supplies.[1]

Not all natural gases are adapted to the manufacture of gasoline. As already stated, some gases are dry and contain very little if any gasoline; others or wet or casinghead gases may not contain sufficient gasoline to make it profitable to use them. A chemical analysis will show the expected yield of gasoline from a particular gas and will determine the probable quantity of gasoline to be obtained from any plant equipment, but the installation of a small experimental plant is a better test. This subject has been fully discussed in reports issued by the United States Bureau of Mines.

The following tables show that the total number of gasoline plants in operation in the United States increased from 176 in 1911 to 250 in 1912, and that the daily capacity almost doubled.

[1]Chapter on natural gas, Mineral Res. U. S., p. 48. (1912).

These figures include not only the regularly established compressor plants but also those which use the simple method called the gas-pump or vacuum process.

It will be seen that the natural gas gasoline industry was confined to eight states[1] in both 1911 and 1912. West Virginia takes first place in the quantity of gasoline produced in 1911 and 1912; Pennsylvania, which was third in 1911, takes second place in 1912; Ohio, although showing considerable gain in 1912 over 1911, drops to third place in 1912; Oklahoma and California are next in order in both years and are followed by Colorado and Illinois, which exchange places in 1912; New York is eighth on the list.

The total production of gasoline from gas in 1912 was 12,081,179 gallons, valued at $1,157,476 as compared with 7,425,839 gallons, valued at $531,704, in 1911. The average price increased from 7·16 cents per gallon in 1911 to 9·6 cents per gallon in 1912, a gain of 2·44 cents per gallon.

The estimated quantity of gas used in the extraction of 12,081,179 gallons of gasoline in 1912 was 4,687,796,329 cubic feet, an average yield of 2·6 gallons of gasoline per thousand cubic feet of gas used.

Various uses are made of the residue or exhaust gas, which is the gas left after the gasoline has been extracted. In some places it is sold to gas companies and run through their lines to consumers for domestic and industrial purposes; in other places it is used to drive gas engines and the gasoline plant of the operator; but it is most commonly returned to the original producer for field purposes. In some places it is entirely wasted.

In the following table are given statistics of the production of gasoline from natural gas in the United States in the years 1911 and 1912, by States:—

[1]The only gasoline produced in Kentucky came from natural condensation in the pipes.

TABLE XX.

Production of Gasoline from Natural Gas in the United States in 1911, by States.

STATE.	Number of operators.	PLANTS.		GASOLINE PRODUCED.			GAS USED.		Average yield in gasoline. Gallons.
		Number in operation.	Daily capacity. Gallons.	Quantity. Gallons.	Value.	Price per gallon. Cents.	Estimated quantity. Cubic feet.	Value.	
West Virginia	47	72	16,819	3,660,165	$262,661	7.18	1,252,900,600	$76,074	2.92
Ohio	26	39	6,454	1,678,985	118,161	7.04	469,672,000	37,574	3.57
Pennsylvania	43	50	5,669	1,467,043	109,649	7.47	526,152,663	52,615	2.79
Oklahoma	8	8	4,800	388,058	20,975	5.40	144,629,000	4,378	2.68
California, Colorado, Illinois, New York	7	7	3,358	231,588	20,258	8.75	82,343,000	6,320	2.81
	131	176	37,100	7,425,839	$531,704	7.16	2,475,697,263	$176,961	3.00

Production of Gasoline from Natural Gas in the United States in 1912, by States.

STATE.	Number of operators.	PLANTS.		GASOLINE PRODUCED.			GAS USED.		Average yield in gasoline. Gallons.
		Number in operation.	Daily capacity. Gallons.	Quantity. Gallons.	Value.	Price per gallon. Cents.	Estimated quantity. Cubic feet.	Value.	
West Virginia	66	97	22,366	5,318,136	$513,116	9.6	1,972,882,212	$163,749	2.8
Pennsylvania	69	83	10,524	2,041,109	217,016	10.6	722,730,117	62,010	2.8
Ohio	25	43	7,791	1,718,719	173,421	10.1	576,123,700	46,090	2.98
Oklahoma	11	13	11,910	1,575,644	99,626	6.3	701,044,300	24,901	2.25
California	7	7	6,669	1,040,695	112,502	10.8	600,743,000	25,573	1.7
Illinois	4	4							
Colorado	2	2	2,008	386,876	41,795	10.8	114,273,000	9,662	3.4
New York	1	1							
Kentucky	1	(a)							
	186	250	61,268	12,081,179	$1,157,476	9.6	4,687,796,329	$331,985	2.6

HEATING VALUE OF NATURAL GAS.

Natural gas with a heating value approximating 1000 heating units per cubic foot compared with a manufactured gas approximately 600 heating units, results in the conclusion that the relative value of the natural gas, for perhaps ninety per cent of all utility purposes, may be considered as being proportional to these heating units, or some 65 per cent greater in value than the manufactured gas. The fact that the use of natural gas, because of its lower candle power, compels the consumer to adopt the incandescent gas burner, ultimately tends to his benefit, because the efficiency of the light obtained from this burner is much higher than the efficiency obtained from the open flame of even a high candle power gas. Considering the sand pressure and supply this comparison of the two gases shows even greater contrast.

Manufactured gas at prices approximately 80 cents to $1 per thousand cubic feet to the general domestic consumer would compare with natural gas, supplied under the same conditions, at a value approximately $1.30 to $1.60 per thousand cubic feet. The ultimate saving to the consumer who could receive natural gas for 50 to 60 cents is apparent.

Concerning the heating value of gas, based upon natural gas practice, Mr. Thomas R. Weymouth[1] says:—

"When it is impossible to obtain a calorimetric determination of the heating value of a particular gas, the next best procedure is to compute it from the chemical analysis of the gas.

This, of course, is done by multiplying the percentage of each gas present by its corresponding heating value per cubic foot, and adding the products. The specific gravity is obtained by computation in precisely the same manner. Such computed results are necessarily subject to whatever errors there may be in the analysis of the gas, and unless this has been done with great care and precision, a wide discrepancy may exist between the calculated and actual values.

It is frequently desirable to get an approximate knowledge of the heating value of a gas when neither a calorimetric determination nor a chemical analysis is available.

In such cases, a fair "guess" may be made from a determination of the specific gravity of the gas, provided it is known to be a normal "dry" gas without freakish tendencies. The specific gravity is readily determined by the effusion method, in which the time required to pass a given quantity of the gas through a pin hole orifice in a thin plate under a given head, or pres-

[1] Journal of the American Society of Gas Engineers.

sure, is divided by the time required to pass the same quantity of air through the same orifice and under the same pressure; the square of the quotient being the specific gravity of the gas, referred to air. For most reliable results, the air and gas should be run at the same temperature, to avoid the necessity of a correction for this factor.

Approximately a formula for determining the heating value from the specific gravity may be derived from the following considerations:

In the analysis for an average natural gas, the combustible gases, methane and ethane, comprise 93·5 per cent of the whole, and ethylene and carbon monoxide comprise 0·2 per cent each. No great error will be made, therefore, if these two latter gases are considered as being a part of the paraffin group, especially since ethylene and ethane do not differ greatly in either heating value or specific gravity. The inert gases may likewise be combined in one group, of which the resulting gravity may be considered equal to 1·0. Consequently for approximate results, the average natural gas may be regarded as made up of three distinct gases, methane, ethane, and "inerts."

Representing the relative volumetric proportions of these gases, expressed chemically, as m, e, and i, respectively, the following relations will obtain:—

$$m+e+i=1\cdot 0 \qquad (1)$$

$$H=897m+1594e \qquad (2)$$

$$G=0\cdot 552m+1\cdot 0368e+1\cdot 0i \qquad (3)$$

in which H= the lower heating value in B.Th.U. per cubic foot of natural gas at gas standard and G=the specific gravity of the gas. Eliminating m and e from equations (1) (2) and (3), the heating value of gas may be expressed in terms of i and G as follows:

$$H=1440G—v541i+100\cdot 6 \qquad (4)$$

The sum total of the percentages of the "inerts" is 0·061=i. Substituting this in equation (4)

$$H=1440G+6\cdot 6 \qquad (5)$$

Applying equations (5) to an average gas of which the specific gravity is 0·6135, it would indicate the gas to have a fuel value of H=890 B.Th.U. per cubic foot, as compared with a value of 887·3 as computed from analysis.

It was fair to conclude, therefore, that for purely approximate work, a reasonable notion of the heating value of natural gas may be obtained from the known specific gravity by using equation (5).

[1]RELATIVE HEATING VALUES OF NATURAL GAS AND PETROLEUM.

An interesting comparison can be made as to the relative heating values of natural gas and petroleum. The heating values of natural oils from Eastern America range from about 17,500 B. T. U., to 21,600 B. T. U. per pound—the average of 29 oils, listed by Poole,[2] in his work on the Calorific Values of Fuels, being about 19,600 B. T. U. In Poole's list only two Canadian oils—both of which are from Western Ontario, are mentioned—a Bothwell oil, specific gravity 0·857, B. T. U. 20,410; and a Petrolia oil, specific gravity 0·870, B. T. U. 20,530. These, unfortunately, appear to be the only two determinations avail-

[1]By A. W. G. Wilson.
[2]Second edition, p. 251.

able for Ontario oils. For purposes of comparison, the heating value of Ontario petroleums may be taken, in round numbers, as 20,400 B. T. U. per pound, or 176,700 B. T. U. per imperial gallon.

Direct determinations of the calorific values of Canadian natural gases are not available. The average calorific value of forty samples[1] of Ontario natural gas, as calculated from their chemical analyses, is 1,040 B. T. U. per cubic foot. Curiously enough this is also the average calorific value given by Poole for four samples of natural gas from Ohio, the nearest gas-field in the United States.[2]

Assuming the two measures given above as average values, we find that 1,000,000 cubic feet of Ontario natural gas possess the same heating value as 5,886 gallons of petroleum; or 1,000 cubic feet of gas have the same heating value as 5·89 gallons of oil. A barrel of oil (35 imperial gallons) would have the same heating value as 5,950 cubic feet of natural gas.

The present rates charged for the principal places where natural gas is used are shown in the following table:—

[1]Ontario Bureau of Mines, Vol. XXIII., page 254.
[2]See Poole, *op. cit.*, p. 254.

SELLING RATES OF NATURAL GAS.

Name of Company.	Town Supplied.	Rate per M Cu. Ft. Domestic.	Industrial.
National Natural Gas Co.	Hamilton	$.35	
Union Natural Gas Co.	Alymer	.30	
Dunnville Gas Development Co.	Dunnville	.25	.20
Union Natural Gas Co.	Courtright	(First three years 30c.) .40	.25
Southern Ontario Gas Co.	St. Thomas	.30	
Hill and Melich (Minimum of $15 per year for each domestic consumer.) (Minimum 400,000 for industrial consumer.)	Canboro	.45	.35
Southern Ontario Gas Co. (During May and October, 45c.; rest of the year, 30c.; for domestic consumers.)	London (Commencing April 1, 1914.)	.45	.40
National Natural Gas Co.	Hamilton	.37½	
Canadian Western Natural Gas, Light, Heat and Power Co.	Calgary	.30	.15
Ingersoll Gas Light Co.	Ingersoll	.45 net	
Dominion Natural Gas Co.	Simcoe	.30	
Ontario Pipe Line Company	Hamilton	.40	
Beaver Oil and Gas Co.	Harrow	.25	
Central Pipe Line Co., Ltd.	Aylmer Malahide Bayham Vienna Port Burwell	.25	.12
Moncton Tramways Electricity and Gas Co., Ltd.	Moncton Hillsboro	.38	.15
Brantford Gas Co.	Brantford	.35 net .40 gross	.12
Chatham Gas Co., Ltd.	Chatham	.35 .25	
Dominion Gas Co.	Hamilton, Brantford, Galt, Paris, Dundas, St. George, Binbrook, Bartonville, Dunnville, Attercliffe, Cayuga, Selkirk, Jarvis, Hagersville, Vittoria, and Simcoe, Lyndoch, Vienna, Tilsonburg	.37	.20
Beaver Oil and Gas Co.	Kingsville Leamington Wheatley and Ruthven	.25	.15
Oxford Oil and Gas Co., Ltd.	Woodstock	.25	
Petrolia Utilities Co., Ltd.	Petrolia	.30	.12 to .14 .25 gas engine.
Sterling Gas Co., Ltd.	Port Colborne Humberstone	.32	.27
The Norfolk Gas Co., Ltd.	Port Dover	.25	.15 to .20
The United Gas Companies, Ltd.	St. Catharines Thorold Fenwick	.40 to .70	.35
Sarnia Gas and Electric Light Co.	Sarnia Point Edward	.35 gr. .30 net	.25 to .12½
Windsor Gas Co., Ltd.	Windsor Walkerville Sandwich	.30	.12 & .15
United Fuel Supply Co., Ltd.	Sarnia, Petrolia, Brigden, Dresden, Point Edward, Marthaville, Corunna, Paincourt	.25 & .30	.10 to .15
The Consumers' Gas Co., Ltd.	Wallaceburg	.40	.12
Canadian Western Nat. City of Medicine Hat Gas Dept.	Medicine Hat	.15	.05
Redcliff Realty Co., Ltd.	Redcliff	.12½ $2 to $3½ per Mo.)	$10 to $100 per Month.
The Port Colborne-Welland Natural Gas and Oil Co., Ltd.	York and Caledonia	.25	.25

CHAPTER X.

CONSERVATION OF OIL AND GAS RESOURCES.

Marked and gratifying progress has been made during the last five or six years in the real conservation of the national petroleum and natural gas reserves in the United States. This has been along the practical lines of preventing large actual waste in production and in an approach toward securing the maximum efficiency from the marketed product. The general recognition of the fact that both oil and gas pools are exhaustible and that there has been in the past large waste in production has led many bright minds to the study of practical methods of overcoming this waste and of winning and turning into merchantable use every barrel of oil and every cubic foot of gas in the ground. Many wells, and, in fact, fields have been abandoned long before the available oil was exhausted, and the trend of experiments and effort has been toward reopening some of these old wells, and in new wells prolonging their lives.

In the early development of new fields in the hurry to tap the oil stratum in advance of rival operators the overlying oil sands are neglected and are usually cased off. In some instances these have since been developed and some of them have proved large producers.

On the other hand, improved methods of drilling, better geologic knowledge and greater oil demand have induced deep drilling in many of the older fields, some of which are now enjoying a new lease of life, notably parts of the Clinton fields of eastern Ohio, the St. Mary's pool in West Virginia, and some of the Pennsylvania fields. It is considered not improbable, according to L. C. Huntley of the Bureau of Mines, that the mid-continent fields have a deep-sand future.

Spacing of wells is an important factor in prolonging the life of a field, and while little in the way of regulating can be accomplished in territory where there are a number of small holders each working against the other, where large operators control sufficient acreage, more conservative practice is the rule.

The practice of using nitroglycerine for shattering the sand, as in the Glenn Pool, Oklahoma, has resulted in an increased productivity of many wells. Many older wells can also be made productive by cleaning. Roswell Johnson, Professor of Petroleum Engineering, University of Pittsburgh, makes the statement regarding the mid-continent fields that there are operators who never clean their wells, others who do it as a last resort, and others who do it periodically. The methods of cleaning are:—the removal of accumulated sand by tools and sand pump; the hot billet treatment which is probably most useful where the oil carries a large percentage of paraffin; the gasoline treatment which is very useful where the refiner owns the lease and can thus recover the gasoline; and freshening the hole with a small torpedo. Increased production may sometines be obtained by using large casing. An interesting innovation last year in eastern Ohio gives promise of very beneficial conservation of old oil fields in the future. Compressed air was forced into the nearly exhausted oil bearing sands through a well situated centrally in a group of old wells and the increase of all the wells was marked.

Loss is often occasioned by the neglect and consequent corrosion of casing, causing the admission of water to the oil bearing stratum. This cause of decreasing production needs only the simple remedy of proper attention. In most fields where producing wells are closely grouped, as many as possible are pumped together from a common power plant. But in the high grade oil fields especially each well requires different handling. Pumping by heads is a step in the right direction, yet it is impossible to judge the best possible time to pump and the proper height of oil column to leave in the well at all times. At least one automatic control device, with valves set to start pumping upon the accumulation of a certain maximum pressure and to stop pumping upon the exhaustion of the oil to a certain set depth, has been tested with success, and there can be little question as to the advisability of the use of such devices at a great many wells. An automatic control for the pumping of oil wells, says Mr. Huntley, governed by natural underground conditions at each well would increase the production of districts now being abandoned with large quantities of oil still remaining in the ground. Such automatic devices are on the market, but owing to the inertia of the producer relative to trying out seemingly revolutionary methods they have not been given a fair trial.

The ideal regulation of private oil development would insure the same results as if, for instance, the Government should develop large tracts of its own oil lands. Under the guidance of its specialists it would thus doubtless so drill these lands as to avoid the waste that results from private ownership in small tracts with its accompanying competitive line drilling. Government wells would be so spaced as to eventually extract all of the extractable content from oil reservoirs but without unnecessary and undesirable duplication of wells. This would be conservation of capital without loss of the natural resources involved. Drilling under these conditions, and the consequent complete draining of the pools, would with little question occupy a much longer period than drilling and drainage under the competitive conditions of private ownership, and production from the field would thus be distributed over a much longer period. This should steady prices, since smaller quantities of oil would be thrown upon the market in the early history of the field, lessening the tendency to depress prices at this period, while on the other hand larger quantities would be thrown upon the market during the later history of the field, which would tend to prevent the inflation of prices at a time when the production of the field would be greatly decreased if developed privately in small tracts. The general effect would be conservation of capital because there would be fewer wells.

Concerning the prevention of the tremendous waste of oil and gas, known as gushers, particularly in the California field, Ralph Arnold and V. R. Garfias of the Bureau of Mines, say: "With the state of our knowledge regarding the situation of the 'gusher' and 'gasser' strata in the developed field, there is no excuse for the general lack of precautions taken before the depth is reached at which the flow is expected. The additional cost of safety devices is insignificant in comparison with the total cost of drilling, and with the amount that can usually be saved if the rate of production is regulated. Experience has shown that a gusher or a gasser will yield a greater total production if allowed to flow only to a fraction of its capacity. One of the most successful apparatus devised to control whatever flow of oil or gas is encountered is a blowout preventer, which has given general satisfaction."

There may be some excuses for a single blow out or "wild" well in a new field where conditions are unknown, but there is seldom any excuse for a repetition of such a disaster in the same field, for it can be prevented by proper precautions in drilling.

In California, as elsewhere, an important problem is that of the exclusion of the water before or after the oil sands are reached by the drill. The most successful method is probably the cementing process which is used throughout the eleven principal oil districts of the state. To prevent the flooding of the oil sands by the waters above or below, cement is forced into the space outside the casing in order to form a water tight bond between the casing and the walls of the hole.

Strange as it may seem, until a comparatively few years ago natural gas was believed by probably a majority of people to be inexhaustible, and consequently an enormous waste of this most perfect of fuels has resulted. This idea possibly resulted on account of the relatively slight use and exhaustion of the gas from some of the most ancient wells which, in fact, seemed inexhaustible. Gas has been used from many wells for many centuries in both China and Japan, while the region of eternal fires in the Apsheron Peninsula on the shores of the Caspian Sea where inflammable gases issue from the rock fissures, was known over a thousand years ago and the fires were worshipped by the Parsees.

Arnold and Garfias also describe a method of drilling through gas or oil strata to deep oil sands below which muddy water is forced to the bottom of the well as the drilling proceeds and this mud mixture further forced through the casing into the porous sand stratum penetrated by the drill, thus building a plaster wall of clay throughout the gas-bearing strata. The gas thus excluded can be recovered afterwards by drilling shallower wells to the upper sands.

This method of applying mud-laden fluid to well drilling is described in further detail by J. A. Pollard and A. G. Heggem in Technical Paper 66 of the United States Bureau of Mines. The statement is made that one of the greatest wastes of natural gas is that which often takes place in drilling oil wells and that if the well is being drilled by the usual methods the gas becomes a hindrance to drilling and the driller regards it as a nuisance; or the gas may be found in a field where it has little or no immediate commercial value, and hence is allowed to escape into the air without restraint. At other wells the gas is taken from the sands through hundreds of feet of open drill hole, the last or inner string of casing being stopped far above the gas sands, thus leaving the lower part of the hole uncased. When such a well is shut in, much of the gas escapes into the porous beds below the casing and above the gas sands, and is wasted. Not only so, but the gas may travel through the porous beds for miles and cause blow outs in other wells being drilled in the same vicinity. Some of these unexpected flows of gas have been ignited, causing injury to workmen, and burning of drilling rigs.

The mud casing is effected by drilling with the mud laden fluid in the hole; as the drilling progresses the particles of clay held in suspension in the fluid are forced into the porous rocks and sands forming the sides of the drill hole and thus constitute a gas tight natural casing. Methods are described by Messrs. Pollard and Heggem by which a gas well can be thus cased with mud fluid in the hole in a few hours without the slightest risk to the workmen. It is also entirely feasible to case wells already dry drilled that are blowing. The advantages of the method have been fully demonstrated, and, according to the Bureau of Mines, too much emphasis cannot be placed upon the importance of its use where gas and water are encountered; it not only greatly reduces the danger to the workmen but effects a large saving in the amount of casing needed and entirely eliminates the waste of gas while drilling is in progress. Additional to this, the methods offer a further advantage in that they absolutely prevent the contents of one bed mingling with those of another; thus water cannot enter the pay sands, neither can oil or salt water contaminate the fresh water of other beds.

For many years the oil driller had no use for the gas and got rid of it as a nuisance. This practice is largely being discontinued, and the gas is at once utilized, or is conserved in the ground for future use. In some cases in bringing in new wells the pressure is so great as to at first baffle attempts to cap the gas flow, but in no case is this believed to be impossible. A gratifying example of the subjugation of a supposedly uncontrollable well was that of the Gilbert well, Louisiana, which was successfully closed by the owners. This was one of the greatest "wild" wells ever known. Even with the conditions improved, McDowell estimates the value of the gas wasted in the Oklahoma fields during the past five years to be more than the value of all the oil produced in that time. In drilling for oil in the Buena Vista hills, California, one gas well was opened that wasted an estimated 55,000,000 cubic feet a day for three months. The final control of the well was a notable engineering feat.

A remedy for the gas waste during oil production is possible by proper cooperation between gas and oil companies. Such cooperation exists in West Virginia, Ohio, and Pennsylvania, where the gas companies and the oil companies are generally under the same management. Gas can be saved from oil wells by providing a prompt market for the gas. A partial solution is to compress natural gas in steel cylinders for transportation and for use on railways and in automobiles.

Since the discovery that some of the California gas is rich in gasoline, much gas formerly wasted has been conserved on this account. Plugging the dry and abandoned wells is required by several state laws and should be further extended and enforced.

The laws of Pennsylvania, Ohio, Indiana, and California provide for the efficient capping of every gas well when not in use. There should be similar laws in all states and provinces having gas fields. If the owners emphatically refuse to close their "wild" wells, the Louisiana remedy can be applied; that

Blown out gas well, Caddo field, Oil City, La., U.S.A. (The position occupied by the columns of water is the site of a well which was blown out.)

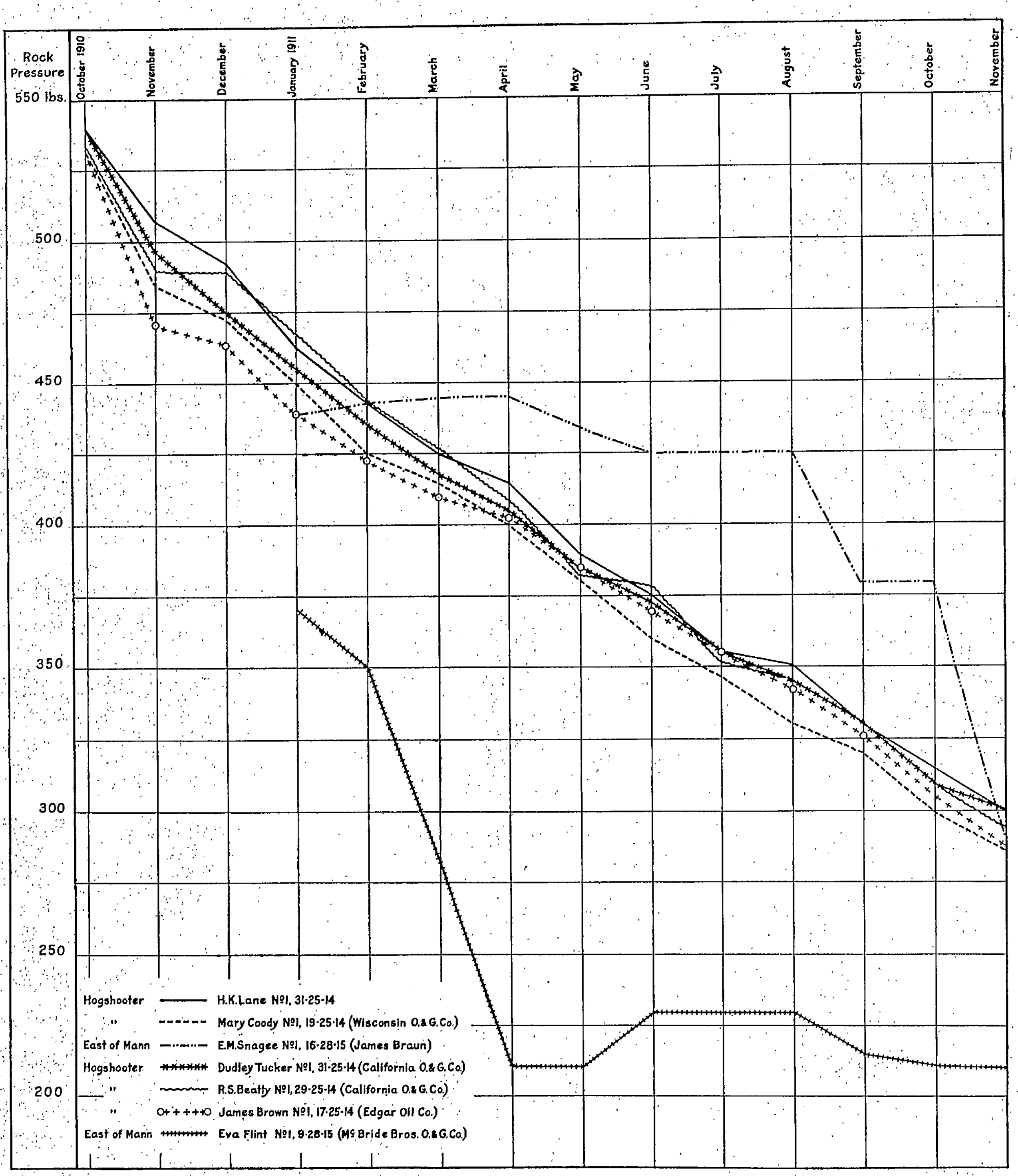


Fig. 15. Diagram showing the decline in rock pressure of natural gas in the Hogshooter district, Oklahoma.

is, empower a state commission to close the wells and levy the cost on the companies. In Louisiana the commission on the conservation of natural resources, after making an exhaustive examination of the situation in the Caddo field, recommended—

That the owners of the wild wells in the Caddo field be at once notified to take immediate steps to close the same;

That in the event of their failure or refusal to do so, the State, through its engineering department, forthwith take steps to bring about control of the wells and stop waste at the expense of the owners;

That if it be found that through failure of the law or otherwise the State can compel owners to bear the expense, then, and in that event, the State interest is sufficient to warrant the State in going to any reasonable expense to close the wells at the public cost.

The State of Louisiana has been called upon to close only one "wild" well, for the reason that all but one have been closed by the owners, and in this one the gas escaped from a shallow sand, 900 feet above the supply which is used commercially.

I. C. White, in speaking of the waste of gas of the West Virginia oil fields, suggests an effective method of conserving the gas by setting an extra string of casing in the 10 to 30 feet of gas sand lying over the oil sand.

Both gas and oil can be saved when they flow from the same well, as is verified by the fact that this is done by a few progressive operators, who use a gas trap, which separates the oil and the gas by the gravity method. The great difficulty seems to be to find a market for the gas in a new oil field which has no natural gas mains or other means of transportation at hand. It would seem that legislation might require the wells to be shut in until arrangements were made to bring gas lines to the oil wells, or until gasoline plants and other means of utilization were provided. If applied with discretion such legislation would work no injustice to the oil producer, as his ultimate profits would be larger through the sale of the gas. Some prominent gas producers have stated that every legal and legislative means should be used to force the oil companies to save their gas, even casing-head gas. They believe this can be accomplished without waste.

In the utilization of gas a real conservation is being effected by both the use of meters with consequent charge per cubic feet of gas used as against the flat rate, where the gas was allowed to burn at all times—from thousands of burners all night—and the increased use of gas as a household fuel rather than for manufacturing. Edward Orton wrote 14 years ago the natural gas ought to be confined exclusively to domestic use. A rolling mill will use from 1,000,000 to 5,000,000 feet a day. How far will 1,000,000 feet go in the support of household use? A house of 12 rooms, using gas in cooking range, laundry, and in six grates, uses on an average for the year about 400,000 cubic feet a month, or 1,333 feet a day. One million feet would supply 750 such establishments, or what the smallest rolling mill would use in a day would serve such a home for more than two years. But instead of using 1,333 feet a day, the average residence will find all its necessities met by less than one-half the amount named. Five hundred feet will make an ample daily supply for the majority of city or village homes—a supply for perhaps 1,800 homes.

The constructive efforts of oil and gas engineers have been so effective that many guides to better methods of developing fields have been devised which will be of the greatest value in the conservative development of new fields in Canada. The gratifying extent to which such methods have already been applied in the older oil fields of Canada is evinced by the long life of these fields which reached the maximum production so long ago.

In the following pages Prof. Roswell H. Johnson has formulated the methods of improving the efficiency of oil well drilling including the preparatory stages.

METHODS OF CONTROLLING GUSHERS.

The problems of shutting in wells, of which control is lost when they are drilled in, are usually to be solved only by the particular exigencies which arise when control of the well is lost.

Up to the spring of 1910, the Lakeview Oil Company's first well in the Sunset-Midway field of California proved to be not only the greatest oil well in the United States but control of it was lost. The daily flow soon reached 30,000 barrels. It destroyed the derrick, and for the better part of its life resisted all efforts towards its control. The flow increased to at least 40,000 barrels per day. The temporary storage made by damming a canyon, thus providing a lake, was soon filled, and much oil was lost. The flow was lessened, and finally controlled, by surrounding the well with a crater of bags of sand, and thus forming a pool of oil above the mouth of the well which to some extent choked the flow. Since that time, several other wells which will in all probability have as large a yield have been brought in, but by exercising great care have been largely kept under control, with the exception of one well brought in late in 1913 by the Standard Oil Company of California, which was carelessly set on fire, and extinguished only with great difficulty. The extinguishing of this well may be laid to the credit of chemicals—it was accomplished by the frothing process.

The greatest oil well in the world for daily output was undoubtedly the Potrero del Llano No. 4 of the Mexican Eagle Oil Company in the State of Vera Cruz, Mexico. This well produced as high as 160,000 barrels a day. By careful preparation for the contingency of striking a great gusher, the casing of this well was well anchored before the well was drilled in and a device for controlling it was planned by F. Laurie. This method will undoubtedly serve for other wells of great capacity where the casing is secured in the hole. The method is as follows:—

A heavy clamp is placed immediately under the collar of the 8-inch casing of which there are about 1,700 feet in this well. To this clamp, on opposite sides of the casing, are fastened 2-inch rods, hinged near the lower ends. The upper ends of these rods pass through a clamp above an 8-inch T joint having two gate valves. At the lower end of the T joint is a swedge bell nipple, 8-inch to 10-inch. By means of guys, the T joint on its hinged supporting rods was swung from a horizontal to a vertical position, bringing the bell nipple directly over the end of the 8-inch casing. The supporting rods are provided with threads and nuts at their upper ends and by means of these nuts the bell nipple was forced down over the end of the casing. An 8-inch pipe was connected to the T and the upper valve was gradually closed, the oil being thus forced through the pipe into the reservoir. The first controlling device had been tested to only 800 pounds, for it was not considered safe to close the well completely. A new T joint, bell nipple, and valves, tested to 2,000 pounds, were later substituted, and the well was completely closed. That is its present condition except for a small leakage about the valve gaskets. An earthern reservoir somewhat over 60 acres in extent was quickly and efficiently provided, but in 60 days this was filled with 3,000,000 barrels of oil, although the flow was checked as much as was deemed safe.

EXTINGUISHING BURNING OIL WELLS.

Much helpful experience in the managing of oil fires has been gained in the Caddo oil field of Louisiana. Well No. 6 in Section 33 near Jeems Bayou, Caddo district, Louisiana, belonging to the Producers Oil Company, yielded when drilling in 12,000 barrels per day. It was struck by lightning on the afternoon of June 19, 1910, but within 48 hours the well had been successfully extinguished. When it was set on fire, the well was flowing through a leaky pressure valve. Drillers were endeavoring to stop this leak with a housing when the storm came up necessitating their leaving the derrick on account of danger to the "greasy" men, including Mr. James Sharp, field manager of the Company, who were all thoroughly drenched with oil. They had barely gotten under the water of the bayou nearby when the well was struck. Twenty-five steam boilers were ordered from Shreveport, brought by rail to Mooringsport, thence by barges and towed through the shallow water of Ferry Lake and Jeems Bayou to the nearest spot to the well. A temporary bridge was built over the swamp, the boilers were hauled to position and filled with water, natural gas fuel was supplied, and the well was extinguished in just two days, by steam.

On May 12, 1911, a well known as No. 7 owned by the same company was set on fire by some unknown means—generally attributed to an onlooker who was watching the work of closing the well. It had come in late in the day before, flowing 20,000 barrels of oil and no water. It had been closed down to 8,000 barrels a day. Four men were burned, one fatally, three batteries of 16 boilers each were installed in 36 hours but were powerless. At the end of the week, Mr. Sharp decided to tunnel to the well pipe. A side pipe was tapped in through this tunnel and the oil diverted through the tunnel away from the well, and the fire was successfully extinguished.

During the summer of 1913, a large well burned for a week at Mooringsport, La. It was finally extinguished by the use of steam from a battery of 50 boilers in record breaking time, and, while the danger to the workmen was great, there were no casualties.

The first large gas well fire to be extinguished, and the well successfully closed in was the Maggie Vanderpool, a wild-cat well drilled for oil by the New York Oil and Gas Company in Indian Territory, about one mile south of the Kansas state line and about 4½ miles southeast of Caney, Montgomery county, Kansas. It was extinguished under the supervision of Mr. J. C. McDowell. The well showed dry gas and was, therefore, to be deepened in the hope of striking oil. When deepened only 2 or 3 feet into the sand, the flow of gas developed into 30,000,000 cubic feet per day with a rock pressure of over 600 pounds. The gas had been packed off but the packer failed to hold the same. A new packer was inserted and further drilling was about to be begun when the well was struck by lightning. An effort was made to extinguish the fire by swinging a large steel bell with a pressure valve over the mouth of the well, the bell having a side connexion below the valve which was connected with a side line of pipe and through which it was hoped to divert the gas, and thus extinguish the fire. This was finally accomplished, although the cutting action of the sand shot out by the gas cut the first bell to pieces.

The most successful work which has been done lately in stopping the waste of natural gas has been accomplished in the Caddo parish of Louisiana where two very large gas wells have been running wild for about five years. The first, known as the Gilbert well, formed a large fountain in the center of a lake some 600 feet in diameter. It was extinguished by drilling a well at an angle toward the wild well and as near as possible, and when the producing sand was reached mud was pumped in under as much pressure as possible until the wild well died down, and the accumulated water and oil above it choked the flow. The other wild well near the railway track at Oil City, Caddo parish, was closed late in the summer of 1913 through the intervention of the Louisiana Conservation Commission in the following manner: The Commission secured the co-operation of the oil and gas producers of Shreveport, La., who raised a fund for closing in the wild well. These producers formed a committee who drilled a relief well as near as practicable to the wild well with the idea of pumping water into the relief well and so flooding the gas sand and choking off the volume of gas, thus killing the wild well. A reservoir was constructed to hold water as a reserve supply when pumping should begin through the relief well. This well was drilled to a depth of 852 feet and cased to a depth of 792 feet, leaving an open hole of 40 feet for an outlet for the water pumped through this well into the gas stratum. Forty barrels of water an hour passed through the pump with 310 pounds pumping pressure. Later the volume of water was increased to 180 barrels an hour, and the pressure decreased to 50 pounds. Though there was no noticeable effect at first on the wild well, in a few days its action was considerably diminished and it soon appeared to be entirely dead. The water left in the crater of the wild well now settled entirely leaving the casing of the old well exposed. The hole of the old well was closed with sand, cement, and dirt, and no signs of a revival of its activity have been observed.

EFFICIENCY IN THE EXTRACTION OF OIL AND GAS.

By Roswell H. Johnson.

The wisest management of our oil and gas resources demands (1) the production of maximum amounts with a minimum sacrifice of human effort; and (2) the utilization of this product with the maximum satisfaction to ourselves. These topics have been discussed admirably in Dr. David T. Day's "Petroleum Resources of the United States," U.S.G.S. Bulletin 394, Arnold and Clapp's "Wastes in the Production and Utilization of Natural Gas," U.S. Bureau of Mines Technical Papers 38, and in Huntley's "Decline of Oil Wells," U.S. Bureau of Mines Technical Papers 51, and also in Technical Papers 38, 42, and 66. Fortunately these six papers are still in print and readily available. Though this chapter will touch upon nearly every important point in these valuable articles, it will deal chiefly with those phases of waste and conservation less fully treated by them if at all.

The discussion falls under two general heads, increased efficiency in production and in utilization.

EFFICIENT PRODUCTION.

The present methods of producing oil and gas leave very much to be desired. We may reasonably hope, if proper research is given to the subject, that in the next decade such advance will be made as to secure the product with a decided reduction in drilling expense, and what is more, to extract a far higher percentage from the sands that are reached. Unfortunately, current practice fails to make use of even those improved methods that have been already proposed or demonstrated.

LEASING.

The method of leasing to-day is peculiarly wasteful, for the reason that the royalty to be paid to the land owner is a fixed percentage. It is perfectly obvious that as the decline continues, the well must be abandoned when the producer's fraction of the production, say seven-eighths, no longer exceeds the maintenance charge, although the well could still yield more than the maintenance charge, if this one-eighth was not deducted. The obvious method, to correct this, is to exempt the production of a certain amount of the product from all royalty. This exemption should equal the maintenance cost of the well under less favorable circumstances, such as the necessity of operating one or two wells independently. This varies of course from field to field, but may be roughly estimated as $0.60 per day. In return for this concession on the part of the land owner, the producer in turn should also make a concession as to the percentage of the royalty. This can probably be accomplished most equitably by limiting the increase of royalty to the time during which the wells are larger than a standard size, as for instance, 25 bbl. per day.

With a decline of 15 per cent a year, which is not unusual, and with a royalty of one-eighth, the life of a well may be prolonged an additional year, as is shown in the accompanying diagram (Fig. 16).

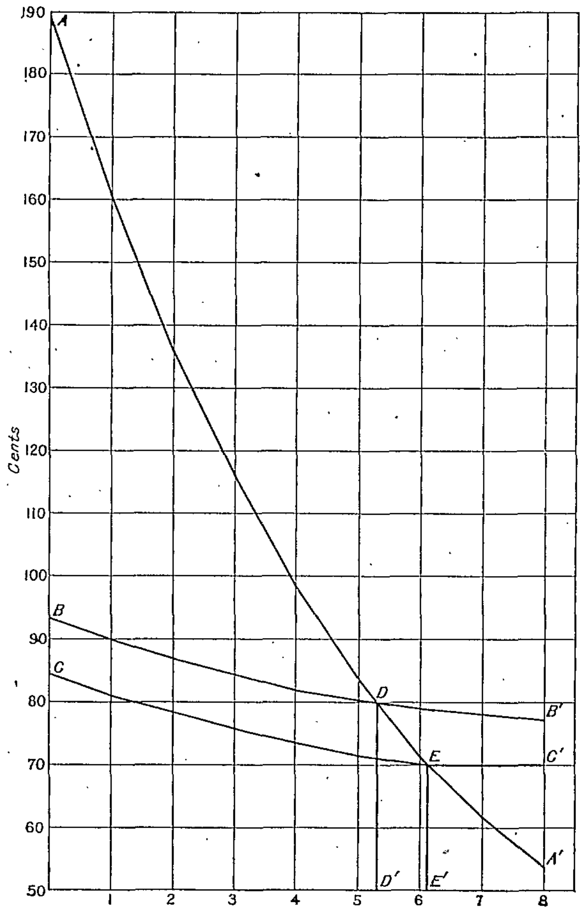


Fig. 16. To show that a fixed exemption from royalty prolongs the life of a well. Price of oil—$1.89. Maintenance—$0.70 per well per day. Exemption from royalty of $0.70 worth of oil per day. A-A'—income from well. B-B'—maintenance and royalty without exemption. C-C'—maintenance and royalty with exemption. D-D'—time of abandonment without exemption. E-E'—time of abandonment with exemption. D'-E'—the prolongation of working life of well—9·6 months.

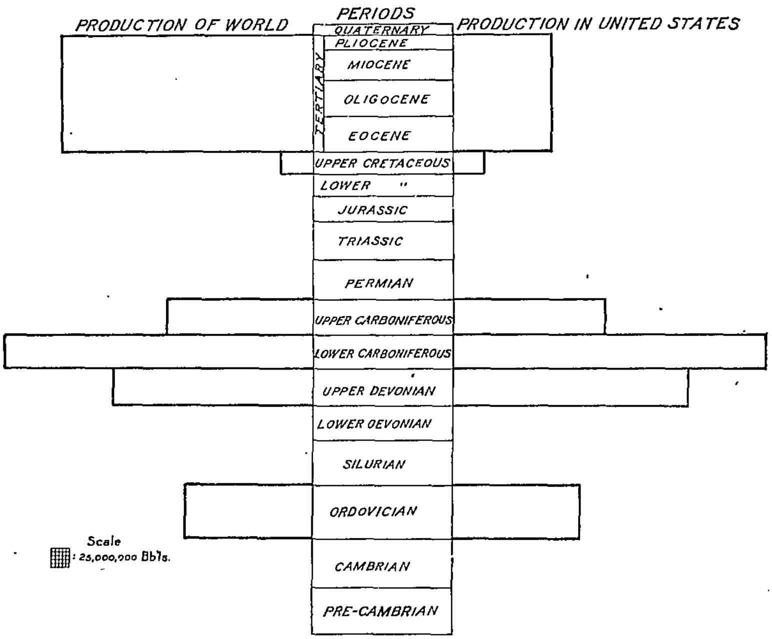


Fig. 17. Stratigraphical Distribution of Petroleum Production to 1913.

Tertiary	1,935,763,780	barrels.	California, Gulf Coast; Foreign except Canada.
Upper Cretaceous	42,548,025	,,	Marion Co.. Corsicana to Powell Texas; Wyoming; Colorado.
Pennsylvanian	343,843,256	,,	Electra and Henrietta, Texas; Oklahoma; Kansas.
Mississipian	726,815,070	,,	Illinois; one.half of the Appalachian field.
Upper Devonian	540,304,235	,,	One-half of the Appalachian field.
Devonian	14,099,053	,,	Canada
Ordovician	318,095,570	,,	Luna-Indiana.

WELL RECORDS.

The necessity of more accurate logs of wells has been reiterated by every student of this subject. Indeed, inaccurate and inadequate logs, it must be said, are to be attributed much more to careless, indifferent and ignorant contractors and drillers than to any lack of appreciation on the part of superintendents and managers. However, the requisites of a good log include more than is usually appreciated, and as time goes on, more and more complete logs are sure to be demanded. A log should give an accurate steel tape line measurement to the top, at least, of the most widely used key horizon in the field, and on the top of each producing sand. In addition it should give the top of the water, if there is any, the bottom of the sand and the bottom of the well. Other desirable items are a shallow reference horizon, a reference horizon as near as possible to the sand, and every sand yielding oil, gas, or water, and other limestones or red beds unless very numerous, for the purpose of correlating the sands. These figures may be obtained by strings on the sand line, a method less accurate than the tape line but so much cheaper as to be permissible for the less vital parts of the log. An improvement, within feasible limits, in logs alone would probably save Canada 5 per cent of its dry holes.

METHODS OF LOCATING.

All too many oil producers have settled down into a fatalistic habit of thinking that the success of tests is so uncertain that no care or skill is required in their location. This is a very costly blunder. While all experienced persons know full well the uncertainties of drilling, the demonstrable success of improved methods in locating wells is so manifest that a neglect of geological considerations bespeaks incompetence. No extended description is here possible, but the following brief outline may arouse interest for further study of these methods.

In locating test wells the age of the rocks should be favourable. Commercial gas has been produced as low as the Potsdam formation in the Cambrian period, and oil as low as the Trenton formation in the Ordovician period. There are no good theoretical reasons why both should not be found in commercial quantities lower in the Cambrian. Prospecting in the Pre-Cambrian is not to be encouraged, though occasionally, when the Pre-Cambrian is in some particular relation with other formations, it has derived oil or gas from them. It must be said that in America, however, the producer finds much more encouragement in the formations from Ordovician to Upper Pennsylvanian, and again from Upper Cretaceous through the Tertiary. (Fig. 17).

The nature of the beds is of vastly more importance than their age. Ideal conditions are furnished by extensive dolomitization of limestone or beds of porous sandstone, 5 to 100 feet in thickness, lying within shales twice or more as thick again. The shales should be grey, black, brown or greenish in colour. White, yellow, red, and purple shales are unpromising. Outcrops bearing asphalt or ozokerite (mineral wax) are indicative of the presence of petroliferous beds, but by no means are infallibly

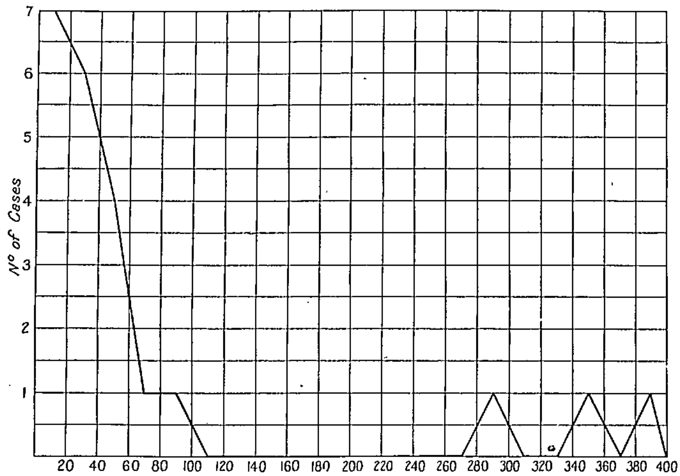


Fig. 18. Graph of frequency of various dips in feet per mile. The pools were those in a district of southeast Ohio and northwest Virginia.

safe indications. Nor on the other hand, does the lack of such evidence condemn a region. When drilling is not upon the crest of an anticline, dips of less than 5 per cent are to be preferred, but are not necessary (Fig. 18).

The expected sandstones should be at a suitable depth at the selected point. An adequate cover without too much faulting is to be desired. This requires a greater thickness in the case of gas where high pressures are desirable, than with oil. Yet it is rarely wise to go to the very considerable expense of deep drilling when the expected sand lies below 3,000 feet.

However, other exceptionably favourable circumstances might make it worth while, such as very promising geological conditions, high price of oil, or very large amounts of land owned or leased by the company.

Tests in new territory are best located at the highest points of well-marked domes. In the event of the dome being unsymmetrical in its dips, the well should be drilled toward the lesser dips from the centre, since the dome in the sand will not lie directly under the dome on the surface. And next, where domes are not available, anticlines with level axes are to be preferred. Anticlines that plunge become proportionately less valuable.

When oil or gas has been discovered in one well, skill is necessary to locate adjacent wells, and also to choose and secure leases wisely, in order that there may be a minimum of dry holes and worthless leases. The producer may proceed according to several methods.

(1) The first of these is the method of *strike*. By this new locations are made away from the discovery well in the two directions of the strike, that is, in such a direction that the sand is found at the corresponding level. This can be ascertained by learning the lay of the beds at the surface. From this data a map of some upper formation is prepared and when enough holes have been drilled the convergence or lack of parallelness between this upper bed and this sand can be mapped and allowed for. Then a map of the particular oil sand can be made.

(2) *Method of dip.*—In the event that a well has oil only in the lower part of the sand and gas in the top, when oil is sought for, the next well should be drilled down the dip, in order to reach the sand where the oil occupies a greater relative thickness of the sand. Conversely, where the oil is within a few feet of the top of the sand and is underlaid by water, the next well should be up the dip.

(3) *Method of streak.*—The oil reservoirs have neither uniform thickness nor great extent from side to side. More frequently than not, the oil sand extends farther in one direction than in the opposite, making what is known to the producer as

a streak. In any one particular horizon, these streaks, though variable, generally have a prevailing direction. A comparison of near-by streaks in the same sand, or if these are lacking, of other sands in the same field, offers some guidance. The producer should be alert to detect the thinning or reduced porosity in the several directions in order that the streak direction may be inferred as early as possible. The method of streak is also valuable in connecting up two groups of wells, each centered around a successful test in one streak. This possibility should always be kept in mind when the two groups are not separated by a distance exceeding the reasonable and common area of the reservoirs in that sand. And again this is possible when the producing sand is at a corresponding depth below a reference horizon and when the gas, oil, or water of the two groups are of similar quality.

(4) *Method of inferred shore line.* In fields where development has not gone far enough to determine the prevailing direction of the streak directly, an inference of some value may be based upon the probable shore line at the time of deposition. This requires the broad knowledge and experience of a geologist, who, in brief, would base his conclusions on the following principles. In general, the shore line will lie at right angles to the direction of deepest water on the one hand, and of the dry land on the other. The direction of deepest water is indicated by increased thickness and purity of the limestones and the increased fineness of the material. The direction toward the continent is shown by increased coarseness of the material and the greater time interval represented by the unconformities. The present distribution of outcrops of different ages can also be used but with great care, since subsequent movement and erosion of the beds introduce many complications.

The prevailing direction of the long axis of these sand bodies (or of the sand axis, if the data is not adequate for recognizing the former) is most easily expressed by means of polar coordinate paper as in Fig. 19. The relative importance of streak and strike in determining the long axis of any field is well represented, after the strike has been determined, by plotting the angle, which the long axis of the pool makes with the strike, as in Fig. 20.

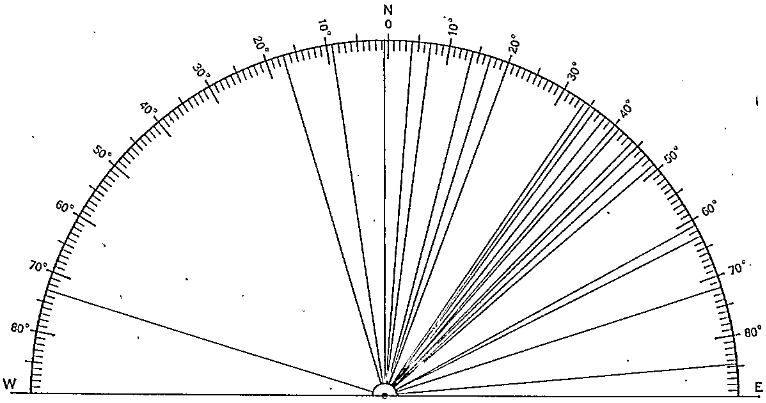


Fig. 19

The direction of the long axis in the same pools, showing the origin of the common belief of N. 45° E. as the prevailing direction in this region and yet how variable it is.

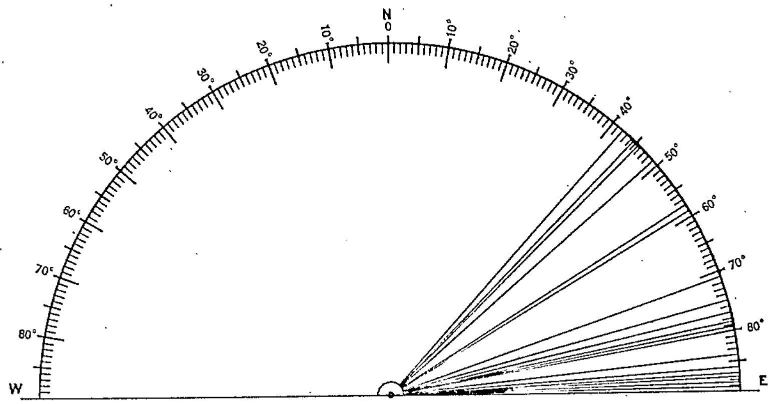


Fig. 20

The deviation of the long axis from the strike in the same pools: figures = degrees of angle.

(5) *Method of proximity.*—The rule of drilling next to good wells doubtless seems too axiomatic to be dignified as a method. Yet one of the most important decisions a producer must make

is that of leasing nearer to or farther from a discovery well of established production at correspondingly graded prices. It is therefore imperative that he estimate the relative values of

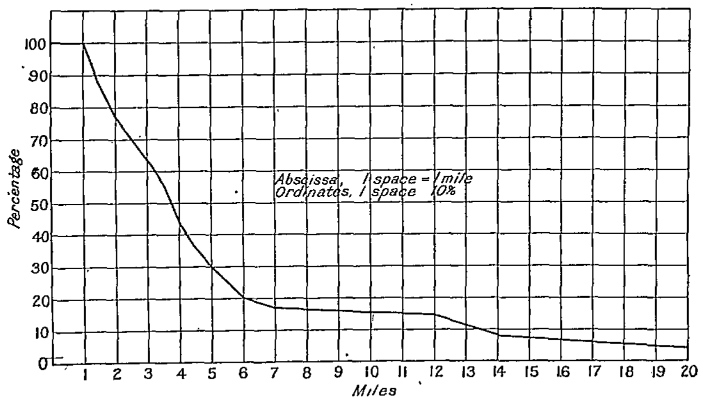


Fig. 21. The percentage of the number of the same pools as long or longer than the distances indicated.

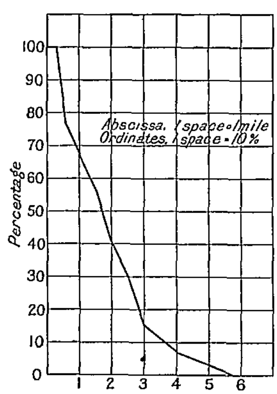


Fig. 22. The percentage of the number of the same pools as broad or broader than the distance indicated.

different degrees of proximity. To do this we take statistics of the dimensions of the known pools in that sand or in sands that seem most comparable. These should be plotted in a cumulative curve of frequency, separately as to the long axis (Fig. 21), short axis (Fig. 22), and for both axes of the pools, Fig. 23. From such curves the relative chance of a pool being of any particular size may be calculated, and from this, after making some allowance for the insurance of risk, a proper price for leases at given distances from the discovery well can be decided upon. Further allowance should be made, however, for any unusual porosity or thickness of the sand in this discovery well.

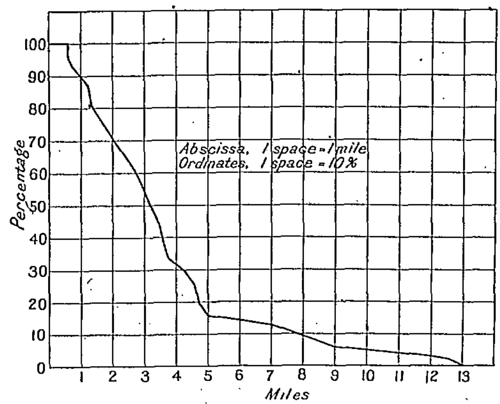


Fig. 23. The percentage of the number of the same pools having an average diameter as great or greater than the distances indicated.

(6) *Method of pressure decline.*—An unusual persistence of pressure after prolonged flow is of the highest value as indicating contiguous, undrilled areas.

(7) *Method of chemical analysis.*—When the gas from a gas pool is dry and light, we may infer that that reservoir contains no oil, and save ourselves the expense of drilling further down the dip, so far as that sand is concerned. If on the contrary, the gas is heavy and oily in odour, we have strong indications, unless the sand is of extremely fine porosity, that prospecting down the dip does offer encouragement. But when the gas is intermediate in quality, rather than markedly light or heavy, then a chemical analysis or compression test should be had.

The results would guide the producer's further operations and also determine whether a gasoline recovery plant is advisable.

The analysis of oil may be of use in making locations in the following circumstances: (1) To find if two pools some distance apart may be in the same sand, as in that event, there would be a stronger chance of production in that sand in the intermediate territory. (2) To determine whether a given sand is the same as an outcropping sand showing asphalt or ozokerite. (3) A very heavy oil at a considerable depth causes the suspicion as to a nearby fault or outcrop, whereas one of extraordinary lightness has probably moved a long distance and has been subject to considerable fractional filtration. It is, therefore, less likely to be a successful commercial proposition, as the recent strike at Calgary, Alberta. On the other hand, it is an indication of the general petroliferous character of the strata.

In the case of salt water, an analysis is also of value. The nature of the salts it contains will assist in the correlation or non-correlation of the two sands in question. It will also help determine whether the water pumped with the oil comes from the producing or some upper sand. But most important of all is the fact that methane and the next four members of the paraffin series are soluble in water to an extent of about 3 per cent, which varies of course with temperature and pressure. We may then analyse the water for a particular sand and deduce from the content of methane and ethane the presence or absence of natural gas in the same sand farther up the dip. And if the analysis shows the higher paraffins such as propane and butane, we should expect oil also in the same reservoir farther up the dip. If a test hole on the side of an untested anticline encounters water, we may by this method determine whether another test up the dip will be worth while.

Producers might wisely urge the Canadian Government to make a large number of comparative analyses to be used as standards of comparison, and further, that the various, possible analytic methods be compared with respect to their economy and efficiency for this class of work. In the meantime, however, we may employ current methods. The Pittsburgh Testing Laboratory is prepared to test for dissolved gases in salt water.

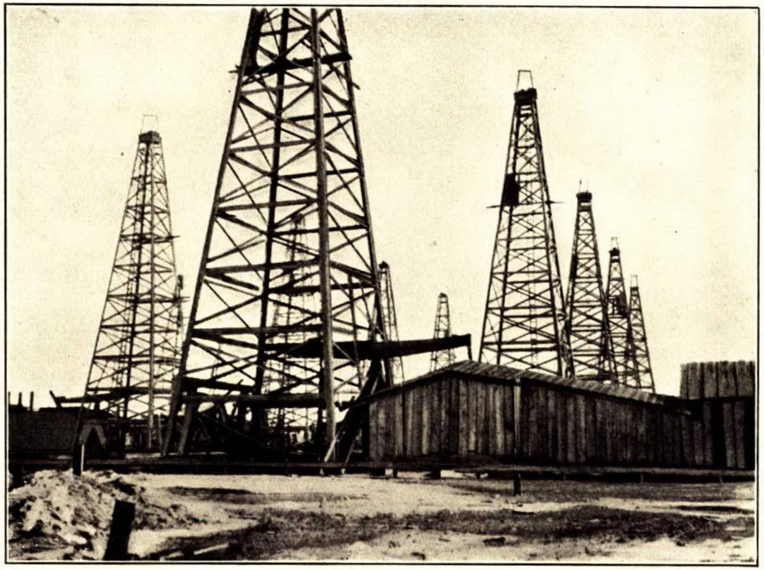
The Bessemer Gas Engine Co., is constantly making gas analyses, for the purpose of ascertaining whether the quality of the gas warrants the installation of a gasoline recovery plant. The method of sampling is of superior importance in either case and should be done according to explicit directions.

(8) *Geothermic method.*—Hoefer believes, and presents some evidence to substantiate his theory, that the increase of heat with depth is greater over oil deposits. The Carnegie Geophysical Laboratory is investigating along this line. But it must be said that the outlook for a successful use of this method is not very promising. It is difficult to see any connexion between the isogeotherms and oil. It would appear theoretically more reasonable to look for the association of gas with isogeotherms. But nothing can be done in a practical way until the whole subject has been very much more thoroughly reported upon.

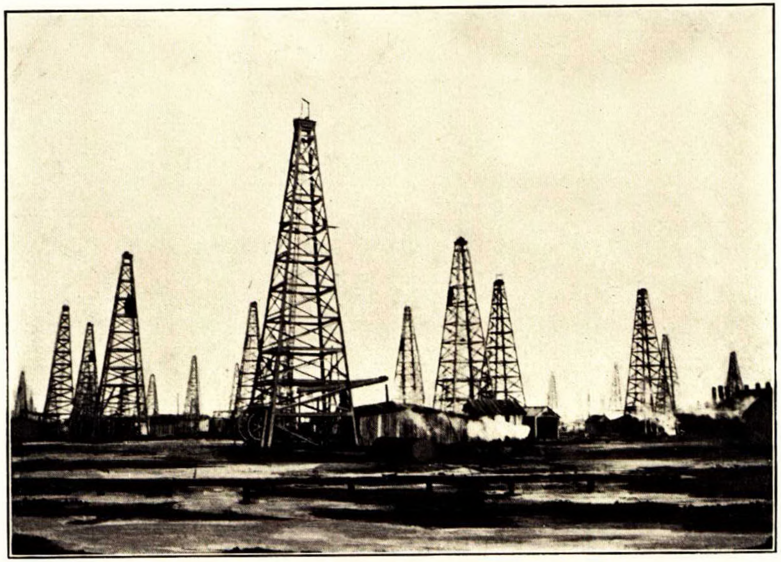
SPACING OF WELLS.

In the Oklahoma field half a million dollars has been spent on unnecessary wells in two square miles. Nearly any field shows most extraordinary waste from too close spacing. A marked contrast in the closeness of wells may be observed in almost any field where one company owns a very large tract and a group of small, competing leasers hold adjoining properties. No general rule can be made as to the proper distance between oil and gas wells. For each sand, the producers must watch closely the results of wells drilled later among the older wells. Since it is the common practice to lease in blocks or multiples of blocks of ten acres which equal 660 feet square, it is wise to put oil wells at this distance of 660 feet from each other, if this is approximately the distance that would have been selected for other reasons. There is a strong tendency to observe this distance among mid-continent and Illinois producers at the present time. In California, they still drill closer than that ordinarily, because of the large size of the wells. And in the Appalachian field the leases are so irregular in shape that there is less incentive to conform to this particular distance.

PLATE XIX.



Wells in Jennings field, Jennings, La., U.S.A.



Wells in Spindle Top field, Texas, U.S.A.

Gas wells may be spaced at much greater distance, 1,320 feet being sufficiently close.

When wells for either oil or gas are drilled on a very large tract of land and so the off-setting of neighbour's wells is not a consideration, there is a more economical arrangement than the the old one of locating the wells in straight lines crossing each other at right angles. By a staggered, or quincunx arrangement, all of the given area may be brought within closer range of some one well, as is shown by Fig. 24. Unfortunately the staggered arrangement is seldom feasible on smaller leases held by competing producers.

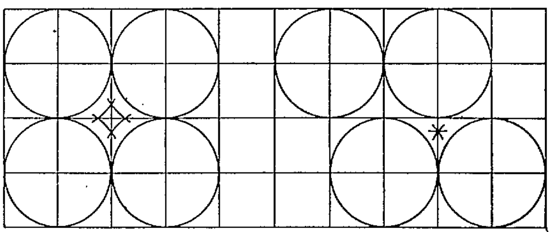


Fig. 24. To show rectangular versus staggered arrangements of wells. The area in the small square is farther from the wells than any point in the staggered arrangement.

On these small leases there is generally a well located in each corner. Between these corner wells, other wells are distributed at a distance from the property line equal to the distance at which the neighbour's wells stand back from the line. However, it is by no means advisable to put in as many wells between the corners as the neighbour does. Very frequently a conference between two neighbouring producers will lead to an agreement not to drill an additional well between the two that may be already producing along a 1,320 foot side. (See pp. 240-242). Whereas, without such an agreement, one of the producers might drill in between, which would nearly always lead his neighbor to meet him with an offset, though it would be to the ultimate interest of both not to drill these accessory wells. The same situation arises inevitably on all sides of a lease. A producer should always seek to enter into an agreement with each one of his neighbours, to the end that their wells may be as near 330 feet back from the line and as near 660 feet apart along their lines as each will consent to. This is, of course, if 660 feet has been decided upon as the best distance for that particular sand and depth.

Table XXI gives the territory lost if one does not offset in the most familiar situations that arise:—

TABLE XXI.

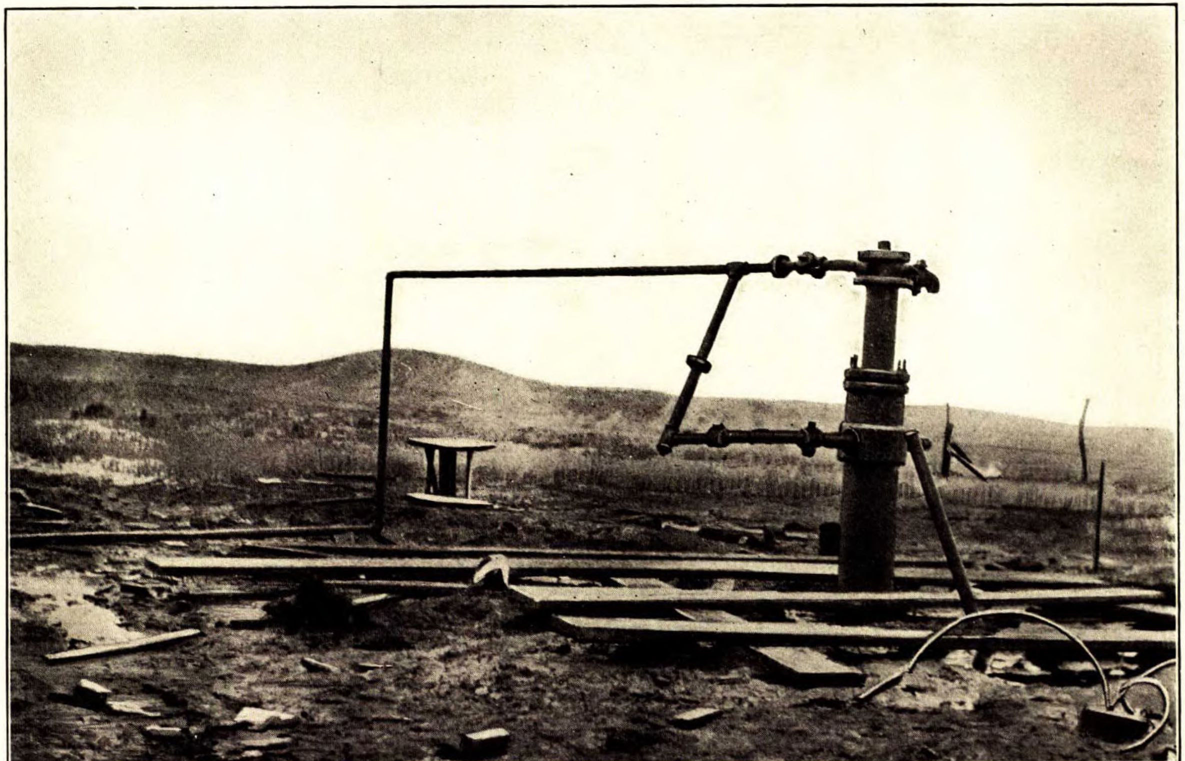
Offsetting.

	200 ft. from line	150 ft. from line
Along the long side of an eighty:—	Acres	Acres
Case 1, 5 wells meeting 8 on the side of 4 tens loses......	1·05	1·69
Case 2, 5 wells meeting 6 on the side of 2 forties loses....	·55	·90
Case 3, 4 wells meeting 5 on the side of an eighty loses...	1·01	1·88
Along the side of a forty:—		
Case 4, 3 wells meeting 4 on the side of a forty loses.....	·24	·42
Case 5, 3 wells meeting 4 on the side of 2 tens loses......	·13	·41
Case 6, 2 wells meeting 3 on the side of a forty loses......	1·39	2·45

The method of ascertaining the lost area is to draw lines on the map midway between each line well and its two opposing line wells, if one is not exactly opposite. This is done by drawing circles with each well in question as a center and joining the points of intersection with a line. These lines then make triangulars with the lease boundary showing areas lost or gained.

The area of the lost territory thus outlined must now be computed as well as any territory which may be gained from the neighbour. This may be done by making this construction on cross section paper, counting the number of squares or fractions of squares included in the area. A more exact method is to compute the area of the triangle by the well known formula of the base times one half the altitude. In the event that the area is polygonal instead of triangular, it is divided into triangles and the area of each computed and added together.

In unusually shaped leases, it is well to plan several methods of placing wells. If the cost of wells, the price of oil, and



Well producing oil from two horizons; one through inner casing and one from space between casing.

the royalty are fairly constant, it is quite possible to construct tables showing how much production to the acre the lease must have to warrant the drilling of a particular extra well. The tremendous loss occasioned by the cutting up of an oil or gas pool into many small holdings will be discussed later under the head of large versus small companies.

In fields where the dip is high, such as is likely to be the case in some of the new fields to be developed in Alberta, it is better to have wells drilled closer along a lease boundary, paralleling the strike and less close to one paralleling the dip, as the interference of well with well is much less in the former case.

DEPTH TO WHICH WELLS SHOULD BE DRILLED.

This is an extremely important consideration, second only in importance to the selection of the location. And as regards depth, as in the case of locations, geological knowledge and skill are necessary. Quite commonly the tradition is established in a field that it does not pay to drill below a certain "farewell sand." In some instances this decision has been a wise one, but all too frequently it has been the result of ignorance of the formations below, and has resulted in the premature abandoning of thousands of wells. Before any test is drilled, the producer should investigate the formations he is likely to meet, so as to have some idea of the depth. This advance knowledge is also useful to him in drawing up the drilling contract, and in deciding on the method of drilling and the size of the hole. A good illustration of the losses occasioned by loose work in this matter is that of the Cherokee Nation, where most of the early wells were stopped at the Bartlesville sand. Whereas, only 150 feet deeper, more or less, depending upon the location, there is another sand distinctly worth while, and to which new tests now extend, and to which old wells, about to be abandoned, are being deepened. Another illustration, also in Oklahoma, is offered by the region from Owasso, to the Arkansas river, where it is quite probable that some producers have stopped wells at the Pitkin limestone, mistaking it for the Boone limestone or the Mississippi lime, which is not very much deeper, and is yet distinctly worth drilling to. The Bridgeport, Illinois, pool is another instance where the early unsuccessful tests were almost all discontinued at too shallow a depth, many of them causing the surrender of leases that have since become productive. The most frequent cause of too shallow drilling is the indifference paid to the dip by drillers or producers who have come from older fields, where the dip is so slight as to be ignored by them. A well was unwittingly started at Boulder, Colorado, that could not have reached the producing sand till a depth had been reached more than twice that of the producing wells of the North Boulder pool. In most fields the geologist can predict the age and general nature of the strata to depths exceeding that feasible for drilling.

One should take care to drill through the whole of the oil sand, for occasionally the shale which seems to underlie the sand may in reality be merely a break of a few feet of shale with additional pay beneath. Even though a lower pay is not obtained, this pocket is sometimes valuable to receive sand and mud which otherwise would accumulate in the hole and reach up to the level of the perforations and greatly interfere with the pumping later.

However, in the event that the oil is found under very high pressure, the driller needs to be particularly careful in penetrating the sand, inasmuch as any underlying water will rush in the hole more readily than the oil and in some instances drown it out. In these cases of high pressure, it is best to let the well flow until the pressure is reduced, when deepening can more safely be continued.

But where the contents of the pool are not under high pressure, because relieved by neighbouring wells, there need be no such fear of water. Fig. 10 shows how desirable it is to drill through into the water sand, since such a well, while pumping some water, also pumps an increased amount of oil. This happens because the removal of this water leaves a funnel shaped depression in the top of the water sand and in the bottom of the oil sand which invites, as it were, a more ready flow of oil into the hole, both by means of the gradient established and by contact of the oil with the less viscous and more easily flowing water. This method of purposeful deepening of oil wells into the water sands is patented in the United States, but not in Canada.

NEGLECT OF SHALLOW SANDS.

We have in the history of many fields a later development of a shallow sand that was passed through by early operators, being considered too insignificant for production, or because gas only was sought at the time. There have been many instances in Oklahoma where oil has oozed slowly from some shallow sand around the casing to the surface. Such a sand has in nearly every instance, later proved worth while when properly shot. It is remakable how shooting has made sands productive which at first seemed disappointing.

Unless absolutely necessary, the operator should avoid drilling test holes by the rotary method, as in that case he gets poorer logs, and may pass through a very fair oil sand without detecting it, because of the weight of the considerable quantity of mud and water which hold back the oil and gas.

PUMPING.

The best results in pumping, after the pressure has declined, is obtained by frequent, intermittent pumping rather than by prolonged, occasional pumping. In wells of reduced pressure, one of the principal factors to bring the oil to the hole is gravitational seepage, and of course this cannot be effective when the oil stands high in the hole unless the main mass of oil pay extends higher up the dip. Devices for automatic pumping, controlled by the accumulation of the fluid, have not as yet been successful. A mechanical turning on and shutting off of power would be quite feasible, if the pumping were by electricity or compressed air, but is next to impossible with the common steam or gas engine powers of to-day. Producers should appreciate the great economy of pumping several wells by one power. All too frequently the installation of multiple powers is too long delayed. We can anticipate with the improvements time will bring, improved powers that will not only pump a larger number of wells, but will also pump from greater depths.

It is customary at the present time to continue pumping in the usual way till the receipts have fallen below the maintenance charges. Then the well is abandoned without any additional efforts to get the last of the oil. If we calculate the amount of oil per acre from the porosity of the sand, we find that the amount actually extracted is considerably less than 50 per cent in the case of firm sandstones, and even in the loosest sands is seldom more than this. In the aggregate this loss is staggering. The time has come when we should make a determined effort to obtain the unreached oil.

The first step in this direction is doubtless a more careful conservation of well pressure, as it is this which is especially effective in driving the oil to the hole. To this end, it is advisable to equip all drilling holes where high pressure is expected with proper casing gates or well cappers. By this means a sudden strike of oil or a prolonged flow after a shot may be piped into the tank without that occasional long and useless gushing over the derrick.

The discharge from the flow line should be into a gas trap, because it is unwise to let the well pressure decrease rapidly, and because this gas is unusually rich in recoverable gasoline.

It is desirable to tube the well early with the perforation set low in the sand, for this does not seriously reduce the production, and it has the merit of keeping the pressure of the gas in the upper part of the sand in place, where it is valuable for its power of expulsion. From the gas trap the line should go to a covered tank. This, if other circumstances, such as aridity, favour its use, should be of iron instead of wood, for the greater tightness. The vapour also from the top of such tanks should be piped to a gasoline recovery plant.

When flowing has nearly ceased, equipment for pumping is put in. It is desirable to have the pump high, so that the oil enters the perforations in the gas anchor a little above the top of the sand while the pressure is such that the oil is forced into the hole far above the level of the sand. The casing head should be kept closed at this stage, so as to save pressure. Care should be taken not to pump after the oil has been pumped down to the perforations. When production has dwindled, after applying this method, and the pressure is found to be low, the perforations should be lowered below the bottom of the sand, if there is no water. Or if there is water, then they should be placed partly below the level of the water. From this time on, pumping should be at frequent intervals, so as to keep the level of the fluid low. It is quite true that this increases the paraffining of the sand, but it is necessary to get the full effect of gravitational seepage, and the paraffining of the sand face will be very much less than it would have been earlier, when the pressure was high. The casing head can now be connected with the gasoline recovery plant. But the gas should be pulled upon only slightly at first, then gradually more and more till as high a vacuum is attained as is feasible. Then in turn this method will also be abandoned as too unproductive.

There will ordinarily be little trouble from paraffining until the perforations have been set low. After this when the production is considerably reduced, it is desirable, after as much cleaning as is necessary, to treat the sand face with an electric well heater for 100 hours. In case the producing company consumes its own product, it would be advisable to follow the heating with a naphtha bath.

When production has reached an unprofitable point, the well should not be abandoned, but held in reserve until the whole pool can be brought under the management of one great company or of several co-operating companies. Only by concerted action can the next effort by the water flush method be used to extract the remaining oil. Water should be turned down the well situated at the lowest point of the sand. It can be gotten either from one of the shallow sands or else introduced from the surface. This should be run in fast enough to keep the hole filled up, in order to have a good head and correspondingly rapid penetration. Then an adjacent well should be given test pumpings, if not regularly pumped, until the on-flow of this water increases the oil output. After a period of much improved oil production, it will yield more and more water in ever increasing proportions. Then when the amount of oil is no longer in paying quantities, this well in turn should serve as a point of entrance for water. In this way, the oil is gradually flushed up the pool to the highest wells. When only these highest are producing, discontinue introducing water at the lowest wells, so as to prevent the oil being washed by the water up

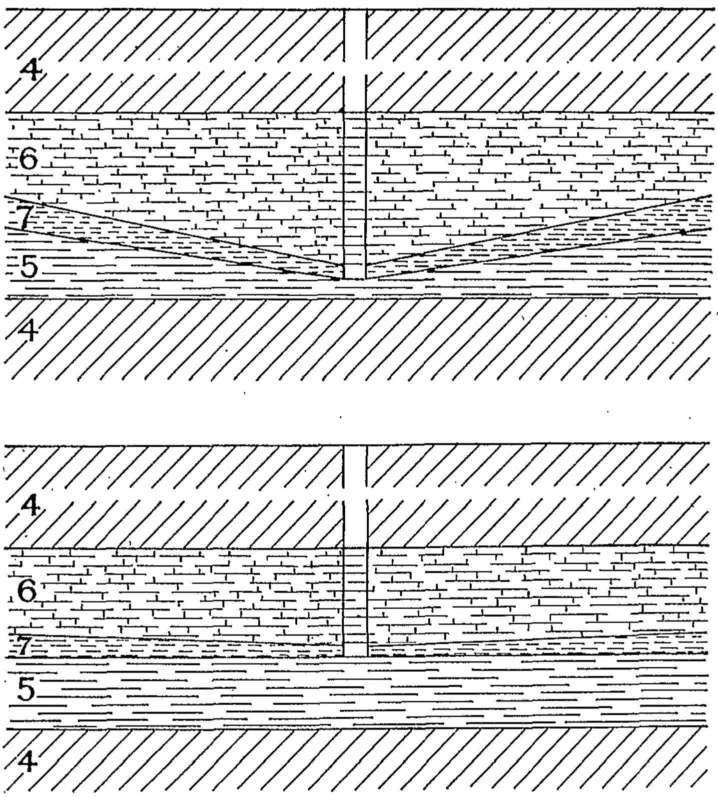


Fig. 25. Upper. Showing the accumulation of the oil in the lower part of the sand as it becomes drained. The oil becomes dependent upon gravitation for movement to the well. As it flattens out, the gradient becomes less and the movement declines. 4, shale; 5, water; 6, drained sand; 7, oil.

Lower. Showing the effect of deepening the well into the water sand and so causing a flow of water to the well and a funnel shaped depression in the water surface, which increases the flow of oil to the hole.

the dip past these wells. Theoretically, it would seem wise to keep the wells farther down the dip open, so that compressed air could be forced in. This air, bubbling through the water-filled sand ought to disengage some oil that the moving water alone could not dislodge. The accumulation of the air in little domes and pockets in the top of the sand would dislodge oil that had been retained there, so that it would move on up the dip to the pumping wells. Whether this compressed air system will warrant the expense, only actual trial can prove. But judging from the outcome of laboratory experiments, the prospect is promising.

CONCENTRATION.

The relative economy and efficiency of large and small producing companies is a matter of great interest and importance. The following theoretical considerations, as well as actual practice, all point to the overwhelming *advantage* of large units of capital and management. The advantages are:—

(1) Access to a much larger percentage of well records in the vicinity.

(2) Ability to employ more efficient and more highly specialized men.

(3) The considerable reduction in the number of offsets to be drilled.

(4) Ability to connect up the largest number of wells that each power is capable of pumping.

(5) Economy in labour, by having one pumper tend several neighbouring powers.

(6) The more continuous utilization of the plant and equipment, such as pulling machines, for instance.

(7) Saving in time and teaming by maintaining carefully distributed and well stocked store houses.

(8) The ability to install a gasoline recovery plant, because of the company's control of the necessary number of neighbouring wells.

(9) The conservation of pressure and the use of water flushing can be more frequently employed when the whole

pool is owned by one company, or at most, by but a few companies whose managers could easily reach an agreement, which would be difficult were there, instead, many small lease holders.

(9) Important experiments can be tried, such as testing the relative merits of competing methods and materials.

(10) Economy of surveying.

(11) By holding several contiguous leases, instead of a few scattered ones, a large company may "feel out," from established production, location by location, relatively unhampered by property lines.

(12) By holding several contiguous leases, the large company will far less frequently be forced to drill according to the terms of the lease, before the needed information is in hand.

(13) The logs in a large company are nearly always more carefully recorded and are always available. Whereas, among many small companies, there are invariably some who keep very poor logs or hold them secret, and in some cases there are some who even falsify their records. By means of this fuller information, casing requirements and the proper depths of tests can be anticipated, sometimes saving an unnecessary hole, or preventing the premature discontinuance of one.

(14) Lower prices and better quality in supplies are possible when purchased in large lots.

(15) The economy of a large company drilling its own wells without letting them out to contractors. Or, if because of the difficulty of getting a competent superintendent of drilling, the company decides to contract after all, this can be done at far cheaper rates than ordinarily, from the circumstance of there being many wells close together in one contract.

(16) A lessened danger from premature flooding by water from improper casing or plugging. Also less gas waste by small, irresponsible or incompetent neighbors.

INTEGRATION.

These foregoing reasons apply to the greater efficiency of concentrated or large producing companies. The following considerations indicate the higher efficiency which results from the integration of the industry, that is, the bringing under one management of the various successive steps in the oil and gas industry, such as production, transportation, refining, and distribution.

(1) With intergration, it would be possible to store oil in relatively few central, large, steel tanks, when otherwise, the oil would deteriorate more rapidly in numerous small, and more leaky tanks.

(2) Gasoline recovery plants, installed for handling gas from wells, might also recover gasoline from the pipe line company's storage tank vapours.

(3) By controlling, to a certain degree the rate at which wells are drilled, the danger of overproduction may be reduced, and at the same time, the production may be better adjusted to the needs of the refinery.

(4) The oil and gas business should be in the hands of the same company, as otherwise the one sided eagerness of the oil producer may not only lead him to waste vast quantities of gas, but also renders the search for gas more difficult and expensive on the part of the gas company.

(5) Pipelines and laterals can be planned in a more systematic and foresighted way. Competing lines to a small pool, which in a year or so would barely supply even one of the lines, could thus be avoided.

(6) Water and fuel for pumping and drilling can be cheaply supplied from the nearest available source.

(7) The guarantee of a regular production for the refinery makes for greater economy and efficiency there as well as in the marketing of the oil.

As a partial off-set to these advantages of both concentration and integration, there are the following five foes to efficiency in all large scale business.

(1) Unwarranted favoritism in employment and promotion.

(2) Slacking up, because the personal interest is less keen and vital.

(3) The temptation to sacrifice the interests of the company to those of officers, superintendents and foremen.

(4) Jealousy among departments or divisions of the company.

(5) A clique spirit that tends to advance the men already with the company, when sometimes new and valuable men from the outside are needed.

These difficulties are not necessary, and can be overcome in a large measure by a high degree of executive ability on the part of the management. In practice, the losses from these five causes are evidently less than the gains, because, as a matter of fact, the large, integrated companies are constantly buying more properties, so that the percentage of leases held by great companies is steadily increasing.

WISER UTILIZATION OF OIL.

Once the petroleum is pumped to the surface there is very little preventible loss, other than that in casing head gas and by evaporation, both of which have been already discussed. Yet there is one very serious loss of a different and wilful type—the burning of good oil for inferior uses. For instance, it is common to burn a grade of oil under the boilers that is capable of being refined into lubricating oil, and which may even carry a fair percentage of gasoline, kerosene, and paraffin. Doubtless in California, where coal is scarce and oil inferior and plentiful, this is justifiable. But to burn the residuum of most Canadian oils except for specific purposes, would be a lamentable use to make of a product that would be worth so much more in the future for higher purposes. When an oil is to be used for the production of power, far greater efficiency can be had by the internal combustion engine, of either the carboretor or Diesel type. The following table from Oliphant, as quoted in Westcott's "Handbook of Natural Gas" is conclusive:—

Average amount of natural gas required to operate gas engines or for steam engines where natural gas is used as fuel under boilers, in cubic feet per indicated H.P. per hour.

Type of Engine.	*Gas, Cu. Ft.*
Large natural gas engine, highest type	9
Ordinary natural gas engine	13
Triple expansion condensing steam engine	16
Double expansion condensing steam engine	20
Single cylinder and cut-off steam engine	40
Ordinary high pressure, without cut-off, steam engine	80
Ordinary oil well pumping steam engine	130

CONSERVATION OF GAS.

The most serious cause of the waste of gas is that by the oil producer who is not himself a distributer of gas and who, in his eagerness for oil, is ruthless in its waste. Only four years ago in Oklahoma gas wells sent into the air more than 10,000,000 cubic feet a day, just because operators wanted to get rid of it, so they could get their oil out. This should be illegal. No operator should be allowed to enter a gas sand unless without casing it off promptly, or having legitimate means of using it himself. If the gas of a shallow sand is of too low pressure to sell to the gas company, he should nevertheless be forced, with rare exceptions, to save it by installing pumps to lift it to the necessary pressure to put it in the line.

The escape of casing head gas should also be prohibited with a few exceptions.

Another cause of considerable waste is the current habit of blowing the water off gas wells. This sacrifices too much gas, and if the gas is being sold so cheaply that the operator cannot afford to pump off the water or blow it out through a small inner tubing, then the price of gas must be lifted to a point where he can.

Still another disastrous procedure is to call upon the wells for a very high percentage of their capacity, owing to the danger of flooding with water. In my opinion this is quite safe with certain wells that are well up the dip, but for other wells, already threatened with water, it is distinctly unwise.

It is of course imperative that the government should insist upon all abandoned gas wells being plugged so as to protect the gas sand from water from other sands, and also to protect coal mines from gas from abandoned wells. All too often gas sands have been abandoned because their pressure was no longer adequate to put gas into high pressure mains. These wells, still containing much valuable gas, will produce under a vacuum, after their own pressure is entirely gone. The very slow decline of wells being treated in this way, near Pittsburgh, is remarkable. Gas is thus brought into the gas sand proper from the surrounding sand of low porosity that would otherwise be unproductive.

WISER UTILIZATION OF GAS.

Gas is so wonderfully well adapted to the household needs of cooking, lighting, heating, and for small gas engine power units, that its use for inferior purposes is to be deplored. Yet in many oil fields we find flambeaux one or more feet high burning night and day. And staggering quantities of gas are being burned in smelters and mills at prices ranging from one-fifth to one-tenth of what it commands for household purposes. Even in the home it is sometimes used in the very wasteful and inadequate fan-tail burner. The following data quoted from Oliphant in Westcott's "Handbook of Natural Gas" shows how vastly superior is the mantel light.

"Where natural gas can be had at 25 cents per 1,000 cubic feet and 50 candle power can be obtained from the consumption of $2\frac{1}{2}$ cubic feet per hour with a mantel, the cost per candle power per hour is but·00125 of 1 cent.

"In an ordinary Argand burner with chimney it will give about 12 candle power in consuming 5 to 6 cubic feet per hour. If consumed in an ordinary tip, 7 to 8 cubic feet per hour will yield 6 candle power. All natural gas has not the same illuminating value. In some districts it carries a small percentage of heavier hydrocarbons, which add much to its illuminating properties."

It would therefore seem reasonable to prohibit by law the selling of natural gas to one consumer at less than one-half the price paid by another consumer, also to prohibit more than a certain fraction of capacity of the well to be taken, during the early life of the well. But to prevent undue hardship, such a law would have to go into operation very gradually.

The notoriously unscrupulous waste of gas when burned on flat rates indicates the need of selling all gas by the meter. In fact, gas is generally sold so much too cheaply as to offer no incentive for economy on the part of the consumer. Bearing in mind the relatively small quantities of gas in the ground, and the comparatively short time it will last, it would seem best for the state to fix a minimum price. In any event, gas companies should never enter into a contract with a consuming city to furnish gas for all time at the same rate. In later years it will be only just to pay a higher price for the gas, as it will have to be piped farther and as the supply begins to dwindle the percentage of successful wells will be smaller and the wells themselves will be smaller.

CHAPTER XI.

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APPENDIX.

TESTS FOR PETROLEUM, AS SUGGESTED BY THE INTERNATIONAL PETROLEUM CONGRESS.[1]

SYSTEMATIC METHODS OF TESTING PETROLEUM PRODUCTS.

At the International Petroleum Congress held in Bucharest, in 1907, a preliminary scheme of testing was offered for use, until a commission appointed at that Congress could establish more satisfactory international methods.

This Commission reported a number of tests at a meeting in Vienna in 1912, which were adopted by some of the countries present and not by others.

The following scheme of examination of petroleum products is a translation of the tests adopted by the International Petroleum Commission, to which have been added some additions and criticisms of the methods proposed, in the form of footnotes supplied by Dr. Day. It simply represents progress in the direction of uniform testing methods.

I. The ODOUR of an illuminating oil is not characteristic as to its illuminating value. If a test (should) be considered necessary, it should be made by shaking (about) 100 cubic centimeters of oil in a bottle of 200 cubic centimeters capacity, with a clear width of neck of 18 mm., at a temperature of about 20°C. for a minute, (and then noting the odour).

II. The test for COLOUR and FLUORESCENCE of an illuminating oil is matter for future agreement. The test for colour is to be made with a colorimeter, using standard glasses whose colour value is to be determined by comparison with normal liquids yet to be agreed upon. Before testing the colour, the petroleum must be filtered through paper.

III. SPECIFIC GRAVITY is to be determined by the usual methods (officially standardized thermo-areometers, pycnometers, Mohr scales, areometers for small quantities, alcohol floatation process) according to the nature and quantity of the material and the accuracy desired. The standard temperature is fixed at 15°C., the unit of weight to be water at +4°C., and the specific gravity to be reduced to vacuum. The determination of specific gravity may be made at higher or lower temperature and reduced to the normal temperature at 15°C. by means of coefficients of expansion to be determined by each country for its own petroleum, provided only that the specific gravity does not lie so near a limit that errors could thereby occur. In this case the determination must be carried out at 15°C. or at a temperature very near to this.

IV. In case the determination of SPECIFIC VISCOSITY is desired, it is recommended to use the Engler viscosimeter modified by Ubbelohde for illuminating oils (described in Post, Chemisch-technische Analyse, Vol. 1, part 2, p. 312, and in the periodical "Petroleum"—(Berlin)—1909, IV, No. 15, also "Moniteur du Pétrole," 1909).

[1]Translated from the German by Dr. David T. Day and Dr. Frederick E. Carter. Some comments by Dr. Day are also added as footnotes.

V. The determination of the FLASH POINT of illuminating oils is to be made in the Abel-Pensky apparatus.

Exportation and transport regulations in the different countries are postponed for further deliberation.

The rules for the determination of the flash point of illuminating oils, whose flash point is higher than 50°C., will be based on experiments still to be carried out.

VI. COLD TEST. Fresh samples must always be used, and not such as have been previously cooled off to a lower temperature for any considerable time. Testing is necessary only when precipitation might be harmful in the use of an illuminating oil. If on cooling a sample in the test glass precipitation or solidification is observed, then the determination of the cold test must be carried out according to the method recommended for lubricating oils. The freezing point of the distillation residue left from illuminating oils at 275°C. may also be determined. Due regard is also to be given to changes noted during the cooling.

VII. The FRACTIONAL DISTILLATION is effected in the Engler bulb according to the continuous method. (Compare L. Ubbelohde, "Mitteilung aus dem Königlichen Material-prüfungsamt" 1909, p. 261 and "Moniteur du Pétrole" 1908, pp. 280, and 282). The height of the barometer is to be given and, by making a test with a thermometer of equal dimensions, a correction for the emergent mercury filament to be made. The condenser tube must be entirely dry. The boiling point is that point at which the first drop falls off from the exit tube of the Engler bulb.[1]

The limits of temperature within which the distillates are taken off must be divisible without remainder by 25.

Ordinarily the fractions are measured volumetrically, the residue, boiling above 300°C. and remaining in the retort, being weighed. For more exact investigations, the weight of the distillates and of the quantity used is determined.

VIII. ILLUMINATING POWER. As the unit of measurement of illuminating power the Hefner amyl acetate lamp is used. For changing from this unit into other units, the tables published by the "Verein der Gas und Wasserfachmänner" are used. For exact photometric determinations the grease

Unit	*H.*	*V.*	*E.*	*P.*	*C.*
Hefner	1	·833	·877	·091	·092
Vereins	1·2	1	1·05	·109	·111
English	1·14	·95	1	·104	·105
10 c.p. Pentane lamp	11·0	9·16	9·6	1	1·01
Carcel	10·80	9·0	9·5	·98	1

spot is not appropriate. It is necessary to use the photometer of Brodhun, or Lummer, or other modern apparatus.

The illuminating power of an illuminating oil does not depend solely on its composition, but most particularly upon the construction of the lamp

[1]It is better to take the temperature when the first drop falls from the condenser because frequently this occurs before a drop falls from the exit tube of the distilling bulb.

and (the) chimney used to determine the illuminating power. For these tests (of illuminating power), the following points must be observed:—

The size of the burner, of the chimney, and the distance from the edge of the burner to the level of the oil before and after the experiment must be given.

Before the experiment dry the wick (for two hours) at 100°C. (212°F.), then plunge it at once, warm, into the lamp oil, and let it soak there for an hour. The top of the wick should be trimmed with care by means of scissors until an even flame is obtained.

The duration of the combustion should be in general six hours. In particular cases an appreciable longer duration of combustion may be used.

During the first quarter of an hour turn up the flame to the highest point possible. Later, a quarter of an hour before the first photometric measurement, turn it up again, then leave it to itself (without touching it).

The photometric measurements should be done after the first, second, third, fourth, fifth, and sixth hours.

In determining the total consumption of oil, weigh the lamp before and after the test.

In order to obtain more exact determinations, the lamp should be weighed at each photometric determination. Differences in the temperature of the oil are without sensible effect upon the weight. In addition to the mean illuminating power and the total quantity of oil burned, the consumption per candle-power per hour is to be given. The kind of wick used must be given. The International Commission has left this subject to the study of a special commission.

IX. Behaviour of Burning. This subject also has been left to subsequent study by the Commission.

X. Degree of Refining:

Acid Content. 1. Shake 100 cubic centimeters of illuminating oil with 10 cubic centimeters of distilled water with addition of a few drops of an aqueous solution of methyl orange, 1:1000. The water must not become pink.

2. Dissolve 100 cubic centimeters of the illuminating oil in 100 cubic centimeters of a freshly neutralized mixture of 4 parts of ether, 1 part of 95 per cent alcohol, and 1 drop of phenolphthalein solution. Add a drop of one-tenth normal sodium hydrate solution, and shake in a cylinder with a stopper. If the illuminating oil is neutral, the pink colouring does not disappear during the shaking.

If an acid reaction has been detected by either of the two qualitative tests, then the quantitative determination of the acid content is to be undertaken by the known analytical methods. Meanwhile it may be of value to test the behaviour towards sodium hydrate by using the so-called "soda test" (Muspratt, "Technische Chemie" 1898, p. 234, or Post Chem. Tech. Analysen Ed. 3, vol. 1, p. 320) in which sodium hydrate solution (1·02 Sp. Gravity) diluted with water in ratio 6:100 is used. However, the result of the soda test alone is not decisive, but when it discloses nothing, a possible acid centent or "acid figure" is to be determined by 1. or 2., or if no free acid is present, the ash content. (See XII).

Xa. *Hydrocarbon Characteristics*: The determination of hydrocarbon content is referred to a committee for further study.[1] The problem of this committee is to be the preparation of methods for determining the various hydro-carbons groups that go to make up petroleum and its products.[2]

XI. STORAGE STABILITY. For studying the liability to alteration of petroleum in storage, a SPECIAL COMMITTEE is named to collect and work up material relating to this question for presentation to the next meeting of the International Commission.[3]

XII. ASH CONTENT. For determining the ash content, about 1 litre of filtered oil will be used, taking into consideration the filter residue qualitatively and, if necessary, quantitatively. The ash must be indicated in percentage by weight. The ash is determined by distilling off the sample to about 30 cubic centimeters. This residue is poured off along with the last portions of the distillate into a platinum dish, evaporated to dryness with removal of the vapours, and incinerated.

XIII. SULPHUR DETERMINATION. The determination of the sulphur is effected quantitatively either according to the method of Engler-Heussler ("Zeitschr. f. angew. Chemie" 1895, p. 225, Engler, "Chemikerzeitung" 1896, p. 1897, Post. Chemisch-Techn. Analysen, Vol. 1, part 2, p. 321), making if necessary at the same time a blank test to eliminate errors arising from the SO_2 content of the air of the laboratory, or else by the method of combustion in the bomb.

XIV. WATER DETERMINATION. Water determination for illuminating oil is dispensed with. In case of the occurrence of clouding, it must be determined if this results from the water content.

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[1] Nominated as members of SPECIAL COMMITTEE are Engler, Holde, Zaloziecki, Edeleanu, Gurwitsch, Nicolardot, Allen, and Sluyterman van loo.

[2] In this regard Dr. Engler has already communicated the following partial method worked out in his laboratory by Dr. Tausz and Dr. Pfeiffer: For qualitative detection of the unsaturated hydrocarbons a small quantity of benzine is shaken and boiled with concentrated aqueous mercuric acetate solution. Olefins and cyclic unsaturated hydrocarbons dissolve cold and are oxidized in boiling. In this process they reduce the mercuric acetate, which precipitates on cooling. Moreover butylene colours red, amylene yellow, and hexylene pink. For their quantitative determination the unsaturated compounds are for the most part thoroughly shaken with mercuric acetate at ordinary temperature and distilled out of the solution after adding hydrochloric acid. These regenerated unsaturated hydrocarbons are identified as formolite in the usual way in which the cyclic ones are identified. The remainder of the unsaturated hydrocarbons of the benzine, not dissolved by mercuric acetate is destroyed (decomposed) with fresh mercuric acetate by boiling with a return condenser whereupon the remaining more stable hydrocarbons are distilled off, separated by a special method, and determined quantitatively. The difference between the volume of the benzine used and that of the last named distillate gives the content in unsaturated hydrocarbons. The correction for unavoidable losses is found by a blank experiment.

The subsequent analysis is qualitative. The aromatic hydrocarbons are detected as formolite. In their presence the formolite reaction with the total distillate is repeated, until the hydrocarbons distilled off no longer give formolite. For detecting the cyclo-hexanes in this remainder a sample is passed at about 300°C. in a hydrogen atmosphere over finely divided nickel. If the condensate now shows the formolite reaction, then there were cyclo-hexanes present. Zelinski thinks they can be determined quantitatively by dehydrating with palladium black. Naphthenes and paraffines are recognized as usual from the physical constants of the carefully fractionized remainder.

[3] Dr. Singer is named as chairman, and the following are members: Allen, Guiselin, Gane, Sohn, and Bergner.

BENZINE (Gasoline, Naphtha, etc.)

1. SPECIFIC GRAVITY. Same as for illuminating oils.

II. DISTILLATION. The tests are the same as for illuminating oils. Fractionating is to be effected while making the limits of temperature divisible by 10. Final point of the distillation to be regarded as that temperature at which the bottom of the retort appears (to be) dry, or when white vapours make their appearance.

III. DEGREE OF REFINING. Tests to be omitted until a uniform method is fixed.

IV. FLASH POINT. In case such test is to be made, (German Abel-Pensky apparatus) is to be used.

V. ACID CONTENT. The rules given for illuminating oils are to be used, mutatis mutandis.

VI. HEAVY HYDROCARBONS. Referred to the Committee on point Xa for illuminating oils.

VII. WATER DETERMINATION. The same rules as for illuminating oils.

VIII. CALORIFIC VALUE. To be determined by bomb or other suitable apparatus. Indication must be given as to which apparatus was used.

IX, X and XI. (High boiling contituents, odour and colour, and illuminating power). These were referred to a Special Committee to investigate and report as in the case of illuminating oils.

LUBRICATING OILS.

I. COLOUR. Transparency of the oils in a thin layer is to be determined by letting them run over a glass surface. Colour is to be determined, as a rule, by simple ocular inspection in a test tube. In special cases, examination is made in rectangular vessels 10 centimeters in height, 10 centimeters in length, and 15 millimeters in width (inside measurement), made of pure white glass of 5 millimeters thickness of wall, and by both transmitted and reflected light. The colour is of no influence on the lubricating value, and as a rule is regarded only as an assistance for identification.

II. SPECIFIC GRAVITY. (a) Limitation of the specific gravity with reference to the proposed use is not necessary, and must not be subjected to too narrow limits. Only when oils of a determined origin are demanded, certain limits of gravity may be set for classification purposes, and these must not be drawn too narrowly. (b) Specific gravity serves only as a means of classifying mineral oils of known origin, and for tests of identity and comparison. (c) The determination of the specific gravity is effected according to the nature and quantity of the material and the degree of accuracy desired, according to the usual processes (officially standardized areometers, pycnometers, Mohr scales, areometers for small quantities of oil, alcohol floatation process). For thick oils, the method of mixing with kerosene is to be carried out. The standard temperature of 15°C. is fixed; as unit of weight, water at +4°C.; also specific gravity is always to be reduced to vacuum. The determination of specific gravity may also be effected at higher or lower temperatures than 15°C., and be corrected by the coefficients of expansion to the normal temperature of 15°C. Each country must determine for its own mineral oils the coefficients of expansion (correction figures). In case the specific gravity so calculated lies so near to a limit that errors might arise, the determination must be carried out at 15°C., or the coefficient of expansion (correction) exactly determined.

III. Flash Point. (a) In all cases where it is a question of obtaining the greatest possible exactness, the Pensky flash point apparatus must be used; in other cases also the open cup preferably with a mechanical device for bringing up the test flame and with an adjustable burner. (b) In case of absence of other prescribed methods a porcelain cup 4 cm. in width and 4 cm. in height is to be used for the determination of the flash point in the open cup, This is to be set in a sand bath up to the level of the oil. (For mode of experiment see Holde, Untersuchung der Mineralöle und Fette Ed. 3, p. 13). In determining the flash point in the open cup a thermometer with a short bulb is to be used, similar to that used with the Pensky apparatus; the centre of the bulb must be in the centre of the oil. Indication must always be given whether the work was prosecuted with or without consideration of the correction for the emergent stem of the thermometer. The officially standarized thermometers for the Pensky apparatus are so graduated that the indication of error includes the last mentioned correction (at the same time).

IIIa. Evaporation. Referred to a special committee.

IIIb. Distillation Test. Distillation test in general to be effected in the Engler bulb, using 100 cubic centimeters. Distillation to be carried on to 270°C., the temperature being taken in the vapour.

IV. Burning Point. This determination is carried out in the open cup, as in the case of the flash point. The heating must be continual, at the rate of about 4°C. a minute—at the outside 6°C. a minute.

V. Specific Viscosity. The Commission has referred this subject to a special committee.

VI. Capillarity. Also referred to a special committee.

VII and VIII. Cold Test. (a) For the simple determination the test tube method is sufficient, to be carried out in the following way: Into two test tubes of 18mm. diameter, the oil is to be poured to the height of 3 cm. In one of these test tubes a thermometer is dipped into the liquid. Both samples are kept for an hour in a freezing mixture at the desired temperature. The sample without the thermometer is then tilted, and the consistency, that is, the flowing capacity of the oil, determined. (b) In case of numerical comparison of the flowing test by the U-tube process, the sample in the test tube is to be cooled off for an hour to the experiment temperature, while maintaining 50mm. water pressure in the tube with width of 6 mm. (limit of error of plus or minus 0·3), pressure action lasting for a minute with a stipulated minimum rise.

(c) Preliminary treatment of the samples: For the consideration of the changes in the cold point conditioned by the influence of temperature changes, the samples are to be tested in two separate experiments, in the condition when delivered and after heating for ten minutes to 50°C. In the case of the oil tested in the heated condition, the determination is to be repeated for safety if the oil (left over) from the first test is sufficient. (d) For removing chance impurities, the oil before heating is to be poured through a sieve with a one-third mm. mesh. For this purpose very thick oils must be heated slightly. (e) Oil containing water must be decanted, and afterwards filtered through cotton wool dried at 100°C.

IX. Asphalt-Like Bodies. Referred to special committee.

X. Water and Mechanical Admixtures.

(a) *Water.*—The water content of oils is to be determined quantitatively, only in case the qualitative test has shown a notable water content. In case of pure mineral oils, which at 50°C., have an Engler degree of less than 8, the determination is made in the following way: About equal weights (each about 100g.) of the original and of the dehydrated oil are heated in glass dishes on a boiling water bath until the formation of foam (scum) has ceased, and the loss in weight determined. From the difference in loss of weight of the two samples the water content in the original oil is to be calculated. The dehydration of the oil, before heating, is effected by shaking the slightly heated oil in an Erlenmeyer flask with calcium chloride, and afterwards filtering on a dry filter. In case of oils of more than 8 Engler degrees, it is sufficient to establish the loss of weight by heating, and a parallel experiment with dehydrated oil is superfluous. In other cases, for instance with oil of high water content (solid fats), the determination according to Marcusson is to be employed, depending on the distillation of a considerable quantity of oil with xylol and the measurement of the water distilled over. All the other usual methods of testing (usual) for this purpose can be used, but the process must always be specified.

(b) *Mechanical Impurities.*—5 to 10 grams of well shaken oil are dissolved in a glass cylinder in 100 cubic centimeters of benzine (in case of light coloured oil from which no asphalt will separate, benzine may be used also). After standing all night, the solution is poured through a weighed filter. The cylinder is well rinsed out and the filter washed with the solvent until the wash liquid after evaporating on the water bath no longer gives a residue. The filter is dried at 105°C. to a constant weight and then weighed.

XI.—Ash and XII and XIII—Stability to Heat and Air in Storage and XIV, XV and XVI—Stability Towards Water Vapour, Superheated Steam and High Pressure—deferred for further investigation.

XVII. Degree of Refining.—*Free Acids*:

(a) Existing processes for determining free acids in lubricating oils are retained. Mineral acids are to be determined in the aqueous extract of about 100 grams of oil, with the use of methyl orange as indicator as in the case of illuminating oil. Organic acids are to be determined by titration with alcoholic 1/10 normal caustic alkali; an alcohol-ether mixture is used to dissolve 10 cc. of a light oil, and in the case of a dark oil absolute alcohol is the solvent. (b) The quantity of mineral acid is to be calculated in percentage of SO_3, the organic acids expressed as "acid figure." (The acid figure indicates the number of milligrams of KOH necessary to saturate the free acids contained in 1 g. of oil.)

Free Alkali.—Determine the presence of alkali in the aqueous extract of at least 100 grams of oil.

Salts (Ash Content).—Inorganic salts are determined in an aqueous extract of 100 cubic centimeters of oil. The presence of alkali soaps in case of pure mineral oils generally makes itself manifest by permanent emulsion and slightly alkaline reaction of the aqueous extract, in which case the qualitative detection of the alkali soap is effected by the following method: In a test tube of 15 mm. diameter 5 cubic centimeters of 0·5 Baumé caustic alkali solution is heated to boiling over the Bunsen burner. An equal quantity of oil is added and it is heated again for a minute to boiling, in such a way that the two liquids mix as intimately as possible during the boiling. This sample is then set for two or three hours in a boiling water bath. Then the sample, on inspection, must show the following results: The oil, in case it is pure, must be clear, and the alkali extract must appear transparent in so far that small print can be read through it. Clouding indicates napthenic acid salts, and in that case the ash determination must be carried out.

XIX. ADMIXTURES. (a) *Fatty Oil*: Fatty oil is detected qualitatively by the heating for a quarter of an hour of 3 or 4 cubic centimeters of the oil to be tested in a paraffin bath (oil bath) at about 340°C. with a small piece of sodium hydrate or, in doubtful cases, with metallic sodium. After cooling off to ordinary temperature, the oils show some lather in case of presence of fatty oils, or else they gelatinize. The soap lather is in the case of cylinder oils the deciding sign of the presence of fatty oils. Napthenic acid may produce similar phenomena. Quantitatively fatty oil is determined according to the approximate quantity and the degree of exactness desired, by determining the saponification figure or gravimetrically according to Spitz and Hönig.

XX. PARAFFIN. The determination of the paraffin content can generally be dispensed with in testing lubricating oils because any high percentage of paraffin would become apparent during the cold testing. In special cases, for instance in litigation tests, etc., the alcohol-ether process of Engler and Holde for paraffin determination can be used.

XXI. LUBRICATING CAPACITY. This point, as well as the study of transformer oils, sampling and measuring mineral oils kept on supply in tanks, ships, and so forth, is deferred.

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CANADA

DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER; R. G. McCONNELL, DEPUTY MINISTER.

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR.

REPORTS AND MAPS

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32. Investigation of electric shaft furnace, Sweden. Report on—by Eugene Haanel, Ph.D.

47. Iron ore deposits of Vancouver and Texada islands. Report on—by Einar Lindeman, M.E.

†55. The bituminous, or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by R. W. Ells, LL.D.

58. The mineral production of Canada, 1907 and 1908. Annual report on—by John McLeish, B.A.

†Publications marked thus † are out of print.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1907-8.*

†31. Production of cement in Canada, 1908.

42. Production of iron and steel in Canada during the calendar years 1907 and 1908.

43. Production of chromite in Canada during the calendar years 1907 and 1908.

44. Production of asbestos in Canada during the calendar years 1907 and 1908.

†45. Production of coal, coke, and peat in Canada during the calendar years 1907 and 1908.

46. Production of natural gas and petroleum in Canada during the calendar years 1907 and 1908.

59. Chemical analyses of special economic importance made in the laboratories of the Department of Mines, 1906–7–8. Report on—by F. G. Wait, M.A., F.C.S. (With Appendix on the commercial methods and apparatus for the analysis of oil-shales—by H. A. Leverin, Ch. E.)

Schedule of charges for chemical analyses and assays.

†62. Mineral production of Canada, 1909. Preliminary report on—by John McLeish, B.A.

63. Summary report of Mines Branch, 1909.

67. Iron ore deposits of the Bristol mine, Pontiac county, Quebec. Bulletin No. 2— by Einar Lindeman, M.E., and Geo. C. Mackenzie, B.Sc.

†68. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

69. Chrysotile-asbestos: its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E. (Second edition, enlarged.)

†71. Investigation of the peat bogs, and peat industry of Canada, 1909-10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenberg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. v. Anrep, Jr.; also a translation of Lieut. Ekelund's pamphlet entitled 'A solution of the peat problem,' 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. v. Anrep. (Second edition, enlarged.)

82. Magnetic concentration experiments. Bulletin No. 5—by Geo. C. Mackenzie, B.Sc.

† Publications marked thus † are out of print.

83. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others.
  Vol. I—Coal washing and coking tests.
  Vol. II—Boiler and gas producer tests.
  Vol. III—
    Appendix I
      Coal washing tests and diagrams.
  Vol. IV—
    Appendix II
      Boiler tests and diagrams.
  Vol. V—
    Appendix III
      Producer tests and diagrams.
  Vol. VI—
    Appendix IV
      Coking tests.
    Appendix V
      Chemical tests.

†84. Gypsum deposits of the Maritime provinces of Canada—including the Magalen islands. Report on—by W. F. Jennison, M.E. (See No. 245.)

88. The mineral production of Canada, 1909. Annual report on—by John McLeish, B.A.

  NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1909.*

  †79. Production of iron and steel in Canada during the calendar year 1909.
  †80. Production of coal and coke in Canada during the calendar year 1909.
  85. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1909.

89. Reprint of presidential address delivered before the American Peat Society at Ottawa, July 25, 1910. By Eugene Haanel, Ph.D.

90. Proceedings of conference on explosives.

92. Investigation of the explosives industry in the Dominion of Canada, 1910. Report on—by Capt. Arthur Desborough. (Second edition.)

93. Molybdenum ores of Canada. Report on—by Professor T. L. Walker, Ph.D.

100. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by Professor W. A. Parks, Ph.D.

102. Mineral production of Canada, 1910. Preliminary report on—by John McLeish, B.A.

†Publications marked thus † are out of print.

†103. Summary report of Mines Branch, 1910.

104. Catalogue of publications of Mines Branch, from 1902 to 1911; containing tables of contents and lists of maps, etc.

105. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

110. Western portion of Torbrook iron ore deposits, Annapolis county, N.S. Bulletin No. 7—by Howells Fréchette, M.Sc.

111. Diamond drilling at Point Mamainse, Ont. Bulletin No. 6—by A. C. Lane, Ph.D., with introductory by A. W. G. Wilson, Ph.D.

118. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

142. Summary report of Mines Branch, 1911.

143. The mineral production of Canada, 1910. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1910.*

†114. Production of cement, lime, clay products, stone, and other materials in Canada, 1910.
†115. Production of iron and steel in Canada during the calendar year 1910.
†116. Production of coal and coke in Canada during the calendar year 1910.
†117. General summary of the mineral production of Canada during the calendar year 1910.

145. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

†150. The mineral production of Canada, 1911. Preliminary report on—by John McLeish, B.A.

151. Investigation of the peat bogs and peat industry of Canada, 1910-11. Bulletin No. 8—by A. v. Anrep.

154. The utilization of peat fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910-11. Report on—by B. F. Haanel, B.Sc.

167. Pyrites in Canada: its occurrence, exploitation, dressing and uses. Report on—by A. W. G. Wilson, Ph.D.

170. The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

184. Magnetite occurrences along the Central Ontario railway. Report on—by E. Lindeman, M.E.

201. The mineral production of Canada during the calendar year 1911.—Annual report on—by John McLeish, B.A.

†Publications marked thus † are out of print.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1911.*

181. Production of cement, lime, clay products, stone, and other structural materials in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

†182. Production of iron and steel in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

183. General summary of the mineral production in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

†199. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1911. Bulletin on—by C. T. Cartwright, B.Sc.

†200. The production of coal and coke in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

203. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

209. The copper smelting industry of Canada. Report on—by A. W. G. Wilson, Ph.D.

216. Mineral production of Canada, 1912. Preliminary report on—by John McLeish, B.A.

222. Lode mining in Yukon: an investigation of the quartz deposits of the Klondike division. Report on—by T. A. MacLean, B.Sc.

224. Summary report of the Mines Branch, 1912.

227. Sections of the Sydney coal fields—by J. G. S. Hudson, M.E.

†229. Summary report of the petroleum and natural gas resources of Canada, 1912—by F. G. Clapp, A.M. (See No. 224.)

230. Economic minerals and mining industries of Canada.

245. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

254. Calabogie iron-bearing district. Report on—by E. Lindeman, M.E.

259. Preparation of metallic cobalt by reduction of the oxide. Report on—by H. T. Kalmus, B.Sc., Ph.D.

262. The mineral production of Canada during the calendar year 1912. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1912.*

238. General summary of the mineral production of Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

†Publications marked thus † are out of print.

†247. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

†256. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1912—by C. T. Cartwright, B.Sc.

257. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Report on—by John McLeish, B.A.

†258. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

266. Investigation of the peat bogs and peat industry of Canada, 1911 and 1912. Bulletin No. 9—by A. v. Anrep.

279. Building and ornamental stones of Canada—Vol. III: Building and ornamental stones of Quebec. Report on—by W. A. Parks, Ph.D.

281. The bituminous sands of Northern Alberta. Report on—by S. C. Ells, M.E.

283. Mineral production of Canada, 1913. Preliminary report on—by John McLeish, B.A.

285. Summary report of the Mines Branch, 1913.

291. The petroleum and natural gas resources of Canada. Report on—by F. G. Clapp, A.M., and others:—

Vol. I.—Technology and Exploitation.

299. Peat, lignite, and coal: their value as fuels for the production of gas and power in the by-product recovery producer. Report on—by B. F. Haanel, B.Sc.

303. Moose Mountain iron-bearing district. Report on—by E. Lindeman, M.E.

305. The non-metallic minerals used in the Canadian manufacturing industries. Report on—by Howells Fréchette, M.Sc.

309. The physical properties of cobalt, Part II. Report on—by H. T. Kalmus, B.Sc., Ph.D.

320. The mineral production of Canada during the calendar year 1913. Annual report on—by John McLeish, B.A.

Note.—*The following parts were separately printed and issued in advance of the Annual Report for 1913.*

315. The production of iron and steel during the calendar year year 1913. Bulletin on—by John McLeish, B.A.

316. The production of coal and coke during the calendar year 1913. Bulletin on—by John McLeish, B.A.

317. The production of copper, gold, lead, nickel, silver, zinc, and other metals, during the calendar year 1913. Bulletin on—by C. T. Cartwright, B.Sc.

†Publications marked thus † are out of print.

318. The production of cement, lime, clay products, and other structural materials, during the calendar year 1913. Bulletin on—by John McLeish, B.A.

319. General summary of the mineral production of Canada during the calendar year 1913. Bulletin on—by John McLeish, B.A.

322. Economic minerals and mining industries of Canada. (Revsied Edition).

336. Notes on clay deposits near McMurray, Alberta. Bulletin No. 10—by S. C. Ells, B.A., B.Sc.

The Division of Mineral Resources and Statistics has prepared the following lists of mine, smelter, and quarry operators: Metal mines and smelters, Coal mines, Stone quarry operators, Manufacturers of clay products, and Manufacturers of lime; copies of the lists may be obtained on application.

IN THE PRESS.

291. The petroleum and natural gas resources of Canada. Report on—by F. G. Clapp, A.M., and others:—

Vol. II.—Occurrence of petroleum and natural gas in Canada.
Also separates of Vol. II, as follows:—
Part I, Eastern Canada.
Part II, Western Canada.

323. The Products and by-products of coal. Report on—by Edgar Stansfield, M.Sc., and F. E. Carter, B.Sc., Dr. Ing.

325. The salt industry of Canada. Report on—by L. H. Cole, B.Sc.

331. The investigation of six samples of Alberta lignites. Report on—by B. F. Haanel, B.Sc., and John Blizard, B.Sc.

334. Electro-plating with cobalt and its alloys. Report on—by H. T. Kalmus, B.Sc., Ph.D.

FRENCH TRANSLATIONS.

†4. Rapport de la Commission nommée pour étudier les divers procédés électro-thermiques pour la réduction des minerais de fer et la fabrication de l'acier employés en Europe—by Eugene Haanel, Ph.D. (French Edition), 1905.

26a. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†28a. Summary report of Mines Branch, 1908.

56. Bituminous or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by R. W. Ells, LL.D.

81. Chrysotile-asbestos, its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E.

100a. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by W. A. Parks, Ph.D.

149. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

155. The utilization of peat fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910-11. Report on—by B. F. Haanel, B.Sc.

156. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D.

169. Pyrites in Canada: its occurrence, exploitation, dressing, and uses. Report on—by A. W. G. Wilson, Ph.D.

180. Investigation of the peat bogs, and peat industry of Canada, 1910-11. Bulletin No. 8—by A. v. Anrep.

195. Magnetite occurrences along the Central Ontario railway. Report on —by E. Lindeman, M.E.

196. Investigation of the peat bogs and peat industry of Canada, 1909-10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenburg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. v. Anrep; also a translation of Lieut. Ekelund's pamphlet entitled "A solution of the peat problem," 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. v. Anrep. (Second Edition, enlarged.)

197. Molybdenum ores of Canada. Report on—by T. L. Walker, Ph.D.

198. Peat and lignite: their manufacture and uses in Europe. Report on—by Erik Nystrom, M.E., 1908.

202. Graphite: its properties, occurrences, refining, and uses. Report on—by Fritz Cirkel, M.E., 1907.

†Publications marked thus † are out of print.

219. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

226. Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel, M.E. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.)

231. Economic minerals and mining industries of Canada.

233. Gypsum deposits of the Maritime Provinces of Canada—including the Magdalen islands. Report on—by W. F. Jennison, M.E.

263. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

264. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

265. Annual mineral production of Canada, 1911. Report on—by John McLeish, B.A.

287. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

288. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

289. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Bulletin on—by John McLeish, B.A.

290. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada during the calendar year 1912. Bulletin on—by C. T. Cartwright, B.Sc.

308. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma. E., and others—
Vol. I—Coal washing and coking tests.

IN THE PRESS.

179. The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

204. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

223. Lode Mining in the Yukon: an investigation of quartz deposits in the Klondike division. Report on—by T. A. MacLean, B.Sc.

246. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

308. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others—
Vol. II—Boiler and gas producer tests.
Vol. III—
Appendix I
Coal washing tests and diagrams.
Vol. IV—
Appendix II
Boiler tests and diagrams.

314. Iron ore deposits, Bristol mine, Pontiac county, Quebec, Report on—by E. Lindeman, M.E.

MAPS.

†6. Magnetometric survey, vertical intensity: Calabogie mine, Bagot township, Renfrew county, Ontario—by E. Nystrom, 1904. Scale 60 feet to 1 inch. Summary report 1905. (See Map No. 249.)

†13. Magnetometric survey of the Belmont iron mines, Belmont township, Peterborough county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1905. (See Map No. 186.)

†14. Magnetometric survey of the Wilbur mine, Lavant township, Lanark county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1905.

†33. Magnetometric survey, vertical intensity: lot 1, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†34. Magnetometric survey, vertical intensity: lots 2 and 3, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†35. Magnetometric survey, vertical intensity: lots 10, 11, and 12, concession IX, and lots 11 and 12, concession VIII, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

*36. Survey of Mer Bleue peat bog, Gloucester township, Carleton county, and Cumberland township, Russell county, Ontario—by Erik Nystrom, and A. v. Anrep. (Accompanying report No. 30.)

*37. Survey of Alfred peat bog, Alfred and Caledonia townships, Prescott county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*38. Survey of Welland peat bog, Wainfleet and Humberstone townships, Welland county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*39. Survey of Newington peat bog, Osnabruck, Roxborough, and Cornwall townships, Stormont county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*40. Survey of Perth peat bog, Drummond township, Lanark county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*41. Survey of Victoria Road peat bog, Bexley and Carden townships, Victoria county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*48. Magnetometric survey of Iron Crown claim at Nimpkish (Klaanch) river, Vancouver island, B.C.—by E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

*49. Magnetometric survey of Western Steel Iron claim, at Sechart, Vancouver island, B.C.—by E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47.)

*53. Iron ore occurrences, Ottawa and Pontiac counties, Quebec, 1908—by J. White and Fritz Cirkel. (Accompanying report No. 23.)

*54. Iron ore occurrences, Argenteuil county, Quebec, 1908—by Fritz Cirkel. (Accompanying report No. 23.) (Out of print.)

*57. The productive chrome iron ore district of Quebec—by Fritz Cirkel. (Accompanying report No. 29.)

†60. Magnetometric survey of the Bristol mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 67.)

†61. Topographical map of Bristol mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 67.)

†64. Index map of Nova Scotia: Gypsum—by W. F. Jennison. †65. Index map of New Brunswick: Gypsum—by W. F. Jennison. †66. Map of Magdalen islands: Gypsum—by W. F. Jennison.	(Accompanying report No. 84.)

†70. Magnetometric survey of Northeast Arm iron range, Lake Timagami, Nipissing district, Ontario—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 63.)

†72. Brunner peat bog, Ontario—by A. v. Anrep. †73. Komoka peat bog, Ontario—by A. v. Anrep. †74. Brockville peat bog, Ontario—by A. v. Anrep............. †75. Rondeau peat bog, Ontario—by A. v. Anrep. †76. Alfred peat bog, Ontario—by A. v. Anrep. †77. Alfred peat bog, Ontario: main ditch profile—by A. v. Anrep.	(Accompanying report No. 71.) (Out of print)

†78. Map of asbestos region, Province of Quebec, 1910—by Fritz Cirkel. Scale 1 mile to 1 inch. (Accompanying report No. 69.)

†94. Map showing Cobalt, Gowganda, Shiningtree, and Porcupine districts —by L. H. Cole. (Accompanying Summary report, 1910.)

†95. General map of Canada, showing coal fields. (Accompanying report No. 83—by Dr. J. B. Porter.)

†96. General map of coal fields of Nova Scotia and New Brunswick. (Accompanying report No. 83—by Dr. J. B. Porter.)

†97. General map showing coal fields in Alberta, Saskatchewan, and Manitoba. (Accompanying report No. 83—by Dr. J. B. Porter).

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†98. General map of coal fields in British Columbia. Accompanying report No. 83—by Dr. J. B. Porter.)

†99. General map of coal field in Yukon Territory. (Accompanying report No. 83—by Dr. J. B. Porter.)

†106. Geological map of Austin Brook iron bearing district, Bathurst township, Gloucester county, N.B.—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†107. Magnetometric survey, vertical intensity: Austin Brook iron bearing district—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†108. Index map showing iron bearing area at Austin Brook—by E. Lindeman. (Accompanying report No. 105.)

*112. Sketch plan showing geology of Point Mamainse, Ont.—by Professor A. C. Lane. Scale 4,000 feet to 1 inch. (Accompanying report No. 111.)

†113. Holland peat bog, Ontario—by A. v. Anrep. (Accompanying report No. 151.)

*119–137. Mica: township maps, Ontario and Quebec—by Hugh S. de Schmid. (Accompanying report No. 118.)

†138. Mica: showing location of principal mines and occurrences in the Quebec mica area—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†139. Mica: showing location of principal mines and occurrences in the Ontario mica area—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†140. Mica: showing distribution of the principal mica occurrences in the Dominion of Canada—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†141. Torbrook iron bearing district, Annapolis county, N.S.—by Howells Fréchette. Scale 400 feet to 1 inch. (Accompanying report No. 110.)

†146. Distribution of iron ore sands of the iron ore deposits on the north shore of the River and Gulf of St. Lawrence, Canada—by Geo. C. Mackenzie. Scale 100 miles to 1 inch. (Accompanying report No. 145.)

†147. Magnetic iron sand deposits in relation to Natashkwan harbour and Great Natashkwan river, Que. (Index Map)—by Geo. C. Mackenzie. Scale 40 chains to 1 inch. (Accompanying report No. 145.)

†148. Natashkwan magnetic iron sand deposits, Saguenay county, Que.—by Geo. C. Mackenzie. Scale 1,000 feet to 1 inch. (Accompanying report No. 145.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†152. Map showing the location of peat bogs investigated in Ontario—by A. v. Anrep.

†153. Map showing the location of peat bog as investigated in Manitoba—by A. v Anrep.

†157. Lac du Bonnet peat bog, Manitoba—by A. v. Anrep.

†158. Transmission peat bog, Manitoba—by A. v. Anrep.

†159. Corduroy peat bog, Manitoba—by A. v. Anrep.

†160. Boggy Creek peat bog, Manitoba—by A. v. Anrep.

†161. Rice Lake peat bog, Manitoba—by A. v. Anrep.

†162. Mud Lake peat bog, Manitoba—by A. v. Anrep.

†163. Litter peat bog, Manitoba—by A. v. Anrep.

†164. Julius peat litter bog, Manitoba—by A. v. Anrep.

*165. Fort Francis peat bog, Ontario—by A. v. Anrep.

(Accompanying report No. 151.)

†166. Magnetometric map of No. 3 mine, lot 7, concessions V and VI, McKim township, Sudbury district, Ont.—by E. Lindeman. (Accompanying Summary report, 1911.)

†168. Map showing pyrites mines and prospects in Eastern Canada, and their relation to the United States market—by A. W. G. Wilson. Scale 125 miles to 1 inch. (Accompanying report No. 167.)

†171. Geological map of Sudbury nickel region, Ont.—by Prof. A. P. Coleman. Scale 1 mile to 1 inch. (Accompanying report No. 170.)

†172. Geological map of Victoria mine—by Prof. A. P. Coleman.

†173 " Crean Hill mine—by Prof. A. P. Coleman

†174. " Creighton mine—by Prof. A. P. Coleman.

(Accompanying report No. 170.)

†175. " showing contact of norite and Laurentian in vicinity of Creighton mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†176. " Copper Cliff offset—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†177. " No. 3 mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†178. " showing vicinity of Stobie and No. 3 mines—by Prof. A. P. Coleman. (Accompanying report No. 170.)

Note.—1. Maps marked thus * are to be [illegible] only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†185. Magnetometric survey, vertical intensity: Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†185a. Geological map, Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186. Magnetometric survey, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186a. Geological map, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187. Magnetometric survey, vertical intensity: St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187a. Geological map, St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188. Magnetometric survey, vertical intensity: Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188a. Geological map, Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†189. Magnetometric survey, vertical intensity: Ridge iron ore deposits, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190. Magnetometric survey, vertical intensity: Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Acccompanying report No. 184.)

†190a. Geological map, Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191. Magnetometric survey, vertical intensity: Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191a. Geological map, Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†192. Magnetometric survey, vertical intensity: Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

Note.—1. Maps marked thus * are to be found only in reports.
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†192a. Geological map, Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193. Magnetometric survey, vertical intensity: Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193a. Geological map, Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†194. Magnetometric survey, vertical intensity: Bow Lake iron ore occurrences, Faraday township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†204. Index map, magnetite occurrences along the Central Ontario railway—by E. Lindeman, 1911. (Accompanying report No. 184.)

†205. Magnetometric map, Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman, 1911. (Accompanying report No. 303.)

†205a. Geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario, Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman. (Accompanying report No. 303.)

†206. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: northern part of deposit No. 2—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†207. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 8, 9, and 9A—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposit No. 10—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208a. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: eastern portion of Deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208b. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: western portion of deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208c. General geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario—by E. Lindeman, 1912. Scale 800 feet to 1 inch. (Accompanying report No. 303.)

Note.—1. Maps marked thus * are to be found only in reports.
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†210. Location of copper smelters in Canada—by A. W. G. Wilson. Scale 197·3 miles to 1 inch. (Accompanying report No. 209.)

†215. Province of Alberta: showing properties from which samples of coal were taken for gas producer tests, Fuel Testing Division, Ottawa. (Accompanying Summary report, 1912.)

†220. Mining districts, Yukon. Scale 35 miles to 1 inch—by T. A. MacLean (Accompanying report No. 222.)

†221. Dawson mining district, Yukon. Scale 2 miles to 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

*228. Index map of the Sydney coal fields, Cape Breton, N.S. (Accompanying report No. 227.)

†232. Mineral map of Canada. Scale 100 miles to 1 inch. (Accompanying report No. 230.)

239. Index map of Canada showing gypsum occurrences. (Accompanying report No. 245.)

240. Map showing Lower Carboniferous formation in which gypsum occurs in the Maritime provinces. Scale 100 miles to 1 inch. (Accompanying report No. 245.)

241. Map showing relation of gypsum deposits in Northern Ontario to railway lines. Scale 100 miles to 1 inch. (Accompanying report No. 245.)

242. Map, Grand River gypsum deposits, Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 245.)

243. Plan of Manitoba Gypsum Co.'s properties. (Accompanying report No. 245.)

244. Map showing relation of gypsum deposits in British Columbia to railway lines and market. Scale 35 miles to 1 inch. (Accompanying report No. 245.)

†249. Magnetometric survey, Caldwell and Campbell mines, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†250. Magnetometric survey, Black Bay or Williams mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†251. Magnetometric survey, Bluff Point iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†252. Magnetometric survey, Culhane mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

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†253. Magnetometric survey, Martel or Wilson iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†261. Magnetometric survey, Northeast Arm iron range, lot 339 E.T.W. Lake Timagami, Nipissing district, Ontario—by E. Nystrom. 1903. Scale 200 feet to 1 inch.

†268. Map of peat bogs investigated in Quebec—by A. v. Anrep, 1912.

†269. Large Tea Field peat bog, Quebec " "

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†284. Map of northern portion of Alberta, showing position of outcrops of bituminous sand. Scale 12½ miles to 1 inch. (Accompanying report No. 281.)

†293. Map of Dominion of Canada, showing the occurrences of oil, gas, and tar sands. Scale 197 miles to 1 inch. (Accompanying report No. 291.)

†294. Reconnaissance map of part of Albert and Westmorland counties, New Brunswick. Scale 1 mile to 1 inch. (Accompanying report No. 291.)

†295. Sketch plan of Gaspé oil fields, Quebec, showing location of wells. Scale 2 miles to 1 inch. (Accompanying report No. 291.)

†296. Map showing gas and oil fields and pipe-lines in southwestern Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 291.)

†297. Geological map of Alberta, Saskatchewan, and Manitoba. Scale 35 miles to 1 inch. (Accompanying report No. 291.)

†298. Map, geology of the forty-ninth parallel, 0·9864 miles to 1 inch. (Accompanying report No. 291.)

†302. Map showing location of main gas line, Bow Island, Calgary. Scale 12½ miles to 1 inch. (Accompanying report No. 291.)

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†311. Magnetometric map, McPherson mine, Barachois, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

†312. Magnetometric map, iron ore deposits at Upper Glencoe, Inverness county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

†313. Magnetometric map, iron ore deposits at Grand Mira, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

Address all communications to—

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Canada
DEPARTMENT OF MINES
Hon. Louis Coderre, Minister, R.W. Brock, Deputy Minister.
MINES BRANCH
Eugene Haanel, Ph.D., Director
1914

H. E. Baine, Chief Draughtsman.
Base map from plate of Dept. of the Interior.

To accompany report on "Petroleum and Natural Gas Resources of Canada" by Frederick G. Clapp and others.

No. 293

CANADA

DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR.

Petroleum and Natural Gas Resources of Canada

IN TWO VOLUMES

VOL. II.

DESCRIPTION OF OCCURRENCES.

PART 1, EASTERN CANADA
PART 2, WESTERN CANADA

BY

Frederick G. Clapp,
and Others

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VOL. II

DESCRIPTION OF OCCURRENCES

PART 1

Canadian Fields in Detail

EASTERN CANADA

CHAPTER I

NOVA SCOTIA

GEOLOGY[1]

Stratigraphy

The Canadian Geological Survey recognizes the occurrence, in Nova Scotia, of bed-rock geological formations ranging from the Pre-Cambrian to the Triassic. The Pre-Cambrian rocks of Nova Scotia occur only in Cape Breton, underlying about one half the island. The rocks of this group include gneisses, schists, crystalline limestones, and granites and other intrusives. The next youngest series of rocks is often called the Gold bearing series. They were formerly regarded as Lower Cambrian, but Mr. Faribault[2] now believes that they should be classified as late Pre-Cambrian. This series forms an almost continuous belt along the whole length of the Atlantic coast of Nova Scotia; this belt is about 270 miles in length, varies in width from 10 to about 75 miles, and underlies more than one third of the total area of the province. The series consists of a great thickness of conformable quartzites and slates, closely folded in long east and west anticlines and intruded by many large batholiths of granite and some dikes of diabase. In the vicinity of granite intrusives the sediments have been metamorphosed into gneisses and schists. A series of

[1]Paragraphs on geology by Alfred W. G. Wilson.
[2]See Guide book No. 1, International Geological Congress, 1913, p. 258.

Post-Cambrian batholithic intrusives, largely Devonian granites, occupy the western and central portions of the province and also occur in a number of more or less isolated areas in the eastern and northern parts of the mainland. The main mass of Devonian granite occupies the southwestern part of the province and extends as far east as Halifax. It has a length of about 115 miles and a width of about 30 miles. The next largest area lies south of the Cobequids in Cumberland county and occupies a strip of territory about 10 miles in width and 75 miles in length. Smaller areas occur east of Halifax and scattered through the interior as far east as Canso.

Strata classed as Cambrian are confined to a small area in Cape Breton island.

A series of strata, consisting of shales, quartzites and associated volcanic rocks, destitute of fossils, outcrops in the Cobequid mountains; a similar series extends eastward to the strait of Canso and into Cape Breton island. Because of their stratigraphic position they are tentatively classed as Ordovician.

Silurian rocks occur in a number of isolated localities in Nova Scotia. A small area outcrops on the north side of the Cobequids, between Wentworth and Waugh river. Two smaller areas, covering about five and a half square miles, occur in Pictou county about 10 miles southeast of Tatamagouche, and four other smaller areas occur in the southeastern part of the same county, about four miles south of New Glasgow. Larger areas occur in the eastern part of Pictou county and in the adjoining portion of Antigonish county, extending east as far as Malignant cove, 3 miles beyond Arisaig. These rocks occupy about 96 square miles in all. The Silurian rocks differ in character in different parts of the province; sandstones, shales and limestones occur, and occasionally these have been metamorphosed by dynamic action or igneous intrusion.

Devonian rocks occur in a strip of territory which extends from Minas basin to the strait of Canso and thence across the southern portion of Cape Breton island. Mississippian rocks (Lower Carboniferous of the earlier surveys) occupy more or less isolated areas along this same belt of territory. The best known of these occur in the vicinity of Windsor and east of Truro. The Pennsylvanian or Upper Carboniferous series comprises the coal bearing rocks of Nova Scotia. These rocks occupy a number of basins which extend from Cumberland county in the vicinity of the Bay of Fundy to the southeast of Cape Breton island. Important coal bearing strata occur in Cumberland north of the Cobequid hills in the vicinity of Minas basin and Cobequid bay, in Pictou, in Antigonish, in Guysborough, in Richmond, Inverness, Victoria and Cape Breton counties.

Rocks which are classed as Permo-Carboniferous border Northumberland strait on the south in Pictou and Cumberland counties. Deposits classed in the same horizon occur in the west of Cumberland county along the coast of Chignecto bay. The Triassic rocks of Nova Scotia outcrop along the south shore of the Bay of Fundy. They are associated with, and partly buried beneath a series of Post-Triassic diabase flows. These trap sheets are a prominent topographic feature of the Fundy shore.

GEOLOGICAL STRUCTURE.

Nova Scotia lies within the region of Appalachian folds. The central and southern portion of the province consists of a core of granite, formed largely by Devonian batholiths, bordered by the more or less intensely metamorphosed rocks of the Gold bearing series. As has already been noted this formation now lies in a series of closely folded east and west anticlines, which have also been subjected to great denudation and degradation. The rocks of the succeeding periods to the base of the Carboniferous have also been subjected to folding, plication, and metamorphism. The Carboniferous and later strata are comparatively undisturbed, though they are thrown into minor undulations or folds and are faulted. They usually occupy synclinal basins which are bordered by the folded and metamorphosed rocks of the earlier periods. The Permo-Carboniferous and Triassic rocks are little disturbed and occur in nearly flat lying or only slightly undulating beds.

HISTORY OF DRILLING OPERATIONS.

In Nova Scotia, as reported by Brumell, efforts were made about 1864 to find oil by the Pioneer Oil and Salt Company near Lake Ainslie in Cape Breton, where oil had been seen to rise on the water for many years. The wells were sunk 600 feet and only traces of oil were found. At a later date a test well was sunk to a depth of 500 feet at Baddeck with no better results. Several companies were organized about that time to test for oil in the vicinity, namely, Pioneer Oil and Salt Co., the Victoria Oil Co., Cape Breton Oil and Mining Co., Inverness Oil and Mining Co., and American Oil Co.

In July, 1912, it was reported that the Lake Ainslie Oil Co. of Lake Ainslie, Cape Breton, was putting down a number of wells and had struck a 75-foot oil sand. This report has not been substantiated and it seems probable that instead of 75 feet of oil sand, the drill must have penetrated 75 feet into an oil shale either of that thickness or cutting across the beds of the rocks dipping at a fairly high angle.

Indications.—The only indications known in Nova Scotia are showings of oil reported by Brumell, as seen frequently on the waters of Lake Ainslie, and scums on the surface of swamps and springs in the vicinity. Oil-bearing shale, however, is now becoming generally known in portions of Nova Scotia, and promises to furnish material for as flourishing an industry as the oil shales of Scotland.[1]

POSSIBILITIES OF OIL AND GAS IN NOVA SCOTIA.

General Statement.

Up to the present time oil and gas have never been found in commercial quantities in Nova Scotia, and it is improbable that more than showings will be found anywhere; although small pools may not be impossible. Some seepages have been reported at various times, and in certain limited areas formations occur which contain oil and gas in other parts of the world, but which are here, as a rule, not structurally favourable.

[1]Gilpin reports the presence of indications of oil at Cheverie, Hants county, permeating the gypsum and limestone of that locality. They are believed to have risen from underlying bituminous shales. A.W.G.W.

GENERAL GEOLOGICAL DISCUSSION.

Throughout the entire southeastern half of Nova Scotia we may safely say that there is absolutely no chance of finding oil or gas in quantity, since the formations consist entirely of Pre-Cambrian crystalline rocks and Post-Cambrian intrusive volcanic rocks, which never contain oil pools. This portion of the country which is absolutely unfavourable covers Shelburne, Queens, Yarmouth, Lunenberg, Halifax, and Digby counties entirely, and all except a narrow strip along the north side of Annapolis, the southern corner of Kings, the southern edge of Hants, and the southeastern half of Guysborough.

It should not be understood that the portion of Nova Scotia lying outside the counties mentioned is favourable, because such is not the case. The remaining portion of Annapolis county along the Bay of Fundy consists of a belt of Triassic formation in which no oil fields have ever been found. The greater part of Kings county consists of the same formations, and in addition there is an area in the eastern corner of the county, adjacent to Minas basin, where the surface consists largely of Devonian and Lower Carboniferous formations, in which oil and gas exist to a certain extent in New Brunswick.

The northern half of Hants county consists also mostly of Devonian and Lower Carboniferous formations, as does a large portion of Colchester, Pictou and Antigonish counties, and the northern half of Guysborough. The western end of Colchester county consists largely of Triassic formation, in which oil and gas fields have never been found, and throughout the southern half of Cumberland county are large masses of volcanic intrusive formations, the vicinity of which is rendered particularly unfavourable by their presence. Intrusive volcanic formations are also present in the eastern part of Pictou county.

The northern half of Cumberland county, a small area in the northern end of Colchester, and at the northwest corner of Pictou county, consist at the surface mainly of Middle Carboniferous and Permian formations, which do not contain oil and gas in the Dominion of Canada, but which in New Brunswick are occasionally underlain by oil and gas producing formations. However, it is believed that these formations will not be productive in Nova Scotia, for the reason that structurally they are so much broken up and contorted. Some areas of the Lower and Middle Carboniferous rock occur in Cape Breton island and in Cape Breton and Inverness counties, but these areas are in close proximity to large masses of Laurentian rock, which outcrops extensively throughout Cape Breton in very irregular patches, and, consequently, it is not believed that conditions in Cape Breton are any more favourable for oil and gas than in other portions of Nova Scotia.

POSSIBILITIES OF THE OIL-SHALE INDUSTRIES IN NOVA SCOTIA.

According to R. W. Ells[1], the bituminous oil-bearing shales of Nova Scotia are richer in oil and by-products than the Scotch oil shales.

Regarding the history of the industry in Scotland, Ells says:—

> The Scotch shale industry was first started nearly 60 years ago in the district a few miles west of Edinburgh. About 1850 the discovery of a small spring of rock oil in connection with a coal bed led to attempts to manufacture burning oils by refining, and the presence of this oil with coal led further to the inference that in some way oil and coal beds were associated; so that after the exhaustion of the small quantity of native oil, attention was directed to the distillation of crude oil from coal itself, with a fair amount of success. The discovery of the peculiar mineral at Torbane hill, which on examination was found to be very rich in hydrocarbons, and to yield from 120 to 130 gallons crude oil a ton, gave a fresh impetus to the industry. The bed of Torbane hill mineral lasted about twelve years, or to 1862, when it became exhausted, having been worked down to a thickness of about three inches. Attention was thereupon directed to the shales themselves, of which a number of oil-bearing bands or strata were found interstratified with grey, black, red or brown sediments, comprising marls, thin limestones, sandstones, etc. In all some 10 to 12 beds of oil-shales were found in a thickness of rather more than 3,000 feet. The process of retorting and distilling these shales commenced with the exhaustion of the Torbane hill mineral, and from a small industry at first, has, with many ups and downs, continued to the present day, until now the manufacture of crude oil and sulphate of ammonia with their subsequent refining into the various by-products, is one of the leading industries of Scotland. The production of crude oil in Scotland yearly is

[1]Ells, R. W., Trans. Min. Soc. Nova Scotia, vol. XIV, pp. 1-5 (1910).

now more than 62,000,000 gallons from shale alone, and of sulphate of ammonia over 50,000 tons, with more than 22,000 tons of paraffin wax, the amount of shale mined annually for many years being more than 2½ million tons. It will be readily seen therefore that this enterprise, starting in a comparatively insignificant manner, has through the enterprise, thrift, perseverance, and intelligent management of a few Scotch capitalists reached very large proportions.

The industry, as may well be imagined, has passed through many stages, some of failure and others of success. Competition from foreign countries has been sharp, not only from the United States but from the Russian and other fields, where crude oils obtained by boring were produced more easily and cheaply than would seem possible by the manipulation of oil-shales obtained by mining; yet with the continued improvements made in the process of retorting and the subsequent treatment of crude oils, and by the utilization of the various by-products, success has eventually crowned their work, and the shale-oil industry of Scotland has been for some years on a thoroughly satisfactory basis and giving good returns on capital invested. It may be said, however, that of the many companies engaged in the business of oil-shale development, aggregating more than 100 companies, the greater part of these have long since ceased operations, some by direct failure, others by absorption by other and stronger companies, until at the present time the number of companies engaged in the oil-shale industry is only seven, and of these only four possess fully equipped refineries, the others manufacturing crude oil and sulphate of ammonia only. In spite of this great decrease in numbers of persons operating, it may be said that the production of crude oil and sulphate of ammonia, as well as other by-products, shows a manifest increase with each succeeding year, owing to the great improvements constantly being made in methods of working, in perfection of plants, in better organization, etc. Thus while for some years the profits of the industry were very uncertain, and often the manufacturer was entirely without profitable returns, the dividends on the work for the last few years have been very satisfactory, those of the four refining companies for the last year (1908) being from 7, 15, 17½ and 50 per cent. As illustrating the extent of the industry also it may be said that the wages paid are about 3½ million dollars annually, the men employed being about 8,300, including nearly 4,000 miners.

He says further that:—

Near the close of the Scotch workings on the Torbane hill mineral the discovery of the very similar mineral named stellarite was made on the Acadia Coal Company's property at what is now Stellarton, the name of the town being taken from the name given to the mineral found there in 1859, This bed of coal and shale is found near the base of the coal measures below the McGregor seam, and is divided into three parts, as follows:—

Bituminous coal	1 ft. 4 in.
Stellar oil-coal	1 ft. 10 in.
Bituminous shale	1 ft. 10 in.
	5 ft.

The Stellar oil-coal resembles very closely the Torbane hill mineral of Scotland, which also occurs near the base of the Coal Measures in that country. The yield of crude oil is very similar in both cases, the Scotch mineral being from 90 to 130 gallons per ton, the stellarite from 125 to 130 for a part of the bed and from 60 to 65 for the other parts, while selected samples are reported as yielding nearly 200 gallons. Such a seam in the Scotch industry would certainly be regarded to-day as a bonanza, since the torbanite was worked till it reached a reported thickness of only a few inches before it was finally abandoned. The nearest approach to this mineral in New Brunswick was the vein of albertite found in Albert county, which by analysis gave 100 gallons crude oil per ton, but this mineral occurred in vein form and not in a bed like the oil shales of Scotland and New Brunswick or Nova Scotia.

The bed of stellarite was worked for a couple of years, in all about 4,000 tons being taken out, most of which went to the United States for distillation or for admixture with bituminous coals in gas making.

About the same time, several of the oil shale areas in New Brunswick were opened and at Baltimore in Albert county a retort and still were erected in which several thousands of tons of a rich oil shale found in the vicinity were used in the manufacture of crude oil which was afterwards refined and used very generally in this province and in Nova Scotia. The shale mined on the Memramcook river at Taylorville was shipped to Boston to the retorting works erected in that city. Its value as a producer of oil was readily recognized, but the discovery of the great oil wells of western Canada and of the United States, with their cheap production of crude petroleum, soon closed the shale industry both in Nova Scotia and New Brunswick. Owing to the crude nature of the retorts and stills in that early stage of the industry it is no wonder that entire satisfaction did not attend these early attempts. The same hardships were encountered in the early days of the industry in Scotland, and only by persistent improvements in plants, by the exercise of rigid economy along all lines, and by close attention to the business end of the undertaking have the promoters at last achieved success.

Ells in the same connexion says that the

> Scotch companies have successfully combatted the opposition arising from the native oils of the United States, of Russia, and other foreign countries, and to-day are not only able to point to an ever increasing annua output of oil of the highest possible grade, with the attendant by-products, but to an ever increasing dividend sheet as well, and for some years the amount of oil produced from a limited area of the oil shales a few miles west of the city of Edinburgh is several times larger than that obtained from all the oil wells of Canada.

In Nova Scotia, as stated by Ells,[1] the oil shales occupy a similar position geologically that they do in Scotland and are

[1]The Oil shales of the Maritime Provinces—Nova Scotia, Min. Soc. Jour. Vol. 14, pp. 1-12, 1910.

similar in general character. In Nova Scotia, these oil shales are unconformably overlain by limestones probably to the Perry sandstone formation of the upper division of the Devonian of Eastern Canada. These oil shales are interbedded in less bituminous shales which in some places are calcareous or sandy. The oil shale bands vary in thickness from a thin film up to several feet.

In 1909, Ells[1] made a rather detailed study of the oil shales of eastern Canada, and found that a number of the localities in Nova Scotia referred to by Campbell in Howe's Mineralogy contained too low a percentage of hydrocarbons to be of value for crude oil or ammonium sulphate.

Ells says further that there are great thicknesses of black and greenish shales between Split Rock along the south coast of Minas basin, at the mouth of the Avon and the villages of Walton and Noel. "On the west side of the Avon," Ells goes on to state, "similar dark shales are well exposed at Horton Bluff, Locharville, and the vicinity of Hantsport." But he says that these deposits about the Avon are in most cases deficient in hydrocarbons, the shales although often black are carbonaceous rather than bituminous. In the field tests made by Ells, most of these shales showed but slight tendencies to ignite.

Pictou County.

"The outcrops of Pictou oil shale," as stated by Ells[2], "are comparatively numerous in the Pictou coal basin. They are indicated on the recent map of the Pictou coal field by Dr. H. S. Poole, 1904, and can be seen at several points in Stellarton on the property of the Acadia Coal Co.; on McLennan's brook below the old fulling mill bridge formerly opened by Andrew Patrick; on Marsh brook opened by Haliburton's pit; on Shale brook; on Steep brook; and elsewhere, the large body of black bituminous shale forming a conspicuous feature at

[1]Ells, R. W., The commercial value of the oil shales of eastern Canada, based on their contents by analyses of crude oil and ammonium sulphate. Trans. Min. Soc. Nova Scotia, Vol. XV, pp. 20-57. 1910.

[2]Trans. of the Min. Soc. of Nova Scotia, Vol. XIV, 1909-1910, p. 10.

several places." Ells says further that the black shales at Pictou belong to a higher geological horizon than those of Antigonish, the Avon river, Cheveris and Walton.

H. E. Coll[1] says, "in the Vale coal mine in Pictou, oil has been dripping from the roof. This has been going on for some years." It appears that these oil shales may become saturated with oil to such an extent that the oil oozes out in the form of springs or drippings from a mine, but will not flow or seep fast enough to yield oil in commercial quantities by drilling.

Ells[2] says that:—

In a section given by Logan along Marsh brook, mention is made of a bed of oil shale, the thickness of which is not clearly defined but is said to be four feet. A small pit was sunk on this seam by a Mr. Haliburton. During our examination of this area last year this pit could not be definitely located, but several tests were made of shales along Marsh brook, though no deposits as rich as these found on McLellan's brook were seen. The analyses of three samples of the shales from this area will be found in the list given of analyses made from samples taken along McLellan's brook.

On a map issued by the Geological Survey, of the Pictou coal field, 1904, which is largely the work of Dr. H. S. Poole, the locations of several outcrops of oil shale are given. It was, however, found somewhat difficult to locate these outcrops on the ground so as to secure specimens for analysis. A number of locations were, however, selected at various points along McLellan's brook and in the vicinity, including Marsh and Shale brooks, and samples were taken from what were regarded as the most promising outcrops. These have been analysed by the Department of Mines at Ottawa, to determine the contents in crude oil and ammonium sulphate.

In all, eight samples were selected for analysis, the results of which are as follows:—

[1]Trans. of the Min. Soc. of Nova Scotia, Vol. XIV, 1909-1910, discussion following Ells' paper on oil shales, p. 12.

[2]Ells, R. W., The commercial value of oil shales in eastern Canada, based on their contents by analyses in crude oil and ammonium sulphate. Trans. Min. Soc. of Nova Scotia, Vol. XV, pp. 45-46. 1910-1911.

Analyses of Samples.

	Crude Oil (Imperial gallons).	Sulphate of Ammonia (pounds).
McLellan's brook, near New Glasgow, a branch of East River of Pictou; from Patrick's old slope, 27 chains below the old fulling mill	42	41 per ton
McLellan's brook, Black's old mill site	14·5	35 "
Marsh brook, the lower end at the fork with McLellan's brook	8	undetermined
Marsh brook, 150 feet above McKay's house	3	"
Marsh brook, 300 feet above McKay's house, from area blasted	14	"
Shale brook, upper end	4	"
Shale brook, near forks with McLellan's brook	9	"
From bed of black shale, one mile west of Woodburn station, in small brook 500 feet north of railroad track, from bed 10 feet thick	14·3	"

It will be seen from the above list of analyses that most of the samples selected are not sufficiently rich in hydrocarbons to repay any attempt at development, but that in the case of the stellarite found at Stellarton and at Patrick's slope on McLellan's brook, the results of the several analyses made would appear to warrant further investigation, sufficient at least to prove conclusively the extent and thickness of the oil shale deposits at these places.

Antigonish County.

Regarding the oil shales of Antigonish county Ells[1] says:—

Of the shale deposits of Antigonish county, it may be said that several of the tests recently made showed a sufficiently high percentage of crude oil and sulphate of ammonia to warrant the expenditure of capital in the development or further testing of certain portions.

This remark applies more particularly to outcrops seen in Hallowell grant along Sawmill brook, which is about ten miles north of the town of Antigonish. Other areas in the vicinity do not seem, from the tests recently made at Ottawa, to contain sufficient hydrocarbons to warrant much expenditure in development work. The shales, while black and highly carbonaceous, resemble many of those seen along

[1]Ells, R. W., The commercial value of the oil shales of eastern Canada, etc. Jour. Min. Soc. Nova Scotia, Vol. XV, pp. 46-50 (1910).

the lower part of the Avon river, and are too poor in hydrocarbons to render the extraction of the crude oil or sulphate of ammonia profitable under the most favourable circumstances.

Hallowell grant or Big Marsh, includes a number of outcrops of shale. They are alluded to in the report of Mr. J. Campbell already referred to, in Howe's Mineralogy of Nova Scotia, 1868. From the description there given, it was at one time hoped that large and valuable deposits of hydrocarbons would be found. Black carbonaceous shales outcrop along the post road extending north from the town of Antigonish to Big Marsh post office. They cross the road in several well defined bands, have a general east and west strike, and near the post office contain irregular beds of a dirty bituminous coal, associated with black and grey shales and greyish sandstone. These have been opened up to some extent in search of a fuel supply. The analyses of the coal were made by the Mines Branch, Ottawa, several years ago, but the results, as then published, were such as to discourage further development at the time. The percentage of ash in the coal ranged from 27 to 46 per cent being such as to render the coal practically valueless as a fuel. The volatile combustible ranged from 21·5 to 29 per cent. A careful examination of a number of outcrops of shale, supposed to be of the oil bearing series, was made during the past season.

Attempts were made in the field to test the value of several of these outcrops by ignition in stoves, forges, and even by the blowpipe, but in some cases even the last named test failed to produce a flame. As a last resort a number of samples carefully selected from the most promising looking beds, were sent to the laboratory of the Mines Department to ascertain the exact value of these in crude oil and ammonium sulphate.

In all, samples from eight localities were chosen, in order to give the shales as fair a test as possible over a considerable area. It was found that the black matter of the shales themselves was almost entirely carbonaceous and not due to the presence of hydrocarbons. In fact it has been observed in the adjacent province of New Brunswick, that the shales richest in hydrocarbons were grey rather than black, as can be seen in the case of the grey shales of Turtle creek, Albert county.

The first test of the Antigonish shales was made from a deposit of black shales, including both the plain and curly varieties, located on a farm of Mr. Dan McDonald, near the forks of the road going east a short distance north of the Big Marsh post office. Here a pit had been sunk many years ago, referred to in Campbell's paper, 1868, to a depth of 60 feet, of which the upper 40 feet seemed to be a plain black carbonaceous shale. This appeared to be almost incapable of ignition by ordinary test. The lower 20 feet was of the curly variety, and when tested in the forge kindled with difficulty. In the laboratory at Ottawa, the test by Mr. Leverin gave 4·8 imperial gallons of crude oil and 8·7 pounds of ammonium sulphate per ton, the yields in both cases being insufficient to render the mineral of value for economic use.

A short distance east of the forks of this road a small brook, known as McLellan's, crosses the road to the south. On this both varieties of shale, the curly and the plain, occur. Samples selected and analyzed at Ottawa gave for the curly variety six gallons of crude oil per ton, but the ammonium sulphate was undetermined. The samples of plain black shale gave neither oil nor ammonia. The next brook, going east, crosses this road a short distance beyond the house of John Boyd. From the presence of a sawmill at the road crossing near Boyd's house the stream was named Sawmill brook for convenience or reference. The banks are frequently steep in many places and are composed of black and grey shales, some of which is of the curly variety, other parts are plain, as stated by Mr. Campbell in 1868.

A number of these shale beds were tested in the field by the application of heat. Some portions kindled fairly readily and burned quite freely. Several outcrops of both varieties, both black and brown, are seen; and at one place, known locally as the "Banks," the shale forms cliffs of 100 feet or more in height. Much of this is quite bare of vegetation, the forest growth having been destroyed some years ago by fires, which in places burned to a considerable depth in the shale itself. The fire is reported as having burned in the shale for some months before it could be extinguished. The shale deposits at this place appear to possess considerable value. A number of samples were taken, and were analyzed in Ottawa with fairly satisfactory results, as follows:—

Analyses of Samples.

Description of Sample	Crude Oil, (Imperial gallons)	Sulphate of Ammonia (pounds)
From the surface at the Banks: curly variety....	11	22
From bed of Sawmill brook near by: curly shale ..	10	38
Plain shales....................................	10	34
From branch of Sawmill brook, adjacent: sample of freshly mined shale........................	10	17

It would appear from these tests, which include the shales over a considerable area, that much of the material so tested is not sufficiently rich in hydrocarbons to give profitable returns either in crude oil or in sulphate of ammonia, though the percentage of the latter is fairly high in several cases. Possibly the fact that parts of the area had to some extent been burned over may have reduced the percentage of crude oil. This place on Sawmill brook, in so far as our examinations in Hallowell grant extended, seems to be well worthy of further investigation.

Farther east near the shore of George bay, at a place known as the Beaver settlement, several holes have been sunk on bands of black shales regarded as oil bearing. One of these areas was examined and the rocks were found to be a very black carbonaceous shale, which contained the remains of plant stems and fish scales. Parts of these black shales kindled in the forge quite readily, and the deposit at this place seemed to be quite extensive, being exposed from east to west for several miles. The samples collected were from the farm of Hugh McInnis, near the shore of the bay, and on analysis at Ottawa, the black shale gave 7·45 gallons of crude oil per ton, but the percentage of ammonia sulphate was not determined.

On the commencement of the examination of the black and grey shales of the formation just described, which is known as the Horton series, and is widely distributed over Nova Scotia, it was hoped that the deposits of Cheverie, Hantsport, and other districts in that vicinity, including Newport, Truro, etc., might on careful examination show well defined areas sufficiently rich in hydrocarbons to be utilized in the distillation of crude oil and the manufacture of ammonium sulphate on a large scale. More especially was this hoped for from the fact that all geological determinations on these rocks had showed conclusively that these shales of the Horton series were the equivalents, as regards horizon, of the shales of New Brunswick, so rich in hydrocarbons. In this examination, I may say I was greatly aided by the late Mr. Hugh Fletcher, whose intimate knowledge of the geology of the province was of the greatest assistance in work of this kind. In so far, however, as our field work on these shales was concerned, the absence of hydrocarbons seemed to be so general that in many cases it was deemed unnecessary to submit samples of them to detailed examination by analysis in the laboratory at Ottawa.

Kings County.

Dark shales which outcrop along the south side of Minas basin, supposed to have been of value commercially for oil and ammonium sulphate, have been shown by Ells[1] to contain too low a percentage of oil to justify their use for commercial purposes.

Hants County.

Shales supposed to have been of commercial value for oil occur along the south side of Minas basin, but according to Ells they contain too low a per cent of hydrocarbons to be of value for oil or ammonium sulphate.

[1]Ells, R. W., Commercial value of oil shales, etc. Trans. Min. Soc. of Nova Scotia, Vol. XV, p. 33, 1910-1911.

CHAPTER II

PRINCE EDWARD ISLAND

GEOLOGY[1]

Stratigraphy

The Upper Carboniferous or Permo-Carboniferous rocks which occur in southeastern New Brunswick and along the south shore of Northumberland strait, pass beneath the strait and re-appear in Prince Edward Island. These are overlain conformably by a series of conglomerates and red sandstones, impure limestones and shales, which underlie the greater portion of the island.

Dr. J. W. Dawson thus describes the geology of the island[2]:—

The principal addition to our knowledge of this formation[3] is that contained in the Report of Dr. Harrington and myself published in 1871[4]. In this we separated as Upper Carboniferous, or 'Permo-carboniferous', an underlying series of red and grey sandstones and shales, holding carboniferous plants, extending from near Cape Wolfe toward the north point, and a similar series found at Governor's Island and Gallas Point in Hillsborough Bay. These are undoubtedly extensions of the Carboniferous of Nova Scotia. All the rest of the island is occupied with Triassic rocks; in one place, Hog Island in Richmond Bay, associated with trap. The general relations of these rocks are seen in the sections.

The beds of the Triassic series, as seen in Prince Edward Island, consist chiefly of soft red sandstone, with some buff-colored beds and red and mottled clays. Associated with them are conglomerates and hard calcareous and concretionary sandstones, passing into bands of arenaceous limestone, which is, in some places, a dolomite. The following section in Orwell Bay and its vicinity shows the beds resting on the Upper Carboniferous of Gallas Point, and may be taken as typical. It is in ascending order:

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[1]Introduction by Alfred W. G. Wilson.
[2]Dawson, J. W., Acadian Geology, 4th edition, Appendix 1, pp. 28-30.
[3]Triassic.
[4]Report on the Geological Structure and Mineral Resources of Prince Edward Island—Dawson and Harrington.

		Feet
1.	Bright red sandstones with white bands	30
2.	Red shales with white stains and red sandstones with cylindrical casts of fucoids	60
3.	Red and purplish sandstones with grey bands and layers of ferruginous conglomerate with obscure remains of plants	88
4.	Beach, probably representing soft beds	48
5.	Red flaggy sandstone, with conglomerate and concretions of red oxide of iron, containing remains of plants	50
6.	Bright red sandstones and red shale with greenish stains	30
7.	Marsh, probably soft beds	24
8.	Red shale and green bands capped with bright red sandstones	75
		405

(Here the section is broken by Orwell Bay, which probably represents some thickness of soft beds.)

9.	On the high cliffs near Belfast are very bright red sandstones and shaly beds, with grey blotches and cylindrical fucoids—about	120
10.	Over the last are seen, in the country east of Belfast, soft red sandstones with beds of conglomerate with rounded quartz pebbles and arenaceous cement (thickness uncertain)	
		525

As seen in this section, the whole thickness of these beds cannot much exceed 500 feet. Of this the lowest 270 feet, being Nos. 1 to 5 inclusive, of the above section may be referred to the lower division, or 'Bunter,' and the remainder to the upper division of the formation, or 'Keuper'. The dips are so low, and the beds so much affected by oblique stratification, that those of the Trias cannot be said to be unconformable to the underlying Carboniferous rocks; and for this reason, as well as on account of the similarity in mineral character between the two groups, some uncertainty may rest on the position of the line of separation. What is stated above depends on fossils, or a somewhat abrupt change of mineral character, and on a slight change in the direction of the dip. These beds spread over the greater part of the island, presenting a nearly horizontal attitude, or lying in very flat synclinals and anticlinals. They are well seen in the coast cliffs in many places.

Structure.

The rocks of Prince Edward Island either lie in low folds or are gently inclined. A low anticline has been mentioned by Dawson and others extending through Gallas point, and other slight anticlines are known to exist elsewhere on the island.

HISTORY OF DRILLING OPERATIONS.

In 1908 the Geological Survey of Canada put down a test well and, later, four others for the purpose of ascertaining, if possible, the depth of coal beds which were supposed to exist

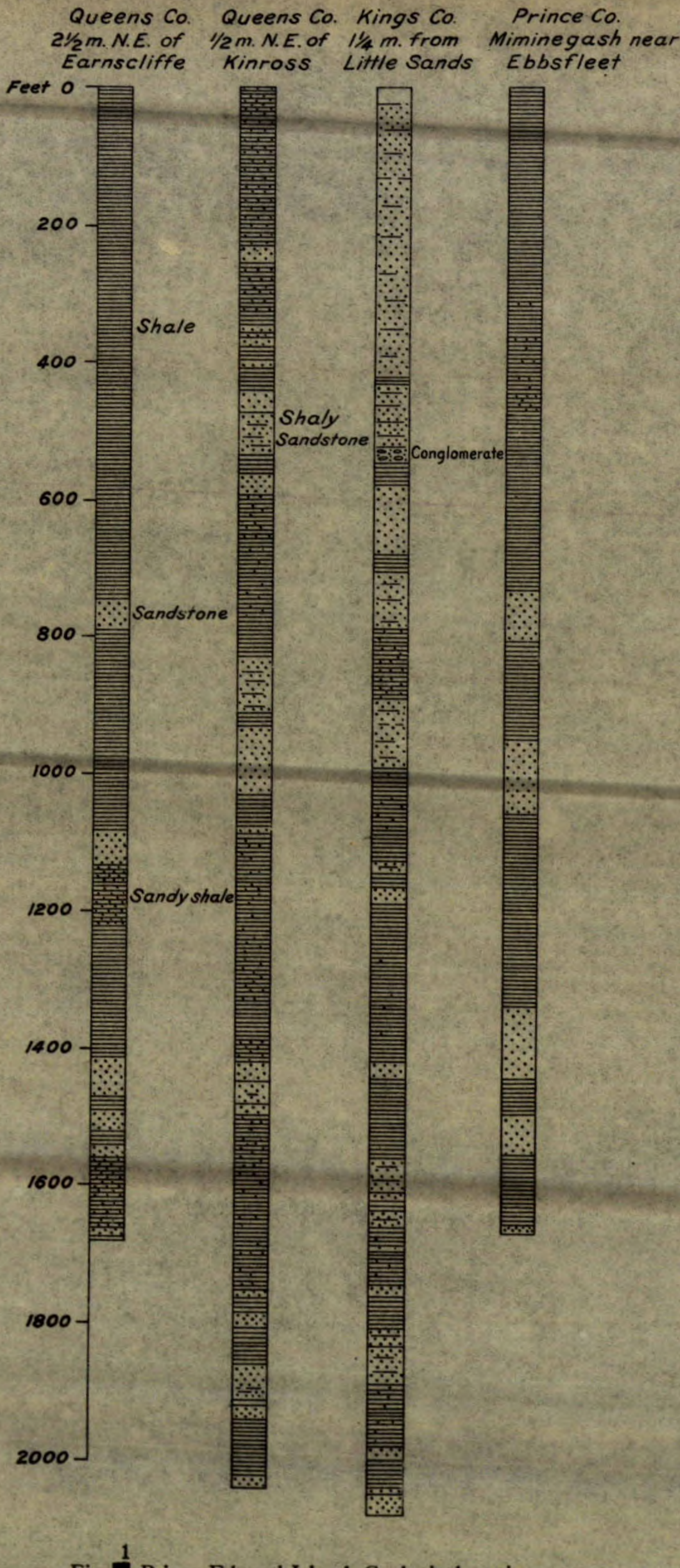


Fig. 1 Prince Edward Island, Geological sections.

in the Carboniferous rocks underlying the island. The Government also desired information regarding the possibility of oil and gas in the island.

The region selected for this drilling was the low anticline extending through Gallas point, this being an exposure of the oldest rocks on the island, so that it was hoped the coal-bearing beds might be reached in a shorter distance than in any other part of Prince Edward Island. No oil or gas was struck in any of these wells.

The following log gives the conditions found in the first boring:—

Log of well drilled on the James Twedie farm, on Gallas Point.

Material.	*Top Feet*	*Bottom Feet*
Red sandstones. Soft water	0	65
Red shales. Soft water	65	145
Red sandstones	145	205
Red shales	205	295
Blue shales	295	395
Light red sandstone	395	405
Blue sandstone. Small amount of fresh water	405	435
Red shales. Salt water	435	635
Red shales. Salt water	635	995
Red sandstone	995	1015
Red shale	1015	1125
Grey shale	1125	1155
Red sandstone	1155	1165
Red shale	1165	1170
Red sandstone	1170	1190
Grey shale	1190	1195
Grey sandstone	1195	1205
Red shale	1205	1355
Red shale	1355	1395
Red sandstone	1395	1415
Red shale	1415	1620
Red sandstone	1620	1660
Red shales	1660	1725
Fine red sandstone	1725	1750
Red shales	1750	1870
Red sandstone. Salt water	1870	1875
Red sandstone	1875	1880
Grey, porous sandstone. Salt water	1880	1910

The well records shown in the accompanying figure represent drillings at four locations in Prince Edward Island.

OIL AND GAS POSSIBILITIES IN PRINCE EDWARD ISLAND.

No oil or gas have ever been found on Prince Edward Island, and it is a question whether they will be found, although, judging from the geological structure, conditions should be more or less favourable for these substances at a considerable depth in localities which are geologically suitable.

The surface of the island is composed of rocks which are known as the Permo-Carboniferous, which is believed to be underlain by an extension of the Carboniferous Coal Measures of Cape Breton and Nova Scotia, but which is so deep that it has never been reached by boring, and a definite statement of the presence or absence of coal, as well as of oil and gas, cannot be made.

As has already been noted in a preceding paragraph, in order to learn whether the island had deep-lying mineral resources, particularly oil, gas or coal, five bore holes were sunk in recent years by the Dominion Government, under the direction of the Geological Survey, with the object of learning something about the underlying formations. A contract was let to an experienced driller for 10,000 feet of boring, to be done with a standard drilling rig. These holes were located at points where geological investigations had shown that anticlines crossed the island. Not only would the arches of these anticlines be more favourable for the accumulation of oil or gas, but the boring would naturally start in the lowest exposed geological formation, materially reducing the total thickness of beds which it would be necessary to penetrate to reach the underlying oil bearing strata, if such exist. Judging from the geological work of Sir Wm. Dawson and Dr. Ells, the Gallas Point anticline appeared to be the best location for the initial drilling. The location of the several wells was as follows:—

Well No. 1, on the James Twedie farm, a little south of the anticlinal axis.

Well No. 2, two miles north on the opposite side of the axis.

Well No. 3, near Kinross, on same anticline about seven miles inland.

Well No. 4, near Little Sands on the next recognized anticlinal axis.

Well No. 5, near Miminegash, on the west side of the island, close to the axis of the most westerly anticline.

Three of these wells were started 18 inches in size, the remaining two being 13 and 10 inches respectively. Complete well logs of these borings were kept by Mr. E. D. Ingall of the Geological Survey of Canada, and are reported by him with necessary descriptions[1].

It will be noted that no results were obtained from any of the borings, with the exception of finding large flows of water at various depths, which at great depths became brackish and salt.

The greatest depth reached was 2,082 feet, but none of the wells are known with certainty to have penetrated to the underlying Carboniferous. One of the deeper holes was abandoned owing to caving and the burying of the tools. Consequently, neither the Carboniferous Coal Measures nor the possibilities of the island for oil or gas have been tested. There appears to be no particular reason why further drilling should not be done to much greater depths in the future with the idea of finding oil or gas, although it cannot be stated that the oil measures which outcrop on the New Brunswick mainland would be found at a prohibitory depth. In order to show the general character of the formations on Prince Edward Island, a log is given on the deepest boring on the island.

Log of well No. 4, 1½ miles from "Little Sands," Kings county[2].

Material	*Top Feet*	*Bottom Feet*
Sandy clay	0	25
Firm, red, shaly sandstone	25	420
Bright red, firm shale	420	430
Firm, red, shaly sandstone	430	442
Firm, red sandstone	442	450
Shaly sandstone, red	450	520
Conglomerate of coarse-grained sandstone	520	540
Firm, bright red shale	540	580
Red, shaly sandstone	580	680
Firm, red shale	680	710
Coarse, red sandstone (conglomerate)	710	740
Shaly sandstone, red and firm	740	790
Red shale	790	800
Red, sandy shale	800	880
Coarse, shaly sandstone or conglomerate	880	890
Shaly, red sandstone	890	990
Firm, red shale	990	1020
Firm, red sandy shale	1020	1100
Firm, red shale	1100	1130
Shaly sandstone, red	1130	1150
Firm, red shale	1150	1170
Shaly sandstone	1170	1190
Firm, red shale	1190	1360
Firm, red sandy shale	1360	1420
Sandstone, somewhat shaly	1420	1450
Shale, red	1450	1560
Sandstone	1560	1595
Shaly sandstone	1595	1620
Shale	1620	1640

[1]R. W. Brock, Sum. Rept. Geol. Survey, Canada, for 1909, pp. 30-37.
[2]*Op. cit.* pp. 34-35.

Material	*Top* *Feet*	*Bottom* *Feet*
Shaly sandstone	1640	1660
Sandy shale	1660	1690
Sandy shale	1690	1720
Shale	1720	1730
Sandy shale	1730	1740
Sandstone	1740	1760
Sandy shale	1760	1770
Shale	1770	1790
Shaly sandstone	1790	1810
Sandstone	1810	1820
Shaly sandstone	1820	1830
Shale	1830	1840
Shaly sandstone	1840	1880
Shale, sandstone	1880	1885
Shale, red and firm	1885	1970
Red, sandy shale	1970	1980
Red, shaly sandstone	1980	2000
Red, sandy shale	2000	2010
Firm, red shale	2010	2040
Shaly, red sandstone	2040	2050
Firm, red sandstone	2050	2082

Water was encountered in this well as follows:—

	Depth *Feet*
Large flow of fresh, hard water	35
Salt water here first noticed to affect the freshness of the water in the hole	150
Water quite saline; and level in well is affected by rise and fall of the tide	200
Above water cased off	442
Salt water encountered, but not enough to flood the well	450
Great flow of salt water in conglomerate or coarse sandstone—too much to handle with bailer; rises and falls with tide	540
Above cased off	890
Fresh water struck in this layer	910
Flow of water increasing and becoming too great to bail out; drilling continued under water	950
Water becoming brackish	1010
Water decidedly saline	1140
Water up to tide level	1190
Above cased off	1414
Fresh water in small quantity	1430
Considerable flow of fresh water	1560
More water	1610
More water, too heavy to bail out	1650
Above cased off	1713
A little brackish water	1750
Quite a large flow of brackish water	1820
Large flow of brackish water, too great to be bailed out	1860
Above cased off	1895
Moderate flow salt water	1990
Heavy and increasing flow of salt water	2060

This hole was cased with 10 inch pipe to 890 feet; with $8\frac{1}{2}$ inch casing to 1414 feet; with $6\frac{5}{8}$-inch casing to 1713 feet; with $5\frac{1}{4}$ inch casing to 1895 feet.

At the lowest depth, 2082 feet, the pressure of the large flow of water was so great that drilling could not be continued.

CHAPTER III

NEW BRUNSWICK

GEOLOGY[1]

Stratigraphy

GENERAL STATEMENT

The oldest rocks in New Brunswick form a broad complicated belt along the southern coast of the Province. North of this is a broad basin of the younger, Carboniferous rocks, with a northeast-southwest axis, and widening greatly toward the Gulf of St. Lawrence. This central basin is flanked on the northwest by a northeast-southwest belt of older rocks reaching from Chaleur bay to the River St. Croix. Northwest of this belt and occupying the northwest third of this Province is a great region of steeply dipping altered slates and limestones chiefly of Silurian age. The following table, after Ells[2], gives the principal divisions of the geological column, as recognized by the more recent surveys—compared with surveys made in 1870. From the same report most of the following notes on the geologic formations have been taken.

GEOLOGICAL DIVISIONS IN NEW BRUNSWICK.

Comparison of Nomenclature of Report 1870-1 with that of 1907.

	1870-1	1907
Triassic........	New Red Sandstone.........	Trias of the south coast.
Carboniferous..	Middle and Upper Carboniferous......................	Millstone-grit, Upper or Permo-Carboniferous of the east coast, the productive coal measures of Nova Scotia being apparently absent.

[1]By F. G. Clapp.
[2]R. W. Ells, The Geology and Mineral Resources of New Brunswick, Geological Survey of Canada, 1907, p. 16.

Carboniferous	Lower Carboniferous	Marine limestone, gypsum, conglomerates at base, shales, sandstone, etc., below the Millstone-grit.
	Perry Sandstone group; Lower Carboniferous	Upper division of the Devonian, including the "Albert Shales." Perry conglomerate, shale and sandstone.
Devonian	Mispeck	Mispeck shales and conglomerate.
	Cordaite	Cordaite shale and sandstone.
	Dadoxylon	Dadoxylon sandstone and shale.
	Bloomsbury	Bloomsbury division at base.
	Pale argillite series	Devonian not yet divided.
Silurian	Dark argillite series	Upper Silurian, in part metamorphic.
	Mascarene series	Siluro-Devonian.
Cambrian	St. John group	Cambrian, Etcheminian, div. O at base, Cambrian divs. 1, 2 and 3.
Pre-Cambrian	Huronian, Kingston, Coldbrook, Coastal	Pre-Cambrian with associated igneous masses.
	Laurentian	Pre-Cambrian, in part igneous and in part altered Silurian and Devonian.
	Intrusive Rocks	Granite, gabbro, diorite and diabase, felsite, etc., of various ages.

DESCRIPTION OF GEOLOGICAL FORMATIONS.

Pre-Cambrian.—The areas of altered slates and quartzites, associated with crystalline limestones and various granites and other igneous rocks in the southwest part of the Province which were correlated with the Laurentian, have been recently determined to be metamorphic phases of younger formations so that no true Laurentian is recognized in the Province. The Huronian of the southern region has been divided into the Kingston, Coldbrook, and Coastal series, but these upon later work are found not sharply demarked and the succession can not be made out. They are made up of mica schists, felsites, argillites, thin limestones, slate conglomerates, and chloritic gneiss, as well as gabbro, diabase, diorite, and volcanic agglomerates. The Huronian occupies a broad belt in Charlotte, Kings, and St. John counties, adjacent to the Bay of Fundy. This belt is marked longitudinally by six anticlines which bring up the Pre-Cambrian rocks, the intervening synclines being occupied by Cambrian slates.

The Pre-Cambrian rocks of northern New Brunswick greatly resemble those already described. They occupy an extensive tract of country extending diagonally across the northern portion of the province, reaching nearly from the main southwest Miramichi river to the Tobique river and northeastward to Chaleur bay.

Cambrian.—The rocks of the St. John group are intimately associated structurally and geographically with the Pre-Cambrian rocks as already described. The lowest rocks of the group consist of purplish quartzose sandstones and conglomerates with shales. These are succeeded by red and greenish argillites, often micaceous, light to dark grey sandstones and shales, the latter often fossiliferous.

In the northern part of the Province, the Cambrian consists of grey, red, green, and black slates with quartzose sandstones, sometimes schistose. Certain bands of red and green slates are persistent for long distances and can be traced from Chaleur bay southwestward into York county nearly across the Province. These slates flank both sides of the Pre-Cambrian area in this section.

Ordovician.—The Ordovician rocks include formations between the Potsdam sandstone and the Hudson River or Lorraine shales. No subdivisions of the series have been made in New Brunswick owing to the impossibility of separating them from the rocks of the Cambrian, likewise metamorphic. They form a broad belt, flanking the older rocks in Charlotte, Kings, and Queens counties in southern New Brunswick, and in the northern part of the Province occupy a large part of York county and extend into the adjoining part of Maine. The rocks are slates and sandstone, in places metamorphosed into schists and gneisses by the larger areas of syenite and granite which intrude them, sending off dikes and veins in all directions.

Silurian.—Rocks of this system occur at several places in the southern part of the Province. Along the coast of Charlotte county they are found in lenticular basins infolded in other rocks, the relation being very often intricate and obscure as in the case of the Mascarene series. Certain fossiliferous beds, however, are probably of Niagara age. These beds extend in a continuous belt along the south side of the granite area from Oak bay as far east as New River. They also occur along the St. John river near the line between Kings and Queens counties. In the northern part of the Province, however, the Silurian rocks are by far the most extensive of the older systems. They occupy the entire county along the St. John river above Woodstock, together with much of the valley of the Tobique river as well as extending across the Restigouche and to the Lake Temiscouata region and eastward to Chaleur bay, continuing into the southern part of the Gaspé peninsula as has been noted. The rocks are slates and limestones much altered but here and there fossiliferous.

Devonian.—This system has a considerable development in the southern part of the Province, being noted for the plant remains yielded by some of its members. It is made up of five groups, viz: The Bloomsburg series is made up of reddish conglomerates, sandstone, and shales associated with large masses of igneous rocks. This series is followed by the Dadoxylon, grey sandstone and shales, abounding in plant remains as well as those of insects and crustaceans. The Cordaite division, next above, consists of greenish and purplish shale and sandstone with abundant remains of Cordaites. These rocks pass upward without apparent break into the Mispeck division of purplish tinted conglomerates. The uppermost division, the Perry series, consists of reddish brown sandstones and conglomerates, changing upward into grey sandstones and shales with plant remains. The Devonian of the northern part of the Province occurs in isolated areas lying unconformably upon the older rocks in Charlotte, St. John, Albert, and Westmorland counties. A larger area extends from Maine to the St. John river and has a width of 12 miles in Charlotte county. Another area is found in Carleton county.

In the northern part of the Province there are but limited areas of Devonian rocks, mostly in the vicinity of Chaleur bay, excepting areas in Charlotte and Victoria counties.

Carboniferous.—This system displays three divisions: Lower, Middle and Upper. The Lower Carboniferous division is made up of marine limestones and gypsum deposits with top and basal members of greenish or reddish conglomerates. The Albert oil shales form the basal member adjacent to the older rocks of southeastern New Brunswick. Thick beds of ash rocks, conglomerates, and breccias, together with various traps, are associated with the rocks of this division in many places. The Lower Carboniferous forms a broad bonding band, not much disturbed by folding, around the central Carboniferous basin of the Province, and lies between it and the older rocks along the southeast coastal border. In the northern part of the Province the Lower Carboniferous division is represented by the Bonaventure formation of conglomerates and red sandstones, which lies horizontally on this upturned Silurian and reaches its greatest development in the Gaspé peninsula.

The Middle Carboniferous rocks occupy the triangular central basin reaching from near the southwestern corner of the Province to Chaleur bay in the north and to the eastern point of the Province, enclosing an area of about 10,000 square miles. These rocks belong to the Barren or Millstone Grit series, the productive Coal Measures of Nova Scotia being wanting in this Province. A thin seam of coal, rarely thicker than 20 to 24 inches, extends over the greater part of the area. The thickness of the series over the central part of the basin is not great, as shown by borings and by the projecting masses of underlying metamorphic slates. In the vicinity of Dorchester, in Westmorland county, a thickness of 1000 feet has been measured.

The Upper Carboniferous series underlies the foregoing in the vicinity of Dorchester and extends over a considerable portion of the eastern part of Westmorland county. In places the Upper Carboniferous rests directly upon the Lower Carboniferous.

Triassic.—The Triassic rocks consist of bright red, rather soft, sandstone which inland is associated with pebbly conglomerates and with interstratified sandstone and shale. Areas of these rocks occur on the north side of the Bay of Fundy about 20 miles east of St. John, in Albert county on the shore of Salisbury bay, and between Red Head and Gardner creek. These rocks also occur on the island of Grand Manan.

Igneous Rocks.—The principal igneous rocks not intimately associated with the sedimentary series are the intrusive granites and syenites and the later trap rocks. The former are much the more important. Two belts of these intrusives enter the Province from the State of Maine. The southern belt extends from Passamaquoddy bay to St. John river, with isolated areas to the eastward. The northern belt is of greater extent, reaching from the St. Croix lakes to within 35 miles of Chaleur bay. Several areas of granite occur also on the shore of this bay. These granites are clearly intrusive. They have metamorphosed the Silurian rocks but are not found in the conglomerates older than Devonian, hence are supposed to date from about the beginning of Devonian time.

The trap rocks which are largely developed along the lower Restigouche river, and along the upper part of Chaleur bay, are also for the most part of Devonian age.

Superficial deposits.—These deposits consist of glacial till or boulder clay, unmodified drift constituting the lowest member of the series, upon which at places are found stratified gravel and sand representing old shoals and banks, and raised beaches.

Structural Geology.

The Pre-Cambrian rocks of southern New Brunswick are arranged in a series of six parallel northeast-southwest folds which bring these rocks to the surface while the Cambrian slates occupy the synclines between. The location of these folds is plainly shown on a geological map of the Province and need not be further outlined here.

Where the Devonian and Lower Carboniferous rocks abut against the Pre-Cambrian rocks in Albert and Kings counties, they dip steeply to the north, but this inclination flattens out northward and the Middle Carboniferous rocks of the central basin lie nearly flat, though thrown in a system of gentle folds. These occur also in the northern and eastern parts of the Carboniferous area. Among these gentle folds, there are four more important than the others, which should be located. The first extends in a northeasterly direction from the Miramichi river to Bathurst; a second fold extends from the head of Grand lake to the vicinity of Richibucto head on Northumberland strait; a third passes north of Moncton and reaches the strait a few miles north of Shediac; the fourth anticline, which is confined to the extreme southeastern portion of the Province, follows the Aulac ridge to Bay Verte and Cape Tormentine.

The older rocks which border the Pre-Cambrian area northwest of the central basin region are naturally folded and plicated sharply, and the same is true of the great expanse of Silurian rocks in the northwestern portion of the Province.

OIL AND GAS DEVELOPMENTS.

Historical.

Surface indications of oil in the form of seepages from the Albert shales have long been known in Albert and Westmorland counties, and by 1859 had aroused the interest, not only of local people, but of oil men in the United States as well. In the year mentioned, Dr. H. C. Tweedel, an oil chemist and refiner of Pittsburgh, Pa., secured the lease of certain properties near Dover and St. Joseph in Westmorland county, and drilled four wells, none of which exceeded 190 feet in depth at the former locality, and one at the latter. Considerable flows of gas are reported to have been encountered in each well and small amounts of oil secured, but owing to inability to shut off the fresh water entering them, the wells were quickly ruined and the enterprise abandoned, nothing further being done in the way of development for 15 years.

In 1876, H. A. Whitney succeeded in again interesting American capital in the field, and two companies—the St. Joseph Petroleum Company and the Emery Oil Company—were organized to undertake its development. The former company, under the direction of R. S. Merrill, sunk one well at St. Joseph and one at Dover in 1879; while the latter, under Lewis Emery of Bradford, Pa., sunk five wells (exact location not stated) in the same districts. Some of the wells reached a depth of 1,000 feet or over and several of them yielded oil in commercial quantities. Owing partly to the low price of petroleum resulting from the rapidity increasing production in the United States, and partly to the limited production of the wells, in addition to the many difficulties encountered in drilling and the ruin of the wells by the entrance of water, the developments did not prove profitable and the enterprises were abandoned. Prof. John F. Carll, state geologist of Pennsylvania, advised drilling at some distance from either of the then producing fields, but no steps were taken toward sinking the well recommended.

The next move looking to the development of the oil and gas in this district was in 1899, when Matthew Lodge of Moncton interested the Provincial Government in oil and gas development, the result being the passage by the legislative session of that year of "An Act to encourage the Discovery and Development of Oil and Natural Gas within the Province of New Brunswick." In accordance with this act, oil and gas were declared to be minerals under the general meaning of the Mining Act.

Thereupon, the New Brunswick Petroleum Company, Limited, organized with Frederick W. Sumner as president and Matthew Lodge as secretary, applied for and obtained in

1899 a license from the Crown to prospect and develop oil and gas over an area of 18,000 square miles within the Province for five years, with the right of an extension of five years if certain conditions—one of which was that the Company should expend $100,000—were complied with. At the end of the latter period, the Company, if the conditions imposed by the government were fulfilled, had from the goverment the drilling rights on 10,000 square miles for a term of 99 years, with privilege of renewal for a like additional period.

Following investigations by Prof. N. S. Shaler, H. B. Goodrich, F. H. Oliphant and others, the New Brunswick Petroleum Company, Limited, commenced drilling in 1900 to 1901 and continued until 1906, expending in its operations, it is claimed, over $200,000. The period of greatest activity was from 1903 to 1905. In all, 72 wells were drilled in the Dover and St. Joseph districts in Westmorland county, one at Beersville in Kent county, and four on the west shore of the Petitcodiac between that river and the present gas field in Albert county. The wells in Kent and Albert counties were without result, but of those drilled in the St. Joseph and Dover fields, about half produced oil in commercial quantities. The majority yielded from ½ to 2½ barrels per day, although one well is stated to have produced at a rate of 50 barrels a day at the start. In all, several thousand barrels are reported to have been pumped and marketed.

In 1906 negotiations were begun with English and Scottish capitalists to take over the drilling of the New Brunswick company, and after geological investigations by Sir Boverton Redwood, Dr. J. A. L. Henderson, O. P. Boggs and others, a syndicate known as the Maritime Oilfields, Limited, was organized, and on November 4, 1908, acquired the drilling rights of the New Brunswick Petroleum Company, Limited, for a period of six years, with the option—in consideration of certain payments —of taking over at or before the expiration of that period, the full rights of the aforesaid Company included in the 99 year lease granted it by the Crown under date of August 16, 1907.

The authorized capital is £100,000, in 99,000 ordinary shares of £1 each, and 20,000 deferred shares of 1s. each; all the shares are issued and fully paid. The capital was increased from £41,000 to the present amount in July, 1901, and is shortly to be again increased by creation of a further 50,000 ordinary shares in order to acquire the head lease of the property. A royalty of five per cent is payable on the value of the output of oil and natural gas. The Moncton Tramways, Electricity and Gas Company, in which the Maritime Oilfields, Ltd., holds about a sixth interest, has agreed to purchase for 39 years all the gas required by them for supplying the various markets in southern New Brunswick.

Drilling was begun almost immediately under the direction of Dr. J. A. L. Henderson, petroleum engineer and technologist, the fieldwork being in charge of General Manager O. P. Boggs, an oil man of wide experience. Three unsuccessful holes were drilled in Westmorland county, including one near Leger's Corner, three miles east of Moncton, one four miles west of Memramcook, and one near Dover. The next well to be brought in (No. 3 of the present field) obtained some oil and 150,000 cubic feet of gas per day, and was followed by well No. 5, with 1,000,000 cubic feet. After this, producing wells came in rapid succession. Up to September, 1913, 33 wells had been drilled in the Stony Creek field and several more were drilling. Of the completed wells, eight were dry holes. Of the 25 producing wells, 11 produced both oil and gas, 12 gas alone, and 2 oil alone. The original yield of gas ranged from 17,000 to 7,000,000 cubic feet per day, but the production of oil was generally only a barrel or two per day. All of the wells are still producing oil or gas, although in diminishing quantities.[1]

In September, 1913, drilling was in progress at Sussex, about halfway between Moncton and St. John, and 40 miles south of west of the Stony Creek field. A depth of 1,000 feet had been reached and small pockets of oil had been struck at 140 feet and 450 feet. Sussex is situated on an anticline in Lower Carboniferous rocks and structurally has about the same relation to the southern Pre-Cambrian area as the Stony Creek field has to Caledonia mountain.[2]

[1]Up to January 1, 1914, this company had put down 42 wells, on three of which drilling was still in progress. There were 31 wells producing oil or gas or both.

[2]This well was abandoned on striking hard limestone.

Areal Distribution and Geology of the Albert Shale Series.

Since it is the sandstone members of this series of oil shales which yield the oil and gas found in New Brunswick, the distribution and geology of that formation will be described before taking up the individual fields.

Caledonia mountain forms the northeastern termination of the Pre-Cambrian area, stretching northeastward from St. John. The Albert shales dipping sharply northward, outcrop along the north flank of the Caledonia mountain and, except where covered by the transgression of the Lower Carboniferous rocks, extended westward in a belt averaging half a mile wide for more than 25 miles to the vicinity of the village of Elgin, and have been recognized in isolated outcrops for a distance of 50 miles to Apohaqui station. The anticlinal nose of the eastern point of Caledonia mountain brings the Albert shales to the surface in the vicinity of Albert Mines, and again on the east side of the Petitcodiac river opposite Edgett landing, and also on the Memramcook river in the vicinity of upper Dorchester. All of these areas show anticlinal structure.

Another anticline brings the Albert shales to the surface in a belt from 1 to 2 miles wide reaching from College Bridge station near the Memramcook river to Dover, on the Petitcodiac river. On the south flank of this anticline are located the St. Joseph, Dover, and Stony Creek oil and gas fields. The south slope of this anticline east of the Petitcodiac river is marked by highly inclined strata, the dips ranging from 30° to 60°. On the north slope the dips are lower, ranging from 10° to 20°. West of the Petitcodiac river the dips are lower and the rocks less disturbed, the dips ranging from 5° up to 15°.

A second belt parallel with the above, is also indicated by exposures along the north side of Indian ridge, 8 miles north of Moncton and 16 miles north of Dover and Memramcook, but the shales so far observed at this point are less bituminous than those of the districts last named, and it is not known to what extent they underlie the extensive Carboniferous area to the north. Borings near Coal Branch in Kent county, about midway between Biersville and Mt. Carlisle, are reported to have struck oil and gas at a very moderate depth. Should this report be confirmed, it would, by indicating the existence of oil-bearing strata beneath the rocks of the great central coal basin, increase enormously the area from which possible future supplies of petroleum in New Brunswick may be drawn[1].

The age of the Albert shales has been a matter of dispute as may be noted from the table of formations already given. In 1870-1871 they were thought to be Lower Carboniferous while in 1907 they were held to be Upper Devonian. In Ells' report on the "Oil Shales of New Brunswick and Nova Scotia" published in 1910 they are given as Devonian. On the map (Map 35A) issued by the Geological Survey in 1911, they were regarded as Devonian. However, in 1913, Young[2] on evidence cited, correlates the Albert shale series with the Horton series as of Lower Carboniferous age.

The Albert shale series consists of a group of thinly bedded, usually dark coloured slates, calcareous slates, limestones, and sandstones. Interbedded with these, whether or not at more than one general horizon has not yet been determined, are slates relatively rich in hydrocarbons and of a distinctive appearance. These so-called oil shales, when retorted, yield varying amounts of crude oil and nitrogen—about 27 to 56 imperial gallons of crude oil and about 30 to 110 pounds of ammonium sulphate per ton. In these oil shales and associated beds, in places, are numerous remains of fishes. ....From the Albert series have been recovered several species of plants.

The stratigraphic character of Albert shales is best shown by the following logs of deep drill holes in the vicinity of the Old Baltimore Oil Works at Rosedale 10 miles south of west of Hillsborough, given by Ells[3]. Some 40 years ago works were in successful operation here extracting oil from the shale, but the opening of the great oil fields of Ontario and the United States reduced the price of oil until these works were compelled to close.

Boring No. 1, diamond core-drill.

Elevation above sea-level, 710 feet, April, 1900.
H. B. Goodrich, geologist in charge.
This hole was located on the flat of the east branch of Turtle creek, 1800 feet northeast of the corner at Rosedale post office. The boring evidently commences in the overlying Lower Carboniferous sediments, and the log is as follows:

[1]Bailey, L. W., Geol. Survey of Canada, 16th Ann. Rep. New Ser., 1904, pp. 288-289A.
[2]Young, G. A., 12th Inter. Geol. Cong. Guide Book No. 1, Part II, issued by the Geological Survey of Canada, 1913, pp. 355-356.
[3]Ells, R. W., Oil shales of New Brunswick and Nova Scotia, Part II, Geological Survey of Canada, 1910, pp. 14-16.

	Feet Thickness	Depth
Gravel, surface drift	—	7
Green and red, coarse and fine conglomerate	60	67
Red marly shales, occasional pebbles	14	81
Conglomerate	4	85
Red clay shale	6	91
Unconformity, dips of above, N. 10-15 deg. representing the Lower Carboniferous formation.		
Albert shale series		
Fine sandstone, shale layers	7	98
Shale, calcite veins, holds oil and will burn	9	107
Shale with fine sandstone	4	111
Banded shale, calcite, pyritous, small quantity of oil	13	124
Oil shale, contains much oil and burns readily	3	127
Oil shale, burns, but not so readily	7	134
Bituminous sandstone and shale	10	144
Oil shale, but not a true oil shale	1	145
Bituminous shale, oil-bearing, burns more or less freely	27	172
Slightly bituminous claystone with shale bands	32	204
Shales and fine sandstone	10	214
Very fine sandstone (claystone) with shale layers	36	250
White sandstone	1	251
Black bituminous shale, with sandy layers, burns	19	270
Very fine-grained, probably calcareous sandstone	22	292
Black bituminous shale, burns freely	77	369
Black bituminous shale with sandstone beds	24	393
Fine dark sandstone with 3 feet shale	14	407
Light brown oil-stained sandstone	3	410
Fine sandstone, with shaly streaks, brecciated	20	430
Black bituminous shale, bands of fine sandstone	49	479
Very fine brown sandstone, in part rich in oil	27	506
Black shale rich in hydrocarbons	11	516
Sandstone and shale, slightly bituminous	47	563
Fine grained sandstone	12	575
Fine black shale	27	602
Fine white sandstone	17	619
Clay shale, slightly bituminous	10	629
Fine white sandstone	2	631
Grey clay shale	8	639
Fine white sandstone	9	648
Black shale	46	694
Fine white sandstone	8	702
Black shale	7	709
White sandstone	5	714
Shale and sandstone	11	725
Fine sandstone to bottom	21	746

It will be seen that the lower part of this boring traversed a considerable thickness of white sandstone. This rock does not appear at the surface in any observed portion of the shale field of Albert county. The contact with the underlying crystalline rocks was, evidently, not reached.

Boring No. 2 at Baltimore, diamond core-drill.

Elevation above sea-level 891 feet. Begun September 1, 1900.
H .B. Goodrich, geologist in charge.
Location near summit of ridge west of Rosedale post-office near E. Steven's house.

	Feet Thickness	Depth
Gravel and clay	—	20
Grey clay-shale, faulted, dips N. 15-20 deg	73	93
Quartzose mica sandstone, with thin shales	13	106
Micaceous fine grained sandstone with shales	26	132
Black clay shale	6	138
Oily sandstone	7	145
Whitish brown whetstone rock	5	150

	Feet Thickness	Depth
Sandstone and shale	8	158
Oil-bearing sandstone with oil streaks	22	180
Grey shale and white sandstone	5	185
Black and green shale, no oil, dip N. 15 deg	38	223
Quartzose sandstone	7	230
Shale and sandstone	12	242
Grey and green shale	36	278
Fine micaceous sandstone	11	289
Shale and white sandstone	4	293
Grey and green shale, faulted, dip 20 deg	37	330
Sandstone and conglomerate	9	339
Shale	4	343
Whitish sandstone with some shale	8	351
White micaceous sandstone with oil at bottom	22	373
Green shale and sandstone, no oil seen	80	453
Mostly grey sandstone with shale partings	27	480
Grey shale broken and faulted	39	519
Claystone and micaceous sandstone	28	547
Dark grey shale	26	573
Claystone with shale bands	7	580
Grey clay shale	27	607
Sandy reddish shale	7	614
Hard fine grey sandstone	8	622
Grey shale	7	629
Grey sandstone	10	639
Dark grey shale	17	656
Hard dark grey sandstone and shale	62	718
Sandstone and fine conglomerate	12	730
Grey shale	12	742
Grey shale or slate to bottom of hole	35	777

From the above log it will be seen that the chocolate coloured shale so characteristic of the Albert shale formation elsewhere was not recognized and that there are considerable thicknesses of sandstone, both grey and white. At the Albert mines, the sections from the shafts and along the brooks show the brown beds more abundantly, with but small areas of the sandstones.

Bore-hole No. 3, at Baltimore, with churn drill.

Elevation above sea-level, about 800 feet. Begun December 4, 1900.
Location is approximately 10 degrees southwest of a vertical line from face of big tunnel on the Baizley lot, and is at least 95 feet above level of that tunnel at collar.

	Feet Thickness	Depth
Soil		1
Shale slightly bituminous, close grained and brown	29	30
Hard claystone, or sandstone non-bituminous, brown bituminous shale, small showing of oil	13	43
Shale slightly calcareous and bituminous; grey shale or claystone, calcareous and bituminous; shale with streaks of fine bituminous sandstone; hard grey calcareous shale, slightly bituminous; grey shale slightly bituminous; calcareous bituminous shale with streaks of claystone, and sometimes with calcite veins, broken, with sandy layers	70	113
Brown shale, probably oil shale, bed of about 2 feet hard rock, probably rough claystone, calcareous shales, a bed of oil shale 2 feet thick	53	123
Grey shale, slightly bituminous, very bituminous shale, but probably not an oil shale, in places with calcareous bands; calcareous shale and claystone; grey calcareous slightly bituminous shale	47	170

	Feet Thickess	Depth
Fine calcareous sandstone, with harder calcareous and bituminous shale and sandstone, passing into hard grey bituminous shale......................................	43	213
Hard, very bituminous shales, possibly oil shale; calcareous shale and sandstone, faulted, bituminous claystone, calcareous shale and claystone slightly bituminous to bottom of hole..................................	35	248

Hole for entire distance in bituminous shales and claystone; a slight find of gas was given off, but no flow of oil at surface.

Principal concentration of hydrocarbons appears to be at 112 feet to 123 feet; secondarily important at 212 feet to 214 feet.

The Oil and Gas Fields.

ST. JOSEPH OIL FIELD.

St. Joseph College is situated about 2 miles south of Memramcook and the oil field is known by both names although all but one of the wells have been within a half mile of the College. The first wells were bored by Dr. Tweedel in 1859 and, though not over 190 feet in depth, struck a small quantity of oil. Several other wells were drilled in this field in 1879-1880 by the St. Joseph's Petroleum Company. In 1900-1901, six wells were sunk in this territory by the company formed by Matthew Lodge. A description of these wells by Harold B. Goodrich is quoted from the 14th Annual Report of the Geological Survey of Canada, pp. 204-5 A, as follows:—

In May, 1900, the rig was removed to St. Joseph's College and Well No. 2 was put down to a depth of 1,040 feet. There was much gas, and at 365-370 feet an oil sand and flow of oil was struck. Several accidents made it impossible to take advantage of this oil, and the well was sunk further. At 670 feet, salt water was found. The drilling was entirely in the Albert shale series, which for the last 200 feet was mainly close-grained sandstone with shale bands.

No. 3 was begun one mile north of the College on February 27, 1901. The drilling was through hard and soft layers of Albert shale. A poor record was kept, and it is possible that a slight flow of oil or gas may have escaped the drillers' attention. No petroleum is shown by the record, although the shales were highly bituminous. At 555 feet the well was abandoned owing to quicksands. The last ten feet was in red sandy marl or conglomerate.

Well No. 4 was commenced in May, 1901, at a point 400 feet north of No. 2 at the College. The total depth was 408 feet. At 176 to 204 feet there were twenty-three feet of oil-bearing sandstone. This was not recognized at the time, so boring was continued. Later the hole was filled up to this depth; it was torpedoed and a pumping apparatus was placed. While it has not been pumped continuously to date, there has been a considerable product which shows no sign of decreasing. The oil is of excellent quality.

Well No. 5 was located, on August 5, 1901, 200 feet S.W. of No. 4. The geologic section is practically the same as the latter; bituminous calcareous shales, with small hard limestone beds. At 174-178 feet there was a sandstone with considerable gas. At 247-275 feet is an oil bearing sand (the same thickness as that of No. 4). No attempt was made to pump this well, but instead it was plugged and now awaits further development in the field.

The last week in August, No. 6 was located 100 yards N. by W. of No. 4. Up to date we have reached 226 feet and are still sinking. In that distance we have passed through three separate flows of gas. Almost the entire section is bituminous black shale. The present indications for a producer are excellent.

In Well No. 7, which was located on September 11, about 200 yards north of No. 4, we are now down to about 340 feet. The section was similar to that of No. 6. At about 190 feet we struck gas, which was later cased off. At 326 feet there was a flow of petroleum, probably from fissures in the shale. We decided to bore still further, hoping for an increase in the quantity of oil. However, as the well is in excellent condition we can at any time use the present supply.

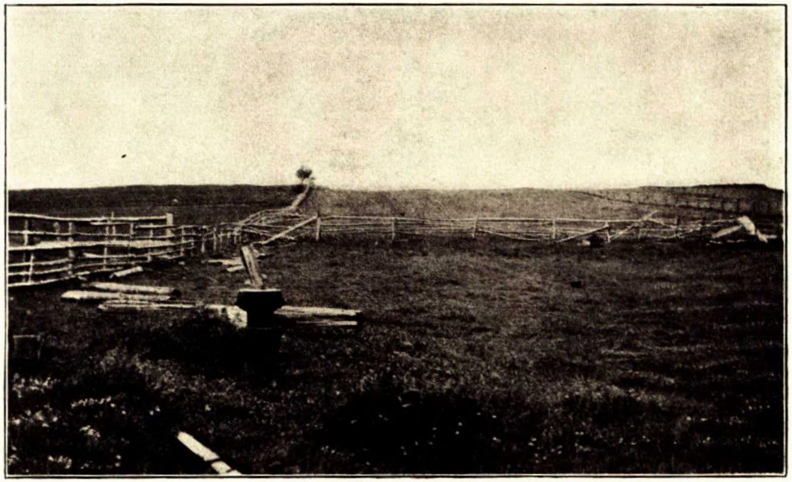
The above wells were visited in July at which time, with a 2½ inch pump, worked by steam, the yield was four barrels for a period of six hours, or at a rate of from eight to ten barrels per day. The oil was a heavy, dark green lubricating oil, well adapted as a machinery oil, and estimated as having a value of about $7.50 per barrel. Its specific gravity at 60° Fahr. is 0·860, while that of the American crude oil varies from 0·79 to 0·88. It is thought by those in charge that it will probably yield at least 30 per cent of burning oil, 15 per cent of lubricating oil, and 10 per cent of solid paraffin.

The complete logs of wells Nos. 4, 5, and 7 as furnished by Goodrich are given by Ells[1] as follows:—

	Feet	
	Thickness	*Depth*
Bore-hole No. 4:		
Surface soil		6
Grey shale with black bituminous bands	50	56
Shale with hard bands	21	77
Black shale	43	120
Close grained sandstone or claystone	33	168
Dark bituminous shale	16	169
Hard rock, probably fine-grained sandstone	7	176
Oil-bearing sandstone	28	204
Grey shale	41	245
Darker shale to bottom of hole	65	310
Bore-hole No. 5:		
Red clay and gravel		13
Hard grey shale	42	55
Hard grey shale and sandstone	5	60
Very hard shale with fine layers sandstone	40	100
Grey and black shale with hard limestone	26	126
Grey bituminous shale	4	130
Grey bituminous shales with sandy beds	10	140
Greyish and black bituminous shale	20	160
Greyish black bituminous shale with limestone	14	174

[1]Ells, R. W., The Bituminous or Oil shales of New Brunswick and Nova Scotia, Geol. Survey Canada, 1909, part 2, p. 17.

PLATE I.



Old Memramcook oilfield, Memramcook, New Brunswick.

	Thickness (Feet)	Depth (Feet)
Sandstone with small show of gas and oil	4	178
Hard grey and black shale	42	220
Dark soft highly bituminous shale	20	240
Dark shale with sandstone	7	247
Oil sands	28	275
Shales to bottom of hole at	12	287
Bore-hole No. 7:		
Surface soil		20
Grey shale	92	112
Hard limestone	5	117
Grey and black bituminous shale	10	127
Hard rock, probably limestone	10	137
Grey and black, slightly bituminous shale	70	207
Hard rock sandstone or limestone with shale	16	223
Black shale	5	228
Hard sandstone or fine claystone	8	236
Black shale	3	239
Hard brown sandstone, flow of gas	17	246
Black close-grained shale, bituminous	27	273
Reddish shale	4	277
Black bituminous shale	46	323
Grey non-bituminous shale	47	370
Oil-bearing sandstone	37	407
Sandy shale to bottom of hole	4	411

During the winter of 1903-1904 there were 10 or 12 wells in the St. Joseph field which were regularly pumped, and the yield of oil was about 2500 barrels. Operations have been entirely suspended in this field, at present, and the only evidence of the former existence of an oil district are the old conductors and the ruins of an old refinery at Memramcook.

DOVER OIL FIELD.

Dover is situated just where the belt of Albert shales strikes the Petitcodiac river. Just above Dover a well was sunk in the early days of drilling but without much success. Another shallow well was drilled a mile below Dover but abandoned. The site of the old Dover field is between 2 and 3 miles south of east of the village. Here on the south flank of the anticline some 30 wells have been drilled. The whole field is now entirely abandoned, and nothing remains but the stumps of the old conductors. Some of the wells are full of oil but none are flowing. The wells average 300 to 400 feet apart.

There are three groups of oil sands, of which the upper one comes to the surface along the crest of the anticline in the west bank of Petitcodiac river. The oil sands groups range up to over 100 feet in thickness. Some of the wells yielded as much as 24 barrels daily, and one is reported as high as 50 barrels, but the majority of the wells ran from $\frac{1}{4}$ to $2\frac{1}{2}$ barrels per day. The oil came to the surface alternately with a very strong brine, from which it was separated in the tanks.

The crude oil is of a dark green colour, its composition being[1]:—

68 to 70 gravity naphtha	5·5	per cent
Refined oil distillate	27·0	" "
Wax distillate	37·0	" "
Cylinder stock	29·4	" "
Loss	·008	" "

Since the discovery of gas in the Stony Creek field, the operating company, the Maritime Oilfields, Limited, has discontinued operations in the Dover field as having less chance to yield propitious returns, owing to the greater disturbance of the oil-bearing strata in the latter field offering greater opportunity for leakage and escape of the hydrocarbons.

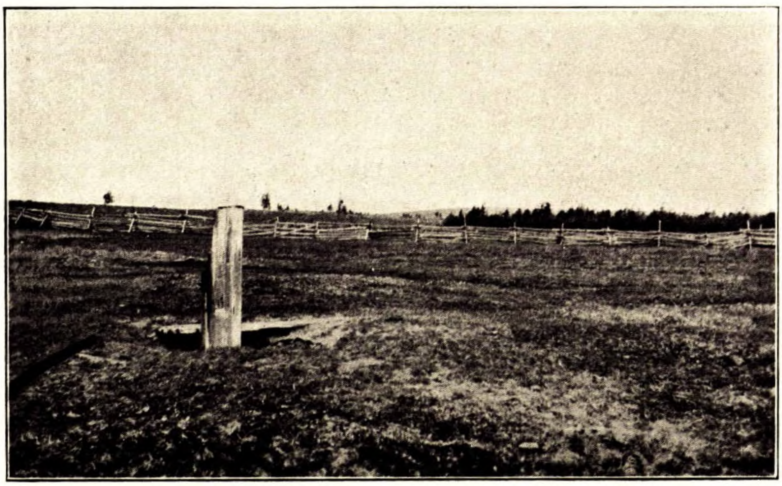
The location of the wells in the Dover field, as well as in the Stony Creek and St. Joseph fields, is shown on the accompanying map, which also shows the distribution of the Albert shales and the relation of the oil and gas fields to the geological structure of the region.

STONY CREEK GAS AND OIL FIELD.

Location and extent of producing territory.—The Stony Creek gas field is located on the west side of the Moncton-Hillsboro highway, about 9 miles south and a little east of Moncton and about 4 miles north of Hillsboro. The most easterly of the producing wells is 3,000 feet from the west shore of the Petitcodiac river, while the most westerly well is approximately 17,000 feet from the water, making the length of the field about 14,000 feet or 2¾ miles. The northernmost producing gas well in the eastern section of the field (No. 17) is about 4,000 feet and the southernmost (No. 12) about 7,050 feet south of Stony creek, giving this section of the field a width of about 3,500 feet. The general trend of the group of producing wells is approximately N. 70 degrees W. or S. 70 degrees E. The field, as at present developed, is slightly narrower at the western end than at the east.

[1]Bailey, L. W., Geol. Survey, Canada, 16th Ann. Rept., New Series, 1904, p. 288A.

PLATE II.



Views in Old Dover oilfield, Dover, New Brunswick.

Looking across Petitcodiac river toward Stony Creek oilfield from Dover oilfield, New Brunswick.

Geology of Eastern Albert County.—The geological formations of eastern Albert county, compiled originally from the reports of the Geological Survey of Canada (Ann. Rept., 1885, Pt. E, p. 33, etc.) are, in descending order, as follows:—

Geological Column, Eastern Albert county.

Age.	Series.	Thickness (feet).	Character.
Middle Carboniferous.	Millstone grit (Pottsville).	500	Grey quartz conglomerate and freestone with coal streaks.
Lower Carboniferous (Mauch Chunk and Pocono).	Upper conglomerate series.	1,950	Red and grey conglomerate, grey limestone and gypsum.
	Red shale series........	450	Red and grey calcareous shale with thin sand and conglomerate.
	Lower sandstone and conglomerate series.	700	Grey, micaceous, and petroliferous sandstone with some reddish conglomerate.
Lower Carboniferous or Devonian.	Albert series...........	850	Grey and brown calcareous or bituminous shales and sands.
Lower Carboniferous or Devonian.	Basal conglomerate......	200	Greenish conglomerate with slate fragments, etc., often absent.

The thicknesses shown in the foregoing table were calculated mainly from surface exposures, which are scattered and often inconclusive and the actual maxima are likely to be largely in excess of the figure given. Thus in the Company's well at Baltimore Siding (No. 27) the upper conglomerate series is more than 2,650 feet deep; in well No. 22 the red shale series is about 600 feet thick; while in well No. 9 about 1,800 feet of the Albert series was penetrated. On the other hand, the thickness of any of the beds may be locally greatly reduced by unconformities.

Relations of formations.—The successive formations are not found in an uninterrupted and parallel series, but are separated by breaks or unconformities at three horizons, (1) at the base of the Millstone grit; (2) at the top of the Albert series; and (3) at the base of the Albert or basal conglomerate series. These unconformities frequently cut out certain portions of the section which might be expected to be present.

The unconformity between the Millstone grit and the Lower Carboniferous conglomerate is the highest, but least conspicuous of the three, and is indicated by the fact that the Millstone grit is found resting upon formations of varying ages at different points rather than by any appreciable difference of dip between it and the underlying formations. In the Stony Creek field the unconformity is indicated by the greatly reduced thickness of the Lower Carboniferous conglomerate, the thickness of which ranges from 150 to 700 feet as compared to over 2,650 feet at Baltimore Siding (Well No. 27).

The second unconformity is very pronounced and is marked by both erosion and structural differences. Following this deposition the beds of the Albert series were uplifted and folded, often quite strongly, and were then deeply eroded before the deposition of the succeeding formations. In the Stony Creek field the old erosion surface is marked by the contact between the shales and the conglomerates east of Well No. 15 and by the contact of the grey Albert shale with the red shales or marls west of this well. Its altitude at Well No. 9 on the east is about 200 feet above tide, while in Well No. 33 it is nearly 700 feet below sea-level. The old land mass seems to have stood above sea-level, while the lower sandstones and conglomerates of the general section were being deposited elsewhere; and for this reason, the latter are apparently not represented in the Stony Creek field. The great thickness of greyish shales below the red shales or conglomerates suggests, it is true, that the lower sandstone and Albert shales may be combined, but as there is only one unconformity at this horizon—namely at the top of the Albert series—and as this is represented by the break between the Albert series and the red shales, the assumption that the lower sandstones are many seems to be the only tenable hypotheses.

The third unconformity, or that at the base of the Albert series or the basal conglomerate, represents the long period of erosion and disturbance preceding the deposition of these formations. It is not exposed at the surface in the vicinity of the Stony Creek field, nor has it been reached by wells at this point.

Character and correlations of producing sands.—The producing sands in the Stony Creek field are chiefly somewhat soft, medium grained, grey to brown sandstone of varying thickness, capped by blue or grey calcareous shales or shaly limestones. The producing sands appear to belong entirely to the Albert series, although shows of oil and gas are occasionally found in the coarser sandstones or conglomerates of the overlying Lower Carboniferous.

The producing sands are often very variable in composition and texture, changing rapidly in places from sandstone to shale and limestone or vice versa. The variations are more sudden and noticeable in the western part of the field than in the eastern, and are more pronounced across the strike than parallel to it. The sands bear a striking physical resemblance to many of those of the Chemung in the northern Pennsylvania, which formation includes the Bradford and other well known oil and gas sands of that country.

According to our interpretations of the well records, there are in addition to occasional "stray sands," three groups of sands in the eastern section and two in the middle and western sections; although in the extreme western portion of the field, the sands occur as isolated beds difficult of correlation rather than in well defined groups.

Local geology.—The following additional notes descriptive of local geology are taken from Young[1].

The present developments of the Stony Creek field are confined to an area about 2 miles long by 1½ miles broad, fronting on the west bank of Petitcodiac river and lying between Stony creek on the north and Weldon creek on the south. Between the two creeks the land rises rather sharply from the level of the tidal river to an altitude of 460 feet. Of the 23 wells drilled by the Maritime Oilfields Company, 4 are on the steep east front of the hill and the remaining 19 are scattered over the top of the hill.

[1]Young, G. A., Twelfth International Geological Congress; Guide Book No. One. Issued by the Geol. Survey, Canada, 1913, pp. 359-361, part II.

Along the river front, strata of the Albert series are visible at low water over a stretch of about 2 miles. At the north end of the section, they are overlain by coarse, red conglomerate; proceeding southward, at the first exposures they lie nearly horizontally, beyond this they dip in various directions between south and west, at angles of 10° to 20°. The measures consist of thin-bedded limestones and dark shales with sandstone beds which in places are impregnated with hydrocarbons. The measures apparently lie on the crown of an anticline but there are indications that in places the strata are crumpled and faulted.

The lower slopes of the ridge facing the river to the east and the valley of Weldon creek to the south are occupied mainly by nearly horizontal coarse red conglomerates and sandstones with some shales. These measures are conformably overlain by the quartz conglomerate, and over this, by the light-coloured sandstone of the Millstone Grit. Possibly the lower red strata belong to the Millstone Grit. But it may yet be proved that they are considerably older. On the north side of the ridge along the valley of Stony creek, the measures underlying the pale-coloured Millstone Grit beds consist of red and green shales, and sandstones, with beds of grey sandstone, quartzose conglomerate, etc. Thus the Albert series out-cropping along the eastern base of the hill extends westward under it, as shown by the borings, and is overlain by red strata capped by grey beds. The Albert series is of very early Carboniferous age, the grey beds of mid-Carboniferous age. The exposures indicate, in general, that the measures of all the divisions have relatively gentle dips.

The wells stand at elevations varying between 250 feet and 460 feet above sea-level, and in depth they range from 1,200 to 2,060 feet. After passing through a thickness of overlying formations usually amounting to about 350 feet, they enter the Albert series, of which a maximum thickness of 1,800 feet has been penetrated without encountering any signs indicating the approach of the base of the formation.

The strata of the Albert series, as found in the various wells, consist mainly of thinly-bedded, shaly beds, usually black or dark green in colour and varying in composition from argillite to limestone. Besides the shaly strata, fine-grained quartzose sandstones are comparatively common, the numbers of individual sandstone beds in a single well varying from 3 to 15. In thickness the individual sandstone beds vary from a few feet to 100 feet or more. There is rather a general tendency for the sandstone beds to occur in groups, in a number of instances three such groups separated by intervals of 150 to 350 feet of shale being encountered in a single well. The aggregate thickness of a single group of sandstones may rise to 180 feet but more often lies between 3 and 90 feet. The individual beds of a group of sandstones may be separated by shaly layers varying in thickness all the way from a few feet to 30 feet or more.

Though slight traces of oil or gas have been found in the shaly beds and, in one instance, in strata overlying the Albert series, the oil and gas are confined, practically, to the sandstone beds in the Albert series. In the case of one well which the drillers recorded as apparently passing through disturbed, broken strata, practically all the sandstones are free from oil or gas. In the producing wells, a small number of sandstone beds do not afford any trace of oil or gas. Usually the number of such dry beds is small in comparison with the total number of sandstone beds in a well, and the dry beds, as a rule, occur towards the top of the well, but such beds are also recorded as occurring beneath others with showings of oil or gas. Usually by far the greater number of the sandstone beds are recorded as at least showing oil or indicating the presence of gas, and in some of the wells, sandstone beds of two different horizons yield large volumes of gas.

In the case of about one half the number of wells, all the sandstone beds (except such as are dry) of each well are recorded on the logs as being either all oil sands or all gas sand. In the remaining cases, oil and gas sand irregularly alternate or they occur in two groups of which, in some wells, the oil sands form the higher group while in others the gas sands form the higher groups.

In two wells, strong flows of salt water were recorded. In one case, the salt water was struck near the bottom of the well, being first met in a 12 foot sandstone bed lying 68 feet below an oil sand that, with other immediately overlying sands, yielded oil at the rate of 5 barrels per day. In the second instance, after having passed through two sands, both giving indications of oil, and one giving a small show of gas, a salt-water sand was struck at a depth of about 810 feet. This well was continued to a depth of 1,250 feet, and in the additional distance of 440 feet passed through four beds of sandstone with an aggregate thickness of 245 feet but which were barren of oil or gas except in the case of the lowest bed which was said to give a "show of gas".

From seven of the wells the total calculated yield of gas, as derived from measurements made with a Pitot tube, was nearly 4,000,000 cubic feet per day, the closed pressure of the individual wells varying from 20 to 200 pounds per square inch. From twelve other wells, varying results were obtained. One well had a closed pressure of 525 pounds, rising in three days time to 610 pounds, and an estimated flow of 3,695,000 cubic feet per day; a second had a closed pressure of 475 pounds and an estimated flow of 8,893,000 cubic feet per day; and a third had a closed pressure of 560 pounds with an estimated capacity of 6,417,000 cubic feet per day. In these three cases the volume was estimated from observing the rate of rise and of pressure at one minute intervals. As regards oil, in the case of one well, 60 barrels accumulated in 20 hours; from another after an interval of 7 days 87 barrels were pumped; while a third gave an estimated yield of 40 barrels in 25 hours. The above figures have been taken from the records of the Maritime Oilfields Company who are developing the field.

The sands are reported to be dry of water, and the gas has collected in them at points of local undulations, that is, in secondary anticlines. The oil wells in the Stony Creek field are seldom shot and the gas wells are never shot. The first wells were drilled about 600 feet apart but now they are up to one-half a mile apart. The rock pressure is lowest near the river and highest toward the west end of the field, where it was over 700 pounds per square inch in some wells. The oil from the wells (some yielding as little as one gallon or so per day) is piped to a loading tank by the roadside from which tank wagons distribute it. The oil is retailed locally for $4 per barrel, but most of it is sold to the Intercolonial railway at Moncton for $1.75 per barrel to make Pintsch gas and for other purposes.

Petroleum production of Stony Creek field.—As none of the wells were systematically pumped or bailed for oil, it is difficult to make a reliable estimate of the original yield. Some of the wells filled with oil to a height of 500 feet or more at the start and from some of them from 50 to 80 barrels were bailed out; but the production after the start was probably rarely over a few barrels per day. The field manager has estimated the yield for the field, after the first excess was removed, at 30 barrels per day.

Quality of oil.—The oil produced in the Stony Creek field is of a clear dark green colour, about 39 degrees Baumé. This is somewhat heavier than some of the Pennsylvania oils, which average about 40 degrees Baumé. In the following table, in addition to the two Stony Creek oils, three from the Dover-St. Joseph fields, and one from Pennsylvania are given for comparison:—

Analyses of New Brunswick and Pennsylvania Oils.

Stony Creek Oils. (Recd. Apr. 18, 1910.)			Dover-St. Joseph Oils. (Recd. Apr. 18, 1910.)		Pennsylvania Oil.	
Commercial Product.	No. 3.	No. 5.	No. 1.	No. 2.	No. 3.	Average.
Benzene and gasoline	14·0	15·2	2·0	3·2	None	15·0
Kerosene	37·6	38·0	23·5	29·1	27·3	47·0
Heavy oil and paraffin	42·4	42·0	67·0	61·7	69·8	32·0
Coke and loss	6·0	4·8	7·5	6·0	2·9	6·0
Specific gravity	·8392	·8363	·857	·852	·862	·824
Flash point	68F°	68°F	40°F	....	95°F	....

Of the above samples, the two from the Stony Creek field were analyzed by Dr. J. T. Donald, official analyst to the Canadian government, Montreal, while the three from the Dover-St. Joseph fields appear to have been analyzed in the office of Sir Boverton Redwood, London. The United States Geological Survey is the authority for the figures showing the average of the Pennsylvania oils.

Disposal of oil.—Nine of the oil wells are pumped by the rod system from a pumping plant located near Well No. 5 at the east end of the field and close to the Moncton-Hillsboro road. Others have individual arrangements for pumping. The oil is collected in wooden tanks at the wells and in a series of covered wooden tanks at the pumping station, from which the product is shipped in barrels or tank wagons.

It is used for rough lubrication, as a wood preservative, and as a welding fuel at the Intercolonial railway shops at Moncton, etc. It has also been used by the railroad in the manufacture of Pintsch gas.

Quality of gas.—The composition of the gas is somewhat variable, as indicated by the following analyses by Dr. J. T. McDonald, analyst to the Dominion government, Montreal:—

Analysis of Gas from Stony Creek Field.

Components.	First Sample. (Submitted Mar. 10, 1910.)	Second sample, Well 12. (Submitted Nov. 22, 1913)
Sulphuretted hydrogen	....	None.
Carbon monoxide	None.	None.
Carbon dioxide	None.	None.
Oxygen	Trace.	None.
Nitrogen	Trace.	7
Illuminants	None.	None.
Methane	73	85
Ethane	27	8
Hydrogen	....	None.
Total	100	100
Properties.		
Specific gravity (air 1)	·686	·614
Weight of 1,000 cu. ft	55 pounds.	49¼ pounds.
B.T.U. per 1,000 cu.ft	1,280,000	1,063,000
Large calories	320,000	....

Equivalency of 1,000 cu. ft. to pounds of Pittsburgh coal...... 95
Equivalency of 1,000 cu. ft. to pounds of anthracite coal....... 85

A sample of gas from Well No. 3 analyzed for gasoline by Frank F. Peterson, chief chemist of the Bessemer Gas Engine Company, Grove City, Pa., January 18, 1912, showed "hydrocarbons in excess of CH_4" 34 per cent; carbon dioxide, none; oxygen, 2 per cent; the "estimated yield based on two stage condensing pressures not lower than 250 pounds per square inch," being equal to $\frac{1}{2}$ gallon of gasoline per 1000 cubic feet. Up to the present time the attempt is not made to extract such small amounts of gasoline.

Disposal of the gas.—The gas from the Stony Creek field is piped to Moncton through a $9\frac{5}{8}$-inch pipe, 10 miles in length, and to Hillsboro through a $4\frac{1}{4}$-inch pipe (inside diameters) $6\frac{5}{8}$ miles long. The former is laid $3\frac{1}{2}$ feet and the latter $1\frac{1}{2}$ feet below the surface. The gas at Moncton is distributed by the Moncton Tramways, Electricity and Gas Company.

The gas is sold by the distributing company at 38 cents net per 1000 cubic feet and 15-16 cents net for commercial purposes. The maximum consumption to date, including both Moncton and Hillsboro, was in February, 1913, when approximately 98,000,000 cubic feet were used, or about 3,400,000 per day. In August, which was the month of lowest consumption to the time of this investigation, about 48,000,000 or 1,600,000 cubic feet daily were supplied. Approximately one-fifth is used for domestic purposes, the balance being used for fuel and other industrial purposes by the Intercolonial railway shops, etc.

Volume and pressure of gas in Stony Creek field in New Brunswick.—Up to September, 1913, the total number of wells which had been completed in this field was thirty; and three wells were drilled at that time. The amounts of gas found in these thirty wells ranged from 0 up to a maximum of 7,000,000 cubic feet per day initial volume, and the total initial volume of all the wells was about 50,000,000 cubic feet per day. It should not be assumed, however, that the field ever reached this maximum production at any one time. The original rock pressure in this field ranged from 30 pounds up to 725 pounds per square inch, according to the location of the well and to the depth and identity of the producing sand.

The present capacity of the gas wells is much less. In September, 1913, the volume, as determined by the Associated Geological Engineers in Pitot tube measurements, was about 10,000,000 cubic feet per day.

PETROLEUM PRODUCTION IN 1911-12.

The following figures give the reported production of petroleum in New Brunswick, the figures being taken from the reports of the Canadian Department of Mines[1].

Year	*Barrels*	*Value*
1911	2,461	$3,019
1912	2,679	3,799

NATURAL GAS PRODUCTION IN 1911-12.

The quantity of natural gas produced in New Brunswick in 1912 is reported as 173,903,000 cubic feet, and its value is given as $36,549. No natural gas was sold in this Province previous to 1912, the output from 1909 to 1911 inclusive being used in further drilling. The production in 1913 is estimated as 800,000,000 cubic feet. During the year ending September 30, 1913, eleven new wells were begun in the Stony Creek field, two of them being still in progress of drilling. The following is a detailed statement of the depth and initial production of these new wells:—

Well No.	Depth feet	Initial Flow cu. ft. per day	Remarks
31	2,050	33,624	
32	1,115	6,896,640	
33	2,120	38,500	
34	1,745	65,000	
35	1,362	2,500,000	
36	1,640	2,168,480	
37	2,141		Work temporarily suspended
38			Drilling proceeding
39			" "
40	1,230		Abandoned. Hard limestone
41	1,130	884,520	

[1]John McLeish, Sum. of Min. Production of Canada for 1912. Canada Dept. of Mines, Mines Branch, p. 28.

Cost of Wells and Kinds of Casing.— The following are the average lengths and weights of casing used in this field:—

Size	*Weight*	*Length*
in.	*lb.*	*ft.*
13	54	150
10	32	400
8	24	1000–1500
$6\frac{5}{8}$	17	1200–2000
$5\frac{3}{16}$	17	

NOTE: If they obtain salt water below the gas this size of casing is used, but salt water was only found in one well, and hence the $5\frac{3}{16}$" casing has only been used in one well.

The cost of wells in this field is about $10,000 each. They use a rubber packer made by Broter, of Kane, Pa.

The Albert Mines.

In 1849 Dr. A. Gesner discovered on Frederick brook near the present site of the Albert mines, a vein or bed of a bright, jet-black, shiny mineral, afterwards identified as mineral pitch or bitumen, and called albertite. This mineral proved on investigation to be of great value and was mined for nearly 30 years at great profit. The records of production were destroyed but it was known that in each of the years 1865 and 1866 the output of albertite was 20,500 tons, while the total from 1863 to 1874 amounted to 154,800 tons, and during the entire period of working it was probably not far from 230,000 tons.[1] The prices ranged from $15 to $20 per ton.

Albertite is a solid bitumen representing the residuum of petroliferous seepages. It occurs in veins in the Albert shales at several points in Albert and Westmorland counties. While in itself an indication of petroleum in past times rather than at present, it is generally associated with petroliferous shales, and in the Albert mine liquid petroleum was actually collected in buckets from seepages from sandy beds included in the shales associated with the albertite. Albertite is not a coal, notwithstanding the opinions of certain interested parties or legal decisions, but is a petroliferous residuum and therefore to be classed among the indications of oil, at least to the extent indicated above.

[1]Ells, R. W., The Bituminous or Oil Shales of New Brunswick and Nova Scotia, Geol. Surv. Canada, 1909, part 2, page 9.

The following description of the occurrence of this mineral is taken from Young[1]:—

The Albert series at Albert Mines outcrops over an area about $1\frac{1}{4}$ miles long in an east and west direction and having a variable width of from $\frac{1}{4}$ to $\frac{3}{4}$ mile. The strata are comparatively well exposed in the eastern part of the area, along the various branches of Frederick brook. The measures, in general, dip to the south with angles varying from 15 degrees to nearly 90 degrees. On one branch of the brook, the crown of an anticlinal fold is visible, and it has generally been stated that the measures lie in an anticlinal fold whose axis strikes east and west. The strata as exposed consist chiefly of dark, thinly bedded shales, and thin beds of dark limestones. At certain horizons occur oil shales heavily impregnated with hydrocarbons. Two main varieties of oil shale are present. In the case of one variety—"curly shales"—the rock is compact, splintery, and the bedding planes in many instances are minutely crenulated. In the case of the second variety—"paper shales"—the beds split into thin, slightly flexible sheets.

The mining operations at one time carried on in this area and the extent of which is indicated by the large dumps, were conducted for the purpose of winning the substance albertite, fragments of which are abundant in the mine dumps. Albertite, by many authorities classed with asphalt, and supposed to be a solidified form of petroleum, is a black substance, having a conchoidal fracture and a hardness of about 2 on the ordinary scale of hardness. It is easily fusible and readily ignites in an ordinary flame. It is essentially composed of hydrogen and carbon with about 3 per cent of nitrogen, 2 per cent of oxygen, and a trace of sulphur. The mineral occurs filling fissures, usually narrow, not only in the Albert series but in younger Carboniferous strata. Most of the reported occurrences of such veins have been within a radius of a few miles from Albert Mines. The only large vein ever discovered was that occurring at Albert Mines. This vein, it is said, was mined over a distance of about $\frac{1}{2}$ mile to a depth of 1,100 feet or more, beyond which it became too narrow to be profitably worked. The vein was nearly vertical and followed an almost straight course along the general direction of the anticlinal axis in the country rock, but varied in width up to 15 feet and sent apophyses into the adjoining strata.

Regarding the origin of the albertite oil shales, and natural gas and petroleum occurring in the accompanying sandstones as developed in the Stony Creek oil fields, two general views have been held. On the one hand, it has been thought that the various hydrocarbons are of secondary origin, derived from sources outside of the Albert series. The second view is that the hydrocarbons are indigenous to the shales and that they have been derived from organic matter entombed in the sediments. This latter view of the origin of the hydrocarbons seems particularly applicable to the known facts in connexion with the Albert series.

[1]Young, G. A.. Twelfth International Geological Congress; Guide Book, No. 1. Issued by the Geol. Survey, Canada, 1913, pp. 366-367, Part II.

OIL AND GAS INDICATIONS.

Oil springs.—Oil springs or seepages are of widely distributed occurrence in New Brunswick. They are naturally most abundant where the petroliferous Albert shales come to the surface, especially along the rim of the Carboniferous basin in Albert and Westmorland counties. The localities characterized by pronounced seeps in the counties mentioned include the Stony Creek, Weldon, Hillsboro and the Baltimore shale district of Albert county, and the Belliveau, Dover, Memramcook, Dorchester, Pré d'en Haut and Rockland districts on the east side of the Petitcodiac river in Westmorland county.

Oil seeps are not, however, limited to the areas of Albert shales, nor even to the vicinity of the edge of the Carboniferous basin. Among the seeps or stains reported in the higher Carboniferous rocks at some distance from the rim of the basin may be mentioned those near Rockport (Sackville), Lakeburn and Legers Corner (Moncton), and Barachois (Shediac), in Westmorland county, Coal Branch Station, Kent county, Coughlan (Blackville), S. Renous (Blissville), Doaktown, and possibly other localities along the Miramichi valley in Northumberland county, and Shippigan island, Gloucester county, located close to the outcrops of the sands, but generally many miles distant. Where traces of oil are found on the outcrop, it is because they have moved outwards from distant pools, or are the relics of some ancient pool, the balance of which has often escaped years ago. Therefore, no large oil pool should be expected in the vicinity of the Old Dover and Memramcook pools, where the sands reach the surface, or where the Albert shales outcrop.

In some countries, as in Mexico, oil seepages are of different types, reaching the surface through faults or fissures, and in such localities, particularly if the formations are of recent age, good oil pools are frequently found directly below; but this type of seepage is not known in New Brunswick.

Gas springs.—Gas emanations, although less noticeable, are presumably even more numerous than oil seeps, with which they are often associated. In Albert county, gas emanations

Canada
Department of Mines
Hon. L. Coderre, Minister; R. W. Brock, Deputy Minister

GEOLOGICAL SURVEY

ECONOMIC GEOLOGY — NEW BRUNSWICK

LEGEND

PRE-CAMBRIAN — PALAEOZOIC
DEVONIAN — CARBONIFEROUS

C2
Millstone Grit
(grey and purple tinted shale, sandstone and conglomerate)

C1
Lower Carboniferous
(gypsum, limestone, shale, sandstone and conglomerate)

D
Albert series
(black oil-shale, brown, grey and calcareous shales, grit and conglomerate)

A
Pre-Cambrian
(slate, schist, diorite and granite)

Symbols

Gypsum

Limestone

Oil-shale
(locality in which oil-shale of economic value is known to occur; index number refers to tabulated analyses)

Oil-shale
(locality in which oil-shale of prospective value is known to occur)

Borehole

Oil and gas well of Maritime Oilfields, Limited
(information relating to wells was furnished by Maritime Oilfields, Limited, now operating)

Geological boundary

20
Dip and strike

TABULATED ANALYSES

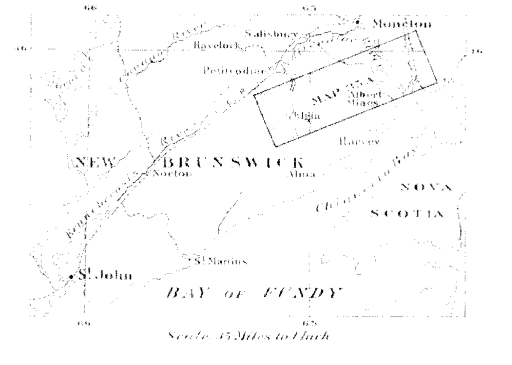
No.	OIL (gals per ton)	AMMONIUM SULPHATE (lbs per ton)
1	42-47	85-101
2	27	29
3	30-49	50-80
4	30	38
5	40	41
6	54	110
7	40	77
8	49	67
9	56	30
10	30	75
11	4	
12	14	

C.H. Seneca..., R.B. Yorston...

MAP 35A
(Reissued 1914)

Reconnaissance Map of Parts of ALBERT AND WESTMORLAND COUNTIES

NEW BRUNSWICK



Scale $\frac{1}{62500}$

Miles

Kilometres

Note: For practical purposes assume 1 MILE TO 1 INCH

GEOLOGY

R. W. ELLS	1908, 1909
S. C. ELLS	1908, 1909

TOPOGRAPHY
(subject to revision)

S. C. ELLS	1908, 1909

Reprinted for Mines Branch, to accompany Report on "Petroleum and Natural Gas Resources of Canada" by Frederick G. Clapp.

Map No. 294

LEGEND

Culture

Streets, roads and buildings

Roads not well defined

Trails

Railways

Mine Tramways

Churches

Schools

Post Offices

Quarries

Shafts

Tunnels

Dikes

Wharves

L.H.
Lighthouses

Water

Rivers and streams

Rivers and streams
(approximate)

Relief

Contours
(showing approximate locations and elevations above sea-level; Interval 40 feet)

Contours indefinite

Approximate magnetic declination 22° West

TOPOGRAPHICAL BASE
RATED GRADE 4

occur in the vicinity of Stony Creek oil field, near the Albert Mines, water wells penetrating the sandy shales at Elgin, and at various other points. In Westmorland county, gas emanations are said to occur in the vicinity of the old oil developments. Near Sussex, Kings county, gas is reported in a quarry in the hills one mile southeast of the town and south of the railroad, the flame running along the bedding plane of the freestone for several feet when ignited.

The foregoing are all within a short distance of the border of the Carboniferous basin. Gas emanations from the higher Carboniferous rocks at some distance from the boundary have been reported at Legers Corner and Chartersville (Moncton), Westmorland county, at Buctouche, Kent county, at Shippegan island, Gloucester county, etc.

The statements concerning the futility of drilling near oil springs apply equally in the case of natural gas, which is practically never found in large quantities near the outcropping of the containing stratum.

Petroliferous shales and sands.—Petroliferous shales, containing from 20 to 50 gallons of oil per ton, are found at a number of points in the north and east foothills of the Caledonian range in Albert county. The beds, which are referred to the Albert shale series, lie against the great mass of Pre-Cambrian crystalline rocks, giving rise to the range of hills mentioned, and are strongly folded and faulted. All dips up to vertical are noted. The best known localities are the Baltimore or Rosevale district in southwestern Hillsboro parish, and the Albert Mines and other localities in Hillsboro and Coverdale. Oily shales or petroliferous sands of the same series are noted at numerous points along the Petitcodiac river from Shepody bay to Stony creek in Albert county. A large area of nonpetroliferous shales of the same general type occurs near Elgin.

In Westmorland county oil shales and sands occur at intervals along the Petitcodiac from Dover to its mouth, while the same series, although not so petroliferous, extends from the Petitcodiac river south of Dover to the Memramcook river between Memramcook and College Bridge station. Outliers of the same shales are mapped at Dorchester, near Taylors

Village, and opposite Edgett landing, and possibly occur at other scattered localities. Shales of similar general character, but essentially non-petroliferous, are brought up by the strong anticline near Indian mountain, north of Moncton.

TEST BORINGS FOR OIL AND GAS.

Distribution of test borings.—Although a considerable number of scattered borings have been put down in search for oil and gas in New Brunswick, a large percentage were sunk for water or in testing for coal. Those sunk in search of oil or natural gas are limited mainly to the Dover and St. Joseph oil fields between the Petitcodiac and Memramcook rivers, and the Stony Creek gas field across the Petitcodiac from the Dover oil developments. The Maritime Oilfields, Limited, has, however, drilled a few wells in outlying territory, as noted elsewhere.

In selecting sites for drilling, the presence of oil or gas springs or the outcrops of petroliferous shales and sands seem to have been the determining factors in a majority of cases. Geologically, the wells of the developed oil and gas fields are located, with the exception of a number of the St. Joseph oil wells, on slopes intermediate between the axes of the adjacent anticline and syncline. In the outlying territory the same principle seems to have been followed by the Maritime Oilfields, Limited, the wells being in no case located on the crest of known anticlines.

Results of drilling in the Dover and St. Joseph oil fields.—The number of wells in these two fields was approximately eighty. About half of the wells are stated to have been commercially productive, the original yield varying from ¼ to 50 barrels a day. A total of several thousand barrels is reported to have been pumped by the New Brunswick Petroleum Company. The production fell off rapidly, however, and all wells were abandoned in the course of a few years.

The early wells were only about 190 feet deep, but the majority of the later ones were from 500 to 800 feet, while several were from 1000 to 2000 feet or over in depth and one was 3000 feet in depth.

The upper sands of the St. Joseph and Dover fields may be regarded as having been tested with reasonable thoroughness, but in general the wells failed to reach the deeper sands, while owing to the failure to effectually shut out the water, the yield of most wells was below the normal; nevertheless, the yield was probably fairly typical of that to be expected elsewhere in the Province where the geological conditions are similar.

Results of drilling in the Stony Creek field.—The Maritime Oilfields, Limited, began operations in this field in 1909, and to date have drilled between 35 and 40 wells, the majority of which have produced gas in paying quantities, the original yield ranging, it is stated, from 17,000 to nearly 7,000,000 cubic feet per day. The aggregate initial yield of the first 23 wells was about 50,000,000 cubic feet daily, but the present production (September, 1913) is about 12,000,000 cubic feet per day. The rock pressures run as high as 725 pounds per square inch, which may be taken as about the maximum original rock pressure in the deep sand.

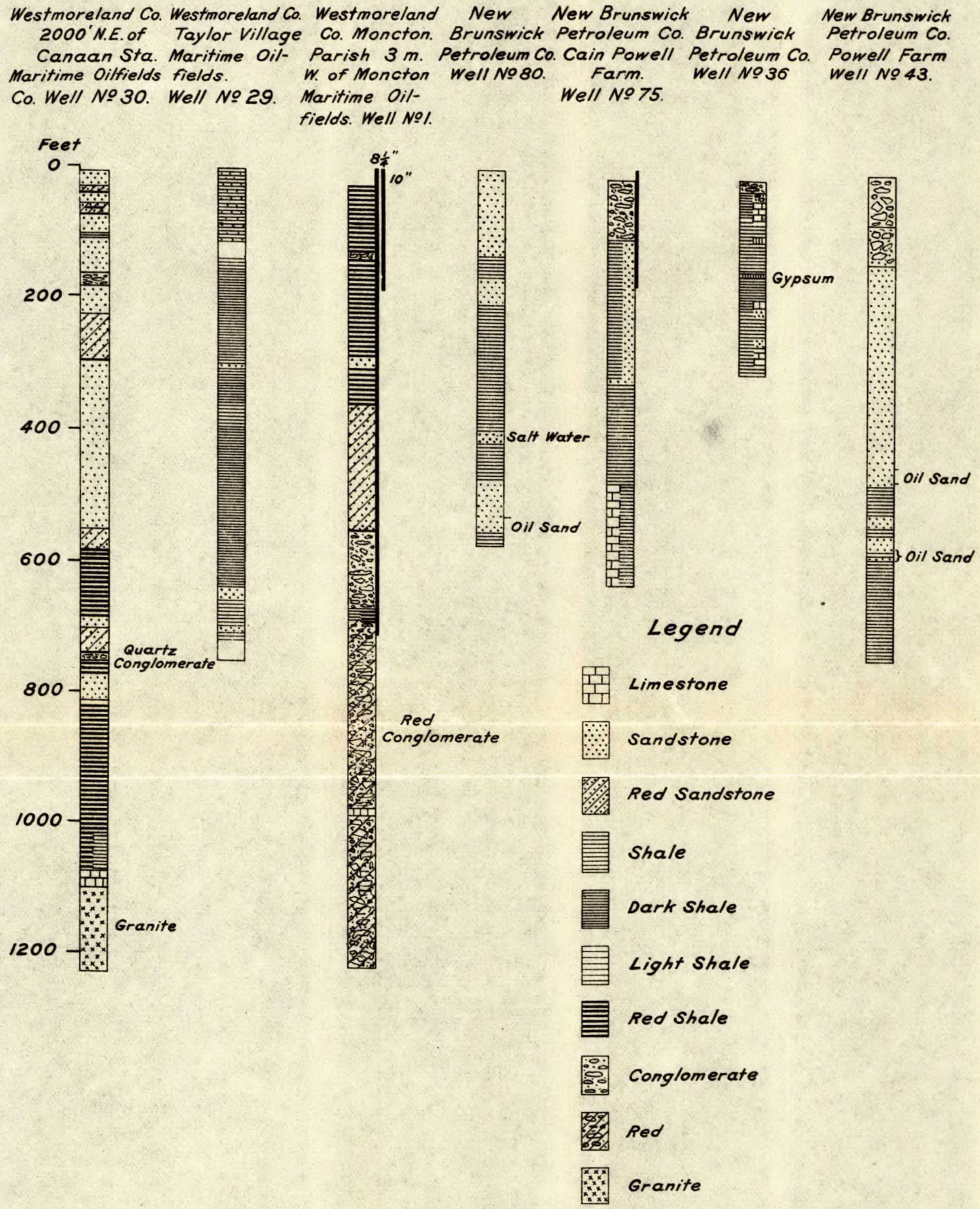
In addition to their yield of natural gas, many of the wells have supplied small quantities of petroleum, the original production sometimes being several barrels per day. In September, 1913, from 250 to 300 barrels per month were being pumped from the wells of this gas field.

The yield of gas and petroleum is probably fairly representative of the possibilities of a field developed in disturbed areas along the margin of the Devono-Carboniferous basin.

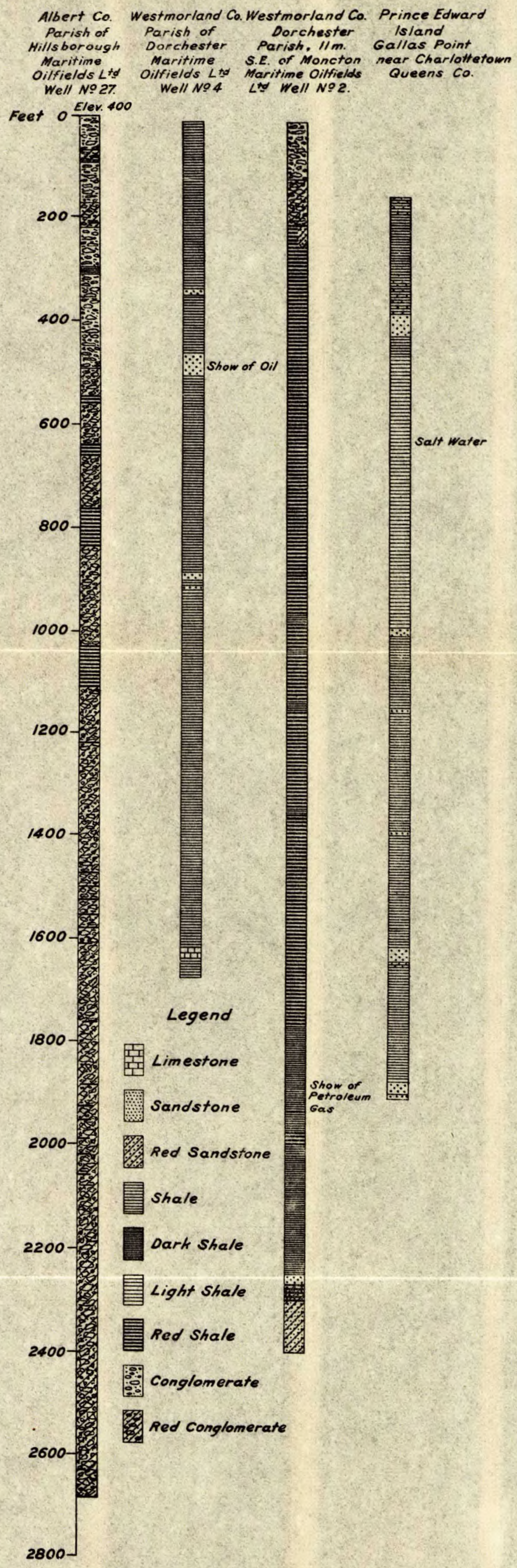
Table of New Brunswick Test Borings.

(For locations, see map, and Figs. 2 and 3).

County.	Locality.	Depth.	Remarks.
Gloucester	Shippigan Island	300	Entered bituminous shales with shows of oil and gas.
Northumberland	Chatham	400	Bottom in Lower Carboniferous red shale, probably about 100 feet below Millstone Grit. No record of oil or gas.
	Chatham (pulp mill)	800+	"Mostly in freestone." No oil or gas is reported.
Kent	Beersville (New Brunswick Petroleum Co.).	350	In Middle Carboniferous sandstone. Shows of oil and gas. Well shot, but no commercial production secured.
	Buctouche (between Buctouche and Richibucto.	600	"Stevens" well. Oil shows reported to have been found.
	Cocagne (3 miles west of Lower Bridge).	857	Mostly in freestone. No record of oil or gas.
Westmorland	Canaan (Well No. 30 of Maritime Oilfields, Limited).	1,230	Struck dark micaceous granite at 1,098 feet. Upper portion is red shales.
	Lutz Mt. (John Harris lot).	735	Grey to red sandstone and shale. No record of oil or gas.
	Lutz Mt. (Peter Wilson lot).	624	Grey to red sandstone and shale. No record of oil or gas.
Westmorland	Legers Corner (Well No. 1 of Maritime Oilfields, Limited, 3 miles east of Moncton).	1,220	Mainly in Middle Carboniferous shales and conglomerate. Did not penetrate Albert shale. No oil or gas.
Westmorland	Dorchester parish (Well No. 2 of Maritime Oilfields,Limited) between Memramcook and Dover.	2,400	Red conglomerate (Middle Carboniferous) 0-208 feet; shales, prevailingly red. (Lower Carboniferous) 208–1,768; shales, presumably black (Albert series?) 1,768–2,250; red sandstone 2,250–2,400. No oil or gas.
Westmorland	Taylor's village (Well No. 29 of Maritime Oilfields, Limited).	750	Mainly blue and grey shale, of Albert series. Dips high. Oil horizons not encountered.
Westmorland	Dover (Well No. 4 of Maritime Oilfields, Limited, lying directly east (magnetic) from Well No. 3 of Stony Creek field.	1,675	In Albert shales, similar to Stony Creek field. Sands present but not productive.
Westmorland	Dover (Well No. 1 of New Brunswick Petroleum Company, Limited, one mile north of village.	(?)	First 400 feet in dark shales, balance in reddish sandstone and feldspathic rocks.
Albert	Turkey creek (west of Rosevale).	(?)	Oil seeps from two diamond drill borings in oil shales.
Albert	Baltimore siding (Well No. 27 of Maritime Oilfields, Limited).	2,645	Entirely in red conglomerate and interbedded shales and sandstones, presumably of Middle and Lower Carboniferous. No oil or gas.
Kings	Dunsinane (between Petitcodiac and Sussex).	1,292	Middle Carboniferous sandstone and conglomerate. Some coal, but no record of oil or gas.
	Sussex (Bank of Nova Scotia).	700	Two or more pockets of gas. Rig burned by ignition.
	Sussex (mineral well).	250	Sufficient gas to burn. Stated to have been hydrogen sulphide.
	Sussex (Maritime Oilfields, Limited, Well No. 40).	1,200+	Mainly in hard grey shales, only small pockets of gas encountered.
Queens	Newcastle Bridge	171	Sandstone and shale. No record of oil or gas.
	Newcastle Bridge	366	Lower 150 feet in hard grey sandy slate, with quartz and calcite veins.
Sunbury	On Little River (Sheffield parish).	399	Lower 139 feet in hard grey sandy slate with quartz and calcite veins. No record of oil or gas.



2
Fig[redacted]. Selected well logs in New Brunswick.
(By F. G. Clapp and M. L. Fuller)



3

Fig. [redacted]0. Selected well logs in New Brunswick.
(By F. G. Clapp and M. L. Fuller)

The above depths of borings, except those on the Maritime Oilfields, Limited, are based largely on those given in the reports of the Canadian Geological Survey. Common reports often erroneously give much greater depths.

GENERAL CONCLUSIONS.

In general it may be said that outside the developed oil and gas fields the borings so far made have not afforded, because of insufficient depth or poor locations, any real test whatsoever of the oil or gas possibilities within the Province of New Brunswick. To be conclusive, new borings located in accordance with approved structural principles and carried to the Albert shales, or in their absence, to the underlying crystalline or metamorphic rocks, will be necessary to establish the presence or absence of petroleum or natural gas.

CHAPTER IV

PROVINCE OF QUEBEC

GEOLOGY[1]

Stratigraphy

GENERALIZED SECTION

A generalized section of the formations occurring in Quebec will include the following[2]:—

Period.	*Formation.*	*Thickness.*	*Material.*
Devono-Carboniferous	Bonaventure	1200+feet	Red conglomerates and sandstones.
Devonian	Gaspé sandstone	7000– "	Red, brown and grey sandstone.
"	Various limestones	2000 "	Limestones and calcareous shales.
Silurian	Silurian		Limestones, clay-slates, and sandstones.
Ordovician	Lorraine and Richmond	2000 "	Greyish shales and sandstones.
"	Utica	300 "	Black bituminous shales.
"	Trenton-Black River	600 "	Limestones.
"	Chazy	300 "	Mostly limestone.
"	Beekmantown	300–450 "	Magnesian limestone.
Cambrian	Potsdam	300–700 "	Sandstones.
Pre-Cambrian Laurentian, Huronian, etc.			Mostly gneisses, limestones and granites.

[1]Edited and revised by Alfred W. G. Wilson.
[2]Table of formations compiled by F. G. Clapp.

DESCRIPTION OF GEOLOGICAL FORMATIONS.

Laurentian and Pre-Cambrian: The greater part of the territory north of the St. Lawrence river, and as far north as Hudson strait, with the exception of a very narrow strip close to the river and extending from near Quebec to Calumet island on the Ottawa river, is underlain by highly crystalline igneous and metamorphic rocks. These rocks comprise batholithic granites, gneisses, anorthosites, gabbros, crystalline limestones and quartzites. This type of rock never holds oil or gas in commercial quantities.

The Geological Survey maps the larger part of this area as Laurentian and undivided Pre-Cambrian. Within this territory are, however, a number of areas underlain by rocks of sedimentary origin, the youngest of which are mapped as Keweenawan or Animikie. One of these areas lies along the basin of the Kaniapiskau, and has a lineal extent of over 500 miles. Smaller areas occur east of this near Lake Miskikamau and on the Naskaupi river above Lake Melville. Two other small areas, one in the vicinity of Lake Mistassini and the other bordering Richmond gulf on the east side of Hudson bay, are also shown.

Potsdam Sandstone.—This sandstone is the lowest sedimentary formation recognized in the basin of the St. Lawrence in the province of Quebec. Where contacts are found it is seen to rest directly upon the underlying floor of Pre-Cambrian crystallines. On the island of Montreal the total thickness developed varies from 300 feet to 700 feet.

Beekmantown Limestone.—This formation rests immediately upon the Potsdam. It varies somewhat in character from a dolomite or magnesian limestone to an arenaceous and cherty one. It appears to be from 300 to 450 feet in thickness.

Chazy Limestone.—This formation immediately succeeds the Beekmantown and consists of limestone of varying character interstratified with which are shaly layers. In the vicinity of Montreal the thickness of the Chazy is about 300 feet.

Black River and Trenton Limestones.—The Chazy merges upward insensibly with the Trenton group, which consists of limestones of Black River and Trenton age, from which it cannot always be differentiated, since they appear to merge with each other. The Trenton is the formation which contains large quantities of oil and gas in northwestern Ohio and northeastern Indiana, and which has good showings of gas in certain parts of Ontario. While it underlies a large part of the St. Lawrence valley, it also outcrops extensively on both sides of the valley, and there is no great probability that it will be found productive of natural gas or oil in the Province of Quebec. The Trenton group is supposed to be about 600 feet thick in the province. In places, this group rests directly on the granite and gneiss, but in other localities it is separated from the crystalline rocks by Potsdam, Beekmantown, and Chazy.

Utica Shales.—Resting immediately upon the Trenton limestone is the Utica, which forms the cap rock, over the oil and gas in the Ohio and Indiana fields. The Utica consists of black and frequently bituminous shales, its maximum thickness being about 300 feet.

Lorraine Shales.—The Utica passes upwards into the less bituminous and somewhat sandy shales of the Lorraine formation, which have a thickness in the Province of Quebec of about 2,000 feet.

Richmond and Gamachian.—Recent investigations of Schuchert and Twenhofel, on the Island of Anticosti, have resulted in the recognition of a characteristic Richmondian fauna. The strata assigned to this series consist chiefly of shales and thin-bedded limestones prevailingly grey or greenish grey in colour, and have a total thickness of about 1,150 feet. Overlying the Richmond series is about 180 feet of strata, chiefly thin-bedded grey limestones with shale partings and distinct zones of shale, but also containing some sandstone beds. This series has been named the Gamachian series. This name is intended to include all American deposits later in age than the youngest Richmondian of Indiana and Ohio and older than the Anticosti series, which in the United States is thought to have its basal equivalent in the typical Medina and Edgewood stages.

Elsewhere in the province strata that are now classed as Lorraine may, on more careful study, be found to belong to the Richmond.

Silurian.—Isolated areas of Silurian rocks occur in synclinal basins southeast of the St. Lawrence river. They are composed chiefly of limestones characterized by a coral fauna. The main area of Silurian rocks, however, forms a belt from 4 to 10 miles wide reaching from the coast near the mouth of Grand river to the Temiscouata river in New Brunswick. This belt is made up of sandstones and shales of Niagara age, and white sandstones and calcareous rocks of Lower Helderberg age. The rocks of this belt dip steeply and are closely plicated, while the whole series passes unconformably beneath the Devonian formation of the synclinal basin of the central Gaspé region.

Devonian.—The Devonian rocks outcrop in the Gaspé region, and consist of impure limestones in the lower portion followed by purer limestones and both overlain by the Gaspé sandstone which covers a large portion of the region. The latter formation consists of a heavy mass of red, grey, and brown sandstones with many coarse pebble layers. The thickness of this sandstone was estimated by Logan at 7,000 feet but Ells thinks this figure is too high on account of the extensive faulting. The formation contains abundant plant and invertebrate remains which shows its age to be middle Devonian.

Carboniferous.—Skirting the southern margin of the Gaspé peninsula is a great mantle of red conglomerates and sandstones unconformably overlying the Gaspé sandstone and lower formations. The formation is almost horizontal throughout its extent. Its thickness is not known though sections 1,200 feet in height are exposed. Its conglomerates are largely made up of blocks and boulders of the fossiliferous rocks underlying, from Cambrian to Devonian. These blocks and boulders are often of enormous size. The formation was described by Logan as of Carboniferous age, but is now generally believed to represent the later stages of the Devonian as well as the early part of Carboniferous time.

Volcanic Intrusions.—In the southern part of the province of Quebec, occurring as isolated more or less conical hills sometimes several miles in diameter, are a number of masses of syenite and similar volcanic rocks, which constitute the roots or necks of ancient volcanoes. Frequently dikes of similar rock radiate from these masses. These occur in the counties of Hochelaga, Chambly, Rouville, and Shefford. Mount Royal at Montreal is one of the most interesting hills of this type. Large masses of other igneous rocks occur in outlying portions of the Province, in Terrebonne and Montcalm counties toward the northwest, and extending north from the northern edge of Lake Memphremagog. While it is a fact that oil fields are found in Mexico and some other parts of the world where volcanic necks of this type rise up out of sedimentary formations in the midst of a broad depression, it is believed that such conditions do not prevail in the Province of Quebec, because the rocks are ancient and are more or less faulted and porous, and the oil and gas must have leaked away ages ago. If they existed now, they would undoubtedly be evinced by seepages.

Geological Structure.

As that portion of Quebec lying northwest of the St. Lawrence river is underlain by the ancient crystalline rocks without the possibility of the occurrence of oil deposits, its geological structure need not here be described. Between the St. Lawrence river and the southeast border of the Province, the rocks are thrown into a series of long parallel folds with faulting. In the Gaspé region, these anticlinal folds are five in number, named as follows beginning at the north: Forillon, Haldimand, Tar Point, Point St. Peter, and Malbaie or Percé anticlines. These are described more in detail in the section on developments in Gaspé county. In the plain of the St. Lawrence, northeast of the Champlain fault, Palæozoic sedimentary strata occur in very considerable thickness. In certain localities, so far as surface indications go, a number of low anticlinal structures have been developed. Preliminary drilling operations have shown the existence of natural gas in association with one of these folds. Further and deeper exploration is necessary to determine if either gas or oil occurs in commercial quantities.

HISTORY OF DRILLING OPERATIONS.

Gaspé County.

GENERAL DESCRIPTION OF FIELDS.

Gaspé, the most northeasterly county of the peninsula of Gaspé, is the only county in Quebec which has ever produced oil in commercial quantity; and this field was so unsuccessful as never to have been profitable.

The surface of the country, a short distance inland, is usually very rugged, with high ranges of hills, reaching in places, elevations of 1,200 to over 1,500 feet. The country itself is generally densely wooded and except along the lower portion of the several rivers entirely unopened for settlement. Owing to forest covering, and the heavy deposits of drift, which are found over much of the area, good rock exposures are rarely met with off the lines of the principal streams. On many of the side streams also the banks are composed of clay, gravel or other drift. The thickness of these drift deposits has been found in some of the boring locations to be nearly 100 feet.

The area in which boring has been done extends in a northwesterly direction from Seal cove on the south side of Gaspé bay to Falls brook, a branch of the York river, 33 miles distant.

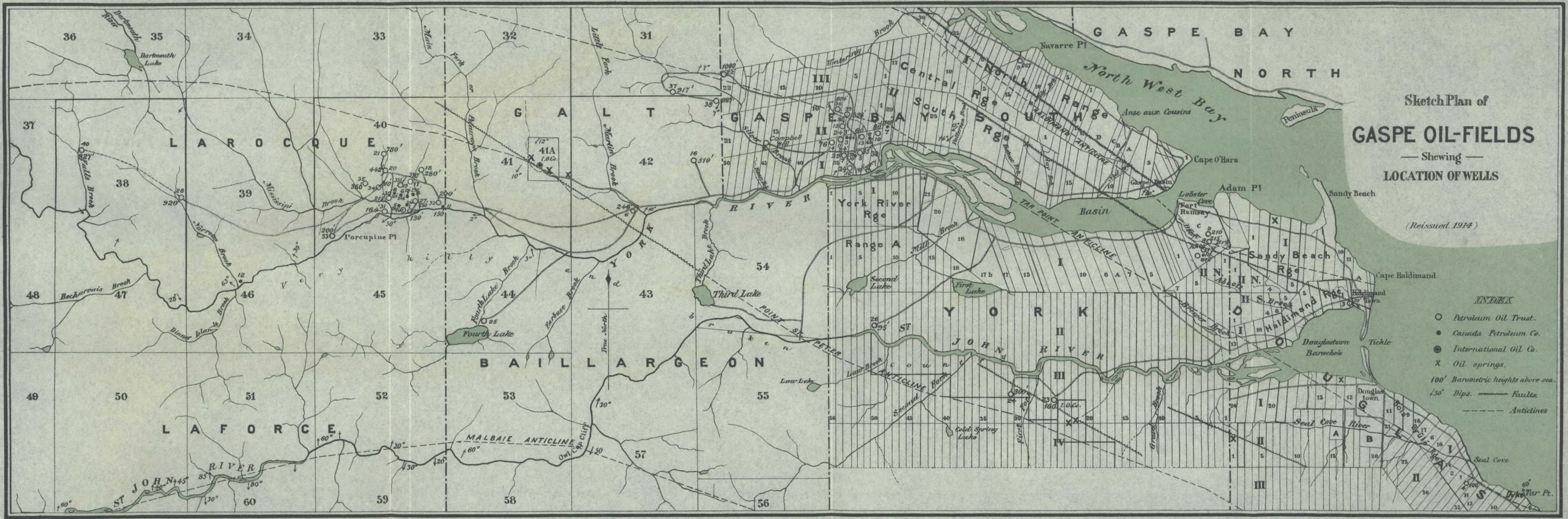
HISTORY OF DEVELOPMENTS.

Wells were sunk in this locality as early as 1868, when the Sandy Beach well was drilled to a depth of 684 feet and was abandoned. In 1889-91 five wells were sunk in the same vicinity by the Petroleum Oil Trust of Montreal, their operations being continued until 1901 and more recently. In one of the wells situated at Seal cove, the total depth was about 3,000 feet. A small show of light green oil, yielding in all about 20 barrels, was obtained in one of the wells.

Most of the drilling in Gaspé county was done in 1891 and 1892. A number of wells were also sunk (forty in all) by the Canadian Petroleum Company. Some of these wells

Canada
Department of Mines
Hon. L. Coderre, Minister; R.W. Brock, Deputy Minister.

GEOLOGICAL SURVEY



C. O. Senécal, *Geographer and Chief Draughtsman.*
V. Perrin, *Draughtsman.*

Scale 2 miles to 1 inch

Chains 80 60 40 20 0 — 1 2 3 4 5 6 7 Miles

Location of wells and tracks, from plans supplied by the Petroleum Oil Company

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Reprinted for Mines Branch, to accompany Report on "Petroleum and Natural Gas Resources of Canada", by Frederick G. Clapp.
Map No. 295.

obtained small amounts of oil, and were pumped for a month or more. The depths were frequently over 2,000 feet.

According to the Geological Survey of Canada, fifty-two wells were drilled altogether in this field. There is no doubt but that the property was very badly managed.

Of the wells drilled in this county, thirty-nine were sunk by the Petroleum Oil Trust of London, twelve by the Canadian Petroleum Company, and one by the International Oil Company.

Wells were still drilled as recently as 1901 by the Canadian Petroleum Company; well No. 28 being sunk in 1898, five miles west of the York river, and two and one-half miles south of St. Peter anticline, the total depth being 3,525 feet, without result. A large amount of salt water was found in most of these wells, Most of the wells range in depth from 1,500 to 2,600 feet.

The greatest depth of any well in the Gaspé field is reported to have been 3,700 feet.

OPERATING COMPANIES.

The Oilfields of Bonaventure, Limited, with office at 66 Broad Street Avenue, E. C., London, England, was registered January 17, 1898, as the Irish Proprietary Oil Fields of Gaspé, Canada, Limited, and owns 1,500 acres of freehold land and 500 acres of mining rights in the Province of Quebec, also two acres of wharfage land at Gaspé. In December, 1899, the name of the company was changed to the Oilfields of Gaspé, Canada, Limited, and in June, 1912, to the present title. Three wells have been sunk and oil struck at 1,000 feet. Negotiations are in progress for the acquisition of rights over 5,000 acres in the Bonaventure portion of the oilfield.

The Eastern Canada Company, Limited, with office at 62 London Wall, London, E.C., England, was registered June 30, 1911, to acquire the oil and mining rights over 60,000 acres in the Gaspé region. The licenses are held in perpetuity from the Quebec Government, subject to a rental based upon 12,000 acres only and a royalty of 30 per cent of the petroleum produced. Boring operations are in progress; depth of No. 1 well in

February, 1913, 570 feet; formation, grey sandstone. In May, 1913, this well had reached a depth of 2,500 feet from the surface.

FORMATIONS PENETRATED BY THE DRILL.

The geological formations forming the surface, immediately below the Glacial Drift, in Gaspé county consist, to the north, of Utica and Lorraine shales, which form a belt with a maximum width of five miles along the extreme northern border of the county. The next succeeding belt to the south is the Sillery formation of Cambrian age, the surface width of which ranges from four miles at the eastern end to twenty miles near the western end. A complicated area of considerable size in the western corner of the county consists of Pre-Cambrian, Cambrian and Silurian rocks; and in the southern corner of the county there are perhaps 150 square miles of Cambrian metamorphic rocks. Along the southeastern edge, bordering the Gulf of St. Lawrence, is a belt not over two miles in width of Carboniferous rocks belonging to the Bonaventure formation. The remaining portion of the county, consisting of more than half its area, is of Silurian and Devonian rocks, with occasional local dikes of trap. As noted on a preceding page, the Devonian rocks consist of impure limestones below, passing upward into purer limestones, these being overlain by the Gaspé sandstone. This series of limestones and sandstones is involved in the folding described below, the axis of the folds exposing Silurian and Devonian limestones, the synclines and flanks of the anticlines being made of the Gaspé sandstone.

GEOLOGICAL STRUCTURE.

The geological structure of the formation occupying the sedimentary areas in Gaspé county is naturally very complex, there being numerous anticlines and synclines and considerable faulting. It might be supposed that the conditions would be very favourable for the existence of oil and gas fields. However, there are a number of extremely unfavourable circumstances, among which may be mentioned the frequently very steep inclinations of the rocks, ranging from 20° to 80°. Moreover, the rocks are much broken, and presumably allowed the oil and gas to escape long ago, except locally. A great many igneous intrusions or dikes exist, in the vicinity of which important oil or gas fields seldom exist in Canada.

The general structure of the Gaspé peninsula is a great syncline, with five anticlines traversing the valley longitudinally. These anticlines from north to south taken in order are as follows:

1:—The Forillon anticline, overthrust and faulted, trends northwest, parallel to the south shore of the St. Lawrence and swings to the southwest with the change in direction of the shore. The overthrust at the eastern end of the fold abuts the Devonian upon the Cambrian.

2:—The Haldimand anticline extends from Cape Haldimand northwest, parallel to and south of Cape Bay and the Forillon anticline, also swinging to the southwest.

3:—The Tar point anticline starts from Tar point on the south shore of Gaspé bay and trends northwest parallel to and at a distance of from 4 to 6 miles from the Haldimand anticline. On the south slope of this fold, about 7 miles west of Gaspé village, a small oil field was developed. The Tar point and Haldimand anticlines show dips ranging up to 200°.

4:—The Point St. Peter anticline starts from the shore at Point St. Peter and trends northwest for about 35 miles, where it swings to the west and south of west. The crest of this fold averages about 5 miles distant from the preceding fold. The considerable oil development near the juncture of the Mississippi brook with York river is on the southern slope of this anticline.

5:—The Malbaie or Percé anticline starts from near Point Percé and trends northwest parallel to the preceding anticlines until it strikes the St. John river at Owl Gap cliff, after which it swings to the southwest up the valley of that river. The flanks of this fold show dips of 30 to 80 degrees, and the area between this fold and the preceding is also marked by steep dips.

South of the Percé anticline, along the coast, the folds have been more or less obscured by the mantle of the Bonaventure formation, which, where present, lies everywhere on the almost vertical edges of the grey and blue limestones of the Ordovician and Silurian. In the interior the structure is not well known, but the rocks have generally very high dips.

Local structural details are given in the notes regarding the wells in later pages. In this region the wells drilled on anticlines found no oil, all the productive wells being in synclines. This seems to be an indication that the breaking of the strata has long ago caused leakage of most of the oil.

INDICATIONS OF OIL.

Indications of oil were noted in the Gaspé peninsula at a very early date and were recorded by Sir W. E. Logan in 1844 and in 1863, by Dr. T. Sterry Hunt in 1865, and by Dr. R. W. Ells in 1888-89 in the Reports of the Geological Survey of Canada. The following is a summary of the indications of oil in the Gaspé as far as known in 1863[1]:—

PRODUCING FORMATIONS.

At the oil spring at Silver brook, a tributary of York river, the petroleum oozes from a mass of sandstone and arenaceous shale, which dips southeastwardly at an angle of 13° and is nearly a mile to the south of the crown of the anticlinal. The oil, which here collects in pools along the brook, has a greenish colour and an aromatic odour, which is less disagreeable than the petroleum of western Canada. From a boring which has been sunk in the sandstone to a depth of about 200 feet there is an abundant flow of water, accompanied with a little gas and very small quantities of oil. Farther westward, at about twelve miles from the mouth of the river, oil was observed on the surface of the water at the outcrop of the limestone. Petroleum is met with at Adams' oil spring, in the rear of lot B of York, nearly two miles east of south from the entrance of Gaspé Basin. It is here found in small quantities floating upon the surface of the water and nearby is a layer of thickened petroleum, mixed with mould, at a depth of a foot beneath the surface of the soil. A mile to the eastward, at Sandy Beach, oil is said to occur, and, again, at Haldimandtown, where it rises through the mud on the shore. These three localities are upon the sandstone and on the line of the northern

[1]Logan, Sir William E., Geol. Surv. of Canada, Rep. of Progress 1843-1863, p. 788.

anticlinal and about two miles west of Tar Point, which takes its name from the petroleum found there, another oil spring is said to be found, three-quarters of a mile south of Seal cove. On the south side of the Douglastown lagoon, and about a mile west of the village, oil rises in small quantities from the mud on the beach. A well has here been bored to a depth of 125 feet in the sandstone, which dips to the southwest at an angle of 10°, but traces only of oil have been obtained. Farther to the westward oil is said to occur on the second fork of the Douglastown river. Traces of it have also been observed in a brook near St. George's Cove, on the northeast side of Gaspé bay. In none of these localities do the springs yield any large quantities of oil, nor have the borings which have been made in two places been as yet successful. The above indications are, however, interesting, inasmuch as they show the existence of petroleum over a considerable area in this region, some part of which may perhaps furnish available quantities of this material.

CHARACTER OF THE OIL.

According to analyses reported by Sir Boverton Redwood, the specific gravity of the Gaspé oil ranges from ·847 to ·949; ten different tests having been made, both in seepages and from oil recovered in three different wells. The sulphur in these oils ranged from ·09 to ·20 per cent, there being no disagreeable odour. The flash point ranged from 46° to 280° F. The oil from sandy portions of the strata is a light amber, while that from the lower Calciferous rocks is a heavier dark oil.

PRODUCTION OF THE WELLS.

The production of all the Gaspé wells was extremely small. The best well in the field is said to have produced in all about 2,000 barrels of oil. Most of them were nearly dry, but oil would percolate slowly into them. In other wells the outcrop was irregular. The average output in 1902 was two gallons per well, from the wells which still produced.

RECORDS AND DEPTHS OF WELLS.

Record of wells bored in Gaspé county may be found in the report of R. W. Ells[1].

[1] Ells. R. W., Can. Geol. Surv.; Ann. Rept., Vol. 15, 1902-3, Pt. A, pp. 346-362.

FUTURE PROSPECTS OF THE GASPÉ FIELD.

The following conclusions published a number of years ago are just as applicable at the present time[1]:—

> From a careful consideration of all the data at present to hand regarding this field as a producer of oil in economic quantities, it must be said that the outlook can scarcely be regarded as favourable. There are no well-defined oil-sands, such as are recognized in the true oil territory, and where oil had been obtained in reported large quantities it would seem to occur in isolated pockets only, since the continuation of the borings to a greater depth have given no favourable results. That oil in small quantities exists in different portions of the sandy strata, and occasionally also in the limestone, is evident from the records, but so far it is plain that nothing which can be regarded as of economic value has been found.

Developments in other Counties.

In 1885 a well was drilled to a depth of 1115 feet near St. Maurice, in St. Maurice county, and a fair quantity of gas was obtained at different depths. In 1906 and 1907 the Canadian Gas and Oil Company drilled a number of wells in the vicinity of Louiseville, Yamachiche, and St. Barnabé in the same county. These wells were only from 225 to 300 feet and the gas was obtained from the superficial deposits or drift. The gas was piped to St. Barnabé, Yamachiche, Louiseville, and Three Rivers.

Following the operations in St. Maurice county, a Canadian company, known as the Combustible Gas Company, with Mr. Cyrille Duquet, of Quebec, as president, secured from the Government the exclusive privilege of utilizing natural gas in the Province. This company made a boring of 1,500 feet at Maisonneuve, near Montreal, and three others of 500 to 600 feet at Louiseville, but with little success.

In 1908 the Quebec Fuel Company was organized for the purpose of testing favourable localities in the Province of Quebec, in search of natural gas, but operations were suspended in 1912. Wells were drilled in Yamaska, Richelieu, and Verchères counties, but only small wells and dry holes resulted.

[1]Ells, R. W., The oil fields of Gaspé. Geol. Survey Can., 15th Ann. Rept., new series, 1902-3, p. 362A.

Some other efforts have been made at various times to find natural gas in paying quantities in the Province of Quebec, ten or more shallow wells having been drilled north of the St. Lawrence river, obtaining small gas wells from a depth of about 800 feet. Seven or eight holes were drilled south of the St. Lawrence river, about forty miles east of Quebec, by the Canadian Oil and Gas Company, but no results were obtained.

FUTURE POSSIBILITIES OF THE PROVINCE.

There appears to be nothing of a favourable nature regarding possible future oil or gas fields anywhere in the Province of Quebec, and drilling is not advised.[1]

Anticosti Island.

In Anticosti, shales and shaly limestones of the Richmond, nearly 1200 feet in thickness, extend nearly the entire length of the island along the north side, while the succeeding formations to the south represent the whole of the Niagara group in a general way. These Silurian rocks are about 1400 feet thick, and are made up chiefly of limestones, with some shaly beds. Both series of rocks dip to the south, varying from a few feet to 200 feet to the mile. The geologic structure of the island is not unfavourable, but the superposition of limestones above shales is not likely to favour the accumulation of oil deposits, and the prospects are therefore unfavourable.

Argenteuil County.

This county is absolutely unfavourable for oil or gas. The greater part consists of crystalline rocks of Laurentian and Pre-Cambrian age, while a small area in the southeastern corner, having Potsdam and Beekmantown rocks at the surface, is too closely related to the crystalline rocks and too low in the geological scale to offer any prospect of oil or gas.

[1]This is a personal opinion of Mr. Clapp and is not in accord with the opinion of the Provincial Mineralogist of Quebec. or that of some of the officers of this Department. Recent field work by the Geological Survey has shown the existence of low anticlinal structures in the plain between the St. Lawrence river and the Champlain fault. The depth of the Trenton is probably over 2,100 feet, and there is the possibility of the development of a small gas field in this locality. The accuracy of this surmise can only be determined by further exploratory drilling. At present natural gas from one well is being used to furnish power for the sinking of a second well near St. Barnabé, St. Hyacinthe county,

Arthabaska County.

Rocks of the Trenton age form the surface in the extreme northwestern part and in the southeastern part of Arthabaska county, but near its northwestern edge a fault of considerable magnitude has brought the Sillery formation, consisting of red, grey, and green shales and greenish-grey sandstones, to the surface over a considerable area. There appears to be no probability of oil or gas in this district.

Bagot County.

The prevailing surface rocks in Bagot county are Lorraine, Trenton and Upper Cambrian sedimentaries, consisting of slates and sandstones, which are considered too low in the series to offer prospects of oil or gas. The Trenton, which is the only formation which contains large quantities of oil or gas elsewhere, is only present under cover in the western part of the county. Moreover, two great faults cross the county.

In several localities wells 100 feet or less in depth have found small showings of gas, but not in any quantity. Some of these borings were in clay and consequently without significance.

Beauce County.

The surface formations in Beauce county are of Pre-Cambrian and Ordovican age; and structural conditions are so complicated that there is no chance of finding commercial deposits of oil or gas.

Beauharnois County.

This county occupies a rather central position in the St. Lawrence basin, and its surface, underlying the drift, consists of sedimentary rocks largely of Beekmantown age; but the north-eastern portion of the county is crossed by a considerable area of Potsdam sandstone. Since the formations which commonly contain oil and gas in paying quantities in other fields are not present here, there appears to be no hope of finding deposits of value.

Bellechasse County.

This county lies in the St. Lawrence basin, and is crossed by northeast-southwest belts of Silurian and Cambrian formations. There may be some chance for small showings of oil and gas, but owing to the presence locally of Pre-Cambrian and other intrusive rocks, and to the narrowing of the basin in this direction, conditions are not believed to be particularly favourable.

Berthier County.

Throughout the greater part of Berthier county, conditions are unfavourable, since the formations are of Laurentian and Pre-Cambrian age, in which oil and gas in quantity never occur. An exception may be the Cambrian and Ordovician formations, which outcrop at the surface throughout the southeastern twenty miles, more or less, of the county, in which showings of gas have been reported in shallow wells, and which dip in a general way toward the southeast. These formations occur in the same belt geologically as that in which small wells were found at Louiseville and Yamachiche; but since conditions are no more favourable in Berthier county, it is believed that the wells here will be as short-lived and financially unsuccessful as the others.

Some years ago borings for natural gas were made near the villages of St. Justin and St. Barthelemi, and gas was reported in small quantities 60 to 80 feet from the surface, presumably in the Trenton limestone[1], but according to these reports, not of commercial value.

Bonaventure County.

In the western and northern parts of this county, the Silurian and a little of the Devonian formation is present, but they consist of sharp anticlines and synclines with high dips, ranging from 30° to 80°; consequently the county is not at all favourable for oil or gas in quantity, although it is just possible that small

[1]R. W. Ells, Geol. Survey Canada, Ann. Rept., Vol. II, Pt. J. 1900, p 61.

amounts may be found. Surrounding the western edge of Chaleur bay is a considerable area of trap, intrusive in the sedimentaries, and having minor dikes in the Devonian in some localities. Farther east in the county, areas of Cambrian metamorphic rocks exist.

Brome County.

The geological formations of Brome county are complicated, ranging in age from the lower Helderburg backward to the Pre-Cambrian. The region is considerably faulted, with many igneous intrusions, and rocks which contain oil or gas in other regions are generally absent. Consequently there is no chance for obtaining oil and gas in commercial quantities.

Chambly County.

The geological formation at the surface in this county consists mostly of shales and occasional thin limestones of Lorraine age. There is, however, a belt from one to three miles in width, bordering the St. Lawrence river, which is of Utica age. In the eastern part of the county is an intrusive mass, from one to two miles in diameter, of volcanic rock. While it is believed that the chances are not particularly good for either oil or gas in this county, there is no doubt that in the Trenton limestone—which occasionally contains these substances in small quantities in Ontario, and in large quantities in Ohio and Indiana—it is present beneath the whole county—there might be some chance for finding oil or gas were it not that all tests at Montreal on the opposite side of the river have been of negative result.

Champlain County.

The greater part of Champlain district consists of gneissic and granitic formations such as never contain oil or gas in quantity. A belt ranging from seven to twelve miles in width bordering the St. Lawrence river across the southeastern end of the district is of a different character, consisting of sandstones, shales and limestones, ranging in age from Potsdam, Beekmantown, Chazy, Black River, Trenton, Utica to Lorraine, and in this belt it has been supposed in the past that some chances of natural gas might exist. All the formations are of Ordovician age except the first mentioned, which is a member of the Cambrian. The dip is everywhere towards the south. The geology of this district is described in some detail by Ells [1]. As has been occasionally the case in other parts of the Province, a find of natural gas was reported in Champlain township, Champlain county, in 1899 on lot 503, but this proved to be only a surface accumulation in the drift formations underlying a bed of clay.

A well at St. Genevieve drilled several years ago is said to have reached a depth of perhaps 1800 feet, but was unsuccessful so far as oil or gas was concerned. A well drilled to a depth of about 250 feet is said to still produce a small quantity of gas, this being the only one left of several shallow wells which produced sufficient gas for individual houses.

From what is known of the stratigraphy and the geological structure, together with the insignificant results of drilling, it is not believed that either oil or gas exists in large quantity in Champlain county.

Charlevoix County.

This county is absolutely unfavourable for oil or gas, since the formations consist of crystalline rocks of Laurentian and Pre-Cambrian age, in which oil or gas are never found in quantity.

Chateauguay County.

The formations occupying the surface in the central part of Chateauguay county are entirely of Potsdam age, but in a belt from three to six miles in width along the northeastern side of the county and also in a small patch in the western end of the county the Beekmantown is present at the surface. The Chazy formation just touches the extreme northern point of the county. Since these formations are all older than rocks which claim oil or gas in commercial quantities, there is no hope of commercial results by drilling.

[1] R. W. Ells, Rept. on the Geology of the Three Rivers Map Sheet, Geol. Survey Canada, Ann. Rept., Vol. XI, Pt. J. 1900, p. 70.

Chicoutimi County.

This county is underlain by crystalline rock of Laurentian and Pre-Cambrian age, which never contains oil or gas in quantity.

Compton County.

The geological formations of Compton county range in age from Pre-Cambrian to Trenton, and include some areas of metamorphic and other areas of intruded igneous rocks. Owing to the great complications in the geology, and to the fact that the formations containing oil and gas are not at present under cover, there is no hope of oil or gas in quantity in Compton county.

Dorchester County.

The geological formations of Dorchester county are somewhat varied, ranging in age from Pre-Cambrian to Silurian, and forming belts extending in a northeast-southwest direction across the county. There are, however, some intrusive rocks, and, owing to this fact, to the general broken nature of the structure, and to their proximity to the crystalline border, it is not believed that there is any particular chance of finding oil or gas in quantity.

Drummond County.

Crossing the centre of Drummond county in a northeast-southwest direction is a region of anticlinal structure, which is bounded on the northwest, according to the Canadian Geological Survey, by an extensive fault line, and which is not far from the St. Lawrence and Champlain fault, a few miles farther northwest.

Along this anticline, the formation at the surface consists of Sillery shales and sandstones for a breadth of one to five miles. On both sides of this outcrop the Trenton and Black River limestones outcrop throughout extensive areas; while on the northwestern edge of the county, and separated by the St. Lawrence and Champlain fault, is a belt of Lorraine shales. It might be assumed that in this county the anticlinal structure would be favourable for natural gas; but owing to the presence of fault lines and to the fact that the Trenton and underlying formations occupy extensive areas at the surface, it seems rather improbable that any important field will be found.

Gaspé County.

This county is the only one in Quebec which has produced oil in commercial quantities. The geology and oil developments of Gaspé county have already been described.

Hochelaga County.

The surface formation in Hochelaga county consists almost entirely of Trenton limestone, but the Chazy outcrops in a small area west of the city of Montreal and the Utica shale touches the west side of the St. Lawrence river south of that city; all the formations have a generally moderate eastward dip. Several localities some square miles in area in this district are, however, composed of dikes of eruptive rock.

A few showings of natural gas have been reported at various times in the vicinity of Montreal, but in all cases they were of insignificant size and generally insufficient even for individual houses. Many wells in the city of Montreal have been drilled from 300 to 2,000 feet in depth entirely in the sedimentary rocks; and while good water wells have been obtained, no gas of consequence has been struck or is it to be expected. The water wells are described by O. E. LeRoy[1].

Running northwest from the volcanic neck which constitutes Mount Royal, there is a gentle anticline which might be productive were it not that other conditions are unfavourable for gas. Minor anticlines are reported in various parts of the island.

[1]Geol. Survey Canada, Ann. Rept., Vol. 14, Pt. O, 74 pp.

The wells drilled on the island were for the purpose of obtaining water, since the question of water supply on an island with a large population is of great importance. In the paper published by Adams and LeRoy[1] it is stated that 89 holes had been drilled up to the close of 1903, and the list was believed to be complete at that time. Much drilling has been done since, however. Owing to the peculiarly fissured character of the rocks in this locality, and to the presence of Mount Royal, the root of an old volcano having a great many dikes connected with it, the courses of underground waters on this island are very devious. Owing to the fact that the geology of the island is complicated, there is believed to be no prospect of finding oil or gas in quantity in this or adjoining counties.

In eleven wells the water is reported to have overflowed the surface in the past. The maximum thickness of the sedimentary rocks on the island has been estimated by the Canadian Geological Survey as at least 4,300 feet. Few detailed well records are available; but the following will suffice as an example:—

Log of Turkish Bath well at Montreal[2].

Formation	*Top Feet*	*Bottom Feet*
Pleistocene	0	50
Trenton group	50	640
Chazy	640	1425
Beekmantown	1425	1550
Total depth		1550

The depths of a few typical deep wells on the island of Montreal as given in the aforementioned report are as follows:—

A few deep Montreal water wells.

Name	*Location*	*Depth*
Turkish Bath	St. Monique St	1550
Messrs. Viau et Frère	Longue Pointe	1500
Stanley Dry Plate Company	610 Lagauchetière St	1300
Montreal Cold Storage Co	610 St. Paul St	1020
Dawes Brewing Company	Lachine	1003
Excelsior Woolen Mills	967 Ontario St	812

[1]Adams, Frank D. and LeRoy, O. E. The Artesian and other deep wells on the Island of Montreal, Ann. Rept. Geol. Survey Canada, Vol. 14, Pt. O, 1904, 74 pp., 3 plates, 6 figs.

[2]Frank D. Adams and O. E. LeRoy, Geol. Survey Canada, Ann. Rept., Vol. 14, Pt. O, 1904, p. 73.

Huntingdon County.

The formations occupying the surface in Huntingdon county are entirely of Beekmantown and Potsdam age; and since these are lower stratigraphically than any rocks which hold commercial deposits of oil and gas, there is no hope of finding the substances here in quantity.

Iberville County.

The formations at the surface in Iberville district are almost entirely of Ordovician age, and are too low in the geological scale to offer much hope of getting oil or gas below them. Moreover, no evidence of these substances is known, and the district may be considered as unfavourable.

Jacques Cartier County.

The formations underlying Jacques Cartier county consist largely of Trenton and Black River limestone; but in the western third of the county the Chazy and Beekmantown formations reach the surface. In general, it may be said that the conditions in Jacques Cartier county are very similar to what they are in Hochelaga county; and, consequently, there is no hope of finding oil or gas, except possibly very small showings of gas, suitable for supplying single residences.

Joliette County.

The greater part of Joliette county is entirely unfavourable for oil or gas in quantity, since the rocks consist largely of ancient crystalline formations of Laurentian and Pre-Cambrian age, in which oil and gas fields never occur. Crossing the southeastern end of the county there is a belt of Cambrian and Ordovician strata which is a continuation of the belt in Maskinonge and St. Maurice counties, where small gas wells were obtained. Since, however, the wells which were found in the counties mentioned were very short-lived and were failures so far as any financial result was concerned, there appears to be no wisdom in drilling wells for oil or gas in Joliette county.

Kamouraska County.

The formations occupying the surface in Kamouraska county are largely, or entirely, of Cambrian and lower Ordovician age. It is probable, in view of the fact that this county occupies the whole width of the St. Lawrence basin, which is only about forty miles here—being nearly at its narrowest portion—that there is little chance of oil or gas in quantity.

Labelle County.

The conditions in Labelle county are entirely unfavourable for oil or gas; the formations are largely of Laurentian and similar ancient crystalline rocks, and are, therefore, unfavourable for oil or gas.

Lake St. John County.

This county is underlain throughout by crystalline rocks of Laurentian and Pre-Cambrian age, which never contain oil or gas in quantity.

Laprairie County.

The formations occupying the surface in Laprairie county range in age from the Lorraine shales downward to the Beekmantown, the dip being generally toward the northeast. Like the rest of the St. Lawrence valley, this county is not particularly favourable; and particularly as the Trenton formation, which is the lowest known formation producing oil or gas in large quantities, outcrops in a belt across the centre of the county. It is improbable that anything more than showings of oil and gas will be found. The thickness of the formations in this locality is very great, as shown by the fact that a well at Laprairie reached a depth of 2,700 feet, and did not pass out of the sedimentary rocks.

L'Assomption County.

The formation throughout the central part of this county consists of limestone of Trenton and Black River age. There is, however, an area of perhaps sixty square miles on the eastern side of the county, which is Utica shale; and in the extreme western corner of the county there is a belt of Potsdam, Beekmantown and Chazy rocks bordering the Laurentian rocks to the west. Owing to the fact that the formations which might contain oil or gas outcrop within the county, and, consequently, that the substances must have leaked away, it is improbable that anything more than showings will ever be found in L'Assomption county. In the southwestern corner of the county also is as area of crystalline rock less than ten square miles in area.

Laval County.

The formations underlying the central part of Laval county are of Chazy age; while in the northern and eastern borders and in a small patch on the southern border they consist of the Trenton and Black River limestones, and are in a small patch on the southwestern edge of the Beekmantown. The conditions in Laval county are in general similar to those of Hochelaga county, and, consequently, no oil or gas should be expected in quantity.

Levis County.

The formation forming the surface in Levis county is of Cambrian and Ordovician age, and the sediments are of considerable thickness; but, owing to their proximity to the crystalline border, and to other unfavourable features, it is not believed that anything more than showings of gas will be found in this county.

L'Islet County.

The formations occupying the surface in L'Islet county are largely or entirely of Cambrian and lower Ordovician age.

It is probable, in view of the fact that this county occupies the whole width of the St. Lawrence basin, which is only about forty miles here—being nearly at its narrowest portion—that there is little chance of oil or gas in quantity.

Lotbinière County.

Lotbinière county is situated in the St. Lawrence basin in the belt which has been predicted occasionally by geologists as probably favourable for oil or gas fields. The formations are of the anticlinal and synclinal structure to a certain extent and are of Cambrian, Ordovician and Silurian age, having in some places the Trenton under cover. Since this formation contains oil and gas in quantity in the United States, there is a chance of pools existing; but, judging from the unsuccessful prospecting which has been done in fully as favourable territory in other counties in the vicinity and in Ontario, it is not believed that there is much chance in Lotbinière county.

Maskinongé County.

The greater part of this district is absolutely worthless for oil or gas since it consists of granitic and gneissic rocks of Pre-Cambrian and Laurentian age, in which neither oil nor gas ever exists. Along the southeastern edge of the county, however, is a belt ten to twelve miles wide, in which the surface rocks consist of sedimentaries ranging from Cambrian to Lorraine age, and which might be supposed favourable for gas, but which are presumably too shallow and too near the border of the basin to contain any large amount.

In the early eighties, following the discovery of gas at St. Maurice, four wells 500 to 600 feet in depth were drilled at Louiseville.

Mr. William Bell, manager of the Wallace-Bell Company of Montreal, states that the depth of the wells drilled by his company about twenty-nine years ago at Louiseville were as follows: No. 1, 550 feet; No. 2, 300; No. 3, 660; No. 4. 340 feet. Some gas was found in all of the wells, but was not worth piping for the town.

In 1906 and 1907, several wells were bored in the vicinity of Louiseville and Yamachiche by the Canadian Gas and Oil Company. What was supposed to be a good flow of gas was struck in superficial deposits at depths of 225 to 300 feet, and pipe lines were laid to supply the aforementioned towns, with an additional 8-inch line to the city of Three Rivers in St. Maurice county, thirteen miles distant. The prediction had already been made by Mr. Obalski, Superintendent of Mines for the province of Quebec, in his report of the same year, that the gas, being in superficial deposits, would be of short duration; and his prediction was fulfilled when the supply became practically exhausted in a few months. Further boring operations were undertaken in the vicinity, but with little result.

Some years ago borings for natural gas were made near the villages of St. Justin and St. Barthelemi. Gas is reported to have been found in small quantities at depths from 60 to 80 feet from the surface, being presumably in the Trenton limestone[1].

Megantic County.

The formations occupying the surface in Megantic county range in age from Ordovician to Pre-Cambrian; but conditions are rather complicated, and there is no hope of finding any deposits of oil or gas in quantity.

Missisquoi County.

The formations outcropping in this county are in age Utica and Trenton, west of the St. Lawrence and Champlain fault, and are Trenton, Chazy, Cambrian and Pre-Cambrian throughout the remainder of the county. The geological structure is rather complicated, and being without much cover and so near the crystalline outcrop, there is very little, if any, chance for oil or gas in commercial quantity.

Montcalm County.

Conditions in Montcalm county are entirely unfavourable for oil and gas, because the rocks are largely of Laurentian

[1]R. W. Ells, Geol. Survey, Canada, Ann. Rept., Vol. 11, Pt. J. 1900, p. 61.

and Pre-Cambrian age, which are hard and never contain oil or gas in quantity. The Cambrian and Ordovician strata cross the extreme southeastern end of the county, but not with sufficient thickness or structure for holding important deposits of oil or gas.

Montmagny County.

The Cambrian and Ordovician formations are the principal ones occurring in this county, but there is a little Pre-Cambrian. Owing to the narrowing of the basin in this locality and to the general age of the rocks being earlier than common oil and gas bearing formations, there is no hope of finding oil or gas in this county. Moreover, some years ago, eight dry holes were drilled in the St. Lawrence basin, reported about forty miles east of Quebec. It is probable that they were in this county or in its immediate vicinity, in the same geological belt.

Montmorency County.

Montmorency county, like the other counties on the north side of the St. Lawrence, is unfavourable for oil or gas in quantity. The greater part of the county consists of crystalline strata of Laurentian and Pre-Cambrian age, and the area of Ordovician strata along the river is so narrow that nothing can be expected of it.

Napierville County.

This county occupies a rather central portion of the St. Lawrence basin, and the formations at the surface consist from north to south of the Trenton, Chazy and Beekmantown rocks, with a small area of Potsdam sandstone touching the eastern edge of the county. A fault of some prominence also crosses the eastern corner of the county and owing to this fact, and the fact that the formations which commonly claim oil and gas elsewhere are absent, there is presumably no chance for these substances in quantity in this county.

Nicolet County.

The geological formations of Nicolet county consist largely of Lorraine shale with their accompanying thin limestones, except in several belts occupying rather central localities in the county, where Medina shales form the surface. In the extreme southern corner of the county, south and east of St. Leonard Junction, is an area of perhaps fifty square miles of Trenton and Black River limestones. This area is separated from the remainder of the county by the St. Lawrence and Champlain fault, which extends in a northeasterly direction. On the extreme eastern edge of the portion of the county which lies east of St. Leonard Junction is another fault, beyond which lie the Sillery slates, sandstones and conglomerates.

A small quantity of gas was found in the year 1885 at St. Gregoire in Nicolet county, in a well which was drilled to a depth of 1,115 feet on the Hilaire Trudel farm, lot 501 of the cadastre[1].

The flow of this well was estimated by Mr. Obalski in his report for 1885, to be 250,000 cubic feet per day. The well was still flowing in 1887.

The following is the log of the formations reported:—

[1]Theo. Denis, Rept. on Mining Operations in the Province of Quebec, during 1910. Dept of Colonization, Mines and Fisheries, Mines Branch, pp. 71-72.

Log of well near St. Gregoire[1].

Material.	Formation.	Top. Feet.	Bottom. Feet.
Surface	Pleistocene (?)		
Clay		0	48
White sand		48	53
Heavy gravel (gas and water)		53	68
Black sand (water)		68	75
Hard sandstone	Medina (?)	75	155
Harder, fine grained sandstone		155	215
Red shale		215	290
Red shale		290	300
Nearly black shale		300	316
Dark brown schist (show of gas)		316	370
Red shale (more gas)		370	475
Red schists		475	525
Softer red schists		525	580
Gas in red shale	Hudson River (?)	580	640
Dirty lime		640	660
Calcareous rock		660	720
Calcareous oily rock		720	820
Black schist (show of gas)		820	860
Compact black schist		860	1,115
(Gas)		....	1,115
Total depth	....	....	1,115

Some other drilling was done in Nicolet county years ago. In a more recent boring made at St. Gregoire, in 1899, very salty water was found at 605 feet, but no gas in economic quantity. The borings in this and other counties on the southern side of the St. Lawrence river were described in 1887 by La Flamme[2].

It has been assumed by many geologists that there were good prospects for gas in the Deschambault anticline, which is supposed to extend in a northeast-southwest direction through this part of the Province; but since large deposits of natural gas, seldom, if ever, occur in the vicinity of fault lines, the prospects are rather problematical. If oil or gas exist, they would seem to be more probably present in regions of gentle warping in the basin rocks some miles northwest of these faults.

[1]Selwyn, Geol. Survey Canada, Vol. 3, Pt. A, 1887-88, p. 33-34.
[2]Transactions Roy. Soc. Canada, Vol. 6, 1887.

Pontiac County.

No deposits of oil or gas should be expected in Pontiac county, since the conditions are entirely unfavourable, the rocks consisting of the Laurentian and similar hard formations.

On Allumette island, Que., directly north of the town of Pembroke, and entering the adjacent part of Ontario on the east, there is a small area underlain by Beekmantown, Chazy, Black River and Trenton formations, one hundred square miles in area; but this is not extensive enough to be important as a possible oil or gas producing area.

Portneuf County.

The greater part of this county is absolutely unfavourable for oil or gas, since the formations in its northern part are hard and crystalline and almost entirely of Laurentian age—not being suitable for oil or gas. Along the southern edge of the county is a belt some miles in width, which consists of Ordovician strata; and in this belt, some showings of gas have been found in shallow wells. It is not believed that anything better will be found than the showings already made.

Several low and narrow anticlinal ridges exist in the southern part of the county, and the Utica shales are impregnated with oil; but since the anticlines are rather sharp, and since the formation is in general synclinal, it is improbable that any large amount of oil or gas exists.

Pointe aux Trembles, Portneuf County. Reports have crept into print at various times regarding oil near Pointe aux Trembles.. It is extremely improbable, however, that any oil of importance occurs in this locality, since the Utica shales and underlying limestones form a synclinal basin with only a few low and narrow anticlinal ridges, which are too near the Archæan outcrop to offer any probabilities.

Quebec County.

The greater part of Quebec county, like other counties on the north side of the St. Lawrence river, is absolutely unfavourable for oil or gas, since the formations, largely of Laurentian age, are hard and crystalline. The Ordovician strata just touch the southeastern corner of the county, around the city of Quebec; but these are so near the crystalline border as to be unfavourable.

Richelieu County.

The geological formations immediately underlying the surface drift in Richelieu county consist almost entirely of Lorraine shales and limestones.

The geological structure in parts of the county has been considered by many geologists of the Canadian Geological Survey as favourable for gas, along the line indicated by Sir W. E. Logan many years ago as a course of the Deschambault anticline.

Several years ago the Quebec Fuel Company drilled a well in this county to a depth of 2,950 feet, but without success.

Richmond County.

The geological formations occupying the surface in Richmond county are very complicated, ranging in age from Trenton to Pre-Cambrian; and since the region is much faulted, having high dips and some intrusions of igneous rock, there is no chance for oil or gas in quantity in the county.

Rimouski County.

There is a possibility of some oil or gas being found in this county, but it is improbable that pools of any value will be developed. The county is crossed by Cambrian rocks in a belt about fifteen miles wide along the northwestern side, and by a belt of two to ten miles of Pre-Cambrian through its centre, while the southeastern half of the county consists of Devonian and Silurian rocks. The formations are much disturbed and warped into steep anticlines and synclines, having prominent dips, frequently as high as 45° to 90°; but in a few instances as low as 5° to 15°.

Rouville County.

Although Rouville county lies in an extension of the belt which has been considered in the past as favourable for the occurrence of oil and gas, there is believed to be little chance for commercial results within it. The formation occupying the surface throughout the greater part of the county is of Lorraine age, so that the Trenton limestone, which contains oil and gas in some parts of the county, is largely under cover; but nevertheless this formation outcrops on the eastern side of the St. Lawrence and Champlain fault, which crosses the county about five miles from its extreme eastern end, and owing to this fact, and to four intrusions of volcanic rock several square miles in area, the conditions do not appear particularly favourable. There is some chance of small gas wells being obtained. An area of about fifteen square miles in the eastern part of the county consists of Sillery slates and sandstones of Cambrian age.

It is reported that showings of oil were found at St. Paul d'Abbotshood in 1908.

Saguenay County.

This county is underlain throughout by Laurentian and similar crystalline rocks, which are entirely unfavourable for holding oil or gas, and is not worth consideration.

Shefford County.

The geological formations occupying the surface in Shefford county range from Trenton and Black River limestone, which occur in belts running in a northeast-southwest direction across the centre of the county, to Cambrian and Pre-Cambrian formations which occupy most of the remaining portions. The rocks in this county are much faulted and intruded by several igneous masses, and altogether conditions are extremely unfavourable.

Sherbrooke County.

The geology of Sherbrooke county is rather complicated, the hard rock formations consisting of Ordovician, Cambrian, and Pre-Cambrian rocks. Owing to the structural complications produced by intrusions of igneous masses, and to the fact that formations which commonly contain oil or gas are not under cover here, there is no chance for oil or gas in quantity in Sherbrooke county.

Soulanges County.

The formation occupying more than half of the surface in this county is of Potsdam age. There is, however, a considerable area of Beekmantown strata in the southwestern corner of the county; consequently, the formations are earlier than those which commonly claim oil and gas elsewhere, and no results should be expected.

St. Hyacinthe County.

The geological formation in this county consists largely of shales and limestones of Lorraine age, immediately underlying the surface drift everywhere. The geological structure in parts of this county has been considered by many geologists of the Canadian Geological Survey as favourable for gas, along the line indicated by Sir W. E. Logan many years ago as a course of the Deschambault anticline, but few favourable results are reported.

Small amounts of gas are reported to have been found at St. Barnabé in this county in 1910. In the same year, a well was drilled six miles northeast of the town of St. Hyacinthe on the farm of Joseph Fontaine, St. Amable range north, cadastral division 164, the depth of the well being 1880 feet. The reported log is as follows:—

Log of well drilled at St. Hyacinthe.

Material	Formation	Top Feet	Bottom Feet
Surface deposits	Pleistocene	0	125
Reddish, slightly calcareous shales	Medina (?)	125	900
Dark grey calcareous shales	Hudson River (?)	900	1860
Harder rock (show of gas)	Hudson River (?)	1860	1865
Dark shaley rock	Hudson River (?)	1865	1880
Total			1880

The well is supposed to have penetrated the Medina formation and passed almost to the base of the Lorraine shales, but not to have reached the Trenton limestone, which may be expected about 200 feet deeper. The rock pressure of this well, as reported[1] by the Mines Branch of the Province of Quebec, measured 275 pounds per square inch four months after the well was drilled.[2]

St. Johns County.

This county, like the adjacent ones, is not favourable for oil or gas. An important fault line crosses it from north to south, the rocks on the eastern side consisting of Utica shales, while to the west they are of Trenton, Chazy, Beekmantown and Potsdam age. Owing to the fact that no formation is under cover here which commonly contains oil or gas in other fields, there is no chance for commercial results by drilling in this county.

St. Maurice County.

Natural gas in small quantities was discovered many years ago in the vicinity of Louiseville. The first attempt to procure gas for commercial usage was made in 1880, when a well was sunk near Saint Maurice to a depth of 50 feet, without gas being found. In 1883 a strong flow of gas was obtained at a depth of some 70 feet, and in 1885 a company was organized and a well sunk at a depth of 1,115 feet. A fair quantity of gas was obtained from different depths, as shown in the following log:—

Record of well in St. Maurice County[3].

Top	*Bottom*	
0	75	Clay and sand, with some veins of inodorous gas and water.
75	215	Sandstone, somewhat calcareous.
215	640	Red and brown schists, soft, with abundant emanations of gas having the odour of kerosene at 316, 370, 580, 640 feet, the 580 feet vein being most productive.
640	820	Impure limestone, oily beneath; a vein of gas at 820 feet.
820	1115	Black, compact schist.

[1]Theo. Denis, Mining Operations in Province of Quebec during 1910, Dept. of Colonization, Mines and Fisheries, Mines Branch, P.Q., p. 73.
[2]A measurement taken 8 months later is reported to have shown a pressure of 426 pounds. A.W.G.W.
[3]Min. Res. U.S., 1887, pp. 501-2.

In the years 1906-1907, boring was undertaken in the vicinity of Yamachiche and Louiseville in this county and in Maskinonge county by the Canadian Oil and Gas Company. What was supposed to be a satisfactory supply of gas was encountered at depths of 225 to 300 feet in the superficial deposits. In 1907, the Company had a dozen producing wells and several pipe lines. There was a two-inch line 2 miles in length to St. Barnabé, a 7½ mile pipe line 3 inches in size to Yamachiche, and a 9½ mile pipe line 4 inches in size to Louiseville. The Three Rivers line was 13 miles long and 8 inches in size.

The price charged for the gas in Three Rivers while the supply lasted was 20 cents per thousand cubic feet for public buildings; 25 cents for factories; and 30 cents for residences. Thirteen producing wells in that field are reported to have struck gas in commercial quantities. The wells were six inches in diameter and obtained gas at a depth of 225 to 300 feet, presumably in the Lorraine formation. A dry hole was drilled on the Yamachiche river, north of St. Barnabé, which passed through 50 feet of Trenton limestone and then 200 feet of sandstone into the Laurentian gneiss.

The pipe line to Three Rivers was completed in the summer of 1907. The old gas company was bought out and pipes for natural gas were laid in the streets. The gas is reported to have been non-sulphurous.

At various localities in this and adjacent counties, wells 2 inches in size are bored at private houses and supply small amounts of gas.

In the early part of 1907 there were 80,000 to 100,000 cubic feet of gas per day being supplied from the St. Barnabé field. In addition, a well two miles northwest of Three Rivers, reported to be 1,200 feet in depth, supplied some gas with 50 pounds per square inch pressure. The pipe line from St. Barnabé to Three Rivers has now been taken up, but some individual families at Yamachiche and St. Barnabé still have sufficient gas for their own use. The prediction had already been made by the Superintendent of Mines for the Province of Quebec that the gas, being in superficial deposits, would not be lasting; and this prediction was fulfilled when the supply became exhausted in a very few months.

Stanstead County.

The formations occupying the surface in this county range in age from lower Helderburg downward through the Trenton, Cambrian and Pre-Cambrian formations to the Huronian. The geological structure is complicated, much broken up and intruded by igneous masses, and there appears to be no chance for oil or gas in quantity.

Temiscouata County.

The formations forming the surface under the drift in Temiscouata county are by Cambrian, Ordovician and Silurian age; and the St. Lawrence basin is at this locality considerably wider than it is in the counties immediately to the southwest. This county is not believed to be particularly favourable for the occurrence of oil or gas pools; but there is no positive evidence to the contrary.

Terrebonne County.

The northwestern two-thirds of Terrebonne county is underlain almost entirely by Laurentian gneiss and anorthosites, in which oil and gas never exist. The southeastern third of the county is crossed successively in passing from northwest to southeast, by sedimentary formations of Potsdam, Beekmantown, Chazy and Trenton age. These are all so near the base of the geological series, and the entire county is so close to the outcrops, that there appears no chance for oil or gas of commercial quantity within this county.

Two Mountains County.

This county also appears to be unfavourable, although the geology is rather varied. In the northwestern corner beyond the Canadian Northern railway, the formation consists entirely of Laurentian crystalline rocks and associated anorthosites. In the southern corner of Two Mountains county, bordering the lake, is an eruptive mass six miles in diameter consisting of syenite and associated rocks. Along the northeastern side is a large area of Beekmantown rocks, which also outcrop in another area in the centre of the west side. Most of the remaining areas, occupying in general the central portions, consist at the surface of Potsdam sandstone. It will be noted that most of the formations which commonly contain oil or gas in quantity are absent, consequently nothing should be expected of this county.

Vaudreuil County.

Vaudreuil county is likewise rather unfavourable, and it is probable that no extended deposits of oil or gas will ever be found in it. The formation occupying the surface in the eastern half of this county is entirely Potsdam sandstone. In the western part of the county the geology is more varied, there being in its central portions a mass of syenite and associated igneous rocks about twenty square miles in area, northwest of which, occupying the northwestern part of the county, are outcrops of Beekmantown and Chazy age. The remaining portions of the county consist mainly of Potsdam sandstone.

Verchères County.

This county has been considered as rather favourable for oil and gas occurrences, and may be worth further testing. The formations underlying the surface drift consist largely of Lorraine shales and limestone; but in a strip sometimes as much as four miles in width along the St. Lawrence river, the Utica shales are exposed at the surface. Several years ago the Quebec Fuel Company drilled two wells in this county to reported depths of 2,450 and 2,300 feet respectively. Small amounts of gas are reported, with a rock pressure of 250 pounds per square inch, but this report has not been verified.

Wolfe County.

The geological formations of Wolfe county are very complicated, ranging in age from Pre-Cambrian to Trenton, and including some intrusions of igneous rock; consequently, there is no chance of finding commercial deposits of oil or gas.

Wright County.

Conditions in Wright county are entirely unfavourable for the occurrence of oil or gas in any quantity, for the reason that the rocks are mostly Laurentian and crystalline in character, which never contain oil or gas, except where the Ordovician strata touch the extreme southern end of the county, northwest of Ottawa.

Yamaska County.[1]

The geological formations which outcrop in Yamaska county are the Lorraine and Medina. The Lorraine consists of greyish sandy shales and shaly sandstones with occasional thin bands of dolomitic limestone. Near the St. Lawrence the strata lie in a nearly horizontal position, but in the southeastern part of the county they are affected by several faults and folds, and some of the strata stand at high angles. The breadth of the formation is about 16 miles. Two small areas of reddish sandy shales, and sandstones, classed as Medina, occur within the borders of the county. These deposits apparently rest conformably upon the underlying Lorraine.

The Champlain fault probably crosses the southeast corner of the county.

The underlying formations, Utica and Trenton, do not appear to outcrop within the county, though they occur in adjacent counties.

No records of trial borings in this county are available. A small quantity of gas was found in one well in Nicolet county, to the north.[2] The results of recent geological studies in this district are not available, and may be such as to discount the following suggestion. The earlier geological maps suggest the existence of a low anticlinal structure about the middle of the county. An exploratory well located somewhere on a line passing north and south about midway between St. Elphége and St. Zéphirin, and sunk to tbe Trenton, might well be worth while.

[1] Written by A. W. G. Wilson.
[2] See this volume, page 85.

CHAPTER V

PROVINCE OF ONTARIO

GEOLOGY[1]

Description of Geological Formations

The Pre-Cambrian crystalline rocks of Ontario cover much of the territory north of the main line of the Canadian Pacific railway and north of Lakes Huron and Superior, extending to beyond the Hudson bay divide South of the Canadian Pacific railway in the older settled part of the province there is also a considerable area of Pre-Cambrian rocks, which extends as far south as a line running between Georgian bay and Kingston. South of this line the Ontario lowland and the peninsula between Lakes Erie and Huron are occupied by sedimentary rocks, all belonging to Palæozoic horizons. East of Kingston a spur from the main area of crystalline rocks to the north crosses the St. Lawrence river and connects with the area of similar rocks in the Adirondacks. The basin of the Ottawa river as far northwest as Calumet island, is also occupied by Palæozoic sedimentary rocks. East of a line between Brockville and Ottawa the whole width of the province is covered by the same rocks, which extend eastward beyond the provincial boundaries and underlie the St. Lawrence plain in the province of Quebec. North of the Hudson bay divide, in the basin of the Moose river, Palæozoic rocks also occupy a considerable area, having a general gentle inclination towards Hudson bay. There are thus three sedimentary basins in Ontario, the Ottawa valley and St. Lawrence basin, the Ontario-Erie-Huron basin, and the Hudson bay basin. The following is a summary of the geological formations of Ontario with a statement of their minimum and maximum thicknesses and probable average thickness:—

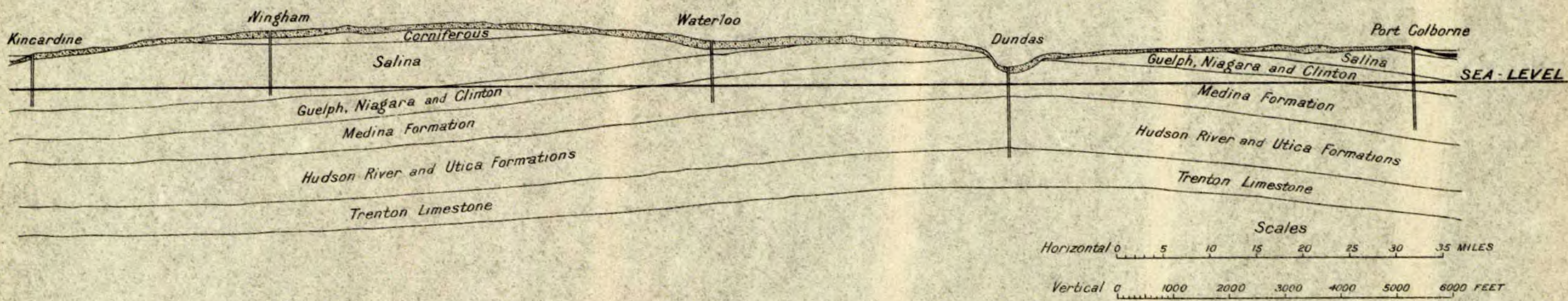
[1]By Alfred W. G. Wilson.

Geological Formations in Ontario[1].

Period.	Formation.	Thickness.		
		Minimum	Maximum.	Average.
	Pleistocene (drift)......	0	150	50
Devonian....	Portage and Chemung (Genessee).	25	200	100
	Hamilton..........	150	350	250
	Onondaga..........	160	300	230
	Oriskany..........	6	25	15
	Monroe............	500	900	
	Salina............	300	1600	1000
	Guelph............	140	160	150
Silurian.....	Niagara...........	100	130	115
	Clinton...........	30	150	90
	Medina............			
	Cataract..........	60	400	300
	Lorraine..........	100	400	300
	Utica.............	150	400	300
	Collingwood........			
Ordovician..	Trenton...........	600	750	675
	Black River........			
	Chazy.............	0	150	50
	Beekmantown......	0	300	100
Cambrian...	Potsdam...........	300	700	400
Pre-Cambrian				

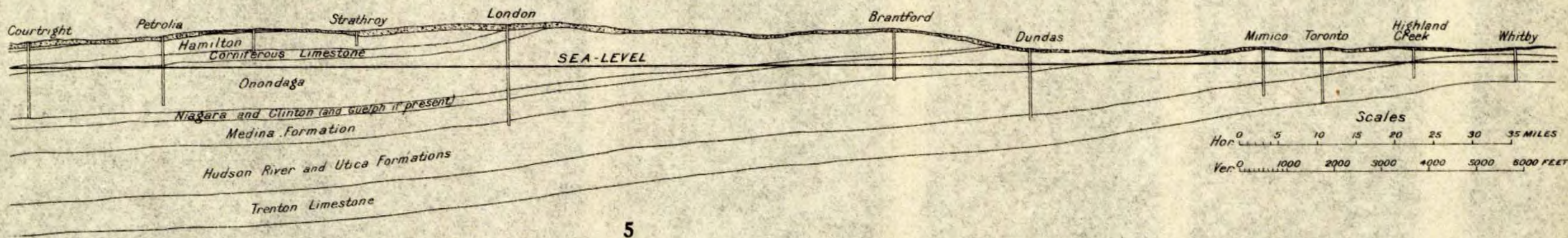
The average total thickness of these formations, all of which belong in the Palæozoic system, may be about 4,000 feet. Descriptions of the sedimentary formations in the older part of the province follow in ascending geological order.

[1]Table of formations by F. G. Clapp.



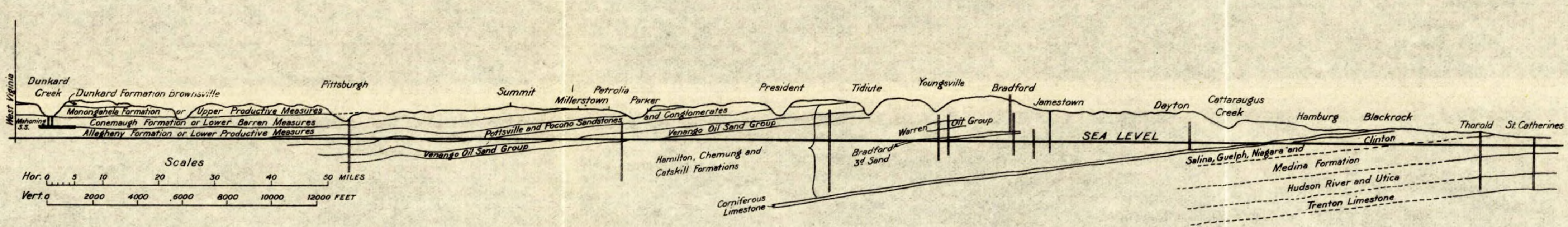
4

Fig. [redacted]. Section from Port Colborne to Kincardine, Ontario. (After Brumell)



5

Fig. [redacted] Section from Whitby to Courtright, Ontario.



6
Fig. [redacted] Section from Eastern Ontario through Pennsylvania.

Potsdam sandstone.—The Potsdam sandstone consists largely of hard grey, or sometimes reddish sandstone. It takes its name from the town of Potsdam in northeastern New York state where it occurs and was first described. The Potsdam is believed to underlie all of the latter sedimentary formations of southern Ontario. It outcrops in the Ottawa-St. Lawrence basin in a belt along the border of the Laurentian area in Frontenac, Leeds, Lanark, and Carleton counties, and is also exposed in the vicinity of the Thousand Islands and northwest of Kingston. A though its total thickness cannot be stated with certainty, it appears to run from 300 to 700 feet.

Beekmantown formation.—The name Beekmantown is derived from the type occurrence of this formation at Beekmantown in New York state. The formation was formerly called Calciferous from the general calcareous character of the rocks. The formation does not occur extensively in Ontario but it is known to outcrop between Brockville and Ottawa in the counties of Leeds, Grenville, Lanark, Carleton, and Russell. It is largely a bluish grey magnesium limestone and varies in thickness up to 300 feet.

Chazy formation.—This formation is named from a town of the same name in New York state. Although not important in Ontario, it occurs below Pembroke in the basin between the Ottawa and the St. Lawrence rivers. Small outliers also occur elsewhere. Its thickness runs as high as 150 feet and it consists of greyish limestones, sandstones, and shales.

Black River formation.—This formation, although separate from the Birdseye in New York state, appears to be identical with it in Ontario. The Black River was named from a stream of the same name in northern New York state where the formation is well developed. The formation as developed in Ontario, varies in thickness from 150 to 200 feet. It consists of bluish and dark grey, bituminous limestones with interstratified shales. The formation is well developed around Kingston, and northwest along the edge of the Palæozoic escarpment to Georgian bay. It also occurs in patches in the Ottawa valley in the counties of Russell, Stormont, and Carleton, and along the north channel of Lake Huron.

Trenton formation.—The Trenton limestone is one of th most important formations in Ontario so far as petroleum an natural gas are concerned. The name of the formation is taken from Trenton in New York state. The formation underlies the whole of southern Ontario and outcrops farther north in a broad belt between Georgian bay and Lake Ontario, extending from Matchedash bay to Collingwood harbour on the west, and from Newcastle to Amherst island on the east. In Carleton county there is an outlying geological basin in which the Trenton is the uppermost rock. The principal parts of the limestone cliffs at Ottawa are of Trenton limestone. In the Ontario-Huron basin the Trenton limestone dips southwest at a moderate rate and passes beneath Lake Erie. Its total thickness is about 600 feet. In character the Trenton is a fossiliferous bituminous limestone generally of a dark grey colour, and it is interstratified occasionally with bituminous shales.

Utica formation.—Overlying the Trenton limestone occurs about 100 feet of black bituminous shale known as the Utica formation, named from Utica, New York, where it is typically developed. This shale is believed to have composed the original cover which held the oil and gas in the Trenton limestone. In Ontario the Utica shale outcrops in the northern part of Grand Manitoulin island and on the south side of Clapperton island. It also is well exposed west of Collingwood harbour, from whence the formation trends southeast toward Lake Ontario, outcropping again between Whitby and Newcastle. Utica shales also occur in the Ottawa valley in small areas around the city of Ottawa.

Lorraine formation.—Succeeding the Utica there are about 700 feet of bluish or drab shales interbedded with calcareous and arenaceous bands which constitute the Lorraine shales. This formation outcrops in northern Manitoulin island on the southwest side of Georgian bay and extends southeast, widening toward Lake Ontario, where it outcrops at a few points on the lake shore between Port Credit and Pickering, and northwest of Toronto along the Humber river. An outlier of this formation outcrops in Carleton and Russell counties in the Ottawa valley.

Medina formation.—A formation of some importance as regards the oil and gas which it contains is the Medina, named from a city of that name in New York state. It consists of red and green shales interbedded with several layers of light grey to reddish sandstone and capped by a bed of light coloured sandstone known as the "grey band." The Medina formation outcrops on the southwest side of Georgian bay and increases in thickness southward towards Lake Ontario. The thickness ranges from 200 to 600 feet, being greatest near the shore of Lake Ontario, where it extends from Dundas to the Niagara river. This formation contains the upper and lower Medina sands of the well drillers known as the White and Red Medina respectively.

Clinton formation.—Although this formation as developed in Ontario is of importance for the oil and gas which it contains, there is no certainty that it is identical with the Clinton sandstone which is productive of oil in Ohio; the latter is believed to correspond with one of the Medina sands. The true Clinton formation outcropping in Ontario is named from Clinton county, New York, and consists of green and drab-grey shale, with thin limestone beds, totalling 80 to 180 feet in thickness. The formation contains a very ferruginous red band, being the Clinton iron-ore bed of New York and other localities. The outcrop of the Clinton extends through the centre of Manitoulin island, along the southwest side of Georgian bay and south along the Niagara escarpment to the head of Lake Ontario, from where it runs east along the base of the escarpment to the Niagara river.

Niagara formation.—Overlying the Clinton is the Niagara; this is the principal formation outcropping at Niagara Falls, and is one of the most important formations in Ontario. It extends through the Manitoulin islands, and the Bruce peninsula, across Central Ontario to Hamilton and through Niagara peninsula to New York state, lying near the crest of the escarpment which runs between the Bruce peninsula and Niagara. Its thickness varies from 240 feet at Hamilton to about 450 feet on Manitoulin island. This formation decreases in thickness towards the south and east, while the underlying formations increase in thickness; except in the vicinity of the Niagara river, the formation is composed almost entirely of dolomite. It is crystalline and of a light grey to dark grey colour. Topographically the Niagara is one of the most important formations in Ontario on account of the development of its prominent escarpment extending across Ontario from west of Collingwood south to Hamilton and east to the Niagara river. This limestone forms the upper part of the Blue mountains, and the upper part of Niagara Falls. At Niagara, however, the limestone composes only 164 feet of the formation, while the lower 80 feet consists of shale.

Guelph formation.—The Guelph formation is named from the city of Guelph in Ontario. Its maximum thickness is about 160 feet, in the central part of the western peninsula, and it diminishes in thickness toward the Niagara river and toward Manitoulin island. It consists of buff to grey granular dolomite, which is sometimes bituminous and even crystalline.

Salina formation.—The Salina formation contains the great salt deposits of Ontario and Ohio. Where exposed at the surface it consists mainly of thin bedded dolomites, pale grey or yellowish coloured, and greenish calcareo-argillaceous shales with some reddish layers. On the east shore of Lake Huron this formation outcrops infrequently between Goderich and the mouth of the Saugeen river from which it turns east and south "rounding the northern end of a wide syncline between Southampton and the head of Owen Sound and running thence southeasterly to the Grand river, from which it takes an easterly course to the Niagara."[1] The thickness of the Salina formation ranges from about 300 feet at Niagara Falls to 508 feet at Kincardine and 775 feet at Goderich. The lower part of the formation contains great deposits of gypsum and rock salt, the latter furnishing the salt in the wells drilled at Kincardine, Wingham, Blyth, Clinton, Goderich, Exeter, and Seaforth. The salt ranges from grey to white in colour. The salt of the Salina formation constitutes one of the most valuable mineral resources of southwestern Ontario. The gypsum contained in this same formation outcrops in some places along the banks

[1]Probably some beds belonging to the Monroe are here included.

of the Grand river. The same formation probably occurs in the Moose River basin, because gypsum beds are exposed on the banks of the river which are from 10 to 20 feet in height. Gypsum also outcrops east of the Abitibi river near mile 276 on the Ontario-Quebec boundary.

Monroe formation[1].—The Monroe formation, which is a marine series of sediments that succeeded the Salina, does not cover a very large surface area in Ontario. In the southwestern part of Essex county, immediately beneath a dolomitic limestone carrying an Onondaga fauna, is a bed of high grade limestone followed by brown dolomites. These beds have been correlated with the upper Monroe of the adjacent state of Michigan. Other rocks which possibly belong to this formation occur along the Lake Huron shore in the vicinity of Goderich and northward. The total area exposed at the surface is small. These rocks, however, are probably encountered in drilling wells. So far as the well records are concerned they do not appear to have been distinguished from the underlying Salina.

Oriskany formation.—The Oriskany formation, the lowest in the Devonian system, is represented in Ontario by about 25 feet of grey and brown sandstones. It outcrops in various places between the township of Windham and the Niagara river.

Onondaga formation.—This formation is one of the most important in Ontario as regards the occurrence of oil and gas deposits. It was formerly known as the Corniferous, deriving its name from the occurrence of nodular masses of chert or hornstone, which it frequently contains. The Onondaga formation outcrops at several points on the shore of Lake Erie between the mouth of the Niagara river and Port Rowan, and isolated areas occur farther west in Essex county. The base of the formation extends northeast from near Goderich to Greenock township, where it curves around the north end of a wide syncline, and then takes a southerly course to Burford township, and then strikes eastward to Bertie township. The Onondaga in western Ontario consists chiefly of grey bituminous limestone

[1]The geology of Western Ontario has recently been revised by officers of the Geological Survey, but the results of the field work are not yet published. The surface distribution of this formation and the other associated formations above and below, has all been re-mapped, and this work clears up many previously obscure points in the geology of the Ontario peninsula.

beds, characterized by the occurrence of large numbers of silicified fossils, some of them in masses of considerable size. The thickness of the Onondaga formation, as shown by well records, ranges from 209 feet, one mile southwest of Belle River, to 310 feet at Leamington, 320 feet at Port Lambton and 248 feet to 378 feet at Petrolia. Owing to the uncertainties existing in all well records, it is not possible, however, to draw a definite line in the records between the base of the Onondaga limestone and the top of the Oriskany formation. The oil in the Enniskillen field is derived from the Onondaga limestone.

It is interesting to note that in the extreme northern part of Ontario in the region southwest of James bay, the Onondaga formation outcrops at a number of points throughout an area greater than all the western peninsula of Ontario. The outcrops in that region consist mostly of porous and cavernous grey fossiliferous limestone which rest directly upon the Archæan. No oil deposits have, however, been discovered in this region in the vicinity of James bay with the exception of a few seepages.

Hamilton formation.—The Hamilton formation is named after the city of Hamilton in the state of New York. It consists of bluish and greyish calcareous shales (called soapstone by the well drillers) with occasional thin limestones and sandy beds. The estimated thickness of the Hamilton formation in Ontario is about 350 feet.

Chemung formation.—The Chemung formation of New York state is represented in Ontario only by a few feet of black bituminous shales which occur in southern Huron and northern Lambton counties. This formation is immensely more important in the oilfields of the United States and is sometimes several hundred feet in thickness.

Pleistocene formations (*superficial*)[1].—The superficial formations are those which consist of unconsolidated clays, sands, marls and gravels deposited sometimes in the stratified form and sometimes as heterogenous mixtures, overlying the bedrock and forming the loose surface soil. These formations include what is commonly termed "the drift" which was deposited during the great ice age by the ice sheets which once covered

[1]By F. G Clapp.

the northern half of North America. The "sands" of the well drillers are not, however, synonymous with the sands of the drift for the reason that the well drillers have given the term "sand" to all sorts of sandy formations which are encountered by the drill and which—although in a consolidated state—are broken up by the drill and appear at the surface in a granular form.

In discussing the superficial formations, it is essential to state that they are in a geological sense unconformable with the formations below them. In other words, no stratification which is found in the superficial formations or drift is parallel or continuous with stratification in formations which constitute the solid rocks. After the formation of the solid rocks mentioned in the preceding articles, and preceding the deposition of the drift, a great period of time, which may have to be measured in millions of years, is supposed to have elapsed during which the hard rock formations were indurated by subterranean agencies, elevated and subsequently denuded by surface agencies, consequently, at the time the great ice age began, the solid rock formations differed much from their original form. The sands, gravels and clays deposited during the ice age or at its close spread over the solid rocks in various forms as boulder clays (till), sand plains, stratified clays, moraines, kames, and eskers, greatly modifying the original topography. This is the reason why, in many cases, a great length of drive-pipe is necessary in drilling wells, in order to shut off leakage of water from the superficial formations overlying the hard rock. The drift formations contain a great many boulders, sometimes of large size, which are a detriment in drilling wells.

HISTORY OF OIL DEVELOPMENT.

The development of the Ontario fields followed closely upon the discovery of oil in Pennsylvania. In fact, Williams in 1857 drilled a deep well in Ontario with successful results before Drake's lucky find at Titusville. In 1860 hundreds of derricks were put up at Black Creek, the depth being seldom over 100 feet and the annual production something less than 150,000 barrels. In 1862, Shaw struck a gushing spring, the daily production of which was estimated at 1,500 to 2,000 barrels. In the beginning, large quantities of oil were allowed to flow to waste. There was naturally great excitement, which served the useful purpose of stimulating search for oil indications.

Another large well was struck at Bothwell, Kent county, and in 1867 at Petrolia other productive wells were drilled, which as late as 1885 were yielding 10,000 to 12,000 barrels monthly. These drew enthusiastic prospectors from the Oil Springs fields, where the first wells had caused great excitement, to the region of Petrolia, which has proved to be the largest pool in Lambton county.

In 1867 there were 25 oil refineries in operation in Ontario, having a weekly capacity of 480 barrels. From this time the production of oil grew rapidly. It is estimated that in 1889 there were 3,500 wells being pumped, 2,500 of which were in the Petrolia field and the remainder in the Oil Springs field, from which latter there was an approximate monthly production of 20,000 barrels.

In 1891 oil was discovered in Welland and Essex counties.

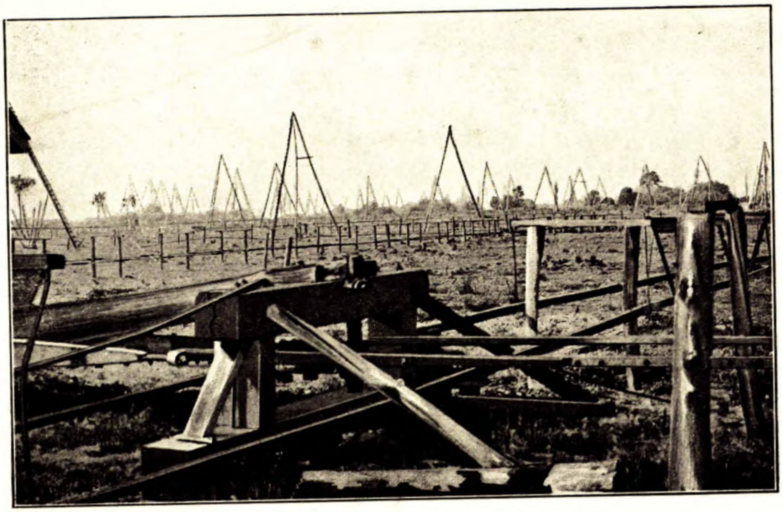
In 1902 Kent county came to the front with a gusher struck at Chatham, and the same year more than thirty shallow wells were drilled in Elgin county.

REFINERIES.

The first refinery in Canada was established at Petrolia about 1861. In the winter of 1867–1868, the Great Western railway was built to Petrolia, making it possible to haul the oil away in tank cars. Much of the oil was exported to England, but the English business dropped off on account of the developments in the United States.

At one time, there were six refineries at Oil Springs, Ontario. That was between 1862 and 1865, but in 1867 the last of these was closed, owing to a lack of crude oil.

In 1868 the principal refining works in Ontario were at London. In 1870, there were over 40 refineries situated mostly at London and Ingersoll. In 1887, there were in operation in Ontario thirteen refineries, nine of which were situated in Petrolia, two in London, one in Hamilton, and one in Sarnia.



Canadian oilfields.

It was reported that two other small refineries, one of which was in Petrolia, and one in Montreal, went out of business during the year. In 1890, there were still two refineries at London, one at Hamilton, one at Montreal, and one at Sarnia. At Petrolia, nine refineries still remained in business in 1890.

In 1889 a rather complete report was made of the conditions of oil production and refining in Canada which is quoted below for its historical interest.

During 1889, thirteen refineries were in operation, nine of which were located in Petrolia, two in London, one in Sarnia, and one in Hamilton, as follows:—

Imperial Oil Company	Petrolia
M. J. Woodward and Company	"
John MacDonald	"
Petrolia Oil Company	"
Consumers Oil Company	"
McMillan, Kittridge and Co	"
Producers Oil Company	"
John McMillan	"
Depper and McCort	"
John R. Minhinnick	London
W. Spencer and Company	"
Sarnia Oil Company	Sarnia
Canadian Oil Company	Hamilton

These refineries employed about 260 men in and about the works, and throughout the oil producing territory there were about 2,000 men employed either directly or indirectly in the production of crude and refined oil. The wages paid for skilled labor in the production of refined were from $2 to $2.50 per day, while ordinary labor in and around the refineries was paid for at the rate of from $7 to $10 per week. The tanking companies operating were:—

Petrolia Crude Oil and Tanking Co	Petrolia
Producers Tanking Company	"
Crown Warehousing Company	"

The proportion of illuminating oil produced to total manufactures of petroleum during the year was 38·7: 100.

In 1891, the number of refineries in Ontario was only ten, the refineries operating in that year being as follows:—

Petrolia:
- Imperial Oil Company
- Samuel Rogers and Company.
- John MacDonald.
- The Petrolia Crude Oil and Tanking Company.
- The Consumers Oil Company.
- McMillan Kittridge Oil Company.
- Premier Oil Company.
- John McMillan.

London:
- John R. Minhinnick.
- W. Spencer and Company.

In the years 1893 and 1894 three refineries closed down, leaving the following in operation in Ontario:—

Petrolia:
- Imperial Oil Company.
- Consumers Oil Refining Company.
- Petrolia Crude Oil and Tanking Co.
- Fairbanks-Rodgers and Co.
- John MacDonald.

London:
- Empire Oil Company.

During the early part of 1898, the oil refining was carried on by five different companies, which operated these refineries; but in 1898 these interests were consolidated into a single company, known as the Imperial Oil Company, which purchased all the refining plants of Petrolia and Sarnia.

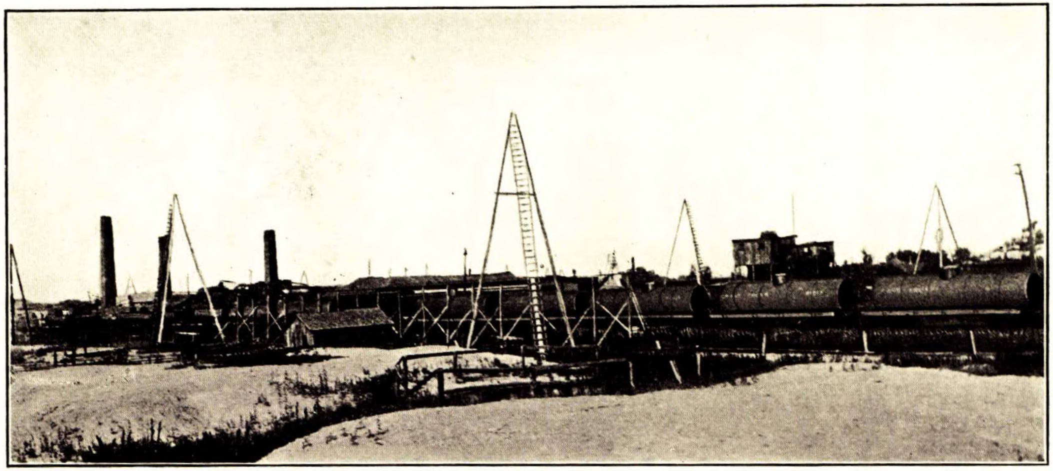
In 1910 there were only two refineries remaining in Ontario, being the refineries of the Imperial Oil Company at Sarnia, and that of the Canadian Oil Company at Petrolia. These refineries distilled a total of about 35,000,000 gallons of crude oil in the year mentioned. In order to illustrate the amount of oil produced and distilled, and its various products, the following table is given, showing the figures of petroleum and petroleum products in the years 1907–1912 inclusive:—

Petroleum and Petroleum Products, 1907 to 1912[1].

Schedule.	1907.	1908.	1909.	1910.	1911.	1912.
Crude Produced (Imp. Gal.)........	27,621,851	18,479,547	14,723,105	11,004,357	10,102,081	8,432,730
Crude Distilled (Imp. Gal.)........	34,961,706	34,675,120	35,530,918	36,171,032	38,632,504	46,270,701
Value Crude Produced ($).........	1,049,631	703,773	559,478	368,153	353,573	344,537
Value Distilled products ($).......	2,568,464	2,347,680	2,501,384	2,511,368	2,294,396	3,592,230
Illuminating Oil (Imp. Gal.)........	18,319,233	17,604,920	17,902,254	18,983,357	20,240,523	23,090,280
Lubricating Oil (Imp. Gal.)........	3,931,767	3,384,940	3,856,778	4,469,038	4,729,257	5,932,166
Benzine and Naphtha (Imp. Gal.)...	4,132,239	3,667,997	3,930,691	4,297,615	4,179,575	4,955,022
Gas, Fuel Oil and Tar (Imp. Gal.)...	5,632,608	4,461,186	4,687,588	5,876,498	4,847,124	6,028,983
Paraffin Wax and Candles (Lb.).....	5,132,394	5,400,003	7,092,278	5,179,391	5,267,485	8,086,841
Workmen Employed (No.)............	435	430	436	428	511	699
Wages Paid ($)......	265,316	247,829	261,014	280,485	314,851	436,852

[1]Thomas W. Gibson, Rept. Bureau of Mines, Ontario, Vol. 21 Pt. I, 1912, p. 35; Vol. 22, Pt. I, 1913, p. 43.

Canadian oil refinery, Petrolia, Ont.



Oil tanks at Petrolia, Ont.

In 1913, a pipe line was under construction from the oil fields at Lima, Ohio, to the plant of the Imperial Oil Company at Sarnia. The distance is 175 miles or thereabouts, and the line will cross the St. Clair river five miles south of Port Huron on the American side. There will be two pumping stations on the line, one at Toledo, Ohio, and the other at Wayne, Michigan. The Imperial Company's plant was being enlarged in preparation for handling the increased amount of oil, which would be necessary.

The refinery of the Empire Oil Company at Wallaceburg, Ontario, was purchased in 1913 by the High Grade Oil Company, Ltd. The refining plant was constructed in 1900 and is situated in Chatham township, just outside Wallaceburg. The Company has eleven acres of land with water frontage and wharf facilities, and owns jobbing stations at Chatham and Toronto.

METHODS OF REFINING.

In the old process of refining different gravities of oil were separated by distillation and the distillates were treated with sulphuric acid and caustic soda. About 1868, the lead treatment was introduced by Mr. Allen, an Englishman. The ordinary process in Ontario seems to have been to produce three grades of illuminating oil, which were given various trade names. There was no improvement in the treatment of oil between 1868 and 1885, but at that time the system of redistillation was introduced; this process took about 24 hours in large stills. It consisted of distilling the oil from the sulphide, making a much more perfect product and bringing the flash point from 95 down to 73 degrees, changing the gravity from ·805 to ·807.

HISTORY OF NATURAL GAS DEVELOPMENT.

During the remarkable development of the oil fields of the county, the oil was accompanied by more natural gas than could be marketed in Canada. Record of the production of natural gas was not kept until 1892, when the value of the year's production was $150,000. This value, fluctuating slightly during the next decade, finally fell in 1902 to $196,000. A rapid rise, however, brought the production for 1911 to approximately 4,000,000,000 cubic feet for the Welland-Haldimand-Norfolk-Brant field. For the year 1912 the value was a little over $2,000,000, representing the output of the 1,247 wells of the Province. There are at present three principal gas fields, known as the Welland Co. field, the Haldimand-Norfolk Co. field, and the Essex-Kent field; the largest producer is the last mentioned.

EXPORTATION OF NATURAL GAS.

On July 22, 1898, the Canadian Government decided not to prohibit the exportation of natural gas, but certain regulations were made. For three years, beginning August 1 of that year, not more than 3,000,000,000 cubic feet could be exported per annum, the gas to be taken in equal quantities from the Standard and Ontario companies. It was provided that rates charged in Canada were to be at least 10 per cent lower than those charged outside Canada, and any corporation or individual was entitled to purchase gas from any Canadian well at 5 cents per thousand cubic feet. On July 27, 1899, a license of occupation was granted by the Ontario Government to the Ontario Construction and Improvement Company, by virtue of which a double line was laid across the bed of the Detroit river, enabling the piping of gas into that city. On April 13, 1900, an order in council was passed on the recommendation of the Attorney-General, directing that three months' notice be given the company that their lease should terminate. Accordingly, this notice was served on April 19 that the lease would be revoked unless cause to the contrary was shown within the three months. The revocation of the license was due to the fears of the people in Essex county that their field would be depleted rapidly, and the subsequent history showed that their fears were well founded. The Essex Standard Company, operating in the Essex county field, delivered gas into Toledo by way of Detroit, having an 8-inch pipe line from Ruthven to Detroit, crossing the river at Sandwich, and from Detroit to Toledo, using an abandoned pipe line from the Ohio fields. In 1900, the quantity of natural gas exported to Detroit was 1,500,000,000 cubic feet per year, or about one-half the output of the Essex county field. The exportation of gas to Toledo, Ohio, was discontinued in that year.

Beginning with the year 1892, large amounts of natural gas were piped from Canada into the United States for sale in the cities of Buffalo and Detroit. The figures regarding these exports up to the year 1896 were as follows[1]:—In 1894 the United States Treasury Department decided that gas imported from Canada was not dutiable and the duty was removed. It had previously been lowered from 20 per cent to 10 per cent.

		M. cu. ft.
At Buffalo —	1892	1,295,490
	1893	1,314,824
	1894	1,067,850
	1895	1,052,800
	1896	696,928
At Detroit —	1894	10,800
	1895	785,990
	1896	966,800
	1897 (ten months)	810,400

making a grand total of exports from Canada of—

1892	1,295,490
1893	1,314,824
1894	1,078,650
1895	1,838,790
1896	1,663,728

PIPE LINES.

The Manufacturers Natural Gas Company have an eight-inch and ten-inch pipe line and do not pump the gas. The pressure averages 50 pounds at the field end of the line and at present the pressure at the city end is 12 pounds.

[1]Ingall, E. D., Ann. Rept. Geol. Survey Canada, Section of Mineral Statistics and Mines, Vol. 10, Pt. S., 1899, p. 140.

The Southern Ontario Gas Company has obtained a right of way for a pipe line along the tracks of the Père Marquette railway in Kent county to the cities of St. Thomas and London.

MARKETS.

Gas is piped from the Haldimand-Norfolk field to Hamilton, Dundas, Galt, Brantford, and elsewhere; the Welland field supplies St. Catharines, Niagara Falls, Bridgeburg, and other towns. The Kent-Essex field supplies Chatham, Leamington, Blenheim, and other towns.

OIL PRODUCING FORMATIONS.

While in Ohio and Indiana the most important source of petroleum and natural gas is the Trenton limestone, in Canada, on the other hand, this formation is very seldom productive. In Canada, the productive portions of the Trenton limestone are those parts of the Cincinnati anticline, on which the upper portion of the Trenton has been replaced by dolomite or magnesium limestone, constituting a chemical change; and the localities where porosity and geological structure correspond with each other are those which are favourable for gas and oil occurrence.

Geological Structure.

In general the Palæozoic geological formations dip toward the south under the entire southern part of Ontario. The geological structure, however, is largely modified by the Cincinnati anticline, which is extremely productive of oil in northwestern Ohio, and extends from that state northward across western Ontario, following a line from near Littles point on Lake Erie to near Kettle point on Lake Huron between which points it extends in a north-northeast direction through Essex Bothwell, and Lambton counties. Its average trend is about north 30 degrees east, but deflects somewhat from this course in the vicinity of Petrolia (Transactions Royal Society of Canada, 1887, p. 107).

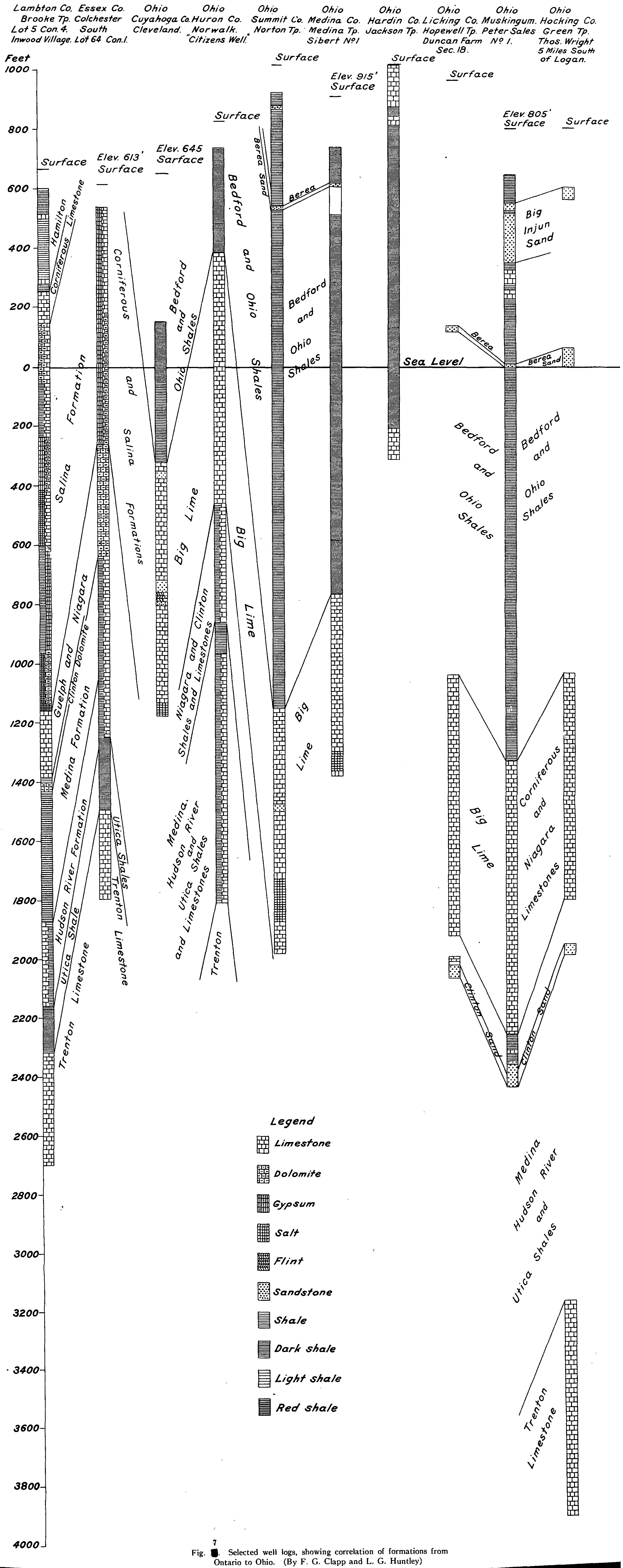


Fig. 7. Selected well logs, showing correlation of formations from Ontario to Ohio. (By F. G. Clapp and L. G. Huntley)

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Fig. ■. Selected well logs, showing correlation of formations from Ontario to New York and Pennsylvania. (By F. G. Clapp and L. G. Huntley)

CINCINNATI ANTICLINE.

The Cincinnati anticline is a great fold which extends from Ontario southward through western Ohio below Cincinnati and Nashville to the southern line of Tennessee in the United States. From Ohio the anticline passes northward with its crest lying intermediate between Toledo and Sandusky, entering Ontario in the counties of Essex, Kent, and Lambton. The occurrence of oil and gas in largest quantities on the Cincinnati anticline, both in Canada and in Ohio and Indiana, is due to well understood geological laws.

DEVELOPMENT OF OIL AND GAS IN THE COUNTIES OF ONTARIO.

Addington County.

No oil or gas in commercial quantity can exist in Addington county since the geological conditions are unfavourable. The northern two-thirds of the county is occupied mainly by rocks of the Laurentian age, in which oil and gas never exist. The southern third is occupied by Trenton limestone and by the associated Birdseye and Black River, which have no suitable cover and consequently will not contain much oil or gas.

Algoma District.

Some drilling for oil has been done in the past on Grand Manitoulin island in Lake Huron, but without commercial results. In 1907 several wells were drilled near Little Current. Showings of oil were obtained at 500 to 700 feet in a very close-grained rock. The showings improved on shooting the well. Some oil was also found at Gore bay but too light to pump. With this exception the entire district is unfavourable for oil or gas and none should be expected in quantity.

History of developments.—The first well was started east of Manitowaning near the east end of Manitoulin island, at some time previous to 1870, and was followed by three other tests. The results were small and the difficulties of transportation made it impracticable to develop the oil; consequently, there is no production at present.

In 1913 operations were again under way on Manitoulin island, being conducted by Sendon Poirier of Nova Scotia, in the vicinity of Green bay and Sheguindah.

Formations penetrated on Manitoulin Island.—The geological formations underlying the Glacial Drift consist of Niagara limestone throughout the greater part of the island. The Clinton outcrops in an east-west belt across the island, however, and a broader belt in the north half of the island is composed at the surface of the Lorraine shales, the Medina being apparently absent. Cloche island between Grand Manitoulin and the mainland consists, however, of Birdseye and Black River limestones.

The wells on Grand Manitoulin are reported to reach the Trenton limestone, the depths of the original four wells being 400, 260, 320, and 160 feet respectively.

Conditions elsewhere in Algoma district.—Although no drilling has been done elsewhere in Algoma district, it is necessary to explain that the formations are unsuitable and that testing could only result in failure. While the geology has not been worked out with accuracy, either by the government geologists, or by private parties, this district, north of Manitoulin island for 200 miles or more, consists of ancient rocks of Laurentian and Huronian age, which are unlikely to contain oil or gas. In the extreme northern part of this district, extending from somewhere north of the fiftieth parallel to beyond the Albany river, is a little known territory reported to be occupied by Devonian and Silurian formations. While conditions are not believed to be favourable for finding oil or gas in that part of Ontario, no conclusive statement can be made in the matter.

Brant County.

Distribution of fields.—The principal new oil field in Ontario is in the Onondaga township field of Brant county, in which both oil and gas are produced, and in which developments have been active in the past few years. A small amount of gas is also found in Brantford township.

History of Development.—Some deep drilling was done in the vicinity of Brantford in 1888, since which time little took place until about ten years ago, when tests were drilled at Cainsville. One well still produces sufficient for several houses. Few traces of oil were obtained until 1910, when the Onondaga field was discovered, 21 successful gas wells being reported in Brant county in that year. In 1909 two wells were sunk on the Van Sickle property. The results were encouraging and led to the drilling, in 1910, of what is known as the "discovery well" on the Harold Howell farm north of these wells, on lot 16, concession III, east of Fairchilds creek. In this well 300,000 cubic feet per day was found with a rock pressure of 250 pounds.

Gas has been found in most wells since drilled in sufficient quantity to flow the oil wells for a short time. In 1910 a well in this pool averaged 5 barrels per day, but in 1912 the production had dropped to about one barrel per day. The best in the pool is said to have made 40 barrels per day for the first 20 days. In 1910 the wells were clustered around the Howell farm, but in 1912 the pool had been extended northeast and southeast and was about two miles in diameter, bounded by the creek and the river. Gas is found in greatest quantity in the southern part of the pool, and the best oil wells are in the northern part. According to Mr. Bunkers, a veteran driller and contractor in the district, the Onondaga pool had not in 1912 been defined by dry holes either to the northeast or southwest. Some operators in the Onondaga pool are:—

Commonwealth Oil and Gas Company.
Standard Natural Gas Company.
Toronto Power Company.
Onondaga Oil and Gas Company.
Telephone City Oil and Gas Company.
Nakomis Oil and Gas Company.
Leamington Oil and Gas Company.
Crystal Oil and Gas Company.

Producing formations.—The chief oil sands beneath Brant county are known technically as the Clinton, Red Medina, and White Medina. Their relative positions are shown in the record on page 118. Of these, White Medina is the principal producer in the Onondaga pool and elsewhere. It is a hard and fine-grained sand, but is not always white. While most of the oil in Brant county appears to be in the White Medina sand, instances are mentioned by operators where it has been found in the underlying red shales. The wells at Brantford obtain gas in the Clinton dolomite and in the White Medina sand. A showing of oil is found in the Red Medina.

Formations penetrated in drilling.—Brant county is covered with an undulating thickness of 50 to 150 feet of glacial drift, consisting of sand, gravel, clay and boulder clay. Underneath these surface materials, the formation in the southwest part of the county is Onondaga, in the central and eastern parts it is Salina, while a small area in the northeast part of the county has the Guelph immediately below the unconsolidated deposits. (See Fig. 9.) In thickness the Salina, Guelph and Niagara amount to as much as 500 feet in some localities, but the boundaries between these formations are undistinguishable in well records. The underlying Clinton dolomite is 20 to 30 feet thick, while the Medina is 500 feet. Unfortunately, the well records are poor, but two sections, in Brantford and Onondaga townships respectively, are given below for what they may be worth:—

Log of well in Brantford township, Brant County, Ontario[1].

Formation	*Material*	*Top* *Feet*	*Bottom* *Feet*
Pleistocene	Surface	0	48
Salina, Guelph, Niagara	Limestone	48	448
Clinton and Medina	Limestone and shales	448	973
Lorraine and Utica	Blue shale	973	1953
Trenton	Limestone	1953	2163
Total depth			2163

Big water between 200-300′	
Gas and water at about	1950
A show of gas was found at	2160
Cased to	520

A shallower record, but one which gives the thickness of formations of special interest and in which gas was found, is added on page 119. A much better geological section, taken from actual measurements on the Niagara escarpment (Geological Section at Grimsby, Lincoln county[2] between Brantford and Hamilton, is given below:—

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 44.
[2]Parks, W. A., The Paleozoic Section at Hamilton, Ontario, Guide Book No. 4. Examinations in Southwestern Ontario, Ottawa, 1913, p. 130.

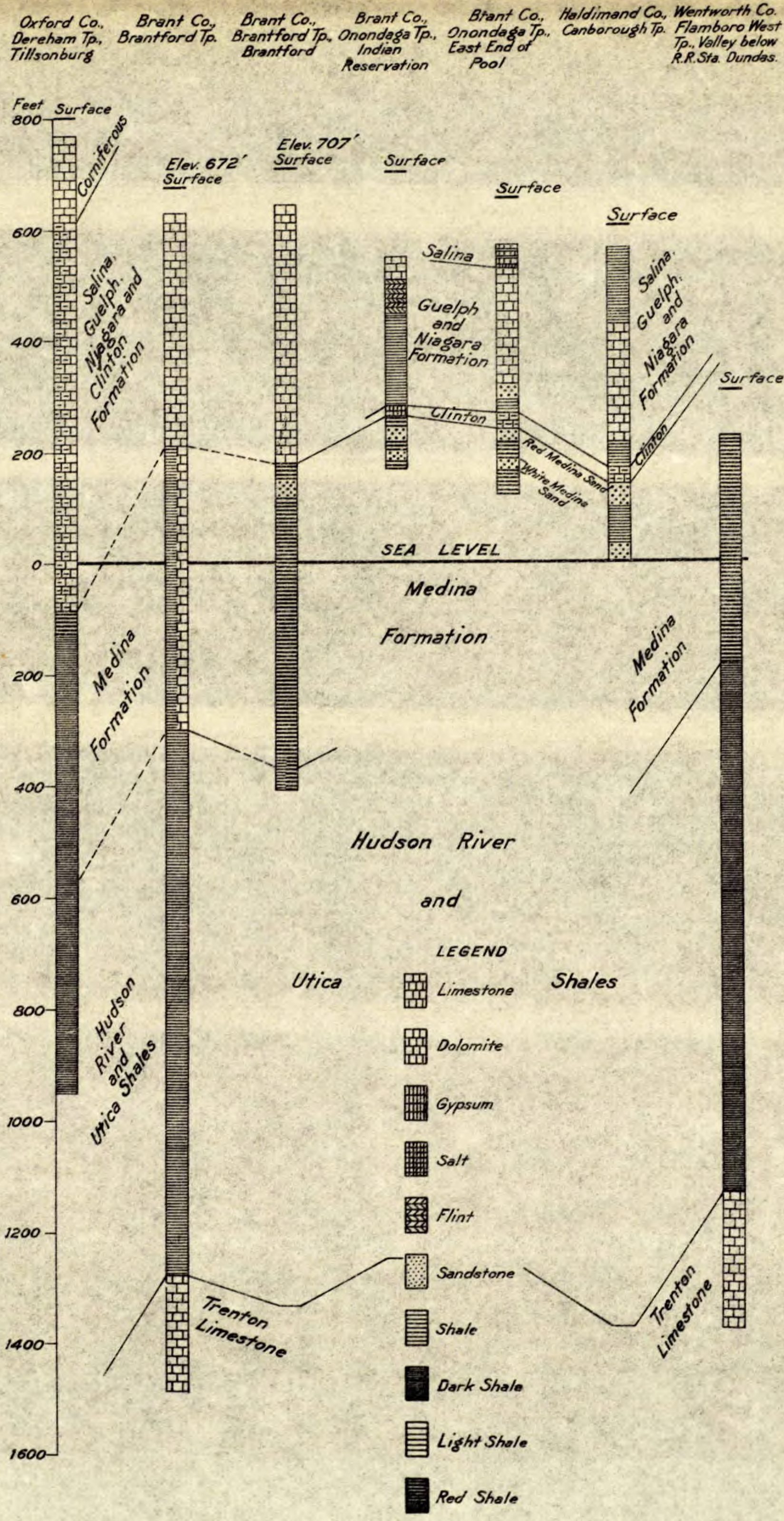

Fig. 9 [redacted]. Selected well logs, showing correlation of formations through Brant county, Ontario. (By F. G. Clapp and L. G. Huntley)

Formation	*Local Name*	*Thickness* Feet	*Total* Feet
Niagara	Lockport dolomite	12	12
	Rochester shale	45	57
Clinton	Clinton thick bed	4	61
	Clinton thin beds	10	71
Medina	Medina grey band	5	76
	Medina mottled sandstone and shale	20	96
	Cataract shale and limestone	74	170
	Basal Cataract sandstone	6	176
	Red Richmond shales	(Not exposed)	

Production of oil.—In 1912 the Onondaga pool had a production of 2500 barrels of oil per month. This production, according to the official statistics[1] was 1,005 for the year 1910, and 13,501 barrels in 1911.

From 1910 to 1912 the wells in the Onondaga pool averaged only one barrel of oil per day. A small amount of oil was obtained in Brantford on the property of the Cockshutt Plow Co., Ltd., where three wells are still capable of a total of four or five barrels a week.

Quality of the oil.—The oil in the Onondaga pool is of amber hue, has a gravity of 32 degrees Baumé and contains 33½ per cent of lubricating oil. It is refined at Wallaceburg and Sarnia. The percentage of benzine and gasoline is small.

The oil from this field is reported as the finest in Canada, bringing $2 per barrel in 1912, plus the government bounty of 1½ cents per gallon, which applies on all Canadian oil.

Production of gas.—It is unfortunate that exact figures of natural gas production are not available. The Onondaga pool was reported to yield in 1912 about 10,000,000 cubic feet of gas per month. The rock pressure declined from 250 pounds per square inch in 1910 to 35 to 45 pounds in 1912. The production of the Middleport wells is from less than 2000 cubic feet to 7000 cubic feet daily.

In the Brantford wells, productions of 2,000 to 750,000 cubic feet per day are reported, the latter being an exceptional figure. The rock pressure at Brantford was originally 250 to 300 pounds per square inch.

Markets for the gas.—All gas from the Onondaga field (about 200,000 cubic feet per day in 1912) goes to Brantford by a line

[1]Gibson, Thos. W., Rept. Bureau of Mines, Ontario, Vol. XXI, Pt. I, 1912, p. 35.

which starts at Middleport. The Middleport end is 2 inches in size, the middle or Onondaga section is 4 inches, while the gas is delivered to Brantford through a 5⅝-inch line.

Brantford township.—Inside the city of Brantford and in its vicinity are a number of small gas wells, used to supply one or two houses for lighting and cooking. Several persons in Brantford started the custom of drilling these wells about ten years ago. The depth is reported to average 650 feet.

The following is a typical record of formations passed through at Brantford, but this is a composite of several actual records.

Materials encountered in drilling at Brantford.

Material	Formation	Top Feet	Bottom Feet
Sand	Pleistocene	0	30
Clay	Pleistocene	30	105
Limestone, shale and gypsum	Guelph	105	135
Limestone	Niagara	135	375
Black sand	Niagara	375	395
Shale	Niagara	395	425
Limestone	Clinton	425	437
Red Medina sand	Medina	437	472
Shale	Medina	472	542
White Medina sand	Medina	542	557
Red shale	Medina		

Much water is found in the Niagara limestone. Hence, the following casing is used:—

$8\frac{1}{4}$-inch drive pipe........................105
$6\frac{1}{4}$-inch casing..........................390

The deepest well ever drilled in the county was sunk at Brantford in 1888, to the Trenton limestone, which was reached at 1953 feet. The well only found a show of gas at 1950 feet. Another test of same depth was sunk the same year by the Waterous Engine Company, the depth being 1118 feet. Although the record is a poor one, it is given below for what it may be worth:—

Log of well of Waterous Engine Company, Brantford[1].

(Surface Elevation 707 ft.)

Material	Formation	Top Feet	Bottom Feet
Surface	Salina	0	63
Limestone	Guelph, Niagara and Clinton	63	520
Blue shale	Medina	520	525
Red shale	Medina	525	550
Sandstone	Medina	550	590
Red shale	Medina	590	1050
Dark blue and red shale	Medina	1050	1118
Little surface water			200 and 300
Total depth			1118

The most extreme drilling at Brantford has been done by the Cockshutt Plow Company, Ltd., which sunk seven or more wells, on and near their property. From 2,000 to 45,000 and in one case 750,000 cubic feet per day of gas were struck, and a little oil. The gas had 250 to 300 pounds pressure.

Log of well at Cockshutt Plow Works.

Formation	Material	Top Feet	Bottom Feet
Pleistocene	Gravel and sand	0	61
Niagara	Limestone	61	330
	Black shale	330	380
Clinton	Limestone	380	393
Medina	Red shale	393	435
	Grey shale	435	482
	White Medina sand with gas	482	500
	Red shale	500	635
	Total depth		635

Onondaga pool and township.—The new field opened four years ago seven miles east of Brantford has now an oil capacity of about 2500 barrels per month, and a gas production of approximately 10,000,000 cubic feet of gas per month. The pressure has declined in four years from 235 pounds to an average of from 180 pounds.

The following is a typical log of a well in this pool, on authority of Mr. Bunkers:—

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V. Pt. Q, 1889-91, p. 43.

Partial log of Douglas No. 5 well, Onondaga pool.

Material	Top Feet	Bottom Feet
Surface	0	77
Clinton limestone	384	393
White Medina sand	489	497
Drive pipe		77
5⅝ inch casing		350
Total depth		497

In the Brant county fields it is customary to drill a few feet below the sand to form a pocket for the accumulation of sediments.

A more complete record is the following, being No. 1 of the Toronto Power Company.

Log of well at east end of Onondaga pool.

Material	Formation	Top Feet	Bottom Feet
Sand	Pleistocene	0	4
Clay		4	82
Shaly limestone	Guelph	82	122
Hard Niagara limestone		122	322
Black sandstone	Niagara	322	352
Shaly dolomite		352	382
Clinton dolomite	Clinton	382	412
Red Medina sand		412	432
Medina shale	Medina	432	467
White Medina sand		467	479
Total depth			530

The best gas wells will average less than 100,000 cubic feet per day. The oil is stored in tanks of from 60 to 250 barrels capacity from which it is transported by pipe-line to loading racks, and thence by tank car to Wallaceburg and Sarnia for refining.

In the Onondaga field, a plant for the recovery of gasoline from natural gas was erected in 1912.

On the Barton farm about one and one-fourth miles north of the town of Onondaga, Leamington parties once drilled a well to a depth of 1100 feet. A small show of gas was struck but the well was abandoned.

Notwithstanding the predictions made, that the Onondaga pool would prove a second Petrolia, the drilling of new wells has not furnished sufficient production to take the place of the decline in oil wells. Many factors indicate that operators have not taken advantage of the varying conditions so as to conserve the best underground conditions for production. Hence, rapid draining of the gas will result in a short life for the pool.

Dumfries township.—No deep wells are ever known to have been drilled in this township. In 1905 a hole 225 feet deep was drilled at Paris, without result.

Future possibilities.—The Onondaga field is believed to have little future, and chances are not good for any extensive pool anywhere in Brant county, although small wells and pools may still be discovered.

Bruce County.

General statement.—No oil or gas fields have been found in Bruce county, and it is quite certain that they do not exist, since most of the commonly productive formations are absent and the others are too shallow in depth.

History of testing.—Notwithstanding the unfavourable conditions, a number of deep wells have been drilled because the county is underlain by rock salt.

History of developments.—The beginning of drilling in this county dates back previous to 1866, when a test was sunk at Kincardine. Several wells have been sunk at that town at various times. Subsequent tests were drilled at Port Elgin in 1869 and 1870, but without finding salt or other valuable materials. Wells were sunk at Kincardine and Southampton in 1868 and at Inverhuron in 1872. Early wells were also drilled at Teeswater. The depths were from 950 to 1250 feet.

In 1900 a showing of gas was reported in lot 1, concession X, Amabel township, in the Trenton limestone at a depth of 1405 feet. The pressure was reported as 425 pounds per square inch. The Grey and Bruce Oil and Gas Company was organized to develop the field, which they presumed existed in the vicinity of Hepworth..

Formations penetrated in drilling.—The geological formations occupying the surface in Bruce county range from Clinton limestone in the extreme north through the Niagara, Guelph and Salina to the Onondaga limestone in the central southern part of the county.

The wells fortunately furnish a number of good records of the strata, two of which are given herewith for reference in drilling other tests.

Log of J. Lineal Smith well at Kincardine[1].

Formation	Material	Top Feet	Bottom Feet
Pleistocene	Common sand	0	7
	Yellow clay	7	15
	Water gravel	15	25
	Quicksand	25	89
Salina	Alternating sand and limestone	89	117
	Limestone	117	296
	Fine grained white freestone	296	325
	Dark limestone	325	601
	Red shale	601	615
	Blue shale	615	730
	Hard blue limestone	730	894
	Hard cherty rock	894	899
	Rock salt	899	911
	Alternate layers of shale and clay, mixed with salt	911	947
	Hard and pure rock salt	947	1007

The following is a record of a test made at Southampton, several miles farther north:—

Log of well at Southampton[2].

Material	Top Feet	Bottom Feet
Surface	0	233
Sand rock	233	251
Sandstone and limestone	251	401
Dark grey and white limestone	401	601
Limestone, soft, light coloured	601	700
Blue and red shales	700	796
White limestone	796	830
Blue and red shale	830	1055
Blue shale	1055	1255
Total depth		1255

In certain of the Kincardine wells, two beds of rock salt were penetrated.

Carleton County.

General Statement.—No oil or gas of commercial importance exists in Carleton county, since the conditions are unfavourable. A number of showings of gas have been found in various localities, but these do not indicate any large deposit.

[1]Geol. Survey Canada, Prog. Rept., 1874-5, p. 286.
[2]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q. 1889-91. p. 59.

General Geology.—The geological formations developed in this county consist largely of Laurentian rocks which are very old, hard, crystalline, and otherwise unsuitable for holding oil or gas. In the central part of the county, an area is occupied by rocks of Trenton, Chazy, and similar age, but nothing more than showings of gas can be expected there, since the region has been much faulted and broken. In some localities, in the centre of the county, the depth through the sedimentary rocks to the granitic rocks is at least 1300 feet, and this depth has been penetrated in one well. Showings of gas were found in the water at Caledonia Springs some years ago.

Drilling Operations.—In 1900, or thereabouts two test wells were sunk for petroleum near Ramsays Corners, Carleton county, the drilling being done by means of a diamond drill. Showings of gas were encountered at a depth of 130, 355, and 413 feet in the Utica shales. The gas pressure was estimated at 200 pounds per square inch.

Notwithstanding the unfavourable conditions, there were in 1888, two applications from rival companies to lay pipes and transport natural gas to Ottawa. In 1889, the Premier Gas Company sunk a boring on the north side of Patterson creek near the southern part of the city to a total depth of 1005 feet, but naturally without success. The well was cased 820 feet. Showings of oil were reported at 900. Unfortunately no reliable record was kept, although specimens were collected and preserved, a detailed report of which is given by Brumell[1].

Many years ago an attempt was made to obtain oil by drilling near the village of North Gower but with no better success.

Dufferin County.

No oil or gas of commercial quantity has been found in Dufferin county, and it is believed that neither substance exists in quantity. The formations consist in the northeastern part of the county of Lorraine shales, and in the southwestern part of the Guelph limestones, while intermediate is the Niagara escarpment, topped by the Niagara and Clinton limestones

[1]Brumell, H. P. H., Geol. Survey of Canada, Vol. V, Pt. Q, 1889-91, p. 23.

and bordered below by the Medina shale. The geological sections will therefore range from the Guelph downward, according to whether a well is situated in the eastern or western part of the county.

Below the mountain, 15 miles south of Collingwood, three wells were reported, years ago, to have passed entirely through the Trenton limestone, 590 feet in thickness, and to have penetrated to a depth of 1750 feet.

Dundas County.

No oil or gas exists in quantity in Dundas county, since the conditions are particularly unfavourable. The formations at the surface consist in the northeastern half of the county of Chazy strata, while in the southwestern half they are of Calciferous age. These formations are entirely below any formations known to contain gas.

Durham County.

No oil or gas fields of commercial quantity have ever been found in Durham county, and they presumably do not exist, the reason being that the formations in the extreme south consist of Utica shales, while the remainder of the surface underlying the glacial drift is occupied by Trenton limestone. Hence, only a small patch in the southern part of the county has a sufficient cover to hold any gas which might be contained in the Trenton and this area is too near the outcrop to have any probabilities.

Elgin County.

Description of the fields.—A small pool at Dutton in Dunwich township is the only oil pool ever discovered in Elgin county. Owing to the decline of the gas supply in Welland and Haldimand counties, the gas companies are making vigourous efforts to develop gas territory in Elgin and Norfolk, for supplying the city of Hamilton. Hence, the Welland-Haldimand-Norfolk county gas field has been pushed westward within the past few years, developing the Vienna pool in Bayham township of this county.

History of Development.—Some shallow wells were drilled in the vicinity of Vienna and Port Stanley about 50 years ago; but only to depths of a few hundred feet, and no results were obtained. The Vienna pool was discovered in 1910, in which year only two producing gas wells were sunk.

Depth of the wells.—The depth of wells drilled in Elgin county ranges all the way from 300 feet in shallow tests at Port Stanley to 2776 feet in a deep dry hole at Eden, Bayham township. The gas in the Vienna pool is found at a depth of 1280 to 1430 feet deep. The oil in the Dutton pool is between 400 and 500 feet from the surface.

Productive formations.—The gas produced to date is derived from the bottom of the Clinton dolomite, a bed 20 to 30 feet in thickness which underlies the Niagara shales. Judging from the results of wells drilled in Norfolk and Haldimand counties, the underlying Medina sands may possibly prove productive somewhere; but these are commonly so broken and shaly that little hope exists from them.

Casing of the wells.—The casing of the Elgin county wells generally consists of two strings, in addition to drive-pipe, but in certain wells three strings of casing have been used. The short string is set in the bottom of the Salina or in the Guelph; while the long string is sometimes set below the Niagara limestone. In the deep test at Eden, the long casing was continued to a depth of 2041 feet, into the Lorraine formation.

A typical casing record in the Vienna pool is as follows:—

10-inch drive-pipe	290
$8\frac{1}{4}$-inch casing	295
$5\frac{5}{8}$-inch casing	752
Tubing	1300

Formation penetrated by the drill.—The surface of Elgin county is flat and entirely obscured by a thickness of 200 to 500 feet of glacial drift. Consequently, geological determinations are difficult. Underlying the drift is a thickness of 1,000 feet of shales, limestones, and flint, which cannot be classified; but the upper portion is presumed to be in general Onondaga, the middle being Salina; and the lower part Guelph and Niagara. In fact there is a fair degree of certainty that the lowermost 200 feet of this mass is of Niagara age. Below it lies 60 to 100 feet of shale, also of Niagara age, while next comes the Clinton dolomite, 20 to 50 feet in thickness; which constitutes the gas-producing rock. Under the Clinton is 600 feet of Medina, consisting largely of red shale, but containing also sometimes 20 feet or less of limestone near its top, as well as traces of sand, known as the Red Medina and White Medina.

Under the Medina, the Eden deep well shows 800 feet of shale, mostly of Lorraine age; but the lower 160 feet is presumably Utica, resting on the Trenton limestone.

The most reliable record of the formations is probably the well drilled in 1911 by the Dominion Natural Gas Company at Eden. It is given below:—

Formations encountered at Eden, Bayham township.

Formation	*Material*	*Top Feet*	*Bottom Feet*
Pleistocene	Surface	0	250
	Flint	250	475
Onondaga, Salina and Guelph	Shale	475	980
Niagara	Niagara limestone	980	1215
	Shale	1215	1280
Clinton		1280	1295
Medina	Red Medina	1295	1318
	Shale	1318	1352
	White Medina	1352	1395
	Red shale	1395	1900
Lorraine	Grey shale	1900	2550
Utica	Brown shale	2550	2720
Trenton		2720	2776
	Total depth		2776

	10-inch drive-pipe	110
	8-inch drive-pipe	242
No. 10,	5⅝-inch casing	875
No. 17,	5⅜-inch casing	2041
	Red shale caved at	2425
	Show of gas (about 10,000 cu. ft. per day)	1291

At the west end of the county the conditions are evidenced by the record of a well 1579 feet deep in Aldboro township, four miles south of Rodney, furnished by Mr. F. F. Bess.

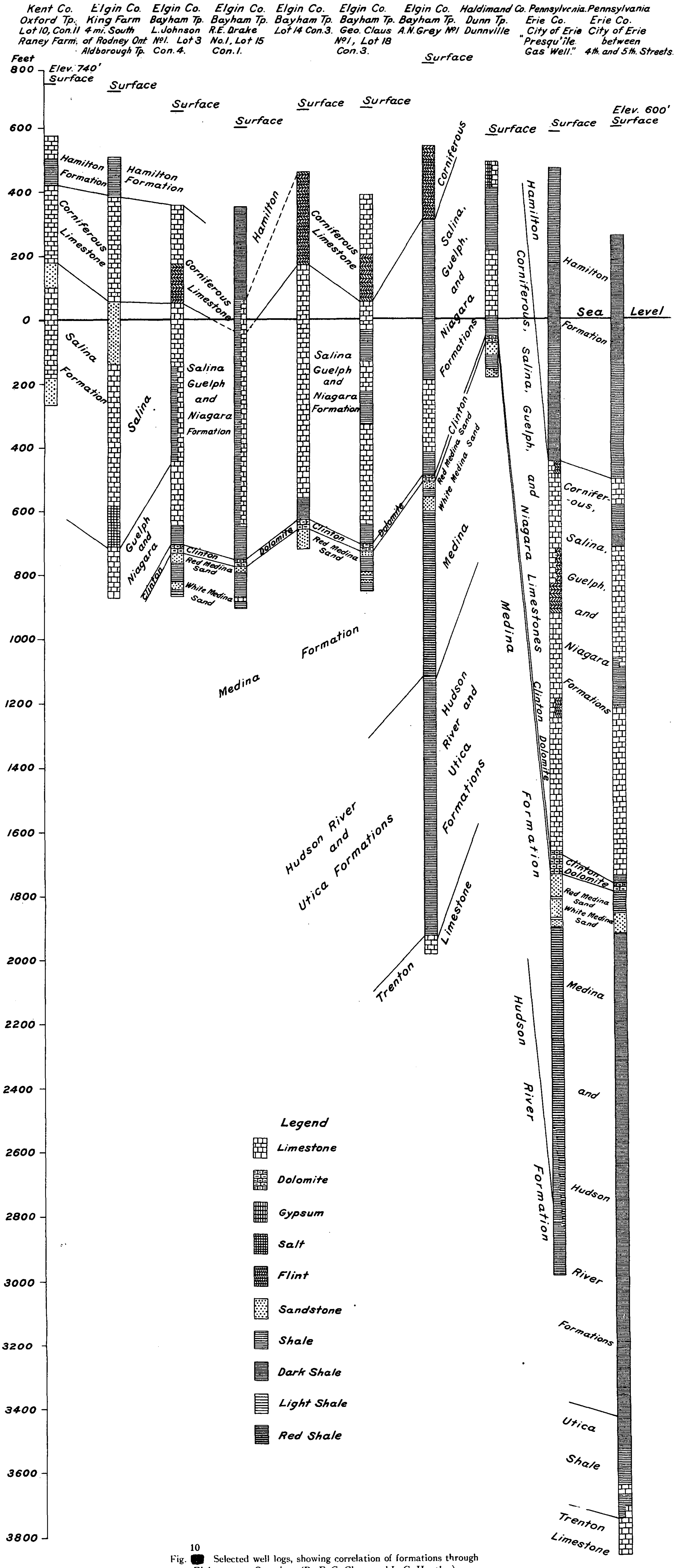

Fig. 10 Selected well logs, showing correlation of formations through Elgin county, Ontario. (By F. G. Clapp and L. G. Huntley)

Log of well in Aldboro township.

Formation	*Material*	*Top* *Feet*	*Bottom* *Feet*
	Surface—mostly clay	0	206
Hamilton	"Soapstone"	206	330
Onondaga	Limestone	330	650
Salina, Guelph and Niagara	Hard sharp sandstone	650	850
	Limestone	850	1300
	Rock salt	1300	1440
	Hard brown limestone	1640	1579

10-inch drive-pipe	206
8-inch casing	330
6¼-inch casing	945
Some gas in small shell of limestone while drilling the soapstone	225
Little gas	1540
Total depth	1579

Geological structure.—From what can be learned with the aid of well records, the formations of Elgin county are known to dip generally towards the south and west, but the dip does not appear to be a regular one, since it is interrupted to a certain extent by minor folds. The dip of the Clinton sand is about 200 feet from north to south, across Bayham township, and within the limits of the gas field it appears fairly flat. Enough data are not at hand to determine the structure of the field itself without further fieldwork.

Production of oil.—In only one small pool in Elgin county has any oil been produced; *i.e.*, in the Dutton pool in Dunwich township. The production by years is as follows:—

Production of the Dutton pool, Elgin county, 1907-1911[1].

Year	*Production* *Barrels*
1898	
1899	3,622
1900	4,791
1901	10,588
1902	8,867
1903	21,483
1904	14,217
1905	20,976
1906	
1907	14,977
1908	13,743
1909	9,513
1910	7,752
1911	6,731

From the above, it will be seen that the production is falling very slowly indeed.

[1]Gibson, Thos. W., Rept. Bureau of Mines, Ontario, Vol. XXI, Pt. I, 1912, Min. Res. U.S., 1905, p. 890.

Production of gas.—In the Elgin county district the thickness of the gas-bearing rock is usually slight, and although the area is considerable, wells are closely spaced, and the influence of heavy production is shown by a heavy drop in the rock pressure. This declining production makes new development a constant necessity, and as the potential gas territory is constantly narrowed by testing, the gas supply will be exhausted in a few years. The production to the end of 1911 is estimated at 126,000,000 cubic feet.[1]

The maximum rock pressure of the gas in the Elgin county field was originally 783 pounds per square inch; but the wells are mostly small, 750,000 cubic feet initial capacity being considered a very good well in this field. The pressure in 1912 was only 420 pounds.

Markets for the gas.—Gas is piped through a 6-inch line by the Dominion Natural Gas Company from the Vienna pool to Tilsonburg, a town of 2800 inhabitants in Oxford county, twelve miles distant; and the Medina Gas Company is supplying Aylmer (with 2100 inhabitants) nine miles northwest. In 1912 the latter Company was negotiating with St. Thomas for a franchise.

Vienna pool and Bayham township.—The Vienna pool follows the creek and the creek road from Vienna southward to Port Burwell. Drilling was started in 1910, and in July, 1912, when the locality was visited by Mr. Huntley, the company had 15 producing wells, all in the Clinton sand. One of these wells was flooded with oil from the Red Medina, and was not connected with the line. This is the Saxon well, in concession II, one mile west of Vienna, in the southwest part of the pool. The Central Pipe Line Company had at that time about nine wells, most of them southeast of Vienna. No dry holes had been drilled in the pool.

One well sprays some light oil, which is caught by means of a drip in the main gas line. In the winter this drip and that of the Dominion Gas Company are said to show a considerable condensation of gasoline.

[1]Gibson, Thos. W., Rept. Bureau of Mines, Ontario, Vol. XXI., Pt. 1, 1912, page 39

The pressure in the Vienna pool in 1912 was about 420 pounds, 100 pounds being carried in the Tilsonburg line. The initial rock pressure was 783 pounds. Wells were still being drilled in 1913.

The Medina Gas Company (Union Natural Gas Corporation of Canada) has a few wells west of the Dominion Natural Gas Company's wells at Vienna. The Company has an 8-inch pipe line from the Vienna pool 14 miles to Aylmer.

Several wells have been drilled at Eden, between Tilsonburg and Vienna, by the latter Company, but only one went as deep as the Red Medina.

In order to show the general character of the formations penetrated the following log is given:—

Log of well on Wilkins farm, Lot 14, Concession II.

Property of Dominion Natural Gas Company.
Drilled in 1911.

Material	*Formation*	*Top Feet*	*Bottom Feet*
Drift	Pleistocene	0	225
Black slate	Hamilton, Onondaga, Salina and Guelph	255	275
Flint		275	325
Slate		325	350
Limestone		350	380
Flint		380	680
Limestone		680	1075
Niagara	Niagara	1075	1320
Slate	Clinton	1320	1348
Clinton		1348	1414
Red shale	Medina	1414	1421
Total depth			1421

Initial flow 750,000 cubic feet per day.
Initial rock pressure 745 pounds.

First gas	300
Sulphur water	320
Salt water and sulphurous water	1080
Little salt water	1135
Big gas	1398
Show of oil	1414

The following record of a dry hole on the edge of the same field is given because it mentions the details of the upper part of the Medina formation:—

Log of Geo. Clause No. 1 well, Lot 18, Concession III.

Property of Dominion Natural Gas Company.

Drilled in 1911

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	269
Limestone		269	459
Flint		459	604
White limestone		604	704
Shale	Onondaga, Salina and Guelph	704	789
Brown limestone		789	884
Shale		884	987
Limestone		987	1093
Niagara limestone	Niagara	1093	1305
Shale		1305	1365
Limestone	Clinton	365	1390
Red Medina		1390	1405
Shale		1405	1458
White Medina	Medina	1458	1470
Shale		1470	1476
White Medina		1476	1493
Red shale		1493	1509

Water	340
Sulphurous water	733
Cave	760
Salt water	1170
Show of gas (5000 cubic feet)	1432
10-inch drive-pipe	259
8¼-inch casing	287
5⅝-inch casing	821
4⅝-inch casing	1310

In 1911 a deep test was drilled on the A. N. Grey farm at Eden by the Dominion Natural Gas Company to a depth of 2776 feet, but only a showing of gas was found in the Clinton. The log of this well is given on page 126.

Dunwich township.—At Dutton, two small companies are still producing oil from 30 to 40 wells. The oil is refined at the Imperial Refinery in Sarnia. The wells are between 400 and 500 feet deep. Evans and Rolfe drilled a well in 1910, to a depth of about 1500 feet, between Dutton and Lake Erie, finding a little gas at about 1400 feet. No log of wells in this township are at hand.

Yarmouth and Southwold townships.—A small show of gas was obtained in 1865 in a well drilled at Port Stanley, but not enough for use.

Aldboro township.—Very little drilling has been done in this township, but several tests have been sunk. In 1910 a deep well was completed by F. F. Bess on the King farm, four miles south of Rodney, the log of which well is given on page 127. Two small showings of gas were found but the well is otherwise unsuccessful. In 1912, a dry hole was drilled in this township by the Wallaceburg-Rodney Gas and Oil Company.

Future possibilities.—Nothing has been seen which indicates the probability of new fields being discovered in Elgin county. Since the Clinton and Medina are presumably present beneath the entire county, and have only been tested in the eastern end, there is some possibility of finding small oil or gas fields, but very little probability, since west of St. Thomas the sands mentioned are muddy and broken and incapable of holding much oil or gas.

Essex County.

General statement.—A gas field once existed along the shore of Lake Erie in Gosfield South and Mersea townships. It has been abandoned since 1907.

There is no gas production in Essex county at the present time, the towns being supplied from the Tilbury-Romney field in Kent county.

The only oil now being produced in Essex county is from a few small shallow wells in Maidstone township, which produce a little heavy dark lubricating oil of rather poor quality.

History of developments.—In the year 1887 several wells had been drilled in Essex county, one at Comber having yielded a barrel of oil per day.

The first gas well in the county was the Coste well No. 1, drilled in December, 1888, with a measured flow of 10,000,000 cubic feet of gas per day. Active development was at once started, with varying success, a few good wells and many dry holes being obtained. There has been some oil development in the county from time to time, but the quantity available in any one well has nowhere exceeded three barrels per day. In 1901 the dwindling supply made it necessary to abandon the pipe lines which had been laid to Detroit, Windsor, and Toledo.

Producing formations.—In Essex county the formations deepen and thicken to the north. The Clinton and Medina formations are broken and muddy, and incapable of holding much oil or gas. The Onondaga limestone has been the principal producing formation, but only a few very small wells were obtained at Comber, Puce, and Belle River.

The wells at Puce and Belle River developed small shows of gas in the Medina, and also encountered much salt water. The pay at Comber is 100 feet deeper than at Leamington. These wells produced from a formation which appears to be the Guelph. The oil and salt formations separate to the north, while they come together at Leamington. Throughout Essex county, large quantities of salt water are encountered, which caused the abandonment of the pools at Comber and elsewhere.

Depths of wells and formations penetrated.—The wells of Essex county are of very variable depth. While in Maidstone township the showings of oil are only 100 to 110 feet from the surface, the oil at Comber was 1160 to 1170 feet from the surface and the gas at Leamington about 1050 feet.

In 1905 a deep test was drilled $1\frac{1}{2}$ miles east of Leamington to a depth of 2894 feet, striking the Trenton at 2488 feet. The best deep record is in Colchester South, and is given below:—

Formations penetrated on Lot 64, Concession I, Colchester South[1].

Formation	*Material*	*Top Feet*	*Bottom Feet*
Pleistocene	Soil	0	110
Salina	Limestone and dolomite in gypsum beds	110	910
Guelph and Niagara	Porous dolomite	910	1125
Clinton	Limestone	1125	1280
Medina	Shale and limestone	1280	1565
Lorraine	Shale and limestone	1565	1915
Utica	Shale	1915	2150
Trenton	Limestone	2150	2450

As illustrated by the logs, the surface material is Glacial Drift from 2 to 120 feet thick, below which is 100 to 200 feet of Onondaga limestone, 400 to 800 feet of Salina, consisting of dolomite, gypsum and shale, then 200 to 300 feet of Guelph and Niagara dolomite and Niagara shale, 20 to 30 feet of Clinton limestone, 100 to 300 feet of Medina sandstone and shale (frequently

[1] E. Coste, Geol. Survey Canada, Vol. XI, 1898, p. 138s

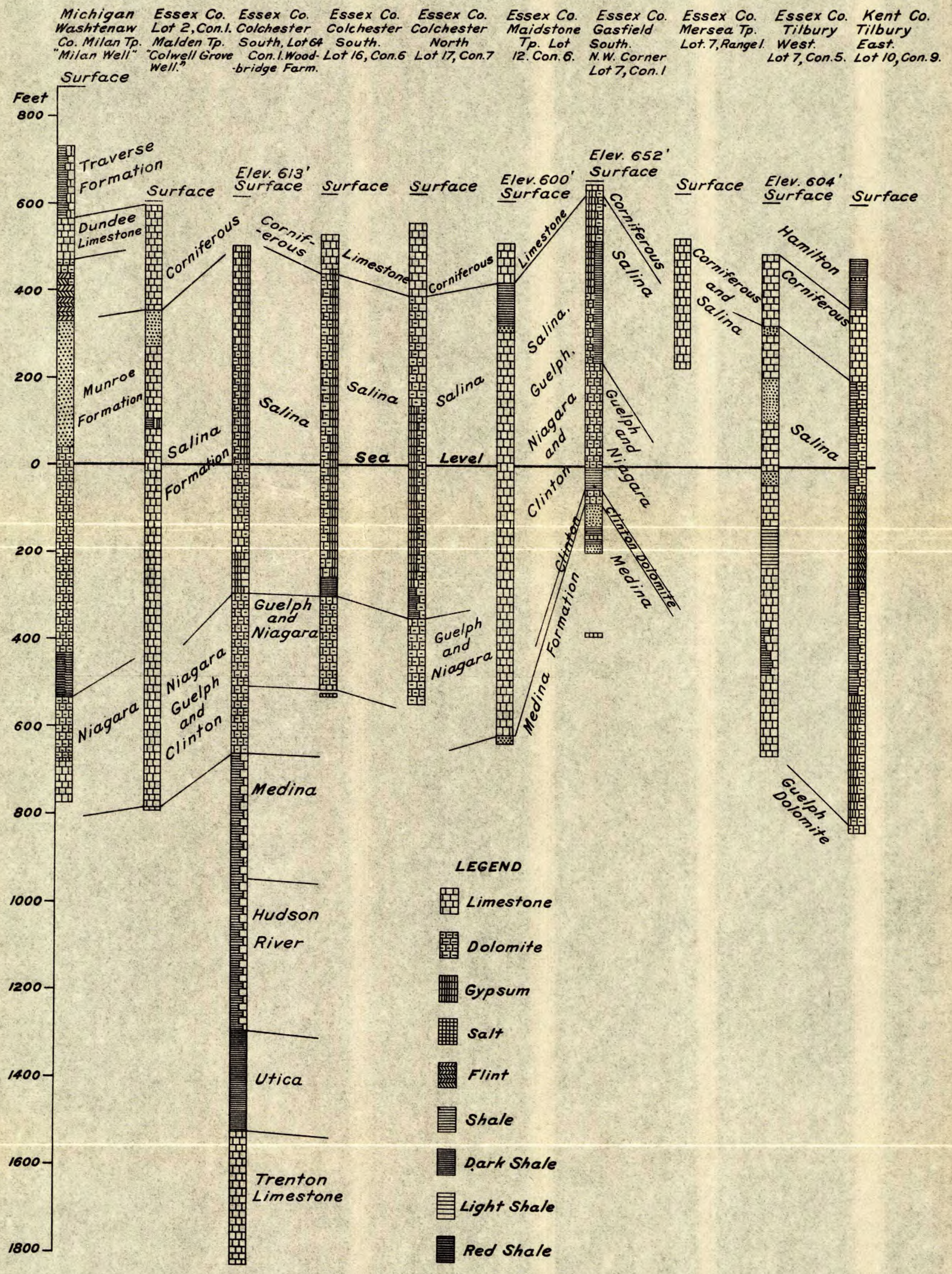

Fig. 11 Selected well logs, showing correlation of formations through Essex county, Ontario. (By F. G. Clapp and L. G. Huntley)

red in colour), 360 feet more or less of Lorraine shales, 220 feet more or less of black Utica shales, and upwards of 220 feet more or less of black Utica shales, and upwards of 300 feet of Trenton limestone, below which the drill has not penetrated. The identity of the formations mentioned above cannot be vouched for in the particular well, but the sequence and thickness must be nearly correct. Some puzzling features occur, as, for instance, the apparent thinning of the Salina to 400 feet in Gosfield South township, as illustrated by one record on Fig. 11.

Casing of wells.—As a rule, the wells are cased a short distance into bed-rock; but in some wells the casing has gone to the middle of the Salina formation. A drive-pipe must always be sunk through the surface materials.

In the deep test at Leamington the following casing was used:—

Size	*Depth Feet*
10-inch	89
8¼ "	582
6¼ "	1561

Geological structure.—In structure the Leamington gas field conforms with a prominent anticline, in which the strata are several hundred feet higher than they are to the east and north. The structure is a manifestation of the Cincinnati anticline, which becomes more prominent southward into Ohio. The formations throughout the county as a whole dip north, and on the eastern edge they dip east. Along the shore of Lake Erie in Colchester South, this dip is as much as 25 feet per mile[1].

Production of natural gas.—Unfortunately no figures of the amount of gas produced are available. The first well is known to have had a rock pressure of 460 pounds, and a daily production of 10,000,000 cubic feet is reported from it.

Production and quality of oil.—The recorded production of oil in Essex county has been as follows:—

[1]Geol. Survey Canada, Vol. XI, 1898, Part S, p. 138.

Production of oil in the Leamington pool[1].

Date	Leamington pool	Wheatley pool	Pelee Island pool	Blytheswood pool	Comber pool
1901					
1902					
1903	1,190	1,195			
1904	25,241	4,490	1,023	669	97
1905	113,806	1,750			

Year	Production (barrels)
1907	6,133
1908	9,334
1909	5,929
1910	141

It will be seen that Essex county has produced no oil since 1910.

While about a dozen wells exist at Puce and Belle River in Maidstone township, they are very small; and at the time the pools were visited by Mr. Huntley the wells were not pumping. At that time there were two 150-barrel tanks almost full at Belle River. The oil is lubricating oil of poor quality, having an asphalt base and containing sulphur.

In the deep test at Leamington, a very small show of oil of 42° gravity Baumé, was found in the Trenton limestone. The well was shot with 220 quarts of glycerine and it bridged.

A few wells in Colchester South have obtained as much as five barrels of oil per day.

Old Leamington gas field, Mersea and Gosfield South.—The first well drilled for gas in the county afforded about 10,000,000 cubic feet per day, being the Coste No. 1 of the Ontario Natural Gas Company, situated on lot 7, concession I, midway between the villages of Kingsville and Ruthven. Two other wells were drilled during 1889 by the Citizens' Gas, Oil and Piping Company on lot 5, concession I, and lot 3, concession II, East Division Gosfield South, to depths of 1126 feet and 1020 feet respectively. A fourth of the same company on lot 6, concession I, was 1085 feet in depth. Well No. 2 produced 7,014,000 cubic feet of gas per day, while the others only obtained small flows. In the same year the Leamington Citizens' Natural Gas Company drilled a well known at the time as The Leamington Citizens' well, on lot 5, concession II. The total depth was

[1]Gibson, Thos. W., Rept. Bureau of Mines, Vol. XXI, Pt. 1912, p. 35; Min. Res. U.S., 1905, p. 890.

1030 feet, great quantities of water being struck, but no oil or gas. A well drilled by the Standard Oil Company to a depth of 1200 feet on lot 7, concession IX, in Mersea township, found small showings of gas.

The production of the field increased rapidly until in 1904 it amounted to 90,000 cubic feet per day; but since that time it has steadily declined, until the final abandonment of the field in 1907. There is no production, either of gas or oil at present. A great deal of salt water existed and its encroachment finally ruined production.

A number of dry holes and wells with showings of gas have been drilled in other parts of Mersea and in Gosfield South outside the gas field.

In Mersea township in 1905, 1½ miles east of Leamington, the Canadian Gas Company, Limited, drilled a deep test to a depth of 2894 feet, reaching the Trenton at 2488. A small show of oil of good quality was found in the Trenton; but the well bridged when shot and was abandoned. The samples from this well are on file at the office of the company in Detroit, Michigan.

The gas in the abandoned field was struck at 1015 to 1050 feet from the surface. The largest production from a single well was 10,000,000 cubic feet per day. The initial rock pressure is reported as 600 pounds per square inch.

Outside of the former gas field in Mersea township, a big flow of salt water was struck in a well drilled in 1889, 1200 feet in depth at Blytheswood, near the corner of lot 7, concession IX. A small showing of gas was encountered at 1050 feet.

Tilbury West township.—About 1887 a well at Comber, drilled to a depth of 1300 feet, yielded a barrel per day of oil. Several other wells were drilled in the vicinity of Comber, and a showing of oil was found in the deep sand at a depth of 1213 feet in one well and at 1240 feet in another. These wells are no longer producing. The Niagara limestone at that locality was struck at 600 feet.

A sample well log in this township is as follows:—

Log of well 1½ miles southwest of M.C.R.R. Station at Comber[1].

Material	*Top Feet*	*Bottom Feet*
Surface clay	0	124
Limestone	124	260
White limestone	260	360
Sandstone	360	370
Limestone in alternate soft and hard layers	370	740
Shale with streaks of hard limestone	740	840
Limestone	840	975
White limestone with shale	975	1025
Limestone with shale	1025	1078
Hard limestone	1078	1203
Very hard limestone	1203	1303
Total depth		1306
Fresh water at		150
Sulphur water at		260
Small gas at		260
Small gas at		1078
Strong flow salt water		1127
Cased to		700

It is impossible to subdivide the formations in this record; but the upper 200 feet more or less are known to be Onondaga while most of the rest is presumably Salina.

Maidstone township.—The only oil produced at present in Essex county is from a few small wells at Puce and Belle River in this township on the shore of Lake St. Clair. These wells occasionally produce a little heavy lubricating oil of poor quality. In the Puce pool in July, 1912, six wells existed on the Corbett farm, between the railroad and the lake. Two of them were connected for pumping oil, and two wells produced a little gas which was used for power; while the owners expressed their intention of cleaning the other two wells and put them to pumping. There was no production from this pool at the time visited, but some drilling was done there in 1913.

A sample well record from Maidstone township is as follows:—

Log of well on Lot 12, Concession VI, near Belle River[2].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Clay	Pleistocene	0	92
Hardpan		92	95
Blue limestone	Onondaga	95	185
Dark shale		185	275
White sandstone	Salina, Guelph, Niagara and Clinton	275	300
Limestone		300	1225

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V. Pt. Q, 1889-91, p. 78.
[2]Brumell, H.P.H., Geol. Survey Canada, Vol. V, Pt. Q., 1889-91, p. 78.

Sandstone	Medina	1225	1250
Shale	Medina	1250	1465
Total depth			1465
Big flow of salt water			130
Water (base of dark shale)			275

Two miles south of Belle River, there are eight wells, seven of which are oil wells, connected by shackles to a gas engine. They produce from an open vesicular stratum in the Onondaga limestone from 110 to 120 feet below the surface; the other is a dry hole. At the time the pool was visited in July, 1912, two 250-barrel tanks were almost full of oil; but as the gas engine was then undergoing repairs, no pumping was done. Two machines were then drilling on the John Miller farm, one mile south of Belle River, and there was said to be four small oil wells on it. In 1913, fifteen or twenty shallow wells were producing oil at Belle River, and there was rumor of a refinery soon to be in operation by H. P. Bostoph. The oil is of asphalt base and contains considerable sulphur. The operating company is the Canadian Lubricating Oil Company of London, England. A deep well drilled on the Corbett farm in 1908 by the Union Natural Gas Corporation, in which this shallow pay was encountered, led to the drilling of the other wells.

Colchester South township.—Previous to 1890 a well about 1300 feet in depth was drilled at what was known as Walker's marsh, on lot 8, concession VI. A small show of gas was obtained at 1000 feet, and salt water at 1100 feet. Several wells drilled at about the same time on concessions V, VI, and VII, to somewhat less depths, produced a little oil, and the Walker No. 2 well is reported to have pumped five barrels of oil per day for a short time; but the others were dry or struck salt water between 1100 and 1200 feet, in the Clinton or Medina formation. Two deep wells drilled in 1898-99 in concession I, Colchester South, struck salt water, and no oil or gas.

About the same time the Union Gas Company drilled two wells on lot 17, concession VII, and lot 16, concession VI, to depths of 1175 and 1154 feet respectively, but without success.

The following is a typical well section in Colchester South, published by Mr. Eugene Coste:—

Log of well on Lot 16, Concession VI, Colchester South.

Material	*Formation*	*Top* *Feet*	*Bottom* *Feet*
Surface	Pleistocene	0	93
White and grey limestone	Onondaga	93	185
Dolomites and gypsum with blue-black shales towards bottom	Salina	185	925
Dolomite	Guelph and Niagara	925	1147
Limestone	Clinton	1147	1154
Total depth			1154
Casing			680

Colchester North township.—A dry hole was drilled during 1889 on lot 283, south of the Talbot road at Essex Centre by the Central Gas and Oil Company, reaching a depth of 1200 feet but finding no gas nor oil, although much water was encountered. The Premier Oil Company drilled a dry hole at Sweetmans mills on lot 19, concession IX, Colchester North, the depth being 1135 feet. Several other dry holes have been drilled at various times; but no producers anywhere in the township.

In Colchester North, the following well record given by Eugene Coste may be taken as representing conditions:—

Log of well on Lot 17, Concession VII.

Material	*Formation*	*Top* *Feet*	*Bottom* *Feet*
Surface	Pleistocene	0	66
Limestone, white and grey	Onondaga	66	235
Dolomite and gypsum with blue-black shales towards bottom	Salina	235	975
Dolomites	Guelph and Niagara	975	1175
Salt water			1175
Total depth			1175

Malden township.—In Malden township, the Colwell Grove well and the Parks well were drilled in 1889 near Amherstburg by the Great Southwestern Gas and Oil Company, to depths of 1418 and 1004 feet respectively. Only showings of gas or oil were encountered, and big flows of salt water were struck at depths of 987 and 1115 feet. Several other dry holes have been drilled at various times in the township.

A log of the Colwell Grove well furnished by Major John Savage is as follows:—

Log of well on Lot 2, Concession I, Malden Township.

Material	Formation	Top Feet	Bottom Feet
Clay	Pleistocene	0	8
Limestone	Onondaga. Salina, Guelph, Niagara and Clinton	8	260
Sandstone?		260	320
Limestone		320	500
Shale and gypsum		500	516
Hard limestone		516	836
Soft limestone		836	1133
Limestone		1133	1398
Grey shale		1398	1418
Total depth			1418
Cased to			508
Heavy flow of salt water			1115

Anderdon and Sandwich townships.—Dry holes have been drilled in these townships, but no successful wells were ever obtained.

Pelee Island.—In 1913 a deep well was being drilled on Pelee island.

Windsor, Essex county.—The following is a log of one of the salt wells drilled in Windsor, where the first well was sunk in 1892.

Log of salt well drilled at Windsor, Essex County, Ontario.

Material	Formation	Top Feet	Bottom Feet
Glacial drift		0	136
Limestone	Silurian and upper Monroe	136	570
Sandstone	Sylvania	570	706
Limestone	Lower Monroe	706	1056

This correlation will show the names of respective materials in the Silurian which are applied across the river in Michigan.

Frontenac County.

It is very unlikely that any oil or gas in quantity will be found in Frontenac county. The formations throughout the northern three-fourths of the county are mainly of Laurentian age, while in the southern corner they consist of Chazy and of Trenton and associated limestones, which, being without cover, are not favourable for production.

Glengarry County.

Conditions in Glengary county are not favourable to the occurrence of oil or gas, and testing is not advised. In the western part of the county the Trenton limestone outcrops on the surface and in the eastern and northeastern parts the underlying Chazy is at the surface, while between these outcrops is a band of Birdseye and Black River limestone, which is generally classed with the Trenton. Nothwithstanding the unfavourable conditions, a test was made for oil in this county as early as 1865 and 1866 on lot 21, concession II, Lancaster township, to a depth of 500 feet. Showings of gas are reported to have been found, but the principal result was water. The record was furnished to the Canadian Geological Survey by Alexander Campbell of Bainsville.

Grenville County.

No oil or gas have been reported in Grenville county, and it is quite certain that they do not exist in quantity, since the conditions are quite unfavourable. Practically the entire surface is occupied by formations of Beekmantown age, which are very close to the bottom of the geological scale, and not likely to contain any oil or gas in quantity.

Grey County.

General Statement.—No oil or gas pools of commercial size have been found in Grey county, and it is quite certain that nothing better than small wells will ever be found, since the conditions are not favourable.

History of Testing.—Nothwithstanding the unfavourable conditions, some drilling has been done, commencing as far back as 1888, when a well was sunk at Delphi, on lot 5, concession XXVI, Collingwood township, near the shore of Georgian bay. It is reported that about 6,000 cubic feet of gas per day was encountered, which, although large for Grey and Simcoe counties, is an exceedingly small flow for a gas well, and not worthy of consideration. In the same years a well was drilled at the village of Thornbury in the same township with only a small showing. Since that time a number of wells have been sunk in various localities, but without success.

Formations penetrated by the drill.—The geological formations at the surface in northwestern Grey county throughout the belt lying northeast of the Niagara escarpment consist of Lorraine and Medina shales, while along the escarpment they are Clinton and Niagara limestones, and southwest of the escarpment the Guelph and Salina formations occupy the surface throughout the remainder of the county. Consequently, the drill will penetrate these formations according to the part of the county in which the well is situated. In a general way, the formations may be said to dip from the northeast towards the southwest. Unfortunately, detailed well records are not available, but the following log is an example of what is encountered northeast of the Niagara escarpment.

Log of well on Lot 5, Concession XXVI, Collingwood township[1].

Formation	*Material*	*Top Feet*	*Bottom Feet*
Pleistocene	Red clay	0	8
Utica	Black shale	8	48
Trenton	Black limestone	48	587
	Total depth		587
Show of gas (6,000 cu. ft. per day)			95

Haldimand County.

Description of fields.—Gas fields are fairly well distributed throughout Haldimand county, the production of the wells being, however, small.

History of development.—The first well in the Haldimand district was drilled about 1889 in the village of Caledonia. The first wells drilled by the Dominion Natural Gas Company in this county were in 1905, there being only one well in the field before this company entered it, and about 95 per cent of the wells are said to be still producing. In 1911 to 1912 a well 2,852 feet in depth was drilled to the granite in Oneida township. Developments in this county have been very active, 159 suc-

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 29.

cessful gas wells being drilled here in 1910. Many wells in this county have been drilled in Lake Erie, especially near Selkirk and Port Maitland. At the close of 1912 it was estimated that a population of 200,000 people were being supplied with gas from Haldimand county fields.

Formations penetrated by the wells.—The surface of this county is largely covered by a coating of Glacial Drift, ranging up to 100 feet thick in some cases. With this exception the uppermost formation consists largely of the Salina; but in the extreme north in some localities in Seneca township it is of Niagara age. The greatest thickness of Salina anywhere in the county is believed to be in the southwest corner. On account of uncertainties in correlation, the Salina, Guelph, and Niagara are grouped together in well records. The Niagara is presumed to constitute the lower 250 feet of the group, and of this the upper 200 feet is limestone and the lower 50 feet is shale. Under the Niagara lies 30 feet of Clinton dolomite, while below the Clinton follows several hundred feet of Medina, containing the Red Medina and the White Medina sands and red and black shales.

The most complete record of the formations penetrated in this county is given by a well drilled in 1911 to 1912 on the Ralph Muchmore farm in Oneida township. This well passed through the Salina, Guelph, Niagara, Clinton, Medina, Lorraine and Trenton formations, entering the granite at a depth of 2,851 feet. The complete log of the well as furnished by Mr. M. E. Rose is given below:—

Log of well in Oneida township.

Formation	*Material*	*Top Feet*	*Bottom Feet*
Pleistocene	Surface	0	60
Salina	Gypsum and limestone	60	125
Guelph and Niagara	Niagara limestone	125	350
	Black limestone	350	365
	Blue shale	365	385
Clinton	Dolomite	385	405
Medina	Blue shale	405	410
	Red Medina	410	422
	Blue shale and shells	422	495
	White Medina	495	505
	Red shale	505	1250

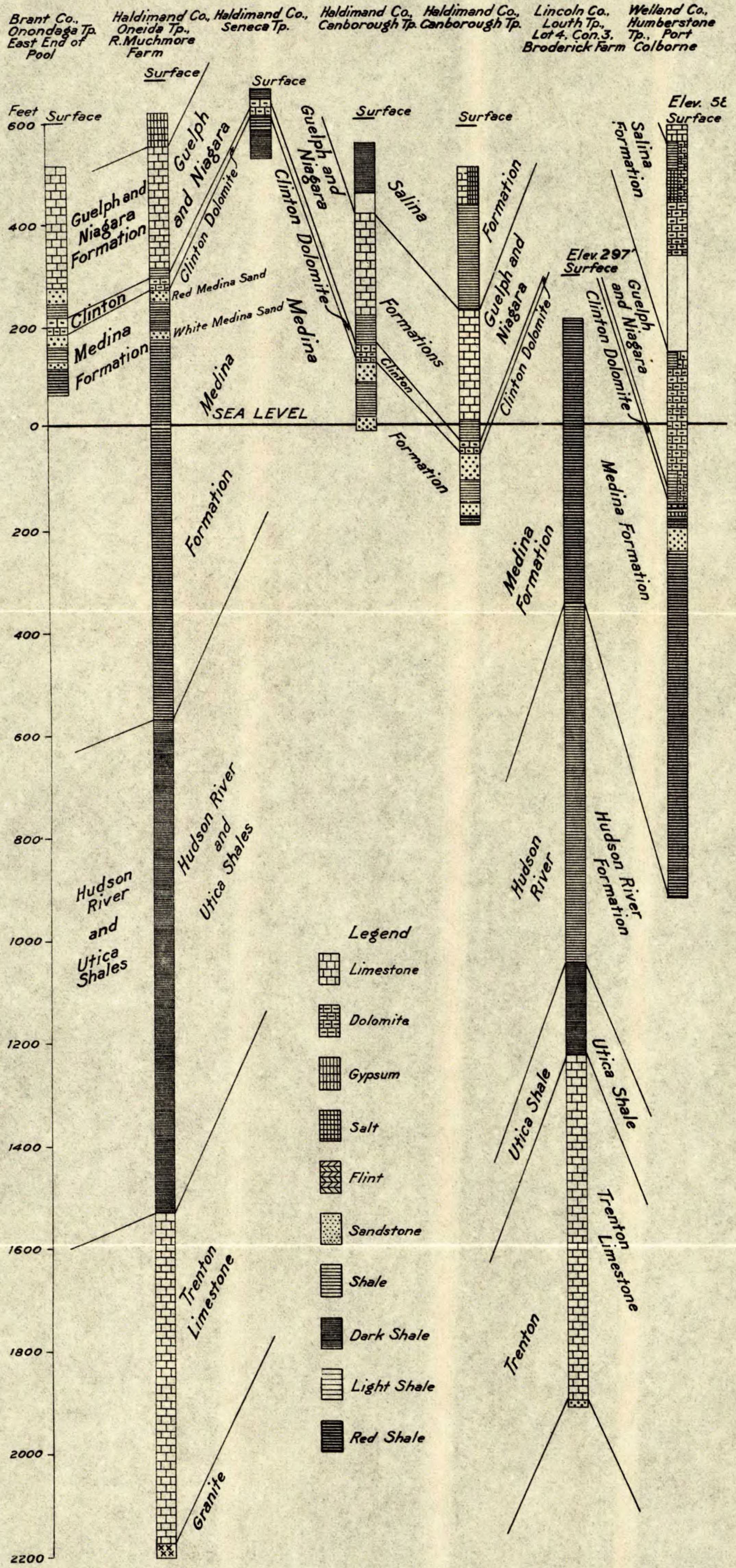

Fig. 12. Selected well logs, showing correlation of formations through Haldimand county, Ontario. (By F. G. Clapp and L. H. Huntley)

Formation	Material	Top Feet	Bottom Feet
Lorraine	Brown shale	1250	1950
	Brown shale and shells	1950	2205
Trenton	Limestones	2205	2851
	Granite	2851	
	Total depths		2852
	6¼-inch casing		375

A log is given below of a well drilled by the Dunnville Natural Gas Company on the west side of Grand river in Dunn township.

Log of well in Dunn township[1].

Formation	Material	Top Feet	Bottom Feet
Salina, Guelph and Niagara	Surface	0	70
	Limestone	70	150
	Shale	150	330
	Limestone	330	557
	Shale	557	602
Clinton	Limestone	602	624
	Shale	624	625
Medina	Red Medina	625	670
	Shale	670	720
	White Medina sand	720	740
	Red shale	740	780
	Total shale		780

The initial rock pressure was 335 pounds per square inch and the average capacity was 150,000 cubic feet per day.

Producing formations.—While in Elgin county the only gas is found in the Clinton, in Haldimand county it occurs in three sands, the Clinton, Red Medina and White Medina. The Red Medina is most productive, but occasionally gas is found in the Clinton or in the White Medina.

Casing of the wells.—Wells in the Haldimand county fields are generally cased with a single string of 5⅝-inch casing, 300 to 600 feet in length, extending to near the bottom of the Niagara limestone. In some instances, 6¼-inch casing is used, however.

Geological structure.—The general dip of the formations is from north to south in Haldimand county, and amounts to over 700 feet from Caledonia to Dunnville. From the centre of Rainham township in this county to Woodhouse township in Norfolk county, the sands are reported to dip uniformly

[1]Geol. Survey Canada, Vol. VI, 1892-3, p. 1055.

westward at the rate of 12 feet per mile. The dip from Walpole mountain south to the lake is reported 28 feet per mile.

Production of gas.—The gas wells in Haldimand county are of comparatively small production. They run from 40,000 to 2,000,000 cubic feet per day, the latter figure being unusual. Some wells of smaller production are used locally. For instance, in Caledonia the production per well will average from 2,000 to 10,000 cubic feet, and in about twenty wells lying north of Caledonia and used for burning lime, the production is still less. The pressure of the gas in the Haldimand fields is reported to have been originally 500 pounds per square inch, but few wells now exceed 200 pounds.

In the Canboro field, in 1912, the average production per well was 100,000 to 150,000 cubic feet per day, although one well was making as high as 600,000 cubic feet.

Markets for the gas.—The gas produced in the Canboro field goes to Dunnville, Hamilton, and St. Catharines. A large part of it goes to Hamilton through the lines of the Dominion Natural Gas Company and is sold to the Ontario Pipe Line Company.

Dunnville field in Dunn and Moulton townships.—In 1898, small pools were developed near Diltz station in Moulton township, but these have been practically exhausted and there is little production in the vicinity. The town of Dunnville was supplied for fifteen years from the Moulton and Attercliffe fields, but these fields have been abandoned. A number of gas wells formerly produced near the town of Dunnville from the Clinton and Medina formations. These had an initial pressure of 335 pounds, and averaged 150,000 cubic feet per day. In 1913 small gas wells were still being obtained and the territory was extended somewhat. The largest wells have only run slightly over one million cubic feet per day, but there is no production in the vicinity at present. At present nearly all gas comes from Selkirk and South Cayuga.

The general character of the strata penetrated in Dunn township is illustrated by the log on page 143.

Selkirk field, Rainham and Walpole townships.—In this field the Dominion Natural Gas Company is the largest operator.

In addition, the Manufacturers Natural Gas Company, Messrs. Root and Waine, The Standard Natural Gas Co., Aikens and Kohler, the Dunnville Natural Gas Co., The Citizens' Natural Gas Company, and various other local companies are operating in the field. The Dominion Natural Gas Company has from 300 to 400 wells in the field, and the various independent operators probably aggregate as many more.

All wells are drilled to the White Medina, and most of them produce also from the Red Medina and the Clinton sands. A few produce from the Red Medina only. The wells in Selkirk and South Cayuga fields are small, averaging below 200,000 cubic feet initial production. Drilling has been carried on a considerable distance into the lake, where the wells are about 800 feet deep.

Cayuga North township.—Up to 1912 six wells had been drilled for gas in and near Cayuga, the last being sunk nine years ago.

The first well was drilled at the planing mill. The Hyland well, one and one-fourth miles west of Cayuga, is said to have measured 810 feet to the top of the White Medina and to have been 875 feet deep. Gas was encountered in all three sands and the initial rock pressure was 400 pounds. There is little gas in the Red Medina at Cayuga and a big flow of water is encountered in the White Medina. The production is taken by the Dominion Natural Gas Company, but the wells were drilled by local people. Three of the wells are still producing, and are connected into the lines of the company mentioned.

Oneida township.—In Oneida township there are about 12 small gas wells. Mr. Milo E. Rose, of Caledonia, has furnished a log of a well drilled by him to the granite three miles south of Caledonia on the Ralph Muchmore farm, the log being given on page 142.

At Mt. Healy, a well was drilled several years ago by J. H. Leslie, on the Kirtland farm. It was 550 feet deep and passed the bottom of the Red Medina at 525 feet. This well had an initial rock pressure of 350 pounds and produced 125,000 feet of gas per day from the Red Medina sand. It was allowed to blow into the air for two weeks, which reduced both the pressure and production.

No detailed log is available in this township.

Seneca township.—In Seneca township there are reported to be forty small gas wells, mostly used for fuel in the lime kilns. In the summer of 1812, Mr. Milo E. Rose, of Caledonia, was engaged in drilling a well to the granite at Tyneside. In July, 1913, the National Natural Gas Co. completed a well estimated at 500,000 cubic feet per day. Several other wells are in progress.

Well logs are scarce in this township but the following is reported by Dr. Berry near the alabastine plant just north of Caledonia:—

Log of well in Seneca township.

Material	Formation	Top Feet	Bottom Feet
Shale	Niagara	0	20
Clinton limestone	Clinton	20	50
Red Medina shale	Medina	50	75
White shale	Medina	75	125
White Medina sand	Medina	125	135
	8¼-inch casing, drive-pipe		41
	6¼-inch casing		361

Canboro township.—The first well in the vicinity of Canboro was drilled in the spring of 1901 for a local company by Mr. John Carmody, and supplied the village with natural gas for four years. A second well was drilled by the same company in 1905, and in 1906 a third well was sunk by local farmers. Each of the latter two wells proved better than the preceding one, producing 500,000 cubic feet per day; and about a year ago two wells drilled in the vicinity proved the best producers up to that time. In the summer of 1912 sixty wells existed in the Canboro field, and only one had been pulled as a failure. In July 1913 one gas well turned out poorly but a good well was obtained on the John Carson farm and more are being drilled.

Three wells have also been drilled between Canboro and the village of Caistorville in Lincoln county. One of them originally showed a production of 250,000 feet per day. The average rock pressure is 200 pounds. The wells in volume run from 46,000 cubic feet to 800,000 cubic feet, the higher figure being the production of the last well drilled at the time the field was visited in 1912. Leasing was then very active in the vicinity, particularly to the north.

The following record of a typical well in the field is given by Mr. J. H. Leslie:—

Log of gas well in Canboro field.

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Salina, Guelph and Niagara	0	40
Shale, etc.		40	140
Guelph and Niagara		180	380
Shale		380	430
Hard white Clinton limestone	Clinton	430	460
Red Medina sand	Medina	460	500
Shale		500	565
White Medina sand (upper 20 feet is shelly and broken)		565	595
Total depth			595
Gas in last 10 feet of White Medina sand.			

One well in the Canboro field produces some gas from the Clinton. The balance are all in the White Medina. Yantzi well No. 3, located on the east side of the pool, sprays a little light amber oil. At the time the locality was visited in 1912 the wells were beginning to make a little salt water in the White Medina. One well was then making 300,000 cubic feet, and another 600,000 cubic feet; but the average daily production was from 100,000 to 150,000 cubic feet per well.

Pockets of from fifty feet to 100 feet are drilled below the pay in all wells in this pool, as at Selkirk and South Cayuga. The wells at Canfield are about fifty feet deeper than those at Canboro, to the top of the same formation.

Four wells have been drilled in the village of Canfield within the last 10 years. The first well drilled in 1902 was about 750 feet deep. This still supplies the town with natural gas for domestic and lighting purposes. In 1912, the closed pressure was approximately 150 pounds. Well No. 2 was drowned out, but gas still seeps through the column of water. The shut-in pressure shows 150 pounds, and the well might be productive if bailed and cleaned. Well No. 3 was drilled 6 years ago, and is used to supply the village of Canfield Junction. Well No. 4 was drilled in 1911 by the local bank at Canfield for their private use and for fuel in the chopping mill. Some wells have been finished in this township as recently as the past year.

The companies operating in 1912 were Root and Waine, supplying gas to Dunnville and Hamilton, and Aikens and Kohler, piping it to St. Catharines. In addition Melick, Most and Keinburger were starting operations and another company represented by Mr. Leslie had leased a large block of territory between Canboro and Caistorville.

Sherbrooke township.—In 1912, the gas territory was extended somewhat in this township, but as in other parts of the county, the wells are small, generally averaging less than 1,000,000 cubic feet per day.

Operating companies.—One of the largest operators in Canada is the Dominion Natural Gas Company, which within the last few years has been drilling many wells in Elgin, Norfolk, and Haldimand counties with good success.

The principal companies involved in the transfer to the Doherty interests of New York, in addition to the Dominion Natural Gas Company, were the Union Natural Gas Company and the Medina Natural Gas Company. The Union controls the natural gas supply in the Tilbury-Romney field of Kent county, and holds a controlling interest also in the United Fuel Supply Company (furnishing gas to Sarnia, Petrolia, Dresden, and a number of smaller places), the Volcanic Oil and Gas Company (which supplies Chatham, Walkerville, Windsor, and a dozen smaller towns), the Northern Pipe Line Company (supplying Wallaceburg and Prairie Siding), and the Ridgetown Fuel Company (supplying Ridgetown and Highgate). Therefore, the New York parties practically control the natural gas business of Ontario. These people have also purchased the Beaver Oil and Gas Company (which has franchises in Leamington, Kingsville, and Wheatley).

Haliburton County.

Haliburton county is in a part of Ontario where the formations are mainly or entirely of Laurentian age, and consequently are unsuitable for holding oil or gas, and these substances will never be found in commercial quantity.

Halton County.

General Statement.—No oil or gas fields of commercial importance have ever been found in Halton county. In 1912 there was some excitement at Milton, but it was not based on reason.

History of developments.—Although without commercial importance, various tests have been sunk in the county at different times, starting many years ago, when a well was drilled near Milton on lot 10, concession I, Trafalgar township, to a depth of 606 feet without results. Showings of oil were obtained at 500 to 700 feet in a very close-grained rock. The showings improved on shooting the well. During 1911 to 1912 several wells, drilled in the vicinity of Burlington and Port Nelson, encountered showings of gas and a previous well at the Queens Hotel in Burlington had encountered a rock pressure of 60 to 70 pounds per square inch, which was soon exhausted. A dry hole was also drilled one-fourth mile from the coast in the same vicinity. In April, 1912, a test was drilled on the Scott farm at Milton, and had a showing of light amber oil at the time the tools were lost. Finding it impossible to recover the tools, a second well was drilled near by and produced one and one-half barrels of light coloured oil per day, reported by Mr. Peat to be 59° and very high in paraffin. Following the drilling of this well, a number of test wells were sunk at Milton, but hope of finding a productive field was in vain and the locality is now abandoned. The first well after the one causing the excitement in the Milton field was completed in the early part of 1912 on the Howden farm in the western part of lot 2, concession V, Esquesing township; the only indication of oil was a small showing in the Trenton. The well was drilled to the granite, which was reached at a depth of 1711 feet. The oil in the first test at Milton is reported to be 58° gravity and to be rich in paraffin. Another well is said to have found a very light showing of oil in the Lorraine shale at a depth of about 575 feet.

Formations penetrated.—The formations underlying the glacial drift in the eastern half of Halton county consist of Medina rocks, while in the western half of the county they are of Clinton, Niagara, and Guelph age. It is unfortunate that good records are not numerous, but there is a record of a shallow well near Milton which reported 200 feet of Medina red shale underlying 67 feet of surface materials, and under the red shale occurs 159 feet of bluish Lorraine shale.

Hastings County.

Hastings county will not contain any oil or gas fields, since conditions are unfavourable. The entire northern two-thirds of the county is underlain by formations of Laurentian age, in which neither oil nor gas exists in quantity, and the strata farther south consist of Trenton and associated limestones, which, being without cover, will never prove productive. Some small showings of natural gas are reported in wells in the southern part of this county, but are of no consequence.

Huron County.

General statement.—No oil or gas fields have ever been found in Huron county, and it is improbable that they exist, since the geological conditions are not favourable. There have, however, been a great many wells drilled in this county for salt, and many of them were commercially successful for that purpose. They are described herein, being of some value in leading to a knowledge of geological conditions which exist in the same formations in counties farther south.

History of drilling.—The drilling in Huron county was started previous to 1865. Much drilling for salt has been done, and consequently it is impossible to give anything like a complete list of the wells drilled and this is not essential in a report on oil and gas, in a county where the substances were not found. In the immediate vicinity of Goderich many salt wells have been drilled, but it is not important to mention these individually, except to give one or two logs for reference in studying the stratigraphy in connexion with oil deposits farther south. The salt industry has been well described in various reports of the Canadian Geological Survey, according to which the principal drilling

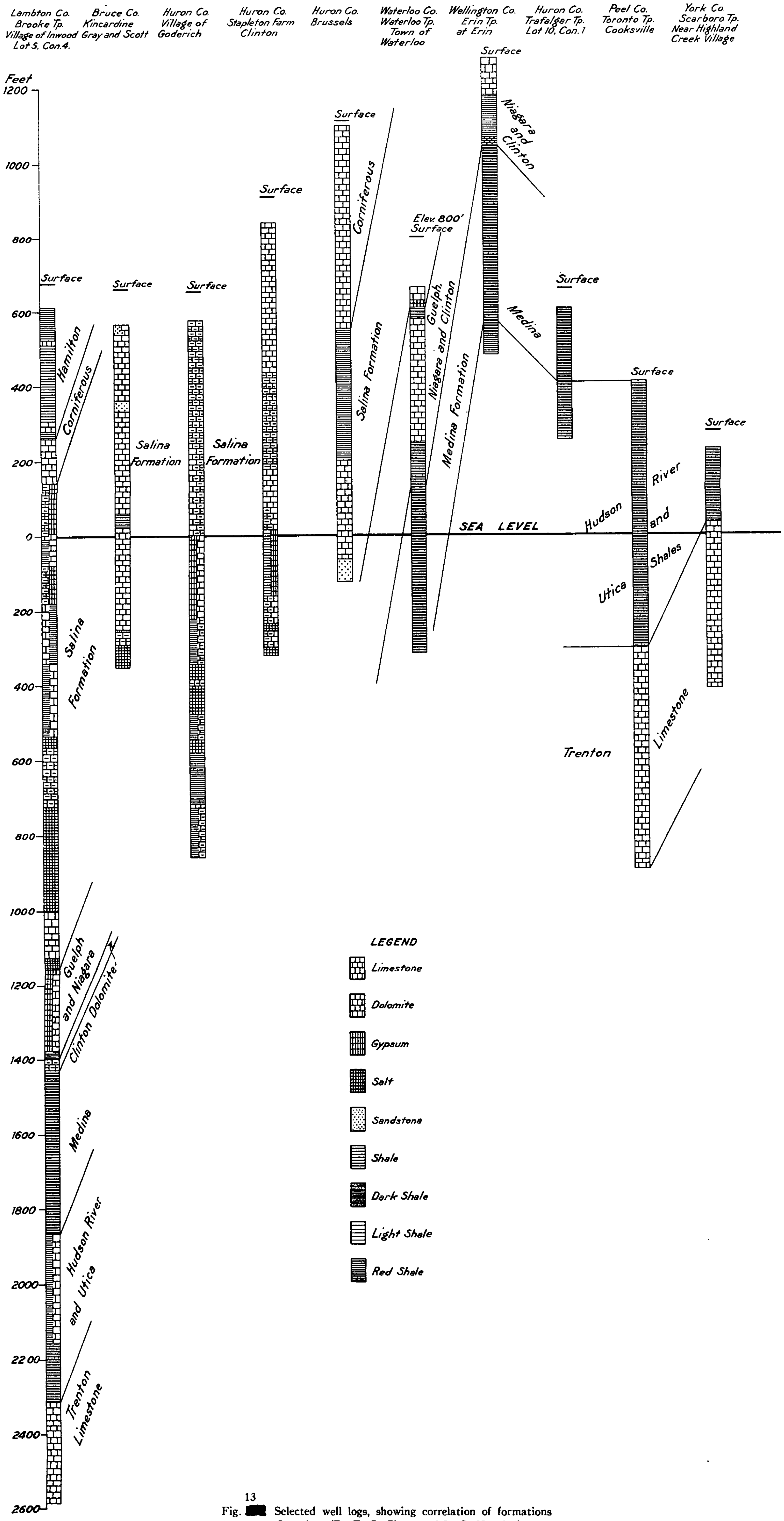

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Fig. [redacted] Selected well logs, showing correlation of formations across Ontario. (By F. G. Clapp and L. G. Huntley)

has been at Goderich, Brussels, Clinton, Blyth, Wingham, Seaforth, Hensell, Exeter, etc[1].

Formations penetrated.—The formations underlying the Glacial Drift in Huron county consist principally of rocks of Onondaga age, except that in the extreme north end of the county, where a little Salina reaches the surface, consequently, the wells drilled in this county are mostly in the Onondaga and Salina formations. The depths of the salt wells range from 1000 to 1250 feet and the depth to the first salt is 950 to 1150 feet. In order to give an idea of conditions the reader is referred to Fig. 13, which makes a correlation between wells drilled in Huron and surrounding counties. The following diamond drill record, drilled entirely in the Salina formation, with the exception of the first 79 feet, may be of interest as showing the condition in rocks penetrated:—

Log of salt well at Goderich[2].

Material	*Top Feet*	*Bottom Feet*
Gravel	0	14
Blue clay	14	45
Boulders	45	55
Gravel	55	59
Boulders	59	72
Sand and clay	72	79
Dolomite with thin limestone layers	79	557
Limestone with corals, chert and beds of dolomite	357	633
Dolomite with seams of gypsum	633	876
Variegated marls with beds of dolomite	876	997
Rock salt, first bed	997	1028
Dolomite, with marls towards the base	1028	1060
Rock salt, second bed	1060	1085
Dolomite	1085	1092
Rock salt, third bed	1092	1128
Marls, with dolomite and anhydrite	1128	1209
Rock salt, fourth bed	1209	1214
Dolomite and anhydrite	1214	1221
Rock salt, fifth bed	1221	1235
Marls, soft, with anhydrite	1235	1371
Rock salt, sixth bed	1371	1377
Marls, soft, with dolomite and anhydrites	1377	1509
Casing		365
Total depth		1517

Other important wells drilled in this county were at Clinton, Brussels and Seaforth, and these are added for reference.

[1]Refer also to report on Salt in Canada by L. H. Cole, Mines Branch, Ottawa, 1914.
[2]Hunt, T. Sterry, Geol. Survey Canada, Rept. Prog., 1876-77.

Log of salt well at Clinton[1].

Material	Top Feet	Bottom Feet
Surface	0	67
Limestone	67	480
Cherty limestone with dolomite	480	684
Limestone	684	860
Cherty limestone with dolomite	860	896
Shale, limestone, gypsum and marls	896	1151
Rock salt, first bed	1151	1166
Shale, gypsum and salt	1166	1214
Rock salt, second bed	1214	1239
Total depth		1239

With the exception of the 67 feet of surface drift, this well was entirely in the Onondaga and Salina formations.

Log of salt well at Brussels[2].

Material	Top Feet	Bottom Feet
Surface	0	16
Limestone	16	116
Magnesian limestone	116	382
Limestone with chert	382	562
"Soapstone"	562	915
Grey dolomite	915	1012
Dolomite	1012	1180
Dark brown sandstone	1180	1244
Salina water		1012
Little oil and gas		1200
Total depth		1244

Kenora District.

It would be useless to test for oil or gas in this district since the surface formations are entirely crystalline, of Laurentian and Huronian age, and unsuitable for containing oil or gas in quantity.

Kent County.

Description of fields.—The principal oil and gas fields of Kent county are commonly classified as the Tilbury-Romney gas field, Tilbury-East oil field, new Tilbury East oil field (or Fletcher field), and the Bothwell oil field. The Tilbury East and Bothwell fields were of considerable importance in the early days of oil production, but at present the Tilbury-Romney gas field is the only field of much importance, as it still supplies a

[1]Brumell, H.P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 57.
[2]Gibson, J., Salt Deposits of Ontario, Am. Jour. Sci., Vol. V, 3rd Ser.

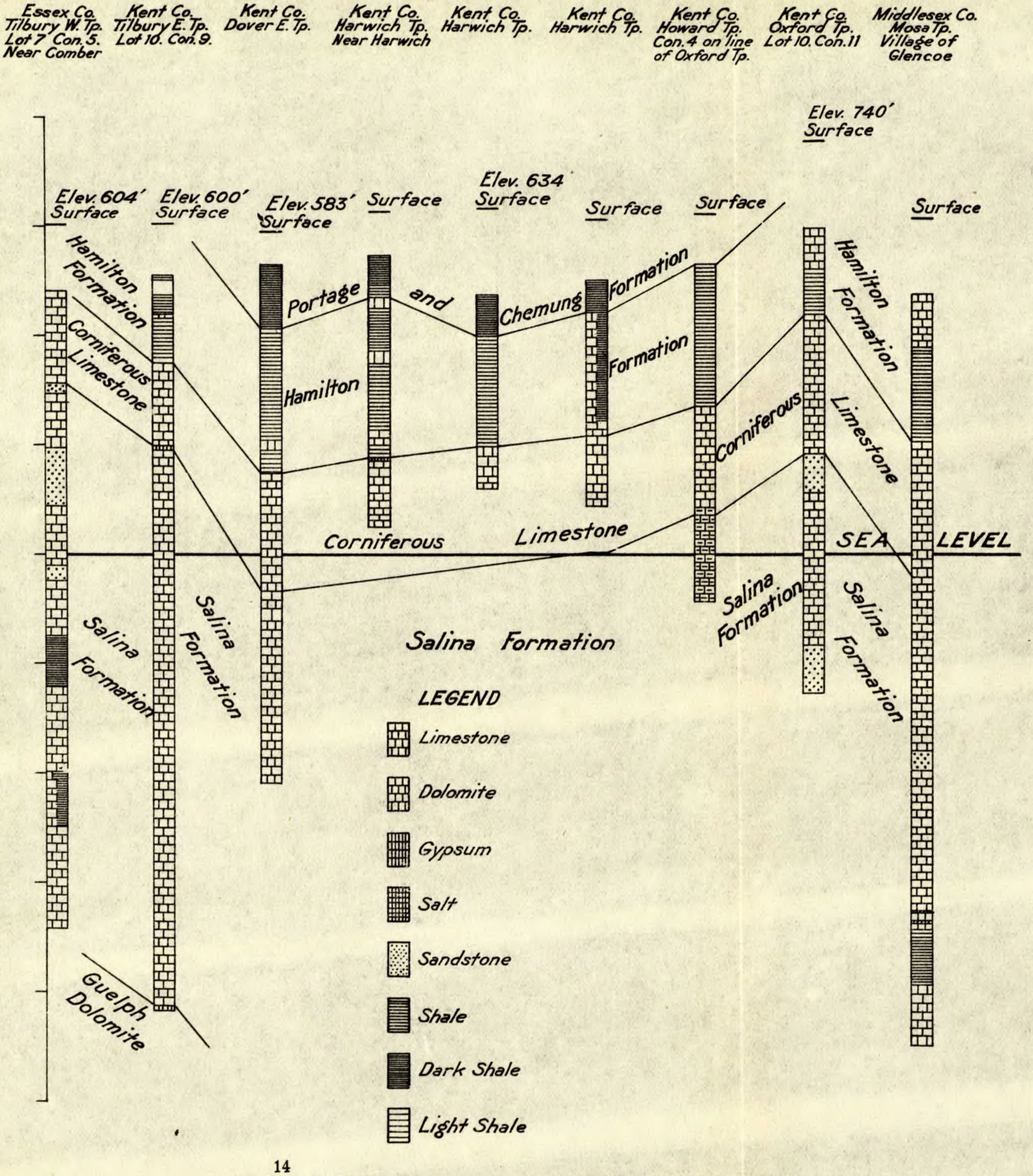

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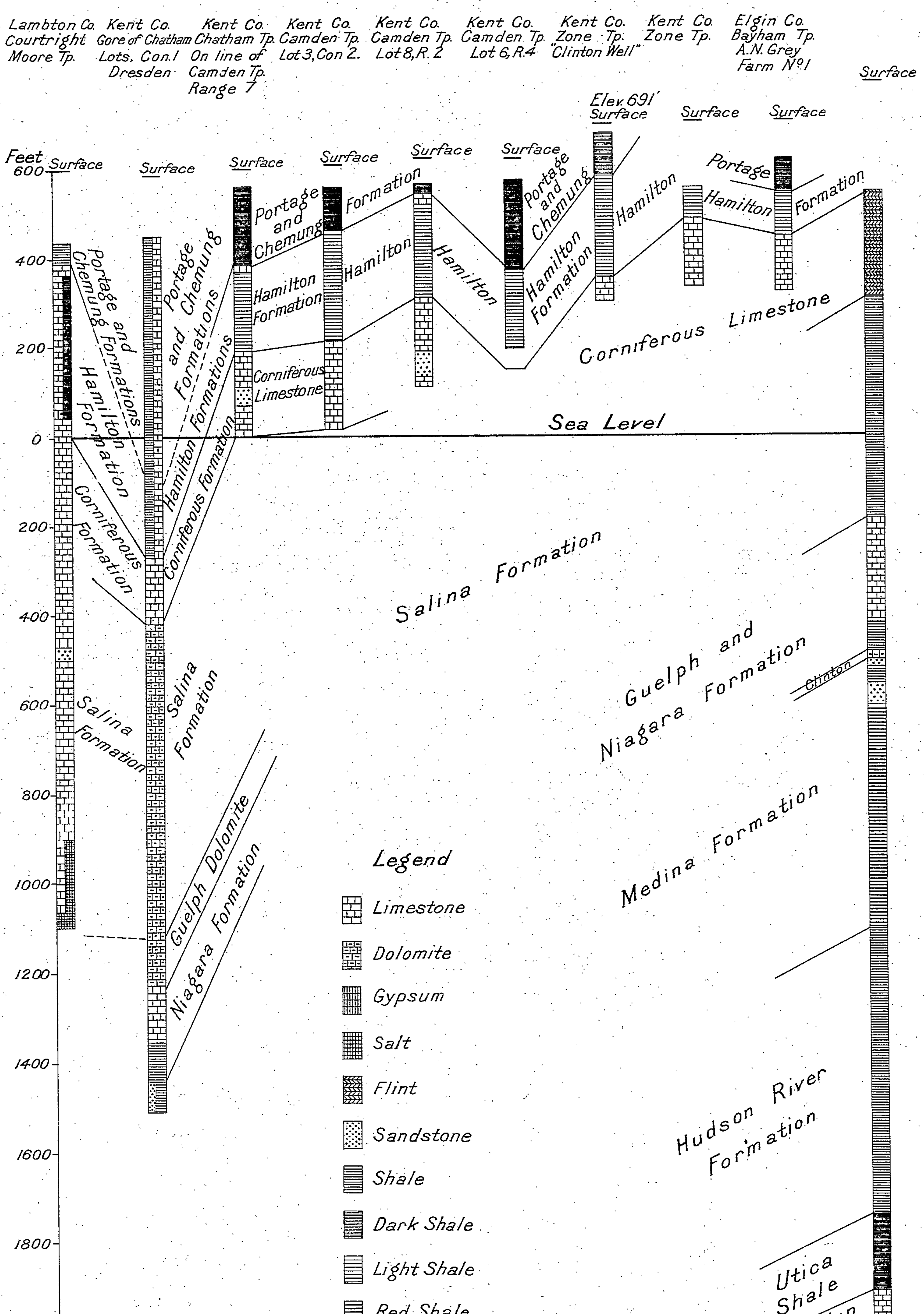
Fig. [redacted]. Selected well logs, showing correlation of formations through Kent county, Ontario. (By F. G. Clapp and L. G. Huntley)



15

Fig. [redacted]. Selected well logs, showing correlation of formations through Kent county, Ontario. (By F. G. Clapp and L. G. Huntley)

Canada

DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER, R.W. BROCK, DEPUTY MINISTER.

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR

1914

H. E. Baine, Chief Draughtsman.
David Westwood, Draughtsman.

Information compiled from reports of the Geological Survey and the Ontario Bureau of Mines, and field work by Frederick G. Clapp and L. G. Huntley.

To accompany report on "Petroleum and Natural Gas Resources of Canada" by Frederick G. Clapp and others.

Nº 296

large quantity of gas which is piped long distances. The distribution of the various fields may be seen on the map of Kent county in Map 296. Outside of the fields mentioned, small oil pools are situated in Raleigh, Harwich, and Camden townships.

History of developments.—The principal development in Kent county closely followed the discovery of the Petrolia and Oil Springs pools in Lambton county in the early sixties, when many wells were drilled. Boring was first undertaken in the gores of Chatham and Camden, gradually receding from the Sydenham river. Subsequent to 1867, however, operations were only desultory and many years elapsed without the drilling of a single well. Oil was first struck in this county in the Tilbury-Romney pool in December, 1905, the first well being situated on the John Kerr farm, in the township of Tilbury East, by the Acme Oil Company of Detroit. The first well produced both oil and gas. This field is the only one that has ever exceeded the production of the Petrolia fields; it has now been practically exhausted and no new development has taken place in it. Since the decline of the old field, however, about thirty new wells have been drilled by the Standard Oil Company of Canada at Fletcher station, in the north end of the old field, north of Michigan Central railway. There are also a few oil wells inside the gas territory.

South of the old oil field in an area of about 60 square miles situated in southern Tilbury East, eastern Romney, and extending into the extreme southwestern corner of Raleigh township, is a gas field, which is at present the most important field in Ontario, and at present supplies all the natural gas used in Essex county. The gas development was in reality started by drilling in 1905 in the old territory and operations were pushed southward. In December, 1906, the first well near Lake Erie was drilled, in what has since proved to be the most productive portion of the field. By May, 1909, the limits of the field became fairly well outlined, but there is no doubt that it extends far beneath the lake. In 1912 when the field was visited by Mr. Huntley, there were 110 producing wells, which had an estimated production amounting to 15,000,000 cubic feet of gas per day. Good wells continued to be struck during 1913.

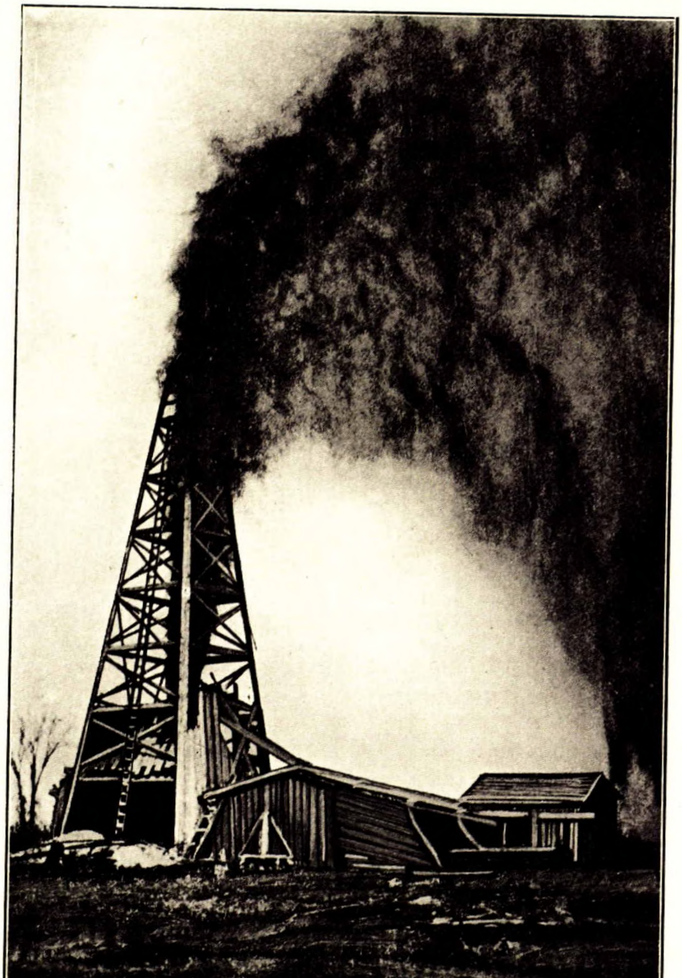
With the exceptions noted, all the oil and gas fields west of Chatham have been abandoned. A little oil is still being pumped from less than a dozen wells in the ninth concession of Raleigh township near Charing Cross, from wells drilled ten years ago.

Production of natural gas in Kent county.—The quantity of natural gas produced in Kent county in the first year of full production, namely 1908, was 848,000,000, and in 1911 this amount had increased to 5,649,000,000; the total production being recorded as 13,379,000,000 cubic feet[1]. The total production was given by him as 13,379,000,000, and if the 1,875,000,000 cubic feet be added, which he estimates were wasted or otherwise lost in the searching for oil, the total production of the field up to the end of 1911 was about 15,254,000,000. Mr. G. R. Mickle estimated that the total production of natural gas from Kent county field will go beyond 100,000,000,000 cubic feet.

Tilbury-Romney gas field.—During the year 1913, good wells continued to be found in this field by the Union Natural Gas Company, which is the dominant company, together with the Glenwood Gas Company and others.

Failing to profit by the lessons of the past, the natural gas companies in southern Ontario, Canada, are in danger of repeating the folly of killing another natural gas field by overtaxing its capacity. Thus in 1891, the Kingsville gas field was opened in southern Essex. It would have supplied all of the western part of the southern peninsula with gas for many years, but a line was laid into Detroit with the result that the field was pulled on too hard and salt water came in and drowned it out. The same thing happened in the Welland district when gas was exported to Buffalo, N. Y. This led the Dominion Government to pass an act prohibiting the exporting of natural gas. Now the same thing is about to happen in the Tilbury field, bordering on the northern shores of Lake Erie for a distance of 10 miles, and about 4 miles in width. It has been supplying the towns in the western part of the southern peninsula for a number of years. The supply in the eastern section is beginning to prove inadequate, and of late a line has been laid from the east to connect with the Tilbury field, it being proposed to help out

Rept. Bureau of Mines, Ontario, 1912, Vol. 21, part 1, p. 39.



The centre of the oil district, Kent county, Ont.

the shortage in the east by a drain on the Tilbury field. This has led to a clash in the courts of Ontario between the Union Natural Gas Company, operating largely in the western field, and the Doherty interests, operating largely in the eastern section. The wise thing to do would be to at least prevent the use of this ideal fuel under boilers and in factories, thus conserving it for domestic consumption where it will do the greatest good to the greatest number.

Productive formations.—The oil produced in the Bothwell, Thamesville, Northwood, and Charing Cross fields is derived from the Onondaga limestone, as was the case with the old Tilbury-Romney field. The natural gas and the upper oil strata in the large gas field in the southern part of Kent county, known as the new Tilbury-Romney gas field, is produced from a dolomite in the lower part of the Salina formation, similar in age to the rock in which the oil is found in the new Tilbury East pool, in the vicinity of Fletcher. The lower oil strata here belong in the Guelph formation.

Material	*Formation*	*Top* *Feet*	*Bottom* *Feet*
Surface materials	Pleistocene	0	43
Black shale	Portage and Chemung	43	223
Limestone	Hamilton	223	235
"Soapstone"	Hamilton	235	407
Limestone	Onondaga	407	482
Sandstone	Onondaga	482	526
Hard limestone	Onondaga	526	605

At the southern end of the county a typical section is as follows:—

Formations penetrated by well in Lot 10, Concession IX, Tilbury East township[1].

Material	*Formation*	*Top* *Feet*	*Bottom* *Feet*
Boulder clay	Pleistocene	0	95
Grey sand	Pleistocene	95	100
Clay and gravel	Pleistocene	100	128
Blue clay shale ("Upper soapstone")	Hamilton	128	165
Middle limestone	Hamilton	165	175
Blue clay shale ("Lower soapstone")	Hamilton	175	242

[1]Coste, Eugene, Jour. Can. Min. Inst., Vol. X, 1907, p. 77.

Material	Formation	Top Feet	Bottom Feet
Yellow limestone	Onondaga ("Big lime")	242	400
Grey, drab, brown, and blue dolomite with gypsum and flint. Shales with darker shaly dolomites and more gypsum 835 to 1135	Salina	400	1420
Bluish-white dolomites, limestone, oil at 1426	Guelph	1420	1429

In the Tilbury-Romney field as many as four horizons of gas are sometimes found in the bottom of the Salina formation, and below them oil is frequently struck.

Depth of wells and formations penetrated.—The total depth of wells in Kent county ranges from 350 to 2,000 feet. The depth to the top of the oil-bearing formation (Onondaga) ranges from 220 feet to 400 feet. The wells in the Bothwell field are only about 400 feet, while a dry hole in Harwich township is reported at about 2,000 feet. The depth to natural gas in the Tilbury-Romney field ranges from 1,100 to 1,400 feet, according to what part of the field and what gas horizons are desired, being found in the lower part of the Salina formation. In the north end of the Tilbury-Romney gas field oil is found at a depth of about 1,400 feet below the gas and not far from the top of the Guelph formation.

The best information regarding the geological formations can be gathered from well logs; and while many of these have been poorly kept, a large number of logs are available in which the formations have been rather accurately recorded by the drillers, so that it is possible to make geological correlations from point to point between the wells. In most of the wells it has been possible to distinguish approximately between the Portage-Chemung, which is recorded by drillers as being composed of black shale, and the Hamilton formation, which is recorded as a soapstone. One must understand in this connexion that the rock is not in reality soapstone, since true soapstone is a very different kind of rock. The soapstone of the oil drillers is a light coloured soapy shale.

The well records in Kent county reveal a thickness of 30 to 610 feet of superficial clayish deposits, which overlie 20 to 200 feet of Portage-Chemung shale. In some instances the

Portage-Chemung is cut out by erosion. The Portage-Chemung in turn rests upon 100 to 150 feet of Hamilton shale, which, judging from well records and from geological outcrops in other localities, contains occasional beds of interlaminated thin limestone. Below the Hamilton lies 150 to 250 feet of a hard fossiliferous limestone, known geologically as the Onondaga, and to the well drillers as the "Big Lime." This is the formation which has produced most of the oil in Kent county; and in fact, the only field which did not derive its oil from this formation is the new Tilbury-Romney field in the vicinity of Fletcher. Below the Onondaga limestone lies a thickness of Salina formation, consisting of limestone, gypsum and salt beds, which, although 1,600 feet in thickness in the Petrolia field in Lambton county, runs only about 1,000 feet in the Tilbury-Romney gas field. Much salt water is encountered in this formation. The lower part of this thickness contains frequent flows of gas in the Tilbury-Romney gas field in the townships named. The deepest formation yet penetrated by the drill in Kent county is the Guelph limestone, which directly underlies the Salina, and in which some oil is found in the new Tilbury-Romney gas field, and oil in the vicinity of Fletcher.

The following well record is typical of the formations encountered in the north side of the county.

Formations penetrated in well at Dresden, Gore of Camden[1].

Material	*Top* *Feet*	*Bottom* *Feet*
Surface	0	43
Shale, black	43	223
Limestone	223	235
"Soapstone"	235	407
Limestone	407	482
Sandstone	482	526
Limestone, hard	526	605

As shown, the production in the Tilbury-Romney field almost quadrupled itself from 1906 to 1907, since which date it has declined. The Bothwell field has declined slowly but steadily; while in the Thamesville field no figures have been reported since 1907.

Pressure and volume of the gas.—The best description of

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, 1889-91, Pt. Q.

the Kent county gas field has been published by the Ontario Bureau of Mines[1]. Unfortunately no exact figures are available of the production of gas in this county. The capacity of wells, however, is much greater than it is in any other field in Ontario. The initial open flow capacity of the wells in this field was in one instance as high as 7,000,000 cubic feet per day. The initial rock pressures range up to 650 pounds per square inch.

The production of this field during 1912 was reported unofficially to be 15,000,000 cubic feet per day.

Markets for the gas.—The various municipal supplies in Kent county are derived from the following sources: Wallaceburg is supplied by the Northern Pipe Line Company; and the United Fuel Supply Company[2], Limited, has lines into Sarnia and Petrolia from the Tilbury-Romney gas field. The gas from this field is piped to Chatham, 14 miles distant, Windsor, 45 miles distant, Sarnia, 55 miles, Blenheim, 14 miles, Ridgetown, 23 miles; taking in Tilbury, Merlin and smaller places on the way. A population of about 50,000 people is served with gas from this field.

Most of the Ontario towns are paying 30 cents a thousand cubic feet for natural gas. At St. Catharines the price is 70 cents.

Operating companies.—Among the companies operating in Kent county are the Roth-Argue-Stearns-Barnard Company, Ltd., operating in the new Fletcher field, the Union Natural Gas Company, Leamington Oil Company, Reserve Oil and Gas Company, Limited (drilling for gas), and the Beaver Oil and Gas Company, Limited (drilling for gas). The Standard Oil Company of Canada also has some good producers in the Fletcher field.

In 1912 to 1913 there was a great change in the names and management of some of the largest gas companies operating in Ontario, extensive purchases being made by Henry L. Doherty and Co., of New York city. The most extensive single transaction in this business was the sale of the entire holdings of the Dominion Natural Gas Company to the firm

[1]Mickle, G. R., 19th Ann. Rept., 1910, Vol. XIX, Pt. 1, pp. 149-153 (1 map).
[2]Gibson, Thos.W., 21st Ann. Rept., Bureau of Mines, Ontario, Vol. XXI, Pt. I, 1912, p. 35.

above mentioned. The Natural Gas plants at Brantford, Woodstock, Dunnville, and that of the Beaver Natural Gas Company of Chatham were also acquired by this firm. They are now delivering to Hamilton about 80 per cent of the natural gas consumed in that city. The National Natural Gas Company was recently awarded a competitive franchise for the city of Hamilton.

Quality of petroleum.—The oil in Romney township is of a heavier grade than in Tilbury township. It is dark green oil with a density of 0·8330—0·8187 and contains sulphur, similar to that of the Lima oil. In the Romney pool, however, it is 0·8860—0·8750 in density. The oil in the Bothwell pool is at present about 35° Baumé, having been formerly 38° to 40° B. In the oil of the Tilbury fields a similar amount of sulphur is present to that in the case of the Lima, Ohio, oils.

Quality of natural gas.—An analysis of the natural gas produced from a well drilled some years ago by the Volcanic Oil and Gas Company, on the David Holiday farm on lot 1, concession VI, Raleigh township, is given below; the gas was struck at a depth of 1,470 feet, at the bottom of the well, 7,000,000 cubic feet of gas per day with a rock pressure of 650 pounds per square inch were produced. The quality was as follows:—

Analysis of gas from David Holiday well, Lot 1, Con. VI, Raleigh township[1].

	Per cent
Hydrocarbons (principally methane)	92·20
Carbon dioxode (CO_2)	1·40
Oxygen	Trace
Carbon monoxide (CO)	0·21
Hydrogen	0·40
Nitrogen	5·59
Hydrogen sulphid (H_2S)	0·20
	100·00

Old Tilbury East oil pool.—Oil was first struck in the old Tilbury pool in December, 1905, on the John Kerr farm by the Acme Oil Company of Detroit, the first well producing both oil and gas. In 1907, the banner year, there were 150 wells in the field and a total of 411,588 barrels of oil were pro-

[1]Coste, Eugene, Jour. Can. Min. Inst., 1907, p. 77.

duced during that year. Since that time the field has declined. The producing formation was the Onondaga. Most of the recent production has come from the northeast extension of the field around Fletcher station, and the former oil field in Romney township has been practically exhausted. A brief record of the first well is as follows:—

	Feet
Gas	1360 to 1375
Oil and gas	1385
Second oil	1410
Third oil	1430
Salt water slightly below	
Total depth	1450

The oil was piped to Coatesworth station of the Père Marquette railway, from where it was hauled by tank cars to the refinery of the Imperial Oil Company at Sarnia.

Oil was struck also on lot 11, concession II, five miles southwest of the pool mentioned. It occurs in the Guelph formation at a depth of 1,290 feet, but was abandoned owing to the presence of too much salt water.

Tilbury-Romney gas field.—This is at present by far the most important natural gas field in Ontario. The gas was discovered in 1905 in a 1,450-foot well in searching for oil; the former being struck at 1,360 to 1,375 feet and the latter at 1,385 to 1,410. The waste of gas during 1906 and 1907 was very large, being estimated by Mr. G. R. Mickle, mine assessor for Ontario, at about 1,500,000,000 cubic feet[1].

The supply was preserved for use and opened up largely through the efforts of the Volcanic Oil and Gas Company and was turned into the Chatham mains on March 19, 1907.

In 1912 the estimated production of the field was 15,000,000 cubic feet per day; and during 1913 good wells continued to be drilled.

The principal operators in this field are the Union Natural Gas Corporation of Canada, and the Beaver Oil and Gas Company. The gas is encountered at depths of 1,100 to 1,450 feet, in the bottom of the Salina formation. Several different gas-bearing strata are encountered throughout an interval of 250 feet. The average record of the strata passed through is approximately as follows:—

[1]Gibson, Thomas W., 21st Ann. Rept., Bureau of Mines, Ontario, 1912, Pt. I, p. 39.

Record of typical well in the Tilbury-Romney gas field.

Material	Top Feet	Bottom Feet
Surface	0	165
"Soapstone" (Hamilton)	165	270
(Onondaga)	270	840
"Big lime" (Salina)	840	1350
Limestone (gas and oil pay)	1350	1420
Total depth		1420

Very few dry holes are encountered in operations in the Tilbury-Romney gas field. The wells are drilled with American Standard drilling rigs, with derricks 72 feet high, and gas is used for fuel in drilling. Operations are still active in this field and wells of several million cubic feet per day are occasionally drilled. In the summer of 1913 nine sets of tools were drilling for gas.

A record showing the casing needed in these fields, though of a different well than that given above, is as follows:—

Record of I. Coatesworth well, Lot 186, Romney Township, drilled in 1911.

	Feet
10-inch drive pipe	190
6¼ " casing	776
3 " tubing	1354
First gas	1160
Second gas	1160
Second gas	1335
Total depth	1345

Drilling in Lake Erie.—In the Tilbury-Romney gas field in Kent county, the richest gas wells have been found close to the shore of the lake; these wells range in some instances from 3,000,000 to 10,000,000 cubic feet in volume. When the Union Natural Gas Co. was formed several years ago to take over the companies operating in western Ontario, certain parties secured a lease from the government of the lake shore in the Tilbury-Romney field and commenced drilling in front of rich leases held by the Volcanic Oil and Gas Company. An injunction followed, the Volcanic Company asking for an order restraining the defendants (Messrs. Simms and Chaplin) from completing the well on the ground that it was being drilled on territory on which the Volcanic Company held a lease. This injunction was in force in the early part of 1912.

During the early part of 1913 there was an interesting contest in the courts between the Glenwood Gas Company and the Dominion Government, the latter having served notice upon the company to stop all drilling operations in the lake until such time as the plans and specifications for such drilling could be submitted to and approved by the Governor General in council. The cause of the notice was a petition forwarded to the governor by some 200 residents along the lake shore, comprising farmers and fishermen, protesting against drilling operations. The claim was made that drilling interferes with fishing operations and effects the riparian rights of the land owners.

In the previous suits, namely, the Volcanic Oil and Gas Co. vs. Chaplin, the matter at issue was whether the company was trespassing on lands originally owned by the adjacent land owners and in the course of years washed into the lake. In that case the injunction was made perpetual, restraining the defendant from drilling within the territory described.

There is no doubt that the production of the wells becomes larger as the lake is approached, and it should be expected that such wells will be more prominent than those on land, since they draw not only from the limited area in their immediate vicinity, but the gas taken out will be replaced by that coming from perhaps a long distance through the producing sand beneath the lake. It has been erroneously stated, however, that the Tilbury-Romney field is continuous with the Ohio fields, since the fields in Ohio south of Kent county, Ontario, obtained their gas in the Clinton sand, which corresponds with one of the Medina sands instead of in the Guelph, as is the case in Kent county.

Several deep tests have been drilled. About 25 years ago a well was sunk in the Salina formation to about 1500 feet. Another deep well, situated on the Goodyear lease, was drilled by Messrs. Garmon and Fairbanks to a depth of about 900 feet. Both these wells are plugged off and are to-day producing from the Onondaga.

Many wells in this field have been drilled in the waters of Lake Erie.

Fletcher field.—The new oil wells in the vicinity of Fletcher station produce from the bottom of the formation in which gas exists in the Tilbury-Romney gas field. The recent production of the Tilbury East pool has been about 2500 barrels per month from the vicinity of Fletcher station. All the oil from this pool is shipped by tank cars to the Imperial Refinery at Sarnia. In the summer of 1913 five sets of tools were drilling for oil.

New Tilbury East field.—The first new well in this field did not come up to expectations, being short lived on account of drowning by water. Some difficulty was experienced in this connexion in 1905, but in later developments the drillers learned how to handle the water and stopped drilling before encountering it.

The best well was one belonging to the Central Oil and Gas Company, which had an initial flow of 1500 barrels per day of oil and salt water, of which 300 barrels was oil. Two months later this well was still producing 50 barrels of oil. Gas wells of large volume were found associated with oil, the most productive being one which had originally 7,000,000 cubic feet of gas with 650 pounds rock pressure and changed later to an oil well. Recently the Glenwood Gas Company has completed its third well good for 1,500,000 cubic feet per day. The Standard Oil Company has finished a big well on the Coatesworth farm with an estimated yield of 4,250,000 cubic feet per day.

North of the Michigan Central railway the lower part of the Salina formation is barren of oil, which is found in the Guelph instead.

New Romney oil field.—Seven miles southwest of the Fletcher field, in the northern part of lots 21, 22, and 23, concession IV, of Romney township, a small pool of oil was discovered in 1905, occurring about 180 feet from the top of the Big Lime (Onondaga limestone) at a depth of 200 to 270 feet from the surface.

The first well had a daily production of 40 barrels of oil and 500,000 cubic feet of gas; a second well gave only 8 to 10 barrels, and a third 60 barrels. One well in the beginning gave easily 300 barrels of oil and 1200 barrels of water. The oil sands lie at 1393, 1418, and 1430 feet depth. Up to January, 1907, 150 wells had been drilled on a surface of two to five miles, and only three or four were without results.

Zone township.—In the Bothwell pool 150 oil wells gave a small production. A few properties have been neglected, but the scarcity of abandoned wells is remarkable, the tenacity of production since the discovery of the pool is exceptional, and constitutes an example of very favourable und ergroundcon-ditions and careful scientific economy in producing methods. Most of the oil is pumped to nearby loading racks, and shipped by tank cars to refineries at Wallaceburg and Sarnia. Some oil, however, is allowed to accumulate in tanks on the lease, and once a month is hauled by wagon to the receiving station at Bothwell.

A typical record of a well in this field is as follows:—

Record of a typical well in Zone township.

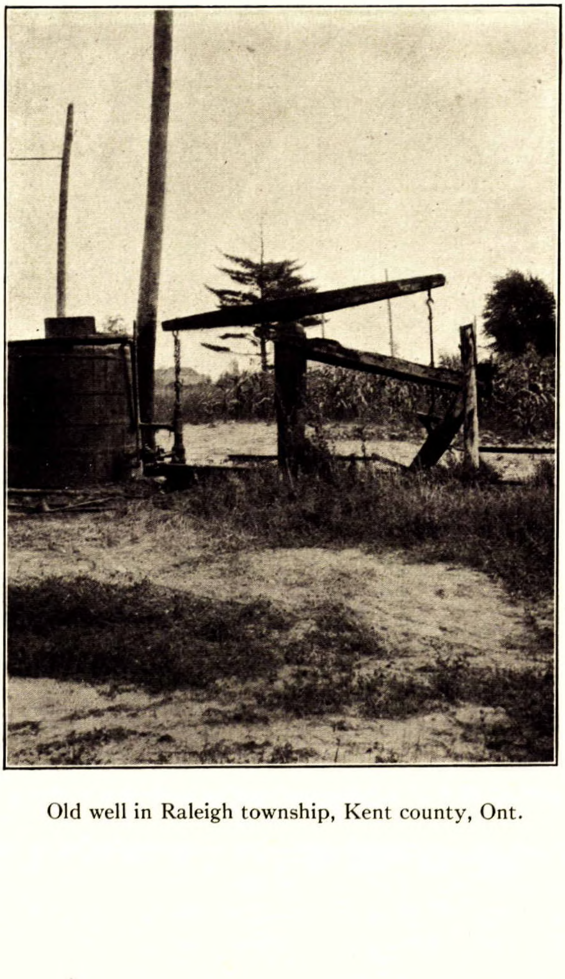
Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface		0	90
Black shale	Portage	90	167
"Soapstone"	Hamilton	167	359
Limestone	Onondaga	359	479
Total depth			479

Raleigh township pool.—Oil was struck in Raleigh township on lot 18, concession II, in November, 1902, at a depth of about 320 feet, or about 200 feet from the top of the Onondaga limestone. This was the first flowing well in the township. By April, 1903, 60 wells had been completed. The first well was known as the Gurd gusher from the name of its owner. It is estimated that while flowing it produced over 1000 barrels per day. About 200 wells were drilled in this pool. The former production at Charing Cross has ceased, and the wells have been practically abandoned; but a little oil is still pumped from less than a dozen wells in concession IX. In 1912 a deep test well was drilled by the Standard Oil Company of Canada midway between Merlin and Lake Erie and was stopped at a depth of about 1700 feet, being a small gas well.

In 1913 wells were still being drilled in southeastern Raleigh township. The structure of the Raleigh field is reported to be[1] anticlinal with a dip of 60 feet to the mile.

[1]Gibson, Thomas W., Ann. Rept. Bureau of Mines, Ontario, 1903, p. 41.

PLATE VIII.



Old well in Raleigh township, Kent county, Ont.

Harwich township.—Three miles southeast of Chatham, along the trolley line, on the Blakely and McIntosh properties, are 25 to 30 wells, which produce from 150 to 165 barrels per month. They are 400 to 440 feet deep and obtain oil from the Onondaga limestone. The pool was opened seven or eight years ago, and 17 or 18 wells have already been abandoned and plugged. The locality is known by oil men as "broken" or "freakish." Another group of wells, one and one-half miles east, was developed about the same time. All have been abandoned, although the pumps are still on the ground. The pool never produced much oil, and was badly managed.

Very little gas has been found in Harwich township, the best showing being presumably in the LaCope well of the Union Natural Gas Corporation, situated one mile west of Blenheim, which had an estimated production of 100,000 cubic feet per day. A test about 2000 feet deep was drilled on the Bisnett farm south of Blenheim and proved a dry hole. In the past years considerable testing of the shallower formations has been done in the vicinity of Blenheim, with few results. There is no oil or gas production in this vicinity at present.

The character of the formation in Harwich township is illustrated by the following dry hole.

Record of well drilled in Harwich township[1].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface materials	Pleistocene	0	78
Black shale	Portage and Chemung	78	138
White shale	Portage and Chemung	138	161
"Soapstone"	Portage and Chemung	161	171
White limestone	Portage and Chemung	171	186
Shale	Portage and Chemung	186	256
Grey limestone	Hamilton	256	276
White shale	Hamilton	276	376
"Soapstone"	Hamilton	376	396
White limestone	Hamilton	396	420
White shale	Hamilton	420	440
White limestone	Onondaga	440	445
Grey "	Onondaga	445	555
Blue "	Onondaga		570
Total depth			570

Orford township.—There never has been any oil or gas production in Orford township, although dry holes have been drilled.

[1]Brumell, H. P. H., Geol. Survey Canada, Ann. Rept., Vol. V, 1889-91, Pt. Q, p. 74.

The stratigraphic conditions are illustrated by the following record drilled years ago on the Raney farm by Hiram Walker and Sons.

Record of dry hole drilled on Lot 10, Concession XI, Orford township[1].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface materials	Pleistocene	0	160
Limestone	Hamilton	160	241
White shale		241	311
Grey limestone	Onondaga	311	401
Limestone		401	555
Fine white sandstone	Salina	555	585
Grey sandstone		585	630
Grey limestone		630	915
Fine sandstone		915	1000

Casing	915
Big flow of sulphur water	630
" " salt water	965
Show of oil	470
Surface elevation	740
Total depth	1000

Chatham township.—There never has been any production in this township. Many years ago a well was drilled at Chatham to a depth of 1000 feet[2]; the complete log is not preserved but the log of a shallow well is given herewith for reference.

Record of well on Concession VII, Chatham township.

Material	*Formation*	*Top Feet*	*Bottom Feet*
Clay	Pleistocene	0	48
Black shale	Portage	48	148
"Soapstone"	Hamilton	148	400
Limestone	Onondaga	400	595
Total depth			595

Camden township.—In the vicinity of Thamesville, a small pool was opened, known as the Klondike pool. Most of the wells have been abandoned and the 25 wells which are still rigged for pumping are now small producers and none were being pumped when visited in 1912. A number of dry holes have been drilled in this township. A typical well log is as follows:—

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 73.
[2]Hunt, T. Sterry, Geol. Survey Canada, Rept. of Progress, 1866, p. 247.

Record of dry hole on Lot 2, Concession III, Camden township[1].

Material	Formation	Top Feet	Bottom Feet
Sand	Pleistocene	0	13
Clay	Pleistocene	13	53
Hardpan	Pleistocene	53	60
Black shale	Portage	60	80
Limestone	Hamilton	80	110
"Soapstone"	Hamilton	110	314
Limestone	Onondaga	314	431
Sandstone	Onondaga	431	477
Hard limestone	Onondaga	477	500
Big flow of salt water		431	
Total depth			500

Gore of Chatham.—There is no production or drilling in the Gore of Chatham with the exception of a little shallow gas encountered in drilling water wells. It is sometimes used a short time for domestic purposes.

In 1896 a deep hole was drilled in lot 5, concession I. The report recorded is as follows:—

Record of dry hole in Gore of Chatham[2].

Material	Formation	Top Feet	Bottom Feet
Surface materials	Pleistocene	0	140
Limestone and shale	Chemung and Portage	140	685
Shale and limestone	Hamilton	685	850
Light limestone	Onondaga	850	1000
Fine-grained dolomite and gypsiferous dolomite	Salina	1000	1700
Dolomite	Guelph	1700	1820
Limestone	Niagara	1820	1925
Calcareous and arenaceous shale	Clinton	1925	2020
Sand and shales	Medina	2020	2085

Bothwell pool.—The Bothwell pool in Zone township, which lies for five miles along the Thames river, and is half a mile wide, was opened in 1864, wells of large production being encountered at a very shallow depth. The pool was later abandoned, owing to the decline of the shallow sand production. In 1896, however, a revival took place, and by 1898 there were 150 producing wells and the field was extended northwest to the present main Bothwell pool. In 1898 this pool produced 4000 barrels per month, from 150 wells. In 1901 there were

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 72.
[2]Geol. Survey Canada, Vol. XI, p. 138s, 1898.

from 200 to 240 producing wells, and 5000 to 6000 barrels of oil per month were produced. At present there are about 370 producing wells, very few of which have been abandoned since the field was opened. About 3000 barrels per month are still produced, and the field shows no signs of complete exhaustion. In July, 1912, there was only one drilling rig in operation in the Bothwell field. The principal oil horizon is found at a depth of 400 feet, in the Onondaga limestone.

About twenty-five years ago a deep test was drilled to a depth of about 1500 feet. The subsidiary pool, west of the main pool, is hereby considered a part of the same. The principal operators in the Bothwell pool are:—

Warren Oil Company,
Crottey and Elliott,
Walker Oil and Gas Company,
Carmon and Fairbanks,
C. O. Fairbanks,
Puddicomb and Brewer.

The oil from the Bothwell pool was pumped to a neighbouring loading rack and was shipped in tank cars on the Grand Trunk railway to Wallaceburg and Sarnia for refining.

A typical record of the wells in this township is as follows:—

Record of "Clinton oil well," Zone township, drilled in 1886[1].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface materials	Pleistocene	0	155
"Soapstone"	Hamilton	155	168
Black shale	Hamilton	186	190
"Soapstone"		190	222
Limestone	Onondaga	222	370
Show of oil			370
Total depth			370

Howard township.—There is no production in Howard township. A dry hole was once drilled south of Ridgetown by the Union Natural Gas Corporation. It went through the Red Medina sand into the red shales having a total depth of about 2000 feet. No record of it is available. A record of a shallower hole on the line of Orford township is as follows:—

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 245.

Record of dry hole in Concession IV, Howard township.

Material	Formation	Top Feet	Bottom Feet
Clay	Pleistocene	0	95
"Soapstone" and light shales with a black band near the base	Hamilton	95	350
Bluish limestone	Onondaga	350	510
Grey sandy limestone	Salina	510	707
Total depth			707

Dover East and Dover West townships.—No oil or gas has ever been produced in these townships. The following log of a well one mile west of the Grand Trunk railway station at Chatham, gives the general conditions:—

Record of dry hole at Chatham.

Material	Formation	Top Feet	Bottom Feet
Surface clay	Pleistocene	0	60
Black shale	Portage	60	178
"Soapstone"	Hamilton	178	378
Limestone	Hamilton	378	396
"Soapstone"	Hamilton	396	433
Limestone	Onondaga and Salina	433	1000
Casing			260
Show of oil			475
Big flow of salt water			700
Total depth			1000

10-inch drive pipe to 138 feet.
8-inch casing pipe to 243 feet.
6¼-inch casing pipe to 835 feet.

A number of additional well logs are given under the various townships; and a number are reported by Brumell[1].

In order to illustrate the stratigraphy in a graphic way, a number of the most interesting known records in this county are shown in Figs. 14 and 15, and correlations made with wells in Lambton, Essex, and Elgin counties.

Geological structure of the fields.—Although the surface of southern Ontario is covered by drift, the outcrops so few, and the country so flat, that little geological structure is determinable on the basis of outcrops alone, it is possible to make some general statements by a comparison of the well records. For instance, the logs in the new Tilbury-Romney gas field show that the formations do not lie as deep in this field as in other localities in Kent county, notwithstanding the situation of the field in the southern part of the county, where greater depths

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, pp. 70-76.

might be expected. Consequently, we have evidence that the Tilbury-Romney gas field lies on a prominent anticline or dome or combination of such structures, presumably the northward continuation of the Cincinnati anticline of northwestern Ohio. Again, in Zone township, the geological structure is evident, the fields consisting of alternating anticlinal and synclinal axes[1], which consist of one main axis and several subordinate ones trending in a common direction, and another series which crosses at a wide angle. The productive oil wells are believed to be situated at the intersection of the two sets of anticlines. Since the dip of the strata is more gentle on the southern slope of the anticlines than on the north, the oil occurs lower on the southern side. In a general way, we may say that the top of the Onondaga limestone ranges in elevation from 250 feet below sea-level to 450 feet above that datum.

Production of petroleum.—The production of these fields has declined during the past few years, the rate in Kent county being as shown in the table.

Production of Petroleum, 1907-1912[2].

(in barrels)

Date.	Tilbury and Romney field.	Bothwell field.	Thamesville field.	Raleigh field.	Richardson Station (Chatham).	Zone pool.
1898		66,404				901
1899		65,044				
1900		47,405				
1901		52,873				
1902		50,141		2,462		
1903		48,880		1,161		
1904		47,654	5,027	3,274		
1905		47,959	2,463		1,249	
1906	106,992	44,827	175			
1907	411,588	42,727	237			
1908	201,283	39,228				
1909	124,003	38,092				
1910	63,058	36,999				
1911	48,707	35,243				
1912	44,727	34,486				

[1]Chalmers, Geol. Survey Canada, Ann. Rept., Vol. XIV, Pt. I, 1901, p. 162A.

[2]Gibson, Thos. W., Rept. Bureau of Mines, Ontario, Vol. XXI, Pt. I, 1912, p. 35. Vol. XXII, Pt. I, 1913, p. 42. Min. Res. U.S., 1905, p. 890.

Gore of Camden.—Several wells were drilled at Dresden about twenty years ago and one or two of them showed oil but they did not prove of much value. A general record of the formations penetrated at this place is given on page 157.

Future prospects in Kent county.—As stated in connexion with the various townships, the oil pools of Kent county are practically exhausted with the exception of the new pool in the vicinity of Fletcher, which is producing from a deep sand. The gas pool in the southern part of the county is also producing from the deep sand as practically outlined. Although a few dry holes have been drilled into the Salina formation in other parts of the county, large untested areas of deep sand territory still exist, and presumably areas in which the geological structure may be favourable, and consequently it is to be expected that some small oil or gas pools may be found in the Salina or in other sands in the county.

As stated in the report on this gas field[1] it will presumably be long lived, the opinion being based not only on the rock pressure of the gas, the thickness of the porous formation and the amount of pore space, but also taking into account the fact that the gas field extends under Lake Erie, presumably for a considerable distance, and consequently the higher pressure under the lake will serve to equalize the pressure while using the gas beneath the land.

Pelee Island, Kent county.—In 1912 a deep well was being drilled on Pelee island, and it was said that the Trenton rock had been practically reached; the well was being drilled on the Finlay farm by Messrs. Jasperson and McKay. A little oil had previously been found in shallow wells on that island at a depth of about 750 feet.

Ridgetown, Kent county.—In 1911, a showing of gas was found at a depth of 300 feet in a water well at Ridgetown. The pressure is said to have been 40 pounds per square inch. Similar shallow showings of gas have been found in surface gravels in Kent and other counties.

[1]Mickle, G. R., The Kent gas field, 19th Ann. Rept., Bureau of Mines, Ontario, 1910 Pt. I, pp. 149-152.

Lanark County.

Oil or gas in commercial quantities will never be found in Lanark county, since the county is largely occupied by formations of Laurentian, Potsdam and Beekmantown age, which, being low in the geological scale, and without cover, are unfavourable.

Lambton County.

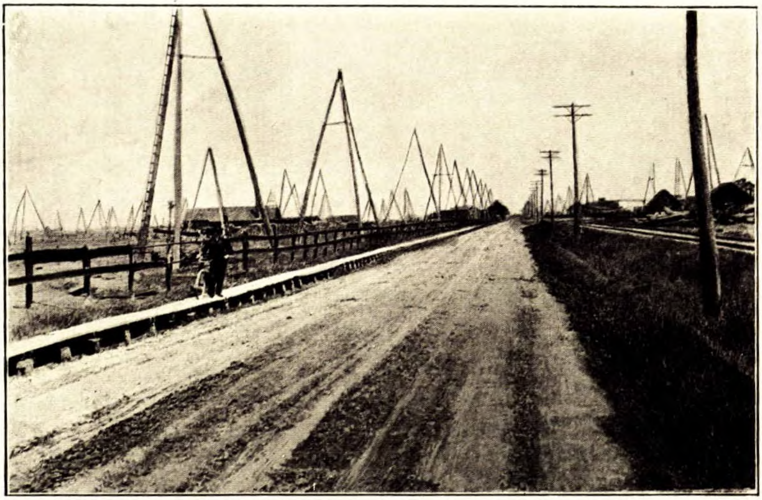
Description of fields.—The most important oil field in Ontario is the Petrolia field in Enniskillen, Sarnia, and Moore townships. The second most important field, commonly classified as part of the Petrolia field, is the Oil Springs pool in southern Enniskillen township. In addition there have been very small pools developed at Shetland in Euphemia township, near Florence in Dawn township, London Road in Plympton township, and on Kettle point in Bosanquet township.

A small and short lived supply of gas is found at numerous places in the western part of Lambton county, in the gravel and shales which lie underneath the Erie clay, but there is no gas field in the county.

History of developments.—The first attempt at utilizing the petroleum in Lambton county, was in 1859, the effort consisting of the extraction of a liquid from gum oil, which found its way to the surface at Oil Springs in what was known as the gum beds. The first wells were surface wells 4 or 5 feet in diameter, dug to a depth of 40 to 60 feet, reaching a bed of gravel, from which the oil would flow into these. Similar wells were dug at Petrolia.

The first rock drilling in Ontario was by Mr. Tripp at Oil Springs about 1861 in search of water. The procedure was to sink and crib a shaft four feet in diameter to the rock in order to protect it from caving. After the cribbing period in the Petrolia fields the surface materials were bored through with an auger. Most of the drilling was done by hand power. In the winter of 1861-2 some very productive flowing wells were struck, the first by James Shaw on February 19, 1862, and several produced

Oil wells and creamery, Petrolia, Ont.



Centre street, oilfields, Petrolia, Ont.

thousands of barrels each per day. Naturally, since these wells were obtained rather unexpectedly, the greater part of the oil was lost through flowing into the creek on account of lack of storage facilities.

At one time there were at least twenty flowing wells in the field. The nearest railway station was then at Wyoming, twelve miles distant, and naturally there was not such great excitement as occurred in other fields which were easier of access. The transportation problem at first was difficult. A few thousand barrels of oil were floated down the creek, but then a plank road was built to the railway and the oil hauled out by wagon. It was manifestly impossible to provide adequate facilities as rapidly as needed, and there was great waste of oil. The flowing wells changed to pumpers in a year or two and water frequently took the place of oil. Some years later Oil Springs became practically deserted.

Petrolia was settled in 1839. Oil was first struck in 1862 at 160 feet in a water well. The principal development was about 1865, within the present corporation limits, but no flowing wells were obtained until 1866, when they were struck in what was known as the King district a little west of the present town. In this field the production of single wells sometimes ran as high as 400 barrels per day. At Oil Springs, however, one well, known as the Black and Mathewson well, flowed about 6,000 barrels per 24 hours for a few days. In the Petrolia fields the wells changed to pumpers in a short time.

As in many oil towns, an oil exchange was opened in Petrolia in the early days, the object being for buyers to meet at a certain hour every day, as in a stock exchange.

The first refinery was established at Petrolia about 1861, being one of the first refineries in Canada. In the winter of 1867-8 the Great Western railway was built to that town, making it possible to transport the oil in tank cars. Originally much oil was exported to England, but this business dropped off on account of the better and cheaper oil produced in the United States.

There were formerly eight large refineries in the vicinity of Petrolia, the output of which, when operating to capacity, would be between 5,000 and 6,000 barrels of refined oil per week. The Crude Oil and Tanking Company afforded ample facilities for storing crude oil in underground tanks, as also did the Crown Producers Company.

An estimate of the total capital invested in the oil business in the Petrolia-Oil Springs district in 1887 was $2,750,000, divided as follows:—

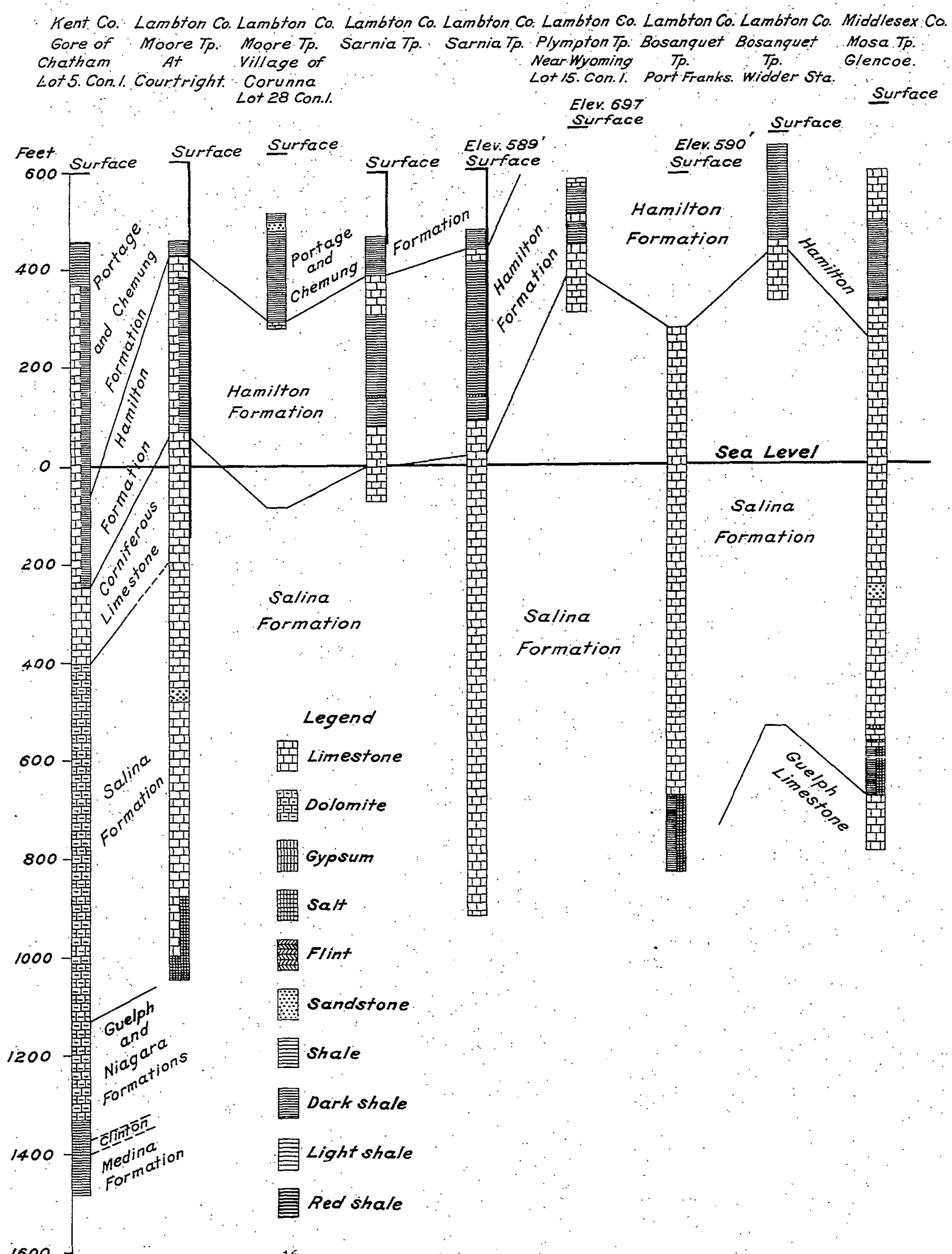
Cost of wells, exclusive of the value of land	$1,500,000
Cost of engines, and other machinery to run the wells	300,000
Storage tanks	150,000
60 miles of pipe line with forging machinery	150,000
The cost of refineries is placed at	500,000
Cooper shops, barrels, chemicals, etc	250,000
Cost of sinking wells, which were sunk some 475 feet, was about	500

Productive formations.—The oil in the Lambton county pools has all been found in the Onondaga limestone. In the Petrolia and Oil Springs fields the pay is struck from 250 to 500 feet below the surface, or about 60 feet from the top of the Onondaga. In character it is a porous dolomitic phase of the limestone, from one to six feet in thickness, brownish and very soft.

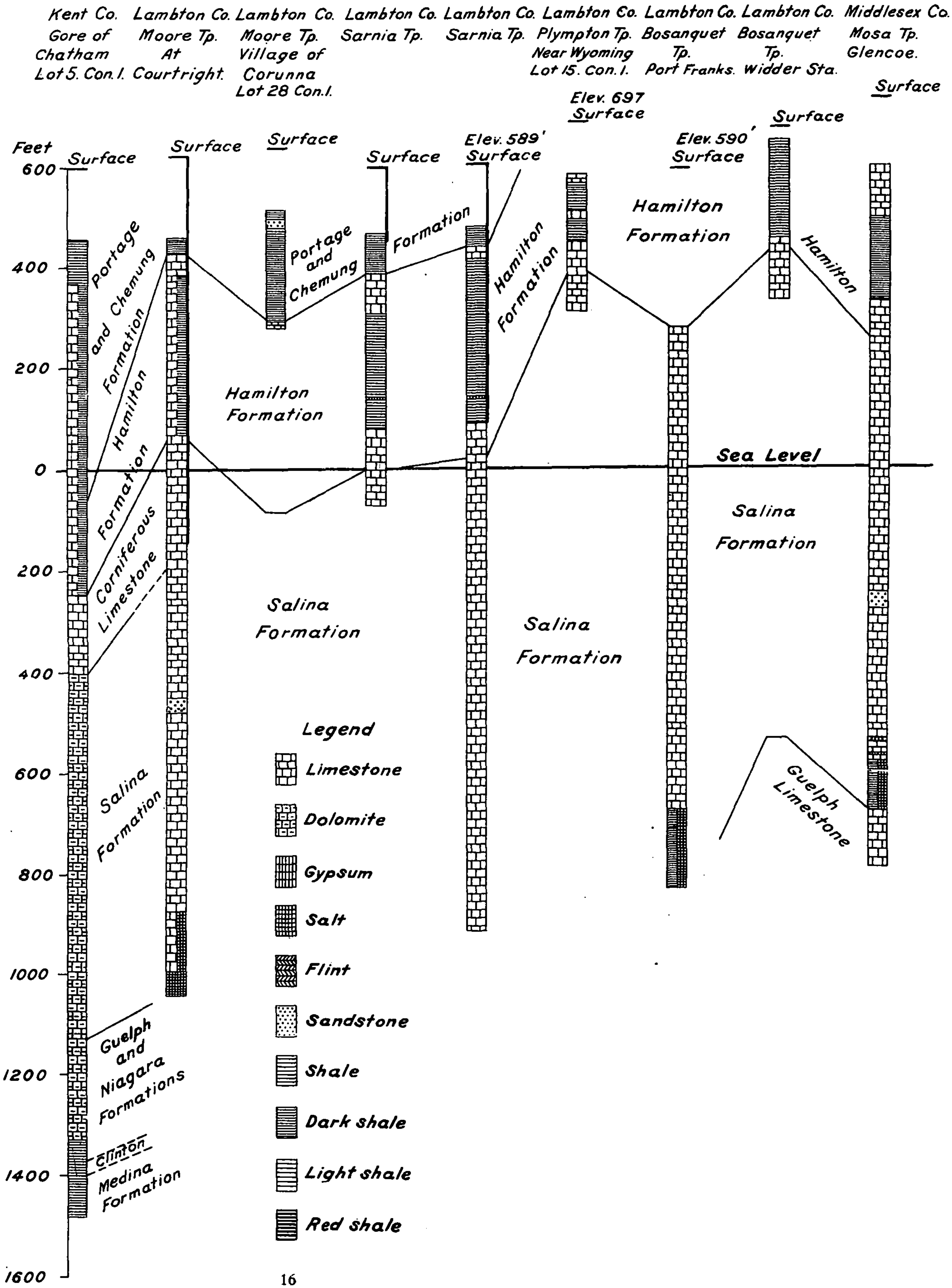
Depth of wells and formations penetrated.—In depth the wells of Lambton county range from 300 to 3770 feet. The depth of the oil-bearing stratum is from 250 to 500 feet in the Onondaga limestone, averaging about 65 feet from the top of the formation in the centre of the town of Petrolia. In the Petrolia field the wells average 470 feet in depth, and in the Oil Springs about 370 feet. All wells drilled more than 500 feet deep were failures below that depth.

The best geological data in the county are derived from well logs, which are abundant and occasionally rather detailed. In many of these wells it is difficult to distinguish between the Onondaga and Salina formations; but in others the change is rather marked. The detailed character and changes of the Salina are seldom recorded, however. In the case of the Hamilton formation the term "Upper" and "Middle" limes and "Upper" and "Lower" soapstones are recorded. We must understand, as previously stated, that the term soapstone is not used in the geological sense, but is the drillers' name for a light soapy shale.

A few typical well records of this county are plotted on Figs 16 and 17. The records of the county reveal a thick-



Fig[redacted]. Selected well logs, showing correlation of formations through Lambton county, Ontario. (By F. G. Clapp and L. G. Huntley)



Fig[redacted]. Selected well logs, showing correlation of formations through Lambton county, Ontario. (By F. G. Clapp and L. G. Huntley)

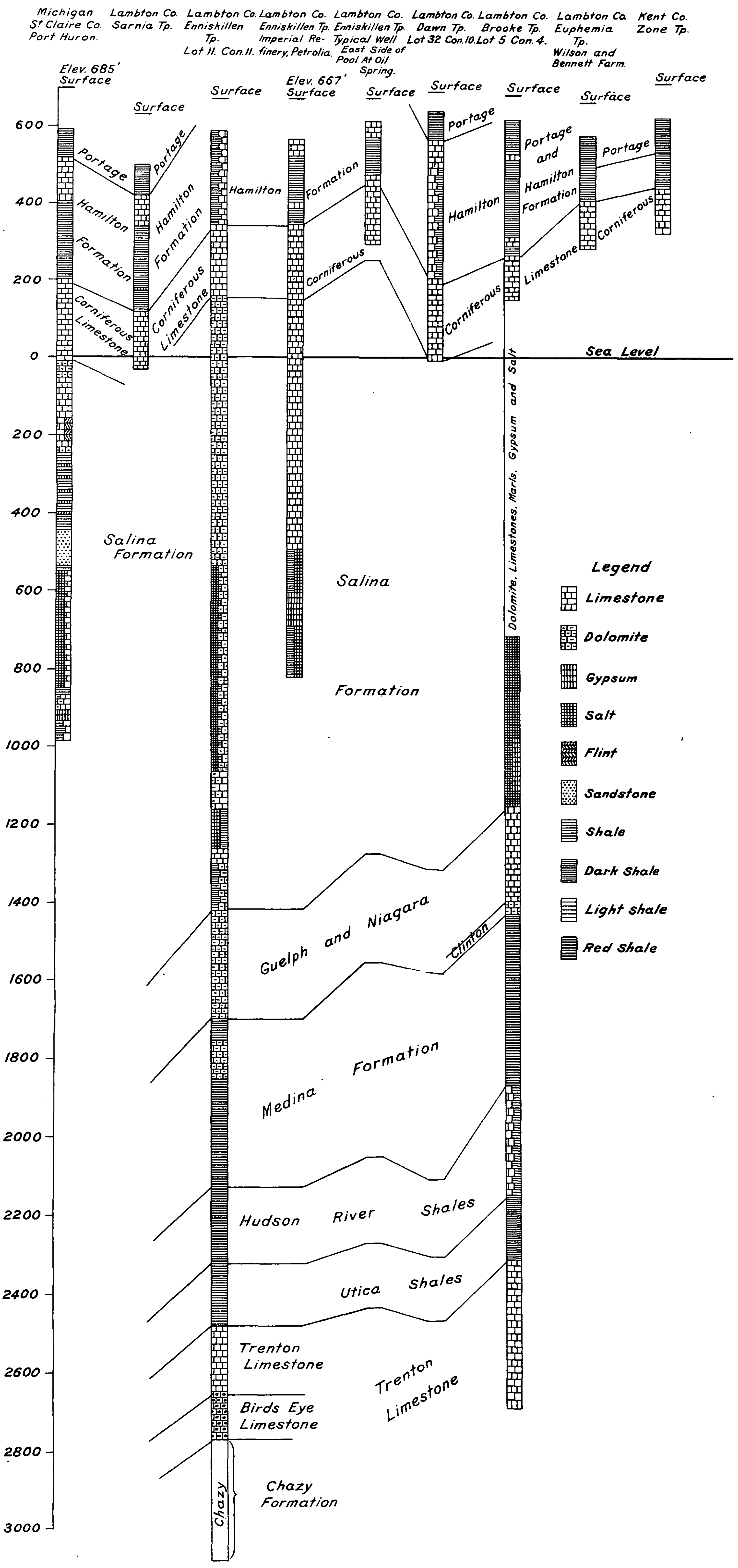


Fig. 17 [redacted] Selected well logs, showing correlation of formations through Lambton County, Ontario. (By F. G. Clapp and L. G. Huntley) ness of glacial drift, consisting of 40 to 160 feet of gravel, sand, clay and boulder clay at the surface, resting on the Hamilton and Portage formations, which are the uppermost hard rocks. The Portage is not always present, but occurs in Moore, Sarnia, Sombra, Dawn, and Euphemia townships, sometimes with a thickness as great as 100 to 200 feet of black shale. The Portage rests upon 290 to 400 feet of Hamilton composed alternately of limestone and shales, somewhat as follows:—

General character of Hamilton formation.

Material	*Common thickness* *Feet*
Upper limestone	40
Upper "soapstone"	200
Middle limestone	20
Lower "soapstone"	50

These subdivisions are, however, very variable. The lower limestone is generally classified as part of the Onondaga, which underlies the Hamilton and has a thickness of from 150 to 200 feet, indistinguishable from the top of the Salina. The Onondaga is a hard limestone, in the upper part of which the oil occurs.

One of the most interesting formations is the Salina, 1400 to 1600 feet in thickness, consisting of alternations of limestone, gypsum, salt, dolomite, and shale. In some parts of the county great thicknesses of rock salt are penetrated in this formation, and many salt wells exist.

While no oil is found in Lambton county below the Onondaga limestone, a few deep tests have been made through the Salina and even the underlying formations, rendering valuable knowledge of the underground conditions. Under the Salina these wells penetrate 220 to 300 feet of Guelph and Niagara limestones and shales, 60 to 400 feet of Medina shales, mainly red in colour, 200 to 300 feet of Lorraine shales, 150 to 200 feet of Black Utica shale, and then the Trenton limestone. This has been penetrated by wells to a depth of 285 to 400 feet, the lower part probably belonging to the Black River formation of geologists. Below the Black River-Trenton one record penetrates 300 feet of Chazy. Three deep well records are given on Fig. 16, and to describe the formation more minutely the deepest is given below:—

Record of deep well drilled in 1902, on R. I. Bradley Estate, Lot 11, Concession XI, Petrolia pool.

Formation	Material	Top Feet	Bottom Feet
Pleistocene	Surface	0	90
Hamilton	Streaks of limestone and shale	90	330
Onondaga	Limestones	330	520
Salina	Streaks of brown, grey and black dolomite	520	1210
	Salt strata and streaks of dolomite	1210	1640
	Salt strata and streaks of dolomitic limestone	1640	1747
	Salt strata and grey dolomitic lime and shale	1747	2105
Guelph and Niagara	Guelph and Niagara dolomitic limestone	2105	2380
	Niagara shale (red and dark)	2380	2440
Clinton	Clinton	2440	2530
Medina	Red Medina	2530	2805
Utica	Lorraine shales (light)	2805	3010
	Utica shales (dark)	3010	3175
Trenton	Trenton	3175	3345
	Birdeye	3345	3460
	Chazy (Canadian)	3460	3770
	Total depth		3770
	13-inch conductor		98
	7⅝-inch casing		186
	6¼-inch casing		1015

A record which is not so deep, but shows the Portage, is as follows:—

Log of well at Agricultural Works in Sarnia[1].

Formation	Material	Top Feet	Bottom Feet
Pleistocene	Surface	0	130
Portage	Black shale	130	210
Hamilton	Limestone	210	290
	Shale	290	450
	Limestone	450	455
	Shale	455	515
Onondaga	Limestone	515	665
	Total depth		665
	Show of gas		515
	Salt water		645
	Cased to		140
	Plugged at		640

Limestone is struck in the Petrolia field at about 100 feet and it is sometimes 35 to 40 feet thick, with streaks of soapstone. Below the limestone is 120 feet of soapstone which is soft and similar to blue clay. Then comes the middle lime, which averages 15 to 18 feet and is not hard. Below this is the lower soapstone. which is a light shale about 40 feet thick. Then 20 to 80 feet of limestone is encountered.

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, p. 889-91, p. 70.

Below 400 feet from the surface, the formation is a sandy limestone or calcareous sandstone extending to about 470, where the oil rock is struck. This is brown, soft and porous, some of it being of a honeycomb nature, with occasional crevices into which the tools drop. The best wells in the early days at Petrolia were obtained in crevices.

Casing.—Water in shallow wells in the Petrolia field was generally shut off by casing to an average depth of about 270 feet, to the top of the so-called middle limestone. Several deep tests have been cased to depths of 500 to 1,000 feet, however, some being cased into the Salina formation.

Geological structure of the fields.—In structure the Petrolia field is known to be anticlinal. The formations dip, in a general way, towards the west and south, in that the top of the Onondaga limestone ranges all the way from 200 feet below sea-level in the southwest corner of Sombra township, to sea-level at Corunna, 300 feet above in the Euphemia pool, 450 feet above at Oil Springs, 350 feet above at Petrolia, 400 feet at Wyoming, and 450 feet in parts of Bosanquet township. That the rise and fall of the strata is not entirely regular is shown by the fact that a single bed varies as much as 200 feet in elevation within the limits of a single township.

The Oil Springs and Petrolia pools are known to be separated by a distinct syncline in which no oil exists, since the upper beds of the Hamilton formation are overlain by the black shales of Portage age, which have at Oil City, between Petrolia and Oil Springs, a thickness of 40 feet, and these shales are absent in both the Petrolia and Oil Springs fields.

The top of the dome structure in the strata is near the northwest corner of the town of Petrolia, and the strata descend in all directions.

Production of petroleum.—In 1867 the daily production in the Oil Springs pool ranged from 100 to 7,500 barrels per day per well from 33 flowing wells; there being a total daily production of 55,300 barrels, or an average of 1,600 barrels from a well.

In 1891 there were, in the Petrolia and Oil Springs pools, 2,700 to 3,000 pumping wells with a total annual production of 600,000 barrels. In 1898, 8,600 wells gave a total monthly production of 57,000 barrels. The production of oil in Lambton county, as elsewhere in Ontario, has declined slowly during the past few years.

Production of Petroleum in Lambton County[1].

Date.	Petrolia field.	Oil Springs field.	Moore pool.	Plympton pool.	Dawn pool.	Euphemia pool.
1898	513,179	133,366	....	25,000	5,923	....
1899	528,641[2]	107,487[3]	....	....	....	....
1900	501,435	99,019	....	....	....	....
1901	432,906	76,059	....	....	....	....
1902	397,628	60,747	....	....	....	....
1903	350,390	56,405	....	....	....	....
1904	278,299	75,530	36,971	....	....	....
1905	250,701	78,125	93,815	....	....	....

Production of Petroleum, 1907-1912[1].

Year.	*Barrels.*
1907	304,212
1908	265,368
1909	243,123
1910	205,456
1911	184,450
1912	150,272
Total	1,352,881

The average daily supply from a well in the Petrolia fields in 1890 was 5 or 10 barrels of mixed water and oil, but the oil in this averaged less than a barrel a day. All flowing wells had been abandoned before that time. In the main part of the Petrolia pool, Doctor Fairbanks puts the average present production per well at about 10 gallons per day, in the better managed properties. The wells in the outlying parts of the pool of course reduce this average. Wells are pumped on six days every week.

[1]Gibson, Thos. W., Rept. Bureau of Mines, Ontario, Vol. XXI, Pt. I, 1912, p. 35; Vol. XXIII, Pt. I, 1913, p. 42.
Min. Res. U.S., 1905, p. 890; 1900, p. 587.
[2]Includes production from Plympton pool.
[3]Includes production from Dawn and Euphemia and from Zone township, Kent county.

The output of petroleum for the last six months of 1887, measured by shipments, which is the only basis for estimating the production in Canada, was the largest ever known in the same length of time, aggregating 510,352 barrels.

Quality of the oil.—The present petroleum from the Oil Springs pool is from 35 to 36 degrees Baumé, while that from the Petrolia pool is from 28 to 31 Baumé. No trouble is experienced from the waxing of rods, or from the formation of sediments either at the surface or underground, except to a small extent in the northwestern part of the field, where salt water is encountered.

The oil in Lambton county is dark brown, and has a density of 0·8695 to 0·8484. The amount of sulphur is 1·5 per cent, but the oil can be successfully cleaned.

Petrolia and Oil Springs fields (Sarnia and Enniskillen townships).—The paying wells in Lambton county are confined to a belt running northeast and southwest for about 20 miles, with a width varying from 1 to 4 miles. This belt is situated some 16 miles east of Sarnia and includes the two districts, Petrolia and Oil Springs. The area of the Petrolia field is 26 and of the Oil Springs pool 2 square miles. The length of the original Petrolia field was about eight miles east and west and from half a mile to two and one-half miles in width. In 1890 there were 2,500 wells in the Petrolia field alone. In the Oil Springs pool 244 wells were drilled in one year beginning July 1st, 1887; the total number of wells in operation on July 1, 1888, was 964. In concession I, of Enniskillen, in 1890, there were 258 wells and in concession II there were 206 wells.

A typical oil well in the Petrolia field had the following record:—

Log of well near Imperial Refinery, Petrolia[1].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	104
Upper limestone	Hamilton	104	144
Upper "soapstone"	Hamilton	144	274
Middle limestone	Hamilton	274	289
Middle "soapstone"	Hamilton	289	332
Hard white limestone	Onondaga	332	400
Soft white limestone	Onondaga	400	440
Grey white limestone	Onondaga	440	465
	Total depth		465
	Oil at		465

[1]Geol. Survey Canada, Vol. IV, p. 795.

The following is a typical record of a well in this pool:—
Log of well on east side of Oil Springs pool[1].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	60
Upper limestone	Hamilton	60	95
Upper "soapstone"	Hamilton	95	196
Middle limestone	Hamilton	196	223
Lower "soapstone"	Hamilton	223	330
Lower limestone	Onondaga	230	370
	Total depth		370
	Oil at		370
	Salt water		252

A number of deep tests have been drilled in Lambton county, the records of which are given on page 175.

The Oil Springs and Petrolia pools are continuing to prove among the most remarkable oil districts in the world, on account of the slow decline of production. From about 7,000 wells in 1897 and 1898, there are approximately 4,000 wells still producing in the Petrolia pool; while the proportion abandoned in the Oil Springs pool is slightly less. No drilling rigs are in operation at present anywhere in Lambton county.

The Oil Springs and Petrolia fields are contracting from the outer edges inward. No water problem has developed, except in the extreme northwest extension of the field, east of Sarnia. Wells on the outer limits are exhausted and abandoned from time to time, and no new production is taking their place. This field exhibits a comparatively rare example of an oil pool declining from the single cause of the exhaustion of the underground supply of oil. The decrease is not complicated by the exhaustion of gas pressure or consequent encroachment of water; nor is the oil of such a character that obstructive waxes and sediments have accumulated at the bottom of the well. The oil rock is open and rather vesicular, and apparently allows the complete exhaustion of the oil in the sand in the vicinity of a well or group of wells, before their abandonment. It has been possible to pump all wells alike, by shackle power, while in some other fields complicating underground factors make each well a separate problem. Careful producing methods

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q. 1889-91, p. 62.

have been used on most leases, the casing and pumps have been carefully watched, and even after the power has been disconnected from a well, it is sometimes pumped or bailed by hand from time to time. Thus the field is unique in its long life, and in the characteristics of its decline.

The best wells at present are found in the comparatively new extension which was developed during 1903 and 1904, in the northeastern part of Moore township. There are still some 200 to 300 wells producing in southeastern Sarnia township, although those in the London Road extension of the field, northeast of Sarnia, have practically all been abandoned. All oil from the Oil Springs and Petrolia fields goes to Sarnia, 16 miles distant, through a 3-inch pipe line for refining at the Imperial Refinery.

The salt water encountered throughout the main Oil Springs and Petrolia pools has diminished in quantity from former years, and is not encroaching at any part of the fields.

Plympton township.—Attempts to extend the Petrolia field into this township resulted in a few wells which produced some oil east of Sarnia, along the London road. With a few exceptions these have been abandoned. Drilling in the vicinity of Wyoming and elsewhere resulted in small shows of oil, and considerable salt water, and was generally successful. There is no production in Plympton township at present. A typical record in this township is as follows:—

Record of well in Lot 15, Concession I, near Wyoming[1].

Material	*Formation*	*Top* Feet	*Bottom* Feet
Surface	Pleistocene	0	104
Black shale	Portage	104	108
Limestone	Hamilton	108	148
Shale	Hamilton	148	178
Limestone	Hamilton	178	193
Shale	Hamilton	193	236
Limestone	Hamilton	236	304
Limestone soft	Onondaga	204	344
Limestone grey	Onondaga	344	380

Small quantities of oil in this well are accompanied by copious flows of saline water.

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 64.

Bosanquet township.—There was some drilling in this township immediately following the discovery of the Petrolia and Oil Springs fields; but no pools were discovered. Showings of gas are reported to have been obtained, however, in the base of the Hamilton formation or top of the Onondaga. A few wells still produce oil on the Kettle Point Indian Reserve, but they are of no importance. An English syndicate which held a lease on this reserve for the extraction of oil from shales, has allowed the lease to lapse, evidently believing the project to be commercially unprofitable, notwithstanding some good laboratory tests made on samples of this shale.

A typical log of the formations in the county is as follows:—

Log of dry hole at Widder Station, Bosanquet Township[1].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Clay	Pleistocene	0	34
Soft shale	Hamilton	34	230
Limestone	Onondaga	230	350
Total depth			350
Show of oil			196

Warwick township.—No oil has been developed in this township. There was some drilling immediately following the discovery of the Petrolia and Oil Springs fields, but no pools were discovered. Showings of gas are reported to have been obtained, however, in the base of the Hamilton formation or top of the Onondaga. Salt wells have been drilled at Kingstones Mills. A well at the Elarton salt works was once sunk to a depth of 1,400 feet. Salt was reported in it from 1,200 to 1,330 feet.

Euphemia pool and township.—In Euphemia township, 40 wells obtained only a small production; the greatest daily production of a single well was one barrel. At present this district produces only about 500 barrels monthly. This pool had only a few wells in 1896, and the production was only 150 to 200 barrels per month. In July, 1912, only about 100 barrels per month were being produced from Euphemia and Dawn townships together. This oil was shipped by wagon to the Bothwell and Newbury stations, from where it went by the Grand Trunk railway to the refinery at London, Ontario.

A typical well record is as follows:—

[1]Geol. Survey Canada, Rept. Prog., 1866, p. 248.

Log of well in Euphemia township[1].

Material	Formation	Top Feet	Bottom Feet
Surface	Pleistocene	0	58
Shales	Hamilton	58	323
Limestone	Onondaga	323	326
Big flow of salt water			350

Dawn township.—A small pool of oil formerly existed between Langbank and Florence. This pool, together with that in Euphemia township, produced only about 100 barrels per month in 1912.

A typical well record is as follows:—

Log of dry hole in Lot 32, Concession X, Dawn township[2].

Material	Formation	Top Feet	Bottom Feet
Surface	Pleistocene	0	50
Black shale	Portage	50	120
Limestone Shale and limestone	Hamilton	190	475
Limestone	Onondaga	475	700
Total depth			700
Salt water			625

Rock-salt is reported to have been struck at 1,100 feet in the vicinity of this well.

Moore township.—Eight wells were drilled at Courtright previous to 1890, but gas was only obtained in three of them. There are about 200 producing wells in the northeast corner of this township, which are probably the best producers in Lambton county at the present time. The wells produce from the same formation as those at Petrolia and Oil Springs, and are of about the average depth. Many wells were formerly drilled in this township in an attempt to extend the Petrolia field. Small shows of gas have been encountered at Courtright in the Onondaga limestone, and salt wells have been drilled through the Onondaga into the Salina formation. Salt wells have also been drilled at Corunna.

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 66.
[2]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 66.

The record of a well drilled by the Courtright Salt Company is as follows:—

Log of salt well at Courtright[1].

(Surface elevation 588 feet)

Material	*Formation*	*Top Feet*	*Bottom Feet*
Sand, etc.	Pleistocene	0	132
Hard-pan		132	160
Black shale	Portage	160	192
Limestone	Hamilton	192	232
Shale and limestone		232	542
White limestone		542	592
Grey limestone	Onondaga	592	692
White, hard limestone	Salina, including lower part of Onondaga	692	1062
Sandstone (probably dolomite)		1062	1094
Limestone		1094	1494
Limestone and gypsum		1494	1630
Salt		1630	1652
Gypsum		1652	1665
Total depth			1665
Salt water			680
Casing to			740

Sarnia township.—The Petrolia belt extends west far into Sarnia township. There are about 200 old oil wells, twenty to twenty-five years old, in the southeast corner of Sarnia township, still producing. No wells now exist in the vicinity of Sarnia. The wells north of this town were very small and short-lived. Some good showings of gas have been found at the Imperial refinery near Sarnia at depths of 330 to 515 feet, but all gas wells in that vicinity are abandoned.

The record of a well drilled in 1875 in Sarnia is as follows:—

Log of well at King's Grist Mill[2].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Sand	Pleistocene	0	9
Blue clay		9	118
Hardpan		118	120
Shale, black	Portage	120	156
Limestone	Hamilton	156	186
Shale		186	449
Limestone		449	454
Shale		454	494
Limestone		494	554
Grey limestone	Onondaga, including upper part of Salina	554	654
Hard limestone		654	1200
Hard and flinty limestone		1200	1400
Limestone and gypsum		1400	1505
Total depth			1505
Fresh water			120
Small gas			400
Salt water			654
Cased to			495

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 68.
[2]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 69.

To illustrate the non-importance of the wells near Sarnia, it may be mentioned that the production of the Dickens well, which has been reported as the most important in that vicinity, only amounted to 20,000 cubic feet of natural gas per day. The gas was used for lighting several dwellings and street lamps in the immediate vicinity.

Sombra township.—A number of dry holes are known to have been drilled in Sombra township, but information regarding them is not available. It is known, however, that salt wells were drilled some years ago at Port Lambton. No oil has ever been produced.

Brooke township.—No oil has ever been developed in this township. A dry hole was drilled to the Trenton at Inwood. The record is as follows:—

Log of well in Lot 5, Concession IV, at Inwood.

Material	Formation	Top Feet	Bottom Feet
Clay	Pleistocene	0	60
Boulder		60	65
Shales		65	150
Upper limestone		150	165
Upper "soapstone"	Hamilton	165	370
Middle limestone		370	395
Lower "soapstone"		395	420
Limestone	Onondaga	420	535
Dolomites, limestone and marls with gypsum and salt	Salina	535	1835
Limestones and dolomites	Guelph and Niagara	1835	2060
Dark shales		2060	2075
Limestone	Clinton	2075	2110
Red shale	Medina	2110	2550
Light grey shales with limestone	Lorraine	2550	2835
Dark shales	Utica	2835	3000
Limestone	Trenton	3000	3380

Black sulphur water was encountered at 500 feet in the Oil Springs and Petrolia oil rock. Rock salt occurred from 1,410 to 1,655 in a solid bed with only three small layers of limestone, and another rock salt bed from 1810 feet to 1835 feet. No oil, gas or salt water was struck.

Deep tests in Lambton county.—Several deep tests have been drilled in Lambton county, all of which have been failures. The last one was sunk in 1902, to a depth of 3,770 feet, the record of which is given on page 176. Another deep well was started on the Fairbanks property at Oil Springs between the famous Shaw and Bradley wells, on the crest of the main anticline, in July, 1912. It was being drilled by local capital from Petrolia, to go to the granite.[1]

Wells drilled for salt.—A number of salt wells have been drilled at Sarnia, Corunna, Courtright, Port Franks and other places along Lake Huron and the St. Clair river. The records of a number of these are given elsewhere. The salt is obtained from thick beds in the Salina formation.

Leeds County.

No oil or gas in quantity is believed to exist in Leeds, since the geological conditions are exceedingly unfavourable. The strata occupying the surface throughout the northern half of the country consist mainly of Beekmantown rocks, while in the southern part they are mostly Laurentian and in the intermediate belt the Potsdam sandstones exist. These formations, being low in the geological scale and without cover, are not favorable for prospecting.

Lincoln County.

General statement.—Showings of natural gas have been found at several localities in Lincoln county, but no important field has been developed.

History of developments.—In 1888 a well 2,200 feet deep was sunk on Broderick's farm in lot 4, concession III, Louth township, by the St. Catharines Natural Gas Company. Showings of gas were found in the White Medina sand and in the Trenton limestone, but not sufficient to warrant utilization. Very little development of natural gas has been done since that time in Lincoln county, although a few shallow wells have been drilled at various times.

Formations penetrated in drillings.—The topography of Lincoln county is somewhat peculiar in that it consists, like Niagara county, New York, of a lower and an upper level. The lower level is composed of the pan-handle in which Niagara, Grantham, and Louth townships are situated and also the

[1]This well is reported to have obtained a good flow of oil in the Trenton. Details are not available.

northern half of Clinton township. The upper level consists of Gainsboro, Caistor, most of Grimsby, and the southern half of Clinton township. The elevation of the lower level ranges from 250 feet to 350 feet above sea level, and of the upper level, 600 to more than 650 feet; consequently, there is a marked difference in elevation along the line of the Niagara escarpment, which averages for the county about 350 feet, and crosses the county from east to west. Consequently about 300 feet of the formations which occur south of the escarpment are not represented north of it.

As in other parts of Ontario, a considerable thickness of Glacial Drift underlies most of Lincoln county. This is true both north and south of the escarpment, although the escarpment itself consists of a nearly vertical cliff formed of rocks of Niagara, Clinton and Medina age. North of the escarpment, the formation immediately underlying the drift is largely Medina shale; south of the escarpment, it is mostly Guelph and Salina, the latter appearing in the extreme southwestern part of the county, in Gainsboro and Caistor townships.

It is unfortunate that few good well records are available in Lincoln county, but there is a log of the original well which was drilled in 1888 in Louth township, the record being as follows:—

Log of well on Lot 4, Concession III, Louth township[1].

(Surface elevation 297 feet)

Material	*Formation*	*Top* *Feet*	*Bottom* *Feet*
Surface	Pleistocene	0	90
Red shale	Medina	90	638
Blue shale	Lorraine and Utica	638	1338
Black to blue shale	Lorraine and Utica	1338	1506
Limestone	Trenton	1506	2173
White quartz sand	Chazy (?)	2173	2200

In the white sand underlying the Trenton formation, about 4,000 cubic feet of gas per day was encountered at a depth of 2,185 feet.

Nothwithstanding the fact that few well sections are available, it is fortunate that excellent correlations can be made

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q. 1889-91, p. 32.

with the assistance of outcrops along the Niagara escarpment and of records in adjacent counties and in New York state. (See Fig. 18.) Geological sections have been measured by many geologists at various points along this escarpment, and give the most reliable data extant regarding the Niagara, Clinton, and Medina formations. The following is a section of the formations measured along the Niagara river:—

Geological section along Niagara River[1].

Material	Formation	Thickness Feet	Total Feet
Lockport, dolomite, cherts, etc.	Niagara	150	150
Rochester shale		68	218
Limestones and shales	Clinton	32	250
Grey band sandstones	Medina	7½	257½
Red sandstone, etc.		50	307½
Cataract shales and limestones		26	333½
Cataract sandstone		25	358½
Total section exposed			358½

A section of the same formation measured at Grimsby is as follows:

Geological section at Grimsby, Ontario[2].

Material	Formation	Thickness Feet	Total Feet
Lockport dolomite	Niagara	12	12
Rochester shale		45	57
Limestone and shales	Clinton	14	71
Grey band sandstones	Medina	5	76
Mottled red (Red Medina sand)		25	96
Cataract shale and limestone		74	170
Band Cataract sandstone (White Medina sand...)		6	176
Total section exposed			176

All the strata exposed on the Niagara gorge continue as far as Grimsby and even to Hamilton, but they decrease in thickness toward the west, and beyond Hamilton the Niagara shale, Clinton dolomite, and Medina red sandstone disappear.

All oil operators should visit the sections afforded by the Niagara escarpment and should study it carefully since it furnishes an excellent key to the underlying formations in counties to the south.

Possibilities for oil and gas.—It is a fact that where geological formations rise in a certain direction and disappear by

[1]Parks, W. A., The Palæozoic Section at Hamilton, Ontario, in Guide Book No. 4, Excursions in southwestern Ontario, Ottawa, 1913, p. 128.

[2]Loc. cit., p. 130.

thinning out, such localities furnish an ideal structure for the accumulation of natural gas, as on an anticline (see discussion on page 94, Vol I). The Clinton dolomite and Medina sands disappear toward Wentworth county, and, consequently, the thinning edge of this formation constitutes a favourable structure for the accumulation of gas in the counties to the south and southwest. For a similar reason, it is apparent that natural gas should exist in Gainsboro and Caistor townships in this county. The cause of only small deposits being found is presumably due to the proximity of the outcrop of formations in the Niagara escarpment, owing to which the gas may have leaked away into the atmosphere. It is barely possible that this may be the reason why the wells in Haldimand county are so small in volume.

Caistor township.—Some wells have been drilled in Caistor township, but the average rock pressure in 1912 was 200 pounds, and the wells ran only from 46,000 cubic feet to 800,000 cubic feet.

Several wells were finished in the vicinity of Caistor and Warner in 1913.

Middlesex County.

General statement.—No oil or gas fields of commercial value have ever been found in Middlesex county. Showings have been struck in a few localities, as stated in the following paragraphs, but the wells may all be ranked as failures. There is no drilling at the present time in the county.

History of drilling in this county.—In the northwestern part of Middlesex county, during the excitement following the development of the Petrolia and Oil Springs fields in Lambton county, numerous wells were drilled throughout the townships of McGillivray, Williams East and West, and Adelaide.

No pools were discovered in Middlesex county, although showings of oil and gas were occasionally obtained at the base of the Hamilton or top of the Onondaga formation. In 1911 a number of wells were drilled at Delaware in Delaware township, obtaining small showings of gas and oil. The latter is of an amber hue, and has an asphalt base. A few other scattered wells have been drilled without result.

Formations penetrated by wells.—As in the other southwestern counties of Ontario, the surface is almost entirely covered by glacial drift, the thickness of which ranges from a few feet up to nearly 200 feet, and which in character is generally sand, gravel, clay or boulder clay. Underlying the drift, the uppermost hard rock formation in the northeastern part of the county is almost entirely Onondaga limestone; in the central part of the county it commonly consists of shales and limestone of Hamilton age; while in the extreme southwestern corner in Mosa township there is sometimes a thickness of 50 feet or less of black Portage shale.

In considering the formations to be penetrated, it is therefore necessary to take account of the portion of the county to be tested, because a well in the extreme northeastern part will not only start at an elevation 300 feet higher than the southwestern portion of the county, but it will begin in a lower formation geologically, since the formations rise toward the east and north. The Onondaga limestone, which constitutes the hard rock formation nearest the surface in Dorchester, Nissouri, Biddulph, and portions of Westminster and London townships, is consequently as much as 600 feet higher in elevation in parts of these townships than in the southwest part of Mosa township.

The Portage shales, occasionally present in Mosa township, seldom, if ever, exceed 50 feet in that township. Underlying these shales, lies sometimes as much as 280 feet of Hamilton limestones and shales, the latter being commonly known by the drillers as soapstone. The exact base of the Hamilton formation is not known with certainty in all well records, because some limestones occasionally occur near its base; but the contact of the lowermost soapstone with the underlying limestone is assumed to constitute the top of the Onondaga. Like the Portage, the Hamilton is absent in the northeastern part of the county.

Underlying the Hamilton is a thickness of 200 to 260 feet or more of Onondaga limestone, the exact demarkation of

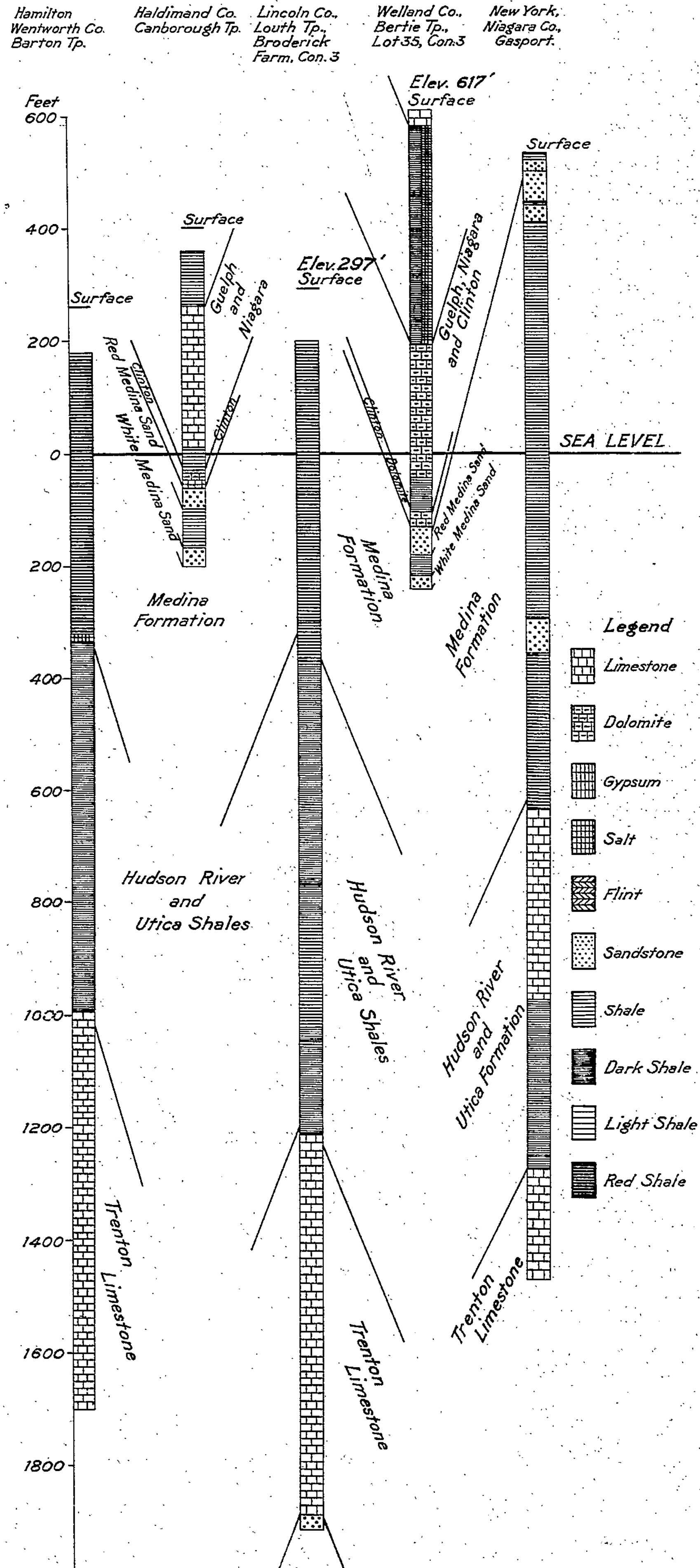


Fig. [redacted] Selected well logs, showing correlation of formations through Lincoln county, Ontario. (By F. G. Clapp and L. G. Huntley)

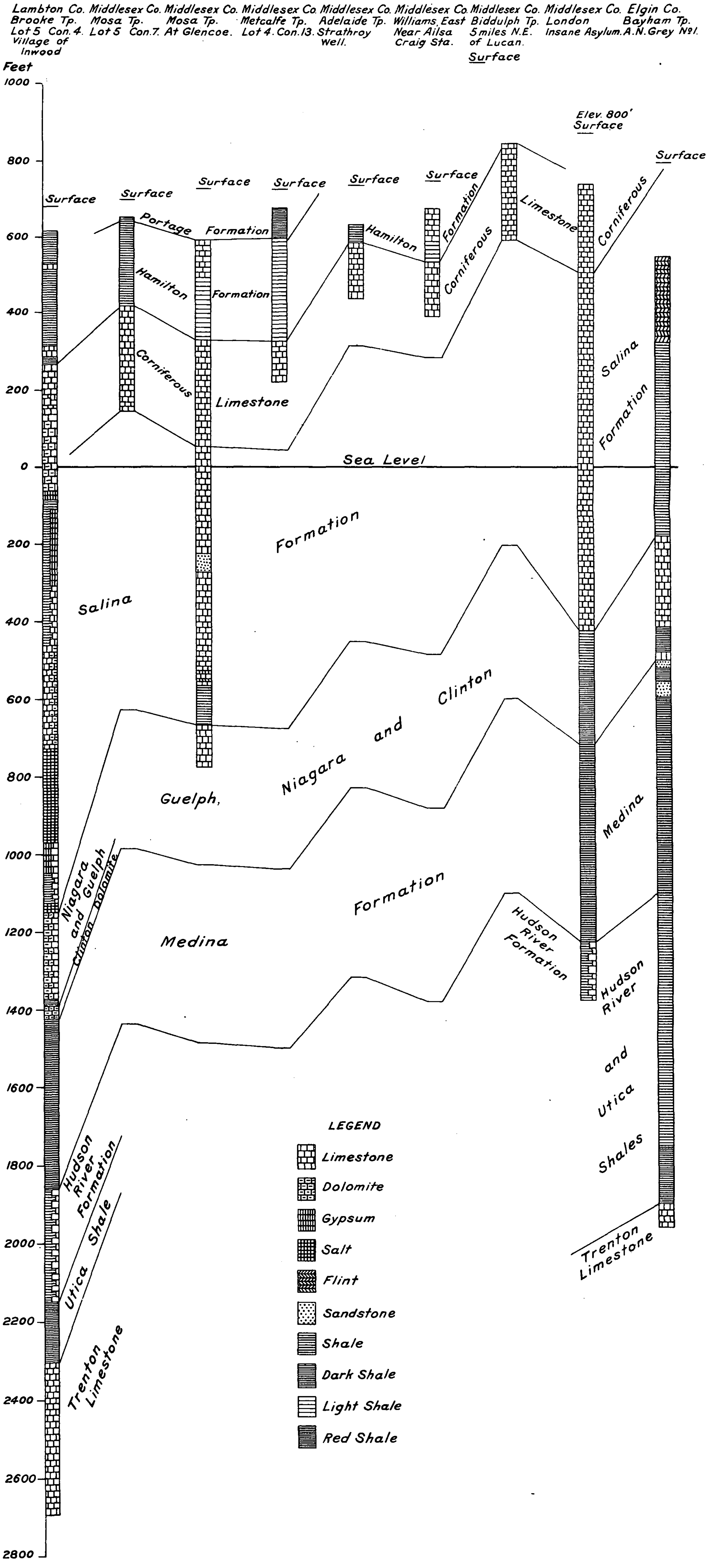


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Fig. [redacted]. Selected well logs, showing correlation of formations through Middlesex county, Ontario. (By F. G. Clapp and L. G. Huntley) which is unknown in well records, because drillers have been unable to distinguish it from the limestone of the underlying Salina. The Salina formation, which in Lambton county is as much as 1,600 feet in thickness, is in Middlesex presumably not over 800 feet. Being indistinguishable in available well records from the Guelph and Niagara limestones, it is necessary to classify the Onondaga, Salina, Guelph and Niagara together in those records as the Big Lime, as is done in Ohio, where the formations are likewise indistinguishable. The Guelph is believed to be about 100 feet thick, and its dolomite may be represented by the 100 feet of hard rock shown at the bottom of the record on page 194. The combined Niagara limestone and shale is supposed to attain a similar thickness. Underlying the Big Lime with its attendant shales and salt beds is a thickness of about 200 feet of dark shale, supposed to be of Clinton age, represented on Fig. 19. Under this lies about 500 feet of red Medina shale, beneath which occur the shales and limestones of the Lorraine age of which about 150 feet are represented in the record below. The total thickness of the Lorraine formation is supposed to be about 300 feet, and of the underlying Utica shale about 150 feet. About 500 feet below the base of the Medina, or from 2,600 to 3,200 feet below the surface in this county, is the Trenton limestone, which may be 400 feet in thickness.

The most complete available record of the stratigraphy in this county is given by the following log:—

Record of well at Insane Asylum, London township[1].

Material	*Formation*	*Top* *Feet*	*Bottom* *Feet*
Surface	Pleistocene	0	130
Hard limestone	Onondaga	130	330
Soft limestone	Salina with Guelph and Niagara, if present	330	600
Hard limestone		600	700
Limestone		700	1300
Salt and shale		1300	1400
Black shale	Clinton	1400	1600
Red shale	Medina	1600	2100
Limestone and shale	Lorraine	2100	2250

Since the foregoing deep well is situated in the eastern part of the county, where neither the Hamilton nor the Portage

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V. Pt. Q, 1889-91, p. 49.

formation is present, a shallow well record from the western part is appended to show the general conditions thereabouts.

Log of well on Lot 4, Con. XIII, Metcalfe Township[1].

Material	*Formation*	*Top* *Feet*	*Bottom* *Feet*
Clay	Pleistocene	0	48
Black shale	Portage	48	123
Soapstone, etc.	Hamilton	123	396
Limestone	Onondaga	396	500

Geological structure.—In a general way, the formations of Middlesex county may be said to dip from the northeast toward the southwest, but the inclination is modified locally by anticlines and synclines, which may be of only slight prominence. Owing to the general drift covering of the county and to its flat surface, the geological structure is not evident to the eye and cannot be deciphered except with well records. This can undoubtedly be done to a certain extent from existing records, but since oil and gas have not been found in commercial quantities in the county, the attempt has not been made.

Delaware township.—In 1911 nine wells were drilled at Delaware by parties from London, Ontario. These wells—which were of varying depths between 400 and 615 feet—entered the Onondaga limestone, and produced small amounts of gas and oil. The best showing of gas was obtained in the Harris well at Delaware, this being the first drilled. The well heads are from 725 to 730 feet above sea-level.

Caradoc township.—A well four miles northeast of Melbourne, between 500 and 600 feet deep, was drilled years ago, having a small showing of gas and oil. A shallow well was sunk in the summer of 1911 at Melbourne, into the Onondaga limestone, without results. Several shallow wells in Caradoc township had showings of oil.

Adelaide township.—Some shallow dry holes were sunk in this township immediately after the discovery of oil in Lambton county. The record of one of these is as follows:—

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 51.

Log of well at Strathroy, Adelaide township[1].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	100
Soft shale	Hamilton	100	150
Hard limestone	Onondaga	150	300

Biddulph township.—A little shallow drilling was done years ago in this township, but no satisfactory well records are available, the best being as follows:—

Record of well 5 miles northeast of Lucan, Biddulph township[2].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	100
Limestone	Onondaga	100	360

Fresh water was obtained in the limestone, but no trace of oil or gas.

London township.—Previous to 1865 a well was drilled at London which struck a big flow of salt water at 114 feet, going to 765 feet, and ending in a soft magnesian marl of Onondaga age.

On lot 13, concession IV, the Sunnyside well drilled previous to 1866, went 400 feet deep, to the limestone, while previous to 1891 a hole was drilled 2,250 feet deep at the Insane Asylum in London, ending in the upper Lorraine formation. The record of this well is given on page 191. Several other dry holes have been drilled at various times in the vicinity of London.

Metcalfe township.—Some shallow drilling to the Onondaga limestone has been done in this township, but without success. The general character of the formations penetrated may be learned from the log on page 192.

Mosa township.—A number of shallow dry holes have been drilled to the Onondaga limestone at various times in Mosa township and in several of them showings of oil were obtained, but no production has been encountered. The following record supplied by Major John Savage illustrates the general character of the formations penetrated:—

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, p. 50, 1889-91.
[2]Brumell, H. P. H., Geol. Survey Canada, Vol. V. Pt. Q, p. 53, 1889-91.

Log of well at Glencoe, Mosa township.

Material	Formation	Top Feet	Bottom Feet
Surface	Pleistocene	0	134
Limestone	Hamilton	134	234
Soapstone		234	396
White limestone	Onondaga and Salina	396	476
White limestone		476	962
Sandstone		962	1000
Limestone		1000	1260
Gypsum		1260	1265
Hardpan		1265	1280
Gypsum		1280	1283
Hard rock		1283	1290
Salt and shale		1290	1394
Hard rock	Guelph	1394	1510
Total depth			1510

In the above record a portion of the Hamilton formation is represented as limestone, and the Portage is not mentioned. Hence, another record is appended to show perhaps a more common sequence of the strata:—

Log of well on Lot 5, Con. VII, Mosa township[1].

Material	Formation	Top Feet	Bottom Feet
Clay	Pleistocene	0	88
Black shale	Portage	88	94
Soapstone, etc	Hamilton	94	337
Limestone	Onondaga	337	514

A showing of oil is reported.

East Williams township.—Some wells were drilled years ago in this township; but only showings of oil were found. The following log illustrates general conditions:—

Log of well near Ailsa Craig station, East Williams township[2].

Material	Formation	Top Feet	Bottom Feet
Surface	Pleistocene	0	65
Limestone	Hamilton	65	70
Soapstone		70	76
Limestone		76	156
Soapstone		156	206
Limestone	Onondaga	206	350

West Williams township.—Some holes were drilled in this township following the development of pools in Lambton county;

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V. Pt. Q, 1889-91, p. 52.
[2]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 53.

but with the exception of several salt wells at Parkhill and elsewhere, none reached a depth of 500 feet, and but small showings of oil were obtained. No satisfactory well logs are at hand from West Williams.

The principal Parkhill well was sunk in 1884, by the Parkhill Salt Works Company to a depth of 1,300 feet, passing into the second salt bed. The surface deposits in this locality were 170 feet thick.

McGillivray township.—Some shallow wells were drilled in this township at the time of the Lambton county development, but only showings of gas were obtained, these being in the base of the Hamilton or top of the Onondaga formation.

Ekfrid township.—Some shallow dry holes have been drilled in this township. In 1912 a showing of oil was reported in Onondaga limestone in a well near Glencoe.

Deep tests.—Although most of the tests in Middlesex county have been comparatively shallow, at least two wells, situated in London and Mosa townships respectively, are of great depth; and, consequently, when considered in connexion with records in the adjoining counties, they give us a good clue to the underlying stratigraphy. The best known deep test is a well drilled years ago at the Insane Asylum at London, and which reached a depth of 2,250 feet. The log appears on page 191. None of these tests have reached the Trenton, which is supposed to be at least 350 feet below the bottom of the deepest well, and at least 1,300 feet below the bottom of the deep well in Mosa township.

Future possibilities.—While there is some possibility of oil or gas in the untested areas in Middlesex county, this county as a whole is believed to lie too near the Onondaga outcrop to offer any chances in that formation. In the Guelph, or Niagara, there might be some prospect were these formations of much value anywhere. The Clinton and Medina are entirely devoid of sands in the London deep well and are therefore unfavourable. The possibilities of the Trenton are untested, but this is too unfavourable, since it is not productive anywhere but on the Cincinnati anticline. Summarizing, we may say that Middlesex county as a whole is not promising, but that some small pools may exist.

Muskoka District.

Muskoka district lies entirely within the limits of the Laurentian rocks, which, being hard and crystalline, are unsuitable for containing oil and gas.

Nipissing District.

Nipissing district includes a large area in northern Ontario, which is entirely unfavourable for holding oil or gas, and in which the substances will presumably never be found in quantity. The geology of Nipissing district is somewhat varied, but in its southern part or as far north as Lake Timagami the surface formation is mainly Laurentian, beyond which it is an alternation of Huronian, Laurentian and intrusive igneous rocks. There is no chance of important oil or gas deposits in this district.

Norfolk County.

History of developments.—Numerous wells were drilled in Norfolk county prior to 1890, and showings of gas were encountered in places, especially in a well drilled in 1870 at Lynedoch on Big creek.

As in Elgin county, the Dominion Natural Gas Company is now making strenuous efforts in Norfolk county to obtain gas. In this county, 11 successful wells were drilled in 1910. Operations are now chiefly in the Simcoe field, south and southeast of the town of Simcoe, in the vicinity of Port Dover and Port Ryerse in Woodhouse township, and extending southwest to and around Port Rowan and Port Royal in Walsingham South. In 1913 small gas wells were still being completed occasionally at Port Dover at about 1,100 feet.

All wells drilled in Norfolk county previous to 1891 were failures.

Geological formations.—The surface formations in Norfolk county range from a few feet to 200 feet in thickness, consisting of sand, gravel, clay, and hardpan. Underlying these, the uppermost hard rock in the county is commonly the Onondaga limestone at the west end of the county, and the Salina formation in the north and east parts.

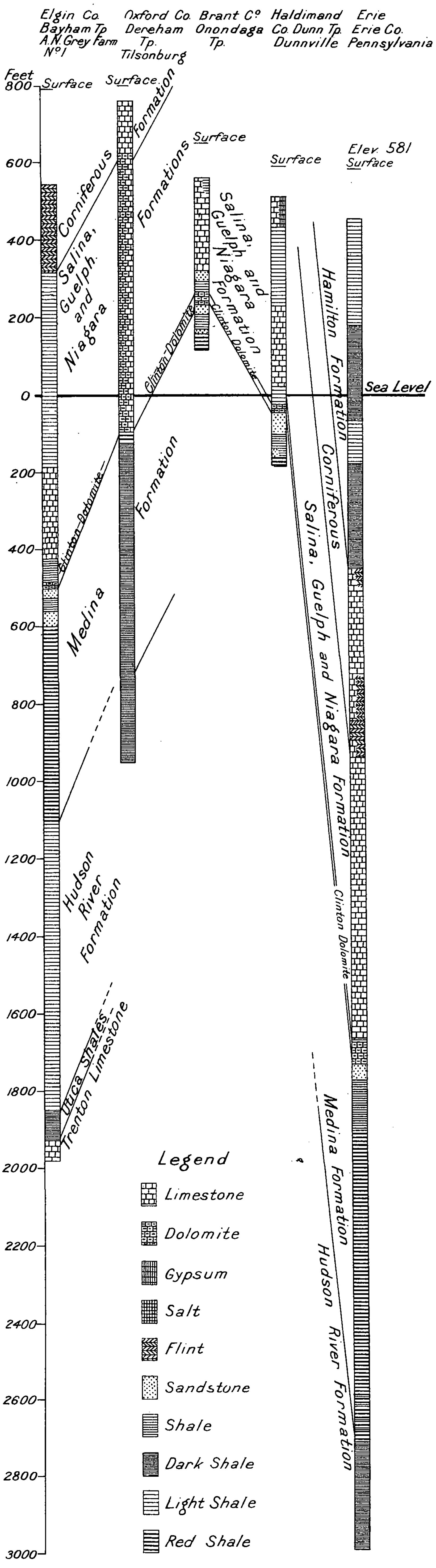

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Fig. [redacted] Selected well logs, showing correlation of formations through Norfolk county, Ontario. (By F. G. Clapp and L. G. Huntley)

The Onondaga, where present, is less than 200 feet thick, except perhaps along the west side of Houghton and Middleton townships.

It is unfortunate that no well records are available to show conditions in Norfolk county. However, judging from a number of good records in adjoining counties, the thickness of the formations ranges somewhat as follows:—

Range in thickness of formations in Norfolk county.

		Thickness	
Character	Formation	Minimum Feet	Maximum Feet
Sand, gravel, clay and boulder clay	Pleistocene	5	100
Limestone	Onondaga	0	200
Limestone, dolomite and shale	Salina, Guelph and Niagara	500	800
Dolomite	Clinton	25	35
Red and black shales and thin sandstones	Medina	600	700
Dark shales	Lorraine and Utica	800	900
Limestone	Trenton		650

In order to give a more graphic idea of probable conditions, a number of records from adjoining counties have been plotted and correlated on Fig. 20.

Producing formations.—In Norfolk county, there are frequently three producing formations, known respectively as the Clinton, Red Medina and White Medina sands. The Clinton is in reality a limestone or dolomite. The rock pressures in the respective sands in the Simcoe field were originally as follows:—

Original rock pressures in the Simcoe field.

Sand	Pounds per square inch
Clinton	475
Red Medina	500
White Medina	700

A 1300 foot well at Lynedoch, however, had a pressure of 650 pounds in the Clinton.

The depth of the Clinton below the surface ranges from about 500 to 1200 feet within the limits of the county, the Red Medina and White Medina being respectively about 30 feet and 130 feet deeper. In thickness the Clinton is 25 to 35 feet, the Red Medina 30 to 40 feet and the White Medina 10 to 30 feet. The best producing sand in the Simcoe field is the Red Medina. A general section of the producing formations is somewhat as follows:—

Typical section of gas sands.

Material	Formation	Thicknes Feet
Depth to Clinton	Clinton	1000
Limestone (gas)		24
Shale		4
Red sand (gas)	Medina	45
Shale		40
White sand (gas)		15
White sand		12
Red shale		500
Total		1640

At Delhi all gas is produced from the Clinton.

Geological structure.—The formations in the Simcoe field dip southwest about 55 feet per mile, and this dip is rather constant throughout Norfolk county.

Simcoe field, Woodhouse and Charlotteville townships.—The production in this field is controlled by the Dominion Natural Gas Company, which, up to 1912, had sunk 36 producing wells and 17 dry holes, situated in a crescent shaped area back of Port Dover and south to Port Ryerse, being about four miles long. The dry holes all lie in the western part of the pool, while the best wells are about the centre lying 1½ miles from the lake. Most of the wells produce from the Red Medina, only three producing from the White Medina in 1912. Last fall the average pressure had dropped to 410 pounds in the centre of the field, from the original 500 pounds. At Port Ryerse two gas wells sprayed some little light oil from the White Medina.

At Port Dover about a dozen producing wells have been drilled within the village limits by a local gas company and are used for supplying the town.

The average depth to the top of the Red Medina in this field is 1057 feet, and the minimum depth about 973 feet. It is customary to drill about 10 feet through the sand to form a pocket.

Charlotteville township.—A 1300-foot well owned by the Dominion Natural Gas Company in the town of Lynedoch produces gas from the Clinton. The initial rock pressure was 650 pounds. It has only been drawn on slightly, and there are no other gas wells within 4 or 5 miles. A dry hole was drilled 1 mile southeast of Lynedoch, and a well was drilled three years ago at Vittoria to a depth of 3030 feet, but produced nothing.

Walsingham North township.—A dry hole was recently drilled at Langton, by the Dominion Natural Gas Company.

Windham township.—No wells exist between Simcoe and Delhi.

Middleton township.—Three years ago a good gas well was drilled in the south end of the village of Delhi. A local company was formed, which sold out in April, 1912, to Stroud Brothers. They now have six gas wells which produce together about 2,000,000 cubic feet per day, and have drilled three dry holes. Another company has drilled one gas well and one which produced water with a showing of gas. The initial pressure in the field ranged from 505 pounds to 560 pounds, but it had declined in June, 1912, to 375 pounds. The oldest well was then one year old, having been drawn on continuously. The entire gas production is used for domestic purposes and for fuel in a canning factory.

The gas at Delhi is found in the Clinton formation, although all wells were drilled through the White Medina. The depth to the Clinton ranges from 1150 to 1200 feet, and the wells are from 1300 to 1350 feet deep. All are located within the city limits. One well at the southeast end of the pool sprayed a very little dark coloured oil.

The wells are cased on top of the Clinton with from 1050 to 1080 feet of 5⅝-inch casing. From 180 to 200 feet of drive-pipe is used, and the wells are drilled wet to near the top of the Clinton, where the water is cased off.

Townsend township.—Four wells, approximately 1000 feet deep, have been drilled in and near the town of Waterford. The first was sunk a number of years ago about 1½ miles south of Waterford, and was abandoned. Another well near by went 100 feet and was stopped. A well was drilled a short distance east of Waterford to about 1000 feet. A pocket of gas was struck, but the well was abandoned. Another just northeast of Waterford struck sulphurous water at 120 feet; drilling was continued to 900 feet but no gas was found. The well still produces water. In the centre of the town a showing of gas was struck 1042 feet from the surface on the property of Col. York. The 5⅝-inch casing is still in the well, and although it never produced, the odour of gas is still noticeable. No oil was encountered in any of the wells mentioned.

Houghton township.—In July, 1912, the Dominion Natural Gas Company drilled a well at Beech Lane. Messrs. Evans and King have two small wells at Beech Lane, and both this company and the Dominion Natural Gas have several dry holes in the vicinity.

Walsingham South.—At this town there were in July, 1912, three producing wells, one owned by Messrs. McManus and Peck and two by the Dominion Natural Gas Company. The pressures were initially 560, 575 and 650 pounds. The first of these, belonging to the Dominion Natural Gas Company, produces from the Clinton sand. Another, on the Barrett farm, found gas in a brown sand between the Clinton and the Red Medina. All three were drilled during the preceding two months. Three dry holes also exist. An older well in the village of Port Rowan started with a production of 550,000 cubic feet daily, but is now down to 15,000 cubic feet. Wells which make only 10,000 cubic feet daily are not abandoned in the Simcoe or Port Rowan districts. In 1912 a well was being drilled on the Clemens farm for the Port Rowan Natural Gas Company.

Future prospects for oil and gas.—Norfolk county has been so thoroughly tested that there seems no hope of finding any field of great volume. The best that can be expected is to obtain numerous small wells similar to those already existing.

Northumberland County.

No oil or gas deposits of commercial importance will be found in Northumberland county, since the surface is underlain almost entirely by limestones of Trenton age, which, having no suitable cover, cannot hold any commercial deposits here.

Ontario County.

General statement.—No oil or gas fields of commercial scale exist in Ontario county, or ever will be found there, since the geological conditions are unfavourable.

History of testing.—Notwithstanding the unsuitable conditions, some drilling has been done at various times in the county, beginning as far back as 1888, when a test was made by the Whitby Gas and Water Company in the town of Whitby on the west side of Byron street, to a depth of 728 feet. Traces of gas were found, being estimated, however, at only 2,000 cubic feet per day. A showing of gas, which is reported to have burned four feet in height, was also found in a water well drilled by the town many years ago. No other deep wells are known to have been drilled in Ontario county.

Formations penetrated.—The geological formations at the surface in Ontario county consist mainly of glacial drift, under which the northern half of the county consists entirely of Trenton limestone, with the exception of a belt of Birdseye and Black River formations, and possibly a little Laurentian, which touch the extreme northern end of the county. In the southern third of the county is an east-west belt of Utica shale several miles wide, and in the extreme south there are several square miles of Lorraine shale. (Fig. 5).

Consequently, the formations penetrated range from Lorraine downward to the granite. Unfortunately, only one well record is available, which is given below, for what it may be worth:—

Log of well drilled at Whitby[1].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	50
Shale	Utica	50	120
Limestone	Trenton	120	720
Arkose beds	Granite	720	728
Total depth			728
Showing of gas			400
Showing of gas			700

Oxford County.

General statement.—The only oil development in Oxford county consists of a few wells near Tilsonburg which were obtained in 1901, but which were soon abandoned. The oil was dark and heavy. It was found in sandstone underlying the Onondaga limestone, and being perhaps of Oriskany age. No drilling has been done in recent years.

[1]Brumell, H. P. H., Geol. Survey Canada. Vol, V. Pt. Q, 1889-91, p. 24.

Geological formations in this county.—The surface of Oxford county is largely covered with a thickness of 1 to 200 feet of glacial drift, below which the Onondaga commonly forms the surface rock. Some Hamilton may exist in western Dereham township.

It is unfortunate that good well records are not available, the best record of the formation being a well drilled in 1865 in Dereham township. The record is as follows:—

Log of well at Tilsonburg, Dereham township.

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	36
Limestone	Onondaga	36	196
Dolomite and limestone	Oriskany, Salina, Guelph, Niagara and Clinton	196	890
Red marl	Medina and Lorraine	890	925
Dark shale		925	1750
Total depth			1750

In order to know the underground stratigraphy of this county, it is important also to study records in Middlesex and Elgin counties.

The Tilsonburg pool.—Considerable drilling was done succeeding the year 1860 in search of oil near Tilsonburg, the first well being sunk by Messrs. Watkins, Miles and Craigie, but with little success. Oil showings were found in the Onondaga limestone immediately underlying the first. The oil excitement was started by a story that the Indians of the district had for many years resorted to an oil spring southwest of Tilsonburg for medicinal purposes.

In 1865 and 1866 a well was sunk by Messrs. Hibbard and Avery at Tilsonburg to a depth of 854 feet for salt. A strong brine was encountered, but no rock salt, oil or gas. In 1873 it was carried to 1450 feet by the Tilsonburg Salt Company. In 1877 the well was deepened to 1750 feet, but still without results. The log is given above. In 1888 and 1889 drilling was commenced again in the vicinity, about four wells being sunk at that time, 200 to 400 feet deep, yielding traces of oil.

The development of oil started in the valley of Big Otter creek in 1901; the first well produced only 840 gallons per

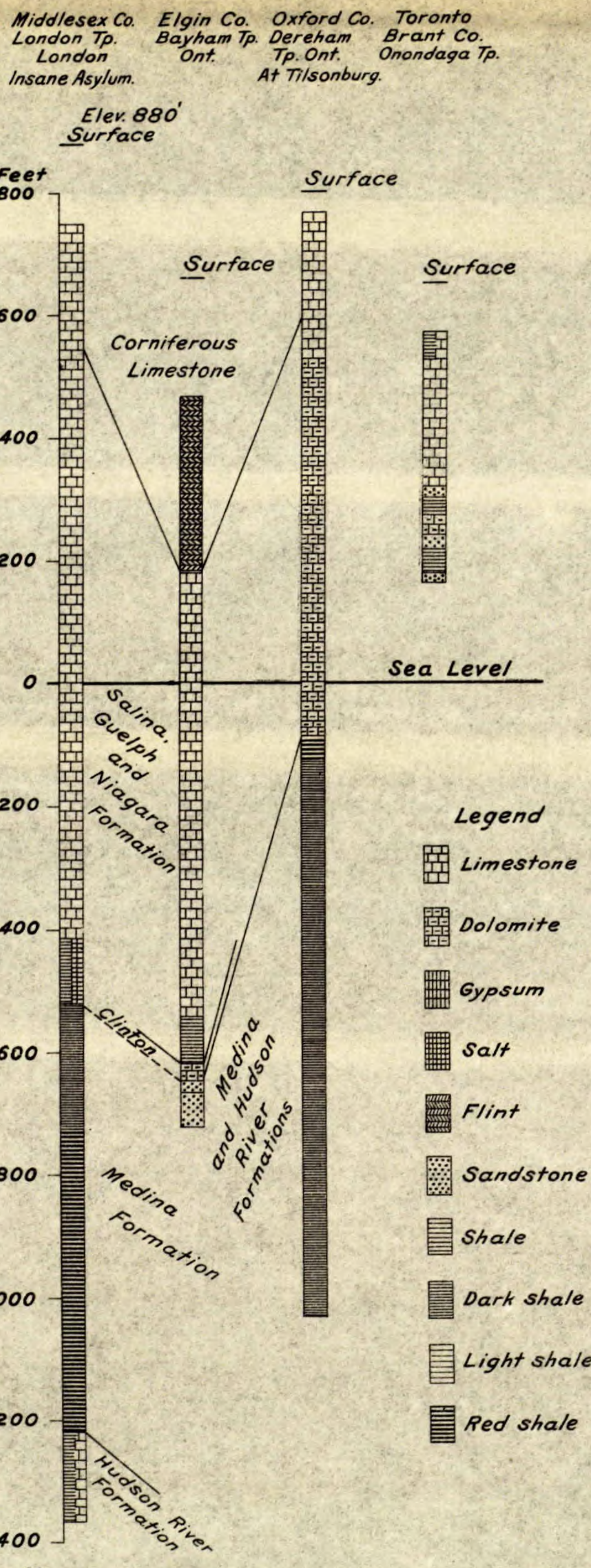

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Fig. [redacted]. Selected well logs, showing correlation of formations through Oxford county, Ontario. (By F. G. Clapp and L. G. Huntley)

day, but later wells ran as high as 1 to 24 barrels, which soon fell off to one or two barrels per day per well. The oil was accompanied by water and by some gas. The depth of the wells ranged in some cases up to 270 feet. Showings of gas were found in the Onondaga. The field has been abandoned without developing any wells of commercial importance.

Drilling elsewhere in the county.—During 1865 and succeeding years, a number of wells were sunk in Dereham and adjoining townships, but without further success than obtaining small showings. A dry hole was drilled in the Salina formation in 1887 at Burgessville in Norwich North. In 1883 to 1885 a well was drilled at Norwich on the property of George A. Cook to 2000 feet, producing only water. We regret that no record could be obtained.

In 1887 a dry hole drilled at Burgessville by local capital went to 605 feet. No accurate record was kept, but a flowing well of sulphur water is known to have been obtained.

Future prospects for oil and gas.—Judging from the knowledge that the Onondaga limestone lies close to the surface, and that the Clinton and Medina formations are unsuitable for holding gas in the deep well drilled at Tilsonburg, there appears to be very little prospect of oil or gas existing in quantity in Oxford county.

Parry Sound District.

Throughout a large portion of northern Ontario an immense area is occupied by Laurentian and associated rocks, and these crystalline rocks are entirely unsuitable for holding oil or gas. Parry Sound district lies in about the centre of this unfavourable area; consequently, it is not worthy of consideration.

District of Patricia.

Conditions in this new district are not particularly favourable to the occurrence of large quantities of oil and gas, although some possibilities of showings exist in the eastern third of the area. The formations are of Silurian and Devonian age, being largely of limestone according to the reports which have been made, and in which favourable oil formations and covers are not known; however, on the lower Abitibi river some petroleum bearing limestone has been reported[1].

The entire central and western part of the District of Patricia consists of the formations of Laurentian and Pre-Cambrian age, in which conditions are particularly unfavourable, and consequently, no oil or gas will be found in this district.

Peel County.

General statement.—No oil or gas fields on a commercial scale have ever been discovered in Peel county, and it is improbable that they exist. Some small wells have been found, suitable for supplying one or more residences, and were used for that purpose.

History of testing.—Several years ago four wells were drilled near Cooksville on the Gordon, Romageau, John Price and Shephard farms respectively, but these have been abandoned. In August, 1913, a gas well was obtained on Romageau farm.

Formations penetrated.—The fourth well in this county was drilled on the Shephard farm near the hydro-electric station to a depth of 1350 feet. Unfortunately no log is available, but the well is presumed to have penetrated the Lorraine, Utica, and Trenton formations to the underlying Potsdam. The log given by Thos. E. Bull was as follows:—

Log of well at Cooksville.

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface sand		0	5
Lorraine shale		5	560
Utica brown shale		560	710
	Trenton	710	1310
Sandstone	Potsdam	1310	1355
Gas (300 lbs. pressure)			1205
(Gas used in a small way in this and the other three wells.)			
Depth			1350

Two other wells were drilled at Cooksville by Mr. Bull, the reported rock pressure of Numbers 1 and 2 being reported 300 pounds and 200 pounds respectively, and the volumes of Num-

[1]Robert Bell, Rept. of Bureau of Mines, Ont., Vol. 21, Pt. 2, 1912, page 195.

bers 2 and 3 being reported 350,000 and 100,000 cubic feet per day respectively. The village of Cooksville has been piped for gas, but it has not been utilized. Recently a well said to have a flow approaching 1,000,000 cubic feet of gas a day was found.

Wells in various parts of Peel county are believed to have penetrated the Utica and Trenton formations, since the Lorraine is at the surface in the northern part of the county and the Medina in the southern part of the county.

Perth County.

General statement.—No oil or gas fields of commercial size have ever been found in Perth county, and it is quite certain that no such fields exist. Showings of gas have been struck in shallow wells, and it is presumed that other showings of the same sort exist, but are so small as not to be available for more than one or two dwellings.

History of drilling.—Notwithstanding the unfavourable conditions, quite a number of wells have been drilled, beginning as far back as 1863, at which time a test was sunk at St. Marys to a depth of 700 feet, and small traces of oil were reported. This was followed in 1873 by a test at Dublin drilled to a depth of 1396 feet for salt. Other salt wells were drilled about the same date at Mitchell and Listowel to depths of 2008 feet and 1200 feet respectively. No rock salt was found, and these three wells were failures in all respects. In 1890 a well was drilled by the Stratford Natural Gas Company at Stratford to a depth of 2,386 feet without finding gas. During 1909 reports appeared that natural gas had been struck in Perth county in commercial quantities, but investigation showed that the gas reported consisted only of traces found in shallow wells, and was of no commercial importance. Some other drilling has been done at various times in the county, but with no better success.

Formations penetrated.—The formations at the surface in Perth county consist mainly of glacial drift, beneath which the Onondaga limestone is nearly everywhere the uppermost hard rock. In the extreme northeastern part of the county, however, the Salina forms the surface; consequently, the drilling is mainly in the Onondaga and Salina formations. The wells drilled about 1873 for salt went as deep as the Niagara limestone, and one of them passed 300 feet into the Medina. Only one deeper well is known, which is the test sunk for gas at Stratford in 1890, finding the Trenton limestone at 2360 feet and a large quantity of salt water in this formation at 2384 feet. Unfortunately no exact well records are available in Perth county.

Peterboro County.

It is quite certain that no oil or gas in commercial quantity will ever be found in Peterboro county. The northern half of the county consists entirely of rocks of Laurentian age, in which neither oil nor gas ever exists. The southern half consists of limestones of Trenton age, associated with the Birdseye and Black River, which, having no cover, can not hold any commercial deposits of oil or gas here.

Prescott County.

Conditions in Prescott county are not favourable for the existence of oil or gas, and no fields are to be expected. The formation at the surface in the southern part of the county consists entirely of Trenton limestone, while along the northern edge it is of Chazy age. The exceptions are a narrow belt between the Chazy and Trenton, which is occupied by Birdseye and Black River limestones, similar to the Trenton; another exception is some patches of Utica shale, overlying the Trenton in the southwestern part of the county.

Since 1805 gas has been known to occur in mineral springs at the Caledonia Springs hotel. Dr. T. Sterry Hunt estimated[1] that 3,000 cubic feet of gas per day were given off from one of the springs. The surface deposits at that locality are about 100 feet thick, resting on Trenton limestone.

[1]Geol. Survey Canada, 1863, p. 535.

Prince Edward County.

No oil or gas in commercial quantity will be found in Prince Edward county, since it is occupied at the surface entirely by limestones of Trenton age, underlying the glacial drift, and since these formations have no suitable cover, they can contain only small and unimportant showings of gas.

Rainy River District.

This district, like other districts of northwestern Ontario, is entirely unfavourable for oil or gas, since it lies in a portion of the Province where the rocks are of Laurentian and Huronian age and are unsuitable for containing oil or gas.

Renfrew County.

Conditions in Renfrew county are not at all favourable for oil or gas, and it is quite certain that neither of these substances exists in quantity. The geological formations consist for the most part of Laurentian rocks, except in a few isolated localities, where the Chazy formation and limestones of Birdseye or Black River age exist.

Russell County.

No oil or gas pools exist in Russell county, since the geological conditions are very unfavourable. The formations in the west-central part of the county consist of Lorraine shales, surrounded by outcrops of Utica in certain places. Trenton limestone, with its associated Birdseye and Black River limestones occupy most of the remainder of the county. There are, however, small areas of Chazy rocks in the extreme north and south. Underlying conditions are somewhat complicated and wells would pass through rocks of various types, none of which are expected to be productive.

Notwithstanding the unfavourable conditions in this county, the Standard Oil Company drilled three holes in Cumberland township some years ago in the triangular area some five miles in extent, along the line of the Grand Trunk railway which runs to Montreal. It was naturally desired to find a supply of natural gas for Ottawa. The entire series of sedimentary rocks was penetrated as deep as the Potsdam formation, when drilling was discontinued on account of the great hardness of the sandstone encountered. Other borings did not reach below the upper part of the Trenton. Very small showings of natural gas were found.

Simcoe County.

General statement.—No oil or gas fields of commercial value have ever been found in Simcoe county, although a large amount of drilling has been done for salt, as well as for water and gas. Some light wells exist in the vicinity of Collingwood, but they are only sufficient in volume for supplying one or two residences.

History of developments.—While oil shale does not belong within the province of this report, it seems pertinent to mention that some attempt was made, commencing in 1859, for distilling oil from shale. In the year mentioned, works for shale were erected near Collingwood in Simcoe county, and seemed to have been for a time successful. The Utica shale was used, being quarried on lot 23, concession III, Collingwood township in Grey county.

Drilling for oil in Simcoe county was started as far back as 1888 when a well was sunk on lot 16, on the west side of Peel street, Collingwood, to a depth of 553 feet. Showings of gas were found, and other wells were subsequently drilled in Collingwood and its immediate vicinity, the depths ranging from 350 to 550 feet, but none of them obtained more than a showing.

At Collingwood and vicinity about a dozen wells have been drilled for oil and gas at various times since 1887. The deepest well in the town is presumed to be the well of E. R. Carpenter near the corner of Third and Oak streets, which was the second well drilled and was 541 feet deep, striking granite at 540 feet. A little gas was encountered at 144 feet from the surface. This well and another owned by Mr. Carpenter measured rock pressures of 18 to 45 pounds at the time the wells were drilled, the figures being taken from a diary kept by Mr. Carpenter. The volume, after being in use for two years, is reported to have measured 750 cubic feet in 24 hours, being exceeded by only one well in the town, which registered 756 cubic feet in 24 hours.

Several wells in the town have been abandoned, but some of them are still in use for lighting houses, and in one individual instance, the gas is used in a cook stove. The gas was insufficient for the fireplace or furnace, however. Other wells in Collingwood are situated at the office of the Collingwood Bulletin, at the Globe hotel, and at several residences.

The gas wells at Collingwood are not mentioned as being of any commercial importance, but for the reason that they are of some scientific interest, because the gas comes from the Trenton limestone, which is very productive on the Cincinnati anticline in Ohio and Indiana. Other small gas wells are reported at Delphi and at Craigleigh. An interesting feature of the Collingwood wells is that their flow is affected by the barometric pressure, and the volume is so small in all cases that this can be observed where it would not be possible in the case of more voluminous wells.

At an even earlier date than those at Collingwood, the Lilley well was sunk in the northern part of Beeton, Tecumseh township, to a depth of 1400 feet, but this well—like others—only resulted in showings. Occasionally seepages of gas in the vicinity were presumably responsible for the wells drilled in early days. In some cases water wells sunk in the surface clay at Beeton to a moderate depth had been rendered useless by the influx of gas. Other shallow wells were drilled in 1909 and 1910 near the village to the underlying granite, this being found at 540 feet in E. R. Carpenter's well at Collingwood, and 300 feet at Orillia, but it was not reached by the deep 1400-foot well at Beeton.

Possibilities for the future.—Since slight showings of gas are rather widely distributed throughout certain parts of Simcoe county, it might be supposed that there would be a chance of developing some field of importance in this county. It is believed, however, that since the Trenton outcrops in this very county under an extended area, and since natural gas in quantity is seldom found near the outcrop, that there is practically no possibility of finding a real gas field anywhere in the county.

Stormont County.

No oil or gas fields exist in this county since the geological conditions are particularly unfavourable. The formations in the northern half of the county consist mainly of Trenton limestone underlying the glacial drift, while in the southern and eastern parts the formations are of Chazy age. Intermediate between the Trenton and the Chazy is a belt of Black River and Birdseye limestone, which are commonly associated with the Trenton.

Sudbury District.

Throughout the greater part of Sudbury district the conditions are entirely unfavourable for oil or gas. The surface formations are mainly of Huronian and Laurentian age.

Thunder Bay District.

Thunder Bay district lies in a portion of Ontario which is mainly occupied by formations of Laurentian, Huronian, Nipigon, and Animikie age, which are entirely unfavourable for containing oil or gas, and where it is useless to drill for oil or gas. A very small area in the extreme northeastern corner of the district is reported on some reconnaissance maps to consist of Silurian rocks; but no oil or gas should be expected in quantity there.

Victoria County.

This county is one of the unfavourable ones, since the formations at the surface consist mainly of limestones of Trenton age, but at the northern end of the county is a small area where

Laurentian rocks occur fringed by a belt of Birdseye and Black River limestone. The Laurentian rocks are unfavourable for containing oil and gas, while the limestones mentioned will not hold it in commercial quantities in this county for the reason that no suitable cover exists.

Waterloo County.

General statement.—No productive oil or gas wells have ever been drilled in Waterloo county, but a number of dry holes have been drilled, principally at Waterloo, Berlin and Galt.

History of drilling.—The first deep drilling was in 1867, when a test was sunk in the town of Waterloo to a depth of 1120 feet, being deepened at a later date to 1800 feet. Another test was made in 1883, but no deep drilling is known since that time. Several years ago a test is reported to have been made at Galt but no record is available.

Formations penetrated by wells.—The holes drilled in this county have been mainly in the Medina formation, although the Salina, Guelph, Niagara and Clinton are penetrated before reaching it. Unfortunately, only one log is available, this being the record of the dry hole drilled in 1867 at Waterloo; it is given as follows:—

Log of dry hole drilled in Waterloo[1].

Material	*Formation*	*Top Feet*	*Botom Feet*
Surface	Salina	0	130
Limestone	Salina		
Gypsum	Salina	170	187
Shale	Salina	187	207
Limestone	Guelph, Niagara and Clinton	207	547
Blue shale	Medina	547	661
Shale red	Medina	661	1120
Bitter water			800
Bitter water			900
Total depth			1800

A record is also available of a test drilled many years ago half a mile east of the Grand Trunk Railway station in Berlin, the well being drilled for water. The formations penetrated are as follows:—

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 41.

Log of dry hole drilled at Berlin[1].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Salina	0	187
Limestone	Salina	187	507
Hard rock	Medina	507	547
Limestone	Medina	547	747
Red shale	Medina	747	927
Green shale	Medina	927	1087
Blue slate	Medina	1087	1250
Total depth			1250
Casing			303
Mineral water			540

The correlations of well logs between this county and surrounding counties are shown in Fig. 13.

Welland County.

Description of fields.—No important deposits of oil have been found in Welland county. In the southern part of the county there has been in the past an extensive gas development, which has long since passed its best days.

History of development of Welland county:—Oil was first discovered in Welland county in 1891 by the Provincial Natural Gas and Fuel Company in their wells Nos. 20 and 28, on lots 11 and 12, concession III, Humberstone township. The oil was found in the White Medina sand at depths of about 780 feet. Only about two barrels per day from each well was produced.

The first successful gas well in Welland county was sunk in 1889, fourteen miles from Buffalo. The gas was encountered in the White Medina sand at a depth of 836 feet. Up to January, 1891, 142 wells were drilled and gas piped to Buffalo, Fort Erie and Bridgeburg.

The Welland county field has been practically abandoned, although 34 gas wells were drilled in it in 1910.

Quality of oil.—The gravity of the oil in Welland county is reported as about 45° Baumé, to be ruby red by transmitted light and dark olive green by reflected light.

Producing formations.—The main supply of gas in this county is obtained from the White Medina sand, although smaller quantities have been found in the Red Medina and in the Clinton, and showings prevail in the Niagara. In addition a show of gas was obtained in the Trenton in the deep well at Thorold.

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 42.

A small well 2940 feet deep is reported in the Welland county field, obtaining its gas in the arkose bed on top of the granite. This is known as the Souder well and is No. 61. It is unfortunate that no definite log of this well is at hand.

Formations penetrated by the drill.—Welland county consists of a nearly flat plain bounded by the Niagara escarpment on the north and by the Niagara river on the east. In the escarpment, along Niagara river and in a few other localities, the rock lies at the surface; but with these exceptions the surface consists of drift, ranging in extreme cases from fifty to one hundred feet in thickness. Below the drift the uppermost hard rock is Onondaga limestone in a few localities in Humberstone and Bertie townships; but elsewhere it consists of Salina in the south of the county, and of Guelph or Niagara to the north.

In the gorge of the Niagara river between Niagara Falls and Queenston the following section of the strata is exposed, all of the formations being penetrated in wells in this county.

Geological section along N. Y. C. & H. R. R. R. Grand Gorge trolley line, Niagara Gorge[1].

		Top *Feet*	*Bottom* *Feet*
Lockport dolomite	Niagara	130	130
Rochester shale	Clinton	68	198
Clinton upper limestone	Clinton	10	208
Clinton lower limestones	Clinton	15	223
Clinton shale	Clinton	5	228
Probable disconformity:—			
Upper massive, quartzose, whitish cross-bedded sandstones	Medina formation	9	237
(Grey band of authors)	Medina formation		
Reddish and greenish bedded sandstones, much cross-bedded and channelled	Medina formation	14	251
Thin bedded reddish sandstones, with shale partings	Medina formation	38	289
Grey sandstone with green shale partings	Medina formation	5	294
Disconformity:—			
Upper dark green shales	Medina	4	298
Thin bedded, green to yellow magnesia and argillaceous limestone	Medina	3	301
Middle green shales	Medina	10	311
Thin bedded argillaceous magnesian limestones	Medina	2	313
Lower green shales	Medina	7	320
Basal or Whirlpool sandstone	Medina	25	345
Hard, heavy bedded, grey, somewhat coarse, cross-bedded sandstones	Medina	5	350
Disconformity:—			
Brick red sandy shales		115	465

[1]Grabau, A. W., Bull. 45, N.Y. State Museum, 1901.

This is the most complete known section of the formations which contain the Clinton and Medina sands.

In order to illustrate the formations which overlie these in certain parts of the county, however, the following record is given of well No. 1 of the Provincial Natural Gas and Fuel Company, in Bertie township, drilled in 1889.

Log of well in Lot 35, Con. III, Bertie township[1].

(Surface elevation 618 feet).

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	2
Dark grey limestone	Onondaga	2	25
Grey and drab dolomites, black shales and gypsum	Salina	25	415
Grey dolomites	Guelph and Niagara	415	655
Black shales	Guelph and Niagara	655	705
White crystalline dolomite; grey toward bottom	Clinton	705	735
Red sandstone	Medina	735	790
Red shales	Medina	790	800
Blue shales	Medina	800	805
White sandstone	Medina	805	810
Blue shale	Medina	810	830
White sandstone (gas rock)	Medina	830	846
Fresh water cased off			284
Salt water			548
Cased to			596
Gas 1,000,000 cu. ft. per day			836
The shot increased this to 2,050,000 cubic feet per day.			

As stated elsewhere, a well in Welland county or in its vicinity is reported to have been drilled to granite at a total depth of 2940 feet; but no log of it has been received. The deepest well of which the log is at hand is of a well in the village and township of Thorold, drilled by the Thorold Natural Gas Company in 1888, as follows:—

Log of well at Thorold[2].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	43
Dark brown limestone	Niagara and Clinton	43	50
Shale	Medina	50	120
Red sandstone	Medina	120	150
Shale	Medina	150	207
Grey sandstone	Medina	207	237
Shale	Medina	237	1050
Shale	Lorraine	1050	1750
Shale	Utica	1750	1905
Limestone	Trenton	1905	2430
Total depth			2430
Salt water			284
Show of gas			2430

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 36.
[2]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 33.

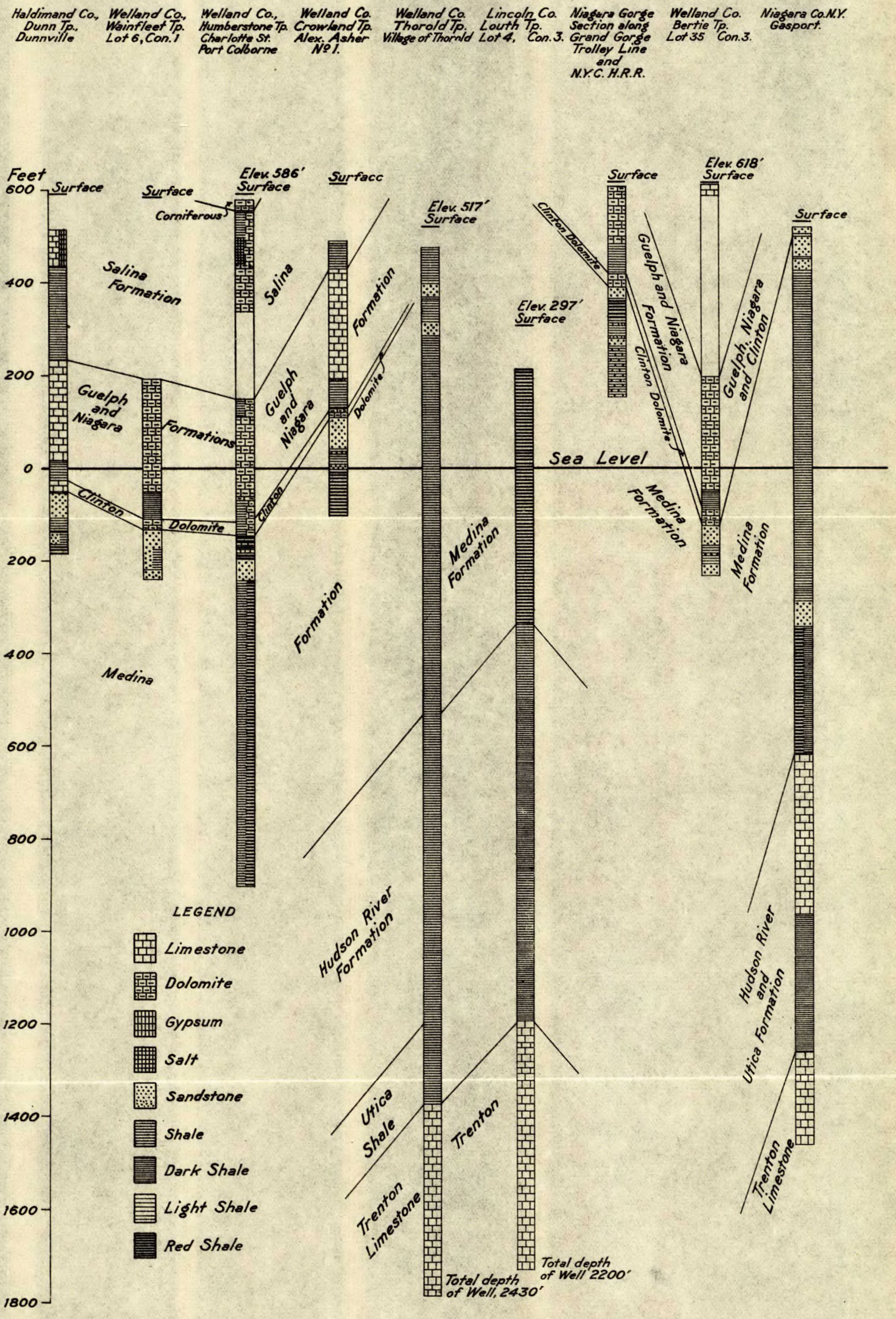


Fig. [redacted]. Selected well logs, showing correlation of formations through Weiland county, Ontario. (By F. G. Clapp and L. G. Huntley)

Geological structure.—The formations of Welland county dip from north to south and are practically flat east and west, the sands being 500 to 600 feet higher in Thorold and Stamford townships than they are near Lake Erie. Detailed surveys have not been made to determine whether or not any anticlinal reverses of dip exist; but enough wells have been drilled to determine this in considerable detail if desired.

Production of gas.—The daily initial production of the first Welland county well was 1,700,000 cubic feet, with 525 pounds per square inch rock pressure. By the end of the year 1891, the daily yield from 22 wells was 56,000,000 cubic feet. The 2,940-foot well referred to on page 213 is said to have been drilled by the Provincial Natural Gas and Fuel Company and the production to have been 250,000 feet per day. Another well half a mile north of it obtained 60,000 cubic feet of gas per day in the same sand and had 1,000 pounds rock pressure. In 1900 the total output of natural gas in Welland county was 700,000,000 cubic feet per year, mostly exported.

Casing of wells.—It is an interesting fact that in one of the deepest wells drilled in this county, which was sunk in 1885 at Port Colborne to a total depth of 1,500 feet, no casing was used except as a conductor through the surface deposits. In most of the subsequent wells in the field, however, casing has been placed a few feet below a great flow of salt water, which is generally encountered in the Niagara limestone. In Humberstone and Bertie townships in the gas field, the ordinary length of casing was originally from 580 to 600 feet, but many of the more recent wells have been cased to the summit of the Medina sand, the total length of casing being from 700 to 800 feet.

Crowland township.—Considerable drilling has been done in Crowland township, and some gas obtained. The conditions are illustrated by the following log of a well drilled by the Welland Natural Gas Company near Welland.

Log of Asher No. 1 well in Crowland township[1].

Material	Formation	Top Feet	Bottom Feet
Surface	Pleistocene	0	110
Shale	Salina	110	190
Lime	Guelph and Niagara	190	415
Blue shale		415	480
Lime	Clinton	480	500
Shale	Medina	500	505
Red shale		505	560
Shale		560	570
White sand		570	575
Shale		575	595
White sand		595	615
Red shale		615	712
	Total depth		712

Show of shale gas 300 and 512 feet.
Sulphur water..........................220 feet.
Casing..................................430 feet.

Midway between Welland and Brookfield, south of the Michigan Central railway, are several pumping oil wells. At Brookfield one gas well exists south of the railway. About two miles east of Welland on the north side of the railway, one small gas well exists.

Bertie township.—Midway between Stevensville and Brookfield several very small gas wells exist south of the railway.

Much drilling has been done in Bertie township and a great deal of gas has been found in the past in the White Medina sand. Consequently good well records are available. One of these is recorded on page 214. Another is given below, being a well drilled in 1891 by the Bertie Natural Gas Company:—

Log of well in Bertie Township.

Material	Formation	Top Feet	Bottom Feet
Flinty lime	Onondaga	0	60
Slate and gypsum	Salina, Guelph, Niagara and Clinton	60	100
Shale		100	105
Shale rock		105	135
Shale and gypsum		135	150
Shale		150	380
Lime		380	495
Sil. lime		495	510
Hard lime		510	620
Shale		620	670
Lime		670	680
Shale		680	690
Red shale	Medina	690	760
Shale		760	770
Shale		770	790
White shale		790	802
Red shale		802	820
	Total depth		870
	Gas		725
	Gas		840
	Water 100 and at various points to		250
	Cased to		660

[1] Geol. Survey Canada, Vol. VI, 1892-3, p. 108.

Many wells were drilled in this township in 1889 by the Provincial Natural Gas and Fuel Company, one being reported as high as 8,500,000 cubic feet per day.

Humberstone township.—This was the most productive township in Welland county. In the years preceding 1890 many wells were sunk here by the Provincial Natural Gas and Fuel Company, the Port Colborne Natural Gas, Light and Fuel Company, the Mutual Natural Gas Company, and by other parties. Showings of gas are found in various formations. but the chief production was from the White Medina, in a stratum known locally as the Second white sand.

The first well sunk in this township is believed to have been in 1866 when a hole 800 feet was sunk one mile west of Port Colborne under the direction of Mr. L. P. Carter. The tools were lost at the depth mentioned and the whole was abandoned, but showings of gas were obtained which were used for some years in a dwelling.

The town of Port Colborne in this township was the first town in Canada to use natural gas. The Port Colborne Natural Gas, Light and Fuel Company was organized in 1885 with Mr. C. McNeal of that place as president, and the first well was drilled in the same year on Charlotte street, Port Colborne. The principal flow of gas was found at a depth of 764 feet in one of the Medina sands. Sulphuretted hydrogen was encountered at 452 feet. No casing was used in this well except as a conductor through the surface deposits. Although much was made of the gas at the time, the daily flow was only about 25,000 cubic feet. The gas was used, however, for several years to light a number of stores and the hotel. Well No. 2 in the same village was drilled in the rear of a factory owned by Mr. H. Richardson about one mile from Well No. 1; the depth was 770 feet, about 25,000 cubic feet of gas per day being encountered 762 feet from the surface. The gas was used to heat and light several private residences. Well No. 3, known locally as the Hopkins well, was situated in the same village a short distance north of No. 1; the depth was 771 feet, gas being encountered at 765 feet. Other small wells were drilled in Port Colborne and vicinity in the years immediately following.

The developments of the Port Colborne Company were rapidly followed up by independent operators, some of the earlier wells drilled by other parties being the Carroll, near Hopkins No. 2, Cronmiller and White well.

When gas was struck by the Provincial Natural Gas and Fuel Company in Humberstone and Bertie townships, a contract was made with one of the gas companies in Buffalo, New York, and during 1890 a pipe line was laid to that city. Buffalo was supplied with natural gas from Canada for many years until 1898 when the exportation of natural gas from the country was forbidden.

Much of the gas from this county has in recent years been taken to Hamilton by the Dominion Natural Gas Company, where it is sold to the Ontario Pipe Line Company.

Log of Well No. 1 of the Provincial Natural Gas and Fuel Company, drilled on lot 35, concession III, Bertie township, drilled to a depth of 846 feet, is given on page 214. Salt water was encountered at 548 feet, but the well was cased to a depth of 596 feet. The initial flow from this well after shooting was 2,050,000 cubic feet per day. The gas is contained in the second White Medina sand. The following list may be of interest as giving the location of the first wells drilled by the Provincial Natural Gas and Fuel Company in this township:—

No. of Well.	Locality.	Depth.	Volume in cu. ft. per day.
1	Lot 35, Con. III	846′	2,050,000
3	" 1, " XV	836′	600,000
5	" 34, " III	842′	8,500,000
8	" 27, " III	840′	47,000
11	" 4, " XIV	816′	300,000
14	" 6, " XV	Over 1,600′	Failure
2	" 2, " II	851′	375,000
4	" 3, " I	875′	2,200,000
6	" 1, " I	897′	70,000
7	" 3, " II	840′	3,000,000
9	" 3, " II	851′	3,500,000
10	" 6, " I	870′	4,500,000
12	" 9, " II	843′	5,500,000
13	" 9, " I	900′	300,000

The general character of the formations in this township is illustrated by the following record of Well No. 20 of the Provincial Natural Gas and Fuel Company:—

Log of well in Humberstone township[1].

Material	Formation	Top Feet	Bottom Feet
Surface	Drift	0	63
Drab and grey dolomite	Salina	63	345
Grey dolomite	Guelph and Niagara	345	585
Black shale	Guelph and Niagara	585	635
White crystalline dolomite	Clinton	635	665
Red shale	Medina	665	720
Red shale	Medina	720	730
Blue shale	Medina	730	735
White shale	Medina	735	740
Blue shale	Medina	740	760
White shale	Medina	760	782
Total depth			782
Salt water			540
Cased			582

Gas in second white sand (761—764) with two oil pays, 4 barrels each.

A little oil was found in this well.

Well No. 1 of the Port Colborne Natural Gas, Light and Fuel Company was sunk in 1885 to a depth of 1,500 feet, the log being given below:—

Log of well on Charlotte street, Port Colborne[2].

Material	Formation (Surface elevation 586)	Top Feet	Bottom Feet
Surface	Pleistocene	0	12
Grey limestone	Onondaga	12	25
Grey limestone	Salina	25	35
Dolomite	Salina	32	35
Shale and dolomite	Salina	35	90
Dolomite and gypsum	Salina	90	147
Dolomite	Salina	147	255
Shale and dolomite in gypsum	Salina	255	440
Shaly dolomite	Guelph, Niagara and Clinton	440	470
Brown dolomite and dark blue shale toward bottom	Guelph, Niagara and Clinton	470	658
Marls and dolomite	Guelph, Niagara and Clinton	658	730
Red shale and thin bands, white sandstone	Medina—main flow of gas 764 feet	730	780
Red and white sandstone	Medina—main flow of gas 764 feet	780	833
Soft red shale with bands of grey and green	25,000 cu. feet day—gas	833	1500

Wainfleet township.—Much drilling has been done in this township and some good gas wells obtained. It followed imme-

[1]Ingall, Geol. Survey, Canada, Vol. V, Pt. SS. p. 122.
[2]Brumell, H. P. H., Geol. Survey, Canada, Vol. V, Pt. Q, 1889-91, p. 34.

diately upon the development of gas in Humberstone, and on lot 6, concession I, the first well was drilled by John Reebe, obtaining a flow of 400,000 cubic feet of gas per day in the Clinton dolomite. A record of a typical well west of Port Colborne is as follows:—

Log of gas well on Lot 6, Concession I[1].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Drab and grey dolomites, shales and gypsum	Salina	0	390
Grey dolomite	Guelph, Niagara, Clinton	390	630
Black shale	Guelph, Niagara, Clinton	630	685
Dolomite	Guelph, Niagara, Clinton	685	715
Red sandstone	Medina	715	760
Red and blue shale	Medina	760	800
White sandstone	Medina	800	820
Production of gas 400,000 cubic feet per day, 685 feet in Clinton limestone.			
Casing			630
Total depth			820

Productive formations.—In Wainfleet township, however, only one Medina white sand is present.

Stamford township.—Some drilling has been done in the past in Stamford township resulting in showings of gas. The first well known to have been drilled in this township was sunk at Niagara Falls South in 1888. Another well was sunk the same year in that vicinity, and showings of gas were obtained in both. Since the record of No. 1 well, sunk on the McGlashan farm, lot 158, is a fairly good one, it is given below.

The total depth was 840 feet. Well No. 2 drilled on lot 172 of the same township was carried to a depth of 1,000 feet, but no record was kept. Showings of gas were found in these wells 215 feet and 380 feet in the Clinton and Medina sands respectively.

A sample well log of McGlashan No. 1, drilled in 1888, is as follows:—

Log of well on Lot 158, at Niagara Falls South[2].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	43
Limestone	Niagara	43	186
Shale	Niagara	186	210
Shale	Parts of Niagara, Clinton and Medina	210	350
White quartzite sand	Medina	350	374
Shale and sandstone	Medina	374	840
Total depth			840
Casing			160
Gas 4,000 feet per day at 215 feet in upper beds of Clinton formation.			

[1]Brumell, H. P. H., Geol. Survey, Canada, Vol. V, Pt. Q. 1889-91, p. 41.
[2]Brumell, H. P. H., Geol. Survey, Canada, Vol. V, Pt. Q, 1889-91, p. 36.

Thorold township.—Some drilling has been done in this township in the past, without success. A deep hole with a showing in the Trenton was drilled in 1888 by the Thorold Natural Gas Company at Thorold to a depth of 2,430 feet. Salt water was encountered at 284 feet, and a showing of gas at the extreme bottom of the well near the base of the Trenton limestone.

Willoughby township, Welland county.—In 1899 six wells were drilled in this township, some going as deep as 900 feet; all were good wells with pressures of 250 to 400 pounds per square inch.

Future possibilities.—Welland county has been so thoroughly tested that there appears little prospect of getting any new pools in the Clinton or Medina sands. The prospect of gas in the Trenton and underlying formations likewise appears small, since no prominent favourable structure is known; but there is just a possibility that the Trenton or the arkose zone may furnish some deep field.

Wellington County.

General Statement.—No oil or gas fields of commercial possibilities have ever been found in Wellington county, and it is believed that no such fields exist, since the geological conditions are not suitable.

History of testing.—Naturally very little testing has been done, but some holes were sunk as far back as 1888, when John Frazier drilled a well at Erin to a depth of 800 feet without success. It is also known that previous to 1866 a boring was made at Eden Mills on lot 1, concession I, to a total depth of 509 feet, nothing but salt water being found.

Formations penetrated.—The formations immediately below the drift in Wellington county consist in a small area in the eastern part of the county, of Niagara limestone; in the central part of the county they consist of Guelph limestone; and in the western part entirely of Salina. Unfortunately few good well records are available, but a record is given below of the test sunk in 1888 at Erin:—

Log of dry hole at Erin[1].

Material	Formation	Top Feet	Bottom Feet
Limestone	Niagara	0	95
Shale		95	195
Blue shale and sand	Medina	195	220
Red shale		220	700
Blue shale	Lorraine	700	800
Total depth			800

Wentworth County.

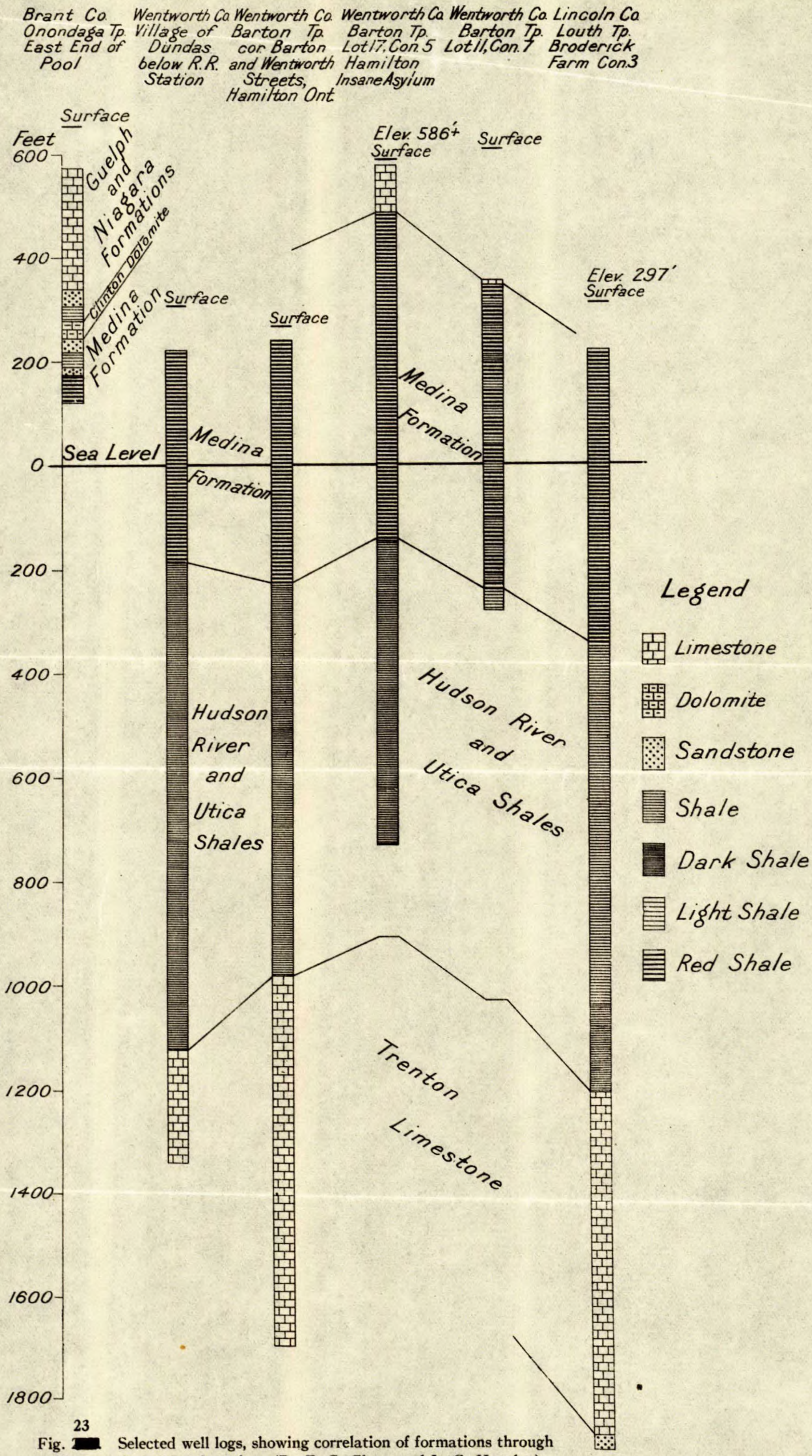
General statement.—No oil or gas fields or important deposits of either substance have ever been discovered in Wentworth county, although small showings of gas existed in several old tests. The thickness of glacial drift in this county runs from nothing up to 100 feet.

History of developments.—The city of Hamilton is supplied with natural gas by the Dominion Natural Gas Company from the Welland and Haldimand county fields. Since the early sixties wells have been drilled at various places in Wentworth county in search of a nearer supply, but none have ever produced either oil or gas in paying quantities. Several dry holes have been drilled in Hamilton itself, one in the yard of the Royal hotel being about 1,000 feet deep and showing little gas. Another well drilled in 1864 to 1865 on lot 11, concession VII, Barton township, was 873 feet deep, and ended in blue shale. It is said to have encountered small showings of oil. Another well at the Insane Asylum in Barton township was drilled on lot 17, concession V, by the Emerson Natural Gas, Light and Fuel Company to a depth of 1318 feet and was dry. At Dundas a well was drilled to a depth of 1,500 feet, encountering nothing but several small showings of gas.

Several comparatively shallow wells have been drilled in Flamboro township, finding a little gas and oil, but all were failures. Sulphurous gas is often encountered in the Niagara limestone, and on one occasion a little thick tarry oil was found. Five small gassers are reported drilled in this county in 1910.

Formations penetrated in the wells.—The thickness of glacial drift in this county runs from nothing up to 100 feet. Like Lincoln county, Wentworth is also divided topographically into

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 43.



23

Fig. [redacted]. Selected well logs, showing correlation of formations through Wentworth county, Ontario. (By F. G. Clapp and L. G. Huntley) an upper and lower level, the demarcation being along the line of the Niagara escarpment. This presents nearly a straight front from the eastern edge of the county westward to beyond Hamilton, but then bends north across Flamboro West and East townships into Halton county. The city of Hamilton is built in the angle on the lower level at the western end of Lake Ontario.

In elevation, the lower level in this county ranges from 250 to 350 feet; and the upper level ranges from 640 to 1,000 feet above sea-level, the elevation increasing toward the northwest and decreasing toward the southeast. Along the escarpment the difference in level between the upper and lower plains amounts to about 300 feet.

This discussion of the topography is necessary in order to understand the distribution of the geological formations which are penetrated by the drill. The lower plain and the lower part of the escarpment consist entirely of Medina shales; while the top of the escarpment is Niagara in age; and the Guelph formation constitutes the surface underlying the Glacial Drift throughout the greater part of the county back from the escarpment.

The Clinton dolomite and the Medina sands outcrop conspicuously below the Niagara limestone along the escarpment, but these three oil and gas-bearing beds disappear northwestward, so that north of Wentworth county they are missing. The Clinton itself is 13 feet thick at Stony Creek and 12 feet at Hamilton and Ancaster; while the Medina red sand is 14 feet at Stony creek, 11 feet at Ancaster; and the Medina white sand is 10 feet thick at Hamilton. (Figure 23).

The following is a geological section in the electric railway cut above Hamilton:—

Section of the Niagara escarpment at Hamilton[1].

Formation.	Subdivision.	Material.	Thickness.	Total.
Niagara	Lockport.	Chert beds	12	12
		Chert with shaly partings	5	15
		Crystalline grey dolomite with green shale partings	2½	17½
		Heavy dark dolomite with black shale partings	4½	22
	Rochester	Limestone and shale	4½	26½
		Shale, limestone and ferruginous band	10	36½
Clinton	Clinton	Heavy dolomite	4	40½
		Thin limestone	4	44½
		Fossiliferous band	2½	47
Medina	Medina	Grey sandstone and shale	12	59
	Cataract	Red and grey shale	70	129
		Blue limestone	10	139
		Grey limestone	10	149
	Queenston	Red shale (at least 200 ft. exposed)	200+	....

A photograph of the Niagara and Clinton formations in the locality mentioned is given in Plates X, XI, and XII.

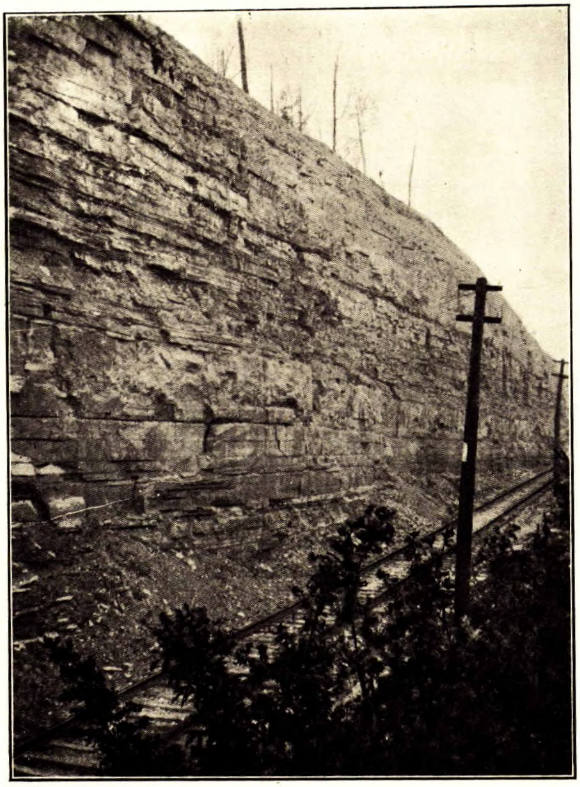
Formations penetrated.—In 1903 a well was drilled at the corner of Barton and Wentworth streets, Hamilton, to a depth of 1,950 feet, a record of which was furnished by Mr. M. D. Jepson and is given below, since it gives a fair account of the formations underlying the Medina sands.

Log of dry hole drilled at Hamilton.

Material	*Formation*	*Top Feet*	*Bottom Feet*
Sandy loam	Pleistocene	0	12
Red shale	Medina	12	480
Black shale	Lorraine and Utica	480	500
Blue shale		500	1250
Trenton limestone	Trenton	1250	1950
	Total depth		1950

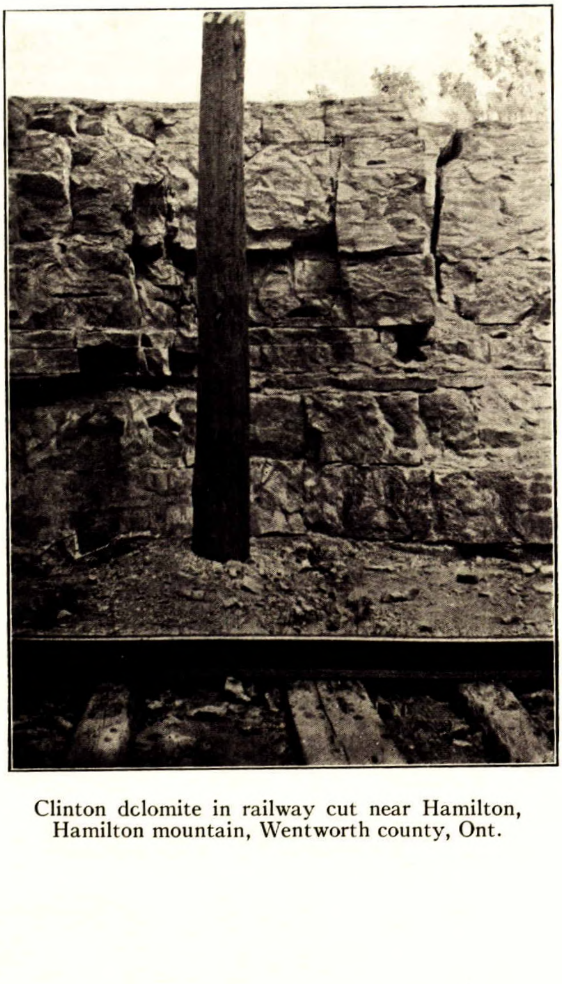
[1]Parks, W. A., The Palæozoic Section at Hamilton, Ontario, Guide Book No. 4. Excursions in Southwestern Ontario, 1913, p. 136.

PLATE X.



Niagara limestone, shale, and Clinton dolomite,
Hamilton mountain, Wentworth county, Ont.

PLATE XI.



Clinton dclomite in railway cut near Hamilton, Hamilton mountain, Wentworth county, Ont.

Plate XII.

Clinton dolomite on Hamilton mountain,
Wentworth county, Ont.

(Top of Clinton is just below trolley wires.)

About the same time two other wells were also drilled in Hamilton, the depths being similar. Only small showings of gas were found.

The city of Hamilton is trying at the present time to decide whether it will be worth while to give a franchise to the Natural Gas Co., which has holdings in Seneca township and which, it is claimed, owns wells which produce 15,000,000 feet per day. More wells are contemplated and R. F. Miller, General Manager of the Company, declares there will be sufficient produced to meet all needs of Hamilton if the franchise is granted—when they promise to pipe it to that city in two months' time. On the other hand, the Ontario Pipe Line Co. declares the supply is limited and that they are ready to meet Hamilton's needs in the coke plant they are erecting for the manufacture of artificial gas. The wells of the Natural Gas Company are only drilled to 600 feet and it is said that their nearness to the surface causes more leakage, and it will not be possible to keep up to their promises.

Possibilities of Wentworth county.—Judging by the testing which has been done and by the fact that the Clinton and Medina sands have become very thin in Wentworth county, there is little prospect for obtaining any oil or gas of value in this county. Another unfavourable fact is that the three sands mentioned outcrop in the cliff of Hamilton mountain and along the entire length of the Niagara escarpment; consequently, whatever oil or gas may have been held in the sands within a few miles of this outcrop must have escaped into the atmosphere thousands of years ago.

The question arises whether there is any prospect for obtaining oil or gas in underlying formations. To this it may be said that below the White Medina sand there is a depth of at least 1,400 feet in Wentworth county, composed entirely of the Medina, Lorraine and Utica shales, which are unfavourable for the existence of oil or gas. Below the depth mentioned, or approximately 1,250 feet below the city of Hamilton, is the top of the Trenton limestone, which is the formation producing oil or gas so abundantly in Ohio, but which has thus far never been proved commercially productive in Ontario. There is no geological structure in Wentworth county which would justify the expectation of finding a large quantity of gas in this formation.

Deep drilling.—Although a number of tests have been drilled at various times for oil and gas in this county, the majority of them have been comparatively shallow, and it is unfortunate that few records are available of the deep wells which were drilled. One good log, which shows the formations underlying the city of Hamilton, is of a well which was drilled below the railway station at Dundas to a depth of 1,650 feet. The record furnished by Mr. James Kerr is as follows:—

Log of well near Dundas, Flamboro West.

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	80
Red shale	Medina	80	480
Blue shale	Partly Medina and partly Lorraine.	480	1030
Black shale	Lorraine and Utica	1030	1430
Limestone	Trenton	1430	1650
	Total depth		1650

Several small shows of gas were found.

Several deep wells also have been drilled in the city of Hamilton going deep into the Trenton limestone. The latter is reported 700 feet in thickness, below which is the Potsdam sandstone, resting on granite.

Mr. Carmody reports that in one well they drilled half a day in the granite. The three wells in question were the same depth, all being completed at 1,950 feet, and there is very little difference in the records. About 3,000 cubic feet per day of gas was obtained about 100 feet from the top of the Trenton. There was a slight showing of oil in the well at Copp Block. The majority of well records are of little importance, since they show few details below the Clinton dolomite.

York County.

General statement.—No oil or gas fields of commercial size exist in York county, and conditions are such that it is useless to hunt for them. Small showings of gas have been reported at various localities, but these are not sufficient, when viewed in the light of geological conditions, to warrant any development.

History of drilling.—Considerable drilling has been done, notwithstanding the unfavourable conditions. Testing began as far back as 1866 or 1867, when a well was sunk at Highland creek in Scarboro township to a depth of 434 feet, but without success. In 1882, a well was sunk for water to a depth of 1,200 feet, in the yard of Coplin's brewery on Parliament street, Toronto, likewise without success. In 1888 to 1891 an attempt was made by the Ontario Bolt Company to obtain gas by drilling to a total depth of 1,261 feet. In 1889 a well was sunk by the government at Mimico in Etobicoke township in search of water, reaching a depth of 1,060 feet, and finding a showing of gas, but without other success.

About 25 years ago a well at the Massey-Harris works, corner of King street and Strachan avenue, was drilled by what was then the Massey Manufacturing Company. The reported depth was about 1,200 feet, and showings of gas were found. A number of other wells with showings have been reported at various times in Toronto and vicinity.

In the early part of 1913 a well was reported to have produced gas on the Van Sickler property at 252 Dupont street, Toronto. The total depth of the well was 1,107 feet, and the flame is reported to have been 12 feet in height before the gas suddenly disappeared, proving that only a pocket had been struck.

Rosebank, a suburb a few miles east of Toronto, has become suddenly active in the gas world. Three high flowing gas wells are reported to have been discovered. The owner of them is a Mr. William Cowan who owns most of the cottages in the suburb.

Formations penetrated.—The geological formations underlying the glacial drift in York county consist at the extreme north end of Trenton limestone. Farther south and occupying a belt one-third of the distance from the north end of the county, is the Utica shale, south of which the Lorraine outcrops over more than half the county, extending to its southeastern corner. The general dip of the formations is from northeast to southwest.

The rocks penetrated in drilling are principally those from the Lorraine shale downward, including the Utica, Trenton and associated limestones. It is unfortunate that few good well records exist, but we have several which are worth mentioning. The best available log appears to be that of the Ontario Bolt Company, drilled between 1888 and 1891 in York township on the east side of the Humber river, three-fourths of a mile from Lake Ontario, penetrating 16 feet into the crystalline rocks. The log of this well is as follows:—

Log of well in York township[1].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Sand	Pleistocene	0	65
Quicksand	Pleistocene	65	80
Hardpan	Pleistocene	80	107
Grey shale	Lorraine and Utica	107	547
Black shale	Lorraine and Utica	547	587
Grey shale	Lorraine and Utica	587	643
Limestone	Trenton	643	750
Soapstone	Trenton	750	755
Limestone	Trenton	755	1235
Fossil rock	Trenton	1235	1245
Crystalline rocks		1245	1261
	Total depth		1261

Another fair well record, not so deep, was sunk in 1889 at Mimico in Etobicoke township by the Ontario government, and reached to the total depth of 1,060 feet. The log is as follows:—

Log of well in Etobicoke township[2].

Material	*Formation*	*Top Feet*	*Bottom Feet*
Surface	Pleistocene	0	7
Blue shale	Lorraine and Utica	7	500
Brown shale	Lorraine and Utica	500	723
Limestone	Trenton	723	1060
	Total depth		1060
Shows of gas		425, 575 and	1052
Water			25
Casing			100

Granite is reported in the well of the Massey-Harris Company at a depth of about 1,200 feet.

Statistics of Petroleum and Natural Gas Production in Ontario.

The following table gives the production of crude petroleum of Ontario by districts, for the last five years, as reported by the Deputy Minister of Mines[3].

[1]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 25.
[2]Brumell, H. P. H., Geol. Survey Canada, Vol. V, Pt. Q, 1889-91, p. 24.
[3]Twenty-second Annual Report, Bureau of Mines, Vol. XXII, Part I, 1913.

Field.	1908.	1909.	1910.	1911.	1912.
	$	$	$	$	$
Lambton	265,368	243,123	205,456	184,450	150,272
Tilbury and Romney	201,283	124,003	63,058	48,707	44,727
Bothwell	39,228	38,092	33,999	35,244	34,486
Leamington	9,334	5,929	141	....	....
Dutton	13,734	9,513	7,752	6,732	4,335
Onondaga (Brant co.)	....	....	1,005	13,501	7,115
	528,959	420,660	314,410	288,634	240,935

In the following table, furnished by the Imperial Oil Company, Limited, is given the production of petroleum in Ontario, Canada, during the years 1898–1912, by districts.

Production of Petroleum in Ontario, Canada, 1898-1912, by districts, in barrels of 35 imperial gallons.[a]

District.	1898.	1899.	1900.	1901.	1902.	1903	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.
Bothwell	66,404	65,044	47,405	52,873	50,141	48,880	47,654	47,959	43,836	40,556	39,820	38,707	36,615	35,094	33,257
Coatesworth (Romney)	......	......	......	......	......	......	......	......	......	49,784	11,165	1,082	......	......	......
Dutton	901	3,622	4,791	10,588	8,867	21,483	14,217	20,976	18,597	14,698	12,268	10,052	7,860	3,598	2,455
Leamington	......	......	......	......	......	1,190	25,241	113,806	......	......	......	......	......	......	......
Blytheswood	......	......	......	......	......	......	669	......	35,958	16,210	18,117	9,367	248	13,501	......
Comber	......	......	......	......	......	......	97	......	......	......	......	......	......	......	......
Staples	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
East Tilbury	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Raleigh including Pardo's Siding and	......	......	......	......	......	......	......	......	115.400	344,358	170,589	115,862	60,416	49,027	43,376
Sandison	......	......	......	......	2,462	1,161	3,274	......	......	......	......	......	......	......	......
Onondaga	......	......	......	......	......	......	......	......	......	......	......	......	1,070	12,602	......
Pelee Id.	......	......	......	......	......	......	1,023	......	......	......	......	......	......	......	......
Richardson Station (Chatham) including Blakely	......	......	......	......	......	......	......	1,249	1,376	940	2,883	2,923	1,689	1,776	711
Thamesville	......	......	......	......	......	......	......	5,037	2,463	1,585	1,139	853	710	141	......
Wheatley	......	......	......	......	......	1,995	4,490	1,750	......	......	......	......	......	......	......
Petrolia and all other districts	b513,179	528,641	541,435	432,906	397,628	350,390	278,299	250,701	247,446	206,285	171,019	156,581	129,372	126,089	95,968
Oil Springs	c133,366	107,487	99,019	76,059	60,747	56,405	75,530	78,125	68,100	55,813	61,252	60,868	55,508	56,248	41,532
Plympton	25,000	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Moore township	......	......	......	......	......	......	36,971	93,815	53,030	32,720	25,667	18,033	14,614	......	......
Dawn	5,923	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Euphemia	5,227	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Zone	901	......	......	......	......	......	......	......	......	......	......	......	......	......	......
	750,901	704,794	692,650	572,426	519,845	481,504	492,502	610,844	585,328	762,503	513,633	414,185	307,533	297,935	217,299

a Min. Res. U. S. 1910, pp. 109–11; 1900, p. 587.
b Includes production from Plympton.
c Includes production from Dawn, Euphemia and Zone.

The following table gives the statistics of natural gas production in the Province of Ontario, Canada, since 1892[1]:—

Statistics of Natural Gas production in the Province of Ontario, Canada, 1892–1912[2].

Year.	Wells Bored in the Year.		Producing wells.	Miles of gas pipe.	Workmen employed.	Gas Production.		Wages for labour.
	Productive.	Non-productive.				Quantity. (Cubic feet.)	Value.	
1892							$150,000	
1893			107	117	59		238,200	$24,592
1894			110	183	99		204,179	53,130
1895			123	248	92		282,986	73,328
1896			141	287	87		276,710	47,527
1897			140	297	84		308,448	42,338
1898			142	315	85		301,599	31,457
1899			150	341	95		440,904	40,149
1900			175	306	161		392,823	43,636
1901			158	368	129		342,183	59,140
1902			169	369	107		195,992	55,618
1903			210	312	138		196,535	79,945
1904			176	231			253,524	53,674
1905			273	462½	130		316,476	88,865
1906			332	550	108	2,534,200,000	533,446	64,968
1907			582	810	191	4,155,900,000	746,499	110,832
1908			656	850	152	4,483,000,000	988,616	106,786
1909			744	987	171	5,388,000,000	1,145,307	103,672
1910	145	30	828	982	186	7,263,427,000	1,271,303	118,786
1911	268	38	1,179	1,296	287	10,863,871,000	1,807,513	183,663
1912	178	41	1,247	1,448	277	12,529,463,000	2,036,245	184,351

[1] The first year in which records of natural gas production were kept was in 1892.

In part from—
Min. Resources, U.S., 1910, pp. 324-5; 1912, pp. 341-342.
Geol. Survey of Canada, Vol. 8, 1893, Pt. S, 1899.

PART 2

CANADIAN FIELDS IN DETAIL

WESTERN

CONTENTS.

PART 2.

CANADIAN FIELDS IN DETAIL: WESTERN

ILLUSTRATIONS.

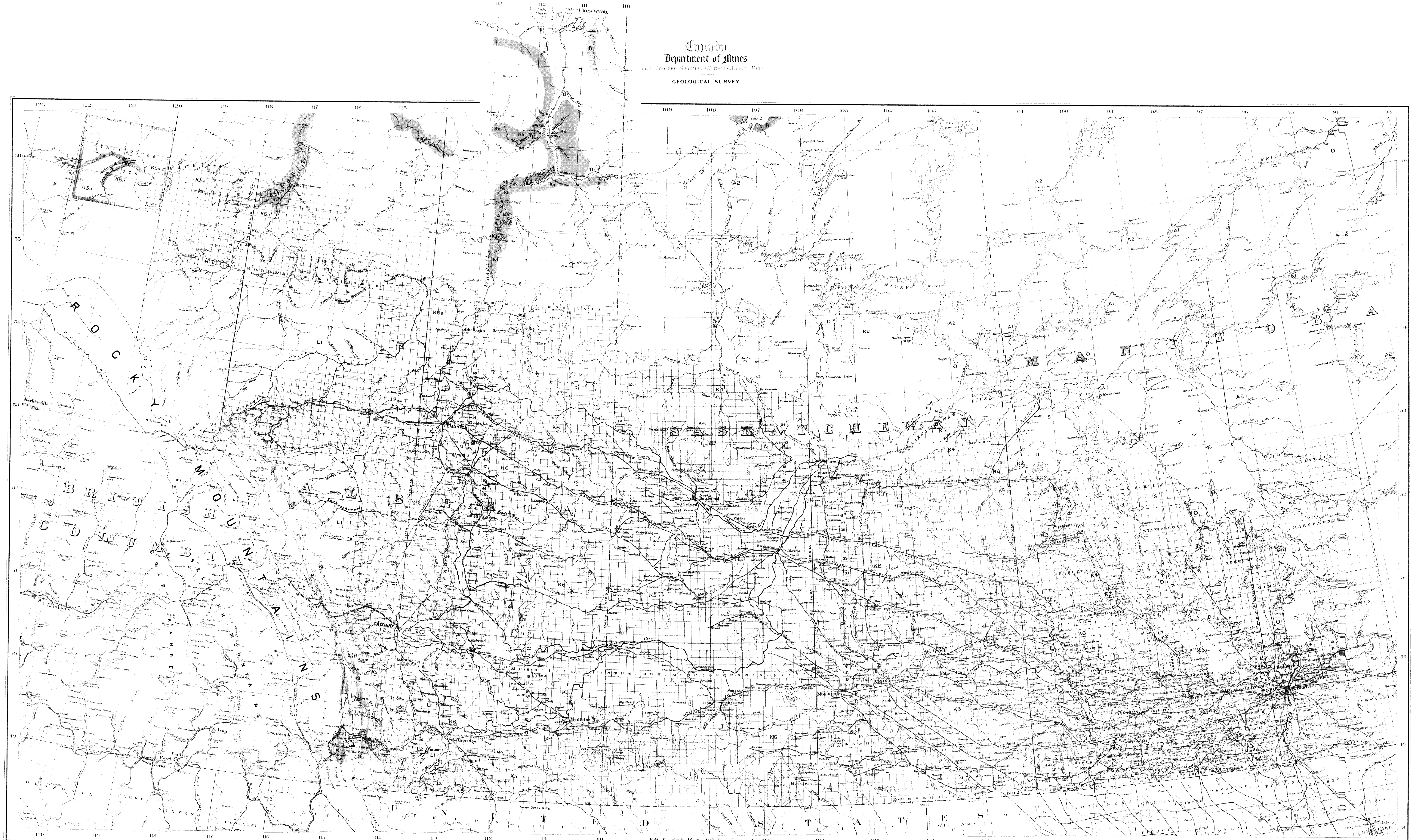
Photographs.

Drawings.

Maps.

Canada
Department of Mines
HON. L. CODERRE, MINISTER. R.W. BROCK, DEPUTY MINISTER.

GEOLOGICAL SURVEY



LEGEND

TERTIARY
T — Oligocene

LARAMIE
L2 — Paskapoo
L1 — Edmonton (Coal bearing)
L — Laramie (Coal bearing)

MESOZOIC — CRETACEOUS
K6 — Pierre and Foxhill (In the east may include portions of the Colorado)
K6a — LaBiche (Upper portion) and Foxhill
K5 — Belly River (Coal bearing)
K5a — Dunvegan
K4 — Niobrara
Ka-Kg
Athabaska Section: Kd LaBiche (lower portion); Kc Pelican; Kb Grand Rapids; Ka Clearwater
Peace Section: Kf Fort St. John; Ke Peace River
Southeast Alberta: Kg Lower dark shales
K3 — Benton
K2 — Dakota
K2a — Tar Sands
K1 — Kootenay (Coal bearing)
K — Mesozoic (mainly Lower Cretaceous)

PALAEOZOIC
D — Devonian
S — Silurian
O — Ordovician

PRE-CAMBRIAN
B — Athabaska sandstone
A2 — Laurentian
A1 — Keewatin and Huronian

Geological boundary (Position defined or approximately known)

Geological boundary (Position assumed)

Note. *The term Laramie is used with the implied meaning given by G. M. Dawson in the Report of Progress for 1880-81-82, page 4 B, as a group term to include all the stratigraphically conformable formations from the top of the Pierre Foxhill to the unconformity below the Oligocene.*

C.-O. Senécal, *Geographer and Chief Droughtsman*
A. S. Jost *and* A. McGregor, *Droughtsmen*

MAP 55A
(Reissued 1914, with minor geological additions)

Geological Map of ALBERTA, SASKATCHEWAN AND MANITOBA

Scale, $\frac{1}{2,217,600}$

Miles: 25 20 15 10 5 0 25 50 75 100 125 150

Kilometres: 50 40 30 20 10 0 50 100 150 200

35 MILES TO 1 INCH

Base map from engraved plates of the Department of the Interior
Geology compiled from published and unpublished maps of the Geological Survey

Reprinted for Mines Branch, to accompany Report on "Petroleum and Natural Gas Resources of Canada", by Frederick G. Clapp.
Map No. 297.

PETROLEUM AND NATURAL GAS RESOURCES OF CANADA

VOL. II

DESCRIPTION OF OCCURRENCES

PART 2

Canadian Fields in Detail

WESTERN CANADA

CHAPTER VI

MANITOBA

GEOLOGY[1]

Stratigraphy

GENERAL STATEMENT

The sedimentary formations of Manitoba are limited to two areas; one underlain by Ordovician and Silurian strata lies along the lower courses of the Churchill and the Nelson rivers and extends along Hudson bay from the mouth of the former river to the southeastern border of the Province; and the other occupies the southwest quarter of the Province, and includes formations from the Ordovician to the Devonian and also Cretaceous and Tertiary strata. These formations outcrop in wide bands parallel to the southwest edge of the Pre-Cambrian, and extend from the United States border to the boundary between Manitoba and Saskatchewan. In the intervening region between these two areas, the rocks are all crystalline and metamorphic Pre-Cambrian deposits. The rocks of the Province, if grouped together, would form the geological section given below. The data for this section and for the descriptions of the geological formations, and the logs of the bore-holes, have been taken from McConnell, Tyrrell, and Dowling as summarized by Wyatt Malcolm in Geological Survey of Canada Memoir 29 E[2].

[1]Chiefly by F. G. Clapp.
[2]Oil and gas prospects of the Northwest Provinces of Canada.

Generalized Geological Section of Manitoba.

System.	*Period.*	*Formation.*	*Thickness. (Feet)*	*Material.*
Tertiary.....	Laramie.......	Laramie (Fort Union)		
Cretaceous..	Foxhill........	Odanah........	400	Light grey hard fissile shales.
	Pierre.........	Millwood......	664	Soft dark grey clay shales.
	Niobrara......		130–540	Calcareous shales and chalky limestones.
	Benton........		160	Soft dark grey fissile shale.
	Dakota........		13–200	Coarse light grey sandstone.
Devonian....	Upper.........	Manitoban	210	Light grey brittle limestone with red and grey shales.
	Middle........	Winnipegosan..	200	Hard white to spongy yellow dolomites.
	Lower.........	LowerDevonian	100	Red and other shales.
Silurian......	Niagara.......		200	Compact light dolomites and argillaceous limestones.
Ordovician..	Utica (?)......	StonyMountain	190	Limestones and shales.
	Trenton.......	Upper mottled limestone....	130	Limestone.
		Cat Head limestone........	70	Dolomite with chert.
		Lower mottled limestone....	70	Limestone.
	Black River (?)	Winnipeg sandstone........	10–100	Sandstone and shales.
Pre-Cambrian	Huronian......			Quartzites, conglomerates, limestones and schists.
	Laurentian....			Granite and granite gneiss.

DESCRIPTION OF GEOLOGICAL FORMATIONS.

Pre-Cambrian:—The Pre-Cambrian rocks of Manitoba are part of the great Pre-Cambrian shield of North America stretching from the Great Lakes region to Labrador and the Arctic Ocean. The Laurentian, a granite-gneiss complex, occupies most of the territory. In this area, there are smaller belts and areas of Huronian and Keewatin, consisting of much altered sedimentaries such as quartzite, conglomerates, limestone, and crystalline micaceous and chloritic schists.

Ordovician-Winnipeg sandstone.—The Winnipeg formation consists of shales and sandstones of varying thickness, ranging from 10 feet in the northern part of the province to 100 feet in the southern part. These sandstones are friable and generally light coloured, though at places they are deeply stained with iron. In the southern part of the province, the upper part of the formation is made up mostly of shale. The age of the formation is Black River, or a transition from Black River to Trenton.

Trenton Group.—The Trenton group is made up of three formations of which the *Lower mottled limestone* is the basal one. This limestone consists of dark-yellowish to greyish white mottled limestone, some beds of which are quite fossiliferous, and the total thickness of which is about 70 feet. *The Cathead limestone* comes next in ascending order. It also has a thickness of about 70 feet, and is made up of fine grained, evenly coloured, yellow dolomitic limestone with numerous concretions of dark coloured chert. The lower beds resemble lithographic limestone, and are very rich in fossils. The uppermost member of the Trenton is the *Upper mottled limestone* which has a thickness of 130 feet. It consists of light, yellowish, and at a few places reddish, mottled dolomitic limestone. In places it is quite porous and contains impressions of salt crystals. It is quarried at East Selkirk, and is used as a building stone in Winnipeg. The rocks of the Trenton group thin out towards the north so that at Reed lake in northern Manitoba only the Upper mottled limestone is present resting on the Winnipeg sandstone.

Stony Mountain formation.—This formation is exposed only at Stony mountain and Little Stony mountain, but has been shown by drilling to extend from Stonewall southeastward to the vicinity of Winnipeg. Towards the north it thins out. The complete thickness as shown in well borings is 190 feet. It consists of shales in the lower part and grey thick bedded argillaceous limestones above. The lower shales are thought to be Utica in age and the limestones with the upper part of the shales is to be correlated with the Richmond group.

SILURIAN ROCKS.

Niagara limestone.—This formation has a thickness of 200 feet and consists largely of dolomites. On the west side of Lake Winnipegosis, it is made up of compact, thin bedded dolomites and at Cross lake of compact and porous dolomites with numerous fossils, while at Grand Rapids on the Saskatchewan river the dolomites are hard, tough, and light-yellowish in colour. The formation has not been recognized in the southern part of the province, although rocks resembling the Niagara are found at Stonewall, 20 miles northwest of Winnipeg. Gypsum has been found in the vicinity of Lake St. Martin. It has also been found by boring about 325 feet beneath the surface, southeast of Winnipeg. It is probable that the gypsum beds and associated shales belong to a higher formation of the Silurian.

DEVONIAN ROCKS.

Lower Devonian formations.—These rocks are softer than the underlying and overlying beds, and do not form cliffs, hence the nature and extent of the formations are not well known. They appear to consist of red and other coloured shales with a thickness of about 100 feet. It is suggested that the softness of these rocks resulted in their erosion and the development of the depressions now largely occupied by Lakes Winnipegosis and Manitoba.

Winnipegosan or Middle Devonian formation.—These rocks form a belt running from the west boundary of the province through Dawson bay of Lake Winnipegosis, to Point Richard on Lake Manitoba, their farther southern extension being concealed by glacial drift. The formation consists of two members; a lower one, 100 feet in thickness, of porous spongy yellow dolomite; and an upper one, likewise 100 feet in thickness, of whitish or light yellow, hard, tough, compact dolomite with many fossils.

Manitoban or Upper Devonian formation.—This formation outcrops in a belt to the west of the preceding. It consists of three members. The lower one is made up of red and grey shale, with a thickness of 70 feet, and is exposed along the west shore of Lake Winnipegosis and elsewhere. The middle member consists of light grey hard limestone, having a thickness of 40 feet. The upper member consists of light grey hard brittle limestone, fossiliferous, underlain by red argillites, with a total thickness of 100 feet. The whole thickness of the Manitoban formation is therefore 210 feet.

CRETACEOUS ROCKS.

Dakota formation.—The Dakota formation is of the greatest importance as it is the chief bitumen bearing formation in the Northwest. It is in these rocks that the tar sands of the Athabaska occur, and that the chief gas reservoirs of southern Alberta are located. The formation is exposed at several points along the northern portion of the Manitoba escarpment. On account of the irregularity of the floor on which it was deposited, it varies in thickness from 13 to 200 feet. It is composed of white or reddish sandstones, either cemented by a calcareous matrix, or often quite incoherent, being then an even-grained white quartzose sand. It grades up into a light green and rather hard sandstone commonly interstratified with thin bands of green shale. These upper greenish beds have yielded a few fossils, mainly coniferous leaves and fragments of wood.

Benton formation.—This formation consists of dark grey, almost black shale, holding a considerable quantity of carbonaceous material. This shale is evenly bedded, breaks down readily into flakes, and is easily eroded. It is associated with thin bands of white, soft, sweet-tasting magnesian clay (bentonite). It is generally destitute of fossils. The thickness of the formation in Manitoba is about 160 feet.

Niobrara formation.—The Niobrara consists of grey calcareous shale or marl, sometimes varying to a band of moderately hard limestone and weathering into steep or vertical bluffs. At the top there is usually greyish chalky limestone, often highly pyritiferous. The more calcareous layers of the formation yield cement rock in certain localities. The thickness varies from 130 to 200 feet, and it is possibly 540 feet in thickness in the Swan River valley.

Millwood formation.—These rocks are well exposed at Millwood on the Assiniboine river. They consist of dark grey soft shales containing crystals of selenite and ironstone septaria with a few fossils. The thickness in southwestern Manitoba is over 650 feet but farther north it ranges from 450 to 500 feet.

Odanah formation.—The Odanah formation conformably follows the Millwood and has a thickness of 400 feet. A good exposure of these rocks is seen in the upper part of Edwards Creek valley and at Odanah. They are made up of light grey, hard, clay shales. They contain a meagre marine fauna.

TERTIARY ROCKS.

Laramie formation.—In the southwestern part of Manitoba, extending for 40 miles along the boundary line of the United States, occurs an outlier of the Laramie, consisting of clays and sands, and known in the United States as the Fort Union formation.

Structural Geology.

As has already been indicated, the sedimentary rocks of the southwest third of Manitoba outcrop in northwest-southwest bands parallel to the border of the Pre-Cambrian and have a general dip of a few feet to the mile to the southwest. Over much of this country the rocks are concealed by glacial drift, and much of it has not yet been thoroughly examined, so that the details of the geological structure are unknown except here and there. Some light anticlines have been detected in the Niagara rocks on the east shore of Lake Winnipegosis. In the same region, the Devonian strata are found to be folded into low anticlines and in places are faulted. At the south end of the lake the disturbance becomes rather pronounced and there are dips up to 20 and 30 degrees.

OIL AND GAS DEVELOPMENTS.

A few scattering holes, some of them reaching considerable depth, have been drilled in Manitoba in the search for oil and gas, but as yet no deposits of importance have been located. Gas is reported to have been struck in August, 1912, at a depth of 120 feet in a well being drilled for water, 3 miles west of Miami. As shown by the following log of a borehole at Morden, 12 miles east of south of the foregoing, the Dakota would not be likely found at less depth than 300 feet, so that the supply of gas probably did not come from that formation.

Log of bore-hole at Morden.

Boring about 150 yards northwest of the railway station.
Altitude, 978 feet above sea-level.

			Thickness (Feet)	*Depth (Feet)*
Alluvium, 15 feet	1.	Light sandy soil	8	8
	2.	Quicksand	3	11
	3.	Quicksand, red	1	12
	4.	Fine gravel, red	3	15
Till, 16 feet	5.	Lead coloured clay with pebbles	10	25
	6.	Limestone boulder, with fine scratches	2·5	27·5
	7.	Small boulders and shale	3·5	31
Pierre (Millwood series) 24 ft.	8.	Dark grey shale	24	55
Niobrara, 160 feet	9.	Hard streak	0·5	55·5
	10.	Dark grey shale	4·5	60
	11.	Hard streak	3	62
	12.	Dark grey shale	6	68
	13.	Hard streak	1	69
	14.	Dark grey shale	11	80
	15.	Hard streak, mixture of stones and shale	1	81
	16.	Dark grey shale	4	85
	17.	Black shale, very gritty	1	86
	18.	Dark grey shale	7	93
	19.	Black shale, hard and gritty	1	94
	20.	Grey calcareous shale	121	215
Benton, 105 feet	21.	Dark grey shale	35	250
	22.	Soapstone	3	253
	23.	Dark grey shale	67	320
Dakota, 92 feet	24.	White sand, with water	4	324
	25.	White sand with particles of coal	54	378

			Thickness (Feet)	Depth (Feet)
Dakota, 92 feet	26.	White shale	2	380
	27.	White sand		
	28.	Soft grey shale	10	390
	29.	Slack shale	10	400
	30.	Grey shale with sandstone	12	412
Devonian, 188 feet	31.	Red and grey shale	88	500
	32.	Porous limestone at		500
	33.	Red and grey shale	100	600

Water at depth of 324 feet strongly charged with sodium chloride.

Other wells have been drilled, of which the logs of four are available and they are given on the following pages:—

Log of bore-hole at Rosenfield.

Altitude 770 feet above sea-level.

			Thickness (Feet)
Magnoketa shale	1.	Black soil	4
	2.	Fine silt or clay	111
	3.	Sand and gravel	10
	4.	Boulder clay (hard pan)	12
	5.	Boulders	6
	6.	Grey shale	62
	7.	Limestone	15
	8.	Red shale	5
	9.	Grey shale	10
	10.	Limestone	30
	11.	Fine, grey sandstone	40
	12.	Chalky limestone	30
	13.	Red shale	160
Galena limestone passing below into the Trenton	14.	Cream-coloured limestone	305
	15.	Red shale	75
St. Peter	16.	Soft sandstone	50
Lower Magnesian	17.	Dark red shale	50
	18.	Reddish and greenish shale	25
	19.	Bluish and grey shale	20
	20.	Red shale	15
Laurentian	21.	Granite	2
		Total	1037

Small flows of brine were struck below Nos. 10 and 14, and from No. 16 the brine produced a flowing well.

Log of bore-hole at Deloraine.

About 100 yards north of the railway station.
Altitude 1,644 feet above sea-level.

			Thickness (Feet)	Depth (Feet)
Pleistocene, 91 feet	1.	Black soil	3	3
	2.	Clay, with some small pebbles	30·5	33·5
	3.	Hard blue clay, with pebbles	56·5	90
	4.	Fine black sand and gravel	4	94
Pierre—Odanah, 292 ft.	5.	Light blue-grey shale	56	150
	6.	Black sand, with water	0·5	150·5
	7.	Blue shale	235·5	386
Pierre Millwood, 664 feet	8.	Soapstone, with thin layers of lime rock	401	787
	9.	Blue clay, with round boulders	188	975
	10.	Dark blue-grey shale	75	1050
Niobrara, 545 feet	11.	Grey shale	25	1075
	12.	Mottled grey calcareous shale	200	1275
	13.	Dark non-calcareous, or but very slightly calcareous shale	135	1410
	14.	Grey calcareous shale	185	1595
Benton	15.	Dark non-calcareous shale	205	1800

In 1892 this hole was deepened to 1943 feet, of which the lower 121 feet were in the Dakota sandstone. In this formation saline water was struck.

Log of bore-hole at Solsgirth[1].

North half of section 30, township 17, range 25 west of 1st principal meridian.
Altitude above sea 1,757.

	Thickness (Feet)	Depth (Feet)
Loam	2	2
Hard blue clay and gravel	42	44
Hard blue clay and stones	10	54
Hard yellow hardpan	12	66
Softer bluish clay	90	156
Blue clay with stones	136	292
Grey clay (shale?)	68	360

Log of bore-hole on Vermilion River.

Township 23, section 22, range 20 west of the principal meridian.
Altitude above sea, 1,300.

			Thickness (Feet)	Depth (Feet)
Pierre-Millwood series	1.	Soft dark grey clay shale	95	95
Niobrara	2.	Fragmental limestone	4	99
	3.	Grey calcareous shale	124	223
Benton	4.	Dark grey fissile shale	178	401
Dakota	5.	Coarse sandstone, with pyrites	19	420
Devonian	6.	Compact white limestone	120	540
	7.	Blue-grey clay shale	10	550
	8.	White gypsum	15	565
	9.	Red shale	110	675
	10.	Shale and limestone	68	743
	11.	Red shale at bottom		

During 1913 prospecting was active a few miles south of Manitou, in the Pembina River valley. While no oil is yet reported, considerable gas was developed. In 1907 oil indications were found in this section and a couple of wells were drilled, each with a showing of gas, but accidents prevented the completion of the wells.

Natural gas strikes have been made at Treherne and Melita. That at Treherne has been used for the past three years for the heating and lighting of a farm house, while the local mill at Melita has been supplied by gas discovered fifteen years ago.

[1]Dawson, G. M.

CHAPTER VII

SASKATCHEWAN

GEOLOGY[1]

Stratigraphy

GENERAL STATEMENT

Information relating to the geology of Saskatchewan is obtainable chiefly from the reports of the Geological Survey of Canada and is contained in reports by Dawson, McConnell, Tyrrell, and others. The results of the work of the geological work in this province have been summarized by Wyatt Malcolm in Memoir No. 29E, of the Survey, already quoted in reference to Manitoba[2]. From this memoir are taken the data used in the following pages in summarizing the stratigraphy and geology of this province. The relations between the sedimentary formations and the Pre-Cambrian crystallines in Saskatchewan are similar to those which prevail in Manitoba. The northern half of the province is underlain by the crystalline and metamorphic rocks, and south of this area the sedimentary formations outcrop in successive bands which dip to the west of south. In the following table of geological divisions, there is summarized the succession, thickness, and character of the different formations which go to make up the geological sections of the province. As is the case in Manitoba the Cambrian is not represented, and strata belonging to the Carboniferous, Triassic, Jurassic, and the earlier part of the Cretaceous do not occur.

[1]By F. G. Clapp.
[2]Oil and gas prospects of the Northwest Provinces.

Table of Geologic Divisions and Formations of Saskatchewan.

System.	*Period.*	*Formation.*	*Thickness. (Feet)*	*Materials.*
Tertiary.....	Pliocene.......		2–50	
	Oligocene......		50–500	
	Laramie.......	Upper.........	750	
		Lower.........	150	
Cretaceous...	Montana......	Bearspaw......	900	
		Belly River....	894	
		Claggett (Millwood).......	250	
	Niobrara......		200–500	Soft grey shales.
	Benton........		175–266	Dark shales.
	Dakota........		200 ?	Soft white to buff sandstone.
Devonian....			500 ?	Heavy buff dolomite.
Silurian.....	Niagara.......		200 ?	Heavy white to spongy and cherty dolomitic limestone.
Ordovician..	Trenton.......	Upper mottled limestone....		Thick yellowish dolomitic limestone.
	Black River....	Winnipeg sandstone........	10–20	Coarse, soft sandstone.
Pre-Cambrian	Keweenawan..	Athabaska sandstone....	400	Coarse white and red sandstone.
	Huronian......			Quartzites, conglomerates, schists, and limestones.
	Laurentian....			Granites and gneisses.

Pre-Cambrian.

Pre-Cambrian crystallines occupy the northern third of the province of Saskatchewan. The rocks are mapped chiefly as Laurentian and undivided Pre-Cambrian and consist of granites and gneisses. There are also a few small known areas in which Lower Huronian or Keewatin rocks occur. These rocks are usually micaceous and chloritic schists or conglomerates, quartzites and limestones.

The territory south of Athabaska lake as far as Cree lake and east as far as Wollaston lake is underlain by the *Athabaska* sandstones, which are mapped as probably Keeweenawan or Animikie, but which may possibly be Cambrian. These sandstones vary in colour from white to dull red and are coarsely granular to conglomeritic in texture. Near the east end of Lake Athabaska they attain a thickness of 400 feet.

Ordovician.

Winnipeg sandstone.—This formation, consisting of light coloured, coarse, friable sandstones outcropping around Lake Winnipeg in Manitoba, extends westward into Saskatchewan, though soon overlapped by the Cretaceous. The thickness is probably about the same as that in the northern part of Manitoba, where it is 10 to 20 feet, thickening greatly to the south.

Trenton group.—The rocks of the Trenton group in Manitoba thin out towards the north so that only the Upper mottled limestone persists as far as the Saskatchewan border and the overlapping edge of the Cretaceous 75 miles west. It consists of thick bedded yellowish-grey dolomitic limestone with the thickness not stated.

Silurian.

Niagara limestone.—In Manitoba, this formation has its greatest development in the northern part of the province in the vicinity of Winnipegosis, Cedar, and Cross lakes. From here it continues westward, fully developed, past Cumberland lake to where it passes beneath the Cretaceous overlap, doubtless extending far to the west and south beneath the overlying formations. In the vicinity of Cumberland House, it consists of thick-bedded white dolomitic limestone—at some places cherty—at others spongy and vesicular. The thickness is estimated at not over 200 feet.

Devonian.

Rocks of Devonian age are widely distributed about Lake Winnipegosis, Dawson bay, and Red Deer lake in Manitoba where they develop the three divisions—Lower Devonian, Winnepegosan, and Manitoban. Toward the west, however, the superficial area occupied by these rocks is more and more restricted by the overlapping Cretaceous formations until in the region southwest of Cumberland lake it is entirely covered by them. In the vicinity of Lake La Ronge, the Devonian is again exposed and probably extends northwest beyond the limits of Saskatchewan to a point west of Lake Athabaska, where it widens out and extends in a broad zone down the valley of the Mackenzie river. From the great development of the Devonian in northern Manitoba, it must exhibit much the same features in Saskatchewan. On the shore of Lake La Ronge, large angular blocks of buff coloured dolomite are so numerous as to indicate strata of the same sort immediately below. The fossils contained belong to about the *Stringocephalus* zone which is Middle Devonian.

Cretaceous.

Dakota sandstone.—The Dakota sandstone is well exposed at several places along the northern portion of the Manitoba escarpment with a thickness up to 200 feet, and extends westward into Saskatchewan. On Carrot river, 4 miles above the Indian Reserve, a soft sandstone containing some carbonaceous material outcrops and is apparently overlain by a hard, purplish sandstone. Though no fossils were found, these rocks are probably

Dakota. East of Lake La Ronge, along the south shore of Wopamekka lake, are bluffs of a white quartz sandstone, containing a lignite bed, and these are probable Dakota. On Beaver river, just above the mouth of Dore river, are 90 foot bluffs of soft white or light yellow sandstone. On the south shore of Ile à la Crosse lake is a light yellow sandstone with thin beds of calcareous ironstone and carbonized plant remains. Both the latter occurrences are probably Dakota.

Benton group.—The Benton shale in Porcupine mountain on the boundary between Saskatchewan and Manitoba has a thickness of about 175 feet. This is a soft, easily eroded, fissile shale soon weathering into soft clay. The formation probably outcrops westward across the whole province of Saskatchewan, and it doubtless extends southward and westward beneath the overlying formations throughout the south half of the province. Wells in this part of Alberta give it a thickness of 266 feet.

Niobrara formation.—Some exposures of the Niobrara have been recognized in Saskatchewan on Carrot river, 40 miles above the Redearth Indian Reserve. A soft grey shale dipping southwest at a low angle is thought to belong to the Niobrara, as also the similar shales of the Pasquia hills. Some of the latter are almost black and rich enough in volatile matter to burn with a bluish flame and a strong odour of petroleum. Typical Niobrara shales outcrop near the south end of Green lake. The formation doubtless extends southward beneath the overlying Cretaceous beds to beyond the United States border, since in the borings at Bow island, Alberta, not far from the southwest corner of Saskatchewan, it has a thickness of 500 feet.

Claggett formation.—This formation does not outcrop so far as known in this province, but it does outcrop in Alberta on Milk river not far from the southwest corner of Saskatchewan, and it doubtless extends northwestward beneath the overlying Cretaceous formation of the plains. It has a thickness of about 250 feet, and consists of dark marine shales very similar to the Benton. Their equivalence to the Millwood formation of Manitoba has been suggested.

Belly River formation.—This formation, which is a continuation of the Judith River beds of Montana, extends northward, in a belt more than a hundred miles wide, into Alberta, and down the valley of the south Saskatchewan river into Manitoba, swinging northward and finally veering back again into Alberta. It must extend far eastward beneath the overlying formations in southern Saskatchewan. It consists of characteristic white cross-bedded sandstone, with yellowish, grey, blue, and greenish shales and clays. Darker sandstones, weathering brown, grey and yellow also occur. The thickness is about 900 feet.

Bearpaw formation.—This formation consists of grey, brownish to nearly black shales with interbedded light grey to yellow soft sandstone. It outcrops in a belt around the area underlain by the Belly River formation in the southwestern part of Saskatchewan and extends eastward across the plains to the Manitoba escarpment, and northwards to an east-west outcrop in central Saskatchewan. The formation is equivalent to the Fox mill sandstone and the upper part of the Pierre shales. Its thickness is about 900 feet in the southwest part of the Province.

Tertiary Laramie group.—The rocks assigned to the Laramie group are a continuation of the Fort Union beds of North Dakota, and are divisible into two divisions. The lower one consists of 150 feet of grey and white clays, sandy clays, and sand with carbonaceous shales and lignites. It is correlated with the Edmonton series of Alberta, and is believed to be Cretaceous in age. The upper division consists of soft silts, clays, and sands, the latter passing into sandstones. It has a maximum thickness of 750 feet. It corresponds to the Paskapoo series of Alberta and is Tertiary in age. The Laramie group occurs in the Cypress hills, in various buttes between the Cypress hills and Wood mountain, in the Coteau, and stretches away eastward from Wood mountain along the United States boundary as far as the east boundary of the province.

Oligocene.—Beds of this age cap the more elevated parts of the upland of the Cypress hills and the Swift Current Creek plateau. They consist of conglomerates with waterworn pebbles of quartzite from the Rocky mountains, and the pebbles are also distributed in lenticular beds and layers in sands and sandstones. They vary in thickness from 50 to 500 feet.

Pliocene.—Gravels of this age, known as the Saskatchewan gravels, are found in pre-glacial depressions in southern Saskatchewan. There is generally a single bed of conglomerate from 2 to 50 feet in thickness composed of quartzite pebbles, with a calcareous or ferruginous cement. They always lie at a lower level than the Oligocene from which they were derived—in great part at least.

Structural Geology.

Cretaceous formations of the plains of Saskatchewan show local irregularities and undulations and in places the dips amount to 20 or 30 degrees. Nothing is known in detail of these folds although they would naturally have an important bearing in any search for oil and gas. A wide low anticline crosses the boundary line of Alberta and Saskatchewan about the 52nd degree of north latitude, in the neighbourhood of the Ear hills and trends northwest into Alberta. The extension of this anticline northwest and southeast brings the Belly River beds to the surface, and is partly responsible for the large area of that formation exposed in southwestern Saskatchewan and southeastern Alberta. As pointed out, the bituminous Dakota sandstone is nearer to the surface in this area than anywhere else in southern Saskatchewan.

OIL AND GAS DEVELOPMENT.

Considerable drilling has been done in Saskatchewan, and at several places small pockets of natural gas have been penetrated, but so far no petroleum has been encountered, and no commercial quantity of gas has been obtained.

PENSE.

The Western Gas and Fuel Company drilling in August, 1912, at Pense, 18 miles west of Regina, struck gas and artesian water at a depth of 1,500 feet. The water itself is a valuable desideratum, as the town had been without adequate water supply for 20 years. The quantity of gas available was not known at the time of writing, but as no later reports are at hand, it is to be presumed that the gas supply was but a limited one. The log of a deep well at Belle Plaine, 8 miles west of Pense, is given on a later page.

ESTEVAN.

In June, 1912, on the Wilson farm, 4 miles northeast of Estevan, gas and water were struck at 450 feet in drilling a well for domestic water supply. The flow of gas is reported to be stronger than in the well in section 1, township 4, range 7, west of the 2nd meridian, and 5 miles north of the Wilson well, from which gas had been burning for half a year. The quantity of gas available in the Wilson well has not been reported. According to reports in the early part of 1913, oil was discovered at Estevan at a depth of 2,000 feet. The discovery was said to be made in a well bored on the property of the Empress hotel in that town, the well being sunk as a water well, which was abandoned at a depth of 1,800 feet on account of a stronger flow of salt water. More recently a considerable flow of gas and indications of oil are said to have been discovered in the well. The Estevan Oil Company, Ltd., was organized for the purpose of further operations.

HANLEY.

On the Andrews farm in section 28, township 50, range 5, west of the 3rd meridian, 10 miles southwest of Hanley and 40 miles due north of Saskatoon, a small quantity of gas burning with a flame about a foot high flows from a well 116 feet deep. No log of this well is available, but it seems likely that the gas is derived from a bed in the glacial drift. The gas has been flowing for 3 years.

SASKATOON.

In May, 1912, a drill hole at Saskatoon had reached a depth of 1,115 feet and the last cuttings were reported to smell strongly of gas and oil. In October, preparations were being made by the Saskatoon Gas and Oil Company to shoot the well, which had then reached a depth of 1,800 feet. No later information is at hand.

NORTH BATTLEFORD.

Drilling was in progress in February, 1913, and near the close of that month had reached a depth of 940 feet. Three small pockets of gas had been struck. The hole was expected to go to 2,000 feet if oil or gas was not found before that depth had been reached.

Oil Shales.

In the Pasquia hills of east central Saskatchewan, there is an occurrence of bituminous shales which may eventually serve as a source of oil and ammonium sulphatum by distillation. The best exposures are found in the valley of Nabi river. The lower part of the section consists of 35 to 40 feet of thick-bedded soft grey bituminous shales and thin-bedded sandstones with fish remains, bivalves, and foramenifera. These are overlain by a half foot of compact, impure limestone with abundant fossil shells. The upper part of the section consists of 120 feet or more of soft, fissile, light grey (almost black when wet) bituminous shales with fish remains and foramenifera. The fossils show these strata to be Cretaceous and probably Niobrara in age.

These shales on ignition leave 70·17 per cent of ash. A sample of this shale taken at random was analyzed by the Mines Branch with the following result:—

Sulphate of ammonia	33·5 pounds per ton.
Crude oil	40·05 imperial gallons per ton.

Well Logs.

The following are all the logs of deep holes drilled in Saskatchewan that are on record:—

Log of bore-hole at Kamsack.

Township 29, range 32, west of 1st meridian.

	Thickness (Feet)	Depth (Feet)
Blue clay	50	50
Shale	721	771
Very hard rock	2	773

It is reported that at 618 feet a coal seam about 8 feet thick was struck.

Log of bore-hole at McLean Station[1].

Canadian Pacific Railway, 24 miles east of Regina.
Altitude 2,248 above sea-level.

	Thickness (Feet)	Depth (Feet)
Black loam	1	1
Yellow clay	25	26
Blue clay	65	91
Gravel and sand	12	103
Blue clay and sand	85	188
Gravel and sand	10	198
Blue clay and gravel	98	296
Sand and gravel	52	348
Boulders	6	354
Blue clay and gravel	96	450
Gravel and sand	35	485
Boulders	5	490
Clay and sand	5	495

Log of bore-hole at Wilcox.

Well 4 miles east of Wilcox, Saskatchewan, on N.E. ¼ sec. 24, tp. 13, range 20, west of 2nd meridian.

	Thickness (Feet)	Depth (Feet)
Clay	45	45
Boulder clay	52	97
Blue shale	213	310
Grey shale	420	730
Black sand	4	734
Grey shale	30	764
Black sand	86	850
Shale	36	886
Sandy shale	5	891
Grey shale	169	1,060
Dark shale	224	1,284
Grey shale	67	1,351
Sand	9	1,360
Shale	25	1,385
Rock and shale alternately	22	1,407
Hard rock	19	1,426
Shale	4	1,430
Hard rock and shale alternately	20	1,450

Log of bore-hole at Belle Plaine.

Station on Canadian Pacific Railway, 18 miles east of Moosejaw.
Altitude 1,877 feet above sea-level.

	Thickness (Feet)	Depth (Feet)
Dark clay loam	3	
Yellow clay	11	
Blue clay	80	
Blue shale	150	
Black shale	75	
Grey shale	125	

[1]Dawson, G. M., Trans. Roy. Soc. Can. vol. IV, 1886, p. 92.

	Thickness (Feet)
Brown limestone	6
Grey shale	444
Reddish sand rock	20
Grey shale	190
Hard white sand rock	2
Grey shale, with thin layers of sand rock	200
Grey, soft shale	175
Black shale	70
Total	1,551

Log of bore-hole at Moosejaw.

Well sunk by the Corporation.

		Thickness (Feet)	Depth (Feet)
Clay	Pierre	5	5
Gravel		14	19
Hard grey clay		396	415
Hard clay, mouse grey		10	425
Hard clay		35	460
Sandy clay		20	480
Hard grey clay		75	555
Sandy clay, grey		45	600
Hard grey clay		177	777
Hard, grey sandy clay		13	790
Hard grey clay		100	890
Grey sand	Probably Belly River	20	910
Sandrock, shale		10	920
Shale and clay		10	930
Sand and hard grey clay		30	960
Sand		8	968
Sand, pepper and salt		42	1,010
Grey sand and clay		10	1,020
Grey clay and shale	Niobrara-Benton	10	1,030
Hard grey clay		30	1,060

Struck water, which is somewhat sulphury, and some gas.

Bore-hole of Keithville.

One mile east of Keithville in S.W. ¼ of N.W. ¼ of sec. 35, tp. 18, range 16, west 3rd meridian.

Owner—Benjamin F. Emerick.

Drilled in 1910.

	Thickness (Feet)	Depth (Feet)
Top soil	10	10
Yellow clay	90	100
Blue clay	56	156
Coarse yellow sand	4	160
Quicksand	20	180
Sand and gravel	13	193
Clay, sand and gravel	10	203
Yellow sand and clay	2	205
Clay	5	210
Sand and clay	25	235
Blue clay	65	300
Yellow sand	13	313
Sand and clay	20	333
Sand	4	337
Blue clay	77	414

Dry Holes.

The following is a tabular list of the deep drill holes of the Province which have yielded neither oil nor gas.

List of Dry Holes in Saskatchewan.

WELL.	Depth.	Year Drilled.	Owner.	Notes.
Fort Pelly	501	1874–5	Dominion Gov't..	At 259 feet, a 9-foot calcareous stratum.
Kamsack.........	773	....	....	See log.
Yorkton.........	1,000	....	Drilled by city...	....
Edwin, Sec. 13, Tp. 15, R 19 W 2nd Mer...........	2,410	1909–10	Abray and Patterson.	Grey shale from top to bottom.
Wilcox..........	1,450	....	....	See log.
Belle Plaine......	1,551	....	....	See log.
Moosejaw........	1,060	....	Drilled by city....	See log.
Keithville........	414	1910	B. F. Emerick....	See log.
Maple Creek, Sec. 15, Tp. 11, R 26 W 3rd Mer.....	1,860	1909	Maple Creek Gas, Oil and Coal Co., Ltd.	Coal at 196 feet and 7 foot seam at 292 feet. Gas at 1,121 feet and at two other points between 1,120 and 1,500 feet.
Langham, Tp. 39, R7, W 3rd Mer.	1,358	1905	Mackenzie, Mann and Co.	In soft shale from top to bottom. Salt water at 1,340 feet

CHAPTER VIII

YUKON AND NORTHWEST TERRITORIES

GEOLOGY[1]

Stratigraphy

Under the above caption is included Yukon and all the unorganized territory in Canada north and west of Hudson bay, including the Arctic islands, and north of the boundaries of the western provinces. Our present knowledge of this vast area is very meagre, but the geological horizons are known to range from the Archæan to the Tertiary, the whole area being also more or less covered with Quaternary deposits.

Archæan.—The greater portion of the area west of Hudson bay as far as a line drawn between the west end of Lake Athabaska, the middle of Great Slave lake, and the eastern third of Great Bear lake is underlain by Archæan, including probably some undivided Pre-Cambrian; the northern boundary is approximately the Arctic ocean. To the south these crystalline rocks pass beneath the Palæozoic strata of Manitoba, or are united with the Laurentian areas of Ontario. Archæan rocks also occur on Baffin island and on some of the adjacent islands.

Within the limits of this territory are a number of small areas of Keewatin and Lower Huronian rocks consisting of metamorphosed sediments and volcanics. There are also several areas of later Pre-Cambrian, probably Keweenawan or Animikie. An area of considerable size lies along the Thelon river to Aberdeen and Schultz lakes, and south of this, also occupying a strip of territory between Baker and Dubawnt lakes. Small areas occur around the east end of Great Slave lake and near Beechey lake on Backs river. A still larger area, that promises to become of commercial importance because of its copper deposits, occurs in the territory between Great Bear

[1]By Alfred W. G. Wilson.

lake and Coronation gulf, and about Bathurst inlet. The rocks are chiefly sandstones and lava flows.

Pre-Cambrian gneisses and schists also occur along the southern side of Baffin island.

Palæozoic deposits.—Palæozoic deposits are found on many of the Arctic islands from Baffin island west to Victoria island. They also occur on the southern side of Southampton island, and on Coats and Mansel islands at the north of Hudson bay, and near Franklin bay on the Arctic coast.

A large area of Palæozoic strata occupies the western part of the Northwest Territories and Yukon. A portion of this has been definitely assigned to the Devonian, the balance is mapped as unclassified, chiefly Palæozoic, and constitutes the northern extension of the Rocky Mountain belt.

Silurian.—Silurian strata have been recognized on Baffin and Southampton islands, and in the basin of the Mackenzie river.

Devonian.—Small areas of Devonian strata are reported from Devon, Ellesmere, and other smaller Arctic islands.

Devonian rocks outcrop along the Mackenzie river from Lake Athabaska to within about 200 miles of the Arctic ocean, and also underlie a broad strip of territory on either side of the river. A narrow band of Devonian strata extends southeast from Lake Athabaska to Lake La Ronge, bordering the main Laurentian areas to the east.

McConnell describes the Devonian of the Mackenzie basin as follows[1]:—

Throughout the Mackenzie district the Devonian is generally divisible lithologically into an upper and lower limestone, separated by a varying thickness of shales and shaly limestones, but in some cases limestones occur throughout. The upper division has an approximate thickness of 300 feet and consists of a compact yellowish weathering limestone occasionally almost wholly composed of corals, interstratified with some dolomitic beds. This limestone is well exposed at the falls on Hay river and also at the Ramparts on the Mackenzie. In both of these places it is underlain by several hundred feet of greenish and bluish shales alternating with thin limestone beds. At the Grand View on the Mackenzie the shales are hard and fissile, and are blackened and in places saturated with petroleum. At the Rock by the River Side, and at other places where the beds are tilted and older rocks exposed, the middle

[1]R. G. McConnell, Yukon and Mackenzie Basins, Report Geol. Survey, Vol. IV, Part D, p. 15, 1888-89.

division is underlain by 2,000 feet or more of greyish limestones and dolomites interbedded occasionally with some quartzites. No fossils were collected from the lower part of this series, and rocks older than the Devonian may possibly be represented in it.

Carboniferous.—Carboniferous rocks have been reported from Melville, Prince Patric, Banks, and some smaller Arctic islands. Low[1] states that:—

The southern boundary of the Carboniferous sandstones, with their included coal seams, crosses the southern part of Banks island in a north-northeast direction, and they consequently cover the northern two-thirds of that island, while the extreme northwest portion of Victoria island is also occupied by these rocks. The western Parry islands on the north side of Melville sound are almost wholly formed of these rocks, whose southern boundary strikes northeast across the northern half of Cornwallis island. They are found again in Grinnell peninsula, the northwest portion of North Devon, and again on the western side of Ellesmere, in the vicinity of Store Bjornekap, being probably largely developed in the northeast part of that great island.

The rocks consist of close-grained sandstones, containing numerous beds of highly bituminous coal and but few marine fossils, and limestones, more or less fossiliferous.

Carboniferous strata have been noted in Yukon but the boundaries have not been determined. McConnell mentions the discovery of Carboniferous fossils in the Kluane district. He describes the associated rocks as bands of limestone, green schists, and dark slaty rocks, passing in places into a hard cherty variety[2].

Mesozoic.—Rocks of this age occur in Yukon chiefly north of the Arctic circle, though some small areas of Cretaceous strata have been mapped between Atlin lake and the Lewis river, and one on the Pelly river. A large area of Mesozoic strata occupies the basin of the Peel river and extends to the mouth of the Mackenzie river. A considerable area is found along the Arctic coast east of the Mackenzie delta as far as Franklin bay, and two smaller areas occur in the basin of the Mackenzie above Fort Good Hope and south of Fort Norman. The north and west shores of Great Bear lake are also bordered by strata of this age. In the southwest corner of the Northwest Territory in the vicin-

[1]A. P. Low, Cruise of the Nepture, p. 222.
[2]R. G. McConnell, Geol. Surv. Summary Report, 1904, p. 6.

ity of Fort Liard we find the northern extension of the great Mesozoic area of northern Alberta. Mesozoic rocks also occur in the Arctic basin, outcropping on the Sverdrup islands. Low maps these as mostly Triassic and states that they consist largely of sandstones with shales, schists and limestones. They also occur on the northern shores of the Parry islands; at Point Wilkie in Prince Patric island; Rendezvous hill, near the northwestern extreme of Bathurst island, and at Exmouth island and places in the vicinity, near the northwest part of North Devon[1].

McConnell describes the Cretaceous along the Liard river as follows[2]:—

Fossiliferous Cretaceous beds were not recognized in descending the Liard until the Plateau belt which borders the eastern foothills was reached. Below Fort Halkett, west of the mountains, a band of soft dark shales crosses the river, which may be in part Cretaceous, but no fossils were found in it. The eastern foothills are built of a great series of alternating shales and sandstones, with some limestones, all folded closely together, which resemble those found in the foothills farther south, and, like them, probably consist largely of Cretaceous rocks, but it was found impossible on a hasty trip along one line to separate these from the Triassic, or from the shales which cap the Palæozoic system, owing to the lithological similarity which prevails throughout. East of the foothills the convolutions gradually cease and the section becomes more legible. The beds here consist of soft, finely laminated shales, interstratified with a few beds of sandstone and ironstone. They have a minimum thickness of 1,500 feet. The shales yielded some fossils among which were several specimens of *Placenticeras Perezianum*, one of the characteristic fossils of series C of the Queen Charlotte islands. With this were species of *Camptonectes* and *Inocerami*. Near the eastern edge of the plateau belt the shales are overlain by massive beds of rather soft sandstones and conglomerates, the thickness of which was not ascertained. The conglomerates are affected by a gentle easterly dip, and descend to the level of the river in the course of a few miles. From the point at which they disappear to the eastern edge of the Cretaceous basin, the rocks consist of dark fissile shales, crumbly sandy shales and sandstones, but the exposures along the valley are infrequent, and the succession soon becomes obscure.

The Cretaceous section along the Liard thus shows two great shale and sandstone series separated by a heavy band of sandstones and conglomerates. The lower shales, from the imperfect fossil evidence at hand, and also from their lithological character, may be referred tentatively to the horizon of the Queen Charlotte islands or Kootanie formation, the upper shales to that of the Benton, while the intervening conglomeritic band probably represents the Dakota. The lithological succession of the Cretaceous

[1]A. P. Low, The Cruise of the Neptune, 1906, p. 226.
[2]R. G. McConnell, An Exploration in the Yukon and Mackenzie Basins, N.W.T., Geol. Survey Report, New Series, Vol. IV, part D, pp. 19-20.

beds here is almost identical with that which obtains in other parts of the Cordilleran belt north of the International Boundary and on the Queen Charlotte islands, and shows that similar conditions of deposition prevailed at the same time over this whole area.

The Cretaceous rocks cross the Liard with a width of over a hundred miles, and north of the river enter a bay in the mountains, the extent of which to the northwestward is not known; southwards they are connected with the great Cretaceous basin of the plains.

Cretaceous rocks on the lower Mackenzie were first encountered by McConnell near the Dahadinni river in latitude 64°N. They consisted of about 200 feet of dark grey shales and sandstones. They continue along the river for 10 or 12 miles and then disappear beneath boulder clay, but probably continue under this as far as the Tertiary basin at the mouth of the Bear river, a distance of 50 miles. Here the Cretaceous beds occupy a depression between two high ranges of limestone mountains and cannot have a greater width than 10 or 15 miles. They are separated from the Cretaceous beds on the western shores of Great Bear lake by the Mount Clark range. The Cretaceous beds again reappear on the banks of the Mackenzie 40 miles below Bear river, and underlie the valley all the way to the Ramparts a distance of 90 miles, with the exception of one break of a couple of miles where they have been removed by denudation.[1]

A third Cretaceous area occurs on the Mackenzie 120 miles below the Ramparts. This is the largest on the river and extends from a short distance below old Fort Good Hope to the head of the Mackenzie delta, and westwards across the Rocky mountains and down the Porcupine river to about longitude 139°W. The rocks on the Mackenzie are coarse shales interstratified with some sandstones and fine grained conglomerates. In the mountains several thousand feet of barren sandstones and quartzites underlain by dark shales constitute the formation. On the Porcupine the same two series, sandstones and quartzites, occur underlain by a great thickness of alternating shales, sandstones and conglomerates. The intermediate dark shales are regarded by McConnell as probably of Benton age, while the lower division so far as fossil evidence goes is regarded as representing the Queen Charlotte Island formation and the Dakota[1].

[1]R. G. McConnell, An Exploration in the Yukon and Mackenzie Basins, N.W.T., Geol. Survey Report, New Series, vol. IV., part D, p. 21.

Cretaceous shales, passing upwards into fine grained conglomerates, occur on the Yukon for many miles above and below the mouth of the Tatonduc. They have been greatly disturbed and are folded up in broad bands with the underlying Palæozoic[1].

Tertiary.—Small areas of Tertiary strata occur on some of the Arctic islands. The deposits consist of slaty clays, shales and sandstones with which are associated lignites and some soft coals[2].

Small areas of Tertiary strata are also shown on the geological map occurring in Yukon about the Frances river which joins the Dease river at Lower Post; north of the Yukon river west of Dawson; and along the upper Porcupine river. A small area is also developed in the basin of the Mackenzie at Fort Norman.

McConnell states that the Tertiary beds in the Mackenzie valley and about Bear river:—

> Occupy a basin of about thirty to forty miles in length and twenty to thirty in breadth. They rest unconformably upon Cretaceous shales and Devonian limestones. They are lacustral in origin and consist largely of discordantly bedded sand, sandy clays, clays and gravels. Beds of purely argillaceous material usually somewhat plastic in character are also present, and seams of lignite and carbonaceous shales not infrequently constitute a considerable portion of the section. The beds on the Porcupine river are somewhat similar. They extend along the river for about 42 miles and consist essentially of light coloured sands, sandy clays, clays and conglomerates, with occasional nodular beds of ironstone, and in one section held a small lignite seam. No fossils of any kind were obtained from them. They are horizontal, or nearly so, and have a minimum thickness of 300 feet[3].

Quaternary.—Quaternary deposits occur in the basin of the Mackenzie often in sufficient quantity to completely cover the underlying formations. They also occupy the delta of the Mackenzie river and probably of the Anderson river, and occur widely distributed in the basin of the Yukon and its tributaries. There are numerous smaller areas of less importance underlain by sands, gravels, clays, and tills, widely distributed over northern Canada.

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[1]R. G. McConnell, An Exploration in the Yukon and Mackenzie Basins, N.W.T., Geol. Surv. Report, New Series, vol IV., part D., p. 21.

[2]Refer to Low, Voyage of the Neptune, pp. 226-229.

[3]R. G. McConnell, *op. cit.*, pp. 22-23 and pp. 99-100.

Geologic Structure[1]

In the Mackenzie valley, according to McConnell[2]:—

The beds, (speaking especially of the Devonian) are practically undisturbed and are seldom affected by dips exceeding a few feet to the mile.

But he states further in this connexion that,—

For some miles above Bear river the Devonian, which forms the top of the Palæozoic system in the district, is overlain unconformably by the Cretaceous, and Cretaceous anticlines of limited extent recur at intervals all the way to the Upper Ramparts.

OCCURRENCE OF OIL[3]

According to McConnell[4]:—

The Devonian rocks throughout the Mackenzie valley are nearly everywhere more or less petroliferous, and over large areas afford promising indications of the presence of oil in workable quantities. The rock is in several places around the western arm of Great Slave lake highly charged with bituminous matter and on the north shore tar exudes from the surface and forms springs and pools at several points.

McConnell[5] says further:—

That the springs are situated a couple of hundred yards from the shore, at the base of a low limestone cliff, which runs inland from the lake, and are three in number, each of them being surrounded with a small basin, three to four feet in diameter, filled with inspissated bitumen, while the soil and moss for some distance away is impregnated with the same material. A small quantity of pitch is annually taken from these springs and used for boat building purposes, while a much larger supply could be obtained if needed. A sulphur spring resembling those at Sulphur point on the south shore of the lake, but much more copious, issues from the foot of the cliff in close proximity to the bituminous springs, and feeds a considerable stream.

The rock through which the petroleum ascends here is a heavily bedded greyish, rather coarsely crystalline cavernous dolomite, and is entirely unlike the bituminous beds south of the lake and down the Mackenzie, which in most cases consist of calcareous shales. The dolomite is everywhere permeated with bituminous matter, which collects in the numerous cavities, and oozing up through cracks, often forms small pools on the surface of the rock.

The age of the bituminous beds here could not be clearly ascertained as they are entirely unfossiliferous, but it is altogether likely that they are older than the Devonian shales and limestone which outcrop along the southern

[1]Written by F. G. Clapp.
[2]R. G. McConnell, Ann. Rept. Geol. Surv., Canada, vol. IV, part D, p.15, 1888-89.
[3]Written by F. G. Clapp.
[4]R. G. McConnell, *loc. cit.* p. 31.
[5]R. G. McConnell, *loc. cit.* pp. 75-76.

shore, and are more nearly related to the dolomites which underlie the fossiliferous Devonian beds at the Nahanni river, and other places. The presence of bitumen in such abundance here also suggests an anticlinal which would bring up lower beds.

Sulphur and tar springs are reported to occur at a point about half way between this and Fort Rae, but as I did not hear of them until I had left the lake, I was unable to visit them. A tar spring is also known to exist under the surface of the water in the deep bay immediately east of the Big Island fishery, as many of the boulders and rocks along the shore in this neighbourhood are coated with bitumen which has been washed ashore, and hummocks of ice stained with the same material are often observed. On the south shore bituminous shales and limestones outcrop at several points, and it would thus appear that the oil-bearing beds underlie the whole western part of the lake.

McConnell says there are also several tar springs near Fort Good Hope, and still farther down in the vicinity of old Fort Good Hope, the river is bordered for several miles by evenly bedded dark shales of Devonian age which are completely saturated with oil. These shales are in places so highly charged with bituminous matter that, according to McConnell, combustion has taken place. At one place along the Mackenzie (15 miles below Grand View) McConnell describes reddened shales, which he states are undoubtedly due to the burning of the bitumen.

Fifteen miles farther down, according to McConnell:—

The Devonian shales are again found. The shales are black in colour, evenly bedded, and highly bituminous. The laminæ, when freshly separated, are moistened on the surface with an oily liquid, and burn when thrown into the fire, and patches of red shales, marking the sites of former fires, alternate with the dark varieties. The shales are exposed in the right bank for some miles, or almost as far as old Fort Good Hope. They dip down the river at a low angle, and are overlain by the Saskatchewan gravels and boulder-clay.

Recently, August, 1912, according to a report published in the "Bulletin" of Edmonton, Alberta, samples of oil have been brought from the Mackenzie about 25 miles below Fort Norman where it seeps from the bed of the river, at low water, and in winter rises through the ice. According to the report, this oil is reddish-black in colour and flows as freely as engine oil, and burns freely, with a strong petroleum smell.

Possible Oil Fields.

From the data at hand, the most promising region in the Northwest Territories for the development of a producing oil field appears to be along the Mackenzie although the evidence is by no means conclusive. The presence of great quantities of oil bearing beds with a formation unconformably overlapping it suggests favourable conditions for the accumulation of oil into pools. In the Coalinga district, California, according to Arnold and Anderson[1] the productiveness of some of the Miocene sediments is greatest where the overlying formation "occupies a position of angular unconformity with the Miocene sands."

At some time in the future, it may be found profitable to open up an oil shale industry on the Mackenzie similar to the oil shale industry of Scotland at the present time.

[1]Arnold, Ralph, and Anderson, Robert, Geology and Oil Resources of the Coalinga district, Cal., U.S. Geol. Surv., Bull. 398, p. 186, 1910.

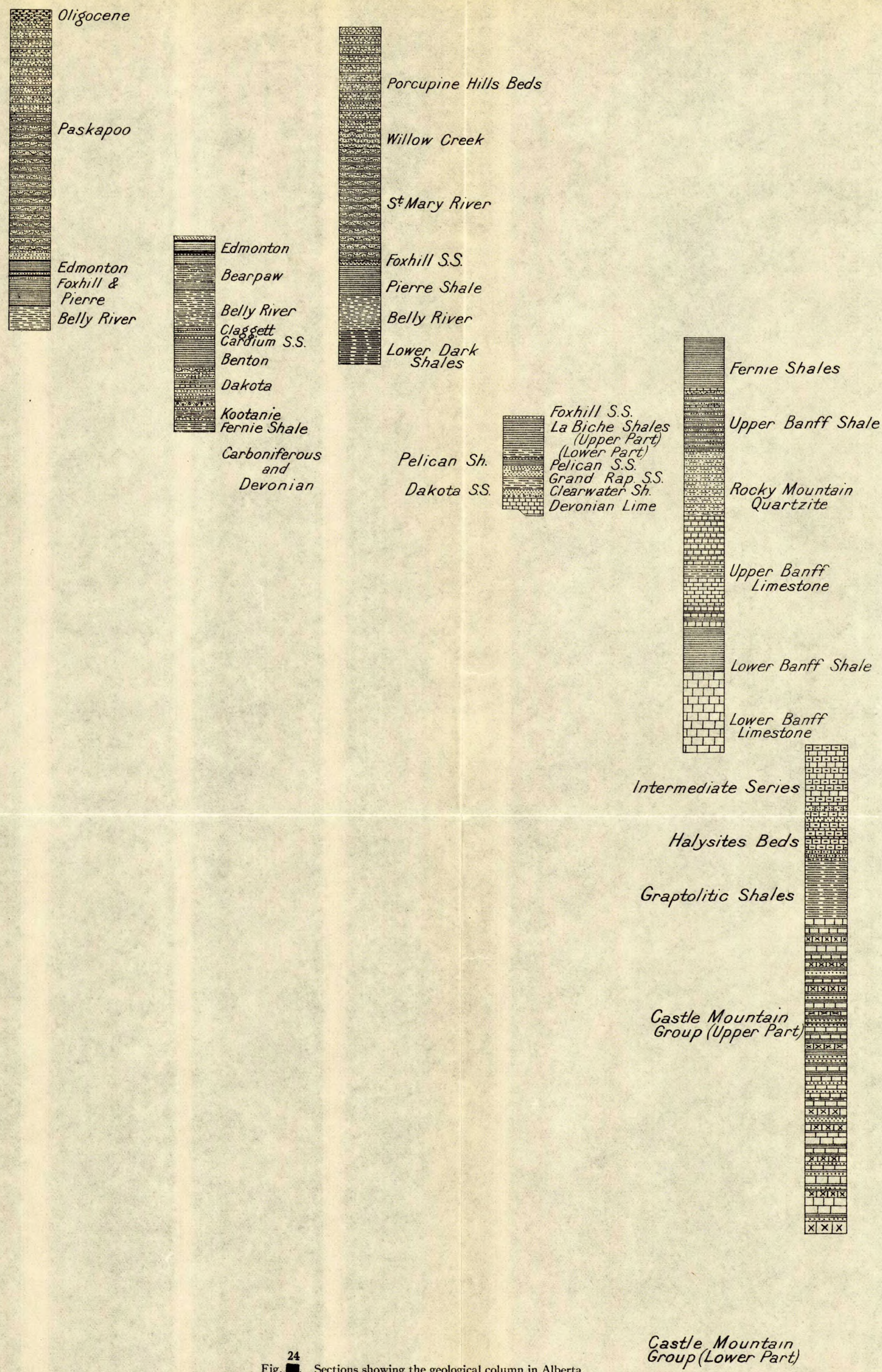

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Fig. [redacted]. Sections showing the geological column in Alberta.
(By F. G. Clapp and L. G. Huntley)

Comparative Table of Formations in Western Canada.

	Group	Alberta	Saskatchewan	Manitoba	Montana	Dakota	Kind of Rocks	Character of Fossils
Tertiary	Oligocene Eocene	Oligocene Paskapoo	Oligocene		Fort Union	Fort Union	Conglomerates and sandy clays	Land and freshwater
			Laramie	Laramie	Lance	Lance		
Cretaceous	Montana	Edmonton Bearpaw Belly River Claggett Eagle	Bearpaw Belly River	Odanah Millwood	Lennep Bearpaw Judith R. Claggett Eagle		Sandstones and clays Sandstones and clays Sandstones Shales Sandstones	Freshwater Land plants. Brackish and marine Brackish and fresh Marine Marine
	Colorado	Niobrara Cardium Benton		Niobrara Benton	Niobrara Benton	Niobrara {Carlile Greenhorn Graneros}	Calcareous shales Shales	Marine Marine
	Dakota	Dakota		Dakota	Dakota	Dakota	Sandstones	Freshwater, land plants.
	Kootanie	Kootanie			{Kootanie Morrison}	Fuson Minnewaste Dakota Morrison	Sandstones and shales	Land plants, brackish and fresh water
Jurassic		Fernie			Ellis	Unkpapa Sundance	Shales and sandstones	Marine
Triassic						Spearfish		
		Upper Banff shale						
Carboniferous	Permo-Carboniferous Pennsylvanian Mississippian	Upper Banff limestone Lower Banff shale			Quadrant Madison	{Minnekahta Opeche Minnelusa} Pahasapa Englewood	Sandstones and shales Limestones	Land plants Marine
		Lower Banff limestone						
Devonian	Upper Middle Lower	Intermediate series	Winnipegosan	Manitoban Winnipegosan Lower Devonian	Threeforks Jefferson		Limestones	Marine
Silurian		Halysites beds	Niagara	Niagara	Maywood		Limestones	Marine
Ordovician	Utica (?) Trenton Black River (?)	Graptolitic shales	Winnipeg sandstone	Stony Mountain Upper mottled limestone Winnipeg sandstone	Upper mottled limestone Cathead limestone Lower mottled limestone	Whitewood	Limestones, shales and sandstone	Marine
		Castle Mountain						
Cambrian	Upper Middle Lower				{Barker Flathead}	Deadwood	Shales, sandstones and limestones	Marine
		Bow River						

CHAPTER IX

ALBERTA

GEOLOGY[1]

Stratigraphy

From Lake Athabaska south to the International Boundary all Alberta is underlain by sedimentary beds of Cretaceous age, which rest unconformably upon the Devonian limestone beds that outcrop in northern and eastern Alberta, and are underlain by intervening Carboniferous rocks along the west side of the province, adjacent to the Rocky mountains. These Devonian limestone beds are in turn underlain by sands and shales probably of Cambrian age. The latter vary in thickness because of the uneven character of the crystalline floor upon which they were deposited.

The entire body of sedimentary rocks thickens westward toward the Rockies where almost the entire geological series is represented in the exposed sections. All these beds thin out to the north and east, and the Carboniferous rocks disappear entirely at some point between their exposures in the vicinity of the Rocky mountains and the outcrops of the lower formations in Manitoba and at Lake Athabaska. Towards the southeast the nearest exposures of Carboniferous strata are found in the Black hills of the Dakotas; where they have a thickness much less than in the Canadian Rockies. It is impossible to conjecture whether or not these Carboniferous rocks are continuous between the localities named.

Geological columns, as observed by different Canadian geologists, at various localities in Alberta, are indicated on pp. 266—270. The same columns are shown graphically in Fig. 24. In the folder table facing p. 265, the correlations

[1]By F. G. Clapp, with additions by Alfred W. G. Wilson.

between the formations in Alberta and those in the other districts in Canada and in the United States are indicated[1].

SOUTHERN ALBERTA (DAWSON).

System.	*Formation.*	*Approximate thickness in feet.*
	Porcupine Hill beds	2500
Laramie	Willow creek	450
	St. Mary river	2800
	Foxhill sandstones	80
Cretaceous	Pierre shales	750
	Belly River series	910
	Lower dark shales	800

CENTRAL ALBERTA (TYRRELL).

System.	*Formation.*	*Approximate thickness in feet.*
Oligocene		270
Laramie	Paskapoo	5700
	Edmonton	
Montana	Foxhill and Pierre	600
	Belly River	600+

ATHABASKA RIVER (McCONNELL).

System.	*Formation.*	*Approximate thickness in feet.*
Laramie		
Montana	Foxhill sandstone	
	LaBiche shales[2] (upper part)	700
Colorado	LaBiche shales (lower part)	225
	Pelican sandstone	40
	Pelican shales	90
	Grand Rapids sandstone	300
	Clearwater shales	275
Dakota	Tar sands	140–220
Devonian		

[1]Dowling, Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, p. 20. See also Geological Notes to Accompany Map of Sheep River Gas and Oil Fields, Alberta.

[2]See Log No. 1.

PEACE RIVER (MCCONNELL).

System.	Formation.	Approximate thickness in feet.
Laramie	Wapiti River sandstone	
Montana	Foxhill sandstone	
	Smoky River shales	
	Dunvegan sandstone	600+
	Fort St. John shales	700
Colorado	Peace River sandstones	400
	Loon River shales	400
Devonian		

YELLOWHEAD PASS (MCEVOY).

System.	Formation.
Laramie	Paskapoo (49)
	Edmonton (49)
Cretaceous	Pierre and Foxhill (42)
Devono-Carboniferous	
Cambrian	Castle Mountain group (14)
	Bow River series (13)
Pre-Cambrian	Shuswap

CASCADE COAL BASIN (DOWLING).

System.	Formation.	Approximate thickness in feet.
Cretaceous		
Jurassic	Fernie shales (28)	1600
Permo-Triassic	Upper Banff shale (25)	1200–1300
	Rocky Mountain quartzite (25)	1600
Carboniferous	Upper Banff limestone (25)	2500–3000
	Lower Banff shale (25)	1000–1500
	Lower Banff limestone (25)	2000
Devonian	Intermediate series (21)	

ROCKY MOUNTAINS ALONG MAIN LINE OF CANADIAN PACIFIC RAILWAY. (MCCONNELL).

System.	*Formation.*	*Approximate thickness in feet.*
Cretaceous	Kootanie to Benton	
Carboniferous passing into Devonian	Upper Banff shale (25)	
	Upper Banff limestone (25)	
	Lower Banff shale (25)	
	Lower Banff limestone (25)	
Devonian	Intermediate series (21)	1500
Silurian	Halysites beds (20)	1300
Ordovician	Graptolitic shales (16)	1500
	Castle Mountain group (upper part) (14).	
		7700+
Cambrian	Castle Mountain group (lower part) (14)	
	Bow River group (13)	10,000

ALBERTA PORTION OF CORDILLERAN SECTION (C.P.R. MAIN LINE. DALY).

System.	*Formation.*	*Approximate thickness in feet.*	*Materials.*
Recent and Pleistocene	Fluviatile		Gravel, sand.
	Lacustrine		Gravel, sand, clay, silt and conglomerate.
	Glacial		Till.
	Erosion surface.		
Post-Cretaceous?	Igneous rock		Nephelite syenite, ijolite, urite, jacupirangite, etc., with dikes.
Cretaceous	Upper Ribboned sandstone	550+	Thin-bedded sandstone and shale with hard bands of sandstone.
	Kootenay Coal measures	2800+	Sandstone and shale with coal seams.
	Lower Ribboned sandstone	1000+	Thin-bedded brown sandstone and shale.

System.	Formation.	Approximate thickness in feet.	Materials.
Jurassic	Fernie shale	1500+	Dark brown to black arenaceous shale; weathers into lens-like fragments.
Permian	Upper Banff shale	1400+	Dark brown arenaceous shale; weathering reddish and yellowish.
	Rocky Mountain quartzite	800	White to grey quartzite and arenaceous siliceous limestone.
Mississippian	Upper Banff limestone	2300+	Thick-bedded dark grey limestones with numerous thin cherty layers underlain by thin-bedded limestone and shale; weathering grey.
Pennsylvanian	Lower Banff shale	1200	Black to dark grey shale, argillaceous and calcareous; weathering light brown.
	Lower Banff limestone	1500+	Thick-bedded grey limestones with numerous dolomitic segrations.
Devonian	Intermediate limestone	1,800+	Thin-bedded limestones, with alternating more massive layers of grey dolomitic and siliceous limestone.
	Sawback limestone (age?)	3,700+	Thin-bedded limestone interbedded with less resistant layers and brownish and yellowish shale.
	Contact relations not known.		
Silurian	Halysites beds	1,850+	Dolomites and quartzites weathering light grey to white, with shale interbedded.

MOOSE MOUNTAIN DISTRICT (CAIRNES).

System.		*Formation.*	*Approximate thickness in feet.*
Cretaceous	Montana	Edmonton (49)	
		Bearpaw (42)	650
		Belly River (40)	850
		Claggett (39)	250
	Colorado	Cardium sandstone (38)	50
		Benton (37)	725
	Dakota (33)		950
	Kootanie (33)		375
Jurassic	Fernie shales (28)		225
Carboniferous and Devonian.			

ALBERTA AREAS (CROW'S NEST SECTION BY LEACH).

System.	*Formation.*	*Approximate thickness in feet.*	*Materials.*
Cretaceous	Allison Creek (Belly River ?)	1,900	Soft, light-coloured sandstones, with small coal seams near top.
	Benton	2,750	Chiefly dark shales with a few hard, siliceous sandstone beds.
	Crowsnest Volcanics	1,150	Trachytic tuffs and breccias.
	Dakota	2,750	Chiefly shaly sandstone with plant impressions, usually green in colour.
	Kootenay	600	Sandstones, shales and coal seams.
Jurassic	Fernie	750	Dark shales with a few thin sandstone beds.
Devono-Carboniferous	Limestone Series	4,000	Massive light-grey limestone.

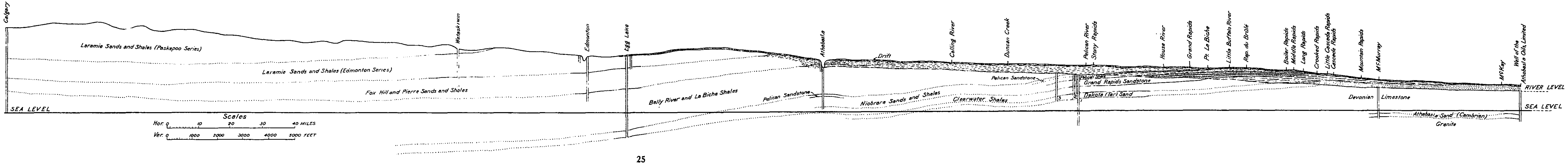

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Fig. [redacted]. Generalized geological section from Grand Rapids to Calgary, showing the "lay" of the strata and also wells drilled at Pelican, Athabaska, Morinville, Edmonton, Wetaskiwin, and Calgary. (By F. G. Clapp and L. G. Huntley)

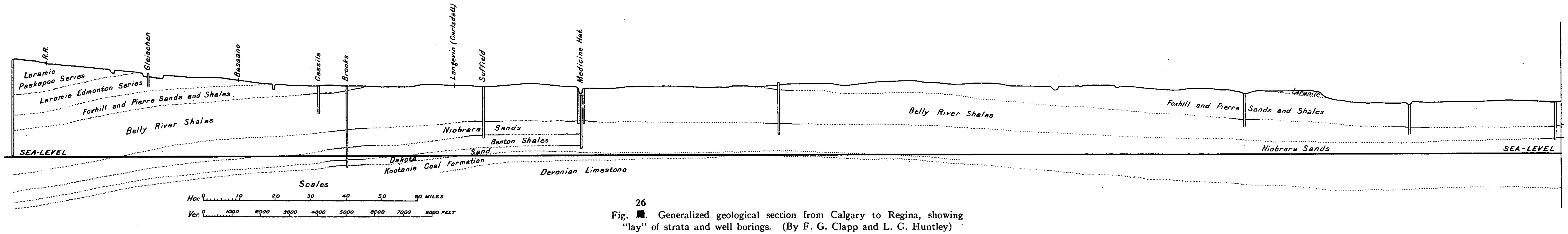
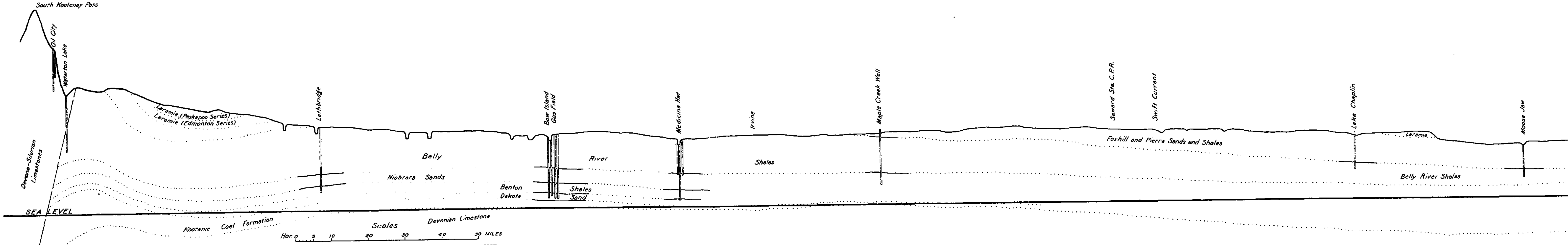


Fig. [illegible]. Generalized geological section from Calgary to Regina, showing "lay" of strata and well borings. (By F. G. Clapp and L. G. Huntley)



27

Fig. [illegible]. Generalized geological section from South Kootenay pass to Regina, showing "lay" of strata and well borings. (By F. G. Clapp and L. G. Huntley)

The great tar seepages of the Athabaska river in northern Alberta exude from the outcrop of the Dakota sandstone, from which sandstone the gas in the Bow island is also derived. However, gas has been found in the sands of the Niobrara formation underlying Medicine Hat, Dunmore Junction, Suffield, and Vegreville; and from the nature and persistence of the sands of this series, it is believed that they will prove of importance in the results of future drilling, as has the Dakota sand heretofore. No gas supply of importance has been developed in the strata lying above the Niobrara beds, although the overlying shales very generally contain pockets of gas, which soon exhaust themselves when struck by the drill. This is particularly true of the gas in the Belly River shales, in which gas is found in Medicine Hat, Suffield, Carlstadt, Topfield, Bruce and elsewhere.

While a few oil seepages are known to exude from older rocks than the Cretaceous in the vicinity of South Kootenay pass, yet the sands of the Cretaceous formations are the only strata in which presumably oil and gas will be developed in large quantities in Alberta.

Structural Geology.

Throughout the entire extent of Alberta, with the exception of a narrow belt bordering the Rocky mountains in the western part of the province, the formations lie in a nearly horizontal attitude. However, as shown in Figs. 25, 26, and 27, a broad syncline or depression occurs just east of the disturbed belt. The axis of this basin is followed in a general way by the Macleod and Edmonton branches of the Canadian Pacific railway. East of this great basin there is evidence of three widely diffused anticlines. The first of these crosses the International Boundary in the vicinity of the Sweet Grass hills in Montana, extending in a northwesterly direction, but probably dying out after reaching the Bow river (Fig. 27). The axis of this anticline will probably be found west of the Bow Island gas field.

The second of these wide arches enters Alberta from Saskatchewan in the vicinity of the fifty-second parallel, and extends in a northwesterly direction almost to Vegreville (Fig. 26). The gas possibilities of this anticline have never been tested by drilling.

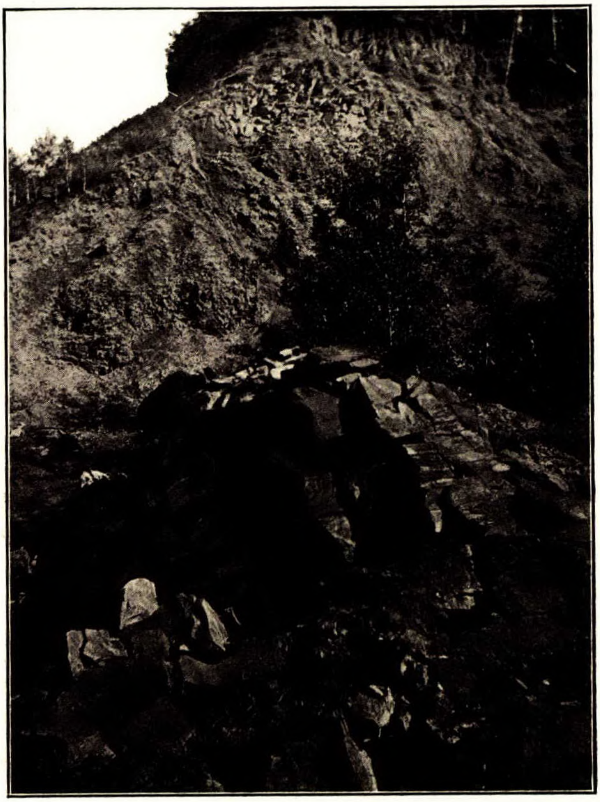
The third of these structural arches has been found to cross the Athabaska river in the vicinity of Crooked rapid (Fig. 26). However, owing to the impossibility of obtaining geological data on this northern region, it has not been possible to trace this anticline definitely for a great distance, it being known merely to extend in a northwesterly by southeasterly direction, more or less parallel with the two similar arches to the south.

Of the three structural arches mentioned above, only that of the Bow river and that of the Athabaska river have been tested as to their natural gas possibilities. A large supply of gas has been developed at Bow island in southern Alberta, near the crest of the first mentioned anticline. A smaller supply has been encountered in the vicinity of the Pelican rapids, some miles south of the axis of the Athabaska River anticline. (See Fig. 28.) A well drilled at Vegreville at the extreme limit of the Battle River anticline in central Alberta has given evidence of being located upon the edge of good gas territory.

Owing to the great depth at which the principal oil and gas bearing sands lie in western Alberta, the oil possibilities of this great structural depression have not been tested at all thoroughly, all wells having as yet failed to reach the principal oil and gas bearing horizons; viz., the Niobrara and Dakota sands.

Wells have been drilled in the disturbed belt lying within the foothills of the Rockies at several places, notably at Waterton lake and at the MacDougal ranch west of Okotoks. However, owing to the greatly disturbed and faulted nature of the formations at these points, it is not presumed that the relatively small showings of both oil and gas which were encountered in these wells offer sufficient indication for the development of a larger supply.

PLATE XIII.



Foreground—blocks of red burnt shale from outcrop of La Biche shale at Red Mud, Athabaska river, Alberta.

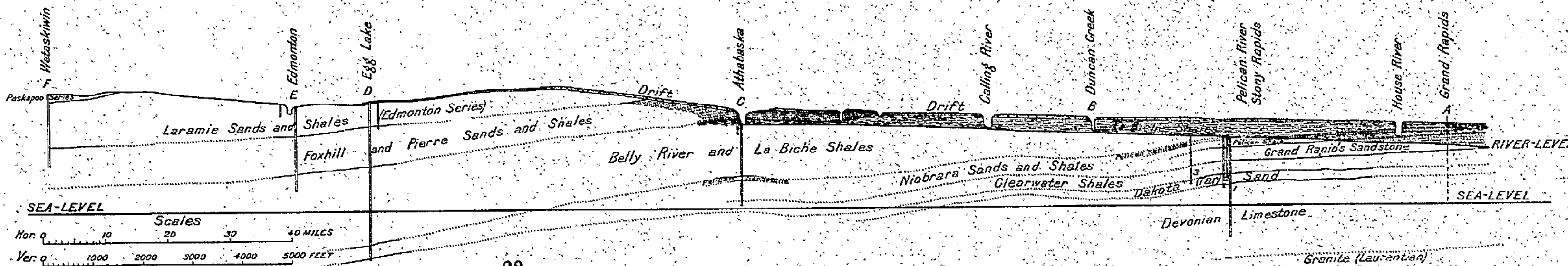


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Fig. [redacted]. Generalized geological section, from Grand Rapids to Wetaskiwin, showing the "lay" of the strata, and also wells drilled at Pelican, Athabaska, Morinville, Edmonton and Wetaskiwin.

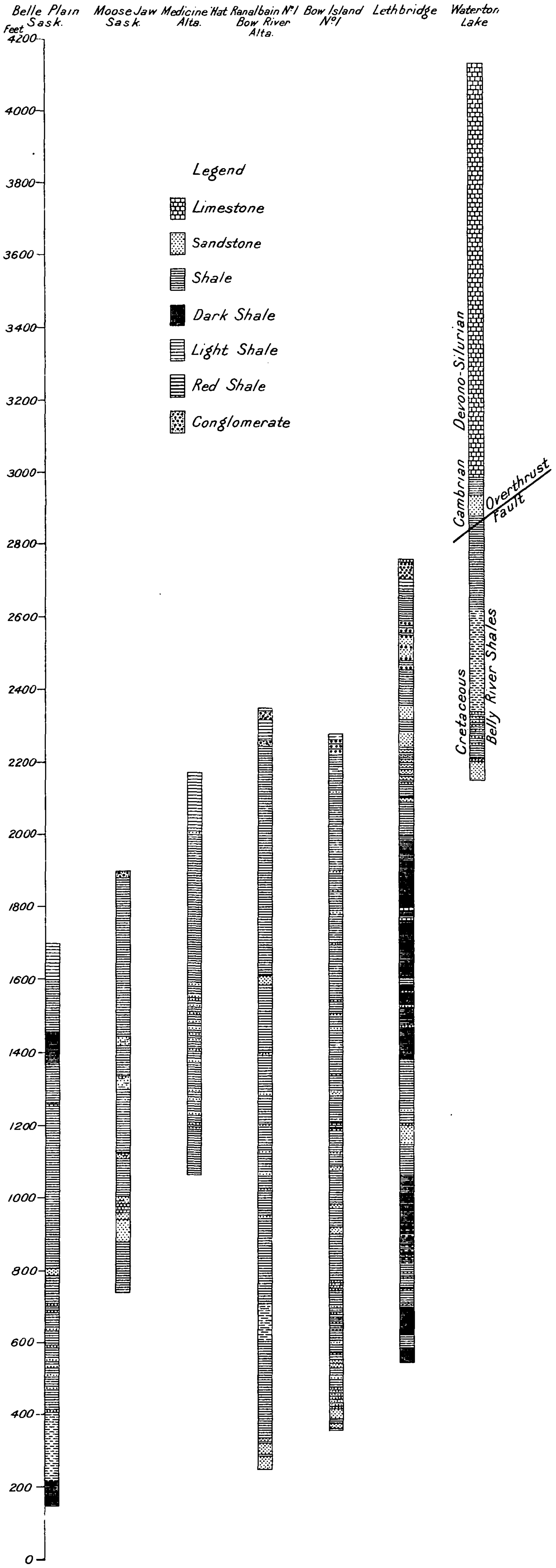


Fig.[redacted]. Sections across Southern Alberta.
(By F. G. Clapp and L. G. Huntley)

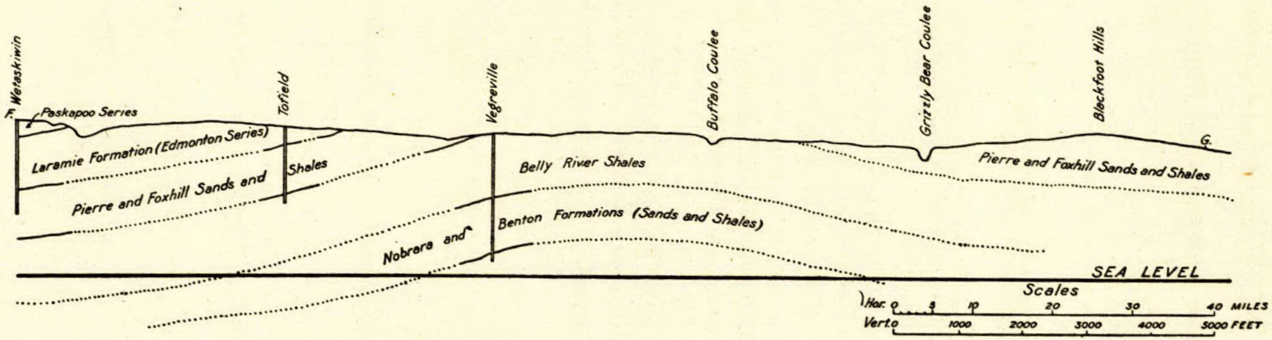


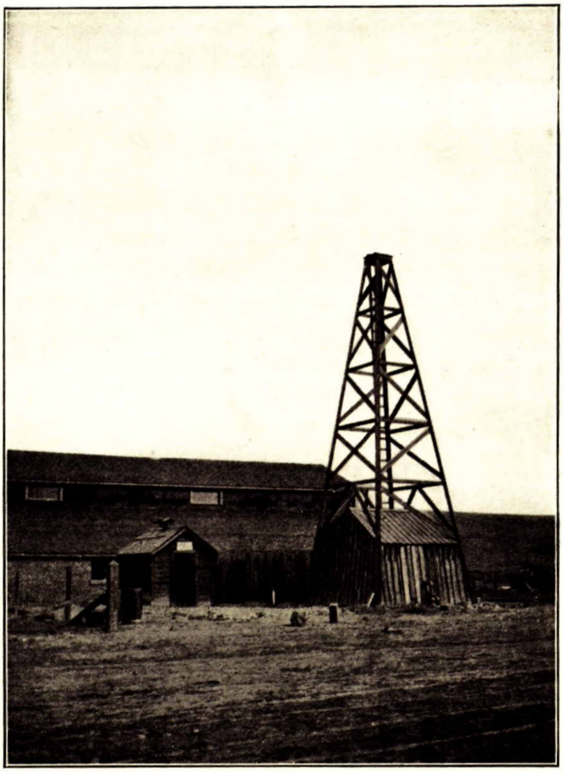
Fig. 29. Geological section showing the lay of the strata across the Battle River anticline from Wetaskiwin to Lloydminster, Alberta, also showing wells drilled at Wetaskiwin, Tofield, and Vegreville (by F. G. Clapp and L. G. Huntley.)

History of Drilling Operations.

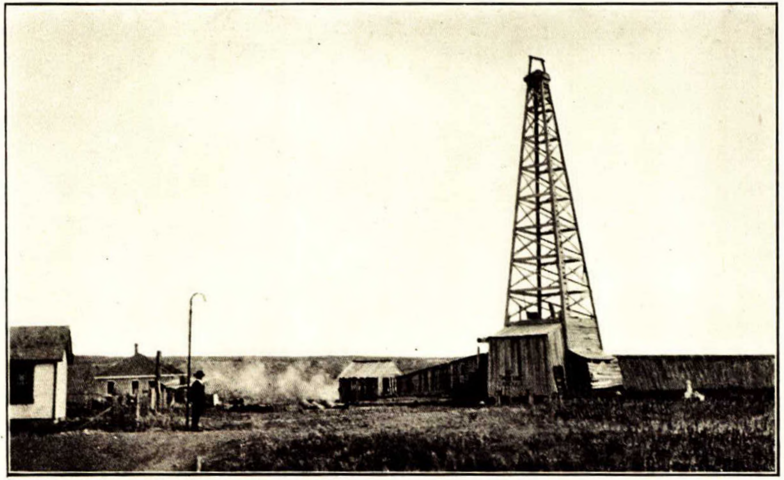
MEDICINE HAT FIELD.

Natural gas in the vicinity of the Medicine Hat field was encountered in a well drilled for water at Carlstadt by the Canadian Pacific railway in 1885. In 1890 a well drilled at Medicine Hat in search of coal encountered a considerable supply of natural gas, the flow being so strong as to lead the town officials to take the matter up with the Canadian Pacific railway, with the view to drilling a deeper well for gas. Sir Willian Van Horne offered to lend the town a drilling machine, the town to stand the expense of the drilling. A considerable flow of gas was encountered at about 650 feet in depth, with a closed pressure of 250 pounds, but was accompanied by a large amount of moisture. In the hope of obtaining a larger supply free from moisture, deeper wells were drilled and the present gas pay was developed in a well drilled by the city in 1905 at a depth of 1,010 feet showing a closed pressure of 550 pounds. The flow was quite dry, being probably near the top of the Niobrara formation. The 600 foot vein is the principal gas horizon before reaching the 1,000 foot horizon, the other being only pockets, according to Mr. Winter. In the summer of 1912 the Medicine Hat field had been extended, and the wells had a capacity of approximately 25,000,000 cubic feet per day. In 1913 the city contracted with Messrs. Martin and Fish to drill nine new wells for gas, two of which had been completed in August of that year. The best well at Medicine Hat is the Tuno well, the production of which is reported to be 6,000,000 cubic feet per day. It is situated two miles west of the city hall and is a ten-inch hole. The completion of the wells recently contracted for will make a total of twenty wells in the field, tapping the Medicine Hat sand, one of which was continued to the Dakota. In addition about thirteen shallow wells have been drilled. At the end of 1912 the gas department of the municipality was drawing from six wells owned by the city, and supplied

Plate XIV.



One of the earliest Alberta wells, Medicine Hat, Alberta.



The Toronto street well, Medicine Hat, Alberta.

1,900 domestic consumers and sixteen factories with natural gas, valued at $70,000 per year. The department operates 56½ miles of pipe line. A number of shallow wells were shut in and not used.

During the latter part of 1913, in order to show exactly what has been done in Medicine Hat in the way of drilling gas wells, the city engineer's office furnished a statement of the number of wells operated or in construction in Medicine Hat, with the depth, name, open flow in cubic feet per 24 hours, one year drilled. The information is the first of the kind issued and was prepared at the request of the Board of Trade, the data being as follows:—

Name.	Depth.	Open flow cu. ft. 24 hours.	Year drilled.
Main street	1,000	2,225,000	1904
Park	1,000	3,000,000	1906
Altawana	1,000	2,500,000	1909
Maple street	1,000	2,500,000	1911
Electric	1,200	4,000,000	1911
Rosery	1,000	2,500,000	1911
Balmoral street	1,200	2,500,000	1911
Central Park	1,300	3,000,000	1913
Stella	1,002	2,200,000	1913
Big Chief	1,100	2,800,000	1909
Rolling Mills	1,050	2,900,000	1910
W. Industrial site	1,202	2,300,000	1913
S. Industrial site	1,202	2,100,000	1913
Craft	1,075	3,300,000	1913
Cousins and Sissons	1,075	2,900,000	1913
Ogilvie	1,033	2,500,000	1912

In addition drilling has been started on Well No. 17, near the Maple Leaf mills site, and the Medicine Hat Brick Company has a well 1,050 feet deep. For some years the Canadian Pacific railway has had a gas well on its right of way near the station, and work has been completed on a second well for the Canadian Pacific railway, the depth, open flow and rock pressure averaging with the other natural gas wells in this city.

The above wells are all within the city limits, and it is notable that there has been no appreciable diminution in the pressure or flow from the same notwithstanding the increased consumption due to the rapid industrial expansion of Medicine Hat.

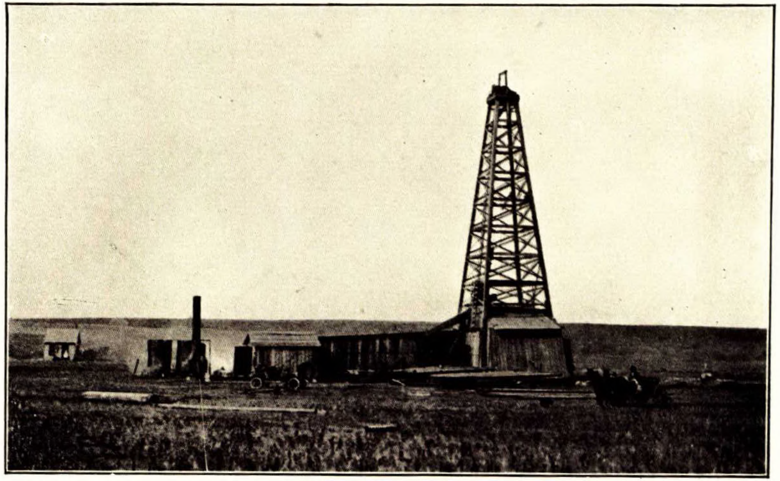
This list does not take into account the string of wells being drilled by the Hunt Engineering Company for the $2,500,000 plant of the Canada Cement Company.

The officials of the city of Medicine Hat defend their action in giving away gas and selling it at such a low rate upon the basis that if this were not done, the gas companies would drain the underground supply for piping to other districts, and as a matter of self defense they must make use of it for home developments while they may; in the earlier history of this development, large flambeaux were burnt, and even more recently one or two wells were allowed to blow wide open. At present these are all closed in and the gas is being used to advantage by the city of Medicine Hat which controls the gas rights in two townships.

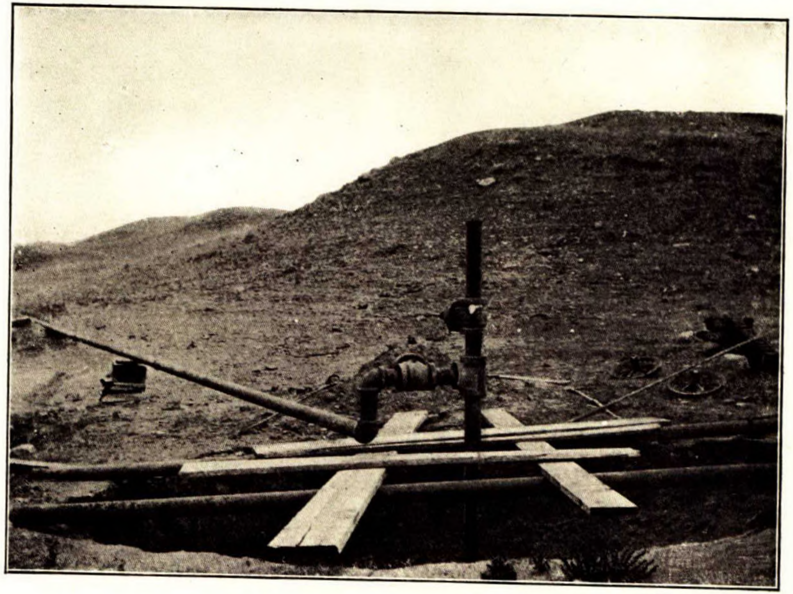
BOW ISLAND FIELD.

The discovery of gas in the Bow Island field was brought about in 1908 by the drilling of a well about 1900 feet deep by the Canadian Pacific railway at their pumping station ten miles south of Suffield, and twelve miles east of the present centre of production. It had a reported volume of 8,000,000 cubic feet of gas per day and 800 pounds per square inch rock pressure. Up to the summer of 1913 sixteen wells had been drilled, producing about 75,000,000 cubic feet per day. The field has been developed by the Canadian Western Natural Gas, Light, Heat and Power Company, Limited, for the purpose of supplying the city of Calgary and fourteen other towns en route, including Lethbridge, Grannum, Okotoks, Claresholm, Nanton, MacLeod, Sandstone and Tregillus, and for which purpose a 16-inch pipe line 160 miles in length has been laid. The first well was drilled in the main field in 1909, the famous "Old Glory Well." Its pressure was 810 pounds and the flow 7,000,000 cubic feet per day. It caught fire and burned for fifteen days before it was finally put out by two boilers of steam. The above company is reported to be backed by stockholders of the Canadian Pacific railway and has taken over all the drilling business of the latter company, including several small gas wells at Carlstadt, Brooks, Cassils, Dunmore, etc.

Shallow gas in Bow Island wells, Numbers 1, 2, and 3, is found at from 800 to 1000, which is cased off and escapes around the casing. Considerable water escapes around the casing of all these wells, but it is artesian water, good for drinking but hard on boilers.



Well No. 12, Bow Island field, Alberta.



Well No. 3, Bow Island field, Alberta.

The following yields of gas have been authenticated by Eugene Coste, President of the Canadian Western Natural Gas, Light, Heat and Power Co., for the first eight wells in this field:—

No. 1	—10,000,000	cubic feet
2	7,000,000	" "
3	15,000,000	" "
4	29,000,000	" "
5	1,250,000	" "
6	4,200,000	" "
7	7,000,000	" "
8	12,500,000	" "

REDCLIFFE.

Four wells have been drilled at Redcliffe for supplying that town with natural gas. Gas was encountered at a depth of approximately 1200 feet in the same producing stratum as at Medicine Hat. The capacities and pressures of these wells are very similar to those in the latter field.

At Redcliffe, at the end of 1912, there were three wells being drawn upon to supply the town, furnishing gas valued at $7000 per year. Gas is sold to 150 domestic consumers and eight factories of various sorts. The price for domestic consumption varies from $2 to $3.50 per month, although the Redcliffe Realty Company was preparing to put in the meter system, to be started in the summer of 1913. The price to industrial plants varied from $10 to $100 per month.

PINCHER CREEK AND SOUTH KOOTENAY PASS DISTRICTS.

Oil seepages have been known for years in the Cretaceous rocks on the Alberta side of South Kootenay pass; and from the Cambrian or Pre-Cambrian formations on Kishinena creek small seepages of light oil have been utilized in the past as a source of cattle remedies and for lighting purposes. The oil in this district was first used by a farmer named Aldrich, who obtained it by means of a blanket from the top of a spring of cold water in the valley of Akamina creek.

History of Developments.—The drilling in the Pincher Creek district appears to have been caused by a report of the Geological Survey for 1898, in which Dr. G. M. Dawson described the various seepages on both sides of the divide and expressed an opinion that boring operations were warranted to prospect for oil.

As stated by Dr. Selwyn[1]:—

> Oil has never been produced in a formation as old as the Cambrian, nor do the rocks here exposed admit of the probability of their being the source of the oil under anything but very extraordinary conditions. These surface geological conditions would seem to render it impossible for oil to occur in this section; but the fact remains that it is found there. It is, as Dr. Dawson very appropriately calls it, 'a somewhat anomalous occurrence of petroleum.' In accounting for the fact, Dr. Dawson says 'the overthrust fault must have been great, as Cambrian rocks extend eastward for over 12 or 15 miles over the summit into Alberta. The oil may have travelled westward underground, but the existence of pronounced faults intervening make this improbable.'

This fact did not deter the wild-catter, and in 1900 and 1901 oil claims were staked and recorded on both sides of the boundary by both American and Canadian companies. The first drilling commenced in 1903, and by 1912 there were twelve wells drilled in the district, varying in depth from 200 to 1900 feet. The principal drilling was done at Waterton lake and at Oil City, the latter located about five miles up Oil creek, a tributary of this lake. Of three oil holes put down at Waterton lake, one was drilled to a depth of 1900 feet, encountering oil in a soft caving formation at that depth. Accounts varied as to the amount of this oil, which was never produced commercially. From the amount bailed out of the well, Mr. Stafford, a driller residing at Pincher, states that the well would have produced 18 to 20 barrels per day. However, the tools were lost, and after a dilatory attempt at fishing lasting for almost six months, the well was plugged and abandoned; and the Western Oil Company, after having spent some $200,000 in this district, quit the oil business and started to invest in coal lands.

The other two wells at Waterton lake produced nothing. At Oil City about ten wells were drilled. One of the first of these, drilled by the late Mr. Lineham to a depth of about 1400 feet, struck a quantity of high gravity oil at 1080 feet. The well flowed naturally for a short time, and probably produced

[1]Summary Rept. Geol. Survey Can., 1891, pp. 9-10, and Rept. of Minister of Mines of British Columbia 1896, p. 529.

LEGEND

PLEISTOCENE & RECENT

Glacial drift and alluvium
including winged out moraines of the Flathead valley

MIOCENE

Ks

Kishenehn formation
chiefly bluish-grey clays; interbeds of sandstone — fossiliferous

chiefly MIDDLE CAMBRIAN ?

Kn

Kintla formation
chiefly thin-bedded red argillite, and interbedded flow of basic lava

Sh

Sheppard formation
chiefly thin-bedded light grey siliceous dolomite, an interbedded flow of basic lava

Pu

Purcell lava
massive basic flow

Si

Siyeh formation
chiefly massive dark grey, siliceous magnesian limestone; also much greenish-grey metargillite

LOWER CAMBRIAN

Gr

Grinnell formation
chiefly thin bedded red metargillite; an interbedded flow of basic amygdaloid.

Ap

Appekunny formation
generally thin bedded, light greenish grey, metargillite; subordinate quartzite and magnesian limestone lenses

BELTIAN

A

Altyn formation
thin to thick-bedded, light grey, generally sandy siliceous magnesian limestone bearing fossil Beltina danai

W

Waterton formation
massive dark grey felspathized dolomite

CAMBRIAN(?)

Intrusive

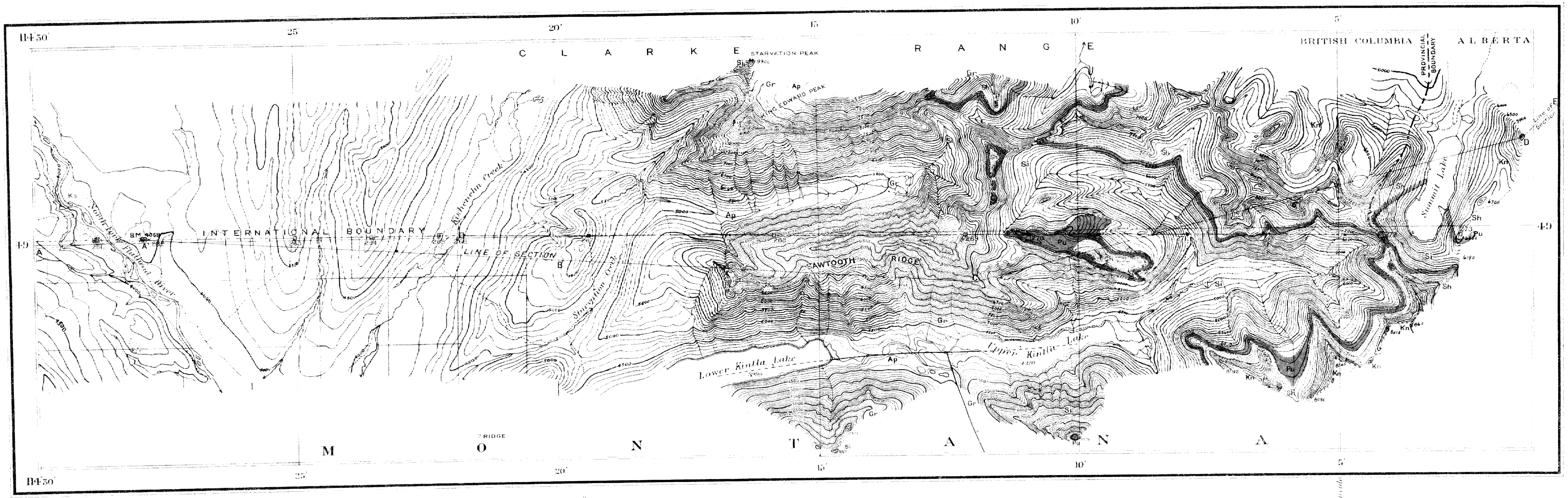
Abnormal Gabbro

Symbols

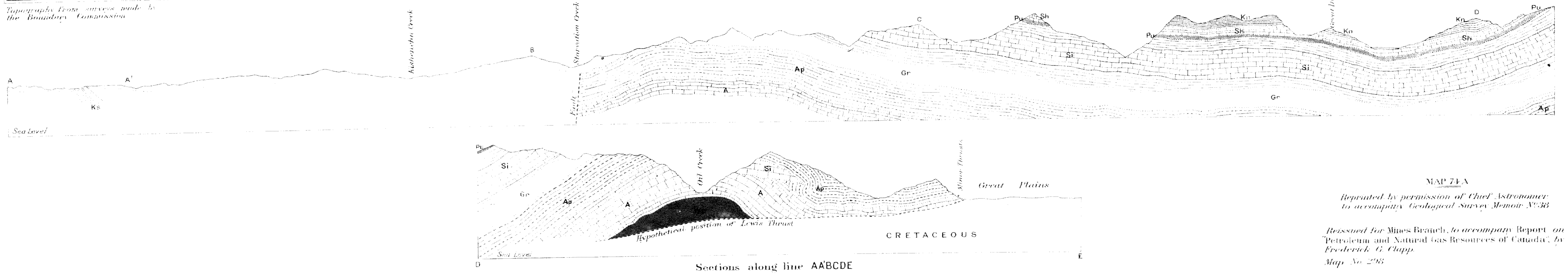
Geological boundary

Fault

Note. *Localities of chemically analyzed rocks shown thus, + 1306*



Topography from surveys made by the Boundary Commission



Sections along line AA'BCDE

GEOLOGY OF THE FORTY-NINTH PARALLEL. By R. A. Daly

Scale: $\frac{1}{62500}$ = 0.9864 Statute Miles to 1 Inch

Miles

Contour interval, 100 feet

MAP 74A

Reprinted by permission of Chief Astronomer to accompany Geological Survey Memoir No. 38

Reissued for Mines Branch, *to accompany* Report *on* "Petroleum and Natural Gas Resources of Canada", *by Frederick G. Clapp.*

Map No. 298

about twenty barrels per day. A small refinery was erected on the ground and the oil refined there. However, the well was poorly packed and was flooded. Nothing was being done on the property in the summer of 1912 due to litigation. Of all the other wells in the vicinity of Oil City, none produced more than two barrels of oil per day, and may be rated as failures. The Pincher Creek Oil Company has drilled several wells. The most recent one, in Pincher Creek, had been drilled to a depth of 700 feet, which they expected to deepen to 1200 feet during next summer. Several small shows of oil were encountered at from 230 to 350 feet.

The Western Oil Company drilled an 1,800 ft. hole between the town of Pincher and the Canadian Pacific railway, the entire distance being in the Cretaceous formations. A small show of gas was encountered at 700 feet in a fine grained sand, and a small show of oil is claimed to have been encountered at a depth of 1,600 feet. This well was drilled on the Mortimer farm. Owing to differences arising between the company and the contractors, the work had stopped, and nothing was being done with the hole in the early part of the summer of 1912. At a depth of 1,500 (?) feet Dowling reports this well to have been in reddish Laramie shale.

On the western side of South Kootenay pass, in British Columbia, two wells have been drilled by the Gloin Oil Company, which recently sold its property to the Royal Canadian Northwest Oil Company. In one of these Mr. Gloin made affidavit that oil to the extent of approximately twenty barrels per day was struck and cased off at a depth of approximately 1,200 feet, the hole being 1,600 feet deep. In May, 1912, the present owners were preparing to pull the casing, to ascertain the exact quantity of oil which existed at this depth. There were no shows of oil around the derrick at this time, although there was a pronounced odour of petroleum from the hole. The oil is said to have been encountered in a coarse red sandstone.

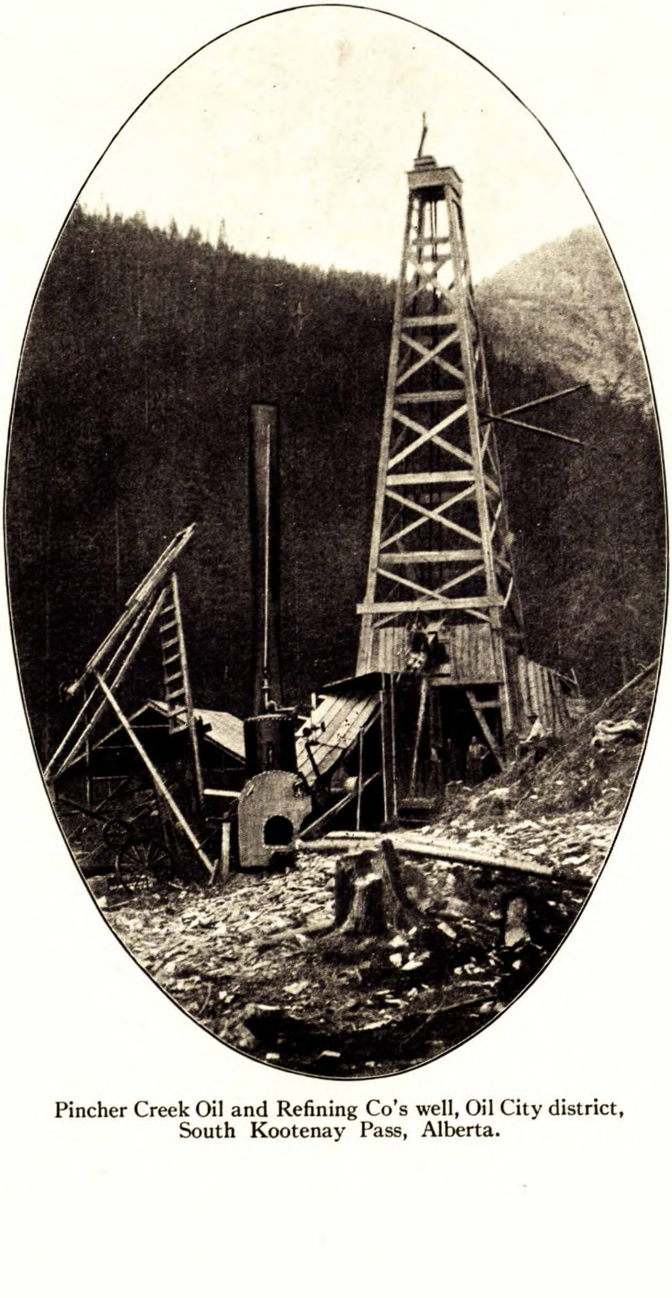
In this entire district, lying inside the first range of foothills, and extending over the first range of the Rockies, the formations are very much tilted and broken, with little opportunity for the existence of a reservoir of oil of any extent. This, combined with the fact that oil has never been found to exist in any quantity in rocks of the Cambrian age, makes the prospects of development of an oil field here seem very slight. Extensive stock selling and booming of the meagre shows already obtained has caused much money to be wasted, with not even a good gambling chance of success. The oil springs and seepages remain of scientific interest only, occurring as they do among formations of such great geologic age; and the two or three wells which alone among the nineteen or twenty drilled might have produced oil in commercial quantities have never been utilized.

The following is a record of wells drilled in the South Kootenay Pass district up to May, 1912.

Record of well-drilling in South Kootenay Pass District.

	Wells	*Section*	*Township*	*Range*	*Drilled by*
Waterton Lake	2	23	1	30	Western Coal and Coke Company.
Waterton Lake	1	26	1	30	Western Coal and Coke Company.
	1	4	2	30	
	1	29	1	30	Pincher Creek Oil and Refining Company.
	2	30	1	30	Lineham Oil Company.
	1	28 (or 33)	1	30	" " "
	1	24	1	1 w. of 5th.	Pincher Creek Oil and Refining Company.
	1	25	1	1 w. of 5th.	Pincher Creek Oil and Refining Company.
	1				(Jack Drader, driller. Do not know company).
	1	32	1	30 w. of 4th.	Western Coal and Coke Company.
	2	Flathead Valley	B.C. side		
	3	Montana and Kintla lake, by Butte Company.			
	3	" or Flathead river, 2½ miles southwest of Kintla lake.			

PLATE XVIII.



Pincher Creek Oil and Refining Co's well, Oil City district, South Kootenay Pass, Alberta.

BOW RIVER.

Five dry holes were drilled to the Dakota sandstone along the Bow river, from fifteen to twenty-five miles northeast of the Bow Island field. This drilling was undertaken by the Southern Alberta Land Company near where their irrigation ditch crosses the Bow river. Later this company drilled a producing well in the Bow Island field.

SUFFIELD.

In 1911 a well was drilled by the Southern Alberta Land Company to supply gas for their townsite at Suffield. This well encountered more or less gas in the Niobrara sands and shales, but owing to a crooked hole and to an accident to the casing, the well was almost entirely ruined. However, a considerable flow came up through 1,200 feet of water which stood in the casing, and was used by the town. A second well is reported to have been drilled in the early part of 1913, and to be a fair gas well. Another well was also drilled ten miles south of Suffield, near the pumping station for field purposes. This was drilled close to the former well put down in 1907–8.

BROOKS.

The Canadian Pacific railway drilled a well at Brooks station to a depth of 2,795 feet, passing entirely through the Dakota sand without encountering either oil or gas in paying quantities. A small show of gas was encountered in the Dakota sand, amounting to approximately 300,000 cubic feet per day, and a flow of salt water in the salt sand. This was plugged off, and the gas used by the town.

CARLSTADT AND CASSILLS.

Small flows of gas have been encountered in four wells drilled by the Canadian Pacific railway at Carlstadt (Langevin) and Cassills[1], the gas originating in pockets in the Belly

[1]Dawson, Geol. Survey Canada, Vol. IV, p. 745. Roy. Soc. Can. Vol. IV, Sec. 4, p. 96.

River shales. The gas was used by the railway for steam, and for lighting and heating the station houses.

The well reported by Dawson to have been drilled at Cassills, 38 miles west of Carlstadt, reached a depth of 997 feet, passed the bottom of the Pierre shales at a depth of 294 feet, at which horizon the Lethbridge coal seam has a thickness of 6 feet.

GLEICHEN.

Dawson also reports a well[1] which was drilled at Gleichen station, 55 miles east of Calgary, in 1885 or thereabouts, which reached a depth of 502 feet.

BASSANO.

Two wells were also drilled at Bassano by the Canadian Pacific railway, but did not tap either the Niobrara or the Dakota sands. The casing was pulled and the wells abandoned, although one is reported to have had an initial capacity of 200,000, and the other 700,000 cubic feet per day.

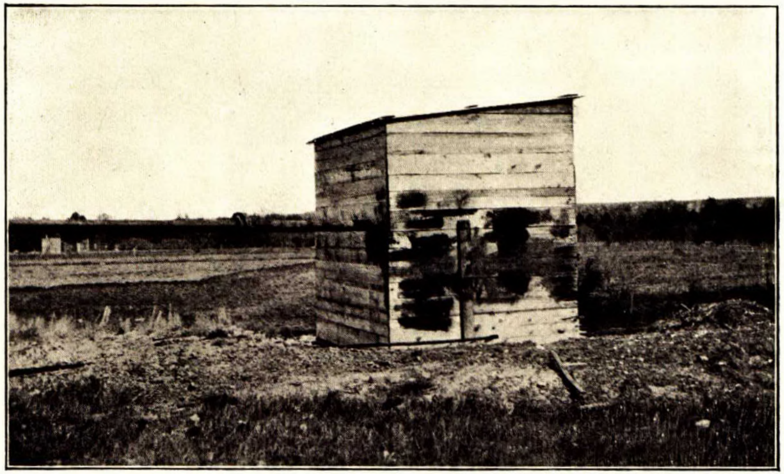
CALGARY.

Two wells have been drilled within the city limits of Calgary, one of which was discontinued at a depth of 3414 feet. A small show of gas was encountered at a depth of 2772 feet, ut it proved of no importance. Otherwise, the well was a failure. This well was drilled in East Calgary near the place where the Canadian Pacific railway crosses the Bow river in section 12 of Southeastern Calgary, township 24, range 1. It was drilled in 1909, and in 1912 produced 80,000 (?) cubic feet of gas per day, with a closed pressure of 285 pounds, according to Mr. Eugene Coste. The other well was drilled within the city limits about twenty years ago, and only reached a depth of 1426 feet. The deep well mentioned ended near the bottom of the Belly River shales.

The other well drilled in the Sarcee Indian Reserve, twelve

[1]Roy. Soc. Can., IV, 1886, p. 99.

PLATE XIX.



Small gas well, Calgary, Alberta.

miles southwest of Calgary, reached a depth of 3,365 feet. Neither of these wells reached either the Niobrara or the Dakota sands, and hence cannot be considered fair tests of the oil or gas possibilities of this locality. The driller of this well had much trouble owing to inclined, greatly folded and crushed rock.

OKOTOKS.

During the summer of 1913 a well was being drilled on the MacDougal ranch west of Okotoks, section 6, township 20, range 2 west of the fifth meridian. Messrs. Dingman, Segur, MacDougal and others are operating in this district in which the formations are greatly disturbed and faulted. A flow of gas was encountered amounting to 2,000,000 cubic feet per day, which soon decreased to less than a million, and was apparently declining rapidly. This gas is reported to contain about 1 gallon of gasoline per 1,000 cubic feet.

About June, 1913, oil was discovered 16 miles west of Okotoks, in the Black Diamond district, Alberta, at a depth of 1,560 feet. It was what is technically known as white oil, being transparent and of an amber colour and having a specific gravity of about 62° Baumé, and consisting largely of gasoline. As a matter of fact, it was used with satisfactory results in the tank of an automobile. The light oil appears to be the result of filtration through clay of the lighter portions of ordinary petroleum, and then too at a higher horizon in this well a flow of gas of 2,000,000 cubic feet a day was struck. Whether it is present in commercial quantities or not, the strike is of importance, as white oils are sometimes found in the vicinity of larger bodies of ordinary petroleums.

By December, a number of companies and individuals had filed on oil lands in this vicinity and announced their intention of sinking wells. If all their plans are carried out, a fair test of the field will be the result because their operations will cover a large area. The company[1] at about this time issued a statement that oil of a very high specific gravity had been encountered in a stratified limestone, through which the oil percolated—about

[1]Calgary Petroleum Products Co.

10 to 15 barrels a day. A test of the oil indicates a light, high grade oil of paraffin base. Gasoline to the extent of 90 per cent was distilled from the oil at 50° to 150°, centigrade. Specific gravity of oil tested was 67·5° Baumé—early sample was 62·5° Baumé.

Dr. H. E. Elliott of California, among the number of those who have secured leases in the vicinity, is of the opinion—in view of developments in other parts of Alberta—that crude oil close to 37° Baumé and containing 30 per cent of gasoline of approximately 76 degrees Baumé, will be found.

There is oil of commercial quality, but how much or how little no one can yet say. The Great Northern railway announces an early extension of that system into and passing through the Black Diamond district.

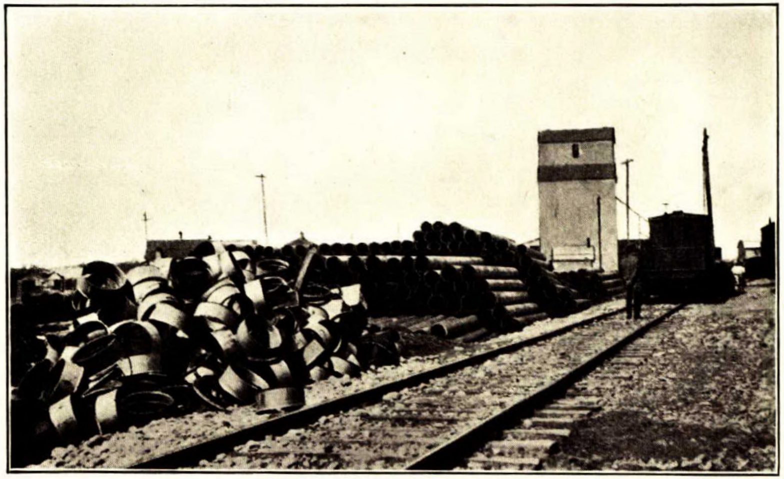
The prairie provinces of western Canada, where farming is carried on on a large scale, and in the development of which tractive implements are used necessitating huge annual importations of liquid fuel, will offer a ready market for the oil should a field develop.

WETASKIWIN.

Two wells were started at Wetaskiwin previous to 1912, but owing to frequent caves and trouble with casing, they did not reach the supposed gas horizons, and Mr. Grant, the contractor, lost considerable money trying to complete the second well.

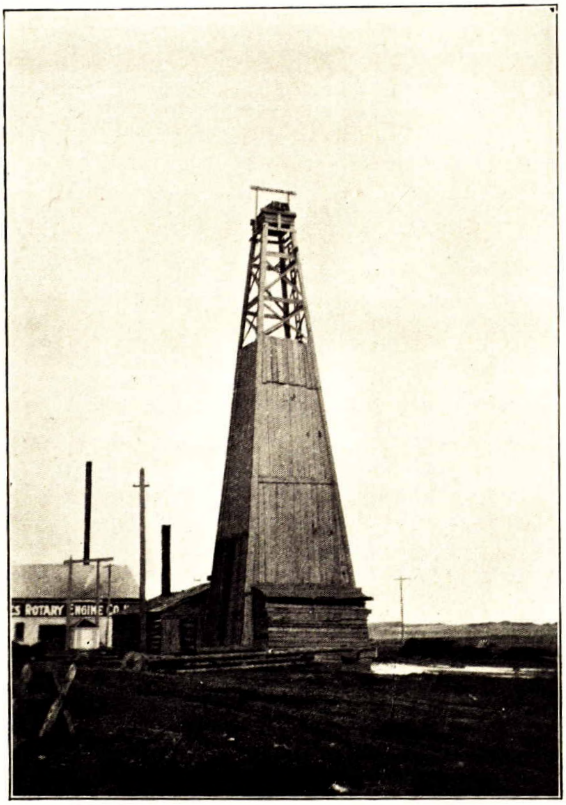
The drilling contracts for the second well at Wetaskiwin called for a 2,000 foot well at $7.50 per foot, unless gas should be struck at a less depth, the city to pay for fuel and for all casing which may be left in the hole. The hole reached a depth of 1,150 feet before it was found impossible to proceed on account of dropping a piece of casing into the hole, which could not be dislodged. However, until 1912 all attempts had been unsuccessful due to accidents and delays in drillings. In the early part of 1913 the drilling contract was taken up by the Northwest Drilling Company of Calgary, who, in June of that year, brought in a small gas well. Gas was encountered in the Pierre

PLATE XX.



Scene at Okotoks, Alberta, showing pipe for main line of Coronation Western Natural Gas, Light, Heat, and Power Co., Ltd.

PLATE XXI.



Original well at Wetaskiwin, Alberta, which has only a showing of gas.

sands and shales at from 1,187 to 1,443. The principal pay was at the depth of 1,347. The hole reached a depth of 1,511 feet, ending near the top of the Belly River shales, which it did not penetrate. The initial flow of this well was estimated to have been 2,000,000 cubic feet per day, but it declined rapidly, and in August, 1913, showed an open flow of only 350,000 cubic feet per day. However, it is expected a still greater flow will be secured. The strike is valuable to the city of Wetaskiwin since it will eliminate the large coal account at the power plant as well as some hundreds of dollars in wages.

TOFIELD.

In June, 1912, the well being drilled by the town of Tofield struck a small flow of gas at a depth of 1,051 feet. The well was flooded by water from an overlying formation, due to an accident to the casing and was abandoned. Later in the year another well was drilled about one-half mile southeast of the first, but failed to develop a gas supply. In the summer of 1913, the third well was drilled close to the location of Well No. 1. The gas in the first well was encountered near the top of the Belly River shales.

VEGREVILLE.

The well drilled by the Northwest Drilling Company for the town of Vegreville in April, 1913, encountered a considerable flow of gas in a sand stratum of the Niobrara formation at a depth of 1,360 feet. The hole was continued to a depth of 2,000 feet, without developing any further gas in large quantities. The pressure and volume of this well showed a gradual increase during the spring and summer of 1913, and gave evidence of its being located upon the edge of good gas territory. In August, 1913, the well showed a closed pressure of 280 pounds, with an open flow of 220,000 cubic feet per day.

EDMONTON.

Two wells have been drilled within the city limits of Edmonton by the Northwest Gas and Oil Company. Well No. 1

was located at the south end of First street and reached a depth of 1,150 feet. Well No. 2 was located upon the north side of Jasper avenue and reached a depth of about 1,800 feet. Both were dry holes and were abandoned.

In a recent report on the strip of country including Edmonton, Dr. D. B. Dowling, of the Dominion Geological Survey, says, " I should hesitate to advise any deep boring and would suggest if any wells in the vicinity show small flows of gas to trust rather to a number of shallow ones than to an expensive deep well." A test well at Nakamun has been started.

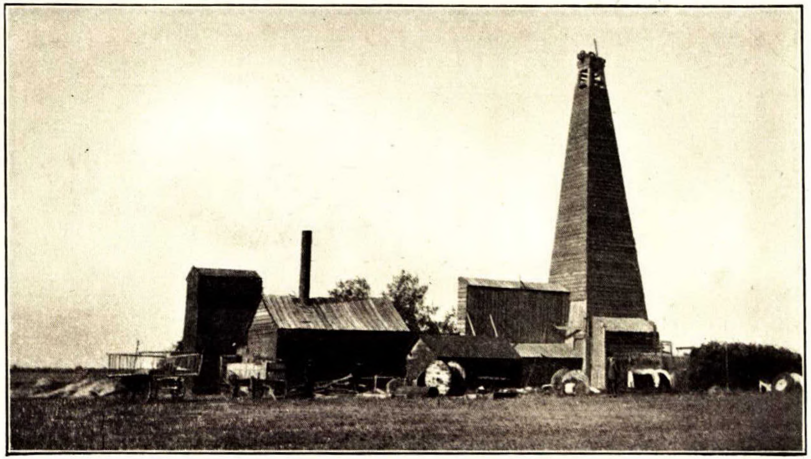
MORINVILLE.

Eighteen miles north of Edmonton near Egg lake, the California-Alberta Oil Company drilled a shallow well to a depth of 490 feet. Small flows of gas were discovered at various points but soon exhausted themselves, and the well was abandoned. Another well was drilled by Edmonton people, the company being managed by H. L. Williams of that city. Drilling was pursued intermittently for five years prior to 1913, and the well reached a total depth of 3,340 feet. More or less gas was encountered in the upper part of the hole, and from 3,040 feet to the bottom of the hole, Mr. Williams reports small oil shows. This well probably reached the top of the Devonian limestone, having passed through the Dakota formation which was very hard and shaly at this point, and contained considerable calcareous water.

VICTORIA.

A well was drilled in 1899 by the Canadian Geological Survey at Victoria on the North Saskatchewan river, about 40 miles northeast of Edmonton. Drilling ceased near the bottom of the Niobrara formation at a depth of 1,840 feet. Small flows of gas were encountered in the shales in the upper part of the hole, but as the well did not reach the Dakota sand, it cannot be considered a fair test of the district. It is believed that the Dakota (tar) sand would be encountered at about 2,100 feet below the river level in this vicinity.

Plate XXII.



Dry hole at Morinville, Alberta.

ATHABASKA.

In 1894 the Canadian Geological Survey drilled a well at this point to a depth of 1,771 feet, failing to reach the Dakota sand by probably less than 100 feet. Owing to the small diameter of the hole at this depth, it was found impossible to continue. Several pockets of gas were encountered near the top of the LaBiche shales, but they were not considered of importance. During the fall of 1912, several shallow wells from 250 to 400 feet in depth were drilled by local people of Athabaska. These encountered the same shale gas found in the government well, and, as was to be expected, they soon declined and proved of no importance.

PELICAN.

In the year 1897, the Canadian Geological Survey drilled a well on the banks of the Athabaska river two miles above the mouth of the Pelican river. This well encountered a large flow of gas in the Dakota sand at a depth of 800 feet. The flow was so strong as to prevent further drilling and to prevent capping the well, which was allowed to blow wide open for fifteen years. In 1911 the Calhoun Oil Company, of which Mr. H. L. Williams of Edmonton was the manager, obtained a lease of this well from the government and commenced drilling a second well a few hundred feet away. This second well encountered a considerable flow of gas at a depth of 625 feet, which was apparently coming from the Dakota sand and the old government well, being fed through this upper, 625-foot porous stratum. This condition is shown by Plate XXIII. In the summer of 1913 a third well was being drilled by the Pelican Oil and Gas Company, which company superseded the Calhoun Oil Company. These three wells are all located within a radius of less than 200 feet. Well No. 1, started by the Calhoun Oil Company, reached a depth of 2,069 feet, being still in the Devonian limestone.

In July, 1913, a fourth well was being drilled by the Pelican Oil and Gas Company at a point six miles south of the old government well, but had shown no result at that time. Boring operations have demonstrated beyond a doubt the existence of large reservoirs of natural gas, and it seems probable that further exploratory work throughout the wide area underlain by the Cretaceous rocks should lead to the discovery of other reservoirs.

FORT McMURRAY.

Two wells have been drilled on the banks of the Athabaska river at the mouth of Horse creek one-half mile south of Fort McMurray. The first well met with an accident; and the second, located about 100 feet east, reached a depth of 1,405 feet in August, 1912. This well was drilled 266 feet in granite. A show of black oil was encountered in the well but not in commercial quantity, and the well was abandoned.

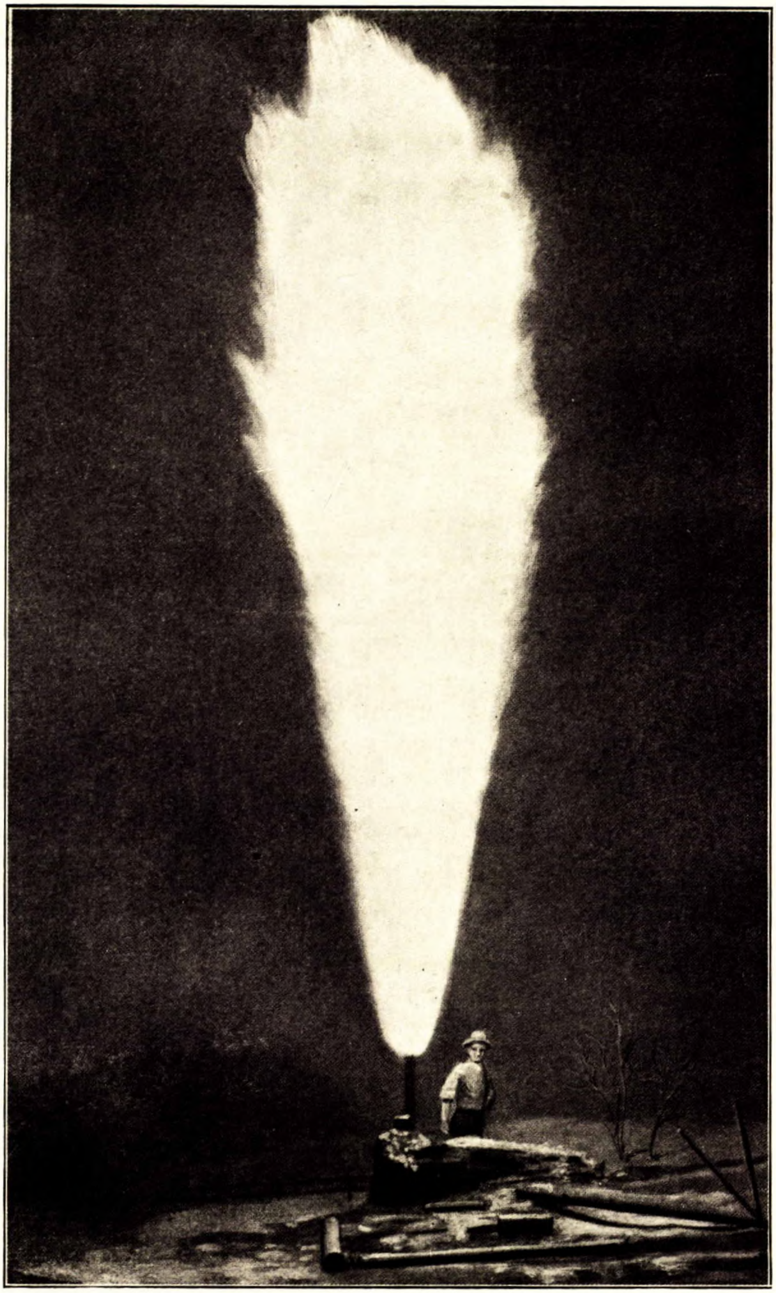
FORT McKAY.

Several shallow wells have been drilled by Alfred von Hamerstein and associates in the district between Fort McMurray and Lake Athabaska. One of these on Tar island is said to have encountered a considerable quantity of heavy oil, none of which has ever been taken out of the country, however.

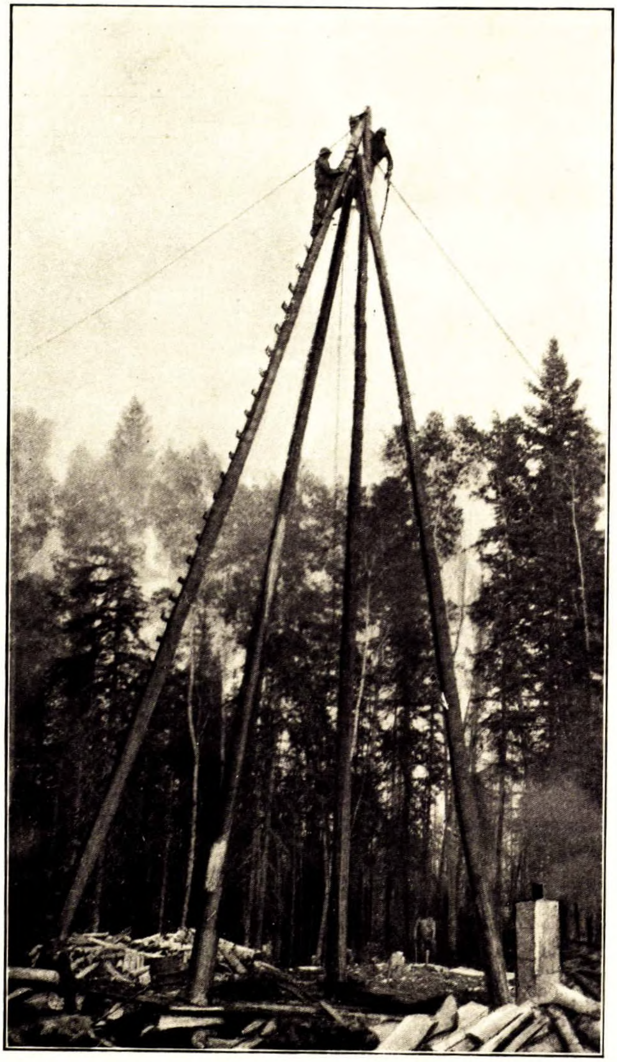
The Fort McMurray Oil and Asphalt Company has also drilled three shallow wells along the river between Fort McMurray and Fort McKay, with no particular results.

The Athabaska Oils, Limited, a Vancouver syndicate, has drilled several shallow wells on the banks of the Athabaska river nine miles below Fort McKay. The deepest of these reached a depth between 1,100 and 1,200 feet, having penetrated the granite at that depth. Two oil impregnated sands were encountered near the top of the first well, corresponding to the Dakota sand, which outcrops along the banks of the river, and which probably has dipped below the surface in the bottom of a low syncline which crosses the river at this point.

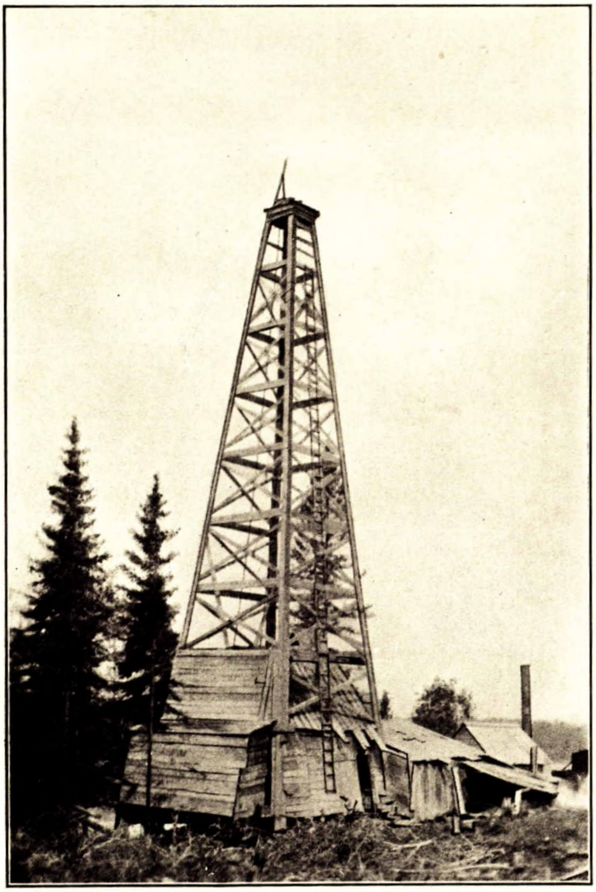
PLATE XXIII.



Natural gas bursting from oil well drilled by the Dominion Government at Pelican portage, Athabaska river, Alberta. Burning since 1897.



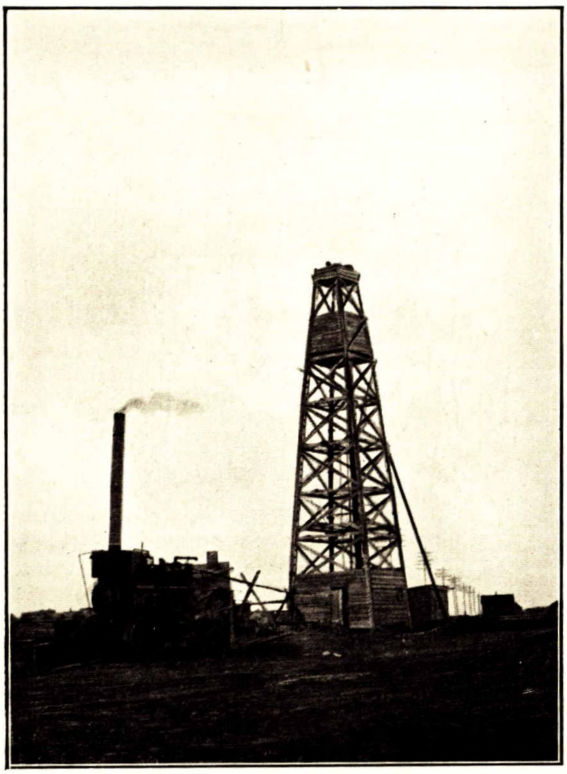
Derrick at No. 2 well in course of erection, Athabaska Oils, Ltd., 9 miles below Fort McKay, Alberta.



No. 1 rig, Athabaska Oils, Ltd., 9 miles north of Fort McKay, Alberta.

Well No. 2, Athabaska Oils, Ltd., 9 miles below Fort McKay, Athabaska river, Alberta.

PLATE XXVII.



Dry hole at Taber, Alberta, showing traction engine used in drilling.

CASTOR.

During the summer of 1913 the Northwest Drilling Company of Calgary was engaged in drilling a well for gas at the town of Castor. On August 1, 1913, the well was at a depth of 1,350 feet, and had encountered a small flow of gas at that depth, according to Mr. Triplett of the above company.

CAMROSE.

In August, 1913, the town officials of Camrose contracted with Messrs. Martin and Fish of Medicine Hat to drill a well for gas near the power house. Gas was struck at a depth of 1,235 feet.

TABER.

A boring was made in 1902 at Taber to a depth of 1,200 feet, and while the well was dry, a showing of oil was encountered at 1,020 feet in the lower part of the Belly River series.

DRUMHELLER.

Natural gas has just been struck at Drumheller in the coal mines of the Drumheller Coal Company. This gas is now issuing from the mines in such quantities that the proprietors, of necessity, have had to close down all the mining operations.

Mr. Drumheller, after whom the town is named, is one of the pioneer coal operators, and while the discovery of natural gas in his mine is causing some hardship in handicapping work, this, in his opinion, is offset by the importance of having gas in the town.

Present Producing Gas Fields.

As described in the preceding section, the only two producing gas fields in southern Alberta are those at Medicine

Hat and the vicinity, and at Bow island, about forty miles northwest of Medicine Hat.

In central Alberta the Vegreville well is being used for power purposes by the town and shows an open flow capacity of from 200,000 to 300,000 cubic feet per day. The gas well at Wetaskiwin, while declining in volume, is being used for fuel at the municipal power house and shows an open flow capacity of from 300,000 to 350,000 cubic feet per day. On the MacDougal ranch, west of Okotoks and south of Calgary, the well being drilled by Mr. Dingman and his associates, while at present showing considerable flow of gas, does not give promise of long life or great vitality. The gas from this well is reported to contain one gallon of gasoline per 1000 cubic feet of gas. In northern Alberta the wells at Pelican on the Athabaska river had a combined capacity of less than 1,000,000 cubic feet per day.

Production of gas in Alberta.—In 1905 the gas from 12 wells at Medicine Hat was valued at $33,000. The value of natural gas produced in Alberta in 1910[1] is reported as $68,568, and its volume was over 450,000,000 cubic feet.

In 1912[2] the production was reported as 780,000,000 cubic feet, valued at $110,165, the value representing as closely as can be ascertained the value received by the owners or operators of the wells for gas produced and sold or used.

Location of Dry Holes.

Dry holes have been drilled at various points in Alberta, at most of which geological conditions indicate the uselessness of future prospecting. Among these may be mentioned the wells at Fort McMurray, Morinville, Edmonton, Victoria, Bassano, Cassills, Brook, and Pincher creek. There is also little apparent prospect of natural gas in large quantities at any of the undeveloped localities described, with the exception of the field southeast of Vegreville.

[1]John McLeish, Summary Rept. Mines Branch, Dept. of Mines for 1910, pp. 177-8.
[2]John McLeish, Summary Rept. Mines Branch, Dept. of Mines for 1912, pp. 159-160.

Oil Wells.

No oil in commercial quantities has been encountered in Alberta up to the present time. Several wells drilled along the Athabaska river south of Fort McMurray have developed small quantities of heavy black oil in the lower part of the tar sand, at points where it lies below the surface. One company in particular is making arrangements to develop this source of oil by drilling numerous shallow wells on its property, hoping to recover the oil by bailing or by some similar means. However, owing to the difficulty of transportation and travelling, no oil has ever been shipped out of this northern county.

The deep well drilled by Mr. Williams, of Pelican, encountered numerous small shows of heavy oil in the Devonian limestone. However, none of these were of enough importance to warrant further prospecting in that vicinity.

A small oil production was developed in the vicinity of Oil City and Waterton lake, on the eastern slope of South Kootenay pass in southwestern Alberta. However, these wells failed to produce in quantities sufficient to warrant further drilling, especially in view of the badly faulted nature of the rocks in this district.

Present Drilling Operations.

NORTHERN ALBERTA.

While several oil drilling outfits were preparing to begin work along the Athabaska river during the summer of 1913, yet the only drilling operations at that time were those of the Pelican Oil and Gas Company in the vicinity of Pelican rapids. This company was working intermittently in deepening several wells which had already been drilled.

The syndicate of local people of Athabaska which held the gas franchise of that town expected to begin the drilling of a deep well to test the Dakota sand at that point.

Operations at Morinville had ceased and one drilling rig from that point had been moved to Nakamun, forty miles northwest of Edmonton, where the formations were being tested for oil.

Mr. Chamberlain and associates are drilling a well a few miles south of the city of Edmonton, on Mr. Chamberlain's farm in section 30, with the object of developing a natural gas supply. A light rotary drilling outfit is being used for this work and the prospects are that the Dakota sand will not be reached, owing to the great depth at which it lies under Edmonton.

A third well was being drilled at Tofield, in August, 1913, by Mr. George Peat, of Petrolia, Ontario. The town of Wainwright was endeavouring to obtain funds to drill a well to test the Battle River anticline in that vicinity. The Northwest Drilling Company of Calgary was drilling a well for gas at Castor, and in August had reached a depth of 1,350 feet. Mr. Dingman and associates of Calgary were drilling a test for oil on the MacDougal farm west of Okotoks, and Mr. Dingman stated that they expected to go through to the Dakota sand. On November 8, 1913, the well was approximately 1,570 feet deep, and drilling in the lower part of the Belly River or upper Claggett formation.

The city of Medicine Hat contracted during the latter part of 1912 for the drilling of nine additional wells to furnish fuel for manufacturing purposes to the plants located near that city. Two of these had been completed in August, 1913.

Well No. 16 in the Bow Island field was being completed in August, 1913, and Mr. Eugene Coste, the president of the Canadian Western Natural Gas, Light, Heat and Power Company, stated that no wells would be drilled during that year.

Oil Seepages.

NORTHERN ALBERTA.

The great tar seepages which exude from the Dakota sand along the Athabaska river in northern Alberta, and which have been described by McConnell and others, represent in their explored portion a body of solid bitumen having a volume of six cubic miles. This body of bitumen is believed to be the residue from an enormous quantity of petroleum from which the lighter constituents have volatilized, leaving only the comparatively solid residue.[1]

Similar seepages of less extent are found on the Clear Water river, on the Loon river, and in the vicinity of Tar island on the Peace river.

These seepages follow a northwest by southeast line, and the oil from which they originated may have been governed in its accumulation by the great arch which crosses the Athabaska river in the vicinity of Crooked rapids. All these seepages apparently lie on the northeast side of the crest of this arch or series of arches.

CENTRAL ALBERTA.

South of Athabaska and between that point and the Red Deer river, numerous occurrences of tar impregnated sand have been reported. The best known of these is found in the vicinity of Egg lake near Morinville and has been described by Dawson. Another occurs in the vicinity of Legal between Morinville and Athabaska, on section 33, township 57, range 20.

The well being drilled at Nakamun, west of Edmonton, was located near a similar deposit of tar sand.

South of Edmonton near LeDuc a tar sand deposit of considerable size is reported to have existed and to have been used by Indians in curing hides. Various other small seepages of tar or heavy oil are reported to exist south of Camrose and to exude from the banks of the Red Deer river.

SOUTHERN ALBERTA.

A small seepage of reddish oil is reported to exude from a creek bottom in the vicinity of MacLeod in southern Alberta.

In the valley of Oil creek, a tributary of Waterton lake, in the extreme southeastern corner of Alberta, numerous oil seepages occur, exuding both from the limestone cliffs of Devono-

[1]A report by S. C. Ells on the Athabaska Tar Sands has been published by the Mines Branch, 1914. Field work is still in progress and a more complete report will probably be issued in 1915.

Silurian age and from the sand and shales of the Cambrian age. On the British Columbia side of South Kootenay pass, in the valley of the Akamina and Kishinena rivers, several seepages of light oil have been reported by Selwyn and others. These seepages have led to the drilling of from eighteen to twenty wells—with no results of importance. No drilling is going on at the present time, and the geological indications do not warrant further prospecting.

Oil seepages are reported in northern Montana near the international border, in the vicinity of Kevin, Montana, and shallow wells drilled in the vicinity encountered a dark oil of good quality at a depth of approximately 100 feet from the surface.

Gas Springs and Water Wells with Showings of Gas.

NORTHERN ALBERTA.

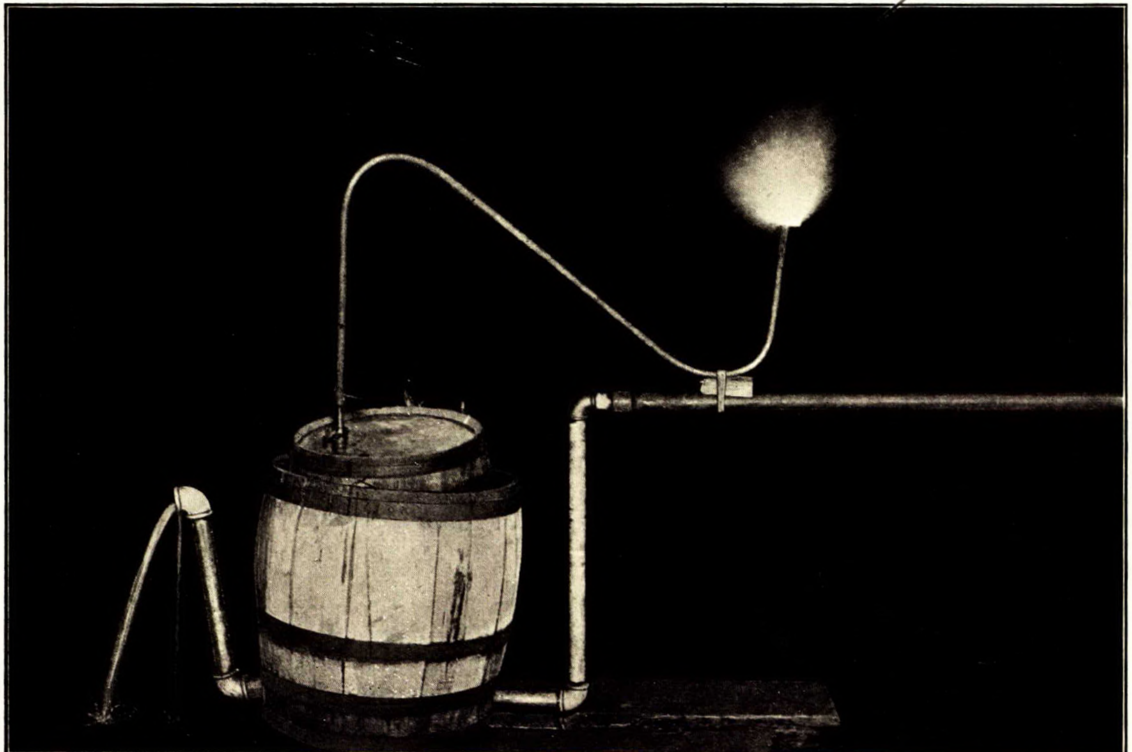
Gas springs are reported by McConnell at the mouth of the Little Buffalo river on the Athabaska, and at a point on the Athabaska river thirteen miles north of Pelican. He suggests the possibility that this gas may have worked its way up from the tar sand through the overlying clear water shale. The gas first mentioned covers an area of approximately 50 feet in diameter, and is reported to have been of sufficient volume to cook a camp meal. At the time the writer visited this locality the volume was considerably less than described by McConnell and it is believed to be decreasing. The gas spring last mentioned is only noticeable at very low water and during the winter time, when it prevents the ice from freezing solid. McConnell also reports gas springs as occurring at Tar island on the Peace river.

Water wells drilled at Athabaska have encountered more or less shale gas.

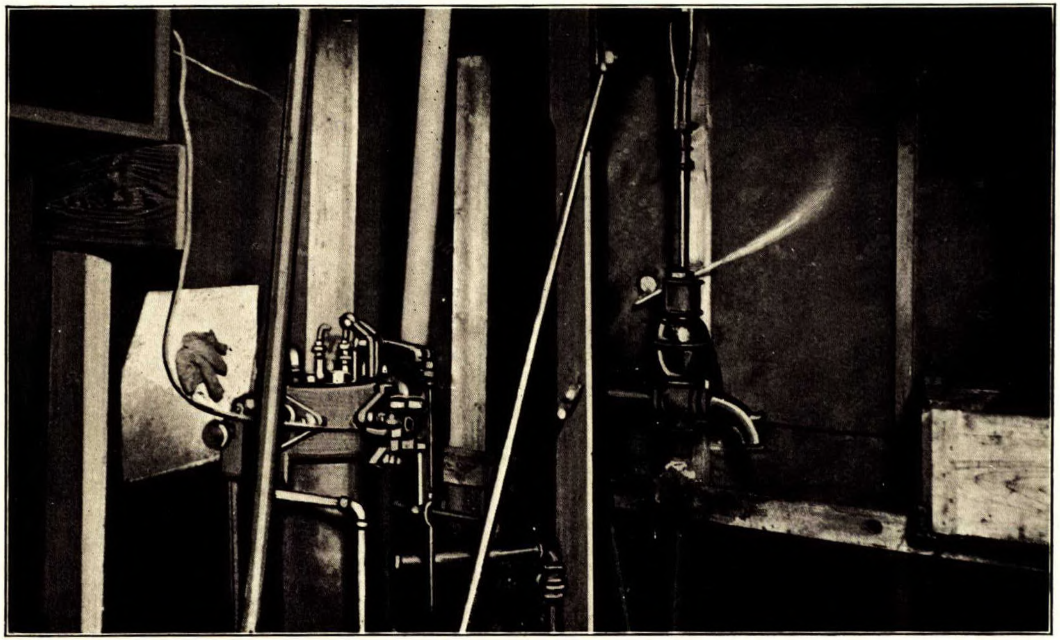
CENTRAL ALBERTA.

Water wells drilled at Vegreville some years ago, encountered more or less natural gas at a shallow depth, which fact led

PLATE XXVIII.



Contrivance for catching gas from water wells at Bruce, Alberta.



Gas from water well, Bruce, Alberta.

to the drilling of the present gas well by the town. Nine or ten water wells in the vicinity of Bruce, southwest of Tofield, show considerable gas derived from the Belly River shales, which underlie this district.

A gas spring is also reported to exude from the bottom of the valley of the Battle river near Wainwright, also having its source in the Belly River shale.

The fact that gas is found so generally at a shallow depth along the axis of the Battle River anticline between Vegreville and Wainwright, while not proof of its existence in large volumes at a great depth, yet is in line with similar occurrences in the Medicine Hat field, which led to the development of natural gas at that point and at Bow island, along the crest of a similar arch.

Gas was encountered in a water well drilled on Bernard de Nobblens' property at Aldersyde, south of Calgary, at a shallow depth, 300 feet.

SOUTHERN ALBERTA.

As stated above, the development of the gas field at Medicine Hat and Bow island was brought about by the finding of natural gas in shallow water wells at Langevin, Carlstadt, Medicine Hat, and at other points in the vicinity.

Salt Water Conditions.

NORTHERN ALBERTA.

In the wells drilled at Fort McKay, Fort McMurray and Pelican, a large body of salt and gypsum was shown to exist in the Devonian limestone. Several strong flows of brine were also encountered in these wells, occurring in rocks of Devonian age. No salt water was encountered in the Cretaceous sands and shales at Pelican, Athabaska, or Victoria. Several comparatively small flows of salt water were encountered in the Morinville and Edmonton wells.

While it is presumed that the trough of the great basin lying in western Alberta parallel to the Rockies will contain considerable salt water throughout the belt in which the formations reach their greatest depression, yet it is not known how far up the sides of the basin this body of salt water will extend. No wells have been drilled to sufficient depth to tap the principal porous sand beds; namely, the Niobrara and Cretaceous sands.

The Dakota and Niobrara sands at Moosejaw and Regina are apparently saturated with salt water, but owing to lack of drill tests, it is not known how far west in Alberta this body of salt water extends; nor is it known whether an intervening oil belt exists between Moosejaw and the Medicine Hat gas field.

No tests west of the Bow Island field have penetrated to a sufficient depth to determine the extent of the salt water saturation in the Dakota sand, with the exception of the well at Brooks station on the Canadian Pacific railway. This well encountered a large flow of salt water, in the salt sand below the Dakota, which was cased off. The well drilled at Taber struck a large flow of water, which flowed on the surface.

Presence of Known Oil and Gas Sands Underlying Alberta.

Throughout Alberta more or less gas is found in pockets in the shales and sands overlying the Niobrara formation. This is particularly true of the Belly River shales, which outcrop at the surface throughout a wide belt from the International Boundary along the Milk river, to Vegreville in eastern Alberta. Gas has also been found in the Pierre shales in small quantities by wells drilled at Morinville, Edmonton, Wetaskiwin and elsewhere. However, no oil and gas have been encountered in commercial quantities in sands lying above those of the Niobrara series. In view of the fact that the sand beds found in the upper Cretaceous measures are of a lenticular nature—not being continuous for great distances—it is not believed that they are of a nature to act as a reservoir for the accumulation of large quantities of either gas or oil. No continuous porous strata are found in the Belly River shale or in the Claggett formation lying above the Niobrara sands.

In view of the persistence of the sands of the Niobrara series and of the Dakota or tar sand which underly the greater part of Alberta, it is in these sands that the greatest probability exists for finding oil or gas in large quantities.

The upper part of the Niobrara formation has been found to consist of porous sand beds at Pelican, Athabaska, Victoria, Morinville, Vegreville, Medicine Hat and elsewhere. Considerable gas in commercial quantities has been encountered in this sand at Medicine Hat and Vegreville, and it is believed that it will prove of importance in the results of future drilling.

The Dakota or tar sand is the source from which exude the tar seepages along the Athabaska river, and in which the gas production in southern Alberta has been developed at Bow island. The Dakota sand has also been encountered in the gas well at Vegreville and that at Brooks station; and, in view of its great continuity, it is the horizon in which it is believed the greatest possibilities exist for the development of both oil and gas production in the province of Alberta.

Depths to Which Wells should be Carried in the Different Fields.

In the following table are shown the depths at which the Niobrara formation and also the Dakota sand have been encountered in wells already drilled, as well as the estimated depth at other localities where wells have not as yet been drilled, or where they were not continued to a sufficient depth to strike either one or both of these formations:—

Depths necessary to reach the Niobrara and Dakota Formations.

	Niobrara. Top (Feet)	Dakota. Top (Feet)
Pelican	00	750
Athabaska	985	1800
Morinville	2900(?)	3250
Nakamun (approx.)	3000	3300(approx.)
Edmonton	3000	3300 "
Tofield	2100	3000
Vegreville	1000	1900
Phillips	900	1800
Wainwright	800	1700
Innisfree	900	1800
Camrose (approx.)	3000	3700(approx.)
Wetaskiwin "	3600	4200 "
Castor	2100	3000
Calgary	5000	5900–6000
West of Okotoks (Dingman's well)	1600	2500
Macleod	2700	3600
Lethbridge	1600	2800
Bow island	1450	2200
Suffield	1260	2000
Brooks	1720	2600
Medicine Hat	1000	1850

Conditions Favourable for Gas Accumulation.

In order that natural gas may exist in any locality three conditions are necessary:—

1. A porous formation to hold the gas.
2. An impervious overlying formation to prevent it from escaping.
3. Suitable geological structures to form an accumulative reservoir for it.

GEOLOGICAL STRUCTURE.

When oil, gas and water exist in any porous stratum which is not perfectly flat, these substances separate according to their specific gravities. That is, water, being heaviest, settles into the syncline or basin where the sand is lowest; oil, being lighter, rests above the water; while gas, being volatile, occupies the upper portions of the stratum, including anticlines, domes and the upper edges of sandy lenses, unless under the pressure present it remains dissolved in the oil.

Longitudinal sections of these several structures are somewhat as shown in Figs. 31, 32, 33, 34, and 35. The question arises, do any of those geological structures exist in Alberta?

This may be answered in the affirmative. As has been stated on page 271 of this report, there exist three main anticlines or arches of the formations underlying Alberta. The first crosses the Athabaska river in the vicinity of Crooked rapids.

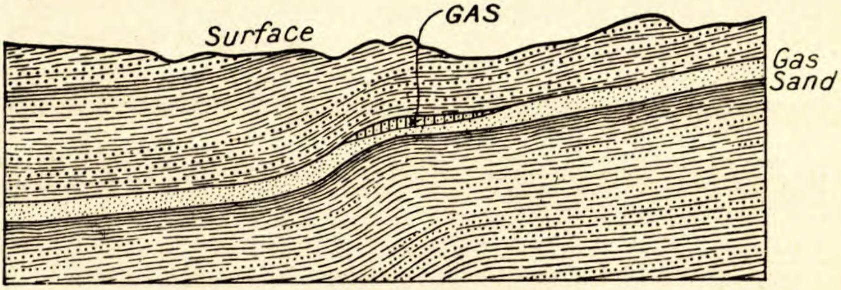


Fig. 31. Section through strata, showing example of gas accumulation on a structural terrace.

The second extends from Vegreville southeast to the intersection of the fourth meridian with the fifty-second parallel; and the third, in southern Alberta, extends from the Sweet Grass hills in Montana to the Bow river. (See Figs. 25, 26, and 30.) The most northerly and the most southerly of these arches have been tested successfully for gas. However, the anticline southeast of Vegreville has not as yet been drilled.

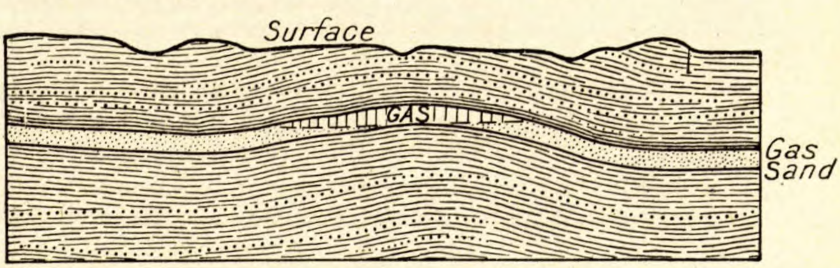


Fig. 32. Section through strata, showing example of gas accumulation on the crest of a structural dome.

Owing to the more complicated structure and the steeper dips which exist along the first range of foothills of the Rockies, it is believed that gas pools of relatively small extent will be developed in this region. The well being drilled by Mr. Dingman and associates, west of Okotoks, has already given evidence of the existence of gas in this vicinity. However, in view of the prevalence of faults and inclined structures along the

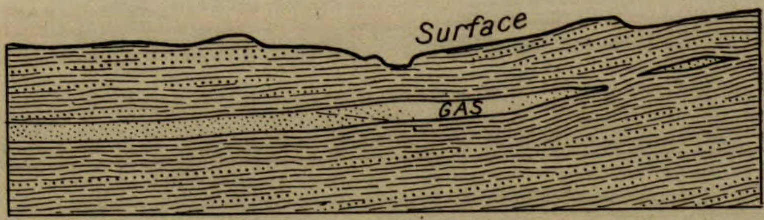


Fig. 33. Section through strata, showing example of gas accumulation in the upper portion of a sand stratum which plays out.

foothills, in general, the territory may be considered unfavourable for the existence of a large supply of natural gas.

Natural gas occurring along the upper edges of sandy lenses of which the gas at Wetaskiwin is probably an example, has not been found to be the source of long-lived pools. While

Fig. 34. Section through strata, showing example of gas accumulation on the crest of a structural anticline.

more or less gas will no doubt be found in different parts of Alberta having its source in such type of structure (see Fig. 33), yet, in general, such wells will be short-lived and have no great vitality. The principal gas fields of Central Alberta will be found to lie chiefly along the axis of the Battle river anticline, in the Niobrara and Dakota formations.

The crest of the northern arch, which crosses the Athabaska river at Crooked rapids, throughout the greater part

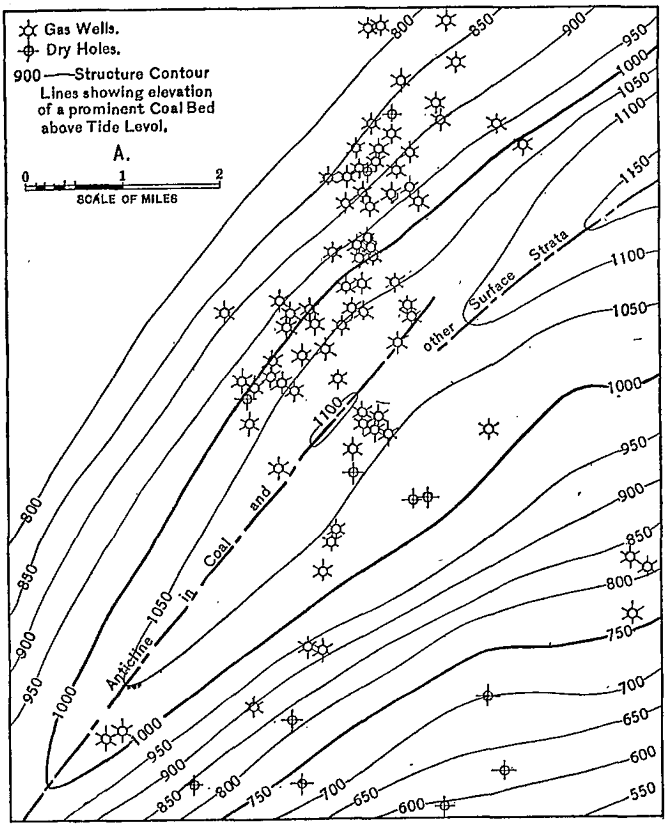


Fig. 35. Illustration of anticlinal gas field in Pennsylvania in which several sands are productive, showing lay and dip of surface strata, with position of all wells.

of its extent is not overlain by a sufficient thickness of impervious shale as to form a reservoir for large quantities of gas under great pressure; and, in view of the great distance from a market for any gas production which might be developed along this anticline, it can be disregarded as a source of a natural gas supply.

GEOLOGICAL CONDITIONS LACKING FOR GAS ACCUMULATION.

In general it may be said that no gas supply of importance can be developed within the great syncline of west central Alberta. However, in the intermediate zone between the three main anticlines described in the preceding paragraphs, and the sycline or depression above mentioned, minor structures favourable for gas accumulation undoubtedly exist, in which small gas pools will probably be developed from time to time.

Conditions Favourable for Oil Accumulation.

GEOLOGICAL STRUCTURE.

As stated in the preceding paragraph, when oil, gas and water exist in any porous strata which is not perfectly flat, these substances separate according to their specific gravity, except where the gas remains dissolved in the oil under pressure. The great trough or syncline, the axis of which extends in a general north-south direction through the western part of Alberta, forms a structural depression which has been found to be favourable for the accumulation of great quantities of oil and salt water in other fields throughout the world. Water, being heavier than oil, will settle into that syncline or basin where the sand is the lowest, while oil being lighter, will be found up the dip above the water. The quantity of water existing in the porous sands of the Niobrara and Dakota formations in this central Alberta basin cannot be conjectured, as no wells have ever been drilled to a sufficient depth to tap these sands, within the limits of this basin. In general, however, it may be said that the lower sands in the central part of this basin will probably be found saturated with water, while along the flanks of this water-saturated zone, oil pools will probably be found to exist.

Oil pools of lesser extent will also no doubt be developed in the disturbed region along the foothills of the Rockies, as is evidenced by seepages which occur in southeastern Alberta near South Kootenay Pass and elsewhere.

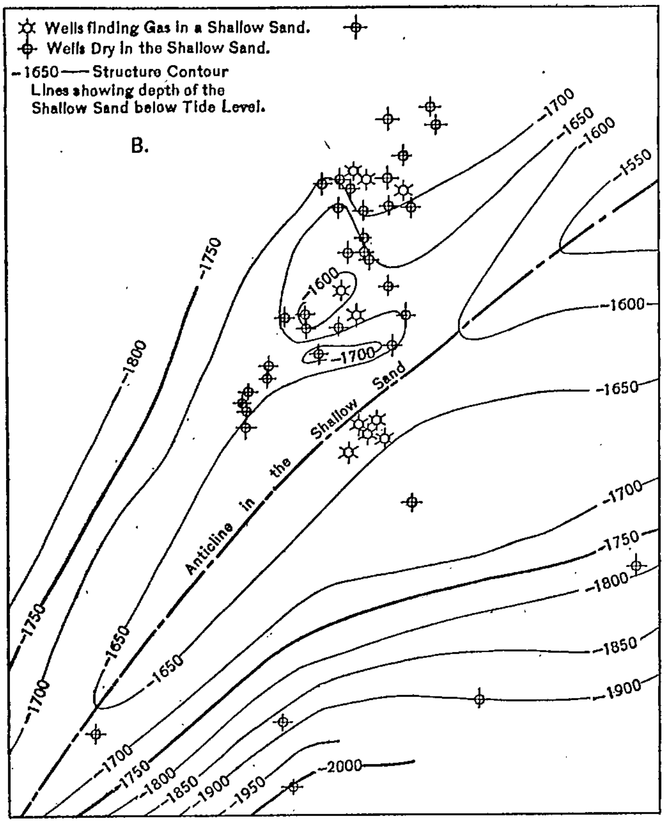


Fig. 36. Illustration of an anticlinal gas field in Pennsylvania in which several sands are productive, showing lay and dip of a shallow sand, with positions of wells drilled to it.

GEOLOGICAL CONDITIONS LACKING FOR OIL ACCUMULATION.

A number of wells have been drilled for oil throughout Alberta, many of which were located upon the evidence of pockets of tar sand, occurring at or near the surface. Others have been located apparently with no reason to justify them except the necessity of drilling a well somewhere as a basis for stock selling. In the first instance it may be said that most of these

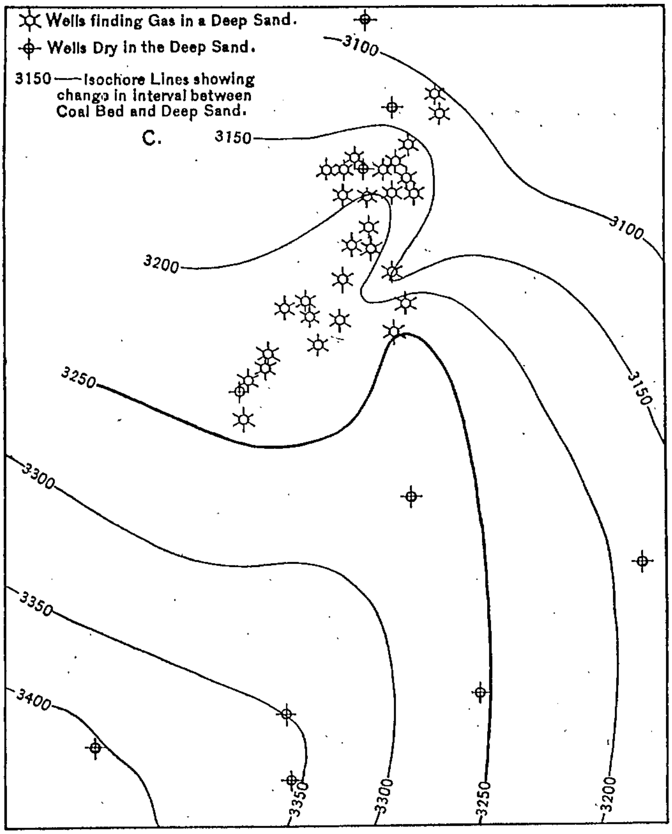


Fig. 37. Illustration of an anticlinal gas field in Pennsylvania in which several sands are productive. This is a convergence map used in calculating the lay of the deep sand for Figure 38, which follows.

small tar seepages or pockets of tar sand, are not, in any manner, proof of the existence of oil at a greater depth underlying the locality in which they occur. Various theories have been given to account for the existence of these isolated deposits of tar sand, but they have not as yet been studied or mapped in sufficient detail to warrant the acceptance of any of these theories. In the case of the occurrences of tar sand in the vicinity of Egg lake near Morinville, which Dawson accounted for as a dike

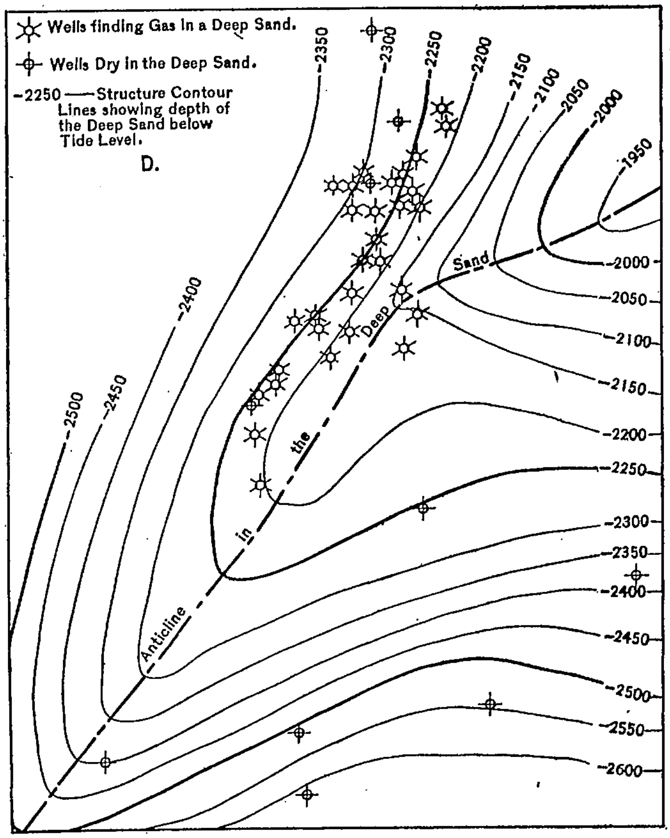


Fig. 38. Illustration of an anticlinal gas field in Pennsylvania, in which several sands are productive, showing lay and dip of a deep sand, with positions of wells drilled to it.

or seepage from an oil reservoir at a great depth, it may be said that this theory has been proved untenable by the drilling of two wells in the vicinity of this deposit, and by the lack of evidence of sufficient geological disturbance to make the fissure theory at all probable.

Existing Pipe Lines.

The Canadian Western Natural Gas, Light, Heat and Power Company during the year 1912 completed a 16″ pipe line for the transmission of gas from their wells in the Bow Island field to Calgary and fourteen towns en route.[1] This is the only pipe line at the present time in Alberta, and has a capacity of approximately 40,000,000 cubic feet per twenty-four hours, on the assumption that only 500 pounds pressure is utilized for transmission purposes, a pressure of 800 pounds being reported in the wells. The line was contracted for at the rate of $1.35 per foot for hauling, ditching, laying the line and re-filling. It was laid by two crews working from opposite ends with traction diggers and an average of 4000 feet of completed line per day per crew is reported have been accomplished. It is reported to have cost approximately $3,000,000 completed exclusive of branch distribution lines to towns en route. The main line is 160 miles in length. The company is controlled by the British Empire Trust Company, Limited, of London, England. The report of that company for 1912 shows that in that year the company drilled 17 wells, giving a daily production of 174,-300,000 cubic feet. Pipe lines aggregating 200 miles in length had been built and 5,000 consumers had been secured and supplied. The company had drilled up to that time 61 gas wells, only two of which had been non-productive. In the spring of 1913 thirteen wells were drawn from, and three were drilling.

Projected Pipe Line.

The city of Edmonton is contemplating securing a natural gas supply either as a municipal enterprise, or by contracting with a private company or individuals to bring gas from the Pelican gas field or from the field southeast of Vegreville. In the following tables are shown the comparative estimated cost of the pipe lines from each of these fields for the transmission of the gas supply for Edmonton.

[1] See Map No. 302.

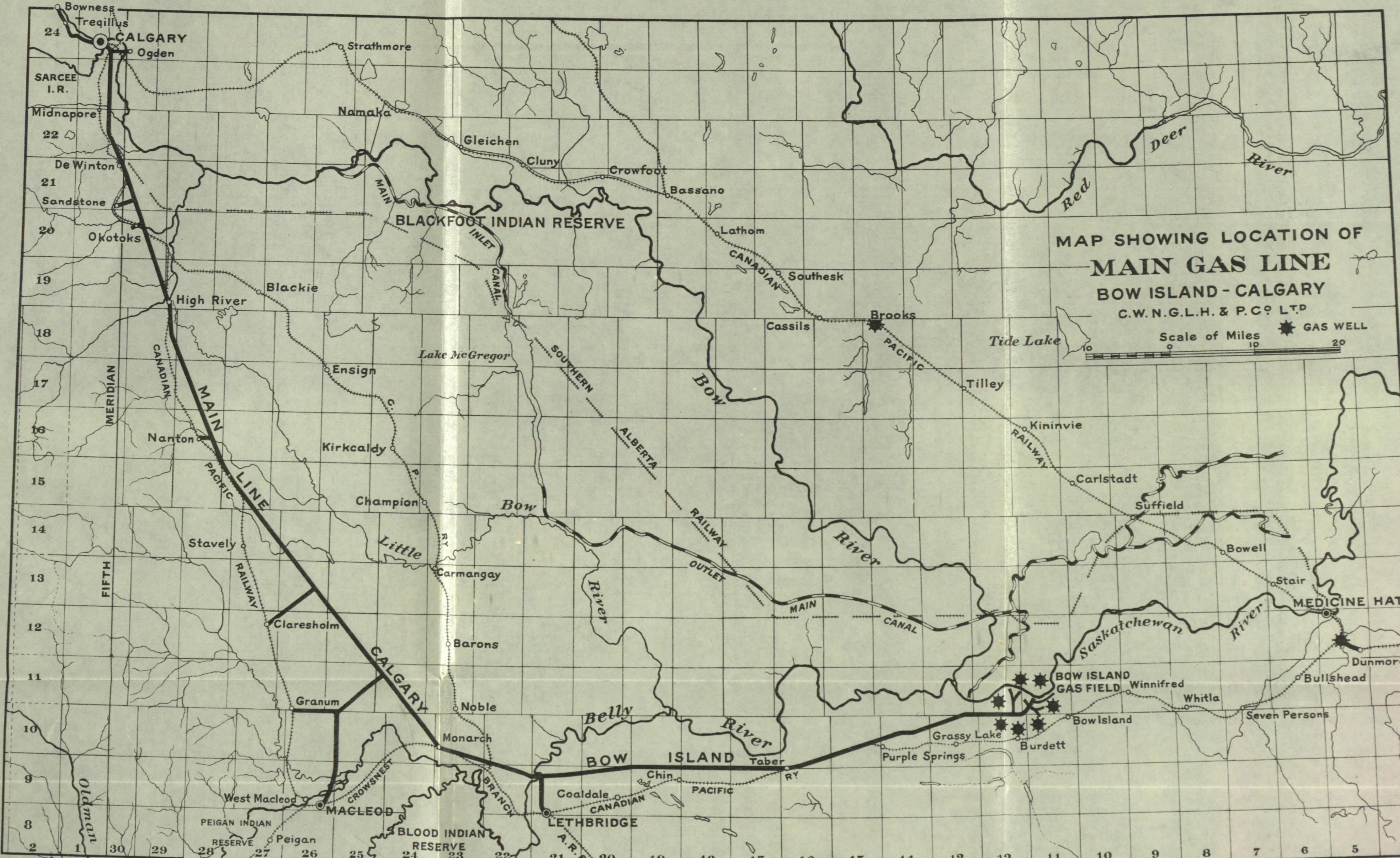
Canada

DEPARTMENT OF MINES

Hon. Louis Coderre, Minister, R.W. Brock, Deputy Minister.

MINES BRANCH

Eugene Haanel, Ph.D., Director



No. 302

To accompany report on "Petroleum and Natural Gas Resources of Canada" by Frederick G. Clapp and others.

ESTIMATED COST OF PIPE LINE TO EDMONTON FROM THE PELICAN FIELD.[1]

60 miles of 12″ 45-lb. pipe @ $1.59 per ft., f.o.b. Edmonton and Athabaska	$503,712.00
60 miles of 14″ 56-lb. pipe @ $2.62 per ft., f.o.b. Edmonton and Athabaska	830,016.00
60 miles of 16″ 64-lb. pipe @ $3.01 per ft., f.o.b. Edmonton and Athabaska	963,568.00
The average length of pipe is 25 feet; hence 12,672 couplings of each size will be necessary. Therefore—	
12,672 12″ Dresser couplings, 50 lb. @ $2.20, f.o.b. Bradford	27,878.40
12,672 14″ Dresser couplings, 63 lb. @ $3.02, f.o.b. Bradford	38,269.44
12,672 16″ Dresser couplings, 72 lb. @ $3.32, f.o.b. Bradford	42,071.04
Freight on couplings from Bradford, U. S. A. to Athabaska	70,297.90
Duty on importing pipe and couplings @ 7½%	102,445.00
Labour, ditching, etc. (50% added to figures in other fields): $3,225.00 per mile, 180 miles @ $3,225.00 per mile	580,500.00
Hauling: 90 miles @ $400.00 per mile; 90 miles @ $6,000.00	576,000.00
Right-of-way, 180 miles @ $300.00 per mile	54,000.00
Use of tools, 180 miles @ $100.00 per mile	18,000.00
Cement and cribbing (in swamps and river crossing)	65,000.00
	$3,871,767.78
Overhead charge and contractor's profit (10% of cost of labour and material)	387,176.78
Telephone line	20,000.00
	$4,279,944.56

ANNUAL OUTLAY ON ACCOUNT OF PIPE LINE FROM THE PELICAN FIELD.

Interest on pipe line investment at 5½%	$235,396.95
Depreciation on line (estimating life at 15 yrs.) 7%	298,896.12
Drilling, average of 10 wells per year, @ $25,000	250,000.00
Connecting with pipe line 10 wells @ $1,000.00	10,000.00
Offices, equipment, maintenance, salaries and repairs	30,000.00
Total	$814,293.07
Interest for 12 months @ 5½% on annual outlay	44,786.12
Total annual outlay	$859,079.19

ESTIMATED COST OF PIPE LINE TO EDMONTON FROM FIELD SOUTHEAST OF VEGREVILLE.

30 miles 8″ 20 lb. line pipe @ 55c. per foot, f.o.b. Pittsburgh	$87,120.00
30 miles 10″ 28-lb. line pipe @ 77c. per ft., f.o.b. Pittsburgh.	124,298.00
30 miles 12″ 36-lb. line pipe @ 90.75 per ft., f.o.b. Pittsburgh.	144,251.00

[1]The author, Mr. Clapp, is responsible for these estimates. The figures given in certain cases appear to be excessive under present conditions, especially with respect to the Pelican field. A.W.G.W.

6,336 8″ Dresser couplings @ $1.40, f.o.b. Bradford, Pa. ..	$ 8,870.40
6,336 10″ Dresser couplings, @ $1.80, f.o.b. Bradford, Pa. .	11,404.80
6,336 12″ Dresser couplings, @ $2.20, f.o.b. Bradford, Pa..	12,939.20
Freight @ $1.25 per cwt. on 12,686,000 pounds............	208,575.00
Duty at 7½% on pipe and couplings......................	44,884.38
Labour, ditching, etc., at $1,800.00 per mile...............	162,000.00
Right-of-way @ $200.00 per mile.......................	27,000.00
Use of tools @ $100.00 per mile.........................	9,000.00
Cement and cribbing in crossing swamps, streams, etc.......	10,000.00
Total..	$851,342.78
Overhead charge and contractor's profit (10% of the cost of of labour and material..............................	85,134.28
Telephone line..	10,000.00
Total..	$946,476.06

ANNUAL OUTLAY ON ACCOUNT OF THE PIPE LINE FROM THE FIELD SOUTHEAST OF VEGREVILLE.

Interest on pipe line investment @ 5½%..................	$52,056.18
Depreciation of line (estimating life at 15 years) 7%........	66,253.32
Drilling an average of 10 wells per year @ $16,000 each.....	160,000.00
Connecting with pipe line 10 wells @ $1,000 each...........	10,000.00
Offices, equipment, maintenance, salaries and repairs........	20,000.00
Total..	$398,309.50
Interest for 12 months @ 5½% on annual outlay............	16,957.02
Total annual outlay.............................	$325,266.52
Daily outlay..	888.40

In the following table, the comparative advantages of the two fields as a source of a natural supply for the city of Edmonton are summarized:—

Field.	Present pressure of gas in the field. Pounds per sq. inch.	Present volume of gas per well.	Probable life of the field.	Miles of pipe-line necessary.	Cost of pipe-line.	Necessary daily outlay account of pipe-line.	Price at which 10 million cu.ft of gas per day must be sold for 15 years to pay for pipe-line outlay.
Pelican	225	840,000 cu. ft.	4 years.	180	$4,280,000	$2,356.10	24c—45c
Vegreville and Southeast.	350	No wells in main field.	15 years.	90	946,500	888.40	9c

PRICES AND AMOUNTS OF GAS NECESSARY FROM EACH FIELD TO COVER DAILY OUTLAY ON ACCOUNT OF BRINGING GAS FROM IT.

Commenting upon the estimated price at which gas from the Pelican field must be sold in Edmonton to pay for the daily outlay on account of this pipe-line, as shown in the preceding table, it many be said in view of the probable short life of the Pelican field, the higher rate of 45 cents per thousand will probably apply. Adding to this the additional amount on account of an intra-urban distribution system, it is estimated that 10,000,000 cubic feet of gas have to be sold at 50 cents per thousand to cover this daily outlay. This 10,000,000 cubic feet per day is the estimated consumption of gas in Edmonton. As the consumption of gas per capita is largely determined by the price at which it is sold, the price of 50 cents per thousand cubic feet would limit the domestic consumption of the city to nearer 5,000,000 instead of 7,000,000 cubic feet per day; or a total consumption for city and domestic uses of 8,000,000 instead of 10,000,000 cubic feet. This proportion is determined by comparison with towns in Ontario where gas is sold at 45 cents and 25 cents per thousand in the same vicinity. In the first case, the consumption is 45 cubic feet per day per capita, and in the case of the 25 cent gas, it is 60 cubic feet per day. In the case of Edmonton, this decreased consumption in the city would necessitate a still higher price for the gas in order to pay expenses, because gas at this price is entirely out of the question for industrial purposes.

As a proposition has been made to the city of Edmonton to supply gas at the city limits at 15 cents per thousand cubic feet, it is appropriate to make an estimate on the basis of the foregoing figures as to the number of cubic feet of gas which must be sold at 15 cents per thousand to cover the daily outlay on account of piping gas from the different fields.

In the case of the Pelican field (Fig. 39) with an estimated daily outlay of $2,356.10 on account of pipe-line, there must be sold.............. 15,707,000 to 28,273,000 cu. ft. per day at 15c per 1000

The large quantity is contingent upon the probable life of the Pelican field being only four years, and assuming the necessity of installing compressor stations. Thus it will be nearer correct to consider that 28,273,000 cubic feet must be sold at 15 cents per thousand, to pay the expenses of a pipe-line.

In the case of the Southeastern field (Fig. 40), with a daily necessary outlay of $888.40 on account of pipe-line, there must be sold.............. 5,936,000 cu. ft. per day at 15c per 1000.

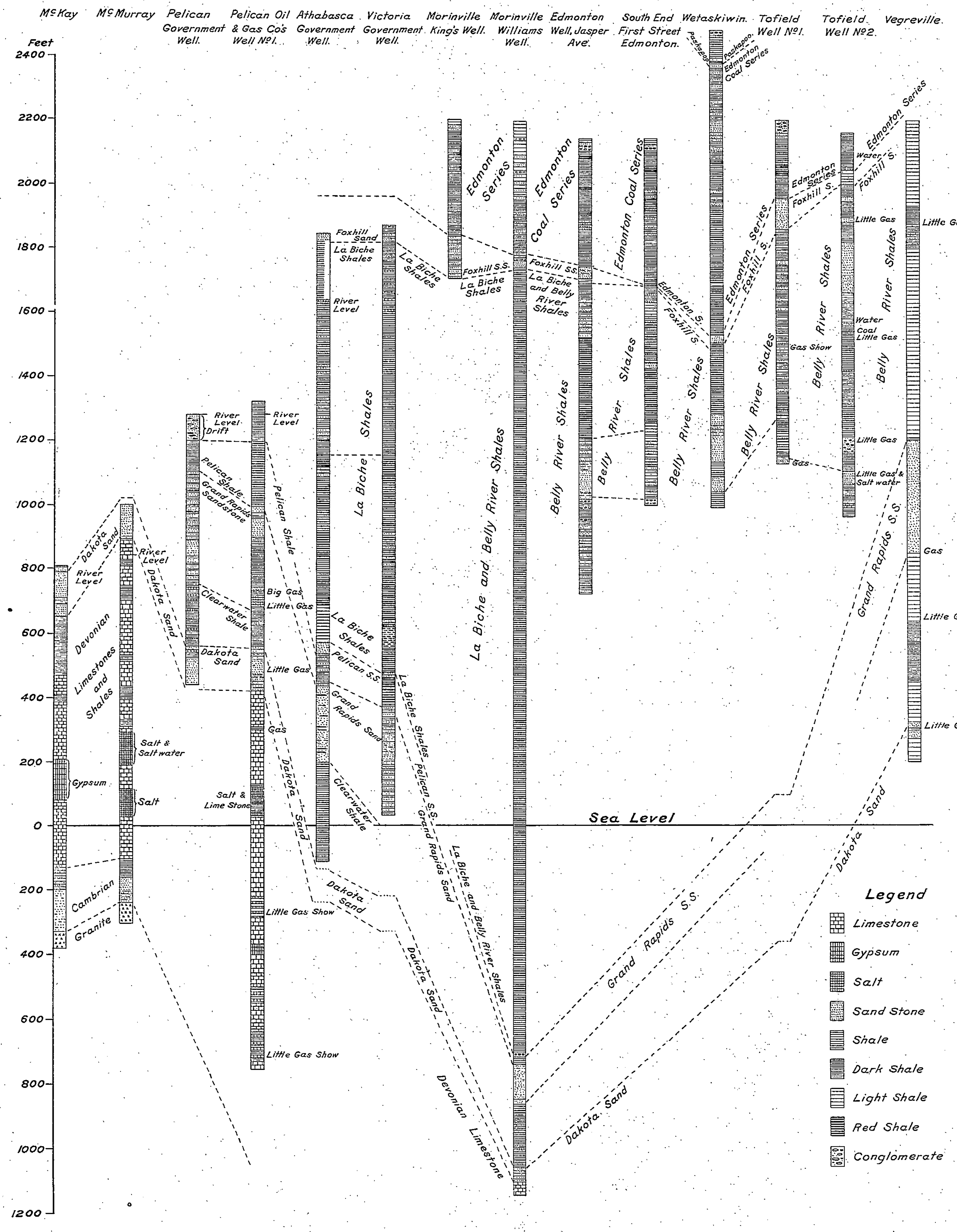


Fig. 39. Graphic section, well logs of Northern Alberta, showing strata passed through and their correlations. (By L. G. Huntley)

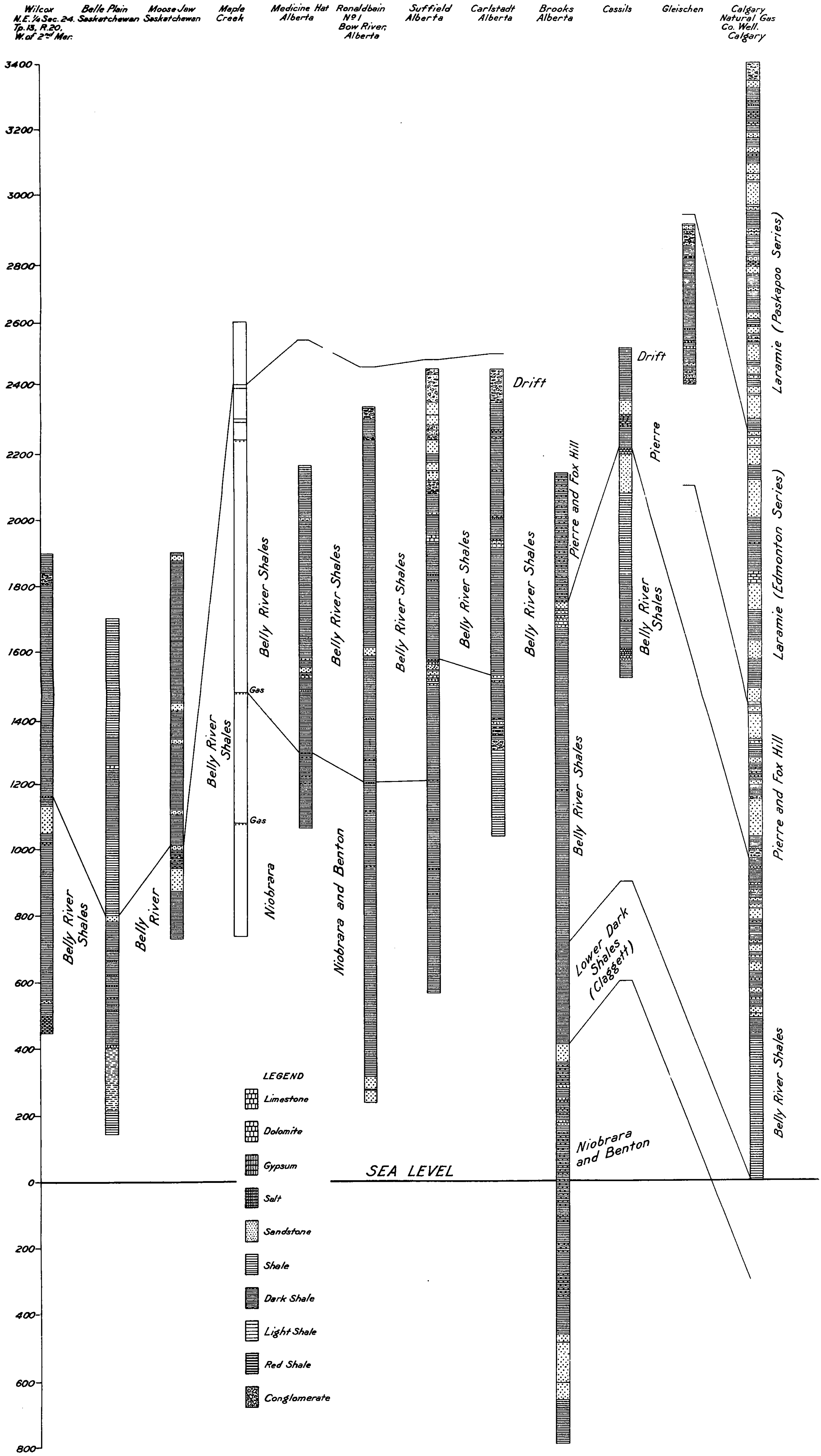


Fig. 40. Sections across Southern Alberta.
(By F. G. Clapp and L. G. Huntley)

Volumes and Pressures in the Different Gas Fields in Alberta.

Field.	Productive Formation.	Total Production (Nominal) Cubic Feet per Day.	Volume per well (Open Flow) Cubic Feet per Day (Initial Flow).	(Pounds) Closed Pressure per Square Inch.
Pelican	Dakota sand	860,000	840,000	225
Athabaska	Shale gas	....	....	Declining rapidly.
Vegreville	Niobrara	220,000	220,000	280
Bruce	Shale gas	In shallow	water wells	Gradually increasing.
Wetaskiwin	Pierre sands.	350,000	350,000	....
Camrose, Aug., '13	Drilling	....	....	....
Castor, Aug., '13	Drilling	....	....	....
Medicine Hat	Niobrara	25,000,000	500,000 to 4,000,000	550 to 600
Bow Island	Dakota sand.	50,000,000 to 60,000,000	1,500,000 to 28,000,000	700 to 800
Okotoks	Belly River shale.	900,000	900,000	Declining rapidly.
Irvine	Shale gas	Small show	....	....
Dunmore	Niobrara	....	2,000,000	590
Suffield	Niobrara	Small flow; well almost ruined	Reported 700,000	500
Redcliffe	Niobrara	Same as Medicine Hat wells.		
Carlstadt	Shale gas	Small flow used by railway.	....	....
Brooks	Dakota	350,000	Reported 500,000	590
Cassills	Shale gas	Small flow used by railway.	....	....
Bassano	Shale gas	Wells abandoned.	200,000 to 700,000 cu. ft. per day reported initially	....
Calgary	Small flow gas.	80,000	80,000	285
Taber	....	Small show gas.	....	96

Methods and Costs of Drilling in the Different Fields.

NORTHERN ALBERTA.

In that part of Alberta north of Athabaska, the great difficulty in drilling for oil and gas is found to be the cost and difficulty of transportation. Men and supplies are transported to the north from the end of the railway at Athabaska by means of scows in the summer time, and by wagon and dog sled over the ice in the winter. Several trips are made during the summer months from Athabaska to Grand Rapids by a Hudson Bay Company steamer, but beyond Grand Rapids all transportation is by the primitive means mentioned.

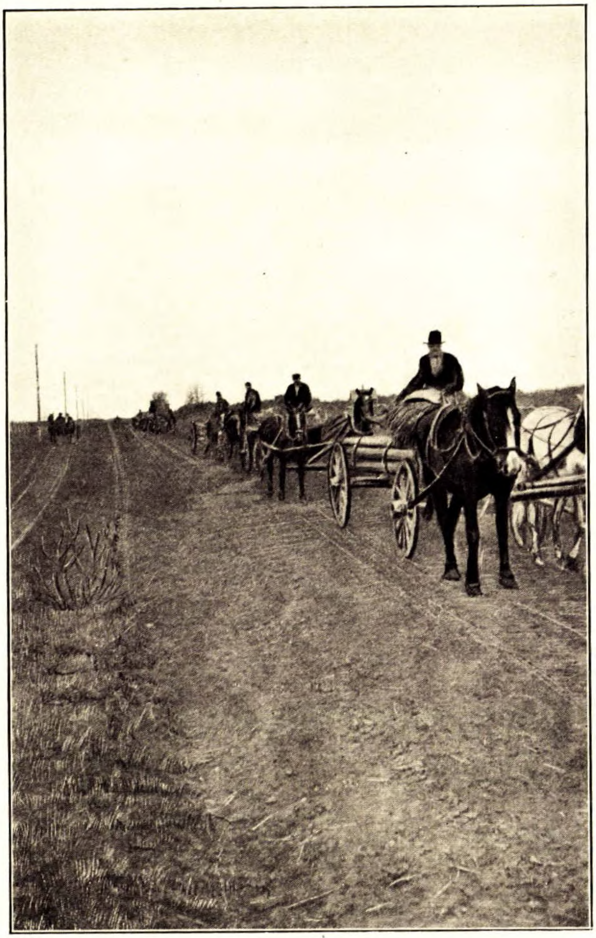
The cost of hauling supplies to Pelican rapids is $2.25 per one hundred pounds. All supplies and drilling outfits which are sent to any point farther north than Pelican are sent by the operating companies for their own account.

In the vicinity of Fort McKay one standard California rig was in use, together with a standard Canadian rig, and another make-shift three-pole derrick. The holes drilled are located near Fort McKay, Fort McMurray and vicinity, and required approximately one season to complete. The hole drilled by the Northern Explorations Company at Fort McMurray was put down by means of a Canadian standard rig with a 56 foot derrick, using Canadian drillers from Ontario.

At Pelican it is reported that in the summer of 1912, the hole being drilled by the Calhoun Oil Company had cost approximately $25,000, at a depth of 1,400 feet. During the summer of 1913, the hole had reached the depth of approximately 2,100 feet, having a 6 inch hole at that point. A California standard cable rig was being used with a 72 foot derrick. The drillers employed by the Calhoun Oil Company, and later by its successor, the Pelican Oil and Gas Company, were brought from the California oil field.

The wells drilled by the Geological Survey for the government at Pelican, Athabaska and Victoria were drilled by the old spring pole method, and the casing used was of such small diameter that great difficulty was experienced in continu-

Hauling boiler from Edmonton to Athabaska, Alberta, 1911.



Hauling casing from Edmonton to Athabaska, Alberta, 1911.

ing the holes to sufficient depths. All wells drilled in northern Alberta have been on oil claims denounced upon government land. No contract drilling has been done in that part of Alberta, although one of the leading contracting companies in Alberta has quoted a tentative price of $12 per foot for drilling north of Athabaska.

Past experience has indicated that it will take the entire season to drill one well along the Athabaska river.

CENTRAL ALBERTA.

In general all the wells drilled throughout central Alberta have been by means of standard California cable rigs using American drillers and methods. An 84 foot derrick is used, reinforced by having an extra 8 × 8 piece bolted up the inside of each leg, the derrick having a 24 foot base.

It is frequently found necessary to brace the derricks with guy lines, in order to guard against the high winds which frequently prevail on the prairie.

American casing is used throughout central Alberta, although it has given some trouble by parting, due to the long heavy strings which it is necessary to use. A great deal of under-reaming is necessary at some places, due to the caving character of the formations, especially in the Claggett and Benton formations. However, in the well drilled at Wetaskiwin by the Northwest Drilling Company, it was found possible to keep from 200 to 250 feet ahead of the pipe at all times with the drill.

No. 1 well at Tofield was drilled by the day, work commencing during the summer of 1911, the well being completed on June 20, 1913. The record of the casing used is as follows:—

1048 feet 8″ × $6\frac{1}{4}$″ 17 lb. Inserted Pipe.
331 feet $11\frac{5}{8}$″ Collar Pipe.
631 feet $9\frac{5}{8}$″ Collar Pipe.
940 feet $7\frac{5}{8}$″ Collar Pipe.

A standard American rig was used with Manila cable to 240 feet, and a wire line for the balance. The under-reamer split the $6\frac{1}{4}$″ casing, allowing gas to escape through the $7\frac{5}{8}$″

casing, and probably admitting water to the gas formation, which was flooded.

Well No. 2 at Tofield was drilled by contract to a depth of approximately 1,200 feet for a price of $9.50 per foot. This well was started during the fall of 1911, and was completed in the spring of 1912, being drilled by the Northwest Drilling Company.

Well No. 3 at Tofield, which commenced drilling in April 1912, was being drilled by Mr. Geo. Peat, of Petrolia, Ontario, for a price of $7.50 per foot.

The gas well at Vegreville was drilled by the Northwest Drilling Company of Calgary, to a depth of 2,000 feet at $9 per foot.

The gas well at Wetaskiwin was taken over by the Northwest Drilling Company from Mr. Grant at a depth of approximately 700 feet, and it is reported that the contract price for drilling was $10 per foot. A liner was used in this well, perforated at all gas pays. This extended from a depth of 1,100 feet to the bottom of the hole, being 398 feet long.

A well was being drilled during the summer of 1912 on the farm of Mr. Chamberlain, two miles southeast of Edmonton. It is stated that the intention is to drill through the Dakota sand, and a light weight rotary rig is being used for drilling purposes by a contractor from the Texas oil fields in the United States. At a depth of 150 feet, 8 inch casing was being used, making it extremely improbable that this hole will ever reach a sufficient depth to test the Dakota sand.

A well was being drilled for the town of Castor by the Northwest Drilling Company during the summer of 1913. The contract price is reported to be $10 per foot. This well was started in the fall of 1912, and had reached a depth of 1,400 feet in August, 1913. Trouble was encountered in a black sand at a depth of 700 feet, and later the casing parted causing more trouble, which accounts for the delay in drilling this hole.

Wells in the Bow Island field are reported to cost about an average of $16,000 each when completed. The cost is in excess of this for wells drilled on the prairie, above the river level, which means an additional 250 feet or 300 feet in depth. The wells are drilled for the Western Canadian Natural Gas, Light, Heat and Power Company by the Northwest Drilling Company of Calgary, reported to be a subsidiary of the first-named company. Owing to the great weight of the long strings of casing used in this hole, trouble was experienced with American casing, which frequently stripped the threads or buckled. German inserted weldless casing was next tried, and after becoming accustomed to its use, it was found to be much superior for the necessities of the Bow Island field, and, according to Mr. Coste, is being used exclusively at the present time. California rigs with 84 foot derricks are used, with reinforced corners, and all derricks guyed against the wind pressure. The casing is cemented on top of the gas sand, while all intermediate flows of gas or water are allowed to escape at the surface around the outside of the casing. Most of the land in the Bow Island district is leased by the above named company, although a few leases are held by other parties. The average haul from the railway to wells in the Bow Island field is approximately six miles. Hauling is all done by the company's teams. Owing to the difficulty and delay in obtaining spare parts for replacing broken tools, a large stock of such extra parts and tools is kept on hand in the Bow Island field. Wells are spaced approximately one mile apart. In the Bow Island field drilling twenty feet per day is considered good work. Medicine Hat wells are said to cost from $4,700 to $8,000 completed, ready to use, depending upon the diameter, and delays of various sorts. Wells drilled off the railway are said to average $25,000 apiece to drill to the Dakota sand. The well drilled by the railway at Brooks station to a depth of about 2,700 feet cost in the neighbourhood of $40,000. However, the wells in the Bow Island field are said to have averaged $16,000 apiece to put to producing. This represents the cost to the company, including derrick, which costs $2,000 in that district.

The well drilled by the Southern Alberta Land Company at 14 miles northwest of Bow island at their town site, was started in June, 1911, and finished in March, 1912.

A driller unaccustomed to the field can safely calculate upon a year's time to complete his first well, provided he is drilling a wildcat. It costs $1,000 per month to drill, while tools and rig alone cost $6,000. Drillers get $150 and tool dressers $100 per month to drill, with board. Two bull wheels are used, the second one being for pipe.

Natural gas is used as fuel for drilling, and is pumped from the river in some instances for two or three miles. Five strings of casing are used, namely 20″, 13″, 10″, 8″ and 6″. The 6″ casing goes to the top of the gas sand. One well had 1,640 feet of 8″ casing, representing a weight of 22 tons, and was still going.

The first wells in that field were started with fifty feet or so of 18″ casing; about 600 feet of 13″ casing, 1,100 feet of 10″; 1,600 feet of 8″ and 1,900 feet of 6″ seventeen pound casing. Considerable difficulty is experienced in drilling through the lower dark shales of the Claggett formation, which cave badly. The contractor supplies the derrick and rig, while the company supplies the pipe and water. The caprock above the gas sand in the Bow Island field is from 15 to 20 feet thick, a grey pebbly material which is believed to correspond with the Dakota limestone.

In the Medicine Hat field all wells are drilled by contract, one contractor quoting the following prices for drilling:—

$7.25 for 10″ hole from 1,000 to 3,100 feet deep.
$6.50 for 6″ hole from 1,000 to 1,300 feet deep.

The principal size of casing used in the Medicine Hat field are 20″, 16″, 12½″ 59 pound; and 10″ 35 pound. Most of the wells are finished with a 10″ hole at from 900 to 1000 feet in depth. The gas rock is twenty feet thick and the casing is set in an 18″ caprock of lime shell.

American rigs are used with methods similar to those at Bow island. However, owing to the lesser depth of the wells in the Medicine Hat field, derricks are not reinforced for handling the heavy strings of pipe necessary in the former field. Several steel derricks are being used by contractors in the vicinity of Medicine Hat, and are reported to give satisfaction.

The Canadian Pacific railway uses natural gas for lighting its passenger trains between Medicine Hat and Kootenay Landing. The gas is bottled in steel flasks 8″ in diameter and 30 feet in length, under a pressure of 170 pounds. Pintsch gas is used on all the divisions but in Medicine Hat they are restocked with natural gas from the gas well in the railway yard. The same apparatus is used, the cars being charged by a Chapman Fuller regulator from 600 pound well pressure, to 150 pounds. The Pintsch incandescent mantle and equipment is used, no change being found necessary, the only appliances required in charging being a pipe line from the well to the coach yard, and a connecting hose to the gas tanks on the cars. One man is said to be able to charge a train to its full capacity in twenty minutes. The first test was made in 1908, at which time a car ran lighted continuously for thirty-nine hours on one charge.

An especially constructed drilling machine has been built for prospecting purposes in southern Alberta by the Northwest Drilling Company. A well was drilled with this machine at the old pumping station of the railway, ten miles south of Suffield, during the early part of 1913. The machine is built to go a depth of 2,000 feet.

The wells are not shot in either the Bow Island or the Medicine Hat gas field. No dry holes had been drilled in the Bow Island field up to the fall of 1913. One well encountered a small flow of water in the first sand which was cased off, and Mr. Coste reports that the well obtained from 4½ to 5 million cubic feet of gas in the second sand. Most of the other wells are entirely dry in this field, and about fifteen square miles are reported to have been tested.

A well drilled at Lethbridge by the Light and Heat Company during 1907-8 is reported to have cost $10,000 including everything for the first 1,500 feet. This well was taken over by the city when the money of the company ran out.

A well was drilled a few years ago at Dunmore Junction, three miles west of Medicine Hat, by the Canadian Pacific railway, under the direction of Mr. Eugene Coste. A light rotary rig was used, probably not being sufficiently heavy for the formations in this district. Considerable delay was experienced and it was decided that the rotary was unsuitable for drilling in the formations in Alberta. However, the rig used at Dunmore was entirely too light for the purpose, and the crew was apparently unaccustomed to its use in the formations encountered.

Several borings were made two years ago at Kipp station a few hundred feet deep. A rotary core drill was used in a hole drilled during 1910-11-12. The hole was finally abandoned, due to an accident to the casing, which tipped sideways and was lost. No. 1 well was drilled by the city of Taber, while No. 2 was drilled by the Sullivan Drilling Company, of Chicago. A crooked hole was drilled at Suffield, and in an endeavor to straighten it, the casing dropped and buckled, and it was found impossible to cement the water off.

A diamond drill hole was put down within the city limits of Calgary about twenty years ago, to a depth of 1,426 feet. The recent holes drilled at Calgary, and in the Sarcee Indian Reserve, were drilled by means of American cable rigs. In the latter hole, the rocks were found greatly inclined, folded and crushed, and much trouble was experienced with a crooked hole. It was, however, continued to a depth of 3,365 feet.

In the vicinity of Waterton lake and South Kootenay pass, in southwestern Alberta, practically all the different methods of drilling have been tested. A number of standard American rigs with 72 foot derricks have been used. Canadian standard cable rig and Canadian pole-tool system have also been used. Several steel derricks have also been used in the drilling of wells in this district. The deepest well in the district, that of the Western Oil, Coal and Coke Company at Waterton lake, was drilled to a depth of approximately 1,900 feet, by means of a pole-tool rig. Several other deep wells in the district have also been drilled by pole-tools, which is claimed to be the preferable system, on account of the highly inclined dolomites which are drilled through. It is claimed that the pole-tool system gives a more positive rotation of the drilling bit than the cable system, and insures a straighter hole than can be obtained by cable tools in the Pincher Creek district. Most of the wells were drilled by contract at an average price of $7.50 per foot in depth. It is estimated that the wells in this district cost approximately $10 per foot completed, including everything. The company furnishes pipe and fuel, while the contractor furnished derrick, tools and labour.

The Lineham well at Oil City, 1,020 feet deep, was drilled in less time than two months. Pole-tools were used in drilling this well, and also in drilling the 1,400 foot well one mile below Oil City on the Lineham lease. However, the 1,900 foot well drilled at Waterton lake required several years, on account of the trouble with caving formations and a prolonged fishing job.

Prices and Markets for Natural Gas.

The Canadian Western Natural Gas, Light, Heat and Power Company has contracts with Calgary and other towns along the route of their pipe line from the Bow Island field, to sell gas at 35 cents per thousand cubic feet for domestic use, and 20 cents per thousand for industrial purposes.

The town of Medicine Hat has drilled a number of wells for gas, turning them over to industrial plants free of charge, for fuel purposes. The city has also drilled, and is operating a number of gas wells, selling gas for industrial purposes at a rate of 5 cents per thousand cubic feet, and for domestic purposes for 15 cents per thousand. Prior to 1912 a number of contracts had been made with factories to furnish gas free of cost for a five-year period, in order to induce such companies to locate in the city. While this was apparently a short sighted policy on the part of the city, yet they claim that it was only by this means that they could secure for the city the benefits of the natural gas supply from the underlying formations, asserting that if they did not sell gas at a very low rate, gas companies would drain the natural gas away and it would be lost to the city. However, it is understood that the city has taken means to prevent waste, and is making no more contracts for giving away gas. Other wells drilled in southern Alberta have all been drilled either by the Canadian Pacific railway at their town sites, by the Southern Alberta Land Company on their town site, or by municipalities endeavouring to secure a gas supply for local use.

In central Alberta, several companies have made proposals to the city of Edmonton for supplying natural gas, either from the Pelican field 180 miles north, or from the probable field southeast of Vegreville. The proposed prices range from 15 cents to 27, but as the city is still debating the advisability of taking up the production and the distribution of natural gas as a municipal enterprise, nothing has yet been done in the way of drilling wells.

The wells at Vegreville and Wetaskiwin are used for fuel purposes at the municipal power plants. The gas from the old government well at Pelican, which has been leased by the Pelican Oil and Gas Company from the government, is being used for fuel for drilling purposes by the above company.

Quality of Gas and Oil in Alberta.

The gas which has been found in northern and southern Alberta would not yield gasoline by the usual process of compression. However, the gas encountered in the Dingman well on the MacDougal ranch west of Okotoks is reported to contain one gallon of gasoline per one thousand cubic feet of gas.

The following is an analysis made by the Pittsburgh Testing Laboratory of a sample of gas taken by the writer early in August, 1913:—

Analysis of Natural Gas from Alberta.

	Per Cent.
Carbon dioxide	None
Oxygen	·14
Methane	98·55
Nitrogen	1·41
Total	100·10

The following is also given by the California-Alberta Oil Company of gas taken from a small flow encountered in their well at Morinville:—

Analysis of Natural Gas from Morinville, Alberta.

	Per Cent.
Sulphuretted hydrogen	0·0
Carbonic acid	0·0
Illuminants	0·1
Oxygen	0·5
Carbon monoxide (?)	0·3
Hydrogen (?)	8·7
Methane	90·2
Nitrogen	0·2
Total	100·0

The foregoing analyses show that the central Alberta gas is somewhat superior in heating value to gas from the Bow Island field in southern Alberta, as given below:—

Analysis of Natural Gas from Central Alberta.

	Per Cent.
Carbon dioxide CO_2	0·00
Carbon monoxide CO	0·00
Oxygen	0·10
Heavy hydrocarbons	1·80
Methane	86·70
Hydrogen (?)	5·40
Nitrogen	6·00
Total	100·00

The gas in central Alberta resembles that encountered in the Caddo field in northern Louisiana. Its composition is also very similar to that found in the Ontario peninsula. Analyses of these gases are given below:—

Comparative Analyses of Natural Gas from Louisiana and Ontario.

	Caddo-Louisiana Per cent.	Pt. Albino, Ontario Per cent.
Methane (CH_4)	95·00	96·57
Nitrogen	2·56	2·69
Carbon dioxide (CO_2)	2·43	None
Sulphur	0·01	0·74
	100·00 (980 B.T.U's per cubic foot)	100·00 (974 B.T.U's per cubic foot),

Analysis of the gas at Medicine Hat shows it to be composed almost entirely of methane (CH_4), and the following table shows its relative heating power:—

Comparative heating power of Medicine Hat and other gases.

	B.T.U.
Medicine Hat gas	1100
West Virginia	1145
Ohio and Indiana	1095
Kansas	1100
Coal gas	755
Water gas	350
Producer gas	155

Given below are copies of various analyses of samples of heavy oil taken from the wells of the Athabaska Oils, Limited, nine miles north of Fort McKay in northern Alberta. These analyses are furnished by Mr. James D. Tait of the above company.

Analysis of oil from Well No. 1 of the Athabaska Oils, Limited, nine miles north of Fort McKay.

	Per cent.
Water approximately	5
Light oil distilling over up to 150° Centigrade	None
Illuminating oils from 150° to 300° Centigrade	15
Residue	70

F. G. Wait, Chemist, Mines Branch, Department of Mines, Ottawa.

Analysis of oil from No. 2 well at Athabaska Oils, Limited.

Analysis made by Falkenberg at Laucks, Vancouver.

	Per cent.
Specific gravity	1·02
Distillation made from the water—free sample	
Gasoline and naphtha to 150° Centigrade	7·1
Kerosene 150° to 300° Centigrade	60·1
Base fixed at 300° (asphaltum)	32·8

Analysis by the Government Laboratory at Victoria, Dec. 20, 1912.

	Per cent.
Gravity 14·5° Baumé equal to specific gravity	0·970
Specific gravity of oil between 150° to 300° C	·892
Distillates below 150° C	2·00
Distillates between 150° and 300° C	70·00
Distillates between 300° and 350° C	5·00
Residue	23·00

Herbert Carmichael, Government Analyst.

Analysis of oil from No. 1 well.

Analysis made by Price and Sons of San Francisco.
11·20 per cent 48° Baumé.
6·60 per cent 42° Baumé.
11·20 per cent lubricating oil.
72 per cent asphaltum.

An analysis by Dr. Hoffman of a sample of the tar impregnated sand along the Athabaska river is given below. These sands were being investigated by an expedition headed by Mr. Sydney Ells, of the Mines Branch, Department of Mines, during the summer of 1913.[1]

[1]The analyses of samples collected by Mr. Ells in 1913 appear in his report on the Tar Sands of the Athabaska river, published by the Mines Branch in 1914.

Analysis by Dr. Hoffman of sample collected by Dr. Bell.

	Per cent.
Bitumen	12·42
Water (mechanically mixed)	5·85
Siliceous sands	81·73
Total	100·00

The following analyses are reported of samples of oil from the Lineham wells at the Oil creek, in the South Kootenay Pass district:—

Analysis by Arthur D. Little, Inc. Boston, Mass.

	Per cent.
Below 150°C. Light oils	5·1
150–300°C. Illuminating oils	41·0
300–340°C. Lubricating oils	41·1
Paraffine, residue and loss	9·7
Total	96·9

Analysis by Dr. Ellis, Toronto University.

	Per cent.
Light at 150°C. naptha, etc., sp. g. 0·77–52°B	5·7
Illuminating oils 150–300°C. sp. g. 0·82–41°B	56·3
Lubricating oils over 300° sp. g. 0·86	35·6
Residue, tar and coke	2·16
Total	99·76

Logs of wells in Alberta.

Product—Gas.
Authority—Geol. Survey Canada, Memoir 29–E, p. 90.
Province—Alberta, Canada.
Date—1912.
Location—1912.

Gas is reported to have been struck in 1912, at a depth of 1,050 feet about the top of the Belly River formation. The bottom of the Edmonton formation lies at a depth of about 260 feet, at which point some coal was struck.

Authority—Geol. Survey Canada, Memoir 29–E, pp. 89–90.
Drillers—Sullivan Machine Co.
Location—Taber, Alberta, Canada.
Date—1912.

	Top Feet	Bottom Feet
Sandy clay and small boulders		41
Gravel and small boulders	41	51
Shale and sandstone	51	71
Shale and bands limestone	71	93
Taber coal seam at 90 feet		
Dark shale	95	104
Sandstone	104	106
Shale	106	109
Shaly sandstone	109	111
Shale	111	125
Sandstone	125	130
Mixed limestone and sandstone	130	135
Dark shale	135	145
Sandstone	145	149
Shale	149	160

	Top Feet	*Bottom Feet*
Mixed sandstone and shale	160	184
Shale	184	190
Sandstone	190	195
Shale	195	214
Sandstone	214	271
Shale	271	273
Dark shale	273	276
Sandy shale	276	308
Mixed shale and sandstone	308	320
Black shale	320	330
Mixed shale and sandstone	330	337
Shale	337	373, 6"
Shaly coal	373, 6"	374
Shale	374	376, 4"
Coal	376, 4"	377
Dark shale	377	378
Mixed sandstone and shale	378	395
Mixed black slate and coal	395	396, 10"
Shale	398, 10"	405
Limestone	405	405, 6"
Sandstone	405, 6"	411
Shale	411	591
Sandy shale	591	602
Conglomerate	602	604
Sandy shale	604	608
Sandstone	608	627, 2"
Fireclay	627, 2"	627, 3"
Dark shale	627, 3"	635
Sandstone	635	642
Shale	642	646
Sandy shale	646	658
Sandstone	658	670
Fireclay	670	673
Coal	673	673, 3"
Sandstone	673, 3"	744
Light shale	744	744, 6"
Sandstone	744, 6"	810
Mixed sandstone and shale	810	838
Shale	838	905
Shale with sandstone partings	905	930

The above is the depth reached in July, 1912, and operations were being continued.

Product—Gas.
Owner—Canadian Pacific Railway Company.
Location—Medicine Hat, Alberta, Canada.
Authority—Geol. Survey Canada, Memoir 29–E, p. 82.

	Top Feet	*Bottom Feet*
Gravel and sand		37
Shale	37	166
Sandstone	166	183
Sand shale	183	200
Sandstone and shale mixed	200	243
Shale	243	290
Sandstone	290	318
Sand shale	318	660
Struck gas and salt water		177

Struck gas 558, 642, 651.

Product—Gas.
Location—Cassills, Alberta, Canada.
Authority—Geol. Survey Canada, Memoir 29–E, p. 74.
Elevation—2493.

Dark clay loam	2		Drift—52
Yellow clay	10		
Blue clay	40		
Blue shale	110	52	(Pierre) 242
Grey shale	38		
Drab sand rock	3		
Blue shale	85		
Brown shale	6		

Coal	2	(Belly River) 706 (gas)	
Grey shale	134		
Brown sand rock	3		
Black shale	257		
Grey shale	135		
Brown sand rock	5		
Blue shale	85		
Grey sandy shale	40		
Grey shale	45		
Total			1000

Product—Gas.
Owner—Canadian Pacific Railway Co.
Sec. SE¼ 33-18-14 West 4th Meridian.
Authority—Geol. Survey Canada, Memoir 29–E. p. 71.
Location—Brooks, Alherta, Canada.

	Top Feet	*Bottom Feet*	
Sandy clay with sandstone		386	Pierre-Foxhill.
Sandstone and two coal seams	(494 and 540)		
Shale, grey	386	1420	Belly River
Dark shale	1420	1725	Lower dark shales (Claggett)
Sandstone, fine	1725	1775	Eagle.
Sandy shale and dark grey shale	1775	2590	Niohrara-Benton.
Sandstone	2590	2795	Dakota.

(Flow of ahout 20,000 cuhic feet of gas per day).

Authority—Geol. Survey Canada, Memoir 29–E, p. 77.
Location—Gleichen, Alherta, Canada.
Elevation—2926.

	Top Feet	*Bottom Feet*
Sand and clay		8
Quicksand	8	28
Blue clay, with gravel and boulders	28	67
Black sand	67	78
Blue clay	78	100
Cement gravel	100	115
Soapstone	115	155
White sand, small flow water	155	160
Soapstone	160	254
Black sand	254	261
Loose soapstone	261	335
White lime	335	338
Black shale	338	378
Putty rock	378	390
Lime and loose shale	390	400
Soapstone	400	435
Sand rock	435	444
Black shale	444	464
Gravel soapstone with sand and water	464	502

Owner—W. Can. Coal Mng. Co.
Sec. 34-9-23, West 4" Meridian.
Authority—Geol. Survey Canada, Memoir 29–E, p. 78.
Completed June, 1910.
Location—Kipp Sta., Alherta, Canada.
Started 10 feet ahove water level and 50 feet helow sandstone overlying the Bearpaw.

	Top Feet	*Bottom Feet*	
River silt		20	Bearpaw
Clay	20	32	
Shale	32	96	
Sandstone	96	115	
Shale	115	129	
Sandy shale	129	143	
Ironstone	143	144	
Shale	144	166	
Ironstone	166	167	
Shale	167	260	
Sandy shale	260	565	
Sandstone	565	592	Belly River
Coal	592	595	
Shale	595	600	
Sandy shale	600	615	
Shale and sandstone	615	658	

Authority—Geol. Survey Canada, Memoir-29-E, p. 79,
Location—Langevin, Alberta, Canada.
Elevation—2471.

The log here given is taken from the results of two borings, the first 1,155 feet being from one and the remaining 271 feet from the other. The terms employed are chiefly those of the borers' log.

	Top Feet	*Bottom Feet*
Clay loam		30
Quicksand	30	37
Clay	37	49
Quicksand	49	59
Clay and sand	59	68
Quicksand	68	75
Clays	75	83
Quicksand	83	88
(The following general grey and pale tints according to W. A. Simpson). Probably lower part Belly River shales.		
Sandstone	88	104
Soapstone (grey, fine-grained clay)	104	113
Lime rock (fine calcareous sandstone) (Small supply of water)	113	118
Hardpan (dark shale)	118	126
Coarse sand	126	133
Soapstone (greyish clay)	133	193
Lime rock (fine calcareous sandstone)	193	200
Sandstone	200	209
Small coal seam		227
Soapstone	209	227
Sandstone	227	232
White clay	232	271
Soapstone	271	322
Lime rock	322	327
(Beds generally shales of dark to black tints):		
Loose shaly soapstone	327	464
Brown ferruginous clay	464	469
Dark lime rock	469	474
Small coal seam		463
Soapstone	474	524
Gravel (supply water)	524	531
Sandstone	531	537
Lime rock	537	541
Sandstone	541	548
Hardpan (dark shale)	548	558
Clays	558	593
Loose shaly soapstone (fine grey clay)	593	943
(Following generally grey tints; one bed of very black shale about 30 feet thick at 1,000. Fragment of Baculite from about here.)		
Lime rock (fine calcareous sandstone)	943	951
Hard soapstone	951	1041
Sand and soapstone with heds of hard pan and supply of gas	1041	1061
Sandstone with streaks of hard gravel	1061	1111
(Following generally dark to black tints):		
Gravel and clay	1111	1151
Hard lime (great flow gas)	1151	1155
Shales and lime rock (probably Calcareous limestone) with layers of very dark, soft shale in 2" hole, to bottom	1155	1426
Total		1426

Calgary Nat. Gas Co. No. 1.
Authority—Geol. Survey Canada, Memoir 29-E, pp. 88-90.
Location—Sarcee Indian Reserve, 12 miles S.W. of Calgary, Alberta, Can.

	Top Feet	*Bottom Feet*
Drift		64
Sandstone and shale alternating	64	152
Blue shale and grey sandstone	152	205
Blue clay shale	205	246
Sandstone with pebble	246	256
Shale with thin sandstone shells	256	301

	Top Feet	Bottom Feet
Sandstone and shale	301	322
Blue clay shale	322	401
Grey to blue shales and sandstones alternating	401	474
Grey sandstone and shale alternating	474	872
Sand lime	872	894
White to grey sandstone and shale	894	978
Shell "red lime"	978	983
White shale and sandstone in alternating layers 3 to 30 feet thick	983	1143
Sandstone, white and black in alternating layers	1143	1244
Black shale with sandstone shells	1244	1471
Sandstone, hard and soft, grey and black with few bed shales	1471	2036
Black coarse sandstone with pebble	2036	2057
Hard shale with pebble	2057	2121
Sandstone, dark and light grey, coarse and fine	2121	2221
Shale and sandstone alternating	2221	2297
Hard, grey sandstone	2297	2371
Sandstone and shale	2371	2425
Black and grey sandstone alternating	2425	2676
Soft, blue sandy shale	2676	2691
Sandstone, dark grey, hard and soft alternating	2691	2756
Light and dark grey sandstones, alternating with pebble	2756	2961
Top of Belly river		2969
Dark grey sandstone and shales intermixed with coal, 1st coal horizon	2969	2996
Sandstone with pebble	2996	3001
Sandstone, grey, coarse and fine	3001	3050
Sandstone, shale and coal	3050	3071
Black sandstone	3071	3135
Black, sandy shale	3135	3160
Grey sandstone	3160	3185
Black, sandy shale	3185	3202
Hard, light grey sandstone, with pebble	3202	3262

Wister Oil Co. No. 23.
Location—So. Kootenay Pass Dist., Alberta, Canada.
Old Section 23, now in park.
Authority—G. F. Stafford, Pincher Creek.

Surface 4140′
Depth 1984′
1150′ of hard lime.
Red sand at 1200′ (Show of oil eased off.)
Casing to 1400′.
1250 or 1260 to bottom Red sand; then 200 to 300′ Blue marl.
Soft to about 1800′.
Hard streaks from 1800 on.
About 1900′ became soft brown shale, and a big cave occurred. Show of oil.
Baled from 6.00 until 12.00 o'clock, about 5 bbls. of oil. Was not pumped and no tubing was put down.
Drilling finished in March, 1907.

Stafford says well would have been an 18 or 20 bbl. producer, but lost tools, and caved, fished for a year until Company became disgusted.

Says this the only well he saw which looked like a producer.

Dark brown shale	3262	3266
Hard brown to white sandstone with pebble	3262	3306
Black shale	3306	3325
Light grey sandstone	3325	3355
Dark shale	3355	3365

James Miller farm.
Owner—Montana Oil and Development Co.
Sec. T. 34 N. R. 4 E. Meridian 6.
Authority—Howard Price.
Date—Started 7-16-12.
Location—6 mi. westerly from Kevin, Montana.

	Top Feet	Bottom Feet
Black shale	40	160
Lime shell	160	162
Black shale	162	315
Water gas sand	315	320
Hard shell	320	
Shale	320	420

	Top Feet	Bottom Feet
Gas sand	420	430
Sandy shale	430	460
Hard shale	460	470
Black shale	470	650
Grey sandy shale	650	720
Black sand	720	730
Sandy shale	730	770
Light shale	770	850
Sandy shale	850	950
Black shale	950	1045
Grey sand	1045	1065
Gas sand (some gas)	1065	1070
Black shale	1070	1100
Light shale	1100	1115
Red rock	1115	1150
Light shale	1150	1195
Hard shell	1195	1200
Hard sand	1200	1223
Shell	1223	1230
Sand	1230	1300
Light shale	1300	1360
Sand	1360	1390
Hard shell	1390	1400
Light shale	1400	1460
Hard sand	1460	1500
Hard shell	1500	1510
Hard sand	1510	1550
Yellow shale	1550	1560
Gritty sand	1600	1650
Hard shell	1650	1655
Black shale	1655	1675
Hard shell	1675	1680
Lime rock	1680	1730
Black shale	1730	1755
Well abandoned at depth		1755
Casing 13″ 40′ 10″ 320′ 8″ 770′ 6″ 1500′ 6″ 1500′		

Product—Gas.
Owner—Town of Wetaskiwin.
Location—Wetaskiwin.
Authority—W. L. Crane, City Engineer.
Drillers—Northwest Drilling Co.
Date—June, 1913.

	Top Feet	Bottom Feet
Two good seams coal about		400
Blue clay	710	855
Grey sand	855	878
Coal	878	880
Black shale	880	950
Soft grey sand	950	1002
Shaly mud	1002	1115
" "	1115	1187
" "	1187	1216
Little gas		1187
Gas		1216
Sand	1216	1255
Gas		1248
Broken shale and sand	1255	1290
Sand	1290	1372
Gas		1347
White slate	1372	1420
Sand	1420	1465
Gas		1443
White slate (bottom of hole)	1465	1511

Government well.
Sec. T. 66, R22.
1898.
Location—Athabaska, Alberta, Canada.
Authority—Geol. Sur. Can. Memoir 29-E, p. 68.

	Top Feet	*Bottom Feet*
Drift		14
Grey shale, soft and caving badly	14	245
(At 23 ft., 136 ft. and 245 ft., hard streaks were met. Below the hard streak at 245 a strong flow of gas)		
Soft shale	245	400
Shale, slightly harder	400	425
(At 425 a hard stratum about 1 ft. thick)		
Grey shale	425	500
Darker shale, soft, caving badly	500	550
Shale with streaks of sand 1 to 2 ft. thick	550	580
Dark shale, very soft	580	825
(At 780 ft. salt water was struck and a strong flow of gas)		
Shale, harder and bluer	825	900
Soft, dark shale	900	1015
Hard, light shale	1015	1037
Dark shale	1037	1090
Sandstone, carrying water	1090	1130
Dark shale, caving badly	1130	1170
Dark shale, layers sandstone	1170	1207
Dull reddish shale and sandstone	1207	1233
Dark soft shale	1233	1237
Light grey shale, very hard	1237	1242
Light grey shale (soft)	1242	1247
Dark shale, soft	1247	1255
Sandstone, very hard	1255	1260
Soft, dark shale	1260	1285
Hard sandstone	1285	1310
Dull reddish shale and sandstone, soft	1310	1323
Reddish shale	1323	1338
Sandstone and dark shale	1338	1350
Dull reddish shale and a little sandstone	1350	1391
Sandstone with layers of dark shale	1391	1435
Hard sandstone with soft streaks	1435	1448
Sandstone and dark shale	1448	1461
Dark shale (thin streaks of lignite)	1461	1491
Light, hard shale	1491	1531
Shale, not so hard	1531	1540
	1540	1566
Hard sandstone	1566	1576
Hard shale	1576	1601
Hard shale with soft streaks	1601	1613
Hard shale	1613	1626
Very hard ironstone boulder	1626	1633
Hard shale (little gas 1650)	1633	1682
Hard and soft shale alternating	1682	1689
Shale and sandstone	1689	1722
Shale with little sandstone	1722	1731
Shale soft and dark	1731	1736
Hard sand rock	1736	1747
Shale	1747	1752
Shale and sandstone	1752	1759
Shale	1759	1763
Hard, supposed sandstone	1763	1767
Soft shale	1767	1770

Pelican Well No. 1.
Owner—Pelican Oil and Gas Co.
Authority—H. L. Williams.
Elevation—1280.
Dec. 3, 1912.
Location—Alberta, Canada.

	Top Feet	*Bottom Feet*
Blue and yellow shale	1	66
White and grey shale, water	66	82
Blue shale	82	200
Blue and brown shale	200	235
Brown	235	285
Grey, brown shale	285	331

	Top Feet	Bottom Feet
Sand rock 21′, very hard	331	352
Shale	352	365
Sand rock	365	425
Shale	425	507
Brown shell, very hard	507	509½
Grey shale	509½	538
Shell	538	540
Sandstone	540	546
Shale	546	575
Hard shell	575	581
Gray shale, with streaks sandstone	581	644
Struck Pelican flow		625
Grey shale (gas)	644	653
Grey shale (very soft cement like)	653	666
Sand rock	666	671
Grey shale	671	688
Hard brown shell	688	689
Dark grey shell	689	740
Hard shale	740	741
Dark grey shale	741	766
Hard shell	766	767
Dark grey shale, sandy (Bradley verifies this)	767	843½
Sandy shale	843½	872
Sandy shale	872	882
Coarse rock, mixed with oil	882	887
Shale and sand	887	898
Hard rock	898	903
Lime carrying oil	903	997
Limestone	997	1051
Hard flinty shell (strong flow of gas under shell)	1051	1053½
Limestone	1053½	1158
Hard limestone shell	1158	1159
Limestone	1159	1192
Hard shell—gypsum	1192	1197
Blue shale and gypsum	1197	1293
Very hard lime shell	1293	1296
Lime rock	1296	1538
Lime, shale and lime rock	1538	1560
Grey shale and lime (gas)	1560	1700
Limestone	1700	1784
Hard shell	1784	1790
Lime rock—shale streaks	1790	1875
Hard shell	1875	1879
Layer of limestone and shale	1879	2040
Strong flow gas		2040
Limestone and shale interstratified	2040	2069

No. 1 well.
Owner—H. L. Williams.
Authority—Mr. Tait.
Contractor—H. L. Williams, Mgr.
Location—Morinville, Alberta, Canada.

	Top Feet	Bottom Feet
Surface to 280′, clay boulders		
Sand rock	250	260
Blue and brown shale interstratified with thin layers of sandstone	260	440
Sand rock with flow gas	440	465
Blue and brown shale, with one or two thin layers of sandstone	465	1410
Dark blue shale with heavy oil seepages	1410	1415
Blue shale, varying in colour from dark blue to light blue and greenish	1415	2450
Hard ironstone shell	2050	2456
Blue and grey shale with gas	2456	2900
Gravel in which saline water was struck	2900	2902
Greenish shale (like Dobe shale)	2902	2940
Sand rock (oil)—flow gas underneath	2940	3052
Very hard shell with iron	3052	3064
Greenish shale (like Dobe shale in Cal.)	3064	3100
Blue shale, interstratified with thin layers of sandstone	3100	3200
Greenish shale, very sticky (Dobe)	3200	3260
Hard ironstone shell	3260	3262
Blue sandy shale with oil seepages	3262	3310
Blue shale, interstratified with hard lime shells	3310	3350

From 3040 to present depth, more or less oil, increasing shale from 3040, very hard with pyrites, but slacked on exposure.

Product—Oil.
Authority—Geol. Survey Canada, Memoir 29-E, p. 86.
Location—Pelican river, Alberta, Canada.

	Top Feet	*Bottom Feet*
Sand and gravel	1	86
Very soft, dark-bluish shale	86	101
Soft sandstone	101	105
Very soft, dark-bluish shale. At 185 ft. slightly saline water	105	185
Rather hard, reddish-brown shale	185	225
Sandstone (water 225′)	225	234
Sandstone and brown shale	234	245
Hard grey shale (at 253′ more water and gas)	245	253
Light greenish-grey shale	253	280
Soft, greenish-grey shale, cement-like	280	290
Brown shale with strata of grey shale	290	308
Brown shale	308	310
Hard sandstone	310	311
(More gas and water)		
Brown shale and sandstone in alternate strata	311	328
Sandstone	328	340
Brown shale	340	353
Hard sand rock with layers of soft rock	353	365
(At 355′ struck maltha and gas)		
Sandstone, rather hard	365	410
Brown shale	410	427
Brown shale, hard	427	450
Sandstone (more gas and water)	450	465
Grey shale	465	526
Ironstone	526	532
Grey shale	532	553
Sandstone	553	556
Very hard, probably ironstone	556	558
Very hard sandstone	558	563
Brown shale	563	573
Grey shale, streaks of sandstone	573	590
Grey shale, brown shale and sandstone in alternating strata; the cuttings show traces of maltha	590	620
Grey shale (strong flow gas at 625′; considerable maltha coming away with the water	620	625
Very hard sandstone	625	643
Soft grey shale	643	648
Hard sandstone	648	652
Soft grey sandy shale	652	665
Ironstone	665	675
Soft, grey shale	765	684
Hard sandstone	684	685
Soft, dark-grey shale	685	703
Hard sandstone	718	723
Sandstone	723	733
Soft, grey shale	733	743
Soft, grey shale, streaks soft sandstone, strong flow gas		750
Heavy oil mixed all through sandstone and shale	743	758
Soft, dark grey shale and soft sandstone, heavy oil throughout. At 773 heavy gas	758	781
Alternate strata soft grey shale and soft sandstone. Increased quantities of heavy petroleum. Gas increasing in volume	781	800
Same as foregoing. At 820 tremendous flow gas of which roar could be heard 3 miles or more	800	820
Soft sandstone. Hard stream and light flow gas	820	830
Soft sandstone	830	836
Iron pyrites nodules embedded in cement like sandstone. Very strong flow gas	836	837

Mr. Dawson gives the following section from this well:

Sand and gravel (surface deposits)		86
Dark bluish-black soft shales, with some sandstone in upper part (Pelican shales)	86	185
Greyish sands and sandstones and brownish and greyish shales. Grand Rapids sandstones	185	465
Greyish and brownish shales alternating with thin beds of hard sandstone and ironstone. Clearwater shales	465	750
Sands and clays often saturated with heavy oils and tar. Tar sands	750	837

Vegreville No. 1.
Owner—Town of Vegreville.
Finished Apr. 8, 1913.
Drillers—N. W. Drilling Co., J. P. Kelly and L. J. McNallum.
Location—near power house, ½ mile N. of R.R. Sta.

	Top Feet	Bottom Feet
Surface	0	15
Blue mud (13" casing carried 272')	15	272
Brown shale	272	325
Gas		328
Shell 2' thick	330	386
Water		386
Sand	386	410
Bottom of sand		410
Blue mud	410	515
Gas		520
Blue mud	502	1000·3
Sand	1000·3	1356
Gas		1360
Bottom sand		1362
Brown shale	1362	1440
Blue mud	1440	1558
(8" casing to 1558).		
Little gas		1563
Brown shale	1563	1740
Blue mud	1740	1868
Top of sand	1868	
Small flow gas		1870
Bottom of sand		1872
Blue mud	1872	1880
Brown sand	1890	1920
Blue mud	1920	2000
Bottom of hole		2000

No. 2 well.
Owner—Tofield.
Product—Show of gas.
Authority—Geo. Peat.
Elevation—R. R. Sta.
Drillers—Northwest Drilling Co.
Location—Tofield, near tracks east of town.

	Top Feet	Bottom Feet
Clay		20
Shell	20	25
Grey shale	25	60
Grey shale	60	75
Water		70
Cased 13" at 62'		
Brown shale	75	120
Shells and sand	120	173
Broken shale	173	200
Grey sand	200	212
Brown shale	212	270
Grey sand	270	280
Little gas		273
Brown shale	280	340
Grey sand	340	500
Brown shale	500	610
Water		590
Cased 10" at 515'		
Grey sand	610	615
Coal	615	618
Blue clay	618	750
Little gas		625
Blue shale	750	850
Lime shell	850	860
Blue clay	860	935
Blue slate	935	950
Sand and little gas	950	960
Gravel	960	1000
Brown shale	1000	1020
Black slate	1020	1057
Salt and water	1057	1103
Little gas		1063

	Top Feet	Bottom Feet
Blue slate	1103	1125
Dark sand	1125	1135
Blue clay	1135	1147
Dark sand	1147	1153
Dark sand	1153	1158
Lime	1158	1170
Blue clay	1170	1200

No. 2 well.
Owner—Great Northern Exploration Co.
Finished Aug., 1912.
Driller—Neil Cameron.
Location—Ft. McMurray, Alberta, Canada.

	Top Feet	Bottom Feet
Surface—soil		17
Limestone	17	77
Shale	77	92
Lime	92	152
Shale	152	192
Soft shale	192	197
Lime	197	237
Shale	237	242
Lime	242	362
Shale	362	382
Lime	382	462
Shale	462	502
Lime	502	562
Shale	562	592
Lime	592	604
Salt—saltwater	604	704
Limestone	704	779
Salt	779	869
Lime	869	999
Shale	999	1059
Brown sandstone	1059	1119
Brown Medina rock	1119	1139
Red rock—streaked—hard	1139	1405

Owner—California-Alberta Oil Co.
Authority—(Owner) and Geol. Sur. Canada, Memoir 29-E, p. 85, 1910.
Location—Egg Lake, Morinville, Alberta, Canada.

	Top Feet	Bottom Feet
Surface deposits	50	
Chocolate coloured shale, hard to drill	50	70
Gravel, very coarse (flow of water)	70	75
Water and 18-22″ seam of lignite	75	80
Brown shale, black slate, pyrite and dark sandstone	80	160
Shale, slate and coal in thin seams	160	260
Sandstone, with water	265	270
Brown shale and dark grey sandstone	270	300
First gas with pungent odor (cased off)		300
Blue and green soapstone shale (still gas and little oil)	300	320
Green soapstone, shale	340	360
Sandstone with gas of petroleum odor	360	360
Gas and light oil (cased off)		375
Very hard shell		380
Pungent gas, pressure for 1 month averaged 70 pounds, yield 370,000 cu. ft. per day		387
Light grey sandstone (gas still flowing)	387	400
14 inch pipe driven to		421
In same sand, with gas and oil		423
This saturated sand is probably 6 ft. thick.		
Brown shale and hard shells	430	435
Salt water		435
Sandstone, shale, slate and few hard shells	435	490
At 423, the tools came up covered with oil, and every bailer brought up from one to two pints		

The following analysis of gas was also furnished by the Company:—

Sulphuretted hydrogen	0-0
Carbonic acid	0-0
Illuminates	0-1
Oxygen	0-5
Carbon monoxide	0·3
Hydrogen	8-7
Methane (marsh gas)	90-2
Nitrogen	0-2

Owner—Town of Wetaskiwin.
Authority—Geol. Survey Canada, Memoir 29-E. pp. 92-3.
Contractor—Geant.
Elevation—R.R. Station.
Location—Wetaskiwin, Alberta, Canada.

	Top *Feet*	*Bottom* *Feet*
Soil and sand		10
Blue clay	10	92
Sandstone	92	93
Blue shale	93	120
Sandstone	120	122
Blue shale	122	135
Sandstone	135	135½
Blue shale	135½	140
Sandstone	140	140½
Blue shale	140½	163½
Sandstone	163½	165
Shale with small sandstone strata	165	276
Sandstone	276	320
Sandstone and shale strata	320	340
Shale	340	348
Sandstone	348	363
Brown shale	363	403
Sandstone	403	405
Coal	405	413
Brown shale	413	508
Sandstone	508	516
Shale and sandstone strata	516	558
Grey shale (gas)	558	585
Sandstone	585	590
Grey shale	590	740
Coal	740	744
Dark shale	744	788
Sandstone	788	794
Dark shale	794	825
Coal	825	828
Light shale	828	838
Dark shale	838	888
Very light shale	888	894
Dark shale	894	900
Light shale	900	905
Dark shale	905	937
Coal and shale strata	937	944

No. 1 well.
Owner—N. W. Gas and Oil Co., Ltd.
Authority—Geol. Sur. Can. Memoir E-29, p. 76.
Location—South end of First St., Edmonton, Alberta, Canada.

	Top *Feet*	*Bottom* *Feet*
Alluvial soil, sand and gravel		20
Sand and gravel	20	30
Through the gravel into tenacious mud and clay	30	40
Through the gravel into tenacious mud and clay	40	55
Thin film of culm	55	75
Mud (considerable gas)	75	85
3-ft. seam of lignite	85	100
Mud	100	120
Hardpan clay, slate wall	120	150
Tenacious dark grey clay	150	175

	Top Feet	Bottom Feet
Hard clay and sharp sand (6′ coal)	175	200
Thin seam of coal	200	210
Dark grey slate	210	250
From 250 to 300 ft. soft blue shale with thin layers of sandstone	250	300
8-ft. of hard coal. Black slate rock and shale to 450	300	350
Black shale with sand rock to 600 ft	350	500
Formation same as above	500	675
Twenty feet of sandstone	675	720
Slate	720	730
Slight flow of brackish water	730	750
Hard slate	750	790
Flow of dry gas	790	800
Slate continues through gas area	800	840
Dark grey slate, with sharp grey sand shale	840	887
Dark shale	887	900
Slate and soft clay to bottom of well at 1,150 feet	900	1000
Boulder bed from 1,125 to 1,150 feet.		

Product—Gas.
No. 2 well.
Owner—N. W. Gas and Oil Co., Ltd.
Authority—Geol. Survey Canada, Memoir E-29, p. 76.
Location—North side of Jasper Avenue, Edmonton, Alberta, Canada.

	Top Feet	Bottom Feet
Through alluvial soil for 16 ft., then sand and gravel to 35 ft. and soft clay to a depth of 50 feet		
Soft clay and shale continue		50
12-inch seam coal, slate formation, 5′ gravel	50	90
Slate and shale	90	125
Slate and shale continue to 215 feet	125	150
Coal, 8-feet thick	150	215
Black slate and shale from 223 to 260 ft	215	230
9-foot seam hard coal		
Black rock 10 feet thick	230	260
Grey sand and shale continuing for 30 feet	260	270
Black slate rock and clay in alternate layers to 400′	270	300
Black grey shale and sand	300	400
Brown sand with layers of black slate for 30 feet	400	435
Black slate and shale continue	435	465
Black slate and shale of varying degrees of hardness from 470 to 560 feet	465	500
Formation changed for soft grey sand followed by seam of grey slate 10 ft. thick. Grey sand and slate alternating to 610 feet	500	560
Small flow gas struck in dark, soft slate formation which continued to 700 feet	560	630
Dark shale to 790 feet	630	750
Formation continues the same	750	810
Formation continues dark slate and shale. Small flow brackish water	810	850
Small flow gas from 910 to 940 feet	850	910
Very soft, dark shale to 1000 feet	910	940
Soft clay, or shale alternating with thin layers of rock	940	1020
Hard rock to 1,118 feet	1020	1080
Soft, dark rock and shale to 1,160 feet	1080	1118
Dark grey sand rock reached, of the nature of a boulder bed	1118	1160
Boulder bed apparently ended and a soft, blue shale was entered	1160	1189
Second boulder bed of 5 feet followed by hard, blue sand rock for about 12 feet	1189	1196
Soft shale from 1208 to 1243 feet	1196	1213
Five feet of dark grey sand yielding a small quantity of oil, salt water and gas. Soft grey shale, with layers of dark grey sand continued to 1,306 feet	1213	1243
From 1,306 to 1,358 very little change in formation	1243	1306
Dark shale with frequent layers of coal and sand down to 1,412 feet	1306	1358

This well was continued to a depth of about 1,800 feet but the log is not available.

Product—Water.
No. 2 well.
Owner—Town of Camrose.
Elevation—2400.
June, 1911.
Drillers—Maxwell and Mackenzie.
Location—Camrose.

	Top *Feet*	*Bottom* *Feet*
Clay		12
Quicksand	12	39
Shale	39	69
Sandstone	69	99
Black shale	99	111
Sandstone	111	121
Water		121
Coal	121	125
Water		125
Shale	125	130

Product—Water.
Authority—Maxwell.
June, 1911.
Elevation—2400.
Drillers—Maxwell and Mackenzie.
Location—Camrose.

	Top *Feet*	*Bottom* *Feet*
Clay		60
Shale	60	70
Sandstone	70	100
Coal	104	104
Little water		104
Black shale	104	154
Sandstone	154	164
Water		164
Shale	164	195
Sand	195	205
Shale	205	245
Sandstone	245	255
Shale	255	265
Coal with black shale	265	275
Water		275
Shale	275	278

Product—Water.
Owner—Camrose city.
Authority—Maxwell.
Contractors—Maxwell and Mackenzie.
July, 1912.
Elevation—2400.
Location—At power house east of Camrose, Alberta, Canada.

	Top *Feet*	*Bottom* *Feet*
Clay	12	
Sand	27	
Clay	30	
Sandstone	30	
Little water		
Sand	8	
Blue shale	12	
Coal	10	
Clay with water to the bottom of the hole	129	

Owner—California-Alberta Oil Co. (King).
Sec. Morinville.
Authority—Mr. Tait.
July 5, 1910.
Location—Alberta, Canada.
Outfit bought by Nakanum outfit.

	Top Feet	*Bottom Feet*
First 50′ loam and sand with pyrites		
Brown shale and slate	50	70
Gravel, coarse—water	70	75
Water and 18″ to 22″ coal	75	80
Brown shale, black slate, pyrites and dark sandstone	80	160
Shale, slate, thin veins coal	160	260
Sandstone and water	260	270
Brown shale and dark grey sandstone	270	300
First gas, pungent (sulphur)	300	320
Shale, little gas and oil		
Green soapstone shale	340	360
Second sandstone in gas of petroleum odor		360
Still gas, little oil in bailer, gathered 3 bottles		375
Two days' drilling through hard slate shell		380
(Oct, 5. 1910) pungent gas, heavy flow 70, 370,624 cu. ft day		387
Light green sandstone, gas still flowing, having burned from top derrick and under boiler	387	400
14-inch pipe to this point		421
Sand with gas, oil on tools and one or two pints in bailer. Sand saturated about 6′ thick		
Brown shale and hard shells at 435, big salt water 1¼% solid salt. Filled up 200-250′ in hole	430	435
Sandstone shale and slate and few hard shells to 490′	435	463
421′ casing in hole	435	490

Pulled up casing to 480′ to light gas.
Casing collapsed. Hole caved and abandoned.

Authority—Geol. Sur. Canada, Memoir 29-E, p. 69.
Elevation—1660.
Location—Athabaska, Alberta, Canada.

	Top Feet	*Bottom Feet*
Yellowish sandstones, thin beds, with some ironstone, Foxhill or Laramie	0	15
Grey and blackish shales, often very soft, with occasional thin, hard layers of sandstone or ironstone. Much gas at different levels between 245 feet and 780 feet, LaBiche shales	15	1270
Grey sandstone, with a flow of soft water; Pelican sandstone	1270	1310
Dark shales, often soft, a little sandstone; Pelican shales	1310	1413
Grey sandstones and grey reddish and blackish shales, the sandstone sometimes very hard and probably nodular, as in outcrop at Grand Rapids. Grand Rapids sandstone	1413	1641
Dark and light-grey shales, generally hard, with some sandstone layers, particularly towards the base. Clear-water shales	1641	1950

Owner—Western Oil and Coal Company.
Sec. SE ¼ 27-6-30 West 4th Meridian.
Authority—Geol. Sur. Canada, Memoir 29-E, p. 88, 1907.
Location—Pincher Creek, Alberta. Canada,
No record given.

Product—Gas.
Col. Jas. Walker farm, No. 2 Well.
Owner—Calgary Natural Gas Co.
Authority—Geol. Sur. Canada, Memoir 29-E, p. 74-4.
Location—East Calgary near the Bow river, Alberta, Canada.

	Top Feet	*Bottom Feet*
Surface deposits, gravel and boulders		54
Sandstone	54	74
Soft shale, blue	74	111
Sandstone, hard and fine	111	119
Soft shale, white	119	126
Lime crystal, quartzite	126	137
Soft shale	137	143
Slate, white	143	145
Shell, sand, hard	145	147

	Top Feet	Bottom Feet
Shale, white	147	151
Shell, sand	151	152
Slate, white, hard	152	158
Shell, lime, hard	158	160
Slate, white, soft	160	178
Shell, sand	178	180
Shale, blue, soft	180	215
Sand	215	228
Slate, soft	228	252
Sand, grey, hard and soft alternating	252	268
Slate, white	268	275
Sand	275	280
Slate, soft	280	290
Slate, grained	290	300
Sand, grey, hard	300	335
Slate, soft	335	340
Sand, hard	340	352
Slate, dark grained lignite	352	360
Sand, grey, hard, with pebble culm	360	430
Slate, soft	430	432
Sand, grey	432	450
Slate, grey and black carrying traces of coal	450	507
Sand, medium, hard	507	512
Slate, black	512	515
Sand, black	515	530
Slate, hard, brown	530	550
Slate, white	550	575
Sand, grey, fine	575	585
Slate, white	585	590
Sand, grey	590	596
Slate, soft	596	597
Sand, hard	597	610
Sand, grey, soft	610	637
Sand, grey, sharp	637	648
Slate	648	660
Sand and slate in alternating layers 10-12′	660	738
Slate	738	773
Sand, grey, soft	773	792
Slate, dark, soft	792	801
Sand, dark, grey	801	838
Slate	838	843
Shale, sand with pebble conglomerate	843	858
Slate	858	862
Sand	862	875
Sand, blue, hard	875	918
Slate	918	928
Sand	928	954
Slate	954	956
Sand	956	963
Slate, black, grained	963	993
Sand, blue, hard	993	1013
Slate	1013	1025
Sand, blue, hard	1025	1088
Slate	1088	1130
Sand, grey, dark	1130	1144
Slate	1144	1147
Sand, grey	1147	1181
Slate	1181	1183
Sand, dark grey, sharp	1183	1232
Slate	1232	1236
Sand, grey, fine, hard	1236	1243
Shale	1243	1285
Sand, fine, dark blue turning grey	1285	1388
Shale, hard, grey turning to soft and black, then brown	1388	1468
Sand	1468	1473
Shale, brown	1473	1488
Slate, white	1488	1562
Limestone	1562	1598
Sand, grey, sharp	1598	1673
Slate, white turning brown	1673	1766
Sand, dark, grey, fine	1766	1821
Slate, grey	1821	1873
Shale, brown	1873	1898
Coal	1898	1911
Sand, dark grey	1911	1953

	Top Feet	Bottom Feet
Shale, black, grained	1953	1970
Sand, hard, fine	1970	1985
Shale, brown	1985	1991
Sand, black, hard	1991	2065
Shale, brown	2065	2075
Shell, sand	2075	2078
Shale, brown	2078	2086
Shell, sand	2086	2090
Shale, brown	2090	2122
Sand. dark grey	2122	2142
Shale, brown	2142	2155
Shell, very hard and flinty	2155	2157
Shale, brown	2157	2167
Sand, grey	2167	2172
Shale, brown	2172	2179
Shell. sand	2179	2181
Shale, brown	2181	2192
Shell, hard	2192	2197
Sand, brown	2197	2202
Shale, sandy brown with culm or bitumen	2202	2242
Slate, white and sand shells with pebble	2242	2252
Sand, light grey, then dark grey, hard and soft with pebble at bottom	2252	2362
Shale, brown	2362	2374
Shell, hard, brown	2374	2378
Coal—semi-bituminous	2378	2379
Shale, sandy	2379	2388
Shale, brown	2388	2394
Sand slate, black and shaly, calcareous matter with sand and dark brown pebble	2394	2410
Sand with white quartz crystals	2410	2418
Sand, grey, hard pebble, trace of culm	2418	2421
Shale, sandy, with shells of bitumen	2421	2452
Gypsum, calcareous	2452	2454
Shale, sandy	2454	2458
Shale, dark and soapy	2458	2483
Slate, black with sand shells	2483	2488
Slate, black, flaky with bituminous coal seams	2488	2502
Shale, hard and flint like	2502	2508
Shell, black and flaky	2508	2512
Slate, shaly	2512	2524
Shell, flinty, hard	2524	2528
Slate, shaly	2528	2533
Shell, sandy	2533	2535
Slate, shaly	2535	2544
Shell, hard and gritty	2544	2547
Slate, shale	2547	2554
Shell, sandy	2554	2558
Slate, shaly	2558	2560
Coal	2560	2565
Shale, sandy culm	2565	2569
Shell, sandy	2569	2572
Shell, sandy, pebbled	2572	2578
Sand, with streaks of shale and little gas	2578	2610
Shale, black and sandy	2610	2623
Shell, sand	2623	2636
Shale, black with some coal	2626	2636
Sand, shale, coal showing	2636	2644
Sand, black and white with pebble	2644	2656
Coal shale or culm	2656	2658
Coal seam	2658	2665
Shale, sandy	2665	2666
Sand, coarse then fine	2666	2682
Slate	2682	2683
Sand, grey, then darker	2683	2702
Shale, black and sandy	2702	2719
Shell, sand	2719	2721
Shale, black, sandy	2721	2739
Sand, black and hard	2739	2742
Sand, with shale	2742	2752
Sand, fine, black, very hard	2752	2761
Sand, coarse, gas sand	2761	2772
Coal, with tarry-like sand just above it	2772	2776
Shell sand, blue, hard	2776	2779
Slate, black	2779	2794
Soapstone	2794	2795

	Top Feet	Bottom Feet
Sand, coarse, grey	2795	2800
Coal, bituminous	2800	2801
Slate, sandy	2801	2810
Shale, brown	2810	2819
Sand, coarse, grey	2819	2834
Coal, bituminous	2834	2837
Slate, dark brown	2837	2845
Shell, sand	2845	2848
Shale, dark brown, soft	2848	2868
Coal, bituminous	2868	2872
Slate, shale with soapstone	2872	2878
Sand, coarse and grey	2878	2897
Slate, black	2897	2898
Sand, hard, black	2898	2904
Coal, bituminous	2904	2907
Slate, shale, hard	2907	2949
Coal, bituminous	2949	2952
Shale, slate and coal	2952	2967
Total depth of well		3414
Bottom of Edmonton series about		1953
Top of Belly River series about		2454

Analysis of gas.

	Per Cent.
Carbon dioxide	0-0
Oxygen	0-1
Heavy hydrocarbons	1-80
Hydrocarbons of marsh gas series	86-70
Hydrogen	5-40
Nitrogen	6-00
	100-00

CHAPTER X

BRITISH COLUMBIA

GEOLOGY[1]

Stratigraphy

The North American Cordillera, otherwise known as the Pacific Mountain system of North America, borders the whole western side of the continent. This mountain belt, where it traverses Canada, occupies nearly the whole of British Columbia and of Yukon in western Canada. Where it crosses the International Boundary the belt has a width of about 435 miles. While the general geology of this belt, within the boundaries of this province, is well known, much detailed work yet remains to be done. The southern portion of the province, within the railway belt and along the International Boundary, has been studied in greater detail than has been possible elsewhere.

The geological history of the North American Cordillera can be clearly expressed with reference to two large geosynclinals; the eastern or Rocky Mountain geosynclinal and a western or Pacific geosynclinal. It can also be shown that previous to the Mesozoic these two geosynclinals, as regards their relative periods of deposition and erosion, bore reciprocal relations to each other.

The Rocky Mountain geosynclinal lies between the Great Plains and the Purcell trench. It embraces sediments from the base of the Belt (pre-Olenellus) terrane up to and including the Mississippian and is composed of a single group of conformable strata varying in composition and texture according to relative proximity to the ancient shore lines which border such basins of sedimentation. The four type sections which illustrate this principle from east to west are the Lewis, Galtin, Purcell, and Summit series which have an average thickness of about 20,000 feet.

[1]This sketch of the Geology of British Columbia is based on the articles in Guide Books No. 8, Part II, No. 8, Part III, and No. 9, International Geological Congress, 1913. The authors quoted are Daly, Allan, Clapp, Schofield, Leach, LeRoy, Camsell, and Drysdale. In some cases extracts from these guide books have been used without further acknowledgment. The description of the areal distribution of the formations is based on the Geological Map of Canada, issued by the Geological Survey, 1913 edition. For a more complete discussion of the Geology of Southern British Columbia the reader is referred to Geological Survey Memoir No. 38, North American Cordillera, Forty-Ninth Parallel, by Dr. R. A. Daly. *Compilation by A. W. G. Wilson.*

During the Triassic, Jurassic and Cretaceous, sedimentation was continuous in the middle and eastern part of the Rocky Mountain geosyncline with a probable increase in the area of sedimentation of at least the Cretaceous beyond the Rocky Mountain geosyncline proper. This period of sedimentation was brought to a close by the Laramide Revolution (Eocene), whose effects are seen in the folding and overthrust faulting so characteristic of the structure of the Rocky Mountain system. Since that time, this belt has been subject to denudation, the detritus of which is seen in the Tertiary and superficial deposits of the piedmont belt of the Great Plains.

Passing to the western or Pacific geosynclinal, which lies between the Purcell trench and the Pacific ocean, the earliest record is the important Pre-Cambrian (Archæan) sedimentation leading to the formation of the Shuswap limestones, schists and gneisses, the latter at least partly of igneous origin. From this time until the Mississippian period, the western geosyncline was an area of erosion which supplied the material for the formation of the Rocky Mountain geosynclinal. At or near the close of the Mississippian, the western geosyncline area was submerged and received a great load of Pennsylvanian sediments and accompanying lava floods. The record for the Jurassic is meagre, indicating that an upheaval of the Triassic sea bottom had begun as an early preparation for the Jurassic revolution. This was closely followed by the intrusion of many large batholiths of granodiorite and related rocks. Erosion of these Jurassic mountains produced the material for the smaller Cretaceous geosynclinals at various points in the Main Pacific geosynclinal. Orogenic movements, called the Laramide revolution, and batholithic intrusion followed.

During the Tertiary, erosion was dominant in this belt with accompanying deposition in isolated basins. Sedimentation was interrupted by local folding in late Miocene and Oligocene. Vulcanism was prevalent throughout the Tertiary while batholithic was confined to the Miocene[1].

The following section across the Cordillera has been prepared by R. A. Daly:—

[1]S. J. Schofield, in Guide Book No. 9, pp. 19-20.

Table of Cordilleran Formations.

System.	Formation.	Thickness.	
		Feet.	Metres.
Recent and Pleistocene	Fluviatile, lacustrine, glacial... *Unconformity.*		
Oligocene (?)	Kamloops volcanic group.....	3,000+	914+
	Tranquille beds (largely tuffs). *Unconformity.*	1,000	305
Eocene.............	Coldwater group (conglomerate, sandstone, etc.) of interior....................	5,000	1,524
	Puget group of coast.........		
	Rhyolite porphyry at Ashcroft *Unconformity.*		
Lower Cretaceous.... (Comanchean)	Jackass Mountain group and Queen Charlotte Islands group (sandstones, shales, conglomerates) of the west		
	Upper Ribboned sandstone....	550	168
	Kootenay Coal Measures of Rocky Mts..............	2,800	853
	Lower Ribboned sandstone...	1,000	305
	Spence's Bridge volcanic group		
Jurassic.............	Fernie shale of Rocky Mts.....	1,500	457
	Upper part of Nicola group (interior)................		
Triassic.............	Lower part of Nicola group (basic volcanics with limestone....................	10,000∓	3,048∓
	Boston Bar group of coast range (Triassic ?).......... *Unconformity with Pennsylvanian.*		
Permian............	Upper Banff shale...........	1,400	427

System.	Formation.	Thickness	
		Feet.	Metres.
Pennsylvanian...	Rocky Mountain quartzite (thickness, 244m.)..... RockyMts.		
	Upper Banff limestone (thickness, 701m.)........................		
	Cache Creek group of the Western Belt (quartzite, limestone, basic volcanics).....................	9,500	2,896
Mississippian....	Lower Banff shale.................	1,200	366
	Lower Banff limestone (partly Devonian	1,500	457
Devonian.......	Intermediate limestone............	1,800	548
	Sawback limestone (Devonian) (thickness, 1,128m.).............		
Silurian.........	Halysites beds..................	1,850	563
Ordovician.....	Graptolite shale..................	1,700	518
	Goodsir shale.....................	6,040	1,841
Upper Cambrian	Ottertail limestone...............	1,725	526
	Chancellor shales.................	4,500	1,372
	Sherbrooke limestones............	1,375	419
	Paget limestones..................	360	110
	Bosworth limestones..............	1,855	565
MiddleCambrian	Eldon limestones..................	2,728	831
	Stephen limestone-shale...........	640	196
	Cathedral limestones..............	1,595	486
Lower Cambrian	Mt. White sandstone shale.. } Rocky Mts.		
	St. Piran quartzite.......... } Rocky Mts.		
	Lake Louise shale.......... } Rocky Mts.		
	Fairview sandstone......... } Rocky Mts.		
	Sir Donald quartzite........ } Selkirk Mts.	5,000	1,524
	Ross quartzite, upper part, } Selkirk Mts.	2,750	838
	Conformity in Selkirk Mts.; local unconformity in Rocky Mts.		

System.	Formation.	Thickness	
		Feet.	Metres.
Beltian	Ross quartzite (lower part)	2,500	762
	Nakimu limestone	350	107
	Cougar quartzites	10,800	3,292
	Laurie metargillites	15,000	4,572
	Illecillewaet quartzite	1,500	457
	Moose metargillite	2,150	655
	Limestone	170	52
	Basal quartzite	280	85
	Unconformity.		
Pre-Beltian (Shuswap series)	Adams Lake greenstones	10,000	3,048
	Tshinakin limestone-metargillite	3,900	1,188
	Bastion schists (phyllites, etc.)	6,500	1,981
	Sicamous limestone	3,200	975
	Salmon Arm mica schists	1,800	548
	Chase quartzite	3,000	914
	Tonkawatla para-gneiss(?)	1,500	457
	Base concealed.		
	Total thickness (minimum)	135,018	41,150

With this section by Daly may be compared the sections that have been measured across portions of southern British Columbia in the vicinity of the Crow's Nest Pass line of the Canadian Pacific railway.

The following section is given by Leach for southern British Columbia, west of the Crowsnest Pass[1]:—

Name of Formation.	*Age.*	*Description.*
Flathead beds............	Cretaceous......	Sandy shales and shaly sandstones.
Elk Conglomerates, including Flathead beds, 6,500 ft. (1981 m.)............	Cretaceous......	Conglomerates, sandstones and some semi-cannel coal seams.
Kootenay, 1,847 ft. (562·9 m.)..................	Cretaceous......	Sandstones, shales and coal seams.
Fernie, 3,000 ft. (914·3 m.)..	Jurassic.........	Shales, calcareous towards base.
Limestone series, 4,000 ft. (1,219 m.)................	Devono-Carboniferous.........	Massive, light grey limestone.
	Cambrian........	Siliceous argillites.

Proceeding farther west, the following section is given by Schofield for the Purcell range, between Elko and Kootenay lake[2]:—

Pleistocene and Recent............................		Unconsolidated gravels and sands.
	Unconformity.	
Jurassic?............................		Dike intrusion: aplites, lamprophyrs and porphyritic granite.
	Kootenay granite.......	Granite and porphyritic granite
Mississippian ..	Wardner limestone.......	Grey limestone. Thickness 1,000+ft. (305+m.)
Devonian............................		Limestone and shale. Thickness 500+ft. (150+m.).

[1]Guide Book No. 9, p. 24.
[2]Guide Book No. 9, p. 47.

Cambrian? ...	Roosville formation.....	Green siliceous argillites. Thickness 600 ft. (183 m.) (Daly).
	Phillips formation.......	Purplish-red and green siliceous argillites and sandstones. Thickness 550 ft. (167 m.) (Daly).
	Gateway formation.....	Light grey quartzites, siliceous dolomites and limestone. Thickness 2,025 ft. (617 m.) (Daly).
	Purcell lava............	Amygdaloidal basalt. Thickness 300 ft. (91m.).
	Siyeh formation.........	Thin-bedded green and purple mud cracked shales; some limestone. Thickness 4,000 ft. (1,220 m.). (Daly).
	Kitchener formation.......	Thin-bedded dark grey argillaceous quartzites and limestones. Thickness 4,500 ft. (1,372 m.).
Pre-Cambrian.	Creston formation......	Light grey argillaceous quartzite and purer quartzites. Thickness 5,000 ft. (1,525 m.).
	Aldridge formation......	Rusty weathering heavy and thin-bedded argillaceous quartzites and slates. Numerous sills of gabbro at various horizons. Thickness 6,000+ft. (1,830+ m.)[1]

For West Kootenay LeRoy gives the section as follows:—

Quaternary......	Glacial and recent.	
Tertiary.......	Miocene...............	Midway volcanic group.
	Oligocene..............	Kettle river formation, Rossland alkali granite and syenite, Valhalla granite.
Mesozoic.........	Jurassic?..............	Nelson batholith. (Rocks range from granite to gabbro). Monzonite.

[1]Guide Book No. 9, p. 62.

Palæozoic.....	Carboniferous and Post-Carboniferous........	Rossland group. Rocks largely of igneous origin. It includes the Brooklyn and Rawhide formations and the Knob Hill group at Phoenix; the Mount Roberts formation and the augite porphyrite series at Rossland.
	Carboniferous(?).......	Pend d'Oreille group. (Metamorphosed sediments in great part). Slocan series. (Slates, argillaceous limestones and quartzites).
	Cambrian (?)..........	Selkirk series.
Pre-Cambrian..........................		Shuswap series. (Schists, orthogneisses, etc.).

The preceding sections will serve to give the reader a general idea of the geological horizons that are known to occur in British Columbia. In the following notes some further details with respect to individual horizons are added and these are supplemented by a general description of the areal distribution of the formations named.

Archæan.—The crystalline basement in British Columbia as elsewhere is a complex series of metamorphic rocks. In the southern part of the province it consists of a very thick conformable bedded group, called the *Shuswap* series, and a younger group of granite intrusives. These occur in the Selkirk mountains in the central part of the province. The better known section is crossed by the Canadian Pacific railway between Bear Creek station and Stormont siding, having a lineal width of about 85 miles. The Archæan area extends south almost to the International Boundary and north to the vicinity of Quesnel Forks and Mount Robson, where it passes beneath undifferentiated Palæozoic strata. Northwest of this a somewhat smaller area outcrops along the Finlay river in the vicinity of Fort Graham.

Unconformably overlying the Shuswap terrane in the Selkirk mountains is a vast thickness of conformable unfossiliferous sediments, for which, as a whole, the name *Selkirk series* has been adopted. The lower and greater portion of these beds is of Pre-Cambrian age; the uppermost beds, as exposed in the railway section, are referred, on stratigraphic evidence, to the Lower Cambrian. The group is clearly the northern continuation of the Belt series of Montana and Idaho. Walcott has applied the name *Beltian* as a systematic designation for this series. The rocks of the series include quartzites, limestones and metargillites. The Geological Survey map shows these rocks lying in two bands, one on either side of the area of Archæan rocks in the southern part of the province. The eastern belt is much the larger, extending from the International Boundary to north of Mount Robson, and having a width of over 100 miles at the boundary, but narrowing northward.

Palæozoic formations.—The Geological Survey maps as unclassified Palæozoic a large belt of country, traversing eastern British Columbia and Yukon, and including the Rocky Mountain region. This area at its southern end occupies only a narrow portion of the province, being about 70 miles in width where crossed by the main line of the Canadian Pacific railway. Farther north at the Yukon boundary, latitude 60°N., it extends nearly across the province, having a width of approximately 250 miles. In north-central British Columbia, between latitudes 54° 30′ N. and 58° N., a considerable area of Mesozoic rocks, chiefly Cretaceous, intervenes in such a way as to separate a narrow western belt of Palæozoic rocks from the main area on the east. The eastern portion here flanks the Archæan areas about the Finlay river on both sides, and has a total width of about 110 miles. The intervening strip of Mesozoic strata varies in width from 50 to 90 miles, and the Palæozoic spur varies in width from 20 to 50 miles. This western limb lies only a short distance from the Pacific coast, and extends from the Stikine to the Skeena river.

This large area is known to contain Palæozoic formations ranging in age from the Cambrian to the Upper Carboniferous, but only in a few localities, especially in the vicinity of the transcontinental railways, have they been studied in sufficient detail to be differentiated locally into the various Palæozoic horizons. Daly's section, given on a previous page, indicates the horizons that have been identified along the Canadian Pacific railway belt, and gives estimates of the thickness of the different formations.

The Survey also maps as Palæozoic a belt of highly metamorphic rocks which occur along the Pacific Coast, and which underlies the greater portion of Vancouver island and the Queen Charlotte islands and some of the smaller islands adjacent. Clapp[1] describes Vancouver island as being composed of deep formed metamorphic volcanic and sedimentary rock, intruded and replaced by numerous irregular bodies of granitic rocks and fringed along both coasts with fragmental sediments, which rest unconformably upon the metamorphic and granitic rocks. He states further that these metamorphic rocks are largely of lower Mesozoic age, presumably Upper Triassic and Lower Jurassic, but they may include some Palæozoic members. Apparently the oldest rocks, considered provisionally as of late Palæozoic (Carboniferous) age, are a series of slates and quartzose schists, with some fragmental volcanic members. This series extends across the southern end of the island and is called the Leech River formation.

In the railway section we find the following formations:—

Lower Cambrian.—Represented by thick quartzites, quartzitic sandstones, and some shales.

Middle Cambrian.—Represented by certain limestone beds.

Upper Cambrian.—Represented by limestones and including a thick deposit of shales. Dr. J. A. Allan[2] states that there is a total thickness of over 18,578 feet, which represents one of the thickest Cambrian sections yet measured in the world. It essentially consists of 3,800 feet of siliceous beds, principally quartzitic sandstone, 10,275 feet of calcareous and dolomitic limestone, and 4,500 feet of shale much of which is calcareous.

Ordovician.—Dr. Allan[3] estimates the thickness of this formation at over 6,040 feet. The basal portion of the formation consists of alternating hard and soft bands of argillaceous, calcareous, and siliceous shale, which weather light yellowish,

[1]Chas. H. Clapp, Guide Book No. 8, Pt. III, p. 281.
[2]International Congress Guide Book 1913, No. 8, Part II, p. 174.
[3]*Op. cit.* p. 179.

grey and buff. The upper part of the formation consists of banded cherts, cherty limestone and dolomites, thin bedded and very dense, so that they weather into compact angular fragments.

Silurian.—This formation conformably overlies the highest beds assigned to the Ordovician. It consists chiefly of dolomitic (Halysites beds) and white quartzite. The total thickness where measured is 1,850 feet, the white quartzite being 900 feet in thickness.

Devonian.—A formation, consisting of thin-bedded limestones, alternating with harder layers of grey dolomitic and siliceous limestones, has been identified as of Devonian age. This limestone formation is known as the *Intermediate limestone* and has an estimated thickness of 1,800 feet. Some of the beds are highly fossiliferous.

Conformably underlying the Intermediate limestone is a series of massive and thin-bedded dolomitic limestones and shales. It has been possible to measure and estimate a thickness of about 3,700 feet, but the actual thickness is believed to be much greater. McConnell placed this limestone series provisionally in the Cambrian. Fossils have not yet been found in the series. Since it differs lithologically from the recognized Cambrian beds in adjacent localities the age of the formation is still in doubt, but it is older than the Intermediate limestone which is definitely known to be Devonian. This series is named the *Sawback* formation. The beds are lithologically closely related to some of the Silurian beds in the Beaverfoot range to the west.

Recent investigations by Dr. Shimer show that at least the lower part of the Banff limestone, to which reference is made below, are also to be assigned to the Devonian.

Carboniferous—Mississippian formations.—The formations formerly mapped as Carboniferous in the Canadian Rocky Mountain section have recently been shown by Shimer to be partly Mississippian and partly Pennsylvanian[1]. The Mississippian is represented in part by the *Lower Banff limestone,* having a total thickness of 1,500 feet, and the

[1]H. W. Shimer, Summary Report, Geol. Surv., Can., 1910, p. 147,

overlying *Lower Banff shale*, having a total thickness of 1,200 feet. The *Lower Banff limestone* grades into the Devonian limestone below so that it is not possible always to draw a sharp dividing line between these two formations. As noted above, Dr. Shimer, on the basis of fossils recently collected from this limestone, has concluded that the lower part, and possibly the whole, is to be classed as Devonian rather than Mississippian. The *Lower Banff shales* are black to dark grey in colour, and weather brown. They are usually calcareous in composition, but certain layers are argillaceous and arenaceous.

Carboniferous—Pennsylvanian formations.—The Pennsylvanian, as represented in the Rocky Mountain section, consists of two formations, the *Upper Banff limestone* (about 2,300 feet) and the *Rocky Mountain quartzite* (varies in thickness from 800 to 1,600 feet). The limestone series is shaly at the bottom, but more massive towards the top. Cherty lenses and cherty shale interbedded with the lower shaly limestone help to distinguish this formation from the shales below. The quartzite formation lies directly on the Upper Banff limestone.

Permian formations.—Conformably overlying the *Rocky Mountain quartzite* is a formation classed as Permian and named the *Upper Banff shale*. This formation consists of a series of brown, calcareous and arenaceous, often sun-cracked shales, interbedded with thin layers of sandstone. More than 1,400 feet are represented in the section.

Mesozoic formations.—The geological map of Canada shows the Mesozoic of Western Canada distributed in three distinct areas. The character of the mid-continental area, which finds its greatest development in Alberta, has already been discussed. This area crosses the British Columbia boundary near the southwest corner of the province where both Jurassic and Cretaceous strata have been recognized. There is also a very considerable development of this series in the northeastern part of the province, north of latitude 54° 30′ N., and west of the 120th meridian. The territory about the headwaters of the Peace and Fort Nelson rivers, and bordering a portion of the Liard river is known to be underlain by the Mesozoic sediments, which, however, have only partially been differentiated into their respective horizons.

A long narrow belt of Mesozoic sediments occupies the central portion of British Columbia, extending northward from the International Boundary with slight interruptions to about latitude 58° N. It appears to reach its greatest development north of latitude 54° N. South of this it is more or less interrupted by Tertiary effusives which cover a very considerable area in the central part of the province. The horizons represented are either Jurassic or Lower Cretaceous.

A third belt of Mesozoic strata has been developed along the Pacific coast, and underlies Vancouver island and the Queen Charlotte islands. "Lower Mesozoic rocks comprise the larger part of Vancouver Island, and constitute the Vancouver group. They consist chiefly of metamorphosed basic volcanics, principally meta-andesites, the Vancouver volcanics. Certain schistose and more salic volcanic rocks are apparently interbedded with Leech River formation, but the typical meta-andesites, although separated from the Leech River formation largely by faults, are apparently younger and unconformable. Associated with the Vancouver meta-andesite and occurring chiefly in small intercalated lentils, is a formation of limestones called the *Sutton* formation. Besides the limestones, there is associated with the meta-volcanics a series of stratified slaty and cherty rocks, the *Sicker* series, composed partly of volcanic material. These rocks and their associated volcanics have been greatly metamorphosed and converted into schists."

"All of the above mentioned rocks are included and partly replaced by batholithic and dike rocks. The batholithic rocks are chiefly granodiorite with marginal facies of diorite, but in the southeastern part of the island there is a large batholith of gabbro-diorite and quartz-diorite gneisses. All of the batholithic rocks are closely related and appear to have been irrupted during the same period of intrusion."

Triassic-Jurassic.—In southeastern British Columbia, underlying the productive coal measures, is a series of black and dark brown, siliceous, very thinly laminated shales which break up into small fragments on the weathered surfaces. These shales, which are well developed in the Crowsnest Pass area, are of Jurassic age and are called the *Fernie* shales. They have a thickness of about 3,000 feet. Similar shales occur west of Banff, lying above the *Upper Banff* shale, and no sharp line can be drawn between the two formations except where fossils are found. It is altogether probable that similar deposits occur farther northwest along the line of the Rocky mountains. McConnell has reported Triassic rocks from Peace River pass, and similar rocks occur at the great bend of the Dease river in northern British Columbia, and at the Rapids of the Drowned at Hell Gate on the Liard river.

In central British Columbia along the Thompson river valley Drysdale places the Triassic-Jurassic section at 10,000 feet[1]. The rocks consist of various greenstones intercalated with beds of argillite and limestone, some of which contain fossils which place the series in the Triassic, grading up into Lower Jurassic. These rocks constitute the *Nicola* formation.

In the same district there are a number of granitic intrusives, occurring as batholiths, stocks and tongues, which are referred to the Upper Jurassic.

Still farther southwest along the Thompson valley are a group of about 5,000 feet of acidic and intermediate lavas and tuffs called the *Spence's Bridge Volcanic* group. Recently obtained evidence places this group in the late Jurassic or Lower Cretaceous.

Similar Triassic-Jurassic rocks probably occur both southeast and northwest of the Thompson river section along a line approximately parallel to the Coast Range. Gwillim[2] mentions the occurrence of sandstones and conglomerates in the vicinity of Atlin lake, some of the beds of which contained Jurassic fossils.

Cretaceous.—Along the main line of the Canadian Pacific railway the Cretaceous is represented by three formations as follows: *the Lower Ribbon sandstone*, consisting of alternating bands of brown weathering sandstone and shale, having a thickness of about 1000 feet; the *Kootenay Coal Measures*, consisting

[1]Guide Book No. 8, Part II, pp. 239-240.
[2]J. C. Gwillim, The Atlin Mining District, British Columbia, Geol. Survey, New Series, Vol. XII, part B, 1899, pp. 24-26.

of over 2,800 feet of sandstone and shale, enclosing several workable seams of coal. There are fourteen seams exposed at Bankhead, where mining operations are now in progress, and nearly twice as many are reported in the vicinity of Canmore. The coal measures are well defined between two massive sandstone bands. The coal measures are followed by the *Upper Ribbon sandstone.* It comprises thin-bedded sandstone and shales. Near Cascade mountain this formation has a thickness of about 550 feet but exposures both northwest and southeast of this section show greater thickness. The railway section does not give the full thickness of the formation, which Dawson places at about 11,000 feet.

In the Crowsnest Pass area the Cretaceous section is as follows: *Kootenay sandstones* including some shales and coal measures, 1,847 feet; *Elk conglomerate* including conglomerate, sandstone and some semi-cannel coal seams; and the *Flathead beds* consisting of sandy shale and shaly sandstone[1]. The Elk conglomerate and the Flathead beds have a total thickness of about 6,500 feet.

Cretaceous shales and sandstones have been reported from the Liard river valley by McConnell. Similar rocks have been found at a number of other localities along the line of the Rocky mountains between this area and the International Boundary. The Cretaceous rocks throughout this mountain belt have been more or less folded and faulted in common with the other formations which occur in this region.

Small inliers of *Lower Cretaceous* strata have been recognized in the Cordilleran section along the railway belt in the vicinity of Ashcroft and near the Fraser valley north and south of Lytton. Dr. Drysdale estimates the minimum thickness of the Ashcroft remnant at 5,000 feet, while Dawson places the Fraser valley Cretaceous between 7,000 and 10,000 feet. A still greater remnant of Lower Cretaceous strata has been mapped by Daly at the 49th parallel section under the name *Pasayten series*, the Cretaceous members of which have a thickness of about 22,500 feet. The deposits in the Fraser valley near Ashcroft and Lytton consist of carbonaceous shales, sandstones

[1]W. W. Leach, in Guide Book No. 9, International Geological Congress, p. 24.

and conglomerates, occupying local synclinoria striking north and south. They are correlated on lithological grounds with the Queen Charlotte Islands formation of the Pacific coast.

Farther north in the vicinity of Francois lake and in the country southwest of the Bulkley river a great series of volcanics occurs. The series is composed of tuffs, andesites, agglomerates and similar rocks, often occurring in sheets as volcanic flows but frequently showing evidences of deposition under water. Dawson estimates their thickness at over 10,000 feet and has classed them as Lower Cretaceous on the basis of fossils found near Francois lake[1]. Similar strata are reported by Leach from the Telkwa valley, but no fossils were discovered. Immediately overlying them, however, possibly unconformably, is a series of beds composed chiefly of clay shales and containing a number of important coal seams. In no place in the Telkwa district was this formation found to have a thickness of over 300 feet. Fossil plant remains found in the coal-bearing beds indicate that the horizon is Lower Cretaceous[2].

Still farther north about the headwaters of the Skeena, Naas, and Stikine rivers well developed coal measures covering an area over 2,000 square miles in extent are known. In one locality near the southern end of this basin, known as the Groundhog basin, 3,650 feet of strata are exposed in one section, the most important coal seams appearing near the upper and lower limits of the section. The rocks of this coal-bearing group are conformable with the underlying rocks, and both have been thrown into folds and faulted by pressure from the southwest. This group has been named the *Skeena series* and Malloch regards them as probably of Lower Cretaceous age[3].

It is interesting to note that Dr. R. A. Daly discovered fossil plant remains on the Skagit river near the International Boundary line which are similar to those found by Leach on the Telkwa. It is probable that Cretaceous strata similar to those reported from the various areas mentioned above occur at a number of localities not yet studied in detail along a belt running approximately parallel to the coast range northwest

[1]Geol. Survey Report of Progress, 1876-77, pp. 58-64.
[2]W. W. Leach, The Telkwa River and Vicinity, Geol. Survey, 1907, pp. 11-12.
[3]G. S. Malloch, Summary Report Geological Survey, 1911, pp. 72-90.

from the International Boundary and including the localities mentioned above, and other smaller areas which are now known but which have not been included in the descriptions given here.

On the Queen Charlotte islands the Lower Cretaceous is represented by two formations. The lower consists of greenish ashy sandstones, more or less arenaceous shales, and a great thickness of massive or thin-bedded sandstones with occasional layers of well rounded conglomerate and frequent zones characterized by large calcareous nodules. Overlying this is a series of agglomerates and tufaceous sandstones almost exclusively of volcanic origin. To the former Dawson assigns a thickness of about 1,000 feet and to the latter 3,500 feet[1]. These formations do not appear to be represented on Vancouver island.

In the Queen Charlotte islands the Upper Cretaceous is represented by three formations. The lower division consists of blackish and grey shales interbedded with grey and yellowish-grey sandstones and numerous layers composed of sandy argillaceous material, intermediate in character between shale and sandstone; these beds are associated with coal seams. Dawson assigns a thickness of 5,000 feet to this formation. Overlying it is a series of well rounded conglomerates interbedded with grey and yellowish sandstones, having a thickness which varies from 1,900 to over 3,000 feet. The highest beds consist of shales interstratified with sandstones, the whole formation having a thickness of not less than 1,500 feet. The total thickness assigned to the Queen Charlotte Island group is therefore about 13,000 feet.

The Upper Cretaceous is represented on Vancouver island by three somewhat similar series of rocks constituting the *Nanaimo* series. These rest unconformably upon an erosion surface of metamorphic and granitic rocks of Mesozoic age and are confined, for the greater part, to the east coast of the island. They consist of conglomerates, sandstones and shales with some coal. In general the series has been deformed into broad open folds with a northwest-southeast strike and a general northeast dip, but in places it has been closely folded, overturned

[1]Geological Survey Report of Progress, 1878-79, report B, pp. 63-71. Compare also, Report of James Richardson in Annual Report of the Geological Survey for 1872-73.

to the southwest and broken by reversed and overthrust faults. There are a number of coal mines in the vicinity of Ladysmith and Nanaimo which have been opened upon coal seams of this series[1].

The Cretaceous strata on Vancouver island are found along the east side of the island bordering the Strait of Georgia and extending north nearly to Seymour narrows. A smaller area is also preserved near the northern end of the island in the vicinity of Quatsino sound.

Tertiary formations.—Tertiary sediments do not occur to any great extent in British Columbia. Small areas are found in the southern part of the province in the vicinity of Princeton, near Nicola, near Walhachin on the main line of the Canadian Pacific railway, and on the lower Fraser river below Agassiz. Slightly larger areas occur in the vicinity of Fort George and on the Nechako river west of this. A small area has been reported in the valley of the Finlay river above Fort Graham, and another small area occurs near the Lower Post on Dease river near its junction with the Liard. They also occur on Graham island in the Queen Charlotte group.

The Tertiary sediments include the *Coldwater group* of Dawson and the *Puget group*, both developed in the valley of the Fraser river. Both formations are local and their mutual relations have not been determined. The Coldwater group is probably the younger and includes conglomerate, sandstone, shale and some coal beds. Dawson estimated the local maximum thickness of the Coldwater beds to be about 5,000 feet. The Puget beds, developed on the lower Fraser, below Agassiz, consist of sandstones, conglomerates and shales with thin coal beds. They have an observed thickness of about 3,000 feet.

A large area in central British Columbia between latitudes 50° N. and 54° N., and lying east of the Coast Range of mountains is underlain by Tertiary effusives. Several smaller areas are shown on the geological map as occurring in the northern part of the province about the headwaters of the Stikine river, north of Telegraph creek, and south of Atlin lake. The northern part of Graham island, in the Queen Charlotte group, is

[1]C. H. Clapp, Summary Report Geological Survey, 1911, p. 91.

also underlain by members of this series. The rocks consist of basalts, agglomerates, breccias, some trachytes, and tuffs. Dawson mapped them as the "Upper Volcanic group" and referred them to the Miocene. They have more recently been designated the *Kamloops Volcanic* group, and have been referred to the Oligocene on the basis of fossils found in one member of the group, the *Tranquille beds*, a series of local, tufaceous, and partly fresh-water sediments intercalated near the base of the Kamloops volcanics. The Kamloops lavas have a maximum thickness of at least 3,000 feet, and had originally a probable average thickness greater than 2,000 feet. The Tranquille beds are estimated to have a thickness of 1,000 feet.[1]

Batholithic intrusions.—Granitic batholithic intrusives occupy a considerable area in southern British Columbia west of Kootenay lake. They also cut the Palæozoic strata of the Western Belt on a scale unmatched elsewhere in the world, except perhaps in the Pre-Cambrian terrane of eastern Canada. The composite coast range batholith of British Columbia and Alaska is about 1,200 miles in length with an average width of nearly 90 miles. It is composed of granodiorite, and quartz-diorite, with diorite, biotite granite, syenite, and allied types. There is clear evidence of successive intrusion but it is agreed that the general date of irruption, for the greater part, falls in the period from latest Jurassic to the early Cretaceous.

Quaternary deposits.—Quaternary deposits of sand, gravels, clays, and till are found scattered over the province in numerous localities but no special descriptions are essential to the present report.

Geologic Structure.

The geologic structure of British Columbia is perhaps more complex than any other similar area on the continent.

The main structural features, according to Dawson[2], are that of a central Archæan axis or geanticline with a geosyncline on the east and a wider geosyncline on the west. The eastern geosyncline is occupied by the Rocky mountains, whereas the Coast Range is included in the western geosyncline.

[1]Based on notes by Daly and Drysdale in Guide Book No. 8, part II, International Geological Congress, 1913.

[2]Dawson, G. M., Geologic record of the Rocky Mountain region in Canada; Geol. Soc Am. Bulletin, vol. 12, 1901, pp. 58-92.

More or less connected with these major features are numerous minor folds and flexures including many faults. Time and space will not permit here a detailed discussion of the structure, but that great disturbances of the beds exist in many parts of the country is evinced by the fact that in writing of the geology of British Columbia, Dawson[1] speaks of the "extremely broken and disturbed character of the rocks." In this connexion he says in speaking of the Cache Creek formation of the Kamloops map-sheet that

In attempting a brief general description of this formation, it must in the first place be observed that the extremely broken and disturbed character of the rocks, almost everywhere renders it next to impossible to learn much about their attitude or sequence in any one locality. It is very generally impossible to determine whether the dip of the beds is normal or has been overturned.

Speaking further of the Kamloops map-sheet, Dawson[2] says:—

The limestone belt above described, has, within the limits of the map, a length of above sixty miles. There can now be no doubt that this represents a great syncline, upon both sides of which the older members of the Câche Creek formation are displayed; but superimposed upon this general structure are very numerous smaller folds, which generally run in more or less exact parallelism with it, but often in varied directions. The limestone has thus been, as it were, heaped together by repeated folding, in such a manner that it occupies a width much greater than that which can possibly be due to its thickness, with the high dips which are usually found. Similar complex folding affects the underlying rocks of the formation, and it is due to this fact that it is almost impossible to obtain any good estimate of its total thickness or of that of its parts. This folding is not generally of the tightly compressed and linearly direct kind met with in, and near, the mountains of the coast ranges, but is just sufficiently irregular to make it very difficult to follow. Occasional instances are also found—as for example on the upper part of Jack's creek, between the Thompson and Hat creek and in Glen Hart—where the rocks rest at very low angles; but these are in immediate contact with others in which the same beds are found to be nearly vertical.

In another case Dawson[3] says that:—

. . The mountainous axis of the Queen Charlotte islands from Cape St. James to Skidegate channel, and probably still farther northward as far as Hippa island, is composed of a mass of much disturbed, and in some places highly altered rocks, which have at first sight an appearance of great antiquity, but are found on close inspection to owe this appearance to the inclusion of

[1]Dawson, Geo. M., Ann. Rep. Geol. Surv. Canada, n.s., vol. VII., 1896, section B.
[2]Dawson, Geo. M., Ann. Rep. Geol. Survey Canada, vol. VII, p. 40B.
[3]Dawson, Geo. M., Report on the Queen Charlotte islands, Geol. Surv. Canada, Reports for 1878-79; 1880, p. 45B.

Lines 22 and 25. "Victoria, B.C.," should read "Victoria, Alberta." This well record should have followed the last paragraph on page 286. The well is located near the post-office of Pakan, Alberta, on the North Saskatchewan river, in the Electoral District of Victoria.

great masses of easily altered contemporaneous volcanic materials, and to the fact that they have been subjected to an extreme of flexure and disturbance which very frequently takes the character of actual fracture and displacement, as has been observed elsewhere on the Pacific coast. To work out the intricacies of these older rocks, which may be looked on as the nucleus of the islands, would be a work of time, and would involve much patient labour.

Other instances might be cited relating to the generally disturbed character of the rocks of the mountainous portion of British Columbia, but time and space will not permit.

HISTORY OF DRILLING OPERATIONS AND PROSPECTS OF OIL IN BRITISH COLUMBIA.

For several years past prospect drilling for oil in various parts of British Columbia has been going on more or less intermittently, but oil exploration is still entirely speculative.

A well put down to a depth of 1,840 feet by the Canadian Government near Victoria, B.C., shows small quantities of gas at several horizons, but no oil indications. The records of this well follows:—

Victoria, B.C., Canada.
Geol. Sur. Can., 29-E, pp. 91-2.

	Top Feet.	*Bottom Feet.*
Sand		10
Light grey shale, traces sand	10	20
Grey sandy shale	20	30
Light grey sandy shale	30	50
Light grey shale, no sand	50	100
Grey shale, darker in colour	100	110
Grey shale, lighter	110	120
Grey shale, brownish	120	130
Ironstone layer	130	131
Light grey shale	131	140
Light brownish-grey shale, quite hard	140	180
(At 156 struck small vein of gas)		
Dark-brownish shale streaks of ironstone	180	260
Dark brown shale (strata of sandstone)	260	270
Grey shale (ironstone stratum)	270	280
Grey shale with 3 ft. ironstone stratum	280	290
Hard brown-grey shale	290	300
Hard, grey shale	300	310
Softer, dark grey shale	310	340
Harder, dark grey shale	340	350
Hard brownish-grey shale	350	390
Hard, light grey shale with 2 ft. ironstone	390	410
Brown shale	410	420
Brownish grey shale	420	470
Very hard, grey shale	470	480
Light brownish-grey shale	480	500
At 485 ft. water, slightly saline and gas		
Ironstone stratum	500	508
Light brownish-grey shale	508	520
Grey shale, losing brown tone	520	530

	Top Feet.	Bottom Feet.
Ironstone stratum	530	535
Hard, light grey shale	535	540
Grey shale, with stratum ironstone	540	550
Bluish-grey shale	550	554
Dark bluish-grey shale	554	560
Dark bluish-grey shale with ironstone stratum and fragments pyrite.	560	570
Very soft grey shale	570	620
Very soft grey shale with 3 ft. sandstone and ironstone	620	630
Bluish-grey shale, very soft	630	705
Soft, dark shale	705	960
Soft, dark shale with layers sand and gas	960	970
Soft, dark shale	970	1000
Soft, dark shale, streaks sandstone	1000	1020
Dark shale, gas	1020	1030
Dark shale, increased gas	1030	1090
Soft, black shale	1090	1230
Soft, black shale, streaks sandstone	1230	1250
Soft black shale	1250	1320
Brown shale, with sandstone layers	1320	1340
Soft, dark shale	1340	1390
Bluish shale, with thin streaks sandstone	1390	1410
Black shale	1410	1428
Hard sandstone	1428	1430
Black shale	1430	1460
Bluish shale	1460	1500
Bluish shale streaks sandstone with gas	1500	1565
Hard sandstone	1565	1575
Dark shale, mixed with sandstone	1575	1585
Hard sandstone	1585	1600
Shale and sandstone strata mixed	1600	1645
Hard sandstone	1645	1650
Sandstone	1650	1665
Dark shale	1665	1669
Very hard sandstone	1669	1680
Dark blue shale with strata hard sandstone 1 to 4 feet thick	1680	1840

William E. Park published in October, 1913, a rather exhaustive discussion of the outlook for commercial oil in British Columbia, and this discussion is quoted here:—

Though the Pacific province of Canada is more than usually stirred by oil excitement, the oil industry west of the Rockies and north of the International Boundary is still in the purely wild-cat stage. There has been no discovery of commercial importance made in the province up to the moment of writing; though in many quarters drillers are at work, and as is always possible with the driller, a new day may change the entire aspect of affairs.

The possible oil and gas resources of the province are a matter of opinion; and this opinion is in some instances extremely optimistic, and in others just the contrary. The story of what has already been done or is now under way in the course of developing these possible resources, reveals the fact that tests have been made in several sections of the province So far, neither oil nor gas has been found in anything approaching commercial quantities; though indications have frequently been met with.

The borings already attempted naturally indicate the locations considered by operators as the most likely to give profitable results. These borings are about as follows:—

On Vancouver island, on the southwest coast, a couple of holes were put down to a depth approximating 1,000 feet, without success. Bore-holes on the east coast of the island put down for coal have produced neither gas nor oil.

On the Queen Charlotte islands, farther north, boring for oil has been in progress for a year or more. The location is on the northwest end of Graham island. So far as is known, no success has been met with. Other holes on the east coast and in the centre of the island, put down for coal, showed no gas or oil.

On the islands between Vancouver island and the mainland, one or more holes have been put down. One hole on Pender island was put down for coal to a depth of 1,200 feet, but not reaching any, was abandoned. This bore now gives off gas, but it is nitrogen gas, of no commercial value.

These lesser islands weie reported on last summer for a gas and oil boring syndicate by a responsible geologist, whose report indicates very considerable possibilities for oil and gas. The company which secured the survey is now about to test the matter by drilling in the vicinity of the 1,200-foot bore-hole previously referred to; knowing in advance that the hole will have to be sunk to a greater depth than 1,200 feet before the possibilities are within reach of the drill. The operators are very sanguine of success, their optimism being largely due to the presence of seepages of oil, found floating on the adjacent waters, and supposed to emanate from submarine fissures.

In recent years, several holes have been drilled near New Westminster, in the delta of the Fraser river. Regarding these, little reliable data as to the depth can be obtained, but it is known that they did not find oil or gas, at least in any quantity.

On Pitt Meadows, the Coast Development Syndicate, of Vancouver, of which enterprise W. Innes Patterson is manager, has been engaged in drilling. The syndicate has a hole down 1,200 feet, and claims to have met with indications of oil, but drilling has been stopped, as a result of an accident somewhat similar to that which occurred with the Oil Springs, Ontario, deep well, and the hole cannot be sunk any deeper. It is understood that the syndicate intends starting a new well.

Near Horsefly, in the Cariboo district, there are shales carrying several per cent of oil. A half-hearted attempt at drilling was made in this vicinity, but the drillers did not find any fluid oil nor any flowing gas. Similar oil-bearing shales occur on the North Thompson river.

Promoters have claimed to find oil indications in the Kettle River valley, on the north fork, but no serious attempt has ever been made to test this district.

WHERE SEEPAGES OCCUR.

In the southeastern corner of the province, in the valley of the Flathead river, there are undoubtedly small seepages of crude oil. Among others, the Provincial Mineralogist, W. Fleet Robinson, has inspected them and obtained samples of the product. The oil secured is of good quality, but, so far, it has been met with only in the form of seepages, coming up with water in a spring. Similar seepages occur just over the summit to the eastward, in the Province of Alberta, where two or three holes have been drilled to a depth of from 1,200 to 1,500 feet. On the British Columbia side of the mountain range, the British Columbia Oil and Development Co., of Victoria, has taken in a drilling plant, and is now engaged in putting down a hole. This hole is reported to show a little oil, whether from seepages or not is not known, but the hole, in any event, is not down far enough to give conclusive results. This district has, in the opinion of reliable men, distinct possibilities, which thorough drilling tests alone can determine.

Unlike the oil and gas fields of New Brunswick, Ontario and Alberta, the greater part of British Columbia is very mountainous and much disturbed geologically, so that in most parts of the province oil or gas could scarcely exist. The limited areas where these products might exist within reach of transportation and settlement are pretty well represented by the drillings referred to.

Among the pronounced surface indications are those in the Flathead district of East Kootenay, in the southeastern corner of the Province, close to the Washington state line. Some test drilling is now going on in this section.

The operations of the drilling plant on Pitt lake, where Innes Patterson and associates have been drilling, have been suspended for a time. Reports were at one time current of a big strike in this section, but they were without foundation. Some float sandstone showing oil impregnation was found in the vicinity of this well.

The oil occurrences on the coast, some 300 miles north of Vancouver city, are to be developed by Vancouver capitalists, with a view to determining their commercial value, if any. Henry Lye of Vancouver has secured licenses covering an oil seepage at Evans Arm, on King island, and Merton Smith, also of Vancouver, has had a number of locations recorded in the vicinity of Seymour inlet.

Oil shale deposits of a considerable extent exist in the vicinity of Ashcroft, and efforts are being made to organize a company to develop these shales. The shales are similar to those of Albert county, New Brunswick, which have shown a production of 63 gallons of oil from a ton of shale.

The utilization of slack and waste coal from the British Columbia coal mines for the production of petrol is also being urged. This method is being used to a considerable extent in Great Britain, and though the process requires an expensive plant, a number of other by-products are secured. The manager of one coal company has had in contemplation for a considerable time the establishment of a by-product of this nature at Vancouver. The benzol value of coal averages, according to expert estimate, $5 a ton. The amount of waste available for this purpose is quite large, one of the leading collieries having reported a loss last year of 164,854 tons, or nearly one-third of its total output.

APPENDICES

I. "THE PETROLEUM BOUNTY ACT, 1909".

II. "REGULATIONS FOR THE DISPOSAL OF PETROLEUM AND NATURAL GAS RIGHTS, THE PROPERTY OF THE CROWN . . . . . REFERRED TO IN SUBSECTION (B) OF SECTION 3 OF THE DOMINION LANDS ACT." APPROVED BY ORDER-IN-COUNCIL. DATED THE 19TH DAY OF JANUARY, 1914.

APPENDIX I.

[*COPY.*]

9-10 EDWARD VII.

CHAP. 46.

An Act to provide for the payment of Bounties on Crude Petroleum.

[*Assented to 4th May, 1910.*]

His Majesty, by and with the advice and consent of the Senate and House of Commons of Canada, enacts as follows:—

1. This Act may be cited as *The Petroleum Bounty Act, 1909*. Short title.

2. The Governor in Council may authorize the payment out of the Consolidated Revenue Fund of a bounty of one and one-half cent per imperial gallon on all crude petroleum, having a specific gravity not less than ·8235 at 60 degrees by Fahrenheit's thermometer produced from wells in Canada or from shales or other substances mined in Canada on and after the day on which this Act comes into force,—the said bounty to be paid to or divided amongst the producers of the petroleum, the owner or occupier of the soil through which it is mined or won, or such other person interested, or injuriously affected by the mining operations or works, as the Governor in Council by regulation approves. Bounty on petroleum.

3. The Minister of Trade and Commerce shall be charged with the administration of this Act, and may, subject to the approval of the Governor in Council, make such regulations as he deems necessary respecting the payment of the said bounties. Administration and regulations.

4. Chapter 33 of the statutes of 1907, and *The Petroleum Bounty Act, 1908*, chapter 52 of the statutes of 1908, are repealed. Repeal.

APPENDIX II.

[*COPY.*]

REGULATIONS

FOR THE

DISPOSAL OF PETROLEUM AND NATURAL GAS RIGHTS, THE PROPERTY OF THE CROWN IN MANITOBA, SASKATCHEWAN, ALBERTA, THE NORTHWEST TERRITORIES, THE YUKON TERRITORY, THE RAILWAY BELT IN THE PROVINCE OF BRITISH COLUMBIA, AND WITHIN THE TRACT CONTAINING THREE AND ONE-HALF (3½) MILLION ACRES OF LAND ACQUIRED BY THE DOMINION GOVERNMENT FROM THE PROVINCE OF BRITISH COLUMBIA, AND REFERRED TO IN SUB-SECTION (b) OF SECTION 3 OF THE DOMINION LANDS ACT.

Approved by Order in Council, dated the 19th day of January, 1914.

Regulations for the disposal of Petroleum and Natural Gas rights, the property of the Crown, in Manitoba, Saskatchewan, Alberta, the Northwest Territories, the Yukon Territory, the Railway Belt in the Province of British Columbia, and within the tract containing three and one-half ($3\frac{1}{2}$) million acres of land acquired by the Dominion Government from the Province of British Columbia, and referred to in subsection (b) of section 3 of the Dominion Lands Act.

Approved by Order in Council dated the 19th of January, 1914.

INTERPRETATION.

"Minister" shall mean the Minister of the Interior of Canada.

"Adjoining" lands shall be those which are not separated by a section, or by any of the regular subdivisions into which a section may be divided.

"Location" shall mean the tract described in a petroleum and natural gas lease.

"Group" shall mean two or more of the locations described in petroleum and natural gas leases, consolidated for purposes of operation.

"Lessee" means any individual, company, corporation or municipality the holder of a petroleum and natural gas lease in good standing.

"River" shall mean a stream of water the bed of which is of an average width of 150 feet throughout the portion thereof on which the tract applied for fronts.

1. The petroleum and natural gas rights which are the property of the Crown, in Manitoba, Saskatchewan, Alberta, the Northwest Territories, the Yukon Territory, the Railway Belt in the Province of British Columbia, and within the tract containing three and one-half ($3\frac{1}{2}$) million acres of land acquired

by the Dominion Government from the Province of British Columbia, and referred to in subsection (*b*) of section 3 of the Dominion Lands Act, may be leased to applicants at a rental of twenty-five (25) cents an acre for the first year, and for each subsequent year a rental at the rate of fifty (50) cents an acre, payable yearly in advance. The term of the lease shall be twenty-one years, renewable for a further term of twenty-one years, provided the lessee can furnish evidence satisfactory to the Minister to show that during the term of the lease he has complied fully with the conditions of such lease and with the provisions of the regulations in force from time to time during the currency of the lease.

2. The maximum area of a petroleum and natural gas location shall be 1,920 acres, and no person shall be permitted to acquire a greater area except by assignment:

Provided that a person who has been granted a lease for a location, and who subsequently abandons or assigns the same, may, after the expiration of twelve months from the date of the said lease, apply for an area not greater than that abandoned or assigned:

Provided further, however, that such right shall not be granted unless all payments on account of rent or other liability to the Crown, due by such person, have been fully made, up to the date of the registration by the Department of the assignment of his right to such lease, or up to the date upon which the notice of his abandonment of the same was received by the Department.

3. If the tract applied for is situated in surveyed territory, it shall consist of sections, or legal subdivisions of sections, but the several parcels comprising the tract shall be adjoining, the length of the tract not to exceed three times its breadth. In unsurveyed territory, if at least one of the lines bounding the tract applied for has been surveyed, and the returns of such survey have been duly received in the office of the Surveyor General, an application for a lease of the petroleum and natural gas rights under such tract may be considered under the provisions of this section of the regulations.

4. Application for a lease of the petroleum and natural gas rights on surveyed lands shall be filed by the applicant in

person with the Agent of Dominion Lands for the district in which the rights applied for are situated, or with a sub-agent for such district for transmission to the agent; but priority of application shall be based upon the date of the receipt of such application in the office of the Agent of Dominion Lands for the district.

5. If the rights applied for are situated in unsurveyed territory, application for a lease shall be made by the applicant in person to the Agent of Dominion Lands for the district in which the rights applied for are situated, or to a sub-agent for such district, for transmission to the agent.

6. Application for a location situated in unsurveyed territory shall contain a description by metes and bounds of the location applied for, and shall be accompanied by a plan showing the position of such location in its relation to some prominent topographical feature or other known point. The plan shall contain sufficient data to admit of the position of the location applied for being definitely shown in the records of the Department. The location must be rectangular in form, except where a boundary of a previously located tract is adopted as common to both locations, the length not to exceed three times the breadth.

The application shall be accompanied by evidence, supported by affidavit of the locator, to show that the following requirements have been fully complied with:—

(*a*) That the location applied for has been defined on the ground by the locator in person by planting two wooden posts, at least four inches square and standing not less than four feet above the ground—such posts being numbered "1" and "2" respectively. The distance between post No. "1" and post No. "2" shall not exceed 15,840 feet, and upon each post shall be inscribed the name of the locator and the date of the location. Upon post No. "1" there shall be written, in addition to the foregoing, the words "initial post," the approximate compass bearing of post No. "2" and a statement of the number of feet lying to the right and to the left of the line between post No. "1" and post No. "2." Thus—(initial post, direction of post No. "2" is...............feet lie to the right and...............feet to the left of the line between post No. "1" and post No. "2".

When the tract which an applicant desires to lease has been located, he shall immediately mark the line between post No. "1" and post No. "2" so that it can be distinctly seen in a timbered locality, by blazing trees and cutting underbrush, and in a locality where there is neither timber nor underbrush he shall set posts of the above dimensions or erect mounds of earth or rock not less than two feet high and two feet in diameter at the base in such a manner that the line may be distinctly seen.

(*b*) All the particulars required to be inscribed on posts No. "1" and No. "2" shall be set out in the application and shall be accompanied by a plan showing the position of the tract in its relation to some prominent topographical feature or other known point, such plan to contain sufficient data to admit of the location being shown definitely on the records of the Department.

(*c*) The locator shall post a written or printed notice on a conspicuous part of the location applied for, setting out his intention to apply within thirty days from the date of such notice for a lease of the petroleum and natural gas rights under the said location.

(*d*) The application shall be accompanied by evidence, supported by the affidavit of the locator, in due form, to show that the above requirements of the regulations have been fully complied with.

7. In case the tract applied for is located in unsurveyed territory on the margin of a river or lake, it shall not include more than one mile in direct distance along such water frontage, and shall extend back therefrom as far as may be necessary to include a total area of not more than 1,920 acres, the length of the location, however, not to exceed three miles. The tract shall be marked on the ground by two posts firmly fixed in the ground, one at each end of such front boundary. The posts shall be numbered "1" and "2" respectively. It shall not be lawful to move post No. "1", but post No. "2" may be moved by a Dominion Land Surveyor if the distance between the posts exceeds the length prescribed by these regulations, but not otherwise. The side boundaries shall be parallel lines drawn from each end of the front boundary at right angles to the base line of such river or lake, established or to be established by the Department. In

the event of the base line not being established, the side boundaries of the location shall be drawn at right angles to the general direction of the valley of the river, or the margin of the lake. The required notice of application shall be posted conspicuously on the location near the margin of the lake or river on which it fronts.

The boundaries of claims situated on the margin of a lake or river, and any disputes which may arise in connection therewith, shall be subject to final adjustment by the Minister.

8. Application for a lease of the petroleum and natural gas rights under lands situated in unsurveyed territory shall be made by the locator in person to the Agent of Dominion Lands for the District in which the tract applied for is situated, or to a sub-agent for such district within thirty days from the date upon which the tract applied for was staked as above provided, if it is situated within one hundred miles of the office of the Agent or Sub-Agent, otherwise it will not be considered. One extra day, however, shall be allowed for every additional ten miles or fraction thereof that the location is distant more than one hundred miles from the office of the Agent or Sub-Agent.

9. Where two or more persons lay claim to the same location, or to portions of the same locations, situated in unsurveyed territory, the right to the lease shall be in him who can prove to the satisfaction of the Minister that he was the first to take possession of the tract in dispute by staking in the manner prescribed in these regulations, and that he made application for a lease within the specified time.

10. As soon as the survey of a township has been confirmed, all petroleum and natural gas leases embracing any portion of such township so surveyed and confirmed, shall be made to conform to the Dominion Lands System of Survey if the Minister so decides, by the substitution of a new lease describing by sections, legal subdivisions of sections, or regular portions of legal Subdivisions as nearly—as may be—the tract embraced in the leasehold in so far as the township so surveyed is concerned. If any part of the leasehold is in territory which remains unsurveyed it shall continue to be described as in the lease originally issued, until such portion is included in a confirmed survey.

11. As soon as the survey of a township has been confirmed, all petroleum and natural gas leaseholds embracing any portion of the township so surveyed and confirmed, shall be subject to the withdrawal forthwith from the lease, without compensation to the lessese, of any portions which, in accordance with such confirmed survey, are found to be the property of the Hudson's Bay Company.

Provided, however, that upon such withdrawal being made from any location in good standing, the rental paid on the land so withdrawn, in whole or in part, may, in the discretion of the Minister, be refunded to the lessee.

12. The rental for the first year of the location applied for at the rate of twenty-five (25) cents an acre per annum, shall accompany the application filed in the office of the Agent of Dominion Lands for the district in which the rights applied for are situated, and no application for a lease of petroleum and natural gas rights shall be accepted or recorded unless it is accompanied by the full amount of the rental for the first year at the above rate. The lease, when issued, shall bear date from the day upon which the application was filed in the office of the Agent of Dominion Lands. If, during the term of the lease, the lessee shall fail to pay rental in advance for each subsequent year at the rate of fifty (50) cents an acre per annum within thirty days after the date upon which the same became due, the lease shall be subject to cancellation in the discretion of the Minister and to the immediate forfeiture of the rights which the lessee had in the said lease.

13. Provided, that if the lessee, in consideration of the expenditure to be incurred by him in actual boring operations upon his leasehold, makes application, at or before the beginning of the second and third years, respectively, of the term of the lease, for an extension of time within which to pay the rental when due, or becoming due, the Minister may grant such extension of time in writing, and if the lessee, before the end of the year in respect of which application was made, submits evidence to the Land Agent of the district in which the leasehold is situated, supported by affidavit, that during such year actual boring operations have been prosecuted upon his lease-

hold, as required by section 15 of these regulations, the amount expended in such boring operations, exclusive of the cost of machinery and casing, may be deducted from the rental which became due at the beginning of the said year. The balance of rental due, if any, shall be paid at the same time as the evidence in regard to work done is submitted, as above required. Failure to submit such evidence, or to pay the balance or rental due, with interest, will render the lease liable to cancellation, as hereinbefore provided.

14. The lessee shall, within one year from the date of the lease, have upon the lands described therein such machinery and equipment suitable for carrying on prospecting operations as the Minister may consider necessary, and he shall within the same period furnish evidence, supported by affidavit, showing the character, quantity and value of the machinery so installed, the date of its installation and the particular parcel of land upon which it was installed. If the required machinery is not installed within the period specified, and if evidence of its installation is not furnished within the prescribed period, the lease shall be subject to cancellation in the discretion of the Minister. Provided, however, that the Minister shall not require that the value of the machinery so installed on a location shall exceed the sum of five thousand dollars ($5,000.00).

15. The lessee shall commence boring operations on his leasehold within fifteen months of the date of his lease, and he shall continue such boring operations with reasonable diligence, to the satisfaction of the Minister, with a view to the discovery of oil or natural gas. If the lessee does not commence boring operations within the time prescribed, or if having commenced such operations he does not prosecute the same with reasonable diligence, to the satisfaction of the Minister, or if he ceases to carry on the same for a period of more than three months, the lease shall be subject to cancellation in the discretion of the Minister, upon three months' notice to this effect being given to the lessee. Provided, however, that if satisfactory evidence is furnished to show that the sum of at least two thousand dollars ($2,000.00) has been expended in actual boring operations, by recognized methods, upon the leasehold in any year, such expen-

diture shall be accepted as compliance with this provision for the year during which such expenditure shall have been incurred.

16. The Minister may permit a lessee, who has acquired by assignment or otherwise, more than one petroleum and natural gas lease, to consolidate his operations and expenditure, and to install machinery and equipment on one or more of the locations described in the lease affected: Provided that such consolidation or grouping shall apply only to the second and third years of the term of the leases, and shall comprise only such leases as may at the time be included in such consolidation or grouping. Evidence of the installation of machinery on one or more of the locations included in a group shall be that prescribed by Section 14 of these regulations. If the required machinery is not installed on one or more of the locations included in a group within the period specified and evidence of its installation furnished within the prescribed period, and if boring operations are not commenced and continued on such location or locations in the manner set out in Section 15 of these regulations, the leases included in the group shall be subject to cancellation in the discretion of the Minister.

17. The Minister may, in consideration of the expenditure to be incurred by a lessee in boring operations upon one or more of the locations included in a group, grant an extension of time within which to pay the rental for the second and third years of the term of the several leases so included, and upon receipt of the evidence required by Section 13 of these regulations, he may deduct from the rental which became due at the beginning of the year in respect of the several locations grouped, the amount expended in actual boring operations on one or more of the locations, exclusive of the cost of machinery and casing. The balance of the rental due if any, shall be paid at the same time as the evidence in regard to work done is submitted, as above required. Failure to submit such evidence or to pay the balance or the rental due, with interest, will render the several leases included in the group liable to cancellation.

18. Provided, however, that the Minister shall not require that the value of the machinery to be installed on any group

of locations shall exceed the sum of ten thousand dollars ($10,000.00), nor shall he require that the expenditure incurred in boring operations thereon in any one year shall exceed the sum of two thousand dollars ($2,000.00) for each location included in the group.

19. The maximum area of the locations which may be included in one consolidation or group shall not exceed twenty (20) square miles, nor shall the locations so included be separated one from the other by a greater distance than two miles.

20. The Minister may, upon application, grant a lessee during the second and third years of the term of the lease an extension of time within which to pay the rental and to install the prescribed machinery and equipment, and within which to commence actual boring operations upon the location, or upon a group of locations consolidated under the provisions of these regulations: Provided that evidence to the satisfaction of the Minister is furnished to show that an expenditure equal to that prescribed by these regulations in respect of boring operations, is to be incurred in some other acceptable and necessary form of preliminary development, having for its object the discovery of petroleum or natural gas, by which the interestsof the district in which the locations are situated might be materially benefited. Upon receipt of evidence on or before the termination of the year, supported by affidavit and duly corroborated, that such expenditure has been incurred, and that the work done was of a character beneficial to the district, the Minister may deduct the amount of such expenditure from the amount due on account of the rental of the location or locations affected, in the manner prescribed in section 13 of these regulations. In case evidence is not furnished, or if furnished is not acceptable to the Minister, the leases shall be subject to immediate cancellation in the discretion of the Minister.

In case an extension of time is granted during the second and third years of the term of a lease within which to install machinery and commence boring operations on any location under the grouping provisions of these regulations, then the provisions of sections 14 and 15 of the regulations shall apply to the fourth year of the term of the lease of such location.

21. In case the surface rights of a petroleum and natural gas location are covered by a timber license, grazing or coal mining lease, mining claim or other form of terminable grant the lease shall not authorize entry thereon, without the permission of the Minister being first had and obtained, and such permission shall be given subject to such conditions for the protection of the rights of such lessee or licensee as it may be considered necessary to impose.

22. In case the surface rights of a petroleum and natural gas location have been patented, or have been disposed of by the Crown under any act or regulation which contemplates the earning of patent for such surface rights, and the lessee of the petroleum and natural gas rights cannot make an arrangement with the owner of such surface rights, or with his agent, or the occupant thereof, for entry upon the location, or for the acquisition of such interest in the surface rights as may be necessary for the efficient and economical operation of the rights acquired under his lease, he may, provided the mineral rights in the land affected with access thereto and the right to use and occupy such portion of the land as may be necessary for the effectual working of the minerals therein have been reserved to the Crown in the original grant of the surface rights, apply to the Minister for permission to submit the matter in dispute to arbitration. Upon receiving such permission in writing, it shall be lawful for the lessee to give notice to the owner, or his agent, or the occupant, to appoint an arbitrator within a period of sixty days from the date of such notice, to act with another arbitrator named by the lessee, in order to determine what portion of the surface rights the lessee may reasonably acquire:—

(*a*) For the efficient and economical operation of the rights and privileges granted him under his lease;

(*b*) The exact position thereof, and

(*c*) The amount of compensation to which the owner or occupant shall be entitled.

23. The notice mentioned in this section shall be according to a form to be obtained upon application to the Agent of Dominion Lands for the district in which the land in question is situated, and shall, when practicable, be personally served on the owner of

such land, or his agent, if known, or the occupant thereof, and after reasonable efforts have been made to effect personal service without success, then such notice shall be served by leaving it at or sending it by registered mail, to the last known place of abode or address of the owner, agent or occupant, and by posting a copy of the same in the office of the Agent of Dominion Lands for the district in which the land in question is situate. Such notice shall be ten days if the owner, or his agent, resides in the district in which the land is situate; if out of the district and if in the province or territory, twenty days, and if out of the province or territory, thirty days, before the expiration of the time limited in such notice. If the owner, or his agent, or the occupant of the land refuses or declines to appoint an arbitrator, or when, for any reason, no arbitrator is so appointed in the time limited therefor in the notice provided for by this section, the Agent of Dominion Lands for the district in which the land in question is situate shall forthwith, on being satisfied by affidavit that such notice has come to the knowledge of such owner, agent, or occupant, or that such owner, agent, or occupant, wilfully evades the service of such notice, or cannot be found, and that reasonable efforts have been made to effect such service, and that the notice was left at the last place of abode or known address of such owner, agent, or occupant as above provided, appoint an arbitrator on his behalf.

24. In case the two arbitrators cannot agree upon the award to be made, they may, within a period of ten days from the date of the appointment of the second arbitrator select a third arbitrator, and when such two arbitrators cannot agree upon a third arbitrator, the Agent of Dominion Lands for the district in which the land in question is situate, shall forthwith select such third arbitrator.

25. All the arbitrators appointed under the authority of these regulations shall be sworn before a justice of the peace to the impartial discharge of the duties assigned to them, and after due consideration of the rights of the owner and the needs of the lessee, they shall decide as to the particular portion of the surface rights which the latter may reasonably acquire for the efficient and economical operation of the rights and privileges granted him

under his lease, the area thereof, and the amount of compensation therefor to which the owner or occupant shall be entitled.

26. In making such valuation the arbitrator shall determine the value of the land irrespective of any enhancement thereof from the existence of minerals thereunder.

27. The award of any two such arbitrators made in writing shall be final, and shall be filed with the Agent of Dominion Lands for the district in which the land is situate, within twenty days from the date of the appointment of the last arbitrator. Upon the order of the Minister the award of the arbitrators shall immediately be carried into effect.

28. The arbitrators shall be entitled to be paid a per diem allowance of $5.00 together with their necessary travelling and living expenses, while engaged in the arbitration, and the costs of such arbitration shall be in the discretion of the arbitrators.

29. The lessee shall at all times take reasonable measures to prevent the injurious access of water to the oil bearing formation. Upon a well proving to be unproductive, or ceasing to yield oil in paying quantity, or being abandoned for any cause, the lessee shall be at liberty to withdraw the casing from the said well, but in order to prevent water gaining access to the oil-bearing formation, the lessee shall immediately close the well by filling it with sand, clay, or other material which may have the effect of preventing water from gaining access thereto.

In case natural gas is discovered through boring operations on a location, the lessee shall take all reasonable and proper precautions to prevent the waste of such natural gas, and his operations shall be so conducted as to enable him, immediately upon discovery, to control and prevent the escape of such gas.

Should salt water be encountered through operations upon the location, the lessee shall immediately and effectively, to the satisfaction of the Minister, close the well at such a depth as may prevent such water from gaining access to the oil-bearing formation.

The Minister may, from time to time, make such additional regulations as may appear to be necessary or expedient governing the manner in which boring operations shall be conducted, and the manner in which the wells shall be operated.

Failure on the part of the lessee to comply with the above requirements, or to comply with such other requirements as the Minister may consider it necessary to impose in respect of boring and operating, will render the lease subject to cancellation in the discretion of the Minister.

30. The lessee may be permitted to relinquish at any time the whole or any portion of the location described in his lease, provided he has complied in every respect with the provisions of the regulations, and that all payments on account of rental or other liability to the Crown, due in connection with the lease, have been fully made, and provided the portion of the location which may be retained shall be of the prescribed shape, and shall not be of a less area than forty acres.

31. The lease shall in all cases include only the oil and natural gas rights, which are the property of the Crown; but the lessee may, upon application, be granted a yearly lease at a rental of one dollar ($1.00) an acre per annum, payable yearly in advance, of whatever area of the available surface rights of the tract described in his petroleum and natural gas lease the Minister may consider necessary for the efficient and economical working of the rights granted him.

32. Should oil or natural gas in paying quantity be discovered on the leasehold, and should such discovery be established to the satisfaction of the Minister, the lessee will be permitted to purchase at the rate of ten dollars ($10.00) an acre whatever area of the available surface rights of the tract described in the lease the Minister may consider necessary for the efficient operation of the rights granted him.

33. If it is not established to the satisfaction of the Minister that oil or natural gas in paying quantity has been discovered on the leasehold, the lease shall be subject to termination upon two years' notice in writing being given to the lessee by the Minister.

34. The boundaries beneath the surface of a location shall be vertical planes or lines in which their surface boundaries lie.

35. A fee of five dollars ($5.00) shall accompany each application for a lease, which will be refunded if the rights applied for are not available, but not otherwise.

36. The lease shall be in such form as may be determined by the Minister of the Interior, in accordance with the provisions of these regulations.

37. The lessee shall not assign, transfer or sublet the rights described in his lease, or any part thereof, without the consent in writing of the Minister being first had and obtained.

38. No royalty shall be charged upon the sales of the petroleum acquired from the Crown under the provisions of the regulations up to the 1st day of January, 1930, but provision shall be made in the leases issued for such rights that after the above date the petroleum products of the location shall be subject to whatever regulations in respect of the payment of royalty may then or thereafter be made.

39. A royalty at such rate as may from time to time be specified by Order in Council may be levied and collected on the natural gas products of the leasehold.

40. Any company acquiring by assignment or otherwise a lease under the provisions of these regulations, shall at all times be and remain a British company, registered in Great Britain or Canada and having its principal place of business within His Majesty's Dominions, and the chairman of the said company and a majority of the directors shall at all times be British subjects, and the company shall not at any time be or become, directly or indirectly, controlled by foreigners or by a foreign corporation.

Any alteration in the memorandum of articles of association, or in the constitution of the company, or in the by-laws of the company, shall be reported to the Minister, provided that two months' previous notice of the intention to make any alteration which might conceivably affect the British character of the company shall be given in writing to the Minister, and if, in the opinion of the Minister, the said alteration shall be contrary to the cardinal principle that the lessee company shall be and remain a British company under British control, the Minister may refuse his consent to such alteration.

If the company which may acquire a location under these regulations shall at any time cease to be a British company, or shall become a corporation under foreign control, or shall assign any of the rights acquired under the lease without the consent in writing of the Minister being first had and obtained, the lease shall be subject to immediate cancellation in the discretion of the Minister.

41. The Minister may at any time assume absolute possession and control of any location acquired under the provisions of these regulations, if in the opinion of the Government of Canada such action is considered necessary or advisable, together with all buildings, works, machinery and plant, upon the location, or used in connection with the operation thereof, and he may cause the same to be operated and may retain the whole or any part of the output, in which event compensation shall be paid to the lessee for any loss or damage sustained by him by reason of the exercise of the powers conferred by this provision of the regulations, the amount of the compensation, in case of dispute, to be fixed by a Judge of the Exchequer Court of Canada, provided that the compensation in any such case shall not exceed the profit which the lessee would have earned in the working of the location and the disposal of the products thereof, had possession and control of the location and of the buildings, works, machinery and plant not been assumed.

42. If the location described in any lease issued under the provisions of these regulations, shall yield oil in paying quantity, the lessee shall pump and work the wells faithfully and uninterruptedly with due vigor and skill, with good and sufficient machinery and appliances in accordance with the provisions of the regulations and to the satisfaction of the Minister, so long as the said wells continue to yield oil in remunerative quantity.

43. At the end of each year of the term of the lease the lessee shall furnish a statement, supported by affidavit, showing the number of days during the year that operations were carried on upon the location; the number of men so employed; the character of the work done; the depth attained; the total expenditure incurred; a detailed statement setting out fully the purpose for which such expenditure was incurred; the quantity of crude oil or natural gas obtained; and the amount realized from the sale thereof. Failure to furnish such yearly return will render the lessee subject to a fine of ten dollars ($10.00) a day

for each day's delay in furnishing the sworn statement, and after three months' delay the lease shall be subject to cancellation.

44. These regulations shall apply to all applications submitted on and after the first day of August, 1913, in accordance with the provisions of the regulations which were for the time in force.

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DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR.

REPORTS AND MAPS

PUBLISHED BY THE

MINES BRANCH

REPORTS.

1. Mining conditions in the Klondike, Yukon. Report on—by Eugene Haanel, Ph.D., 1902.

†2. Great landslide at Frank, Alta. Report on—by R. G. McConnell, B.A., and R. W. Brock, M.A., 1903.

†3. Investigation of the different electro-thermic processes for the smelting of iron ores and the making of steel, in operation in Europe. Report of Special Commission—by Eugene Haanel, Ph.D., 1904.

5. On the location and examination of magnetic ore deposits by magnetometric measurements—by Eugene Haanel, Ph.D., 1904.

†7. Limestones, and the lime industry of Manitoba. Preliminary report on—by J. W. Wells, M.A., 1905.

†8. Clays and shales of Manitoba: their industrial value. Preliminary report on—by J. W. Wells, M.A., 1905.

†9. Hydraulic cements (raw materials) in Manitoba: manufacture and uses of. Preliminary report on—by J. W. Wells, M.A., 1905.

†10. Mica: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E., 1905. (See No. 118.)

†11. Asbestos: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E., 1905. (See No. 69.)

†12. Zinc resources of British Columbia and the conditions affecting their exploitation. Report of the Commission appointed to investigate—by W. R. Ingalls, M.E., 1905.

†16. *Experiments made at Sault Ste. Marie, under Government auspices, in the smelting of Canadian iron ores by the electro-thermic process. Final report on—by Eugene Haanel, Ph.D., 1907.

†17. Mines of the silver-cobalt ores of the Cobalt district: their present and prospective output. Report on—by Eugene Haanel, Ph.D., 1907.

* A few copies of the Preliminary Report, 1906, are still available.
† Publications marked thus † are out of print.

†18. Graphite: its properties, occurrence, refining, and uses—by Fritz Cirkel, M.E., 1907.

†19. Peat and lignite: their manufacture and uses in Europe—by Erik Nystrom, M.E., 1908.

†20. Iron ore deposit of Nova Scotia. Report on (Part I)—by J. E. Woodman, D.Sc.

21. Summary report of Mines Branch, 1907–8.

22. Iron ore deposits of Thunder Bay and Rainy River districts. Report on—by F. Hille, M.E.

†23. Iron ore deposits along the Ottawa (Quebec side)and Gatineau rivers. Report on—by Fritz Cirkel, M.E.

24. General report on the mining and metallurgical industries of Canada, 1907–8.

†25. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D.

26. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†27. The mineral production of Canada, 1907. Preliminary report on—by John McLeish, B.A.

†27a. The mineral production of Canada, 1908. Preliminary report on—by John McLeish, B.A.

†28. Summary report of Mines Branch, 1908.

29. Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.)

30. Investigation of the peat bogs and peat fuel industry of Canada, 1908 Bulletin No. 1—by Erik Nystrom, M.E., and A. Anrep, Peat Expert.

32. Investigation of electric shaft furnace, Sweden. Report on—by Eugene Haanel, Ph.D.

47. Iron ore deposits of Vancouver and Texada islands. Report on—by Einar Lindeman, M.E.

†55. The bituminous, or oil-shales of New Brunswick and Nova Scotia, also on the oil-shale industry of Scotland. Report on—by R. W Ells, LL.D.

58. The mineral production of Canada, 1907 and 1908. Annual report on—by John McLeish, B.A.

† Publications marked thus † are out of print.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1907-8.*

†31. Production of cement in Canada, 1908.

42. Production of iron and steel in Canada during the calendar years 1907 and 1908.

43. Production of chromite in Canada during the calendar years 1907 and 1908.

44. Production of asbestos in Canada during the calendar years 1907 and 1908.

†45. Production of coal, coke, and peat in Canada during the calendar years 1907 and 1908.

46. Production of natural gas and petroleum in Canada during the calendar years 1907 and 1908.

59. Chemical analyses of special economic importance made in the laboratories of the Department of Mines, 1906-7-8. Report on—by F. G. Wait, M.A., F.C.S. (With Appendix on the commercial methods and apparatus for the analysis of oil-shales—by H. A. Leverin, Ch. E.)

Schedule of charges for chemical analyses and assays.

†62. Mineral production of Canada, 1909. Preliminary report on—by John McLeish, B.A.

63. Summary report of Mines Branch, 1909.

67. Iron ore deposits of the Bristol mine, Pontiac county, Quebec. Bulletin No. 2—by Einar Lindeman, M.E., and Geo. C. Mackenzie, B.Sc.

†68. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

69. Chrysotile-asbestos: its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E. (Second edition, enlarged.)

†71. Investigation of the peat bogs, and peat industry of Canada, 1909-10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenberg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. v. Anrep, Jr.; also a translation of Lieut. Ekelund's pamphlet entitled 'A solution of the peat problem,' 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. v. Anrep. (Second edition, enlarged.)

82. Magnetic concentration experiments. Bulletin No. 5—by Geo. C. Mackenzie, B.Sc.

† Publications marked thus † are out of print.

83. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others.
Vol. I—Coal washing and cooking tests.
Vol. II—Boiler and gas producer tests.
Vol. III—(Out of print.)
Appendix I
Coal washing tests and diagrams.
Vol. IV—
Appendix II
Boiler tests and diagrams.
Vol. V—(Out of print.)
Appendix III
Producer tests and diagrams.
Vol. VI—
Appendix IV
Coking tests.
Appendix V
Chemical tests.

†84. Gypsum deposits of the Maritime provinces of Canada—including the Magalen islands. Report on—by W. F. Jennison, M.E. (See No. 245.)

88. The mineral production of Canada, 1909. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1909.*

†79. Production of iron and steel in Canada during the calendar year 1909.
†80. Production of coal and coke in Canada during the calendar year 1909.
†85. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1909.

89. Reprint of presidential address delivered before the American Peat Society at Ottawa, July 25, 1910. By Eugene Haanel, Ph.D.

90. Proceedings of conference on explosives.

92. Investigation of the explosives industry in the Dominion of Canada, 1910. Report on—by Capt. Arthur Desborough. (Second edition.)

93. Molybdenum ores of Canada. Report on—by Professor T. L. Walker, Ph.D.

100. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by Professor W. A. Parks, Ph.D.

102. Mineral production of Canada, 1910. Preliminary report on—by John McLeish, B.A.

† Publications marked thus † are out of print.

†103. Summary report of Mines Branch, 1910.

104. Catalogue of publications of Mines Branch, from 1902 to 1911; containing tables of contents and lists of maps, etc.

105. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

110. Western portion of Torbrook iron ore deposits, Annapolis county, N.S. Bulletin No. 7—by Howells Fréchette, M.Sc.

111. Diamond drilling at Point Mamainse, Ont. Bulletin No. 6—by A. C. Lane, Ph.D., with introductory by A. W. G. Wilson, Ph.D.

118. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

142. Summary report of Mines Branch, 1911.

143. The mineral production of Canada, 1910. Annual report on—by John McLeish, B.A.

NOTE. *The following parts were separately printed and issued in advance of the Annual Report for 1910.*

†114. Production of cement, lime, clay products, stone, and other materials in Canada, 1910.
†115. Production of iron and steel in Canada during the calendar year 1910.
†116. Production of coal and coke in Canada during the calendar year 1910.
†117. General summary of the mineral production of Canada during the calendar year 1910.

145. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

†150. The mineral production of Canada, 1911. Preliminary report on—by John McLeish, B.A.

151. Investigation of the peat bogs and peat industry of Canada, 1910-11 Bulletin No. 8—by A. v. Anrep.

154. The utilization of peat fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa 1910-11. Report on—by B. F. Haanel, B.Sc.

167. Pyrites in Canada: its occurrence, exploitation, dressing and uses. Report on—by A. W. G. Wilson, Ph.D.

170. The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

184. Magnetite occurrences along the Central Ontario railway. Report on—by E. Lindeman, M.E.

201. The mineral production of Canada during the calendar year 1911. —Annual report on—by John McLeish, B.A.

† Publications marked thus † are out of print.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1911.*

181. Production of cement, lime, clay products, stone, and other structural materials in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

†182. Production of iron and steel in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

183. General summary of the mineral production in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

†199. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1911. Bulletin on—by C. T. Cartwright, B.Sc.

†200. The production of coal and coke in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

203. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, PhD.

209. The copper smelting industry of Canada. Report on—by A. W. G. Wilson, Ph.D.

216. Mineral production of Canada, 1912. Preliminary report on—by John McLeish, B.A.

222. Lode mining in Yukon: an investigation of the quartz deposits of the Klondike division. Report on—by T. A. MacLean, B.Sc.

224. Summary report of the Mines Branch, 1912.

227. Sections of the Sydney coal fields—by J. G. S. Hudson, M.E.

†229. Summary report of the petroleum and natural gas resources of Canada, 1912—by F. G. Clapp, A.M. (See No. 224.)

230. Ecomomic minerals and mining industries of Canada.

245. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

254. Calabogie iron-bearing district. Report on—by E. Lindeman, M.E.

259. Preparation of metallic cobalt by reduction of the oxide. Report on—by H. T. Kalmus, B.Sc., Ph.D.

262. The mineral production of Canada during the calendar year 1912. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1912.*

238. General summary of the mineral production of Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

† Publications marked thus † are out of print.

†247. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

†256. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1912—by C. T. Cartwright, B.Sc.

257. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Report on—by John McLeish, B.A.

†258. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

266. Investigation of the peat bogs and peat industry of Canada, 1911 and 1912. Bulletin No. 9—by A. v. Anrep.

279. Building and ornamental stones of Canada—Vol. III: Building and ornamental stones of Quebec. Report on—by W. A. Parks, Ph.D.

281. The bituminous sands of Northern Alberta. Report on—by S. C. Ells, M.E.

283. Mineral production of Canada, 1913. Preliminary report on—by John McLeish, B.A.

285. Summary report of the Mines Branch, 1913.

291. The petroleum and natural gas resources of Canada. Report on—by F. G. Clapp, A.M., and others:—
Vol. I.—Technology and Exploitation.
Vol. II.—Occurrence of petroleum and natural gas in Canada.
Also separates of Vol. II, as follows:—
Part 1, Eastern Canada.
Part 2, Western Canada.

299. Peat, lignite, and coal: their value as fuels for the production of gas and power in the by-product recovery producer. Report on—by B. F. Haanel, B.Sc.

303. Moose Mountain iron-bearing district. Report on—by E. Lindeman, M.E.

305. The non-metallic minerals used in the Canadian manufacturing industries. Report on—by Howells Fréchette, M.Sc.

309. The physical properties of cobalt, Part II. Report on—by H. T. Kalmus, B.Sc., Ph.D.

320. The mineral production of Canada during the calendar year 1913. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1913.*

315. The production of iron and steel during the calendar year 1913. Bulletin on—by John McLeish, B.A.

316. The production of coal and coke during the calendar year 1913. Bulletin on—by John McLeish, B.A.

† Publications marked thus † are out of print.

317. The production of copper, gold, lead, nickel, silver, zinc, and other metals, during the calendar year 1913. Bulletin on—by C. T. Cartwright, B.Sc.

318. The production of cement, lime, clay products, and other structural materials, during the calendar year 1913. Bulletin on—by John McLeish, B.A.

319. General summary of the mineral production of Canada during the calendar year 1913. Bulletin on—by John McLeish, B.A.

322. Economic minerals and mining industries of Canada. (Panama Edition).

323. The Products and by-products of coal. Report on—by Edgar Stansfield, M.Sc., and F. E. Carter, B.Sc., Dr. Ing.

325. The salt industry of Canada. Report on—by L. H. Cole, B.Sc.

331. The investigation of six samples of Alberta lignites. Report on—by B. F. Haanel, B.Sc., and John Blizard, B.Sc.

334. Electro-plating with cobalt and its alloys. Report on—by H. T. Kalmus, B.Sc., Ph.D.

336. Notes on clay deposits near McMurray, Alberta. Bulletin No. 10—by S. C. Ells, B.A., B.Sc.

The Division of Mineral Resources and Statistics has prepared the following lists of mine, smelter, and quarry operators: Metal mines and smelters, Coal mines, Stone quarry operators, Manufacturers of clay products, and Manufacturers of lime; copies of the lists may be obtained on application.

IN THE PRESS.

338. Coals of Canada: Vol. VII. Weathering of coal. Report on—by J. B. Porter, E.M., D.Sc., Ph.D.

344. Electrothermic smelting of iron ores in Sweden. Report on—by Alfred Stansfield, D.Sc., A.R.S.M., F.R.S.C.

346. Summary report of the Mines Branch for 1914.

348. Production of coal and coke in Canada during the calendar year, 1914. Bulletin on—by J. McLeish, B.A.

349. Production of iron and steel in Canada during the calendar year, 1914. Bulletin on—by J. McLeish, B.A.

350. Production of copper, gold, lead, nickel, silver, zinc, and other metals, during the calendar year, 1914. Bulletin on—by J. McLeish, B.A.

FRENCH TRANSLATIONS.

†4. Rapport de la Commission nommée pour étudier les divers procédés électro-thermiques pour la réduction des minerais de fer et la fabrication de l'acier employés en Europe—by Eugene Haanel, Ph.D. (French Edition), 1905.

26a. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†28a. Summary report of Mines Branch, 1908.

56. Bituminous or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by R. W. Ells, LL.D.

81. Chrysotile-asbestos, its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E.

100a. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by W. A. Parks, Ph.D.

149. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

155. The utilization of peat fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910-11. Report on—by B. F. Haanel, B.Sc.

156. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D.

169. Pyrites in Canada: its occurrence, exploitation, dressing, and uses. Report on—by A. W. C. Wilson, Ph.D.

180. Investigation of the peat bogs, and peat industry of Canada, 1910-11. Bulletin No. 8—by A. v. Anrep.

195. Magnetite occurrences along the Central Ontario railway. Report on—by E. Lindeman, M.E.

196. Investigation of the peat bogs and peat industry of Canada, 1909-10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenburg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. v. Anrep; also a translation of Lieut. Ekelund's pamphlet entitled "A solution of the peat problem," 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. v. Anrep. (Second Edition, enlarged.)

197. Molybdenum ores of Canada. Report on—by T. L. Walker, Ph.D.

198. Peat and lignite: their manufacture and uses in Europe. Report on—by Erik Nystrom, M.E., 1908.

202. Graphite: its properties, occurrences, refining, and uses. Report on—by Fritz Cirkel, M.E., 1907.

† Publications marked thus † are out of print.

219. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

224a. Mines Branch Summary report for 1912.

226. Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel, M.E. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.)

231. Ecomomic minerals and mining industries of Canada.

233. Gypsum deposits of the Maritime Provinces of Canada—including the Magdalen islands. Report on—by W. F. Jennison, M.E.

263. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

264. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

265. Annual mineral production of Canada, 1911. Report on—by John McLeish, B.A.

287. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

288. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

289. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Bulletin on—by John McLeish, B.A.

290. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada during the calendar year 1912. Bulletin on—by C. T. Cartwright, B.Sc.

307. Catalogue of French publications of the Mines Branch and of the Geological Survey, up to July, 1914.

308. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma. E., and others—
Vol. I—Coal washing and coking tests.
Vol. II—Boiler and gas producer tests.

314, Iron ore deposits, Bristol mine, Pontiac county, Quebec, Report on—by E. Lindeman, M.E.

IN THE PRESS.

179. The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

204. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

223. Lode Mining in the Yukon: an investigation of quartz deposits in the Klondike division. Report on—by T. A. MacLean, B.Sc.

246. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

308. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others—
    Vol. III—
        Appendix I
            Coal washing tests and diagrams.
    Vol. IV—
        Appendix II
            Boiler tests and diagrams.

286. Summary Report of Mines Branch, 1913.

321. Annual mineral production of Canada, during the calendar year, 1913. Report on by J. McLeish, B.A.

MAPS.

†6. Magnetometric survey, vertical intensity: Calabogie mine, Bagot township, Renfrew county, Ontario—by E. Nystrom, 1904. Scale 60 feet to 1 inch. Summary report 1905. (See Map No. 249.)

†13. Magnetometric survey of the Belmont iron mines, Belmont township, Peterborough county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1906. (See Map No. 186.)

†14. Magnetometric survey of the Wilbur mine, Lavant township, Lanark county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1906.

†33. Magnetometric survey, vertical intensity: lot 1, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†34. Magnetometric survey, vertical intensity: lots 2 and 3, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†35. Magnetometric survey, vertical intensity: lots 10, 11, and 12, concession IX, and lots 11 and 12, concession VIII, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

*36. Survey of Mer Bleue peat bog, Gloucester township, Carleton county, and Cumberland township, Russell county, Ontario—by Erik Nystrom, and A. v. Anrep. (Accompanying report No. 30.)

*37. Survey of Alfred peat bog, Alfred and Caledonia townships, Prescott county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*38. Survey of Welland peat bog, Wainfleet and Humberstone townships, Welland county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*39. Survey of Newington peat bog, Osnabruck, Roxborough, and Cornwall townships, Stormont county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*40. Survey of Perth peat bog, Drummond township, Lanark county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

†41. Survey of Victoria Road peat bog, Bexley and Carden townships, Victoria county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*48. Magnetometric survey of Iron Crown claim at Nimpkish (Klaanch) river, Vancouver island, B.C.—by E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47.)

Note.—1. Maps marked thus * are to be found only in reports.
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*49. Magnetometric survey of Western Steel Iron claim, at Sechart, Vancouver island, B.C.—By E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47).

*53. Iron ore occurrences, Ottawa and Pontiac counties, Quebec, 1908—by J. White and Fritz Cirkel. (Accompanying report No. 23.)

*54. Iron ore occrurences, Argenteuil county, Quebec, 1908—by Fritz Cirkel. (Accompanying report No. 23.) (Out of print.)

*57. The productive chrome iron ore district of Quebec—by Fritz Cirkel. (Accompanying report No. 29.).

†60. Magnetometric survey of the Bristol mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 67.)

†61. Topographical map of Bristal mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 67.)

†64. Index map of Nova Scotia: Gypsum—by W. F. Jennison.

†65. Index map of New Brunswick: Gypsum—by W. F. Jennison.

†66. Map of Magdalen islands: Gypsum—by W. F. Jennison.

(Accompanying report No. 84.)

†70. Magnetometric survey of Northeast Arm iron range, Lake Timagami, Nipissing district, Ontario—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 63.)

†72. Brunner peat bog, Ontario—by A. v. Anrep.

†73. Komako peat bog, Ontario—by A. v. Anrep.

†74. Brockville peat bog, Ontario—by A. v. Anrep

†75. Rondeau peat bog, Ontario—by A. v. Anrep.

†76. Alfred peat bog, Ontario—by A. v. Anrep.

†77. Alfred peat bog, Ontario: main ditch profile—by A. v. Anrep.

(Accompanying report No. 71.) (Out of print.)

†78. Map of asbestos region, Province of Quebec, 1910—by Fritz Cirkel. Scale 1 mile to 1 inch. (Accompanying report No. 69.)

†94. Map showing Cobalt, Gowganda, Shiningtree, and Porcupine districts—by L. H. Cole. (Accompanying Summary report, 1910.)

†95. General map of Canada, showing coal fields. (Accompanying report No. 83—by Dr. J. B. Porter.)

†96. General map of coal fields of Nova Scotia and New Brunswick. (Accompanying report No. 83—By Dr. J. B. Porter.)

†97. General map showing coal fields in Alberta, Saskatchewan, and Manitoba. (Accompanying report No. 83—by Dr. J. B. Porter).

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†152.	Map showing the location of peat bogs investigated in Ontario—by A. v. Anrep.	(Accompanying report No. 151.)
†153.	Map showing the location of peat bog as investigated in Manitoba—by A. v. Anrep.	
†157.	Lac du Bonnet peat bog, Manitoba—by A. v. Anrep.	
†158.	Transmission peat bog, Manitoba—by A. v. Anrep.	
†159.	Corduroy peat bog, Manitoba—by A. v. Anrep.	
†160.	Boggy Creek peat bog, Manitoba—by A. v. Anrep.	
†161.	Rice Lake peat bog, Manitoba—by A. v. Anrep.	
†162.	Mud Lake peat bog, Manitoba—by A. v. Anrep.	
†163.	Litter peat bog, Manitoba—by A. v. Anrep.	
†164.	Julius peat litter bog, Manitoba—by A. v. Anrep.	
†165.	Fort Francis peat bog, Ontario—by A. v. Anrep.	

†166. Magnetometric map of No. 3 mine, lot 7, concessions V and VI, McKim township, Sudbury district, Ont.—by E. Lindeman. (Accompanying Summary report, 1911.)

†168. Map showing pyrites mines and prospects in Eastern Canada, and their relation to the United States market—by A. W. G. Wilson. Scale 125 miles to 1 inch. (Accompanying report No. 167.)

†171. Geological map of Sudbury nickel region, Ont.—by Prof. A. P. Coleman. Scale 1 mine to 1 inch. (Accompanying report No. 170.)

†172.	Geological map of Victoria mine—by Prof. A. P. Coleman.	(Accompanying report No. 170.)
†173.	" Crean Hill mine—by Prof. A. P. Coleman	
†174.	" Creighton mine—by Prof. A. P. Coleman.	

†175. " showing contact of norite and Laurentian in vicinity of Creighton mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†176. " Copper Cliff offset—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†177. " No. 3 mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†178. " showing vicinity of Stobie and No. 3 mines—by Prof. A. P. Coleman. (Accompanying report No. 170.)

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†185. Magnetometric survey, vertical intensity: Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†185a. Geological map, Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186. Magnetometric survey, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186a. Geological map, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187. Magnetometric survey, vertical intensity: St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187a. Geological map, St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188. Magnetometric survey, vertical intensity: Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188a. Geological map, Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†189. Magnetometric survey, vertical intensity: Ridge iron ore deposits, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190. Magnetometric survey, vertical intensity: Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190a. Geological map, Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191. Magnetometric survey, vertical intensity: Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191a. Geological map, Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†192. Magnetometric survey, vertical intensity: Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 194.)

Note.—1. Maps marked thus * are to be found only in reports.
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†192a. Geological map, Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193. Magnetometric survey vertical intensity: Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193a. Geological map, Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†194. Magnetometric survey, vertical intensity: Bow Lake iron ore occurrences, Faraday township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†204. Index map, magnetite occurrences along the Central Ontario railway—by E. Lindeman, 1911. (Accompanying report No. 184.)

†205. Magnetometric map, Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman, 1911. (Accompanying report No. 303.)

†205a. Geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario, Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman. (Accompanying report No. 303.)

†206. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: northern part of deposit No. 2—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†207. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 8, 9, and 9A—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposit No. 10—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208a. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: eastern portion of Deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208b. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: western portion of deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208c. General geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario—by E. Lindeman, 1912. Scale 800 feet to 1 inch. (Accompanying report No. 303.)

Note.—1. Maps marked thus * are to be found only in reports.
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†210. Location of copper smelters in Canada—by A. W. G. Wilson. Scale 197·3 miles to 1 inch. (Accompanying report No. 209.)

†215. Province of Alberta: showing properties from which samples of coal were taken for gas producer tests, Fuel Testing Division, Ottawa. (Accompanying Summary report, 1912.)

†220. Mining districts, Yukon. Scale 35 miles to 1 inch—by T. A. MacLean (Accompanying report No. 222.)

†221. Dawson mining district, Yukon, Scale 2 miles to 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

*228. Index map of the Sydney coal fields, Cape Breton, N.S. (Accompanying report No. 227.)

†232. Mineral map of Canada. Scale 100 miles to 1 inch. (Accompanying report No. 230.)

†239. Index map of Canada showing gypsum occurrences. (Accompanying report No. 245.)

†240. Map showing Lower Carboniferous formation in which gypsum occurs in the Maritime provinces. Scale 100 miles to 1 inch. (Accompanying report No. 245.)

†241. Map showing relation of gypsum deposits in Northern Ontario to railway lines. Scale 100 miles to 1 inch. (Accompanying report No. 245.)

†242. Map, Grand River gypsum deposits, Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 245.)

†243. Plan of Manitoba Gypsum Co.'s properties. (Accompanying report No. 245.)

†244. Map showing relation of gypsum deposits in British Columbia to railway lines and market. Scale 35 miles to 1 inch. (Accompanying report No. 245.)

†249. Magnetometric survey, Caldwell and Campbell mines, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†250. Magnetometric survey, Black Bay or Williams mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†251. Magnetometric survey, Bluff Point iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†252. Magnetometric survey, Culhane mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

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†253. Magnetometric survey, Martel or Wilson iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†261. Magnetometric survey, Northeast Arm iron range, lot 339 E.T.W. Lake Timagami, Nipissing district, Ontario—by E. Nystrom. 1903. Scale 200 feet to 1 inch.

†268. Map of peat bogs investigated in Quebec—by A.v. Anrep, 1912.

†269. Large Tea Field peat bog, Quebec " "

†270. Small Tea Field peat bog, Quebec " "

†271. Lanoraie peat bog, Quebec " "

†272. St. Hyacinthe peat bog, Quebec " "

†273. Rivière du Loup peat bog " "

†274. Cacouna peat bog " "

†275. Le Parc peat bog, Quebec " "

†276. St. Denis peat bog, Quebec " "

†277. Rivière Ouelle peat bog, Quebec " "

†278. Moose Mountain peat bog, Quebec " "

†284. Map of northern portion of Alberta, showing position of outcrops of bituminous sand. Scale 12½ miles to 1 inch. (Accompanying report No. 281.)

†293. Map of Dominion of Canada, showing the occurrences of oil, gas, and tar sands. Scale 197 miles to 1 inch. (Accompanying report No. 291.)

†294. Reconnaissance map of part of Albert and Westmorland counties New Brunswick. Scale 1 mile to 1 inch. (Accompanying report No. 291.)

†295. Sketch plan of Gaspé oil fields, Quebec, showing location of wells. Scale 2 miles to 1 inch. (Accompanying report No. 291.)

†296. Map showing gas and oil fields and pipe-lines in southwestern Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 291.)

†297. Geological map of Alberta, Saskatchewan, and Manitoba. Scale 35 miles to 1 inch. (Accompanying report No. 291.)

†298. Map, geology of the forty-ninth parallel, 0·9864 miles to 1 inch. (Accompanying report No. 291.)

†302. Map showing location of main gas line, Bow Island, Calgary. Scale 12½ miles to 1 inch. (Accompanying report No. 291.)

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†311. Magnetometric map, McPherson mine, Barachois, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

†312. Magnetometric map, iron ore deposits at Upper Glencoe, Inverness county, Nova Scotia—by E. Lindeman, 1913. Scale 200 feet to 1 inch.

†313. Magnetometric map, iron ore deposits at Grand Mira, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

Address all communications to—

DIRECTOR MINES BRANCH,
DEPARTMENT OF MINES,
SUSSEX STREET, OTTAWA

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