CANADA
DEPARTMENT OF MINES
HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

ECONOMIC GEOLOGY SERIES
No. 5

Oil and Gas in Western Canada

(SECOND EDITION)

BY

G. S. Hume

OTTAWA
J. O. PATENAUDE
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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CHAPTER I

ORIGIN AND ACCUMULATION OF OIL AND GAS[1]

ORIGIN OF PETROLEUM

The origin of petroleum is discussed in almost every text book on petroleum geology and, therefore, only a brief outline of the subject need be given here. There are a number of theories and these may be grouped into two major classes: (1) inorganic; and (2) organic.

INORGANIC THEORIES

It has been suggested that water acting on metallic carbides in the earth might produce hydrocarbons. The objections to this theory are clearly presented by Stigand (1925)[2] who states:

"The existence of improbably large quantities of metallic carbides, within access in the earth, would be required, if only to suffice for originating the amount of petroleum which has been produced, as the amount of metallic carbides demanded is very great in proportion to the petroleum that can be produced from them. Furthermore, the circumstances that large deposits of bitumen or petroleum are only found in the stratified rocks, that the deposits found in the strata of younger age predominate, and that very frequently barren porous beds are intercalated in the petroliferous beds, or the strata subjacent to an oil series do not contain petroleum, all tend to constitute evidence contrary to the supposition of deep-seated origin."

There are also other theories based on chemical reactions between various substances, but in most cases the objections to these theories are so convincing to the field geologist, that they are dismissed by him as being highly improbable.

ORGANIC THEORIES

According to the organic theory, petroleum and natural gas are believed to originate from organic matter buried in sediments that were deposited under special conditions in shallow sea water and in lagoons and estuaries along the seashore. Investigations carried out by Trask (1927 and 1928) under the American Petroleum Institute have shown that some limestones may be source beds of oil. Lime sediments now being formed in the Florida Keys and in the Gulf of Batabano in Cuba yielded on distillation 2·5 gallons of oil a ton, or about 1 per cent of the weight of the sediment, and

[1]Text books on petroleum geology: "Geology of Petroleum", W. H. Emmons, 2nd Edition, 1931, McGraw-Hill Book Co. Inc.; "Geology of Petroleum and Natural Gas", E. R. Lilley, 1928, D. Van Nostrand Co. Inc.; "Outlines of the Occurrence and Geology of Petroleum," I. A. Stigand, 1925, Charles Griffin and Co., Ltd.; "Prospecting for Oil and Gas," L. S. Panyity, 1920, John Wiley and Sons Inc.; "Practical Oil Geology", D. Hager, 1919, McGraw-Hill Book Co. Inc.

[2]The date and, in some cases, page numbers following the author's name will enable the reader to find the complete bibliographic reference in the list of papers at the end of this chapter.

hence may be a source of oil since such a yield means a potential supply of 105,000 barrels of oil a square mile for each foot of sediment. Lime deposits a considerable distance from shore off Key West, however, could not be source beds since they yielded on distillation only a very small amount of oil. Sands and silts from recent deposits in such places as San Francisco Bay, San Diego Bay, Bay of Fundy, and Orinoco Delta, in all of which places there is a fairly strong tidal action, yielded only an insignificant amount of oil, whereas fine mud from shallow water in Pamlico Sound off the coast of North Carolina yielded as much as 2·7 gallons a ton. From the examination of recent sediments from many areas it is concluded that clays are more likely to be source beds of oil than either silts or sands. Furthermore, it appears that sediments that yielded considerable oil showed that a concentration of organic matter had taken place due to special conditions of deposition. The organic matter entering these sediments is derived from plankton, the floating organisms living on the surface of the sea, and since these forms of life are more plentiful near shore than in the open sea it follows that sediments deposited relatively near shore or in shallow, epicontinental seas are likely to be richer in organic matter than those laid down far from land. Plankton, however, is readily carried by moving waters and those that die and fall to the sea bottom will be transported by currents to accumulate in protected depressions on the sea floor or in quiet basins. This seems to have occurred in such basins as Lake Maracaibo, a large, shallow, brackish-water lagoon on the coast of Venezuela, where recent sediments from the shallow parts were found to yield much less oil than those from the deep, central part of the lake. Concentrations of organic matter may occur in deep water in depressions on the ocean floor as was found to be the case in the vicinity of Channel Islands off the coast of California.

In order to estimate the value of recent sediments as sources of oil, probable source rocks of oil of the geologic past showing a wide stratigraphic and geographic range were distilled. The results according to Trask (1928, page 1065) showed that

"the average ignition loss varied directly with the oil yield and was very similar to that from recent sediments. Furthermore the specific gravity of the oil, the temperature of formation of the oil, the gas production, and the average ignition loss of the coke, were all similar to the results from recent deposits. In regard to past geologic sediments, it is unknown how much oil has migrated in or out of the deposits but the striking similarity of the results from such a wide variety of past geologic sediments to corresponding results from recent deposits, supports the view that the better grades of sediments forming today are to be considered as future potential source beds although perhaps not so good as some past geologic deposits."

Some investigators believe that source materials of oil may be derived from the decay of vegetable matter carried to the sea by rivers and streams in the form of humic acids that are precipitated in the presence of salt water. According to Rae (1922)

"microscopic work on shales associated with oil deposits has shown the presence of an unknown, rich, dark, organic, ulmohumic groundmass . . . . . Rivers and streams act as the concentrating agents for millions of tons of organic material, which are later incorporated into marine or inland lake deposits. By subsequent pressure, heat, and catalytic agents, the organic material is converted into petroleum."

Haseman (1930) has reported the occurrence in recent sediments of asphaltum and a few other hydrocarbons which he regards as having been synthesized from humic acids. He believes the humic acids are produced in swamps and precipitated by brackish waters along their sandy margins.

In certain cases the close association of possible source materials with the petroliferous beds seems to offer almost conclusive evidence of origin. For example, the presence of an abundance of diatoms and foraminifera in the Eocene of California led Arnold to conclude that the oil in the overlying Miocene was derived from them. In other places the association of coal with petroleum has given rise to the suggestion that the petroleum as well as the coal has been derived from terrestrial vegetation, but, as pointed out by Stigand (1925), it may be that it is marine vegetation that is involved for

> "it is under shallow water conditions such as on littoral or estuarine tracts or in basins, that petroliferous strata have most frequently been formed. Furthermore, series of strata containing petroleum often exhibit evidence of former land surfaces the presence of which must have been preceded and followed by extensive shallow water conditions and shifting tidal regions; this would be more particularly significant in the case of formations containing successions of coal and lignite seams . . . . . which indicate secular oscillations centring about sea-level."

Such conditions on tidal flats are favourable for the growth of marine vegetation that may possibly have been the source of petroleum in such cases. Redwood (1926, page 184) states that "the salt-marshes of Sardinia are covered from time to time with sheets of seaweed decomposing into an oily substance akin to petroleum" and Emmons (1931, page 57) has pointed out "the fact that iodine is found in seaweeds and also in the waters of certain oil-fields is significant in this connexion". Stuart (1926) page 69) believes that in the oil fields of Burma there is a direct relationship between the oil deposits and silicified wood found in the overlying rocks. He points out that the fossil wood belongs to the genus *Dipterocarpus,* a species of which now growing in Burma is very rich in wood oil and from which natives obtain as much as 40 gallons of oil in one season by tapping the trunk. These trees, due to their high specific gravity, sink to the bottom when immersed in water, and not only might large quantities of oil have originated from their burial, but since the leaves were also rich in oil they were a potential source of oil during the life time of the trees.

From this evidence it is concluded that oil may originate from waxy, gelatinous, and resinous substances of plants either of marine or terrestrial origin, or from the decaying protoplasm of marine animals. Differences in the composition of the source materials necessarily mean differences in the composition of the petroleum formed from them. Changes in the composition of petroleum may arise subsequent to formation as a result of filtration during migration and of interactions between the petroleum and substances in the formations through which it has passed. There may be losses due to natural distillation and the escape of the lighter volatile materials. Thus the petroleum found in an oil field may differ quite widely in composition from the petroleum as first formed, a fact that in many cases makes it difficult to determine the character of the material from which the oil has been derived.

ACCUMULATION OF OIL AND GAS

There are two opposing conceptions regarding the time of formation of oil from organic debris. The first, sponsored by Murray Stuart (1926) and other geologists, is to the effect that the organic material was converted into oil prior to its burial. The oil is believed to adhere to clay particles for which it has great affinity and, later, to be squeezed out into the more porous rocks during the consolidation and deformation of the enclosing strata. The second conception is that the source material of oil is acted on by anaerobic bacteria and a substance called kerogen, low in oxygen, results. After burial of this substance oil is formed from it by heat and pressure during the consolidation or deformation of the enclosing sediments. The kerogen, according to this view, is only an intermediate product between the organic source material and the petroleum, and certain physical and chemical changes are necessary before it is transformed to petroleum. Hawley (1929, page 365) has demonstrated experimentally that petroleum is not formed by shearing pressures in oil-shales and concludes that " temperature is by far the more important agent in promoting the conversion of bituminous material in rocks to oil."

Regardless of how or when the oil is formed, since the source materials are widely distributed through the containing sediments, the oil when first formed must also be widely disseminated. In order that oil fields may result, the oil must collect in porous strata within limited areas. Many geologists believe that oil collects near where it was generated, others, as for instance, Rich (1927, page 1139), believe that large quantities of oil formed during mountain building may have, at least in part, moved a long distance from its point of origin.

GRAVITATIONAL THEORY OF ACCUMULATION

If water, oil, and gas are placed in a closed vessel they tend to arrange themselves according to their specific gravities, the gas, the lightest on top, the oil below it, and the water at the bottom. This tendency was long ago recognized as having operated where oil was found in domed-up strata in the Appalachian and Ontario areas, but it is now understood that though gravity tends to cause a rearrangement of the gas, oil, and water after they have arrived at a place where accumulation occurs, yet, gravitational force alone is not sufficient to cause a migration of oil from a source rock to a porous reservoir rock. It has been shown by various authors that capillarity, deformative movements in the earth's crust, the movement of water, and the movement of gas all influence the migration of oil.

CAPILLARY THEORY OF ACCUMULATION

If a clean glass tube of fine bore is dipped into water, the water rises inside the tube to a higher level than the surface of the external water. This tendency of liquids to enter minute openings or pores, such as is illustrated by a glass tube or by the absorption of water by blotting paper, is the result of capillary action.

Experimental evidence led McCoy (1916, page 798-805) to believe that capillarity is the main force causing oil in a water-saturated sand to migrate, thus making possible the accumulation of oil in reservoirs capable of retaining it. Washburne (1914, page 830) has stated that,

"since water has about three times the surface tension of crude oil, capillary action must exert about three times as much pull upon it. The amount of the capillary pull varies inversely as the diameter of the pore. Hence the constant tendency of capillarity is to draw water, rather than oil, into the finest openings, displacing any oil or gas in the latter."

Shale contains much smaller pore spaces than sand and consequently any slow flow between shale and sand would drive oil from the fine pores in the shale and concentrate it in the coarser pores of the sand. Since gas is not drawn into capillary openings by the action of surface tension and there is no capillary resistance to its movement, it is much more readily concentrated in the coarser pores than oil. It is possible, according to Washburne, where there is no flow between shale and sand, that the force of capillarity alone would be sufficient to draw enough water into the shale to displace the oil and to concentrate it in the coarser pores of the sand. In water-free rocks, oil, because of capillarity, would be drawn into the finer pores and hence the result would tend to be diffusion rather than concentration.

There are limits to the sizes of pores in which capillarity can act. In pores greater than 0·508 mms. in diameter there is no capillary action in the case of pure water. The minimum diameter, according to Washburne, is more uncertain, but is usually placed at 0·0002 mms. In such small openings it has been shown (Johnson and Adams, 1914) that the adhesion is so great that it overcomes the capillary force.

Though in the case of small pores the capillary attraction of water is, theoretically, three times as great as that of oil, certain conditions may greatly modify this force. The capillary action of water in a pore having a thin film of oil is not nearly as great as in a pore that contains no oil, therefore, where water is moving into a finely porous bed and displacing oil originally in that bed, the capillary force exerted by the water is not three times that of oil. Under such conditions the force of capillarity will not be nearly as effective in concentrating oil in the coarser pores as might be supposed.

HYDRAULIC THEORY OF ACCUMULATION

Experimental studies by Mills (1920, pages 398-421) led him to believe that capillary adjustments between oil and water in saturated strata are restricted to short lateral ranges and that wide movements of oil due to such forces are the exception rather than the rule. He concluded that the up-dip migration of oil and gas under the propulsive force of their buoyancy in water, as well as the migration of oil either up- or down-dip caused by hydraulic currents, is among the primary factors influencing the accumulation of oil. The movement of oil under the action of currents is what has been termed the hydraulic theory of oil and gas accumulation.

This theory was developed by Munn (1909) and a general statement regarding it was published by Rich (1921) who states

"The principal cause of the migration of oil and gas is the movement of underground water which carries with it minute globules of oil and bubbles of gas, possibly as fast as they are formed. Accumulation results from the selective segregation of oil and gas, which on account of their buoyancy always tend to work their way upward as they are carried along and are caught and retained in anticlinal or other suitable traps.

The nature of the trap necessary to cause accumulation depends on the rate of movement of the water and corresponding texture of the sands or other medium through which it flows. Where the sands are porous and there is a strong hydraulic head a sharp anticline with large closure is necessary to retain the oil; in fact where the movement is especially rapid, even such a structure may be inadequate. Where the sands are fine and the water movement is slow, slight structural and textural variations are enough to arrest the movement of the oil and gas. Under such conditions broad, flat anticlines with very little closure, terraces, or even minor flattenings of the regional dip, are enough to cause accumulation."

According to this theory any condition that retards the movement of underground water carrying globules or bubbles of oil and gas, will tend to bring about the accumulation of the oil and gas. Such retarding conditions, according to Rich, may be assumed to be present: (1) in anticlinal traps, (2) where the size of rock pores decreases, and (3) where a decrease in the rate of water movements is caused under certain conditions. Rich points out that where oil and gas are carried to an anticline, the buoyancy of oil and gas in the water becomes effective and, as a result, they tend to rise to the top of the structure and to become concentrated there. In cases where the regional dip decreases in amount, giving rise to a terrace structure, there will be a slowing down of the movement of the circulating solutions, and this may be sufficient to cause an accumulation of oil and gas without any reversal of dip. A change from a relatively porous rock to one of less porosity will also cause at least a partial stagnation, allowing the oil and gas to accumulate in the more porous rock, as where a sand lens is surrounded by less pervious parts of the same stratum. It is probable, in such cases, that capillarity plays a considerable part in the accumulation of the oil and gas in the rock with larger pore spaces.

Mills and Rich (1921, pages 347-371) deduced from experiments that a strong water movement through an anticlinal trap might carry along with it all the oil and gas, allowing no opportunity for them to collect in the top of the trap. Moreover, a strong water flow through an anticlinal trap in which there has already been some accumuation of oil and gas might flush away the accumulated oil and gas or, if only a partial flushing resulted, the oil would probably extend farther down the dip on the lee side of the anticline than on the side by which the water entered. Where the water movement is slow, the oil and gas would first concentrate in the crest of the trap and later additions would be on the side from which the water comes. These two cases explain why in some instances the division between oil and water is not at the same level on the two flanks of an oil pool.

ACCUMULATION DUE TO DEFORMATIVE MOVEMENTS

As pointed out by Lilley (1928, page 201) the " compacting of sediments through increasing static pressure plays an important rôle in causing the reduction of pore space in sediments and thus is directly responsible for the initiation of movements " of contained fluids or gases. As a result of experiments carried out in 1928, Beckstrom and Van Tuyl (1928, page 1049) came to the conclusion that " compaction is by far the most important cause of migration of oil from shale into porous reservoirs." Certain authors believe movement is started by differences in pressure due to varying amounts of diastrophism from place to place, although others regard this as but a minor factor in movement.

ACCUMULATION OF OIL AS RELATED TO MOVEMENT OF GAS

Gas has the property of diffusion, but is not drawn into capillary openings by surface tension and hence there is no capillary resistance to its movements. It thus moves through pore spaces in rocks with much greater ease than oil. Gas is soluble in oil in proportion, roughly, to the pressure exerted. The pressure created by gas in the oil and the buoyancy given to the oil by the dissolved gas are both factors in the movement of oil. Absorbed gas also tends to lower the viscosity of the oil and especially so if the gas forms minute globules. According to Mills (1923, page 14) "the escape of gas with entrained oil through fissures has been an important factor in the migration and accumulation of oil in many faulted areas. Compressed gas is the propulsive force by which oil generally moves to producing wells."

STRUCTURAL FEATURES OF OIL POOLS

Oil and gas accumulations are associated with various structural features (Clapp, 1917). The structures of the fields of western Canada are indicated in some detail on later pages, and in this place, therefore, only a generalized consideration is given to the subject, omitting all reference to types of structure not yet recognized in Canada.

ANTICLINAL OR DOMED STRUCTURE

An anticline is an arch-like or dome-shaped fold. If the angle of dip of the two sides or limbs is the same and in opposite directions, the fold or anticline is symmetrical. Any marked departure from this condition produces an asymmetrical fold (*See* Figure 1), and names have been applied to different variations from the ideal form. A dome is a special form of anticline in which the beds dip away from the crest in all directions or quaquaversal fashion (*See* Figure 2).

Regardless of the various theories advanced to account for the accumulation of oil and gas, it is generally agreed that one of the commonest structures in which oil and gas are found is the anticline. In order that oil and gas may accumulate in any anticlinal structure certain conditions are essential. (1) There must be a petroliferous stratum from which oil and gas can be derived. It is thought that oil and gas form from organic materials and originate, respectively, as small globules and bubbles. These must collect if a pool of oil or gas is to form and, no matter what explanation is adopted as the cause of movement, it is agreed that there must be migration of the oil and gas to points where structural conditions allow their accumulation. (2) There must be a porous horizon into which and along which the oil and gas may migrate and be collected in pools of commercial size. Migration for the most part must take place through the pore space of the rocks and the rock of the structural reservoir must be

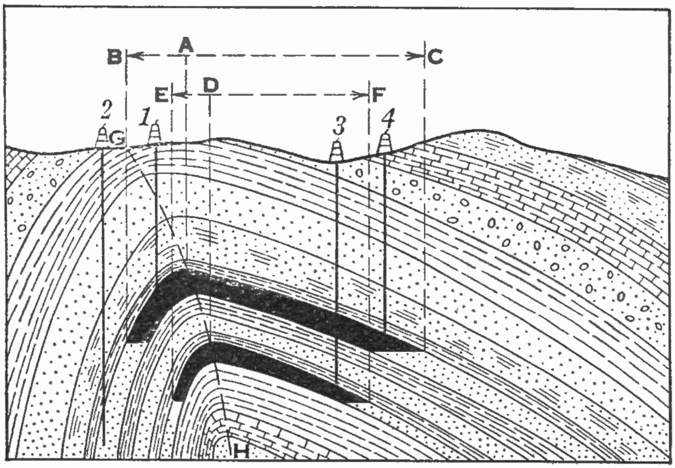

Figure 1. (After L. C. Uren). Simple asymmetric anticline with oil-bearing strata (shown in solid black) reached by three wells (Nos. 1, 3, and 4). The strata on the left dip more steeply than the strata on the right and the dip of the axial plane changes with depth as shown by the curving line G-H.

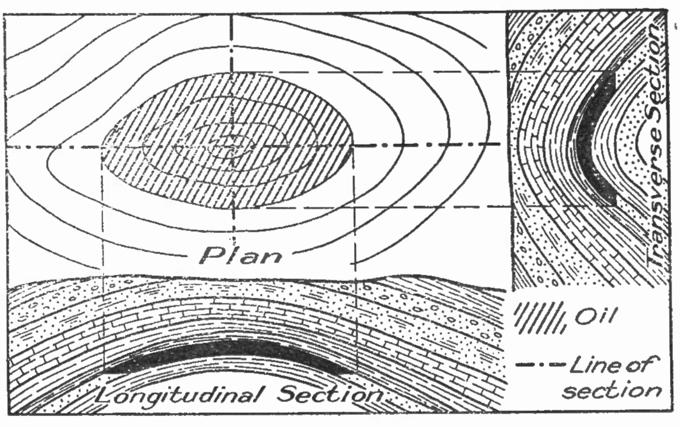

Figure 2. (After L. C. Uren). Dome structure illustrated in plan and vertical sections; an oil-bearing stratum (shown in solid black) is depicted in the vertical sections and the area underlain by it is shown on the plan.

sufficiently porous to hold a large amount of oil and gas if an oil field is to be formed. The amount of oil and gas at any point will depend, among other things, on the amount of oil and gas available, on the size of the reservoir, and on its efficiency as a retainer of the oil and gas. The size of the reservoir will, in turn, depend on the size of the structure and the degree of porosity of the strata. (3) There must be an impervious cap to prevent upward dissipation of the gas and oil after arrival in a structurally favourable reservoir. A highly suitable cover for an oil reservoir is a fine-grained, wet shale. It has been calculated (McCoy, 1919, page 258) that at a depth of 1,500 feet the force necessary to make oil migrate through a wet shale (openings 0·01 micron) is about 4,000 pounds a square inch and, therefore, that there could be no migration of oil through such a shale.

In a symmetrical anticline under ideal conditions, the arrangement of gas, oil, and salt water in a porous stratum acting as a reservoir is as follows: the gas occurs on the crest of the fold, the oil underlies the gas and occurs in the limbs of the fold, and the salt water underlies the oil. This arrangement is such as would result from gavitational segregation. So symmetrical a disposition of the gas, oil, and water does not usually obtain in nature. The anticline may not be of symmetrical form and other factors governing accumulation may also lack symmetry, with the result, for instance, that the oil may be largely concentrated in one limb of a fold. Furthermore, in many oil fields the high pressures revealed in the early stages of production indicate that much of the gas must be absorbed in the oil. As is the case in a number of Canadian gas fields a structure may contain gas and salt water, but no oil. The lack of oil in such cases may be due to the fact that gas is much more mobile than oil and consequently may move much farther from its place of origin or may pass through beds so finely porous as to hold back any oil. Other explanations of the absence of oil might be given, as, for example, that metamorphism has proceeded to such a stage that only gas may be present. Regardless of what the explanation may be the fact remains that many gas fields yield only " dry " gas which shows no evidence of associated oil.

SYNCLINAL STRUCTURE

A syncline is a trough-like fold. If a porous stratum in such a fold contains oil and gas, but no water, the gas will tend to rise along the limb of the syncline and to segregate at the crest of the succeeding anticline, whereas the oil will tend to sink to the bottom of the downwarp or syncline, the movements in both cases being due to gravity. Such occurrences of oil in synclines are known in Canada, but are exceptional. It is probable that the movement of oil under the influence of gravity alone is relatively weak, because other forces, particularly that of capillarity in a fine-grained stratum, are much stronger. The action of capillarity alone in a water-free sand is one of diffusion rather than concentration, but, acting in conjunction with gravity, there might be some concentration, especially in the case of a porous stratum having relatively easy channels of movement through large pores where the force of capillarity would be small. It is probable, however, that irregularities in the character of the pore spaces in a sand would tend to make concentration relatively incomplete.

SAND LENSES

It has already been stated that capillary attraction in the case of pores within the critical limits of size is three times as great for water as for oil and for this reason water will penetrate the finer parts of a sand and force oil to the coarser parts. This, probably, is the controlling factor governing the accumulation of oil in those parts of a porous stratum where the pore spaces are largest. These coarsely porous parts of a stratum usually have irregular forms, pinch out laterally, and are in general lens shaped (*See* Figure 3). Where gas and oil are concentrated in such coarser sand

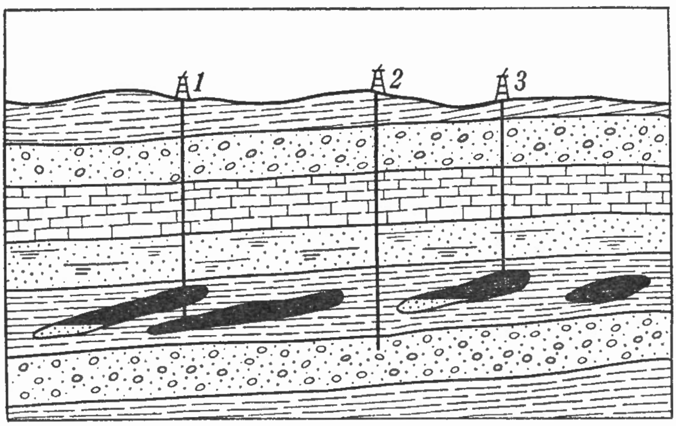

Figure 3. (After L. C. Uren). Lenticular deposits. Lenses of coarse sand in oil-bearing shales serve as local centres of concentration.

lenses, they may be under high pressure. It has been suggested that the pressure may be due to capillarity, but this idea has been refuted by Washburne (1914, page 852). Possibly it is partly due to hydrostatic pressure which in many gas and oil fields is nearly equalled by the gas and oil pressure. Sand lenses containing oil and gas may occur without any relation to other structural features. Since most such lenses are irregular, the gas and oil collect in the higher parts, as in anticlinal structures.

TERRACES

A local flattening of the strata in a region otherwise characterized by a uniform dip gives the terrace structure (*See* Figure 4). Where water carrying along with it oil and gas is moving up the dip and where (Rich, 1921, page 355) the movement is

"so slow that, assisted by the gravity component of buoyancy, it is little more than able to move the oil with it, the flattening at the down-dip edge of a terrace might be enough to arrest the movement of the oil and gas and start an accumulation . . . . This pool would grow from accretions added on the down-dip side and in time might extend for a considerable distance down the dip from the edge of the terrace. In general a terrace should be able to cause oil accumulation only where the movement of the rock fluids is comparatively slow, so that slight obstacles suffice to arrest the movement of the oil globules."

Johnson and Huntley (1916, page 72) in discussing the terrace structure assume that where there is a gravitational separation of oil and gas through water there is a critical gradient which will allow oil and gas to accumulate. Where the dip exceeds in amount the critical gradient, the oil and gas will be carried up the dip, but where the dip falls below the critical gradient the oil and gas will tend to accumulate. It is stated, however, that "it is difficult to ascertain the critical gravitational gradient

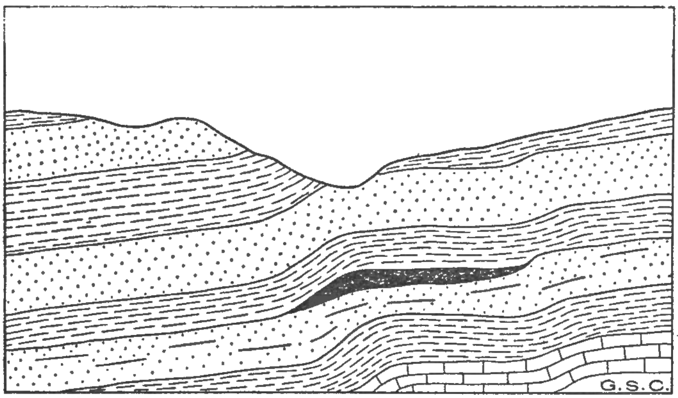

Figure 4. Terrace structure; an accumulation of oil is shown (solid black).

because of two variables: (*a*) degree and types of porosity, and (*b*) direction and effectiveness of the current within the reservoir"; the current is considered as generally flowing up dip. The terrace, these authors believe, must also be wide, otherwise the oil and gas may escape up the dip. These and other factors have led Johnson and Huntley to regard terraces as of low rank among favourable structures and especially so since structures that appear as terraces on the surface may be absent at depth. Small folds on a terrace structure, however, offer favourable conditions for accumulation, since they combine the anticlinal fold with the terrace structure.

FAULTED STRUCTURES

Earlier views that faulted structures were not favourable for the accumulation of oil and gas have been greatly modified by the discovery of many highly productive faulted structures and certain investigators have concluded that in some fields the accumulation of petroleum has occurred as a result of faulting. It has been stated (Pratt and Lahee, 1923, page 231) that "faulting is associated with, and probably is, the controlling structural feature of all the oil fields in the relatively flat-lying beds of the Gulf Coastal plain, from the Lower Cretaceous up to the Pliocene." Faulted structures affording oil production are also known in many other oil fields, especially the Rocky Mountain fields, where the accumulation is thought to be closely related to the faulting. Rich (1923, page 222) has pointed out that too much emphasis may be placed on faulting and that although it may be beneficial in some instances it may be decidedly detrimental in others by providing a channel of escape for oil and gas that would have been retained in an anticlinal structure. Mills (1923, pages 14-15) states that:

"The escape of water through natural passages, such as fault fissures, has induced widespread hydraulic currents through the beds toward these points of diminished pressure, and these water currents, plus buoyancy, have contributed largely toward the migration of oil to favourable rock entrapments in the vicinity of the faults. The propulsive force of expanding gas has been one of the contributing causes for the hydraulic currents.

Paradoxical as it may seem, the escape of gas with entrained oil through fissures has been an important factor in the migration and accumulation of oil in many faulted areas. Compressed gas is the propulsive force by which oil generally moves to producing wells. It is also one of the propulsive forces by which oil has moved with or even ahead of water under conditions of differential pressure brought about by faulting.

The concomitant formation of gas and oil, together with the diffusion of absorbed gas under high pressure throughout the underground water and disseminated oil, are assumed to have preceded the processes herein outlined and have made them possible. Absorbed gas tends to lower the viscosity as well as the specific gravity of the oil, especially where the absorbed gas expands sufficiently to form minute bubbles within the oil. Again under the propulsive force of water currents alone, the oil tends to move less readily than the water, as exemplified by the formation of water cones around producing wells, but where there are considerable proportions of rapidly expanding gas, the oil is propelled ahead of the water. There are, of course, limiting conditions beyond which the folding and fracturing, or even the erosion of petroliferous strata, have permitted the excessive loss of oil and gas. There are also conditions under which faulting has caused barriers to migration . . . . . where open fissures cutting deeply buried petroliferous beds have formed channels for the migration of oil, gas, and water and have then become sealed sufficiently to retain a part of the oil and gas in the reservoir rocks, the processes herein outlined have evidently functioned. . . . . During the more or less extensive movements of oil, gas, and water toward producing wells, the gas and oil tend to segregate above the water into favourably situated parts of the sands. This has been termed induced segregation. It is mildly analogous to what happens when hard or lithified strata containing unsegregated gas, oil, and water under pressure are fractured by faulting or fissuring.

Another important analogy between the deep-seated effects induced by oil and gas wells and the effects of faulting is the deposition of practically the same minerals in the wells and in the natural fissures. Calcite, barite, and gypsum, with inclusions of waxy hydrocarbons, accumulate in such quantities in the wells of the Appalachian and Mid-continent fields as to cause serious production troubles. Calcite, gypsum, and waxy hydrocarbons occur in the natural fissures cutting petroliferous strata in many fields. The origin of both types of deposits, those in the wells and those in the rock fissures, can be traced to the escape of water, gas, and oil from petroliferous strata.

Where the gas originally accompanying the oil and water (primary gas) has escaped through the fissures, the accumulated oil may be practically devoid of gas. . . . . But where considerable gas under high pressure accompanies oil in faulted and fissured structures it seems probable that this gas is either primary gas retained by the early sealing of the fissures, or that it is secondary gas which formed in, or migrated to, the entrapment after the fissures were sealed. It is possible that both phases of gas accumulation are represented in many structures. That there has been an enormous escape of gas incident to the migration and accumulation of oil in most fields is indicated by the high concentration of salts in the waters associated with the oil. This concentration has undoubtedly been brought about through the removal of water vapour in escaping gases."

Discussing the question as to why all the oil and gas does not escape from faulted areas before the fissures are sealed, Mills (1923, page 20) writes:

"The question might just as well be asked: Why does all the oil not flow from a productive sand through the wells that tap that sand? In both cases, the flow ceases when the propulsive force becomes inadequate to propel the oil to the surface. Let it be remembered that under ordinary conditions of recovery, about 80 per cent of the oil originally contained in a productive sand may, and probably does, remain underground when an oil field is abandoned. As in the case with wells, the complete escape of oil through open fissures has probably failed largely because of dissipated gas pressures, whereas the final retention of the oil is due to the sealing of the fissures before the gas pressures in the vicinity of the faults have again built up through regional adjustments."

Fault fissures may be sealed by the minerals mentioned by Mills and also by tar or asphalt. It has been shown (Rogers, 1919, and Pack, 1920) that sulphate waters react with oil, the sulphates being reduced by the hydrocarbons of the oil or gas to sulphides and the oil and gas in part being oxidized. Hydrogen sulphide thus formed is readily oxidized to give sulphur which is quite soluble in petroleum. The high sulphur content of some oils may be in part at least accounted for in this way. As sulphate waters are much more common near the surface than at depth, this action is probably greater near the surface and as the lighter oils are changed into heavier oils by this action, and as evaporation and oxidation also take place near the surface, the oil may be changed to tar or asphalt and thus seal the avenue of escape. According to Pack

"the effect of the deeper waters on the oil is not so extensive as that of surface waters, but it is evident none the less, for in place after place (in the Sunset-Midway field) where water is found in the oil sand a deposit of tar or heavy oil separates the portion of the sand occupied by oil from that occupied by water."

It is thus evident that in this case even at depth tarry materials can effectively seal off a channel of escape for oil.

POROSITY OF RESERVOIR ROCKS

The commonest rocks acting as reservoirs for accumulations of oil and gas are porous sandstones, and dolomites or dolomitic limestones. Other rocks are not of so great importance, although in some fields oil has been produced in quantity from crevices in shales.

The porosity of a sandstone depends on a number of factors, as for example the shape of the sand grains, the manner in which they are packed, the variation in size of the individual grains, and the amount of clay or silt or of calcareous or siliceous cement between the sand grains (*See* Figure 5). If the grains are uniform in size and shape, the amount of pore space is the same no matter how small or large the grains may be, provided they are packed in the same fashion. If the grains are large there will be a comparatively small number of large pore spaces, if the grains are small there will be a large number of small pore spaces, but the total amount of pore space will be the same. Where the grains are arranged in the most compact manner, the amount of pore space is about 25 per cent of the whole volume; where the grains are arranged so as to give the maximum pore space this amounts to nearly 50 per cent of the whole (Slichter, 1899, page 305). As has been pointed out by Johnson and Huntley (1916, page 34):

"A distinction should be made between the theoretical porosity of a rock and its effective porosity. Owing to the fact that in many rocks a considerable proportion of the pores do not communicate even though the theoretical porosity may be high, the yield (of oil) is necessarily very low. A rock with very small pores cannot be drained of its oil content even though such pores communicate, because of friction and where gas or water is also present because of capillarity."

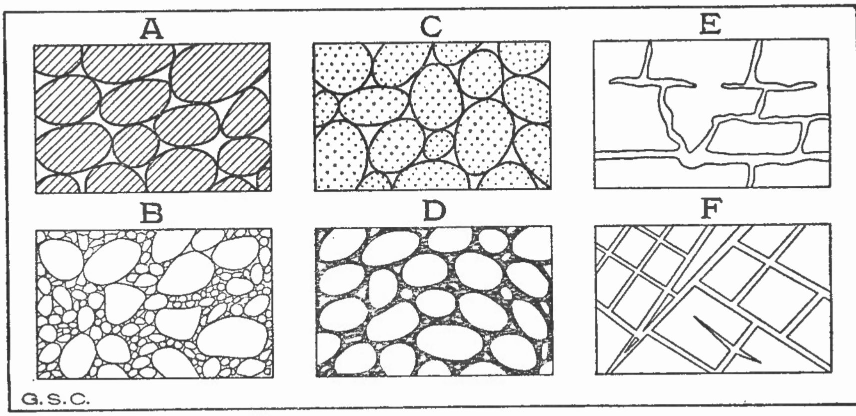

Figure 5. (After E. R. Lilley). Some types of rock textures and structures that affect porosity. A: sedimentary deposit of grains well sorted according to size, interstices comparatively large, degree of porosity high. B: sedimentary deposit of grains poorly sorted according to size, interstices comparatively small, degree of porosity low. C: sedimentary deposit of grains well sorted according to size, the grains themselves porous, the interstices comparatively large, degree of porosity very high. D: sedimentary deposit of grains well sorted according to size, the comparatively large interstices reduced in size by deposition of mineral matter, the porosity diminished. E: rock rendered porous by presence of fissures produced by solutions. F: rock rendered porous by presence of fractures.

Thus, although a fine-grained sand may have as much porosity as a coarse-grained sand, its effective porosity may be very small and in some cases may even be nil. As already indicated, if the grains of a sand are not uniform in shape and size, the smaller grains may fill part of the spaces between the larger grains and consequently reduce the porosity. Silt and clay or materials cementing the sand grains will also diminish the amount of pore space.

Next to porous sands, dolomites and dolomitic limestones form the most important reservoirs for oil and gas.

Analyses, published by Orton (1888, pages 103-105), of rock from different parts of the Trenton formation, first drew attention to the fact that in the Trenton oil fields of Ohio the oil is associated with dolomite. Pieces of reservoir rock, dolomite, blown from the wells, are very porous, whereas the compact limestone with a low magnesium content holds little if any oil and gas. It has been thought that the porosity of the dolomite is due to its formation from limestone, since in the change of a relatively pure limestone to dolomite a shrinkage of as much as 12 per cent may take place. The view that the porosity is wholly due to dolomitization was questioned by Phinney (1889, page 658) because "chips and larger masses thrown out of the wells by the force of gas show that even where the rock is hard and compact small cavities are scattered throughout in such a manner as to suggest that a part of its substance had been removed by solution." It is now generally known that porous limestones and dolomites in certain cases furnish suitable reservoirs for very large amounts of both oil and gas.

Dolomite forms in several ways, as for example by (1) deposition, (2) replacement, (3) leaching. Twenhofel (1926, page 257) concludes that:

"Unless the environmental conditions in the seas of the geologic past were greatly different from what they are at present, there is little possibility that the dolomites were formed by primary organic or chemical deposition. On the other hand, sediments which originally were deposited on the sea floor as calcium carbonate, or with calcium carbonate as the most important constituent, are known to have become dolomitized a few feet below the surface. . . . . . The high content of magnesium carbonate arose either from leaching or replacement of calcium carbonate.

It has been commonly assumed that in the formation of dolomite by replacement, there is an increase in the porosity of the rock formed"

and that the reaction involves:

"A shrinkage of 12·30 per cent in volume. Many dolomites are porous and cavernous, and this characteristic has been assumed to be typical of all dolomites and to have arisen through replacement after solidification. However, many dolomites have more than the required pore space, while others, in essentially horizontal positions, have less than 0·1 per cent. It is difficult to explain these variations as due to replacement alone. Shells which have undergone partial or complete replacement by dolomite in numerous instances show no decrease in volume, and it is obvious that field observations do not support the view that dolomitization involves a decrease in volume. Although it has not been proved that the porosity of some dolomites is due to replacement it is probable that a part of it may arise in this way, but there is a variety of other factors which are determinants of the pore space, among which are the physical characters of the particles composing the original calcite sediments, the cementation, the leaching subsequent to deposition, and the pressure to which the sediments were subjected.

One feature in the distribution of dolomites which is of interest is the fact that the occurrence of dolomite very frequently is regional rather than local."

According to Howard (1928, page 1155) porous limestones may be classified according to the origin of their porosity as follows:

(1) Limestones with primary porosity
- (*a*) Chalk
- (*b*) Oolitic limestone
- (*c*) Primary crystalline dolomite and limestone
- (*d*) Coral reefs

(2) Limestone with secondary porosity
- (*a*) Limestone associated with former erosion surfaces
- (*b*) Limestone with porosity developed as a result of mineralogical changes

(3) Fractured limestones
- (*a*) Strongly jointed limestone
- (*b*) Limestone fractured as a result of crustal movement
- (*c*) Limestone fractured as a result of mineralogical changes

According to this author limestones with primary porosity rarely form oil reservoirs, and limestones in which the porosity has developed below an erosion surface probably form " fully 95 per cent of the known limestone reservoirs."

An unconformity represents a break in sedimentation and may or may not represent a period of time during which the already deposited sediments were subjected to erosion. It is thought that secondary porosity may develop in limestones as a result of leaching and solution during a period of erosion, the porous horizons being confined within the depth of groundwater penetration.

According to Beal and Lewis (1921, page 194):

" Many geologists and engineers engaged in estimating, by the use of porosity, the oil content of sands in the Mid-continent field ordinarily use a factor of 17½ per cent. . . . . The porosity of the ordinary oil sand in California is usually taken as about 25 per cent, undoubtedly a low figure, since sands as loose as those generally average 36 per cent or more in porosity. Porosity in the Appalachian field is estimated at 10 to 12½ per cent, but actually productive portions of the sands probably average at least 15 per cent."

RELATION OF OIL PRODUCTION TO GAS PRESSURE

The amount of oil recovered from oil sands by ordinary methods is by no means the total amount in the sand. Some estimates place the recovery at only 10 to 20 per cent. The amount recovered " depends mainly upon the porosity and size of the pores, upon the available energy within the sand for expelling the oil from the pores of the sand, and upon the efficiency of this energy." The gas dissolved in the oil under pressure is the main force that expels oil from a sand, although gravitation and water pressure are important in some instances. The failure of a well to produce more oil, even though only 10 to 20 per cent of the oil in the sand has been extracted, is not, according to Beal and Lewis, the result of exhaustion of the oil, but is due to the exhaustion of the gas associated with the oil. The conservation of gas in connexion with producing wells is thus of vital importance.

Beal and Lewis have discussed the effect of gas pressure on production, and the following statements are mainly based on their treatment of the subject. Since the amount of gas that can be dissolved in the oil is proportional to the pressure, " doubling the pressure, therefore, doubles the quantity of absorbed gas and hence the energy, being the pressure multiplied by the gas volume, is quadrupled. The expulsive energy thus increases as the square of the pressure, provided there is enough gas associated with the oil to saturate the oil at the existing pressure." Some of the gases present are condensible at the higher pressures and thus go into solution as liquids. The effect in the field is that the expulsive energy may increase at even a greater ratio than the square of the pressure. It is essential, therefore, in the best interests of the life of an oil field, that an amount of gas as small as possible be used to produce each barrel of oil. If large quantities of gas are allowed to escape freely in the initial stages of production it is obvious that the recovery of oil will be much less than the possible maximum.

In many fields the gas pressure is about equal to the hydrostatic pressure, a condition that has been explained (Washburne, 1914, page 857) by the " fact that the weight of water in the rock pores resists the slow outward movement, and that equilibrium is established when the outward pressure is equal . . . . to the hydrostatic head." There are many instances, however, where the gas pressure is much in excess of the theoretical hydrostatic pressure and Washburne believes this excess of pressure may be " assigned in general to greater freedom of communication underneath the sand . . . . to locally more active ascent of rock fluids from any cause, or to greater resistance above the sand." Pressures lower than the theoretical hydrostatic pressure may, on the other hand, be " assigned to the opposite causes, or to leakage, or to dryness of parts of the overlying rock." As proof of the origin from below of pressures in excess of the theoretical hydrostatic pressure Washburne cites (1914, page 856) the fact that such excess pressures are most common in areas where fracturing is prevalent. Also, excess temperatures in oil fields, excess of chlorine in associated water, and the abundance of helium in some deep wells, point to the same conclusion. It has been shown that capillary pressure under certain conditions is quite large, but Washburne believes since there is no change in volume in capillary movement that capillarity itself could not produce any great pressure in an oil sand.

RELATION OF OIL PRODUCTION TO THE SPECIFIC GRAVITY OF THE OIL

A heavy oil being more viscous than a light oil requires more energy to expel it from the pores of a sand. Since in any reservoir there is only a certain amount of available energy due to the gas pressure, it follows, therefore, other factors being equal, that there will be a larger ultimate recovery of the oil if it is light than if it is heavy. For the same reason the initial flow of oil from a sand is likely to be smaller if the oil is heavy than if it were light. The general tendency, however, for an oil well producing heavy oil, is to decline less rapidly than one producing light oil under similar conditions.

RELATION OF OIL PRODUCTION TO SPACING OF WELLS

The relationship of production to spacing of wells has been discussed by Beal and Lewis (1921, page 194), and they point out that the closer the spacing of wells the greater the ultimate recovery of oil. The gas absorbed in the oil is the propulsive force driving the oil to a well and for each reservoir only a certain amount of energy is available. The energy due to the gas pressure may be dissipated in driving either a small amount of oil a long distance or a large amount of oil a short distance. It is desired, of course, to obtain the maximum possible recovery of oil and it is obvious that this end will best be accomplished where the energy is used in driving a large amount of oil a short distance, or in other words where the spacing of the wells is close. There are, naturally, limits to the close spacing of wells and for each field there is a certain spacing which is the most economical.

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CHAPTER II

GEOPHYSICAL METHODS OF LOCATING OIL AND GAS

INTRODUCTION

The occurrence of oil and gas accumulations depends on several conditions: (1) the presence of adequate source materials of oil and gas; (2) the existence of suitable reservoir rocks under sufficient cover to retain any oil or gas; and (3) the occurrence of a geological structure favourable for the accumulation of oil into a limited area. In areas like the plains and foothills of western Canada where the evidences of oil and gas are widespread the presence of adequate source materials may be taken for granted. Also, the existence of porous sandstones and limestones suitable for acting as reservoir rocks is probable. The problem of finding oil and gas is, therefore, fundamentally a problem of finding favourable structural conditions such as are outlined in Chapter I and for this purpose certain geophysical methods have been devised. These are described under: (1) Torsion Balance, (2) Seismograph, and (3) Other Methods.

TORSION BALANCE

The torsion balance is an instrument designed by Baron Roland Von Eötvös, Professor of Physics in the University of Budapest, but modified and perfected to make it applicable to specific problems. It is a gravity measuring apparatus which, however, does not measure the actual value of gravity, but indicates variations due to a deficiency or an excess of mass at any point where the instrument is used.

An account by Captain H. Shaw and E. Lancaster-Jones (1925, page 18) describing the instrument and the principles governing its operation, is summarized here.

" The torsion balance is extremely simple and consists of an horizontal aluminium beam suspended by a very fine wire. At one end of the beam a weight of gold or platinum is fixed while a second weight is suspended some distance below the other end of the beam. The wire usually employed is platinum alloyed with 20 per cent iridium, of 0·04 mm. diameter, but smaller wires and wires of other materials have been used from time to time. The whole suspended system must be adequately protected against all kinds of disturbance, and this is achieved by enclosing it completely in a double or treble walled metallic case, each case being thermally insulated from the others. The instrument is operated in a specially designed double-walled tent which provides additional protection from radiation. These precautions are necessary in order to minimize temperature changes and convection currents in the beam chamber on account of the extreme sensitiveness of the torsion wire. One of the main difficulties has been to prepare wires having a constant equilibrium position and it is of importance to maintain the temperature as nearly constant as possible during observations. With wires such as described above, it is possible to measure values of the order of one-billionth part of the total gravity, but in order to obtain such accuracy the wires require to be specially prepared. They are subjected to a baking treatment and are kept under constant tension for months or even years.

The mirror mounted on the middle of the beam enables its deflection to be observed and this may either be read by means of a telescope or recorded photographically. Means are also provided for clamping the beam and relieving the tension from the torsion wire so that it may be transported from place to place without fear of damage."

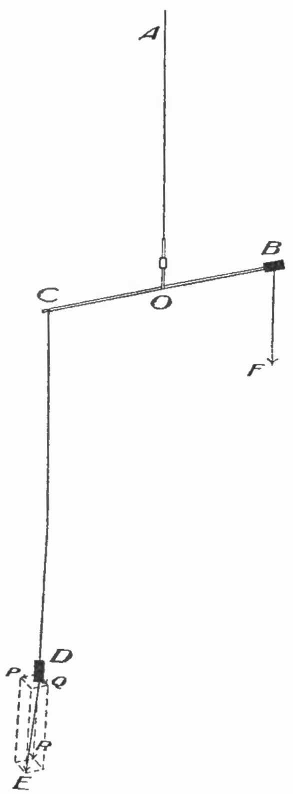

Figure 6. Sketch to illustrate the principle of the Eötvös torsion balance. (From The Mining Magazine, vol. 32, No. 1, page 19.)

The theory of the balance and its operation are as follows:

"Consider a light beam B C (Figure 6) to be accurately balanced by the weights B and D, and free to rotate in an horizontal plane about a fine suspension wire AO. It is well known that the weight of a body is the force with which the earth is attracting the body, and we are accustomed to regard these forces at neighbouring points as being parallel to each other. This, however, is only an approximation to the truth, for in reality the forces of the earth's gravitational attraction at points only a small distance apart are not absolutely parallel. If, for convenience, we consider the earth's gravitational force on B to be represented by a vertical line BF the corresponding force of the weight D will not be parallel to BF but will be inclined very slightly to that direction, say along DE. In the illustration this inclination is considerably exaggerated in order that it may be clearly represented in the drawing. The gravitational force DE may be resolved into three mutually perpendicular directions giving force P, Q, and R, the last named being parallel to BF. Of the other two components P is the force parallel to the direction of the beam, but Q is perpendicular to the direction of the beam and tends to rotate the whole beam system about the suspension wire AO. The wire AO thus becomes twisted, until eventually a position of equilibrium is reached, when the torque due to the minute force Q is just balanced by the torsional force of the wire AO. The beam thus comes to rest in a definite position which can be ascertained by the reflection of a scale in the mirror carried at the middle of the beam. The whole beam system is now rotated into a different azimuth and the observation repeated. From observations of the equilibrium position of the beam in five different azimuths the variation of the gravity at that station can be calculated."

To overcome the difficulty of taking readings in five different positions, Eötvös constructed a double-armed torsion balance (*See* Figure 7) which in reality is a combination of two instruments mounted on one pedestal and in which the arms are set in opposite directions. With this instrument observations are made in three positions. Since the construction of this instrument various improvements have been made, but the principles of operation are the same.

According to Heald (1932, page 41) the effectiveness of the torsion balance

"depends upon its ability to detect changes, from point to point, in the attraction of gravity and to interpret these changes into terms of geology. Its theory is developed

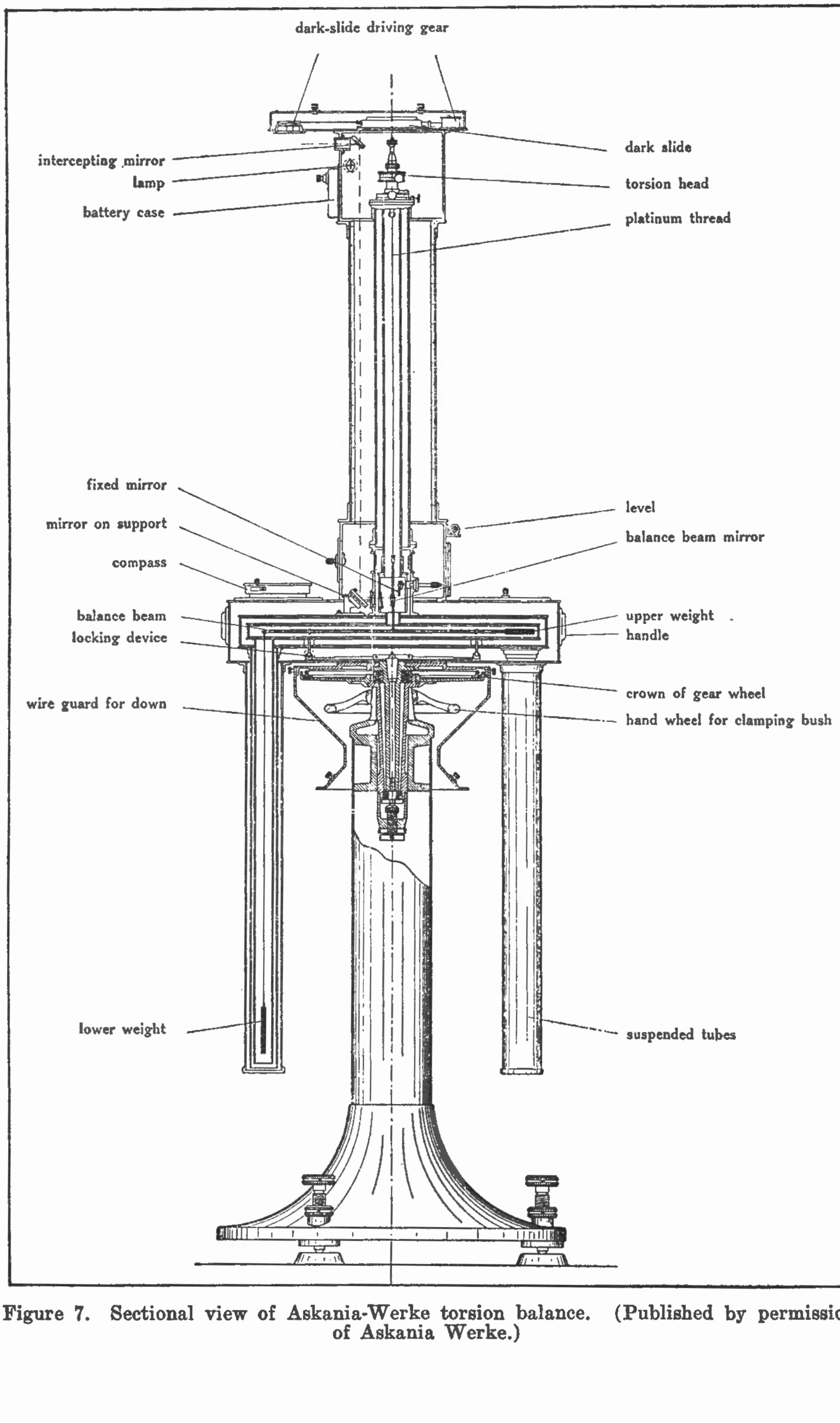

Figure 7. Sectional view of Askania-Werke torsion balance. (Published by permission of Askania Werke.)

from Newton's law that every body attracts every other body with a force that is directly proportional to the mass of the body, and that the attraction becomes less as the bodies are moved farther apart. This law is manifested even with an instrument as crude as a spring balance which, as is well known, will record a heavier weight for an article at sea-level than it will for the identical article when weighed in high country some thousands of feet above sea-level.

The torsion balance, effectively operated, tells us whether the rocks under one area are heavier than those under another, and the rate at which the change in mass occurs. Since the pull of gravity is inversely proportional to the distance between any two bodies that are under consideration, it is apparent that if, far beneath the surface, there is a formation that is relatively quite heavy, and due to folding or faulting, that heavy formation is nearer the surface at one point than at another, the pull exerted by the heavier formation would have the greatest effect at the point where it lies nearest the surface. Under favourable conditions, therefore, the torsion balance will reflect changes in structure of the rocks and will accurately reflect such phenomena as anticlines, synclines, and large faults.

There are, however, many factors that conspire to render the interpretation of the torsion balance data into terms of oil field structure difficult and at times impossible. Every mass exerts an influence on the instrument and the influence of a large mass miles away may be appreciable. The work that has been done has demonstrated the existence of great concentration of heavy material miles below the surface of the earth which has a pronounced effect on the instrument, and that gives results which could equally well be produced by a very large structure within drilling depth. Every hill exerts a lateral pull on the instrument. Every heavy boulder, close beneath the surface, will leave its record, and interfere with the recognition of the effects due to structure.

Since the successful operation of the gravity methods depends on detecting changes in the influence of gravity, it follows that if the rocks underlying a given area are very uniform in character the instrument will not reflect the changes in depth at any given horizon and, therefore, will be ineffective.

Again, there are areas where the geologic structure is so complex that in spite of the existence of beds strongly contrasting in mass, the instrument is affected by so many pulls from different directions, and conditions vary so abruptly from point to point, that it has proved impossible to convert the instrument records into a reasonable geological picture. This is no fault of the instrument but must be attributed to the inability of physicists and geologists to recognize the probable origin of the forces that have given the results recorded by the torsion balance.

From the preceding discussion it may be concluded that the torsion balance will work most effectively in areas where the surface is flat as in extensive prairie, where there are no hidden "pockets" of either light or heavy material hidden close below the surface, where there are certain units among the formations within drilling depth that are appreciably heavier than those overlying them, and where structural conditions are comparatively simple. A change in any of these factors detracts from the usefulness of torsion balance work and may at the present stage of our capacity to interpret, make the work valueless.

At present the torsion balance is totally unsuitable for work in areas where the surface is cut into high ridges and deep valleys, where the rocks at a depth of 1,000 feet or more are closely folded or completely broken by faults, or where the rocks down to the limits of drilling depth furnish no appreciable contrast in the mass of individual units or formations."

SEISMOGRAPH

The seismograph is an instrument that registers and records earth tremors due to earthquakes. The instrument, however, has been adapted to the study of geological structures and its action is described by Heald (1932, page 42) as follows:

"Vibrations, created by a shock, travel through any substance at a rate directly proportional to the elasticity of the substance and the denser the body the less will be the speed. In seismic surveying such waves are produced by firing a charge of dynamite, or other high explosive, and the time it takes them to reach a given point is determined by an instrument designed to detect even very minute vibrations. Since rocks with different physical properties transmit these vibrations at different rates it is apparent that by this method a good deal can be learned about the nature and the attitude of the strata underlying a given area. It is equally apparent that since different rocks behave differently the significance of the results and the accuracy of the interpretation depend critically upon a correct conception of just what geological conditions can produce certain observed results."

Seismic methods are subdivided into "refraction" and "reflection" methods.

Refraction Methods

"Refraction as the term is used in physics, means the departure from a straight line or path which is suffered by a ray or beam of light, sound, etc., as it passes obliquely from one medium through which it travels with a given velocity, into another through which it travels either faster or slower than it did through the first. By means of rather lengthy computations it is possible to take advantage of this refraction principle and to determine from the distance between the shot point and the seismograph, and the time that it takes the wave to travel from the point of explosion to the seismograph, approximately what path was followed by the vibration or elastic wave, and certain of the characteristics of the rocks through which it passed. The time it takes for the vibration to travel from the shot-point to any single seismograph is not, in itself, significant, but by comparing the records obtained by seismographs at a number of different distances from the shot-point the subsurface conditions can be worked out.

The refraction method of seismograph work has been most intensively used in the search for salt domes, but it has also been applied to the search for concealed anticlinal structure, and to determine whether or not certain formations whose presence could be ascertained by this method were within drilling depth. It has been particularly effective in discovering salt domes which lie less than 5,000 feet below the surface, although attempts to secure information from greater depths have not been so uniformly successful. Under favourable conditions it will also map concealed geologic structure very faithfully, but complicated structure gives it a great deal of trouble.

Unlike the torsion balance it will work effectively in areas where the topography is rough, provided certain necessary factors are recognized and included in the computations. However, it may be rendered totally useless by the presence near the surface of a thick bed of highly elastic rocks such as rock salt or dense limestone, for it is extremely difficult to force a vibration or wave through such a bed in order to explore the underlying conditions. Equally effective in defeating seismograph work is a thick bed of unconsolidated material such as loose sand. For example, a seismograph can work effectively in an area covered by sand dunes only if holes are dug through the sand to the underlying more solid material and both the shot and the recording device are placed beneath the bottom of the sand layer. Water, however, is a help rather than a hindrance and good results have been secured in many lake and swamp-covered areas.

The refraction seismograph is particularly suitable to explore territory where there are neither very elastic beds such as heavy limestone, nor incoherent beds, such as loose sand, near the surface; where the formations down to a depth of at least several hundred feet are soft shales and sandstones with a highly elastic bed such as dense limestone underlying this inelastic material; and where the geologic structure is relatively simple. It is not recommended for work in areas where rocks are sharply folded, with individual beds inclined more than 30 degrees from the horizontal, or where there are closely spaced faults."

Reflection Method

"Only a part of any wave or vibration that strikes an elastic layer of rock will penetrate it or travel along it. Another part will be reflected from its upper surface, just as light is reflected from a mirror, and will rebound toward the surface. The reflection method of seismograph mapping uses instruments and technique designed to detect these rebounding vibrations and to compute from them the depth to the layer from which they were reflected. It will not furnish all the information that may be obtained through work by the refraction method, but, on the other hand, it has been proved effective in some areas where refraction work is unsatisfactory, either because of excessive cost or because of geological conditions. In other areas a combination of refraction and reflection work has been found most satisfactory.

One of the merits of the refraction work is that it will tell with a fair degree of precision the depth to the first layer of rock at which there is a sharp increase of the speed with which the elastic wave travels, whereas nowhere in the literature do I find any claim that it is possible to determine from the reflections the depth to the reflecting layer. If a method for such determinations has been worked out it is a trade secret and not general knowledge. In lieu of determining the depth to some characteristic layer by means of the seismograph work itself, as is done in the refraction method, it is customary to begin reflection work in a given area by making a number of readings at some point where the depth to different formations which because of their physical characters may yield good reflections, are known. A producing field or an abandoned dry hole, the log of which was carefully kept, will supply the desired information, although if a dry hole is used it is important to also know that it was drilled straight. Otherwise the conclusions as to the time it takes the vibrations to travel down to some given horizon and to rebound to the surface obviously will be erroneous. It is, therefore, customary to select, if possible, wells or dry holes which were tested for straightness with some one of the well-known methods such as the hydrofluoric acid bottle.

If no wells have been drilled from which the desired information may be secured it may be necessary to estimate the probable speed of the vibration through such rocks as are known to underlie the area, and to proceed on the basis of this assumption. If, for example, the geologists can assure the seismograph operators that a certain percentage of the rocks down to a depth of 6,000 feet comprise shale, another percentage comprises heavy beds of limestone and that the remainder are sandstones, the geophysicists will compute a reasonable speed, based upon their experience in other areas and upon the known average velocities of seismic waves in shales, limestones, and sandstones. The assumption will be appreciably in error except by grace of the most extraordinary coincidence, but this will not greatly affect the significance of the work for the same erroneous assumption will be uniformly applied to every separate computation of depth, and they will all err in the same direction from the true value except in areas of very large, steep structure. Therefore, when the work is finished a contour map of the top of the reflecting horizon, based upon the erroneous assumptions, will be almost indistinguishable from one based upon absolute accurate determinations of the speed through the formations overlying the reflecting formation. However, the map based upon the assumed velocities may indicate that the reflecting horizon is either a good deal nearer the surface or a good deal deeper than the drill may prove it to be.

When it seems vitally important to determine accurately the depth to the reflecting horizon and the exact time it takes the seismic wave to reach it and return to the surface, refraction methods should be used to secure the desired information if no wells have been drilled in the area.

Where conditions are favourable it is possible with the reflection method, to continuously trace the top of some horizon that sends a strong "echo" to the surface, to secure the relative elevations of a great number of points on the reflecting surface, scattered over the area which is under investigation, and to prepare a structure map comparable with one that would be made if the overburden were stripped away and the reflecting bed were exposed for inspection. The most favourable conditions are a thick section of rock such as shale and rather soft sandstone which do not tend to reflect the seismic wave, underlain by a thick reflecting bed such as dense limestone. Smooth, flat topography will facilitate the work, but rugged country will not prohibit accurate results provided the seismograph operators make the appropriate corrections in their computations. The most favourable conditions also call for structure upon which the beds dip at a comparatively gentle angle since the direction of rebound of a ray is affected by the inclination of the surface from which it is reflected. If the beds dip steeply accurate results with the present instruments and technique are improbable.

Unfavourable factors include too many reflecting horizons. In some areas as many as fifteen or more individual horizons give reflections that are recorded by the instrument and the operator is then confronted with the puzzle of determining just what reflections on one record correspond with those on another........................ An unfavourable condition that is less common is the lack of traceable reflecting horizons. The reflection seismograph will detect significant features in some areas where the formations are such as to completely frustrate attempts to map it by refraction methods, but even the reflection work may be defeated by the uniform nature of the formations. Contrast is essential.

A thick elastic bed close to the surface or a thick layer of unconsolidated sand will defeat any attempt to secure information by the reflection method just as it will defeat refraction. Also, complicated structural conditions will bring despair to the operators of the reflection seismograph quite as quickly as to those of the refraction instruments. In fact, in the writer's opinion, no geophysical method has yet been devised which can successfully read the story of a closely folded or complexly faulted area."

The reflection method of seismographic survey has been operated in certain areas in western Canada with what is reported to be marked success. Throughout most of the southern plains area, Mesozoic sediments consisting primarily of sandstones and shales are underlain by dense Palæozoic limestones which constitute a good reflecting surface, and it has been found feasible to outline the structural features of the limestone surface lying at depths of several thousands of feet. Some of these areas are to be tested by new wells and if these should prove successful there is no doubt that the seismic work will be greatly extended.

OTHER METHODS

Various magnetic and electrical methods have been used in oil prospecting. Surveys of large areas have been made by the use of a magnetometer, but in certain cases it has been found "magnetic highs" do not correspond to "structural highs." According to Heald (1932, page 42)

"it is now believed that in most areas the magnetic intensities are significant of conditions in the granitic or other igneous rocks that lie below the formations that may possibly yield oil and that their usefulness depends upon the ability of the geophysicist and the geologist to correctly deduce just how, if at all, these conditions in the igneous rocks may have resulted in geologic structure suitable to induce the formation of an oil pool."

In spite of difficulties of application, however, magnetic methods have been used in the search for gas fields in Alberta with a certain amount of success.

Electrical methods depend on the measurement of resistivity in underground strata that have the properties of conductors of electricity. Beds carrying salt waters of certain types act as fair conductors, whereas dry strata unless they have a high mineral content are insulators for the purposes of electrical prospecting. The property of conductivity in strata in which the pores are filled or partly filled with saline waters depends primarily on the chlorine content of the water. Oil-field waters are usually high in chlorides and carbonates and hence are fair conductors, whereas surface waters have a high sulphate, and a low chloride, content and hence are poor conductors. It follows then that in most oil-bearing strata fair conductor beds are likely to occur and these can be used for resistivity measurements provided they are not too deeply buried, since it is understood the best results are obtained above a depth of 1,500 feet.

According to Heiland (1932, page 1279)

"there are two distinct applications of the resistivity method. First is the method of resistivity mapping. The object of this method is to obtain a contour map of the area, showing lines of equal resistivity. These lines represent the ground resistivity only to a definite depth, and, to facilitate the interpretation of the results, two or more contour maps may be made of the same area, representing the resistivity down to two depths of investigation. The second method is the so-called method of electrical drilling. The results are to give the vertical variation of the resistivity at one point only and the depth at which any changes occur."

The results are plotted as a vertical or depth profile and by measurements at various places a number of profiles are obtained. These profiles are then correlated and from them the structure is deduced.

This method has been used in western Canada in the Rogers-Imperial, Spring Coulée, and other areas in Alberta and in the Dirt Hills of Saskatchewan where a structure favourable for oil and gas accumulation is said to have been outlined.

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CHAPTER III

PHYSICAL FEATURES, GEOLOGICAL STRUCTURE, AND STRATIGRAPHY OF THE GREAT PLAINS AND FOOTHILLS

PHYSICAL FEATURES

The Great Plains of Canada are bounded on the east by the Canadian Shield and on the west by the foothills which are a narrow belt 12 to 35 miles wide lying east of the mountains. From the International Boundary, where their width is 800 miles, the Great Plains extend northward for 1,500 miles to the Arctic Ocean at the mouth of Mackenzie River where their width is less than 100 miles. They include the southwestern part of Manitoba, much of Saskatchewan, most of Alberta, a northeastern part of British Columbia, and a large part of Mackenzie River basin in the Northwest Territories. East of the Mackenzie for many miles south and north of Great Bear River the continuity of the plains is broken by the folded Franklin and Norman mountains which thus lie east of the main Cordillera. In the area west of Simpson the plains sharply abut against the mountains. This same condition is found along Liard River north from its confluence with Fort Nelson River where, according to McConnell (1890, page 54), "the mountains are not fringed by a belt of foothills, such as usually accompany them in other places, but rise abruptly from an almost level plain, and attain at once their full height of about 4,000 feet. The folds and fractures to which the mountains are due also seem to die away with startling rapidity." South of the Liard where it flows east from the mountains to the plains a foothills belt is present and has a width of 38 miles (McConnell, 1890, page 50) and apparently is composed of folded rocks (McConnell, 1890, page 44). South of Liard River the eastern boundary of the mountains has a northwest trend, but north of the Liard the boundary turns eastwards for 150 miles, beyond which it resumes the northwest trend. It appears, therefore, that the disappearance of the foothills to the north of the Liard is in some way connected with the appearance of the more easterly range of mountains. The foothills belt is present from Liard River to the International Boundary, a distance of about 800 miles. Southward from Canada it forms a narrow belt in northern Montana extending, according to Stebenger (1918), through Blackfeet Indian Reserve and disappearing in Sun River area to the south.

The plains of Canada are a part of the Great Interior Plains of United States which extend southwards to the Gulf of Mexico. According to Young (1926, page 128) the Great Plains,

"except for a narrow strip in southern Alberta and Saskatchewan, drain northward to the Arctic Ocean or eastward to Hudson Bay, and the general slope is northward or eastward from elevations of 3,000 to 5,000 feet along the edges of the mountains on the west, to 1,200 or 1,500 feet or less along the eastern border. But, though the region as a whole slopes eastward at a rate of only a few feet per mile, the surface, except locally, is not a plain but is rolling and is traversed by valleys, many of which, even the wider, are trench-like in form; and in various districts, broad, plateau-like areas rise abruptly above surroundings plains. The southern part of the region includes the prairie country of western Canada, which in Alberta extends nearly 400 miles north from the International Boundary. Northward succeeds a strip of mixed prairie and woodland and beyond this the country, except locally, is wooded.

In the southeast, the Manitoba lowland forms the eastern part of the region. The lowland, with an average breadth somewhat greater than 100 miles, extends from the International Boundary northward for 450 miles. Within it lie several large lakes, of which Lake Winnipeg, 250 miles long, is the largest. The lowland surface is a slightly undulating, drift-covered plain sloping gently downwards from west to east and having an average elevation of between 700 and 900 feet above the sea.

The western boundary of the Manitoba lowland is marked by a prominent escarpment forming the edge of the Alberta upland which extends west to the (foothills of) Rocky Mountains and northwest to the latitude of Great Slave Lake where it forms the Mackenzie lowland stretching northward to the Arctic Ocean. In the southeast the boundary of the Alberta upland is sharply defined by the edge of the abrupt drop down the Manitoba escarpment to the lowland to the east. This escarpment, though broken by wide valleys opening eastward into the lowland, is a marked feature which in a breadth of several miles or less rises to heights of 400 to 1,000 feet or more above the Manitoba lowland. Back from the edge of the escarpment, the country in various districts continues to rise across a zone of morainic ridges and hills, beyond which it declines to the general level of the surface of the upland. West of the north end of Lake Winnipeg, beyond the valley of Saskatchewan River, the front of the Alberta upland is marked by at least one group of hills facing northward over a lowland in some respects a counterpart of the Manitoba lowland. The limits of the upland farther northwestward are imperfectly known, but in the extreme north the edge is a series of northward-facing escarpments rising about 400 feet above the Mackenzie lowland and extending from Slave River northwestward to Liard River and possibly westward up the valley of that river.

The surface of the Alberta upland on the whole rises gradually from its eastern and northern limits to the western boundary (on the eastern edge of the foothills). Along its outer, eastern edge, the upland varies in elevation between 1,000 and 2,000 feet above sea-level, but along the flanks of the mountains on the west, it rises to elevations of 4,000 feet. In many places the westerly rising, plain-like or gently rolling upland surface bears plateaux, some of which are of great extent and rise steeply hundreds of feet or even 1,000 feet or more above the surrounding level country. The nearly flat or rolling upland is further diversified by the sharply incised valleys of major waterways which, rising in the Rocky Mountains, flow eastward or northward across the upland, and as they leave it follow wide valleys, in some cases 50 miles broad. These valleys divide the bordering escarpment into sections that, when viewed from the eastern lowlands, appear as detached ranges of hills. In the south, the even surfaces of the general upland and of the plateaux rising above it are further marked by sharply cut valleys and trenches which are remnants of an older drainage system and now hold feeble streams or none at all.

The Mackenzie lowland borders the Alberta upland on the north. It commences at the west end of Lake Athabaska and extends northward along Slave River as a narrow area, but in the latitude of Great Slave Lake it broadens to a width of 250 miles and embraces the full width of the Interior Plains region. It continues north to the Arctic Ocean, bounded on the east by the Canadian Shield and on the west by, successively, Mackenzie Mountains, Peel Plateau, and Arctic Mountains. To the north its width decreases and for a stretch of several hundred miles it is divided longitudinally into two parts by Franklin Mountains, between which and Mackenzie Mountains on the west lies Mackenzie Valley, in places only 20 miles broad. The general elevation of the lowland decreases from 700 feet in the south to sea-level in the north, but besides the Franklin ranges, various ridges, hills, and plateaux rise to considerable heights above the general level. Peel Plateau, which borders Mackenzie Mountains on the north and lies west of the lower Mackenzie River, probably should be regarded as part of the Interior Plains region."

The foothills, as already indicated, form a belt a few miles wide extending from the International Boundary 800 miles northwest to Liard River. They are a series of almost parallel hills and ridges with elevations of 3,500 to 4,000 feet along the eastern or plains edge and rising to as much as 6,000 feet on the western or mountain side. Topographically the foothills merge eastwards into the gently undulating plains, but are more sharply defined from the mountains on the west. The rather abrupt change from the foothills to the mountains is due to the fact that the mountains are composed of hard, massive limestones that stand at rather high elevations, whereas the foothills are formed of softer sandstones and shales that are easily eroded. So far as type of structure is concerned there seems to be little if any difference between the mountains and the foothills. In Crowsnest Pass area the foothills are considered to extend west to the great overthrust mountains whose axis marks the boundary between Alberta and British Columbia (*See* Figure 8). To the north as far as the southern boundary of the Rocky Mountains Park (about latitude 50° 45′), a broad valley intervenes between the main range of the Rocky Mountains on the west and the limestone mountains of Livingstone and Highwood Ranges on the east. This valley is occupied by ridges and hills of Mesozoic rocks that topographically and structurally belong to the foothills. Livingstone and Highwood Ranges, therefore, appear to be outliers of the mountains bordered both east and west by foothills. To the north, in the vicinity of Bow River, the foothills lie entirely east of the first range of mountains and this is the condition northwestward, although other limestone outliers such as Brazeau and Bighorn Mountains occur. These outliers do not appear to differ in type of structure from the foothills.

The rivers that flow eastwards from the mountains to the plains cut across the foothills regardless of structure except where the former river valleys were blocked by glacial debris during the Ice age and the streams were forced to seek new channels. The main rivers and streams that flow across the strike of the foothills are, therefore, antecedent and superimposed on the present structure. Such subsequent streams as are present flow northwest or southeast along the strike valleys to join the main streams. The larger antecedent streams and rivers occupy well-defined valleys usually with steep or precipitous walls and the tributary or subsequent streams join them through canyon-like gaps in the valley sides. The strike valleys of the foothills contain some fairly large muskeg areas and numerous lakes.

In the southern part of Alberta the eastern foothills are mainly bare of trees, but covered with prairie grass. Trees, however, grow in protected areas and close to the mountain front. Northward the trees increase in abundance with poplars in the east and conifers in the west. North of Bow River most of the foothills, both ridges and valleys, are, or in recent times have been, forested. Owing to their high elevation the foothills are subject to early frosts and for the most part are not suitable for agriculture. Ranching, however, flourishes, especially in the southern, more open country.

GEOLOGICAL STRUCTURE

There is a very great contrast between the structure of the plains and that of the foothills. The foothills are characterized by thrust faulting with associated shearing and folding, indicating great compressive forces, whereas the plains are characterized by gentle undulations with a minimum amount of faulting. In southern Alberta as far north as Bow River there does not seem to be any intermediate structural zone between the foothills and the plains, although topographically the one merges into the other. In this area, at least, there is some evidence to support the belief that the foothills are a mass overthrust eastwards along low-angle faults onto the relatively flat strata of the plains. These low-angle faults east of the Highwood foothills area, Turner Valley, Jumpingpound and Wildcat Hills are steep at the surface and constitute the boundary between the intricate foothills and the relatively simple plains structures. The foothills structure is considered to be of the same type as that of the mountains, although there may be differences in the magnitude of thrusting.

North of Bow River, in the area mapped by MacKay (1924-26) in the vicinity of Cadomin and Mountain Park, the foothills have not been interpreted as underlain by low-angle thrusts and the same is true of the foothills in Peace River area, where according to McLearn (1923, Figure 1, page 2, and page 8) sharp, faulted folds on the eastern edge of the foothills occur east of wide areas of relatively slightly disturbed strata. To the north, along Liard River north of its confluence with Fort Nelson River, according to McConnell (1890, page 54) "the mountains are not fringed with a belt of foothills . . . but rise abruptly from an almost level plain and attain at once their full height of about 4,000 feet. The folds and fractures to which the mountains are due also seem to die away with startling rapidity." To the south of this area where Liard River cuts through the mountains from the west, there is, however, a belt of foothills which as stated by McConnell (1890, page 50 D) is 38 miles wide and "is characterized by a much greater irregularity in altitude than is usually the case." The disappearance of the foothills northward seems to be due to an eastward offset in the mountains and it is suspected that there are no foothills north of this offset, since in Mackenzie River Valley west of Simpson the gentle, undulating plains structures occur up to the base of the mountains. In a former report (Hume, 1922, Map 1957), it was considered that the eastern edge of the mountains in this area was a normal fault dipping eastwards. The strata of the plains are younger than those exposed in the mountains and their relatively undisturbed condition along the edge of the mountains did not suggest thrusting. But in southern Alberta the relatively undisturbed condition of the strata in front of the most easterly thrust of the foothills is almost as striking and the effects of the thrusting along the edge of the foothills appear to die out so suddenly that it is possible that in the north the fault along the edge of the mountains west of Simpson is a thrust along a westward dipping plane. On the other hand, since a foothills belt is entirely lacking in Mackenzie River area it is possible that the general structure is entirely different from that of the foothills in southwestern Alberta.

Thrust faulting is the dominant feature of the southern foothills. Approximately parallel ridges of rock are separated by numerous thrust faults which trend in a northwest direction in a rough way following the trend of the mountains to the west. If, as postulated here, the southern foothills are underlain by low-angle thrusts, the numerous faults between the ridges may be subsidiary to the low-angle faults and may join them at depth. The folding within each fault block is probably mainly the result of thrust faulting causing distortion of each fault block under severe compression. The fault blocks override one another from the west and such normal faulting as occurs may be due to a readjustment after the main episode of compression. Locally within the foothills faulted anticlines and synclines of considerable magnitude occur and one of the remarkable features of these structures is the rapidity with which they may plunge downwards at their extremities.

The structural division between the foothills and the mountains seems to be rather indefinite, which is natural if both possess, as is suspected, the same type of structure. In the south the mountains are underlain by the low-angle Lewis thrust fault which has been traced for 50 miles in northern Montana (Willis, 1902) and 85 miles in southern Alberta (Mackenzie, 1922). North of Crowsnest Pass, Livingstone Range lies east of the Lewis thrust which there follows the west side of a valley underlain by Mesozoic strata whose structure it is believed is like that found in the southern foothills. Livingstone Mountains, therefore, seem to be an outlier within the foothills belt and their structure (Rose and Leach, Map 1584) seems to be of the same type as that of the foothills. Other mountain areas occur within the foothills, as for example Moose Mountain south of Bow River, which is a large-scale anticlinal fold. Brazeau and Bighorn Mountains between Red Deer and Athabaska Rivers are mountain ranges with thrust faults along their eastern sides.

Such low-angle faults as are known in the foothills are steeply inclined at their outcrops which in some instances can be traced for long distances. Subsidiary faults which apparently join these at depth are also steep and in most cases the dip of the fault plane is believed to be 70 to 75 degrees or greater. This steepness is shown by the fact that the trace of the fault on the surface is, in most cases, a straight line regardless of topography. In a few cases the fault outcrop has been observed and the fault plane seen to be steep. Prior to drilling it was not suspected that low-angle faults were present in the foothills, although they were known to occur in the mountains, as for example the Lewis overthrust. Drilling in the foothills, however, has shown low-angle faults in a number of localities and it is thought that others occur where no drilling has been done. It may be that northward in the foothills this type of structure disappears, since structural studies in Peace River area have shown more open folding and less overthrusting than in more southerly foothills areas where from some distance north of Bow River south to the International Boundary thrusts seem to be the dominant type of structure. In certain parts of this southern area it is known that the foothills are composed of fault plates overlying one another and it may be that others occur at depth beneath those that can be observed at the surface. In only one area has drilling given any definite data on the angle of dip of these low-angle faults at some distance west of their outcrops. This is in the New Black Diamond area, west of Turner Valley, where three wells penetrated the fault plane and show the fault under the superficial anticlinal structure to have a westward dip of 18 to 20 degrees. In other areas, as for example Fisher Creek, northwest of the north end of Turner Valley, it is suspected the angle of dip of a low-angle fault encountered in drilling is approximately the same as that of the New Black Diamond area. In other areas the dip of the plane of the fault under certain structures that have been drilled seems to be much steeper and in Turner Valley it may be as much as 35 degrees.

In most cases the angle of dip of the fault plane at the surface is inferred to be high because of the occurrence of steeply inclined strata near the place where the fault must occur, although the fault itself may be concealed. Almost all observed faults in the foothills, however, seem to be steep at the surface and, as has already been pointed out, follow a straight line regardless of topography. Where observed they nowhere dip at an angle less than 50 degrees and in by far the greater number of cases the angle is 70 degrees to vertical. The general opinion regarding the low-angle faults encountered in drilling is that they are steeply inclined at the surface and maintain a high inclination for an unknown distance downwards, beyond which they gradually flatten to an angle much less than at the surface. From the data available from a number of areas where these low-angle faults have been proved by drilling, it seems probable that the depth to which the steep dip continues varies in the different areas. This depth may be of vital importance in the case of some structures that superficially appear to be favourable for oil and gas accumulation but in which the productive horizons may not occur above the fault unless it continues to be steep to a considerable depth. It becomes of great importance, however, to be able to recognize faults that change from steeply dipping faults at the surface to less steeply inclined at depth and to be able to forecast the lowest horizons likely to occur above these faults.

In Fisher Creek area in Tp. 21, Range 4, and in Two Pine area in Tp. 23, Range 5, W. 5th Mer., it has been shown (Hume, 1932) that there are faults that have eastward dipping fault planes and along which the upper easterly block has moved west relative to the lower, western block, that is in the reverse way to what usually has taken place along the more common, west-dipping thrust faults of the foothills. If the pressure that caused the faulting was exerted from the west, as is thought probable, then the east dipping faults are underthrusts. A consideration of the mechanics of faulting leads to the belief that such underthrusts would likely originate at a place where the plane of a major overthrust shows the maximum concavity in changing from a steeply inclined plane at the surface to a less steep one at depth. The underthrusts are, therefore, taken as indicating such a change in dip and in Fisher Creek area where underthrusting occurs it is known from drilling that the thrust fault on the east side of the structure is steeply inclined at the surface but is less so at depth. In both Fisher Creek and Two Pine areas there is a zone of underthrusting rather than a single underthrust fault and east of the zone, approaching the outcrop of the major overthrust which underlies each structure, there is a zone of highly disturbed strata. In Two Pine area this greatly disturbed zone, including the zone of underthrusting, is nearly a mile wide, whereas in Fisher Creek area it is somewhat narrower. At no place on either structure has the plane of any one of the underthrusts been observed, but the beds associated with the faults are steeply inclined and hence it is believed the fault planes also have a steep dip of possibly as much as 70 degrees.

If, then, in any area of underthrusting and overthrusting, the underthrusts and the major overthrust with an assumed fairly steep dip are projected downwards from the surface they will meet in what is thought to be the zone of maximum curvature of the overthrust where it changes from a steeply dipping fault to one of less dip at depth. The depth and position of the zone of maximum curvature having been determined, if the major overthrust is projected westward from this point with an angle of dip of 20 degrees, which is the angle of low-angle faulting under one structure, some indication may be obtained of the depth at which the low-angle fault occurs under any structure that at the surface may appear to warrant drilling. If the depth to the fault is found to be sufficient to allow for the productive zones occurring above it and if the surface structure is favourable for oil and gas accumulations then drilling may be warranted. Interpretations of the depth to the fault plane need to be used with care, however, since outside of one structure so little is known concerning the dip of low-angle faults in the foothills and it may be that in some areas their dip is less than 20 degrees.

The low-angle faults seem to have been developed in many instances in coal-bearing strata and apparently the coal seams may occur either above or below the thrust plane. The coal-bearing beds perhaps are less competent than the associated sandstones and hence more easily deformed and it may be that the coal and carbonaceous shales form a gouge on which sliding readily takes place. In New Black Diamond area the coal-bearing Belly River beds were encountered below the low-angle fault underlying this structure, whereas in the Fisher Creek structure northwest of the north end of Turner Valley, the coal-bearing beds occur above the low-angled fault plane and are Kootenay in age. In New Black Diamond area apparently the low-angle fault is nearly parallel to the beds below the fault plane and hence approaches a bedding plane fault. In Fisher Creek area, on the east side of the structure, Kootenay coal-bearing beds and carbonaceous shales outcrop immediately above the fault plane, and although a well drilled a mile west of this place encountered a considerably greater thickness of Kootenay beds above the fault than occur above it at the outcrop, nevertheless the horizon traversed by the fault is approximately the same at both places, showing that in a distance of 1 mile the fault cuts only slightly deeper into the stratigraphic succession, though there is very little doubt that the strata above the fault plane are highly contorted in depth as well as at the outcrop. The relative attitudes of the fault plane and of the beds under it are not exactly known. At the outcrop of the fault there is one exposure of sandstones that is believed to be Belly River. The beds dip west at about 45 degrees. Below the fault plane in the well drilled 1 mile west, at a depth of 2,690 feet, Belly River strata also occur. In the well several hundred feet of Belly River strata were drilled before the well was abandoned, whereas at the outcrop east of the fault there is only a very small thickness of Belly River strata above Alberta shales. It is concluded from this evidence that the westerly dip of the Belly River continues from the outcrop to where it was encountered in the well, and because there is a greater thickness in the well than at the outcrop that the dip of the fault plane is less than the dip of the Belly River strata. The angle of the fault plane at the well is not known but it is assumed to be not greater than 20 degrees. The dip of the Belly River beds at the outcrop is 45 degrees westward. If this same degree of dip continues to the well it would account for the relations explained above and an approach to a bedding plane fault may be present if the dip of the strata below the fault is but slightly in excess of the dip of the fault plane.

The structure of Turner Valley area seems to be somewhat different from the two structures above described. The fault that underlies Turner Valley emerges to the east either in coal-bearing strata at the top of the Belly River or in coal-bearing strata of the Edmonton over which the Belly River has been thrust. A number of wells have drilled through the low-angle fault underlying Turner Valley. Those near the east side encountered Belly River beds below the fault plane; those farther west along the strike but still on the east side encountered Alberta shales and one well (Sterling Pacific No. 1) encountered Blairmore after having drilled a very considerable thickness of Palæozoic limestone above the fault. Such a succession of beds under the fault plane seems to point to an easterly dip of the strata in the eastern side of the field and since at least 90 per cent of the beds in the foothills dip west it is almost certain that somewhere under the west part of the field there will be a reversal of dip to the west. If this is so then there is an anticline beneath, as well as above, the low-angle fault. Nowhere for any great distance under Turner Valley can the low-angle fault approach a bedding-plane fault because it cuts across the strata and in this respect it appears to be different from the low-angle faults of New Black Diamond and Fisher Creek areas.

It has already been pointed out that the low-angle faults in the foothills are steep at the outcrop. Any explanation of low-angle faulting must take this into consideration. Low-angle faults may develop from overturned folds by the stretching and shearing of the overturned limb which took place for example in the "nappes" of the Alps, but in the foothills it is obvious the low-angle faults did not develop in this way since the amount of overturned strata there is relatively small. In the case of the New Black Diamond and Fisher Creek low-angle faults there must have been relatively little folding prior to faulting because the attitudes of the faults so nearly approach that of the beds below the fault plane. The bending of the strata above the fault plane, especially in New Black Diamond and Turner Valley areas, into anticlinal structures would seem to be due to the drag of the beds against the fault plane with the consequent development within the drag-fold of faults subsidiary to the main overthrust. There is no apparent reason why the low-angle faults under these structures, as they approach the present surface, suddenly steepen to high-angle faults, as they appear to do in all foothills structures. Although several suggestions can be made none of them is entirely satisfactory. It may be that as the fracture, which subsequently became the fault, developed from depth toward the surface, there was a place where the thickness of strata above the upper end of the fracture was insufficient to keep it developing at the same angle as in the deeper areas and it suddenly turned steeply to the surface. Movement taking place on this fracture would tend to lift the strata above it as well as push the whole block forward and cause it to over-ride the surface in front of the point of emergence of the fault at the surface. No evidence of such overriding has been found, although it is probable that the total displacement along some faults is not less than 10,000 feet and may even be considerably greater. It may be that the first fault plate that developed in the mountain building over-rode an erosion surface and completely covered the area now included within the foothills belt. Other faults developing at a slightly later date may have originated under the first overthrust mass, each successive fault occurring at a greater depth than the one preceding it. Any one of these fault plates that so developed would be separated by a fault from the underlying mass of strata and by another fault from the overlying mass. If such a fault slice were moving forward relative to the underlying mass it would tend to carry the overlying mass with it, but if it moved faster than the overlying mass then the drag that would develop along the fault plane separating it from the overlying mass would tend to steepen and rotate the lower plane of faulting at or near its junction with the overlying mass. There is some evidence to support the belief that the faults at present exposed were at one time under an overlying fault plate. The present mountain front in the southern part of Alberta is bordered by an overthrust fault and there is reason to believe the thrust plate of the mountains may have been at one time much more extensive and may have covered the whole of the foothills belt. The question of the former probable extent of this mass involves considerations as to the date of the thrusting and the amount of subsequent erosion. In Canada the thrusting cannot be precisely dated on account of the absence of strata younger than early Eocene. The early Eocene beds were involved in the mountain deformation and hence the faulting must be post-early Eocene. According to Mansfield (1927, page 382) the Lewis thrust "is either of late Eocene or early Oligocene age" and it may be safely inferred as stated by MacKenzie (1922) that the faulting belonged to the end phase of mountain-building. There is much evidence both in United States and Canada of extensive erosion subsequent to deformation. Hewett (1920) describing the Heart Mountain overthrust west of Bighorn Basin, Wyoming, shows that McCulloch Peak, in which Madison (Mississippian) limestone overlies Cretaceous strata, was at one time part of the overthrust mass although it is now separated from it by 28 miles. In southern Alberta, Crowsnest Mountain, in which Palæozoic limestone rests on Cretaceous strata, is part of the Lewis overthrust, but is 2 to 3 miles east of it and hence must be an erosion remnant. This shows that the retreat of the thrust plate front is to be measured in miles. Other proof of extensive erosion can be deduced from the fact that the Cypress Hills conglomerate, of Oligocene age, with boulders up to 12 inches in diameter, was derived from the mountains about 200 miles to the west, although all traces of it have been removed from the intervening area. The unmistakable evidence of great erosion subsequent to mountain deformation suggests that the front of the thrust plate which forms the eastern edge of the mountains in many places in southern Alberta, may have at one time extended much farther eastwards to cover the whole or a part of the foothills belt (Hume, 1931). This conclusion is also suggested by the character of the foothills themselves. The ridges in the eastern foothills are low and well rounded, whereas those in the west are much higher and sharper, a condition suggesting less erosion in the west because the same strata and the same structures characterize the eastern and the western foothills. Greater erosion in the east than in the west would naturally result from a gradual westward recession of the front of an overthrust mass whereby the eastern areas would be uncovered and subjected to erosion for much longer periods than the western ones. The character of the drainage system also indicates widespread and presumably deep erosion. All the major streams and rivers flowing from the mountains to the plains cut across the strike of the foothills without showing any marked structural control except where their courses have been diverted by glacial debris and in many such instances the old channels striking at right angles to the general structure can be traced. The drainage from the mountains, therefore, is superimposed on the present surface, a condition that would result from a drainage pattern developed on a former higher surface since destroyed by erosion. In a few places east of the eastern edge of the foothills there are huge blocks of quartzites quite unlike any rocks found in the foothills but similar to rocks known to occur in the mountains to the southwest. These blocks have been interpreted as glacial erratics, but their occurrence in a number of places about equally distant east of the east edge of the foothills suggests that they may be erosion remnants. One of these blocks east of Turner Valley on Sec. 21, Tp. 20, Range 1, W. 5th Mer., is 160 feet long, 55 feet wide, and 20 to 25 feet high, but is broken into two parts. A few smaller blocks occur in the same vicinity but there is no wide distribution of these rocks as would be expected if they were glacial erratics. If they are erosion remnants of a former thrust plate, the thrust plate must have completely covered the foothills area in this part of Alberta. It is known from drilling in many areas that low-angle faults do occur in the foothills yet no "windows" through them have been observed. If, as here suggested, there formerly was in the foothills a higher fault plate that has subsequently been removed by erosion, the lack of deep erosion below it with the consequent absence of "windows" may be due to the long-continued protection afforded by this cover prior to its complete removal. Thus various lines of evidence indicate that in the foothills area there may have been a thrust plate that has since been removed and it is thought that the steepness of dip of the faults at or near the surface with a much less dip at depth may be due to the drag of the fault against a former fault plate as movement proceeded in the lower fault plate relative to the one overlying it.

There is a possibility that there may have been a certain amount of folding in the foothills subsequent to faulting. In Waterton Lakes area the upper part of Mount Crandell is underlain by a fault (Hume, 1933) that was folded with the Precambrian sediments composing the mountain. Since the Mount Crandell fault block is a slice within the vastly greater fault block of Precambrian rocks thrust along the Lewis fault over Mesozoic strata, there is a strong probability that the Lewis thrust is also folded, as was deduced by Willis (1902, page 332) for the Lewis fault in Montana. Mackenzie (1922, page 129) believed that the structural features within the foothills were related to one episode of compression so that if the Lewis thrust is folded the low-angle faults of the foothills may also be folded. It is noticeable, however, that in Waterton Lakes-Flathead area the axes of the later folding seem to follow an east-west trend at right angles to the strike of the formations. No folding later than the faulting has so far been detected in the foothills, but observations leading to such a conclusion would be difficult to make since faults are rarely exposed for any considerable distance. It is, therefore, possible some later folding did occur.

The plains, as already stated, are characterized by gentle folding with very little faulting. One of the main structural features is the Alberta syncline in which Tertiary and late Cretaceous strata outcrop. It extends from the International Boundary northward 440 miles to Lesser Slave Lake, with a maximum width of about 150 miles but narrowing both to the north and the south. East of the syncline the strata dip gently westerly or southwesterly and culminate in an anticline in Ribstone area in eastern central Alberta. On the westward flank of this anticline a number of local folds have been outlined (Hume, 1925 and 1926) and it is probable others exist. In the southern part of Alberta east of the Alberta syncline there is a broad fold along the International Boundary known as the Sweet Grass Arch. It plunges northwards and is no longer evident north of Red Deer River. Several, small, subsidiary folds occur on the arch and these are the locus of prolific gas fields and also provide some oil production.

Throughout the western part of southern and central Saskatchewan the strata dip gently east or northeast and, because still farther east they dip to the west or southwest away from the Canadian Shield, it is believed that the eastern part of Saskatchewan and the western part of Manitoba are underlain by a broad, shallow syncline. Within this broad syncline, however, there may be local folds. Thunder Hill, in Swan River Valley, described by Kirk (1930, pages 132-134), is apparently such a fold and Kirk (1930, page 134) has also suggested that Minitonas Hill, an isolated prominence also in Swan River Valley, 20 miles east of Thunder Hill, may be another. These structures in western Manitoba are hard to explain. It seems unlikely that they are the result of an eastward transfer of pressure from the mountain building many hundreds of miles to the west. They might possibly be due to salt plugs, although there is no evidence that such is the case and no salt domes are known in Canada. Another possible explanation is the settling of sediments around a core of Precambrian rocks or of Palæozoic limestones, but the dip on the flanks is too steep. In Lake St. Martin region, Manitoba, a knob of Precambrian rocks projects through Palæozoic strata. Since the knob was an eminence on the floor of the Palæozoic sea the strata that accumulated on it would have a depositional dip. The angle of dip of the strata laid down on the flanks of the knob would be increased by the compaction of the sediments subsequent to deposition because the maximum compaction would take place where the sediments were thickest. Shales shrink by compaction more than sandstones and limestones such as occur in Lake St. Martin area, and, therefore, if a knob occurred under a thick series of shales such as are found in the Upper Cretaceous the settling might be sufficient to give a distinct anticlinal structure, although the dip of the strata away from the knob would be very gentle. Since Thunder Hill appears to be a very pronounced structure in which, according to Kirk (1930, page 133), the strata are some 300 to 400 feet above their level in the surrounding district the explanation of the structure as being due to a core of Precambrian or other rocks is hardly tenable, although at the present time no other explanation can be suggested.

West of the broad syncline in western Manitoba and eastern Saskatchewan there is a broad arch in central Saskatchewan extending in a northwest direction through Regina area to Hanley, south of Saskatoon. According to Wickenden (1932, page 195) the top of the Lower Cretaceous in a well drilled at Pilot Butte, 9 miles east of Regina, is about 470 feet higher than in a well drilled in Moose Jaw City 40 miles west of Regina. The difference in elevation of the top of the Palæozoic between these two wells is nearly twice this, amounting to 800 to 1,000 feet. In the Simpson well drilled in Tp. 29, Range 25, W. 2nd Mer., about 75 miles north of Moose Jaw, the top of the Lower Cretaceous is about 70 feet lower than in the Pilot Butte well, or 400 feet higher than at Moose Jaw. Jurassic strata are not present in the Simpson well and would not be expected since in southern Alberta sediments of this age thin and disappear to the north and are not present in the Oyen well drilled a few miles west of the Saskatchewan boundary in Tp. 25, Range 4, W. 4th Mer., 220 miles nearly due west of Simpson. The fact that the top of the Lower Cretaceous is several hundred feet higher in the Simpson and Pilot Butte wells than at Moose Jaw indicates post-Cretaceous folding north and east of Moose Jaw. The rise of the Palæozoic surface is more pronounced than the rise of the top of the Lower Cretaceous and, therefore, cannot all be accounted for by the post-Cretaceous folding. It may be that part of the rise of the Palæozoic surface took place in pre-Jurassic time and thus accounts for the absence of Jurassic beds in the north, for the Jurassic sea may only have reached to a certain elevation so that to the north the Palæozoic surface remained above Jurassic sea-level. On account of the steepness of the dip of the Palæozoic surface between the Pilot Butte well and Moose Jaw on the one hand and between the Simpson well and Moose Jaw on the other hand, Wickenden (1932, page 195) suggested that the high Palæozoic area to the north and east of

Moose Jaw may be bounded on the southwest by a fault scarp. The rise in elevation of the top of the Lower Cretaceous to the north and east of Moose Jaw would seem, however, to be more in harmony with folding and it is quite conceivable that some folding of the Palæozoic may have occurred prior to the deposition of the Mesozoic sediments, which is known to have taken place in the Sweet Grass Arch in Alberta.

STRATIGRAPHY

Within the Great Plains and foothills region rocks of widely diverse ages outcrop. The range in age is shown in the following tabular statement.

Recent and Pleistocene. These are mostly unconsolidated deposits consisting of boulder clay, gravel, and sand with some interglacial sands and lignite. Deposits such as these are widespread and over large areas effectually conceal the older strata.

Tertiary. In central Alberta, south of North Saskatchewan River, a large area is underlain by the Paskapoo formation represented in southwestern Alberta by the Willow Creek and Porcupine Hills formations. In southern Saskatchewan and Manitoba early Tertiary (Paleocene) beds occur over extensive areas and gravels believed by Russell (1932) to be of late Eocene age have recently been found near Swift Current. Strata believed to be Tertiary in age cap Turtle Mountain in Manitoba, but the age is not definitely known. Oligocene conglomerates occur in such areas of Alberta as Cypress Hills, Hand Hills, and Swan River Plateau south of Lesser Slave Lake. Conglomerates possibly of Tertiary age are also known (Hume, G.S.C., Map No. 277 A) from the foothills near Cochrane, Alberta. Miocene gravels have been reported by Sternberg (1930, page 29) from Wood Mountain area, Saskatchewan, and represent the youngest Tertiary strata known in the Prairie Provinces of Canada. In Mackenzie Basin the Tertiary is represented by continental deposits over part of Peel Plateau and in smaller areas in the Mackenzie lowlands where they lie unconformably on Cretaceous and Devonian rocks.

Cretaceous. With the exception of those areas covered by Tertiary rocks, Cretaceous deposits cover all except the northern part of the Alberta Plateau. East of the area in central Alberta covered by Tertiary strata, the surface of the plains bevels the Cretaceous, so that, on the whole, progressively older Cretaceous formations appear eastward, the eastern edge being the escarpment overlooking the Manitoba lowland. Cretaceous sediments cover large areas in the Mackenzie lowlands and Peel Plateau and outcrop extensively in the foothills.

Jurassic and Triassic. Strata of these ages outcrop only in the Rocky Mountains and foothills where faulting and folding have brought them to the surface. Jurassic marine strata underlie the younger rocks of the southern plains and probably extend some distance east into southern Saskatchewan. They have not been recognized in well records in northern and central Alberta.

Rocks of this age outcrop only in the Rocky Mountains and foothills. It is known, however, that they extend eastward under the plains of southern Alberta and they may occur in southern Saskatchewan. No strata of this age have been recognized in the area of Palæozoic rocks in northern Alberta, although there is evidence that beneath younger beds they may extend as far north as North Saskatchewan River in central Alberta. Carboniferous rocks do not occur in the Mackenzie lowland but are present in Liard Mountains.

Devonian, Silurian, and Ordovician. These form the Manitoba lowland and occupy large areas within Mackenzie Basin.

Devonian strata underlie the younger beds of all the Great Plains and foothills, but the distribution of the Silurian and Ordovician is more uncertain and they may be entirely absent from southern Alberta. The age of some of the lower Palæozoic rocks penetrated by wells in northern Alberta is doubtful.

Cambrian. Rocks of this age are known in small areas in the Mackenzie lowlands and Franklin Mountains. They are also known in the eastern Rocky Mountains of southern Canada and presumably extend eastward under the foothills and plains. They do not occur on the Manitoba lowland.

Precambrian. Rocks of this age underlie the whole of the foothills and plains. They outcrop in the Canadian Shield east of the area of Palæozoic rocks forming the Manitoba lowland and northward to the east side of Great Bear Lake and the Arctic Ocean. They also occur in the mountains in southern Alberta where they are known as the Lewis series.

PALÆOZOIC

The Palæozoic formations overlap the Precambrian of the Canadian Shield, occupy the whole of the Manitoba lowland and large areas within the Mackenzie lowland, and outcrop extensively among the folded and faulted strata of the eastern ranges of the Cordillera. Palæozoic beds presumably everywhere underlie the younger strata of the plains, but may vary considerably in age and in thickness from place to place.

In the earliest Palæozoic time a great basin of deposition extended over the area now occupied by the eastern Rocky Mountains and deposition of sediments continued, but with certain interruptions, from Cambrian into early Tertiary, when uplift due to mountain building brought the long-continued period of deposition to a close. The Palæozoic seas occupying the basin were at times quite restricted, but at other times they spread far to the east and during some periods probably occupied the whole or nearly the whole of the Great Plains region. There were intervals when parts of the region were above water and subject to erosion while other parts remained submerged and were sites of continuous deposition. These varying conditions affected the distribution of individual formations.

Strata which may have at one time been very widespread are thought to have been greatly reduced in areal extent by erosion prior to deposition of younger beds. In later times the greater part of the region was mantled by Mesozoic sediments and now the Palæozoic strata outcrop only along the borders of the region and are so far apart as to make correlation difficult.

CAMBRIAN

In Cambrian time a thick series of sediments was deposited at intervals, if not continuously, along the eastern part of the Cordilleran region from south of the International Boundary to far north in Mackenzie Mountains. Cambrian sediments now exposed in the vicinity of Bow River in the eastern Rocky Mountains comprise, according to Walcott (1927, page 156), more than 11,000 feet of sands, siliceous silts, and limestones. Presumably these Cambrian beds extend some distance under the foothills and plains, but there is no evidence they were ever present in Manitoba. In the north, Cambrian seas occupied parts of Mackenzie Basin. Rocks of this age have been reported by Williams (1923, page 72) from Cap Mountain area south of Great Bear River and east of Mackenzie River, where they consist of 1,300 feet of quartzites and shales with gypsum. Cambrian strata also occur west of Mackenzie River in Carcajou Mountains west of Norman (Hume, 1923, page 53) and, therefore, presumably underlie at least that part of Mackenzie Basin lying between Franklin and Mackenzie Mountains. Rocks possibly of Cambrian age have been reported by O'Neill (1924, page 25A) from Coronation Gulf on the Arctic coast.

ORDOVICIAN

Earliest Ordovician sediments are exposed in the eastern ranges of the Rocky Mountains. These include the Ozarkian of Ulrich and are represented by the Mons formation (Walcott, 1928, pages 265-266), 986 feet thick in the Ranger River Canyon section near Banff. This formation extends northwest to Red Deer River 25 miles away. It possibly occurs still farther north, since the Chushina formation exposed in Robson Peak area is equivalent to at least part of the Mons. These formations thin rapidly to the east and hence probably did not extend far east of the present mountains. They are succeeded by the Sarbach formation which at Fossil Mountain, 9 miles north of Lake Louise, is nearly 1,100 feet thick and consists of limestone with a small amount of cherty quartzite (Walcott, 1928, page 283). The Sarbach in the Ranger River Canyon section some distance southeast is only 124 feet thick. This again shows a rapid thinning eastward. The Sarbach formation is Beekmantown in age. In Skoki Mountain area, 9 miles northeast of Lake Louise Station, the Skoki formation consists of about 500 feet of limestones and is of Chazy age. The strata overlying the Skoki are Devonian, although in the western Rocky Mountains Ordovician strata of Richmond age and Silurian beds also occur.

In Manitoba the lower Palæozoic section is quite different from that in the west and consists of strata of Ordovician age. On the west shore of Lake Winnipeg the Winnipeg sandstones were deposited on the irregular Precambrian floor and hence vary in thickness up to 100 feet (Dowling, 1901, page 41 F). This is a tangential formation which in different localities is of slightly different age (Dowling, 1903, page 11 FF). In some localities it may be Black River, although in others it may be younger. In the southern part of Lake Winnipeg Basin the Winnipeg sandstone is overlain by a greenish shale not known to outcrop but found in the Stony Mountain, Winnipeg, and Winnipegosis wells (Maddox, 1930, page 180). This shale ranges in thickness up to 110 feet. It is overlain by, in ascending order, the Lower Mottled (Doghead) limestone 70 feet thick, the Cat Head limestone 70 feet thick, and the Upper Mottled (Selkirk) limestone 130 feet thick. These limestones were considered by Dowling to be the equivalents of the Galena-Trenton of Minnesota. More recently Foerste (1928), after studying Dowling's faunal lists, has concluded that they indicate a Richmond age. The sea in which they were deposited spread southward from the Arctic Ocean where limestones of a similar age occur. In Stony Mountain area, Manitoba, dolomites and shales of Richmond age overlie the Upper Mottled limestone and according to the record of the Stony Mountain well are 330 feet thick. They were also penetrated by wells drilled for water in Winnipeg, but these wells began about 100 feet below the top of the Stony Mountain beds (McLearn, 1915, page 72). As cores were taken from these wells the age of the strata is definitely known from included fossils. To the north a well drilled at Mafeking, west of Lake Winnipegosis, penetrated 330 feet of Ordovician limestones underlain by about 50 feet of Winnipeg sandstones. At Reed Lake (Dowling, 1903, page 11 FF), 70 miles northwest of Lake Winnipeg, about 100 feet of limestones resting on sandstones are the equivalents of the upper part of limestones below the Stony Mountain formation. In the vicinity of Cormorant Lake, a few miles north of Saskatchewan River and 40 miles east of the 2nd meridian, there are about 105 feet of limestones of Ordovician age overlying 10 feet of sandstones (McInnes, 1913, page 59). About 130 miles northwest of Cormorant Lake the Cretaceous overlaps the Precambrian and covers the Palæozoic formations, but farther northwest the Palæozoic again appears as a fringe along the edge of the Canadian Shield and is best known from exposures along Athabaska River north of McMurray. This Palæozoic area apparently contains no Ordovician strata and wells at McMurray drilled through the Palæozoic to the Precambrian show a series of anhydrite, gypsum, and salt beds of either Silurian or Devonian age, lying directly on granitic rocks.

In South Dakota, the Black Hills uplift brings Ordovician strata to the surface and these constitute the Whitewood formation (Darton and Paige, 1925) which has a maximum thickness of 60 to 80 feet but thins southward and disappears. It carries a fauna similar to that of the so-called Galena-Trenton of Manitoba. In the Little Rocky Mountains of Montana, the Bighorn limestone, with a thickness of 350 feet, occurs (Collier and Cathcart, 1923, page 173). The same formation occurs in Bighorn Mountains, Wyoming, where it is 300 feet thick (Darton, 1906). It is considered to be Galena-Trenton in age and is the equivalent of the Whitewood formation of South Dakota. Thus the Lower Ordovician rocks of Manitoba may extend southwestward but disappear to the northwest since they are not present in the bore-holes at McMurray on Athabaska River and are unknown in the eastern Rocky Mountains of Canada. They may be present beneath younger strata in the southern part of the Prairie Provinces, but not in the more northerly or westerly parts. They have not been recognized, however, in the Commonwealth Milk River well in Sec. 9, Tp. 3, Range 15, W. 4th Mer., although this well is known to have reached Cambrian strata. The Stony Mountain group of beds of Manitoba may be even more restricted in areal extent than the underlying Ordovician beds. It is probably absent from northern Saskatchewan and Alberta and its presence in the south is doubtful, although some Richmond is present in Bighorn Mountains but apparently is absent from Black Hills. Richmond strata occur in the western Rocky Mountains, but may have been deposited in a sea extending to the Pacific or Arctic and not connected across the Prairie Provinces with the sea in which the Richmond was deposited in Manitoba.

In the Mackenzie lowland Ordovician strata occur, although little is known of their areal distribution or exact age. Beds of Ordovician age occur on the east side of the North Arm of Great Slave Lake (Hume, 1926, page 59) and rocks possibly of Ordovician age occur in some of the mountains bordering Mackenzie River (Williams, 1923).

SILURIAN

The Silurian is represented in Manitoba by dolomites and gypsum beds of the Stonewall formation (Kindle, 1913, page 249). These occupy a belt paralleling the Ordovician on the east and extend from southern Manitoba to Saskatchewan River (McInnes, 1913, page 62). Extensive outcrops occur on the east shore of Lake Winnipegosis (Tyrrell, 1893, page 153 E) where the strata consist wholly of limestones (*Virgiana decussatum* zone)[1]. In Lake St. Martin area these limestones are overlain by at least 150 feet (Wallace, 1925) of gypsum and anhydrite beds, in turn overlain by dolomites (*Leperditia hisingeri* zone). These rocks were formerly called Niagaran (Tyrrell, 1893, page 153E), but it is now known (Savage, 1918, page 340) that *Virgiana decussatum* occurs only in Silurian strata of pre-Niagaran age or of about the age of the Cataract formation of southwest Ontario. The thickness of the Stonewall formation is not definitely known. Kindle (1913, page 251) considered it to be not less than 250 feet. A well drilled at Mafeking on Sec. 2, Tp. 43, Range 26, W. 1st Mer., penetrated 610 feet of dolomites that by reason of their lithology and fossil content are assigned to the Silurian. In the Winnipegosis well, 95 miles to the southeast on Sec. 29, Tp. 30, Range 17, W. Prin. Mer., the thickness appears to be 350 feet. Neither gypsum nor anhydrite was reported from either of these wells. However, as already stated, 150 feet of gypsum occurs in Lake St. Martin district, northeast of the north end of Lake Winnipeg. In a well at Dominion City south of Winnipeg and nearly 200 miles southeast of Lake St. Martin area a thickness of 60 feet of gypsum was reported by Wallace

[1] Formerly called *Conchidium decussatum, See* Kindle, 1915, p. 7.

(1925, page 23) to be underlain by 110 feet of red clay and sand. A short distance to the north, at Arnaud, the gypsum is 25 feet thick and the red clay 135 feet thick. The stratigraphic position of the red clays and overlying gypsum is doubtful. They may be Silurian, but as suggested by S. R. Kirk[1] more probably are Devonian or younger.

In a well (Allan, 1923, pages 50, 51) drilled at McMurray, on Athabaska River, 370 feet of dolomites and shales with alternating beds of gypsum, anhydrite, and salt underlie strata carrying Devonian fossils. It is possible these beds are Silurian, but owing to the widespread occurrence of gypsum and anhydrite beds in the Devonian underlying the Mesozoic strata of the plains of Alberta it seems more probable that they are Devonian. On Clearwater River, east of McMurray along the edge of the Canadian Shield, there are limestones underlying beds of known Devonian age. No fossils have been found in these limestones and, therefore, their age is not definitely known but is possibly Silurian. On Peace River from Little Rapids to 5 miles north of Peace Point (Camsell and Malcolm, 1921, page 62) limestone, gypsum, and anhydrite outcrop that are thought to be Silurian. Strata carrying Silurian fossils occur near Fitzgerald on Slave River and overlie the limestone and gypsiferous dolomites exposed along Salt River near the salt springs west of Fort Smith. Silurian beds occur on Cariboo Island south of Fitzgerald and at several points on lower Slave River (Cameron, 1922, page 18). They also occur along the west side of the North Arm of Great Slave Lake, in this case being of Guelph age (Hume, 1926, page 61). In Mackenzie River area there is a great thickness of Silurian strata. The lowest member, the Franklin Mountain formation (Williams, 1923, page 72), rests on the Cambrian and consists of 500 to 1,000 feet of limestones of approximately Medina-Cataract age. It is overlain disconformably by 500 feet of limestones and chert of the Mount Kindle formation of Niagaran age. These are overlain conformably by 1,600 feet of brecciated dolomite with interbedded gypsum and chert composing the Lone Mountain formation. The Lone Mountain formation has been correlated by Kindle (1921, page 44) with the Bear Mountain formation of Bear Mountain at Norman, where highly brecciated limestones replaced laterally by gypsum beds occur at the top of the section and have a maximum thickness of 450 feet. These limestones overlie 1,000 feet of well-bedded limestones in Carcajou Mountains, and in Bear Mountain overlie red, gypsiferous shales. Strata of the Bear Mountain formation occur along the west flank of Norman Range, along Whitefish Lake east of Norman Range, and in Mount Charles on Great Bear River (Williams and Hume, G.S.C., Maps Pub. No. 1957, No. 1977, and No. 2022). They presumably underlie the younger strata of all Mackenzie Valley from south of Wrigley to the Ramparts of the Mackenzie and may be even much more extensive.

As in many areas anhydrite and gypsum are associated with Silurian beds it formerly was thought that the presence of anhydrite or gypsum was indicative of the Silurian, and this horizon was considered to be much more extensive than is now known to be the case. Anhydrite-bearing Devonian beds have been penetrated by deep wells in southern Alberta and it is prob-

[1] Personal communication.

able that there the Silurian is entirely lacking. The Silurian is believed to be absent from Montana (Knappen and Moulton, 1930, Plate 2) and has not been definitely determined in Colorado. It is, therefore, probable that in southern Alberta the Devonian rests on Cambrian since so far as known there is also no Ordovician.

DEVONIAN

Devonian rocks are very extensive in western Canada and presumably underlie younger strata over the whole of the Great Plains and foothills from the Manitoba lowland to the Rocky Mountains. They underlie all Mackenzie Basin except in a few places where they have been removed by erosion and older rocks exposed. They, however, vary considerably in lithology and thickness as would be expected in so extensive an area.

In Manitoba the Devonian is divisible into three formations (Kindle, 1913, page 248), namely, Elm Point limestone, Winnipegosan dolomite, and Manitoban limestone. The Elm Point limestone is of Middle Devonian age, Lower Devonian strata being absent. The Elm Point outcrops on the east shore of Lake Manitoba and has been described by Tyrrell (1893, page 194 E). It consists of at least 25 feet of light buff or cream-coloured limestone and has a fauna characterized by a variety of *Atrypa reticularis* with a flaring edge on the shell. It is overlain by the Winnipegosan dolomite about 165 feet thick, in which the dominant and characteristic fossil is *Stringocephalus burtini*. This formation outcrops mainly in the vicinity of Dawson Bay, Lake Manitoba. The Manitoban limestone of Middle or Upper Devonian age overlies the Winnipegosan dolomite, is exposed mainly on Lake Winnipegosis, and according to Wallace (1925, page 49) has a thickness of 185 feet. In the Winnipegosis well a small thickness of red shale occurs, apparently at the base of the Devonian. A well at Mafeking in Sec. 2, Tp. 43, Range 26, W. 1st Mer., showed that the Devonian at this place had a total thickness of 310 feet and, in descending order, consisted of cream-coloured and light grey to brown dolomite 150 feet thick, a thin layer of red dolomite underlain by grey and brown dolomite 120 feet thick, and red and greenish, shaly dolomite 30 feet thick.

Devonian rocks outcrop along the western edge of the Canadian Shield in Saskatchewan and are well exposed on Athabaska River north of McMurray in Alberta. Here the complete section as determined by drilling (Allan, 1921, pages 106-8) consists of 440 feet of alternating grey limestones and grey and greenish shales underlain by anhydrite and gypsum beds which, as already pointed out, are probably Devonian. McConnell (1893, page 51 D) states that: " From the Athabaska the Devonian limestone extends in a broad band around the southern end of Birch Mountains, and across Lake Claire to Peace River and up the latter stream to a point 2 miles above Vermilion Falls." From Lake Claire the Devonian continues as a broad band northwestward to Great Slave Lake, Slave River approximately following the Silurian-Devonian contact for considerable distances from Fort Smith northwards.

Devonian strata outcrop very extensively about the western end of Great Slave Lake and in Mackenzie River Basin. On Great Slave Lake there is no Lower Devonian and the lowest Middle Devonian in the vicinity of the lake are the Horn River shales (Whittaker, 1922, page 51) outcropping on Horn River north of Providence. The shales are 60 feet thick with the lower part not exposed. They underlie the Pine Point limestones which outcrop at Fort Resolution and Pine Point on the south shore of Great Slave Lake and on the north shore west of the North Arm (Cameron, 1922, pages 19-21). The Pine Point limestones are 595 feet thick and have been correlated with the Elm Point limestones of Manitoba. They underlie the Presqu'île dolomites which are well exposed on both the south and north shores of Great Slave Lake west of the outcrops of Pine Point limestones. The Presqu'île dolomites are 375 feet thick and contain the *Stringocephalus burtini* fauna, which definitely correlates them with the Winnipegosan dolomites of Lake Winnipeg. The Presqu'île dolomites on the north shore at Nintsi (Windy) Point contain abundant oil seepages. The dolomites are very porous and are a possible reservoir for oil. They are overlain by 200 feet of Slave Point limestones which form a broad band on the south side of Great Slave Lake in the vicinity of the mouth of Buffalo River and on the north shore form bands both east and west of the Presqu'île dolomite exposed at Nintsi Point. They are the youngest Middle Devonian rocks in Great Slave Lake region.

The Upper Devonian of Great Slave Lake area consists of the Simpson shales 250 feet thick, the overlying Hay River shales 400 feet thick, and, youngest of all, the Hay River limestones 300 feet thick. All three formations outcrop in the vicinity of the west end of Great Slave Lake and on various streams and rivers tributary to it and to the upper part of Mackenzie River.

In the vicinity of Norman on Mackenzie River, the Devonian stratigraphy is quite different from that on Great Slave Lake. The oldest Devonian beds in the vicinity of the Ramparts of the Mackenzie and farther north are the Hare Indian River shales of Middle Devonian age (Kindle, 1921, page 45). These shales do not outcrop in the Norman area. They have been tentatively correlated with the Pine Point limestones, but may include representatives of the Horn River shales of Great Slave Lake area. They are overlain by the Ramparts and Beavertail limestones, having a combined thickness of 650 to 700 feet. The Ramparts limestone on account of the presence of *Stringocephalus burtini* is definitely correlated with the Presqu'île dolomite of Great Slave Lake and the Winnipegosan limestone of Lake Manitoba.

The Beavertail limestones in Norman area are overlain by the Upper Devonian Fort Creek shales at least 800 feet thick. The Fort Creek shales are probably about equivalent to the Simpson shales of Great Slave Lake although much thicker. They carry a Portage fauna. Near Norman certain very persistent, narrow dykes cut the Fort Creek shales. It was formerly thought (Hume, 1923, page 58) that they were of weathered igneous rocks, but microscopic examination subsequently proved them to be sandstone dykes. They are only a few inches wide and cut across the bedding of the shales. A sandstone dyke 10 feet wide cuts the Fort Creek shales on top of the " Rainbow arch " on Carcajou River about 50 miles from its junction with the Mackenzie. The Fort Creek shales are succeeded by the Bosworth formation consisting of 1,600 to 2,000 feet of sandstones and shales (Hume, 1923, page 58). This formation consists of alternating shales and sandstones which carry a *Spirifer disjunctus* fauna definitely correlating them with the Hay River shales and limestones of Great Slave Lake area. The sandstones are in part quite porous and along the east side of Mackenzie River north of Norman yield many oil seepages.

In North Nahanni-Root River area, 175 miles south of Norman, the upper Devonian is even thicker than in Norman area, particularly in that part of the section correlated with the Bosworth formation; and it is believed younger Upper Devonian strata are present. This may well be as the top of the Devonian is an erosional plane and in the Ramparts area of Mackenzie River, only 130 miles north of Norman, Cretaceous strata rest directly on Middle Devonian, whereas at Bluefish Creek 9 miles north of Norman, Eocene rocks rest directly on Upper Devonian (*See* G.S.C., Map 1977), indicating that there the Cretaceous has been removed by erosion in pre-Eocene time. The Devonian in certain places was, therefore, exposed not only to pre-Cretaceous but as well to Pre-Eocene erosion and consequently the thickness is quite variable even within a fairly restricted area.

The Devonian has a wide distribution in Mackenzie area and is known to occur east of Mackenzie Delta (*See* G.S.C., Map 1585). To the west of the delta it is concealed beneath younger rocks.

South of Athabaska River at McMurray and Peace River at Vermilion Chutes and between the Devonian outcrops in the east and the Rocky Mountains in the west, the Palæozoic strata are concealed by a thick cover of younger sediments and are known only from drilling (Moore, 1931). It is very difficult in well samples to differentiate the Devonian from the overlying Carboniferous or from the underlying strata as all are limestones. In the Commonwealth Milk River well on Sec. 9, Tp. 3, Range 15, W. 4th Mer., below limestones considered to be of Carboniferous age and above strata believed to be Cambrian there are 300 feet of black oil-shales underlain by dark grey and brownish limestones and shales with anhydrite. These beds are considered by Moore to be Devonian and he correlates them with strata penetrated by the Potlatch-Adams well about 30 miles south of the International Boundary in the Kevin-Sunburst field. In this well (Perry, Table 1, 1929), below what is assumed to be the base of the Carboniferous, 20 feet of oil-shale overlie 920 feet of anhydrite, dolomite, limestone, and shale. Fragments of rock blown from the well by gas flow showed Devonian fossils. In the Eyremore well on Sec. 26, Tp. 17, Range 18, W. 4th Mer., limestone believed to be Carboniferous is underlain by 40 feet of oil-shales resting on 20 feet of hard, dense, grey limestone, below which is 310 feet of pale grey anhydrite. Underlying the anhydrite beds are brownish limestones and shales with a second zone of anhydrite in the lower part. On lithological grounds this whole section is readily correlated with the Devonian of the Potlatch-Adams well in Montana.

In the Duvernay well on Sec. 34, Tp. 55, Range 12, W. 4th Mer., at a depth of 155 feet below the top of the Palæozoic limestones, there is a thickness of 30 feet of oil-shale, underlain by 20 feet of bituminous limestone, below which more oil-shale was encountered. Moore regards the oil-shale zone as marking the top of the Devonian, since it contains *Lingula spatula*, a Devonian species also found in the oil-shale zone of the Potlatch-

Adams well of Montana. In Ribstone area, in Ribstone No. 1 well, the top of the Palæozoic limestone was encountered at a depth of 2,062 feet. Cores taken from the well at a depth of 3,154 feet carried, according to determinations by E. M. Kindle, Devonian, probably Upper Devonian, fossils. In the same well a very poorly defined bituminous zone occurs at a depth of 2,460 feet or 400 feet below the top of the Palæozoic. It is possible that this bituminous zone is the top of the Devonian and if so the upper 400 feet are Carboniferous limestones.

In the McMurray-Athabaska region salt and anhydrite beds underlie limestones carrying Devonian fossils (Allan, 1921, pages 107-8). Since the available evidence points to the occurrence of anhydrite in the Devonian in other parts of Alberta it seems probable that the salt and anhydrite beds of McMurray area are also Devonian, although in more northerly areas salt and gypsum occur associated with Silurian beds. Anhydrite and salt beds are also known from wells in Saskatchewan. In Unity Valley No. 2 well on Sec. 14, Tp. 41, Range 24, W. 3rd Mer., salt in small amounts was encountered at a depth of 3,201 feet, with anhydrite-bearing beds between a depth of 2,928 and 3,124 feet in strata believed to be Devonian. In the Simpson well in Tp. 29, Range 12, W. 2nd Mer., a salt zone reported to be 12 feet thick was encountered at a depth of 3,420 feet. The upper part of the Palæozoic in this well is Devonian, but no definite information is available in regard to the salt horizon. In the Pike Lake well on Sec. 13, Tp. 34, Range 7, W. 3rd Mer., the top of the Palæozoic limestone was encountered at a depth of 2,315 feet and between 3,020 and 3,060 feet there occurred anhydrite-bearing beds. The top part of the Palæozoic limestone in this well is Devonian, but no data is available as to the exact age of the anhydrite beds although it is assumed they also are Devonian. This conclusion seems warranted in view of the widespread occurrence of anhydrite beds in Alberta, and also in Manitoba where according to McLean and Wallace (1914, page 168)

"gypsum occurs in an Upper Devonian horizon on the west side of Lake Manitoba. In Leifur district, and in a northwesterly direction from that district, thin beds are found near the surface. The gypsum found in the bore at Vermilion River was considered by Tyrrell to be of Devonian age . . . . . There are no indications of it in a fairly complete exposure of the Upper Devonian at Dawson Bay, but the gypsum obtained in the bores of Neepawa and Rathwell is probably from this horizon".

CARBONIFEROUS

The Devonian in certain regions was followed by the Mississippian and this in turn by the Pennsylvanian, two divisions collectively known as the Carboniferous. Marine strata of Mississippian and Pennsylvanian ages and mostly limestones occur in the eastern Rocky Mountains and are overlain by beds whose age has been interpreted as either Permian (Shimer, 1926, page 11) or late Pennsylvanian (Warren, 1927, page 34). Carboniferous limestones are known from outliers of the mountains within the foothills, such as Moose Mountain, south of Bow River, and Brazeau Range to the north, and have been encountered in many wells in Turner Valley and vicinity. They also underlie the southern part of Alberta where they have been encountered in many wells. In this area there seem to be two fairly well-marked lithological divisions, an upper zone of white limestones underlain by a zone of dark grey to brown limestones. In the Commonwealth Milk River well on Sec. 9, Tp. 3, Range 15, W. 4th Mer., the upper zone of white limestones was 820 feet thick, whereas the lower zone of darker limestones was 280 feet thick, giving a total thickness of 1,100 feet above the oil-shales, previously mentioned, which are considered to be the top of the Devonian. In the Eyremore well on Sec. 26, Tp. 17, Range 18, W. 4th Mer., the division between the upper white zone and the lower dark zone is even more clearly marked than in the Commonwealth well with 530 feet of the upper, and 220 feet of the lower, zone, or a total thickness of 750 feet. In a few wells, as for example Imperial-Burdett on Sec. 8, Tp. 11, Range 11, W. 4th Mer., Roth No. 1 well at Medicine Hat, and Drazan No. 1 well in Many Islands Lake area, Moore (1931, page 1145) has shown that the upper white crystalline zone is replaced by a red and pink limestone and chert phase which ranges in thickness from 250 feet in Imperial-Burdett well to 370 feet in Roth No. 1 well, and to 85 feet in Drazan No. 1 well. This variation in thickness of the upper zone is believed to be due to the fact that the top of the Palæozoic limestone is known to be an erosional unconformity. There is also, according to Moore, a prominent thinning of the lower, darker member resulting from a disconformity at the top of the Devonian.

The extent of the Carboniferous under the plains of Alberta is not definitely known. In the Duvernay well on Sec. 34, Tp. 55, Range 12, W. 4th Mer., the top of the Palæozoic was encountered at 2,075 feet. At 2,230 feet, or 155 feet below the top, there are 30 feet of oil-shales that Moore regards as the top of the Devonian. These 155 feet of limestones are, therefore, believed to be Carboniferous although no fossils to give an exact age determination were obtained from them. In Wainwright and Ribstone areas of eastern central Alberta it was formerly thought that the Devonian directly underlay Lower Cretaceous beds. This deduction was based mainly on the Athabaska River section at McMurray where no Carboniferous is present. This view, however, is no longer tenable since the Duvernay well in which Carboniferous strata occurs is north, although also slightly west, of Wainwright. In Imperial-Ribstone No. 1 well where the top of the Palæozoic was encountered at 2,062 feet there are 400 feet of limestones, below which is a poorly defined bituminous zone that may represent the top of the Devonian, since Devonian fossils were obtained from cores from this well at a depth of 3,154 feet. Thus it is quite possible there are 400 feet of Carboniferous limestones in this area. This thickness seems to be quite in harmony with the northward thinning of the Carboniferous, since, as already pointed out, the available information indicates that to the north in the Duvernay well there are but 155 feet of beds of this age and at McMurray on Athabaska River they are not present. The farthest east that the Carboniferous has been definitely recognized is in the Fuego well on Sec. 34, Tp. 25, Range 4, W. 4th Mer., where the top of the Palæozoic was encountered at a depth of 3,110 feet and yielded Carboniferous fossils.

The age of the top part of the Palæozoic, which is deeply buried by younger strata, is unknown in southern Saskatchewan. It is possible some Carboniferous may be present, although none occurs (Wickenden, 1932, pages 177-196) under the younger rocks in central and northern Saskatchewan nor is any known in Manitoba.

In Liard River area, east of the mountains, Carboniferous strata occur (Hume, 1923) and presumably, therefore, are present in a belt along the eastern edge of the mountains southward to the international border. So far as known, they do not occur anywhere in Mackenzie Basin.

TRIASSIC

The Mesozoic was a time of extensive deposition of shales and sandstones, many of which are of continental origin. This is in striking contrast with conditions in Palæozoic time when the strata that formed are mainly marine limestones and shales. Evidently at the end of the Palæozoic there was an uplift to the west which not only greatly restricted the inland seas but provided an elevated area, the erosion of which supplied the sediments that constitute the various formations of the Mesozoic period.

The Mesozoic began with the deposition of Triassic strata. In Banff area the Spray River formation, consisting of marine limestones, dolomites, and arenaceous shales, may have a thickness as great as 3,400 feet (Warren, 1927, pages 38-41) and is Lower Triassic in age. No Triassic rocks are known in the foothills south of Bow River, where so far as known Jurassic strata rest directly on Palæozoic limestones. It is probable, therefore, that such Triassic strata as may have been originally present over the western plains were completely removed by erosion. It is thought, however, that in Triassic time there was a sea extending southward from the Arctic, because Triassic sediments occur on upper Stewart River in the Yukon (Keele, 1910, page 39), in Liard River area (McConnell, 1890, page 49 D), and in the foothills on Peace River (McLearn, 1917, page 16; 1921, page 2; 1930, pages 1-5). In Peace River area, the Schooler Creek formation is believed to be Upper Triassic and consists of a lower member of grey, calcareous sandstones, arenaceous limestones, and calcareous shales 2,000 feet thick overlain by 400 to 500 feet of chocolate brown to purplish grey, calcareous sandstones and impure limestones. It is quite apparent, however, that this formation does not extend far eastward, since in the vicinity of Vermilion Chutes on the lower Peace River, Cretaceous strata rest directly on Devonian limestones. No Triassic strata are known east of the foothills of Peace River district and it is thought they are entirely absent from Mackenzie Basin. They occur in the foothills in Cadomin and Mountain Park areas (*See* G.S.C., Maps 208 A and 209 A) and probably, in places at least, between here and Banff area.

JURASSIC

Jurassic strata are present in the mountains and foothills and extend under a considerable part of the plains in southern Alberta and Saskatchewan. Jurassic strata were encountered in a deep well drilled at Moose Jaw (Dowling, 1919, page 44; Wickenden 1932, pages 182-184) where they have a thickness of 250 feet or more. It is probable, therefore, that Jurassic strata underlie the western part of southern Saskatchewan, but more doubtful if they occur in eastern Saskatchewan. Well sections in Manitoba, however, show a considerable thickness of shale above the Devonian Manitoban limestone and below the Cretaceous sandstones. Dowling (1919, page 37) considered part of these to be Jurassic, and Wickenden (1932, pages 179, 184) has definitely determined Jurassic fossils from the Commonwealth Manitou well in Tp. 2, Range 9, W. 1st Mer., and the Dauphin No. 1 well in Tp. 24, Range 20, W. 1st Mer. The Jurassic is believed to thin northward. It is not known in the Viking-Wainwright-Ribstone area. No Jurassic is present on the Athabaska at McMurray nor in Mackenzie River Basin.

The exact correlation of Jurassic strata in the foothills with those under the southern plains of Alberta has not been determined. The Jurassic in the foothills is known as the Fernie formation, whereas that under the plains has been called Ellis. McLearn (1927, pages 67-70) has pointed out that different faunas occur at " almost every locality." For example the Fernie at Blairmore is early Upper Jurassic; the part of the formation on the upper part of Sheep River, the age of which has been definitely determined, is early Middle Jurassic; the Fernie beds in Lake Minnewanka area are the very latest Lower Jurassic to early Middle, and also Upper, Jurassic; in Mountain Park area, the Fernie is lower Middle Jurassic; at Moose Mountain (Hume, 1932, page 44) late Lower, and lower Middle, Jurassic; and at Fernie, B.C., from which place the formation was named, mainly Upper Jurassic, but a Lower Jurassic fauna has recently been reported by Warren (1931, page 110). It is thought, however, that the strata at each locality have a long time range and that it is only by chance that different faunas have been preserved or found in different localities. This would seem to be the case in Kananaskis Valley (McLearn, 1930, page 2) and at Lake Minnewanka (Warren, 1929, page 26) where faunas ranging in age from latest Lower Jurassic or early Middle to Upper Jurassic have been found. The lithology and thickness of the Fernie, however, seem to be quite variable. In Blairmore area there are 900 to 1,000 feet of thin-bedded, calcareous sandstones with light and grey shales (McLearn, 1930, page 67). In Moose Mountain area south of Bow River there are about 220 feet of very black shales with thin limestone bands and brown, sandy shales (Hume, 1932, page 44). In Turner Valley area the thickness is somewhat in doubt due to the difficulty of separating the Fernie from the overlying Kootenay, but it is probably not more than 220 feet and the lithology is much the same as at Moose Mountain. In Mountain Park area the thickness is as much as 1,300 feet (MacKay, 1930), and the strata consist of black marine shales with thin beds of fine-grained, buff-weathering, quartzitic sandstone. To the north in Peace River area, the Pine River formation is considered by Spieker (1922, page 118) to be Jurassic. It consists of blue-black marine shales with a minimum thickness of 300 feet and the base not exposed.

In the foothills south of Bow River the Jurassic beds rest directly on Palæozoic limestones. The same is true in the eastern foothills along Brazeau Range, but 15 miles to the west in Bighorn Range the Jurassic rests on 550 feet of Triassic strata (Webb, 1931, page 342). This indicates for eastern localities in the foothills an erosional break of some magnitude between the Palæozoic and the Jurassic. To the east of the foothills, under the plains, the Jurassic thins and different horizons of the Palæozoic occur under the Mesozoic. It is not known whether the thinning of the Jurassic eastward is due to non-deposition or to an erosional interval of later Jurassic or early Cretaceous time.

LOWER CRETACEOUS

The Cretaceous is a thick series of non-marine and marine strata widely distributed over the plains and foothills and occurring in various places within the Mackenzie lowland. In western Canada, in Jurassic or early Cretaceous time, the area west of the present Rocky Mountains was uplifted (Schofield and Hanson, 1922, page 29) and over the area of the present eastern mountains and foothills non-marine sediments with extensive coal seams were deposited. These beds constitute the Kootenay formation. It consists of coarser materials in the west than in the east and the coal becomes less important and the formation thinner to the east. Within the foothills the thickness of the Kootenay and the number of coal seams it contains are quite variable.

The Blairmore overlies the Kootenay and is also non-marine. In the western foothills the basal Blairmore is a heavy conglomerate with interbeds of sandstones 70 feet thick. This basal phase thins rapidly eastwards and disappears within the foothills. Where it is lacking the division between Kootenay and Blairmore is difficult to determine and farther east in the region of the plains it is more convenient to refer to the equivalents of the Blairmore and Kootenay as Lower Cretaceous. In Turner Valley, as indicated by wells, a coal seam lies 625 to 650 feet below the top of the Blairmore. For a time this coal seam was regarded as being the top of the Kootenay. The base of the formation was arbitrarily drawn at the top of the Home sand 275 to 300 feet stratigraphically lower than the coal seam. It was soon discovered, however, that there are Lower Cretaceous strata below the Home sand and, therefore, the bottom of the Kootenay was later drawn (Hume, 1930, pages 4-5) at the top of the Dalhousie sand about 250 feet stratigraphically below the Home sand. Still later work led to a revision of these opinions and a section prepared by J. B. Webb of the Hudson Bay Oil and Gas Company is now considered to afford the most logical interpretation. This interpretation places the top of the Blairmore below a grit zone (Hume, 1927, pages 4-5) in the overlying Alberta shale and places the base 1,200 feet below at the bottom of the Dalhousie sand where a conglomeratic zone that is correlated with the basal Blairmore conglomerate of western foothills sections occurs. Below the Dalhousie sand, coal has been encountered in a number of wells, and below this a "brown sand." The coal-bearing beds are considered to be Kootenay. In a few wells they are as much as 100 feet thick, in other wells, however, they are absent. The top of the "brown sand" is considered to be the top of the Fernie. In former interpretations, the Dalhousie sand was thought to be in the Fernie, but according to present ideas the Fernie is restricted to about 200 feet of strata from the top of the "brown sand" to the Palæozoic limestone.

If the interpretation of the Turner Valley section, which restricts the Kootenay to a thickness of 100 feet or less, is correct, the Kootenay in the foothills shows a very rapid thinning eastwards and, therefore, is unlikely to extend far under the plains. In the Wabash well on the Stoney Indian Reserve south of Bow River, the Kootenay is stated by Evans (1930, page 30) to have a drilling thickness of 599 feet. It is likely that the stratigraphic thickness is about the same as on Canyon Creek, Moose Mountain, namely, 350 feet. To the north, in Mountain Park area, according to MacKay (1930, Fig. 4), the Mountain Park formation 400 feet thick, the Luscar formation 1,700 feet thick, and the Cadomin conglomerate 35 feet thick, represent the equivalents of the Blairmore of southern Alberta. The Cadomin conglomerate is the thick conglomerate zone at the base of the Blairmore in the western foothills south of Bow River. Below the Cadomin conglomerate of Mountain Park area is the Nikanassin formation, 1,900 feet thick, occupying the stratigraphic position of the Kootenay elsewhere. In Crowsnest area, southern Alberta, the Kootenay contains a great thickness of workable coal seams, whereas in Mountain Park area the Luscar formation, probably of Blairmore age, is the important coal-bearing member. Thin coal seams occur in the Blairmore south of Bow River and coal occurs in both the Blairmore and Kootenay north of Bow River (Evans, 1930, pages 3-33). The lower part of the Blairmore contains calcareous shales and arenaceous limestones in Turner Valley and adjoining areas, and these carry a fauna of gastropods and lamellibranchs. On Elbow River, near Moose Mountain, these strata are 200 to 300 feet thick. Similar occurrences are reported by Evans (1930, page 33) from Ram River in Tp. 38, Range 12, W. 5th Mer. Locally the Blairmore in the foothills carries conglomerate beds. In most cases the pebbles are small, but in some cases cobbles are 4 to 5 inches in diameter. A very large lens of conglomerate occurs in the Blairmore in Highwood area in Sec. 34, Tp. 18, Range 3, W. 5th Mer. Other lenses containing abundant igneous pebbles occur in Sec. 6, Tp. 22, Range 4, and in Sec. 32, Tp. 21, Range 4. The stratigraphic position of these conglomerates carrying igneous pebbles is apparently high up in the Blairmore formation. In Blairmore area Rose (1917, page 110) noted igneous pebbles in a rather persistent conglomerate about 1,250 to 1,500 feet above the base of the Blairmore formation and stated they were absent from the basal conglomerate of the same formation.

In Crowsnest area the Crowsnest volcanics, 1,150 feet thick (Leach, 1913, page 23), overlie Blairmore strata. In Turner Valley area a fine conglomeratic zone with coarse, quartz-sand beds from 1 to 40 feet thick occurs closely associated with the base of the marine beds that directly overlie the Blairmore. This horizon is known as the "grit" zone and is usually considered to mark the division between the Lower and Upper Cretaceous. It belongs with the upper marine beds rather than with the underlying Blairmore. In the area west of Turner Valley, the "grit" contains a few, rounded, waterworn pebbles and it is thought that the material was derived from the Crowsnest volcanics. The "grit" has been seen by the writer in the foothills north of Bow River and a conglomerate with cobbles of chert and quartzites as much as 6 inches in diameter is known (Evans, 1930, page 33) to occur on Ram River at the top of the Blairmore. A similar conglomerate occurs on the south fork of Burnt Timber Creek, whereas at other places the contact between the Blairmore and Alberta shales is marked by a bed of bentonite 6 inches to 1 foot thick.

Non-marine beds are widely distributed under the plains, and although in the western plains, and in Athabaska (McMurray) and Peace River areas these are Lower Cretaceous it is not by any means certain that they are of this age in other areas. Basal sandstones of Cretaceous age occur along the eastern edge of the Manitoba escarpment which is an abrupt descent to the Manitoba lowland of Palæozoic rocks. They are also known (McInnes, 1913, page 65) from Lake Wapawekka region, Saskatchewan. The basal sandstones in Manitoba and Saskatchewan are, according to Kirk (1930, page 115), of Upper Cretaceous age. The fossils found in these beds are not diagnostic Upper Cretaceous forms, but there does not seem to be a break between these beds and the overlying Upper Cretaceous beds. The situation in the east, in Manitoba, is quite in contrast with that in Athabaska River (McMurray) area where, as stated by McLearn (1917, page 146), the basal, non-marine McMurray formation ("tar sands") 110 to 180 thick, the overlying Clearwater marine shales 275 feet thick, the Grand Rapids sandstone mostly non-marine and 280 feet thick, and the marine Pelican shale 90 feet thick, are all Lower Cretaceous. If the basal beds in Manitoba and Lake Wapawekka region are Upper Cretaceous, they occupy the stratigraphic position of the Pelican sandstone of McMurray area, which is marine at the top and bottom but has a middle non-marine member, the whole being 35 feet thick.

In wells drilled south of McMurray and as far east as Pike Lake in Tp. 34, Range 7, W. 3rd Mer., in Saskatchewan, the basal beds of the Cretaceous are sands and shales with coal, and because of the number of wells and their positions so much closer to McMurray area than to Manitoba, there seems little doubt that these basal beds are also Lower Cretaceous. A little coal occurs in the Grand Rapids and McMurray formations of the Athabaska section and its presence in the wells suggests, but is not proof, that the coal-bearing strata in the wells and along the Athabaska are of like age. In Wainwright and Ribstone areas, samples obtained in wells from the base of the marine shales regarded as being Upper Cretaceous in many cases show chert pebbles or fragments of conglomerate. The strata below are non-marine, coal-bearing beds considered to be Lower Cretaceous. Shales interstratified with the coal-bearing beds may be marine as in McMurray area. It seems certain that Lower Cretaceous seas existed in the north and east during the deposition of non-marine beds in the west. Wickenden (1932, page 196) has shown that marine Lower Cretaceous occurs in southernmost Saskatchewan and marine Lower Cretaceous is believed to be present in wells drilled in the eastern part of southern Alberta.

In eastern Peace River area the Lower Cretaceous, marine, Loon River shales, 1,100 feet thick, rest on the Palæozoic limestones. Some oil has been found in Peace River area in arenaceous shales near the base of the Loon River formation. The stratigraphic position of these beds suggests a correlation with the McMurray formation. The Loon River shales are regarded as approximate equivalents of the Clearwater shales because, as stated by McLearn (1930, page 6), a fauna found in the uppermost Loon River shales close to the contact with the overlying Peace River sandstones is similar to a fauna in the Clearwater formation. The Loon

River shales are overlain by the Peace River sandstone which in Peace River area consists of a lower sandstone with a maximum thickness of 160 feet, a middle shale with a thickness of 30 feet, and an upper sandstone with a maximum thickness of 130 feet. The upper sandstone in the southerly part of Peace River area is massive, crossbedded, and carries a discontinuous lignite seam. The thickness of this member becomes less to the north and the upper part is replaced by bedded sandstone and shale of marine origin. The Peace River sandstone is probably about the equivalent of the Grand Rapids formation of Athabaska River area. It is overlain by the St. John formation now considered to be mostly Lower Cretaceous. In the western Peace River area the Lower Cretaceous begins with the Bullhead Mountain formation which has a maximum thickness of 4,400 feet of beds mostly of non-marine origin. The age of the lower part is not definitely known, but may be Kootenay since the upper or Gething member with extensive coal seams carries a Lower Blairmore flora. The Gething member may be a non-marine phase of the eastern Loon River marine shales, but this correlation is only tentative as the age of the overlying Moosebar is not definitely known. The Moosebar formation (McLearn, 1923, page 5) is partly marine and consists of at least 800 feet of shales. It is overlain by 50 to 80 feet of the Gates sandstone which in turn is overlain by the Fort St. John marine shales, 1,400 to 2,200 feet thick. The lower part of the Fort St. John shales and the upper sandstone of the Peace River formation carry faunas similar to those found in the top of the Grand Rapids sandstone.

A summary of the information regarding the Lower Cretaceous stratigraphy of the plains and foothills is given in the following table derived from McLearn (1931, page 6, 1932, page 168).

<table>
<tr><th colspan="2">Athabaska River</th><th colspan="2">Lower Peace River</th><th colspan="2">Peace River Canyon</th><th>Mountain Park</th><th>Blairmore</th></tr>
<tr><td rowspan="12">Lower Cretaceous</td><td>Pelican shale, 90 feet, marine</td><td colspan="2">Fort St. John shale, 1,100 feet, marine</td><td colspan="2">Fort St. John shale, 1,400 to 2,200 feet, marine</td><td rowspan="3">Mountain Park sandstone, 400 feet, non-marine</td><td rowspan="10">Blairmore sandstone and shale, 1,850 feet, non-marine</td></tr>
<tr><td rowspan="4">Grand Rapids sandstone, 280 feet, mostly non-marine</td><td rowspan="4">Peace River</td><td>Upper sandstone, 130 feet</td><td colspan="2">Gates sandstone, 50-80 feet</td></tr>
<tr><td rowspan="2">Shale member, 30 feet</td><td colspan="2" rowspan="4">Moosebar shale, 800 feet, partly marine</td></tr>
<tr><td rowspan="4">Luscar sandstone and shale, 1,700 feet, non-marine</td></tr>
<tr><td>Lower sandstone, 160 feet</td></tr>
<tr><td rowspan="3">Clearwater shale, 275 feet, marine</td><td colspan="2" rowspan="4">Loon River shale, 1,100 feet, marine</td></tr>
<tr><td rowspan="6">Bullhead Mountain</td><td>Gething member, 1,400 feet, non-marine</td></tr>
<tr><td rowspan="5">Lower member, 3,000 feet, non-marine</td><td rowspan="2">Cadomin conglomerate, 35 feet</td></tr>
<tr><td rowspan="3">McMurray, 110-180 feet, non-marine</td></tr>
<tr><td colspan="2" rowspan="3"></td></tr>
<tr><td rowspan="2">Nikanassin, 1,900 feet, non-marine</td><td rowspan="2">Kootenay, 700 feet, non-marine</td></tr>
<tr><td></td></tr>
</table>

UPPER CRETACEOUS

The Upper Cretaceous in the foothills and plains consists of widespread marine and non-marine beds. In the southern foothills marine shales of Colorado age overlie the Crowsnest volcanics, or, where these disappear to the north, the Blairmore formation. In the area between Highwood and Bow Rivers the base of the marine Colorado shales is marked by a fine-grained conglomerate, the "grit" zone, from 6 inches to 40 feet thick and very persistent. The materials of this zone may be reworked material from the Crowsnest volcanics, but the zone is a part of the marine shales as in a few areas, at least, it is underlain by thin bands of marine shales resting on typical Blairmore strata. The Colorado shales in the foothills pass without break upwards into marine Montana shales and the whole shale series was formerly called "Benton". The name "Benton", however, is not applicable and in 1929 a new name, Alberta shale, was proposed (Hume, 1930, page 6). The Alberta shale in the area south and immediately north of Bow River is divided into a lower and an upper part by bands of conglomerate and sandstone to which the name Cardium has been given (Cairnes, 1914, page 27). In many areas in the central and western parts of the foothills of this district, the Cardium sandstones form three bands separated by shales carrying upper Alberta fossils, whereas in eastern foothills sections these bands thin and tend to disappear. In Turner Valley there is only one well-marked sandstone band. This is thought to be the middle band of western sections and about 100 feet stratigraphically below it is a thin, pebbly band that probably represents the lower Cardium band of western sections. The name Lower Alberta shale should properly be confined to the beds below the lowest Cardium sandstone band as Upper Alberta fossils are found above it. However, where, as in Turner Valley, the lower band cannot be used as a mapping unit it has been customary to include in the Lower Alberta all shales below the middle Cardium band. In mapping western foothills areas it is not everywhere possible to determine to which band a Cardium outcrop belongs and, therefore, in such places the boundary between the Lower and Upper Alberta shales may be incorrectly placed. To the east in the plains area the Cardium horizon is not recognizable and hence the name Alberta shale is applied to the whole group. In the foothills area, in the vicinity of Turner Valley, the Lower Alberta shales are about 850 feet thick and the Upper Alberta, including 350 feet of the Cardium zone at the base, about 1,950 feet. In southern Alberta, in Red Coulée area, the total thickness of the Alberta shale is probably not more than 1,750 feet. In Bighorn Basin, north of North Saskatchewan River, the Cardium zone becomes a sandstone formation 390 feet thick and is known as the Bighorn formation (Malloch, 1911, page 36). Below it are shales grouped under the name Blackstone formation, which are probably the equivalents of the Lower Alberta shales of southern foothills areas. Shales above the Bighorn sandstone are called the Wapiabi formation. They represent the Upper Alberta shales and are 1,300 to 1,800 feet thick. The names Blackstone, Bighorn, and Wapiabi have been used by MacKay (1930, page 475) in describing the stratigraphy of Mountain Park area where the Blackstone is considered to be 1,700 feet, the Bighorn 350 feet, and the Wapiabi 1,700 feet, thick.

In the southern plains of Alberta the upper part of the Alberta shales carries large *Baculites ovatus* indicative of a Montana age. These shales are overlain by the non-marine Milk River formation mainly consisting of sandstones with some carbonaceous shales. The Milk River formation is overlain by marine Pakowki shales which thin from east to west and as a distinct marine horizon probably disappear on the east side of the Alberta syncline, so that in the southern foothills the Alberta shales are overlain by a series of non-marine beds, 3,000 feet thick, the Allison (Belly River) formation, that probably represent not only the Pakowki but the underlying Milk River and also horizons above the Pakowki. North and east of southern Alberta the Milk River formation disappears and is replaced by marine shales similar to the Pakowki. In these northern and eastern areas the division between the Alberta shales and the overlying shales that thus occupy the positions of the Milk River and Pakowki, is rather indefinite. However, a peculiar, speckled shale consisting of white or yellowish flakes of carbonate of lime in a dark shale matrix and carrying shell fragments and columnar calcite occurs in the Alberta shales slightly below the base of the Milk River sandstone in southern Alberta. Apparently the same speckled shale occurs to the north and east where the Milk River is absent, and since to the south and west it lies very close to the top of the Alberta shale, it is considered to be the upper contact of the Alberta shales.

The Alberta shales are probably the approximate equivalent of the LaBiche shale of McMurray area in the north. The lower part of the LaBiche shale contains the well known Colorado fossil, *Prionotropis,* characteristic of the Lower Alberta shale of foothills sections; and the upper part contains the *Inoceramus lundbreckensis* fauna of Montana age also known from the upper part of the Upper Alberta shale of southern foothills areas.

All available evidence indicates that the Alberta shales, partly Colorado and partly Montana in age, extend from the foothills east beneath the plains region of Alberta and at least western Saskatchewan. The Alberta shale decreases in thickness from west to east from at least 2,500 feet in the foothills to approximately 1,700 feet in southern Alberta, and 525 feet in Wainwright, and 650 feet in Ribstone, areas. In the latter areas it is overlain by the Lea Park formation of Montana age from which it is separated by the speckled shale zone mentioned above. The Lea Park has been correlated with the Pakowki formation of southern Alberta, but there are reasons for believing (Wickenden, 1932, page 193) that the shales equivalent to the Milk River and Pakowki in the east are the equivalents of the Lea Park, Ribstone Creek, and Grizzly Bear formations which overlie the Lea Park in eastern central Alberta. The writer believes that the Birch Lake formation of the north is probably represented at the base of the Foremost beds in the south. The Lea Park formation thickens between Ribstone and Viking from 410 feet in the east to 650 feet in the west and the non-marine Ribstone Creek formation also seems to thicken towards the west. It is probable, however, that the Grizzly Bear, which is a marine shale series, thins from east to west, but information on the combined thickness of all three formations is not very definite throughout any extensive area.

In Peace River area the Upper Cretaceous began with the deposition of the Dunvegan sandstone, which along Peace River is about 530 feet thick (McLearn, 1918, page 18). It may thicken considerably southward as 50 miles south of Peace River a thickness (Spieker, 1922, page 116) of 2,000 feet is reported for the Dunvegan and an overlying sandstone member called the Sukunka formation. The Sukunka may be part of the Dunvegan or a westward phase of the Smoky River shales which overlie the Dunvegan in eastern sections. The exact equivalents of the Dunvegan sandstones in the southern and Central Plains areas of Alberta are not known, although there are sandy members at the base of the Alberta shales that yield gas at Viking, Bow Island, Foremost, etc. The Dunvegan sandstone, according to McLearn (McLearn and Hume, 1927, page 245) " is evidently a marginal delta or alluvial plain built out into an early Upper Cretaceous sea and submerged at times. It did not extend south to Mountain Park area, but may have extended eastward to the lower Athabaska River where the Pelican sandstone may be an eastward extension of it." The Pelican sandstone is the basal member of the Upper Cretaceous in McMurray (Athabaska) area and is overlain by the LaBiche shales previously mentioned.

The Smoky River formation which was laid down on the Dunvegan sandstone in eastern Peace River area is partly Colorado and partly Montana in age. It is 300 feet thick and consists of three members. The lower member, the Kaskapau shale, contains in the lower part the Prionotropis or Carlisle fauna and in the upper part the *Scaphites ventricosus* or Niobrara fauna with which occurs *Baculites* cf. *ovatus* of Montana age, indicating that the stratigraphic range is about the same as that of the Alberta shale of the southern foothills where the Lower Alberta shale, as already indicated, contains the Prionotropis fauna and the Upper Alberta shale the *Scaphites ventricosus* and *Baculites ovatus* faunas. In the western part of Peace River area the Smoky River formation is 800 feet thick and, like the eastern sections, contains a median sandstone member. The Smoky River formation is equivalent to the LaBiche shales of Athabaska area. In Smoky River area, Peace River region, the Wapiti, a non-marine formation with a thickness of at least 900 feet and the top not exposed, overlies the Smoky River formation. It contains several coal seams and so far as known is of Montana age. It probably represents some part of the Belly River formation, which in the foothills of southern Alberta overlies the Alberta shales.

Overlying the Pakowki shales in the southern plains of Alberta is a non-marine series consisting of the Foremost and overlying Pale Beds. These have been designated Belly River by Williams and Dyer (1930, page 16) although an older usage included the Pakowki and Milk River formations. The Belly River as defined by Williams and Dyer is equivalent to the Judith River of Montana. In eastern central Alberta the equivalents of the Foremost and Pale beds are Birch Lake and the

Pale and Variegated formations. The Pale and Variegated beds are non-marine, but the Birch Lake is partly marine in the type section at Birch Lake (Warren, 1926, page 9). The Belly River as thus used is a lithologic rather than a time term since all the non-marine beds that constitute the Belly River pass eastward into marine beds in Saskatchewan. The Allison of the foothills probably includes some beds younger than the Pale Beds and strata equivalent to the Pale, Foremost, Pakowki, and Milk River formations combined, since as already stated the marine Pakowki thins and disappears westwards.

In southern Alberta, as at Lethbridge (Link and Childerhose, 1931, page 1230), the top of the Belly River formation is marked by a series of coal-bearing beds. This coal series persists throughout the southern foothills and forms a fairly definite horizon marker. In the southern foothills the coal series is overlain by marine shales of the Bearpaw formation and these are recognizable as far north as Highwood River where they are highly arenaceous. North of this, however, the Bearpaw cannot be recognized and the coal series at the top of the Belly River is arbitrarily considered to mark the division between the Belly River and the overlying, non-marine Edmonton strata. Farther north at Bow River and northwards in the eastern foothills, there is no sharp division between the Belly River and Edmonton beds since both are non-marine, but poorly defined coal seams occur at about the same stratigraphic position as the coal series at the top of the Belly River in southern areas and hence a rough division can still be made between the two formations. It is probable that the Edmonton in the eastern foothills consists of several thousand feet of non-marine strata; and on Red Deer River the combined thickness of the Edmonton and Belly River is thought by Evans (1930, page 31), to be more than 8,700 feet. To the north in the foothills, in Saunders Creek area, the non-marine formations are locally grouped by Allan and Rutherford (1923, page 51) under the name Saunders formation with a thickness of 11,000 to 14,000 feet. According to Russell (1932, page 142) the Saunders formation, however, probably includes some non-marine Tertiary beds which in central Alberta are called Paskapoo and directly overlie the Edmonton formation. In Bighorn Basin the non-marine Montana beds have been named the Brazeau formation (Malloch, 1911, page 37). This is thought by Allan and Rutherford (1923, page 51) to be the equivalent of the lower part of the Saunders formation of Saunders Creek and Nordegg area where the lower part is separated from the upper by the Saunders coal series. In Bighorn Basin the top of the Brazeau has been removed by erosion, the part remaining is 1,700 feet thick (Malloch, 1911, page 39).

On the plains of Alberta the Belly River non-marine beds are overlain by the marine Bearpaw formation. In the east, in Saskatchewan, where the Belly River thins and disappears, the Bearpaw marine shales directly overlie other marine Montana shales. The Bearpaw sea extended into the area of the southern foothills, and shales of this age are definitely recognizable as far north as Highwood River and probably occur on the east flank of Turner Valley. North of this, however, strata of Bearpaw age are not recognizable and the shore-line of the Bearpaw sea seems to have crossed central Alberta south of North Saskatchewan River in the western part, but probably somewhat farther north in the eastern part where, however, all sediments of this age have been removed by erosion.

In southern Alberta, along the eastern edge of the Alberta syncline, the Bearpaw formation is overlain by a relatively thin sandstone formerly called Fox Hills. Russell (1932, page 130) has shown that this sandstone is older than the Fox Hills and is to be correlated with the Horsethief formation of northwestern Montana. He has called it the Blood Reserve sandstone and shown that it thins and disappears northward. In southwestern Alberta the Blood Reserve sandstone is overlain by the St. Mary River formation of non-marine beds, and in central Alberta where the Blood Reserve sandstone is absent the Bearpaw shales are overlain by the Edmonton formation. The St. Mary River formation in the foothills of southern Alberta may be 3,000 feet thick, although it is thought by Williams and Dyer (1930, page 54) to be only 1,600 feet on St. Mary River. In Drumheller district the Edmonton is about 1,225 feet thick (Allan, 1925, page 239). According to Russell (1932, page 132) the St. Mary River formation may be approximately correlated with the Edmonton into which it grades on Little Bow River.

In Cypress Hills area, according to Williams and Dyer (1930, page 41), Bearpaw shales are overlain by the following succession of beds: 130 feet of brown sandstones, 110 feet of dark grey shales with Bearpaw fossils, 50 feet of white, silty sandstone, a thin coal seam, and 80 feet of grey, silty shale. These are the so-called Fox Hills beds of this area and they are overlain by 285 feet of sandstones and shales with lignite, that by Williams and Dyer were grouped as the Estevan formation. Above them are white, refractory clays of the Whitemud formation. McLearn (1929, page 41) has shown that at Twelvemile Lake in Saskatchewan, the so-called Estevan beds do not underlie the Whitemud beds but overlie them and should, therefore, be included in what has been termed the Ravenscrag formation. The name Estevan is, therefore, no longer tenable and the name Eastend has been adopted (Russell, 1932, page 132) in its place to designate the strata which in Saskatchewan lie between the Bearpaw and Whitemud formations. It has also been found that the name Fox Hills should not be used because it refers to marine beds, whereas the so-called Fox Hills of Cypress Hills are non-marine. Russell (1932, page 133) is of the opinion that the lower, brown sandstone of the so-called Fox Hills passes eastward into shale similar to the shale overlying the sandstone in Cypress Hills area. This overlying shale carries Bearpaw fossils and according to Russell represents the top of this formation. The sandstones, shales, and coal beds overlying the Bearpaw and underlying the Whitemud formation thus become the Eastend formation and the section in Cypress Hills formerly described as Bearpaw, Fox Hills, Estevan, and Whitemud formations now becomes Bearpaw, Eastend, and Whitemud formations. The upper part of the Bearpaw of this section, however, is younger than the youngest Bearpaw of the more westerly part of Alberta.

The Eastend beds of Cypress Hills area, as already stated, are overlain by the Whitemud formation, a thin group of refractory clays and sandy clays. A series of beds similar to the Whitemud formation has been noted by Sanderson in Horseshoe Coulée west of Drumheller in the upper part of the Edmonton formation and has been correlated with the Whitemud beds by Russell (1932, page 127). In southern Saskatchewan there are at least two Whitemud beds (McLearn, 1929, page 35), but the lower is that now known as the Whitemud formation. It rests on the Bearpaw but in places was partly or wholly removed during an erosion interval that preceded the deposition of the overlying Ravenscrag formation of non-marine beds with coal. The upper horizon of the refractory clays, etc., at one time confused with the beds of the Whitemud formation, constitutes what McLearn (1930, page 58) has called the Willowbunch member of the Ravenscrag formation which ranges in age from late Cretaceous (Lance) to Paleocene (early Tertiary). The Willowbunch member occurs more than 400 feet above the base of the Ravenscrag formation and coal seams occur both below and above it. On account of the preceding erosion interval the Ravenscrag formation in places in southern Saskatchewan rests on the lower, non-marine sandstones of the Eastend formation or even on the Bearpaw formation, whereas in other places it rests on the Whitemud formation.

In central Alberta an erosional unconformity has been noted by Allan (1925, page 240) between the Edmonton formation and the overlying Paskapoo of Eocene age and according to Sanderson this hiatus amounts to as much as 450 feet. According to Williams and Dyer (1930, page 46) the Edmonton formation is pre-Lance in age and the Paskapoo as shown by its mammal content is younger than Fort Union. Hence the erosional unconformity represents at least Lance time and according to Russell (1932, page 138) the lower and middle Paleocene as well.

The Upper Cretaceous of Manitoba has a basal sandstone 19 to 90 feet thick, which on account of its stratigraphic position has been referred to the Dakota. The age, however, has not been definitely established. Sandstones occur at the base of the Cretaceous which outcrops close to the southern edge of the Canadian Shield in Saskatchewan. The age of these sandstones is also uncertain because of the fact that sandstones occur in the McMurray area of Alberta at both the base of the Upper Cretaceous (Pelican sandstone) and at the base of the Lower Cretaceous (McMurray formation) and hence in the absence of fossils no lithological correlation is possible. Above the basal sandstones in Manitoba are marine shales and thin-bedded limestones 1,000 to 1,100 feet thick. These marine beds are the depositional products of a sea that apparently continued through Upper Cretaceous time in the east, but which gave way in western Saskatchewan and Alberta to periods of non-marine deposition such as resulted in the Belly River and other non-marine series of beds. It is known that the upper part of the Bearpaw of Alberta is younger in the east than in the west due to the persistence of the sea in the east when it had disappeared in the west, but it is not known whether the youngest marine Upper Cretaceous beds of Manitoba are the time equivalents of the youngest non-marine Upper Cretaceous beds of Alberta. It is thought by Kirk (1930, page 127), however, that the youngest marine horizon of the Upper Cretaceous of Manitoba thins and disappears westward, as would be expected from the gradual eastward recession of the late Upper Cretaceous sea.

Cretaceous rocks occur in Mackenzie River Basin, but there is little information regarding their exact age. In the vicinity of Norman Cretaceous rocks are known on the Redstone, Dahadinni (Hume, 1924, Map 2022), Keele (Gravel) (Keele, 1910, page 40), Little Bear, and Carcajou Rivers (Hume, 1923, Map 1977) and are exposed in various localities along Mackenzie River. On Little Bear River, the lower part of the Cretaceous consists of sandstone and shales overlain by several hundred feet of dark shales which on account of the presence of Scaphites are considered to be Upper Cretaceous. About 120 miles below the Ramparts of the Mackenzie is another area of Cretaceous strata, which extends down the Mackenzie to the head of the delta and westward across the mountains, including Peel River Plateau (McConnell, 1890, page 21 D; G.S.C., Map No. 1585, 1921).

Farther south in the area of Nelson and Liard Rivers, Cretaceous strata have been reported by McConnell (1890, page 19 D) and by Williams (1923, pages 67-69). The sediments along Nelson River consist of 100 feet of crossbedded sandstones and grits overlain by 650 feet of marine shales tentatively correlated with the St. John, and these in turn overlain by 500 feet of sandstones with thin coal seams possibly equivalent to the Dunvegan sandstone of Peace River area.

TERTIARY

In the description of the Upper Cretaceous strata reference has already been made to the Tertiary sedimentation which followed the deposition of the youngest Cretaceous rocks. As shown by McLearn (1930, page 55) there seems to have been continuous deposition from Cretaceous into Tertiary time in southern Saskatchewan, as the lower part of the Ravenscrag formation carries Lance dinosaurs whereas the upper part is thought to be Paleocene. In central and northern Alberta the late Cretaceous Edmonton formation is overlain by the Eocene Paskapoo. The Paskapoo formation is correlated with the Fort Union and the Upper Paleocene (Russell, 1932, page 138), whereas the Edmonton is pre-Lance in age (Williams and Dyer, 1930, page 46). In the vicinity of Red Deer River, it has been shown by Sanderson that a thickness of 450 feet of the Edmonton was removed during the erosional interval separating the two formations. In the foothills south of Bow River conglomerates and conglomeratic sandstones have been noted (Hume, 1927, page 7) at the base of what is considered to be Paskapoo and farther north similar conglomeratic beds are present both in the Paskapoo and at the base of massive sandstones that are lithologically similar to the Paskapoo and quite unlike the underlying Edmonton strata. Some doubt has been thrown on the value of these lithological distinctions as indicators of the position of the Paskapoo-Edmonton boundary, by the finding by Rutherford (1927, page 41) of a dinosaur tooth in beds that on lithology would be assigned to the Paskapoo.

In the southwestern plains of Alberta, the approximate equivalent of the Edmonton, the St. Mary River formation, is overlain by the Willow Creek formation and this in turn by the Porcupine Hills formation. From Oldman River southward the Willow Creek formation according to Russell (1932, page 138) "... contains brilliant colour bands; brick red, orange, buff, maroon, and slate blue are common tints." These are believed to be due to surface weathering and are absent in the more northerly development of the same formation. The Willow Creek formation consists of soft, argillaceous sandstones rather coarsely bedded. Russell (1932, page 140) correlates the Willow Creek with the lower 700 feet of the Paskapoo, although on Oldman River the Willow Creek is about 1,200 feet thick. The absence of an unconformity at the base of the Willow Creek where it rests on St. Mary River, suggests that the lower part of the Willow Creek may represent the gap that exists between the Paskapoo and Edmonton and may be Lower and Middle Paleocene. The Porcupine Hills formation, which overlies the Willow Creek, consists of massive to well-stratified sandstones. The contact between the two series is gradational. The Porcupine Hills formation may be as much as 2,000 feet thick and is correlated with the upper part of the Paskapoo, that is Upper Paleocene.

In southern Saskatchewan, as already indicated, the non-marine beds of the Ravenscrag formation range in age from Lance to Paleocene. Higher Tertiary beds are believed to occur in Turtle Mountain, southern Manitoba. In Cypress Hills area (Williams and Dyer, 1930, page 69) conglomerates, sandstones, silts, and marls constitute the Cypress Hills formation, of Lower Oligocene age. The Cypress Hills formation unconformably overlies strata from Upper Bearpaw to Ravenscrag and comprises the youngest strata definitely determined in the western plains of Canada. In Hand Hills, near Red Deer Valley, Alberta, similar conglomerates, marls, and sands occur (Tyrrell, 1887, page 77 E) and are thought to be of about the same age as those in Cypress Hills. In certain places on the summit of Swan Hills, south of Lesser Slave Lake, there are unconsolidated gravels of pre-Glacial age and it has been suggested by Allan (1919, page 12) that these may be the equivalents of the Cypress and Hand Hills conglomerates. Similar conglomerates have been found (*See* G.S.C., Map 277 A) in the foothills south of Bow River near Cochrane, but in this case the conglomerates are cemented by a calcareous matrix. No fossils have been found in them. They cap a flat-topped hill at an elevation of 4,350 feet and unconformably overlie Edmonton and Belly River strata. Late Eocene conglomerates and sandstones carrying mammalian remains have been found (Russell, 1932) near Swift Current, Alberta. They rest unconformably on Cretaceous strata. Still younger gravels of Miocene age occur (Sternberg, 1930, page 29) in Wood Mountain area, Saskatchewan. They range from a few feet to 50 feet in thickness and rest unconformably on cream or buff beds of the upper part of the Ravenscrag formation.

Tertiary beds believed by Bell (1922, page 76) to be Eocene have been found in Mackenzie River Valley. They consist mostly of loosely consolidated clays and sands with some thin lignite seams. The burning coal seam found by Mackenzie, when he made the discovery of the river that carries his name, occurs a few miles from Norman and is in Eocene strata. The Tertiary in this area unconformably overlies Cretaceous and Devonian and is found mostly in small, isolated basins. A small area of Tertiary is also known (Camsell, 1906, page 41 CC) on Peel River in the vicinity of Wind and Bonnet Plume Rivers. The strata are sandstones and clays with lignite, and unconformably overlie older strata.

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CHAPTER IV

OIL AND GAS PROSPECTS IN THE FOOTHILLS OF SOUTHERN ALBERTA

INTRODUCTION

Drilling has been done in a number of areas from the International Boundary north to the vicinity of Bow River (*See* Figure 8) and in Coalspur area west of Edmonton. For the purpose of this report these areas are grouped as follows:

- Pincher Creek area.
- Waterton Lake and Cameron Brook area.
- Rice Creek and Willow Creek area.
- Turner Valley area.
- New Black Diamond area.
- The area of the Highwood-Jumpingpound anticline including: (*a*) Highwood anticline, (*b*) Waite Valley, (*c*) Fisher Creek, (*d*) Birch Ridge, (*e*) Two Pine anticline.
- Jumpingpound anticline.
- Morley area.
- Moose Mountain area.
- Wildcat Hills anticline.
- Ghost River area.
- Red Deer Foothills area.
- Coalspur-Lovett anticline.

All these areas lie within the foothills belt, which is 12 to 25 miles wide and lies between the mountains and the plains. The foothills consist of approximately parallel ridges and valleys with elevations ranging from 3,500 to 6,000 feet. The strata exposed are mainly sandstones and shales of Cretaceous and Tertiary age, but there is one series of volcanic rocks in the vicinity of Crowsnest Pass. Underlying the Cretaceous rocks, but within reach of the drill, are Jurassic and Palæozoic rocks, the latter forming the main source of gas and oil in the only producing foothills field, namely, Turner Valley. The dominant structural feature is thrust faulting. Most of the fault planes dip steeply westward and break the foothills into a series of westward dipping fault blocks over-riding one another from west to east. Low-angle faulting has been proved by drilling to occur in Pincher Creek, Turner Valley, New Black Diamond, Jumpingpound, and Wildcat Hills areas and its occurrence elsewhere is suspected. The foothills are separated from the plains by a series of low-angle thrusts and whereas west of the outcrops of these faults the structure within the foothills is exceedingly complicated, east of them the structure of the plains is relatively simple. There is, however, no sharp topographic division between the foothills and plains, but there is a marked division between foothills and mountains due to the fact that the softer sandstones and shales composing the foothills are more easily eroded than the harder,

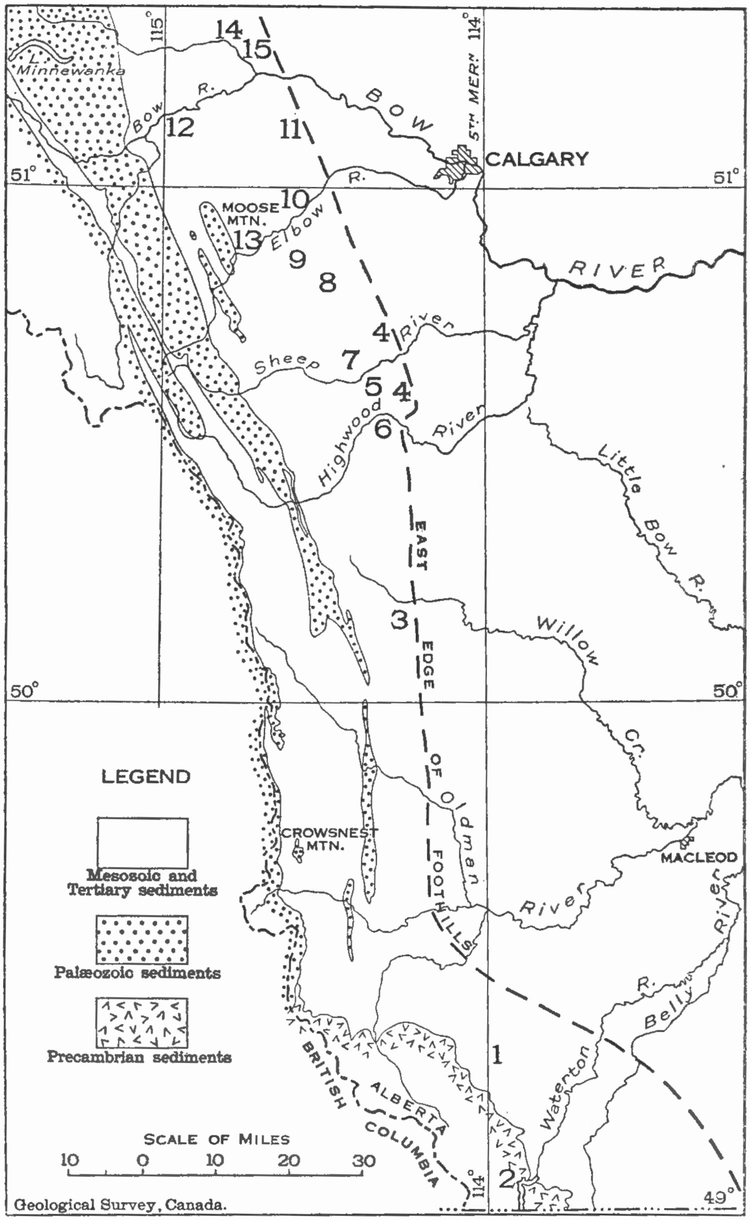

Figure 8. Foothills areas in southwestern Alberta explored by drilling. 1, Pincher Creek area; 2, Waterton Lake and Cameron Brook; 3, Rice Creek and Willow Creek area; 4, Turner Valley; 5, New Black Diamond; 6, Highwood area; 7, Waite Valley; 8, Fisher Creek; 9, Birch Ridge; 10, Two Pine area; 11, Jumpingpound; 12, Morley area; 13, Moose Mountain; 14, Ghost River; 15, Wildcat Hills.

massive Palæozoic limestones that mainly form the mountains. It is believed, however, that the mountains and foothills have the same type of structure, although they may differ in the magnitude of overthrusting.

The stratigraphy of the foothills is given in the following tables. For convenience and because of lack of knowledge of the exact correlation of different formations, the information is presented in three tables dealing with, respectively, the stratigraphy of: (1) the area south of Highwood River; (2) Highwood to Red Deer River; (3) Mountain Park-Cadomin area.

Stratigraphy of the Foothills South of Highwood River

Age		Formation	Description	Thickness Feet	Notes
Tertiary (probably Eocene)		Porcupine Hills	Light grey sandstones with interbedded grey shales and clays. Non-marine	2,500 (Stewart, 1919)	Approximately the equivalent of the Paskapoo of the area north of Highwood River
		Willow Creek	Reddish shales and sandstones with thin limestone bands. Sandstones prominent near top of formation. Non-marine	500	
Upper Cretaceous	Montana	St. Mary River	Highly calcareous, light grey sandstones with interbedded shales. Coal in the lower part of the formation with oyster beds. Non-marine	2,700 on Crowsnest River; 3,000 on Oldman River	Approximately the equivalent of the Edmonton formation
		Bearpaw	Dark shales and sandy shales. Marine	700 in south; less to the north	Not definitely known in the foothills north of Highwood River
		Belly River	Light grey sandstones with interbedded dark and greenish grey shales. Coal occurs particularly near the top. Small conglomerate lenses. Sandstones often highly crossbedded. Non-marine	2,500 to 3,000	
	Colorado	Alberta shales ("Benton")	Dark and grey shales with some sandstone beds. In certain areas can be divided into an upper and a lower member, separated by conglomerates, sandstones, and shales composing the Cardium of the area north of Highwood River. Marine	2,000 on Crowsnest River	

Stratigraphy of the Foothills South of Highwood River—Concluded

Age	Formation	Description	Thickness Feet	Notes
Lower Cretaceous	Crowsnest	Volcanic tuffs and breccias. Local in distribution	1,000 in Southfork area (MacKenzie, 1913, p. 239)	
	Blairmore	Greenish and grey sandstones and shales. Maroon shales may be present in certain localities. A thick, cherty conglomerate at base and lenses of conglomerate within the formation. Non-marine	Thickness to the west 1,800 to 2,865 (Leach, 1912, p. 196)	Contains a dicotyledon flora in upper part and a monocotyledon flora in lower part
	Kootenay	Grey sandstones and shales, many rusty weathering. Coal beds in the uppermost part. Non-marine	600 to 750	
Jurassic	Fernie	Dark grey to black shales with interbedded sandstones and thin beds of limestones		The Fernie is transitional into the Kootenay (McLearn, 1929, p. 87)
Palæozoic		Limestones		

Stratigraphy of the Foothills North of Highwood River to Red Deer River
(G.S.C., Maps 257 A, 258 A, 277 A)

Age	Formation	Description	Thickness Feet	Notes
Tertiary (Eocene)	Paskapoo	Yellowish weathering, massive sandstones and greenish and dark shale. Thin zones of conglomeratic sandstones at the base and within the formation. Non-marine	(?)	Not exposed within the foothills (disturbed) belt, but occurs on the eastern edge

Stratigraphy of the Foothills North of Highwood River to Red Deer River (G.S.C., Maps 257 A, 258 A, 277 A)—*Continued*

Age		Formation	Description	Thickness Feet	Notes
Upper Cretaceous	Montana	Edmonton	Grey and light-coloured, soft sandstones, and greenish and dark shales. Thin coal seams. Non-marine	1,000 to 1,200 (Footnote 1)	Thickness not definitely known, but thought to increase northward
		Bearpaw	Arenaceous shales and shaly sandstones on Highwood River	0–100	Not known north of Highwood River
		Belly River	Light grey, crossbedded sandstones with dark, grey and greenish shales and ironstone bands. Coal at the top of the formation in the south and in the central part of the formation on Bow River. Local lenses of conglomerate. Non-marine	2,000 in Turner Valley-Highwood area. May be thicker to the north	
	Colorado	Upper Alberta shale (Upper "Benton")	Dark grey shales and thin sandstone beds. Glauconite very abundant in sandy beds at top of the formation on Ghost River. Many ironstone nodular bands. Marine	1,600 to 1,850 (Footnote 2)	Montana fossils in top few hundred feet of beds. Colorado fossils (*Scaphites ventricosus* fauna) below
		Cardium	Sandstone bands in many cases capped by fine conglomerate from a few inches to 14 feet thick. Only one prominent sandstone band in eastern foothills, but three in the west and separated by shales carrying upper Colorado fauna. Marine	350	Contains *Cardium pauperculum* and *Scaphites ventricosus* faunas and hence belongs with the Upper Alberta shale
		Lower Alberta shale (Lower "Benton")	Fine-grained, dark shales. A well-marked sandstone horizon about 100 feet above a basal grit zone. Marine	850 in Highwood area. Thicker to the north. 1,150 on Burnt Timber Creek south of Red Deer River	Contains *Inoceramus labiatus* and Prionotropis fauna

Stratigraphy of the Foothills North of Highwood River to Red Deer River (G.S.C., Maps 257 A, 258 A, 277 A)—*Concluded*

Age	Formation	Description	Thickness Feet	Notes
Lower Cretaceous	Blairmore	Grey and greenish sandstones and green, grey, and maroon shales. Lower part highly calcareous with thin limestone bands. Lenses of conglomerate occur within the formation and in the west a heavy bed of conglomerate lies at the base. The conglomeratic sandstone of the Dalhousie sand is believed to represent this horizon in Turner Valley and hence is the base of the Blairmore there	1,200 in Turner Valley and 1,630 on Elbow River east of Canyon Creek. On Ram River and Red Deer River approximately 1,900 to 2,000	The Blairmore in Turner Valley contains a coal seam approximately 625 feet below the top of the formation. Coal seams occur in the Blairmore north of Bow River
	Kootenay	Dark-coloured sandstones and shales. Coal near top of the formation	375 on Canyon Creek, Moose Mountain. Thin (0–100 feet) in Turner Valley	Coal in the Kootenay not commerically important north of Bow River in the foothills
Jurassic	Fernie	Brown to black shales with glauconite. Limestone bands in lower part. Brown, thin-bedded, or ribboned sandstones in the upper part	220 at Canyon Creek, Moose Mountain. Probably about the same thickness in Turner Valley	At Canyon Creek, Moose Mountain, an erosional contact with overlying Kootenay. In Crowsnest Pass transitional with overlying Kootenay
Pennsylvanian? and Mississippian	Rundle	Limestone with much chert in upper and lower beds and crystalline in central part	1,400 in Moose Mountain area	Contains porous horizons particularly in the upper part
Mississippian	Banff shales	Dark shales, limy shales, and limestones	650 to 700	Partly exposed in Moose Mountain

[1] The Ranchmen's well on L.S. 16, Sec. 13, Tp. 20, Range 29, W. 4th Mer., was commenced in the Paskapoo formation, the base of which is thought to occur at 1,000 feet where a coarse sandstone over 100 feet thick was encountered. At 1,930 to 2,000 feet (particularly at 1,990) coal occurs and this is believed to be the top of the Belly River. The thickness of the Edmonton is thus only 990 to 1,000 feet. The Belly River contains a thin coal seam at the base in Turner Valley area and the samples from the Ranchmen's well show coal and shaly sandstone at 4,170 to 4,190 feet, which are thought to represent this horizon, giving a thickness for the Belly River of 2,200 feet. A section measured on Highwood River showed 2,700 feet of Belly River strata, but this section may be partly repeated by faulting although no faults of any considerable magnitude were observed (*See* Hume, 1930, p. 10). This thickness of 3,000 to 3,200 feet of Belly River and Edmonton in Highwood River area is strikingly in contrast with a thickness of 8,000 feet on Red Deer River (*See* Evans, 1930, p. 31).

[2] North of Bow River the thickness of the Upper Alberta shale, including the Cardium, is more than 2,200 feet (*See* Evans, 1930, p. 31).

Stratigraphy of the Mountain Park-Cadomin Area (MacKay, 1930, and G.S.C., Maps Nos. 208 A and 209 A)

Age	Formation	Description	Thickness Feet	Notes
Upper Cretaceous	Brazeau	Soft, grey, crossbedded sandstones and greenish grey shale with bands of conglomerate. Coal in the upper part. Non-marine	11,000	Includes the Belly River and Edmonton and possibly younger strata
	Wapiabi	Black shales with ironstone concretions. Marine	1,700	Correlated with the Upper Alberta shale of southern foothills areas
	Bighorn	Grey sandstones and dark shales with thin conglomerate lenses. Thin coal seams locally. Mostly marine but partly freshwater	350	Equivalent to the Cardium member of the Upper Alberta shale
	Blackstone	Black and dark green fissile shales with lenses and thin beds of impure limestone and iron carbonate concretions. Marine	1,700	Equivalent to the Lower Alberta shale of southern foothills areas
Lower Cretaceous	Mountain Park	Coarse, crossbedded sandstones and olive green sandy shales with lenses of conglomerate composed largely of small black chert pebbles. Non-marine.	400	The Mountain Park and Luscar are apparently the equivalent of the Blairmore formation
	Luscar	Grey, soft sandstones interbedded with dark grey shales and several lenses of conglomerate. Contains all the Lower Cretaceous commercial coal seams. Non-marine	1,700	
	Cadomin	Massive, light-coloured conglomerate composed of pebbles of quartzites and chert cemented in a siliceous matrix. Non-marine	35	Equivalent to the conglomerate at the base of the Blairmore formation
	Nikanassin	Dark grey shales and brown-weathering grey sandstones with thin, impure coal seams. Non-marine	1,900	May be the equivalent of the Kootenay
Jurassic		Black shales with thin beds of fine-grained, quartzitic sandstone. A black chert bed, and quartzitic conglomerate are locally present at the base. Marine	1,300	
Triassic		Thin-bedded, fine-grained, arenaceous shale overlain by soft, alternating, buff and red limestone and grey, fissile shales. Marine	536 at Mountain Park	Probably thickens to the west and thins to the east

Stratigraphy of the Mountain Park-Cadomin Area (MacKay, 1930, and G.S.C., Maps Nos. 208 A and 209 A)—*Concluded*

Age	Formation	Description	Thickness Feet	Notes
Pennsylvanian		Hard, black quartzites	0–90	
Mississippian		Massive, and thin-bedded limestone underlain by grey shale with calcareous bands. Marine	1,500	
Devonian		Massive limestone and black and grey, calcareous shales. Marine	3,300	
Cambrian		Thin-bedded, magnesium limestone with mud cracks, ripple-marks, and pseudomorphs of salt crystals underlain by heavy and thin-bedded, soft, green shales	2,000	

PINCHER CREEK AREA

Reference: Stewart, J.S.: Geol. Surv., Canada, Mem. 112 with Map No. 1712.

The Geological Survey has no detailed information on the structures within Pincher Creek area (locality 1, Figure 8) other than that shown on Map 1712. Several wells have been drilled, of which a number provide reliable information concerning the stratigraphy and show the strata to be repeated by faulting as in other parts of the foothills.

The following logs illustrate the stratigraphy of the area.

Log of Twin Butte (Northwest Company) No. 1[1] *Well*
(Sec. 14, Tp. 4, Range 30, W. 4th Mer.)

—	Thickness Feet	Depth Feet
Alberta shale ("Benton"), possibly including some Crowsnest Volcanics.		
Blue-grey shale	170	170
Grey sandstone	60	230
Arenaceous shale	20	250
Blue-grey shale, in part sandy	1,270	1,520
Blairmore		
Light grey and greenish sandstone alternating with dark grey and greenish shale with carbonaceous materials	1,020	2,540
Kootenay		
Sandstone with coal	2	2,542
Coal	9	2,551
Dark shale, sandstone, and coal	64	2,615
Coal	3	2,618
Dark grey sand with coal	62	2,680
Age?		
Dark grey shale, siliceous	60	2,740
Dark grey shale, calcareous	30	2,770

[1] Published by permission of Imperial Oil Co., Ltd.

The well whose log follows was drilled on the same section as Northwest Company Twin Butte No. 1 and hence affords an interesting comparison.

Log of Alberta Gas and Fuel Company Drywood No. 1[1] *Well*
(L.S. 16, Sec. 14, Tp. 4, Range 30, W. 4th Mer.)

—	Thickness Feet	Depth Feet
Upper Alberta ("Benton") shale		
Grey shale	190	190
Cardium		
Sandstone with small pebbles at 190 feet	40	230
Lower Alberta ("Benton") shale		
Dark shale	465	695
Crowsnest Volcanics		
Volcanic rock interbedded with shale	205	900
Blairmore (Top not well defined)		
Greenish grey sandstone alternating with green and dark grey shales; coarse sandstone beds 80 feet thick (2,260–2,340 feet)	1,440	2,340
Kootenay		
Dark grey, sandy shale	240	2,580
Coal 8 to 10 feet thick	10	2,590
Sandstone and dark shale with coal at 2,670–2,680 feet	90	2,680
Alberta shale ("*Benton*") repeated by a fault		
Cardium?		
Shale with pebbles (Cardium?) 2,680–2,710 feet	120	2,800
Sandstone	20	2,820
Sandy shale	10	2,830
Lower Alberta shales and Crowsnest Volcanics		
Dark grey shale with some volcanic material near base	2,265	4,095

[1] Log compiled from examination of samples, Dept. of Supervisory Engineer. Published by permission of Alberta Gas and Fuel Co.

The Twin Butte (Northwest Company) No. 2 well in Sec. 20, Tp. 3, Range 29, W. 4th Mer., seems to have been drilled entirely within the Alberta (" Benton ") shale. The strata to the bottom of the well at a depth of 4,394 feet are recorded as being dark blue and grey shales, in part arenaceous.

The Alberta Gas and Fuel Company " Jenkins " or " Waterton " No. 1 well in L.S. 3, Sec. 34, Tp. 2, Range 29, W. 4th Mer., like the Imperial Oil Company's Twin Butte No. 2 well, is believed to have been drilled entirely within the Alberta (" Benton ") shale, a condition that is rather surprising in view of the great depth (4,610 feet) reached. As indicated by the samples from the well, sandstones that may belong to the Cardium occur from 460 to 490 feet and from 4,520 to 4,540 feet. At 1,370 feet J. G. Spratt reported considerable slickensiding which may indicate faulting. If true, this may mean that the well from 490 to 1,370 feet was drilled in Lower Alberta (" Benton ") shales and below this, due to faulting, in Upper Alberta (" Benton ") shales. The well would then finish at 4,610 feet in Lower Alberta (" Benton ") shales below the Cardium which occurs at 4,520 to 4,540 feet.

Log of Alberta Gas and Fuel Company Castle No. 1[1] *Well*
(L.S. 2, Sec. 11, Tp. 6, Range 1, W. 5th Mer.)

—	Thickness Feet	Depth Feet
Drift	75	75
Belly River		
Grey sandstone alternating with greenish and grey shale. Ironstone and carbonaceous materials	1,975	2,050
Alberta ("Benton" shale)		
Sandy, grey shale	1,260	3,310

[1] Log compiled from examination by J. G. Spratt, Dept. of Supervisory Engineer, and published by permission of Alberta Gas and Fuel Company.

WATERTON LAKE AND CAMERON BROOK AREA

References: Geol. Surv., Canada, Ann. Rept., vol. I, 1885, pt. B, pp. 38-41 (1886); vol. V, pt. SS, 1890-91, pt. 2, pt. SS, p. 124 (1893).
Daly, R. A.: Geol. Surv., Canada, Mem. 38, pp. 50, 90 (1912).
Dowling, D. B.: Geol. Surv., Canada, Sum. Rept. 1920, pt. B, pp. 16-22.

Waterton Lake, at the entrance to the mountains in southern Alberta, is at an elevation of 4,202 feet. According to Dawson (1886, page 38 B)

"it is separated by a rocky spur of Sheep Mountain into two parts of 7 and 2½ miles respectively in length. The first or upper portion is almost entirely surrounded by high and rugged mountains while the northern part, making a right angle with the former, lies along the base of Sheep Mountain and is bordered by lowland to the north. A river of about a mile in length leads from the lower end of the lake to a third expansion of about 2 miles in length which is surrounded by low hills only."

Waterton Lake is drained by Waterton River which flows northward to Belly River. Cameron (Oil) Creek flows from Cameron (Summit) Lake on the international border and enters upper Waterton Lake at Cameron Falls.

The mountain front is a great overthrust known as the Lewis thrust, by which the Precambrian Lewis series are overthrust onto the Cretaceous rocks of the foothills. The foothills have much less relief here than in more northerly areas, so that although the strata lying immediately in front of the mountains are thrust faulted and folded as elsewhere in the foothills, the topography is more nearly that of the plains. The mountains rise abruptly above the plain-like area and are rugged, their peaks and ridges rising several thousand feet above deeply incised, narrow valleys.

The strata of this area belong to the Lewis series whose known thickness is more than 11,000 feet, the base of the series being not exposed. The rocks are mainly limestones and argillites with smaller amounts of quartzites. Igneous rocks are represented by lava flows, sills, and dykes, but the total thickness of these is small in comparison with that of the sedimentary beds. The sediments exhibit a wide variety of colours; they range from white and grey limestones and quartzites to yellowish weathering argillites and red argillites and quartzites. For this reason the series is readily divisible into a number of easily recognizable formations showing a remarkable colour contrast.

Waterton Lake-Cameron Brook area is part of a larger area of Precambrian rocks that comprises Clarke Range and extends from Waterton Lake to the east side of Flathead Valley. The Precambrian beds of this area extend along the International Boundary for 6 miles east of Waterton Lake and 18 miles west of it to Flathead Valley and disappear beneath younger strata 25 miles north of the International Boundary about 13 miles south of Corbin, B.C. This large area is synclinal in structure, with the central part of the syncline occupied by Cambrian and later Palæozoic sediments but which do not extend as far south as the International Boundary. Except along the mountain front at Waterton and for a few miles west of it, there is very little faulting in the Lewis series, the strata of the east side of the syncline dipping southwesterly at 25 to 35 degrees. The mountain front, however, is cut by a number of faults of which one above the Lewis fault at Waterton underlies the top of Mount Crandell (*See* Figure 9) and has been folded with the Lewis series. This same fault also occurs on the east and northeast face of Ruby Ridge to the west of Mount Crandell, on Cameron Mountain to the south of Mount Crandell, and on Sheep Mountain east of the town of Waterton on the east side of Waterton Lake. The valleys between these mountains are cut below the fault plane. On the southeast face of Ruby Ridge the fault is very apparent and it can be traced across Cameron Valley to Cameron Bend Mountain on the south side of Cameron Brook. West of the fault for a short distance the strata are tilted at angles up to 60 or 70 degrees and in this area of highly disturbed rocks, about 5 miles up Cameron Brook from Waterton Lake, seepages of oil issue through the drift in the bottom of Cameron Brook Valley. It is probable that in this area of disturbed rocks there are minor faults or that the rocks are highly fractured, and there seems little doubt but that the seepages of oil are directly related to this fractured zone.

The seepages of oil on Cameron Brook were seen by Selwyn in 1891 during a visit to this area following some excitement as a result of their then recent discovery. At later dates the seepages were examined by other members of the Geological Survey and by the writer in 1932. If the gravel along the edges of Cameron Brook is stirred oil will rise to the surface of the water to form iridescent films. In the early days, following the discovery of oil, trenches along the edge of the brook were used by a man named Aldridge to collect the oil and although these trenches are now caved in a small amount of oil can still be obtained from them by digging small pits. One large pit of more recent date, situated a short distance south of the brook, contains a small amount of heavy, black, viscous oil with water. Other seepages occur on Lineham Creek, a tributary of Cameron Brook. These issue from grey and greenish argillites of the Appekunny formation dipping gently southwesterly along the edge of a canyon. The amount of oil issuing here seems to be very small, but the odour of petroleum is distinctly noticeable in the vicinity and iridescent films appear on the surface of the creek as water containing a small amount of oil drips into it from the canyon sides. No peculiarity of structure which would in any way explain the seepages was observed in this locality. The seepages on Cameron Brook, however, besides being related to the fracture zone outlined above, are on the southwest flank of an anticline that roughly parallels the lower part of

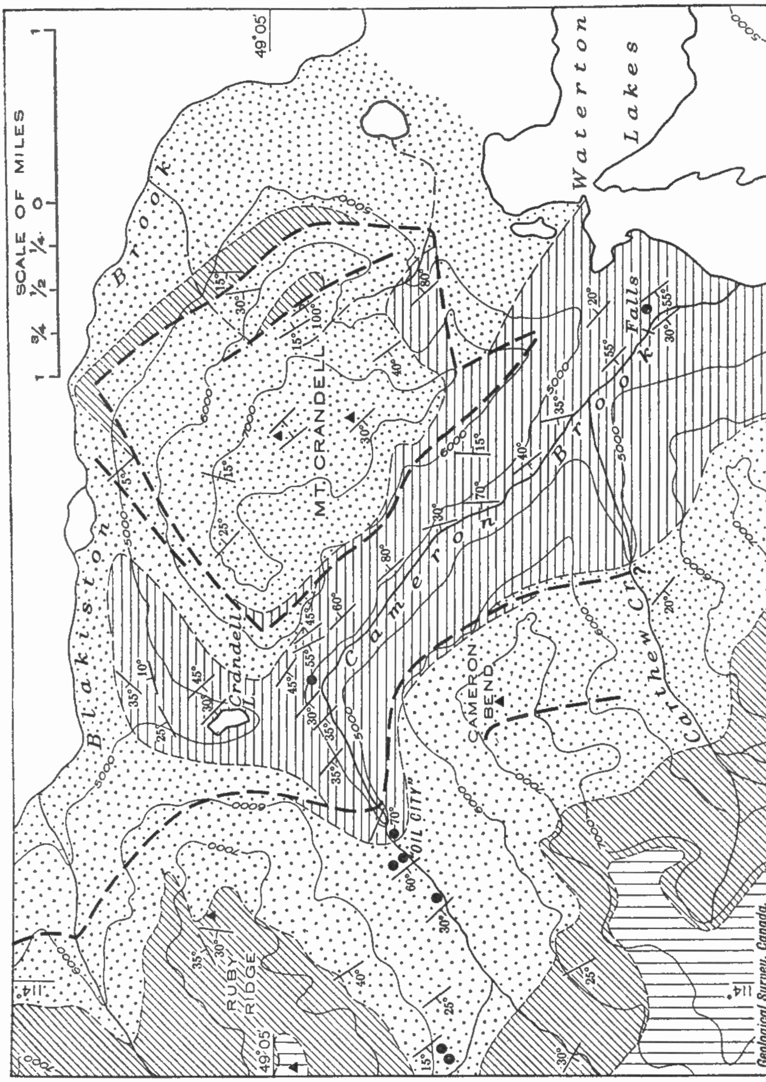

Figure 9. Sketch map of Mount Crandell and vicinity. Siyeh formation shown by vertical ruling; Grinnell formation by diagonal ruling; Appekunny formation by stipple pattern; and Altyn and Waterton formations by horizontal ruling. Bore-holes shown by solid circle and faults by heavy pecked line.

Cameron Brook Valley. The anticlinal structure can be readily observed between Crandell Mountain and Cameron Falls where, according to Daly, 200 feet of strata belonging to the lowest visible member of the Lewis series, the Waterton dolomite, outcrop. Above the Waterton dolomite and forming the core of the anticline are white and grey limestones and quartzites of the Altyn formation. Daly considered this formation to be 3,500 feet thick, but this estimate may be too great as some of the strata are repeated by faulting along the north face of Cameron Mountain. Above the Altyn beds is a series of grey and greenish argillites with bands of quartzites and limestones constituting the Appekunny formation. The seepages on Cameron Brook, as well as those on Lineham Creek, issue from Appekunny beds, the former being only a short distance from the Appekunny-Altyn contact.

Between 1901 and 1907 a number of wells were drilled on Cameron Brook at the site of the oil seepages (Oil City), on Lineham Brook close to the seepages that there occur, and on the flat at the town of Waterton. An incomplete list of these wells, the only Government records obtainable, is given below.

Wells Drilled in Cameron Brook-Waterton Lake Area

Well	L.S.	Sec.	Tp.	Range	Mer.	Depth	Remarks
						Feet	
Rocky Mountain Development Co.; Original Discovery Oil Co.; Patrick Oils, Ltd.; Lineham No. 1.	16	30	1	30	4	1,020	Drilled in 1901. Oil encountered at 1,020 feet.
Rocky Mountain Development Co., No. 2.	10	30	1	30	4	1,500	Drilled between 1903 and 1907. Oil shows.
Rocky Mountain Development Co., No. 3.	9	30	1	30	4	460	Drilled between 1903 and 1907.
Original Discovery Oil Co., Original No. 2.	16	30	1	30	4	1,900	Well site approximately 50 feet west of Lineham No. 1. Drilled in 1919-20. Oil shows, but as no commercial flows were obtained the well was abandoned.
Western Oil and Fuel (Coal) Co.; Can. Oil and Mines Co., Ltd.; Western Oil and Coal Cons.; Western Oil and Coke Co.	W.½	23	1	30	4	1,920	Commenced in 1930. Some oil encountered. Subsequently three other wells were drilled. No. 2 is said to have been on Sec. 29, Tp. 1, Range 30, and reached a depth of 408 feet; No. 3 on Sec. 4, Tp. 2, Range 30, reached a depth of 286 feet; and No. 4 location unknown, reached a depth of 124 feet.
Pincher Creek Oil and Refining Co.; Pincher Creek Oil Co.	9	25	1	1	5		Drilled 1906-10. A little oil at 90 feet. Three more wells were drilled by the Pincher Creek Oil Co., each 300 to 800 feet deep. All gave some oil and one is reported to have produced 100 barrels.

The Geological Survey has samples to a depth of 1,753 feet (1932, page 74) from the Western Oil and Fuel Company's well near Cameron Falls on Sec. 23, Tp. 1, Range 30, W. 4th Mer. The log of this well is as follows:

—	Thickness Feet	Depth Feet
Grey shale	....	86
Grey and purple dolomite	553	639
Very siliceous, dark grey dolomite	7	646
Very siliceous, medium grey dolomite	31	677
Very siliceous, greenish grey shale	44	721
Purple shale	9	730
Light and dark grey dolomite	475	1,205
Medium grey shale, yielding oil on distillation	3	1,208
Medium grey dolomite	25	1,233
Medium grey shale	11	1,244
Light grey shale	4	1,248
Medium grey shale	2	1,250
Light grey shale, slickensided	6	1,256
Medium grey shale	58	1,314
Greenish grey shale	11	1,325
Green shale	31	1,356
Green-grey shale	9	1,365
Light grey shale	15	1,380
Light grey sandstone	6	1,386
Green-grey shale	8	1,394
Light grey sandstone	37	1,431
Green-grey shale	82	1,513
Light grey sandstone	23	1,536
Medium grey sandstone	41	1,577
Dark grey sandstone	5	1,582
Medium grey sandstone	15	1,597
Brownish grey sandstone	17	1,614
Greenish grey shale, slickensided	39	1,753

According to Daly (1912, page 91) the bottom of this well was in "Benton" shales, but from a re-examination of the samples from the well Johnston (1932, pages 74-75 B) has concluded

"that the Beltian siliceous dolomite extends to 1,205 feet and occurs again at 1,208 to 1,233 feet, 3 feet of oil-shale intervening. The age of the oil-shale is not apparent, but it probably is much younger than the Beltian. The lower shales and sandstones do not resemble the "Benton" or Alberta shales, but do resemble the Crowsnest volcanics . . . . The great number of samples showing slickensides indicate that there has been considerable slicing of the lower beds by thrust faulting and it is possible that the volcanics are overthrust on younger beds."

This well appears to establish the fact that the Lewis series is overthrust onto Cretaceous strata. There are conflicting reports as to whether any oil was obtained in the well, but if obtained it must have been in small amounts. As the hard, metamorphosed sediments of the Lewis series are totally unsuitable to act as source beds for oil, it has been suggested that the underlying Cretaceous beds gave rise to the oil now issuing as seepages on Cameron Brook and obtained in small amounts in several wells drilled in that general vicinity.

Recently Oil City Royalties have constructed a derrick near the site of the oil seepages on Cameron Brook and close to Discovery No. 1 well drilled many years ago and in which some oil was obtained. As the location is in the zone of fractured rocks lying above the thrust plane of the Mount Crandell fault, it is possible that the Oil City Royalties well when drilled will obtain some oil from the fractured zone down to a depth of possibly 1,000 feet. No large commercial flow and no sustained production could, however, be expected on account of the lack of conditions necessary to give a large concentration of oil at this shallow depth. It is believed that no adequate test of the oil prospects of this area can be made unless a well is drilled through the Precambrian to the underlying Mesozoic strata in which the oil is supposed to have originated. The depth to the Lewis thrust at the well location is somewhat problematical. As the well will commence in Appekunny strata below which there are at least 3,000 feet of Altyn and not less than 1,200 feet of Waterton dolomite, it can not possibly reach the Lewis thrust under 4,500 feet and, depending on the dip of the strata, the depth may be somewhat greater. The estimated depth of 4,500 feet is based on the assumption that the dip of the Lewis thrust from the Western Oil and Fuel Company's well near Cameron Falls to the well location is westward at an angle of between 4 and 5 degrees,[1] a dip quite in harmony with that observed by Willis (1902, page 332) for the Lewis thrust in Montana where the dip varies from 3 to 7¾ degrees.

The seepages of oil on Cameron Brook and elsewhere are evidence of the existence of oil in this area. As already stated there are no grounds for expecting to obtain oil in commercial quantities from the Precambrian Lewis strata. The prospects of obtaining commercial yields by drilling through the Lewis thrust to the underlying Mesozoic or Palæozoic are dependent on two factors, namely: (1) the amount of porosity in the productive horizon; and (2) the structure below the fault plane.

No predictions can be made as to the horizon likely to be encountered below the Lewis thrust. At Waterton Lake the Lewis thrust is concealed by drift and outwash materials but the fault was studied by the writer in the vicinity of North Kootenay pass. Here the Lewis strata are overthrust onto the coal beds of the Kootenay formation, the coal having acted as the sliding surface and having been ground into a gouge a foot or more thick. The Kootenay beds, although they appear to dip west at a low angle, are in reality overturned and lie above the basal Blairmore conglomerate which in turn overlies higher Blairmore strata. In various places under the Lewis thrust are huge masses of Palæozoic limestone embedded in the Kootenay coal series. It is obvious, therefore, that in certain places the Lewis rocks must overlie Palæozoic limestones from which large masses have been torn and carried forward by the fault movement. The amount of fracturing and shattering of the beds below the Lewis thrust must necessarily have been very great and in such a fractured zone it would seem possible, given favourable structural conditions, for oil to accumulate in commercial quantities.

It has already been stated that the seepages on Cameron Brook are on the west flank of an anticline that roughly parallels the lower part of Cameron Brook. This anticline is below the level of the Mount Crandell fault which on Mount Crandell can be readily shown to have been folded.

[1] The Oil City Royalties well location is approximately 1,000 feet higher than the well of the Western Oil and Fuel Co. at Cameron Falls where the Lewis thrust was penetrated at a depth of 1,233 feet.

As the Mount Crandell fault is probably only a subsidiary of the underlying Lewis thrust, it is inferred that the Lewis thrust may also be folded as has been found by Willis (1902, page 332) to be the case in Montana. If this is so then the Cameron Brook anticline may persist downwards across the Lewis thrust into the Mesozoic or Palæozoic beds that also would then have an anticlinal structure. Such an hypothesis would explain the occurrence of oil in the fractured zone on the west side of the Cameron Brook anticline, and the prospects for oil in any well drilled through the Lewis thrust and on the anticline would depend on the extent to which the structure had produced a condition favouring concentration of oil in the fractured beds under the fault plane.

RICE CREEK AND WILLOW CREEK AREA

Reference: Stewart, J. S.: Geol. Surv., Canada, Mem. 112 (1919), Map., Pub. No. 1712.

Log of Imperial Rice Creek Well[1]
(L. S. 12, Sec. 4, Tp. 14, Range 2, W. 5th Mer.)

—	Thickness Feet	Depth Feet
Alberta ("Benton") shale		
Dark grey shale	440	440
Dark grey shale, green chert pebbles	20	460
Dark grey shale	250	710
Much slickensiding from 660 to 700 feet, indicating fault.		
Belly River		
Dark grey shale and lighter grey to greenish grey sandstone	580	1,290
Dark shale and sandstone	290	1,580
Greenish and light grey sandstone and shale	90	1,670
Light grey to white sandstone, some shale	190	1,860
Dark brown and grey sandstone, and dark shale. Coal at 2,010 feet.	160	2,020
Upper Alberta ("Benton") shale		
Dark grey shale	30	2,050
Coarse, grey sandstone	10	2,060
This sandstone member often occurs in the top of the Alberta shale and represents the transition to the Belly River formation.		
Dark grey shale	1,050	3,110
Cardium		
Dark grey shale, green and grey chert pebbles	10	3,120
Dark grey shale	230	3,350
Dark grey shale, green and grey chert pebbles	10	3,360
Lower Alberta ("Benton") shale		
Dark grey shale, bentonite at 4,010–4,020 feet	660	4,020
No samples	100	4,120
Blairmore		
Dark grey to greenish sandstones and shales	20	4,140
Greenish grey sandstone	450	4,590
Dark grey sandstone and shale	80	4,670
Grey sandstone	20	4,690
Mostly sandstone, some shale	60	4,750
Grey sandstone	240	4,990
Dark grey sandstone and shale	90	5,080
Light grey to greenish sandstone	150	5,230
Fault		
Alberta ("Benton") shale		
Dark grey shale	90	5,320
Dark grey shale, green chert pebbles	10	5,330
Dark grey shale	340	5,670
Dark grey shale, green chert pebbles	10	5,680
Dark grey shale	60	5,740

[1] Published by permission of Imperial Oil Co., Ltd.

The well commenced in Alberta shale, passed through a thrust fault at 710 feet into Belly River, through a normal succession to 5,230 feet, through a second thrust fault and into Alberta shales again.

There is a thin coal member at the base of the Belly River in Turner Valley area. It is thicker northwards.

The Blairmore contact must be approximately at the base of the interval of 100 feet listed under Lower Alberta shale and unrepresented by samples, as the bentonite zone with minutely crossbedded sandstone and shale at 4,010 feet is about 100 feet stratigraphically above the Blairmore contact.

The feature of the Alberta shale in this well is its comparatively small thickness. A comparison with the Turner Valley area follows.

—	Turner Valley Stratigraphical thickness Feet	Rice Creek Drilling thickness Feet
Upper Alberta shale including Cardium	1,900 to 1,950	1,340
Lower Alberta shale	800 to 850	760

The thinning of the Alberta shale may indicate flowage due to a zone of extreme disturbance, or it may be that the Alberta shale was never as thick as in Turner Valley.

Log of Imperial Willow Creek Well[1]
(Sec. 29, Tp. 14, Range 2, W. 5th Mer.)

—	Thickness Feet	Depth Feet
Lower Alberta "Benton" shale		
Grey shale	280	280
Missing	290	570
Blairmore		
Grey and greenish shale and sandstone	730	1,300
Coal—greenish shale	10	1,310
Greenish shale and sandstone	220	1,540
Grey sandstone	40	1,580
Dark grey shale	160	1,740
Light grey, calcareous shale, etc., with a few darker bands	180	1,920
Light grey to white sandstone—coarse	10	1,930
Iron-stained sandstone and shale with small nodules or concretions	20	1,950
Kootenay		
Dark to black, sandy shale	60	2,010
Coal and shale	10	2,020
Mostly dark to black, sandy shale	110	2,130
Missing	30	2,160
Mostly dark to black, sandy shale	70	2,230
Coal and shale	10	2,240
Brownish sand	30	2,270
Coal and shale	10	2,280
Black to dark shale	40	2,320
Light grey sandstone	40	2,360

Log of Imperial Willow Creek Well[1]
(Sec. 29, Tp. 14, Range 2, W. 5th Mer.)—*Concluded*

—	Thickness Feet	Depth Feet
Fernie		
Dark grey to black shale	30	2,390
Dark grey shale with ostracods	10	2,400
Some ostracods have a reticulated surface; others show striations also.		
Light grey sandstone and shale	50	2,450
Sandy, grey shale	40	2,490
Light grey sandstone, calcareous	40	2,530
Dark grey to greenish shales	110	2,640
Brown sandstone and shale, calcareous	130	2,770
Dark grey shale and sandstone	50	2,820
Fine-grained calcareous sandstone	10	2,830
Brown sandstone and shale	80	2,910
Light-coloured sandstone	20	2,930
Mostly brown sand, some dark shale	90	3,020
Sandy limestone	30	3,050
Brown sand with black shale	60	3,110
Sandy limestone	10	3,120
Brown sand with black shale	80	3,200
Very black shale, slickensided	80	3,280
Very black shale, glauconite	10	3,290
Very black shale	150	3,440
Kootenay? (Repeated by a fault)		
Brown sandstone with black shale	40	3,480
Black shale with grey sandstone, coal	60	3,540
Fine, grey sandstone	10	3,550
Dark shales with grey sandstones	40	3,590
Fine, grey sandstone	10	3,600

[1] Published by permission of Imperial Oil Co., Ltd.

TURNER VALLEY AREA

References: Slipper, S. E.: Sheep River Gas and Oil Field, Alberta; Geol. Surv., Canada, Mem. 122 (1921).

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Hume, G. S.: Structure and Oil Prospects of the Eastern Foothills Area, Alberta, between the Highwood and Bow Rivers; Eng. Inst. of Canada, Jan., 1931.

Hume, G. S.: Geol. Surv., Canada, Map 257 A, Pub. No. 2252. Also Maps 261 A, 262 A, and 263 A.

The Turner Valley gas and oil field (locality 4, Figure 8) is about 35 miles southwest of Calgary and lies within the foothills belt of faulted and folded rocks. Drilling activity began in this field in 1913 and a number of wells, some of which gave small flows of gas and oil, were completed. None of these early wells, however, reached the Palæozoic limestone from which the main supply of gas and oil is now secured, and activity ceased during the period of the Great War. In the autumn of 1924 Royalite No. 4 well, drilled in Sec. 7, Tp. 20, Range 3, W. 5th Mer., obtained from the Palæozoic limestone a flow of gas of about 20,000,000 cubic feet a day, with a high naphtha content. The bringing in of this well resulted in the development of the field which as at present outlined is about 13 miles long and 1 mile wide and lies within Tps. 19 and 20, Ranges 2 and 3, W. 5th Mer.

Throughout a great part of Turner Valley the surface is covered by drift, although there is a fairly complete section of the bedrock exposed along Sheep Creek, which cuts across the central part. This section shows that the central part of the valley is underlain by Upper Alberta ("Benton") shales with the Cardium zone repeated in several places by sharp folding. The folding that is most apparent is a central syncline in the Cardium beds with an anticline both to the east and to the west. The central syncline is probably thrust faulted along the strike and other faults can be seen in a few places or are indicated by repetitions of strata in wells. Belly River rocks outcrop along the east and west sides of the valley and superficially the structure suggests a normal anticline with a certain amount of folding and faulting. Drilling, however, has revealed a very complicated structure and shown that the area is underlain by a low-angle fault that outcrops east of the eastern Belly River Ridge. This low-angle thrust is believed to be the major structural feature and the whole structure is regarded as being a drag-fold developed above it due to eastward thrusting. The faults within the field are known to have steep dips and are believed to be subsidiary to and to join the low-angle thrust at depth. Objections to this view have been raised by certain geologists who believe the low-angle thrust formed as the result of folding. If this had happened it would seem that the fold should have become recumbent before being faulted and, therefore, the beds on the east side of Turner Valley should be overturned. Surface evidence does not support this view. The eastern strata are not overturned, although undoubtedly they are overturned at depth in the proximity to the low-angle fault as might be expected from drag-folding along the fault plane.

The stratigraphy of Turner Valley is illustrated by the graphic log, Figure 10. It was formerly thought that the coal that occurs about 650 feet below the top of the Blairmore represented a Kootenay coal horizon and consequently the division between Blairmore and Kootenay was made at this coal seam. Also it was thought that the Home sand was the approximate base of the non-marine strata and hence all strata below the Home sand and above the Palæozoic limestone were assigned (Hume, 1927, page 2) to the Fernie. It was later recognized (Hume, 1930, page 4) that there were non-marine strata below the Home sand and the base of the Kootenay was placed at the Dalhousie sand that formerly was considered

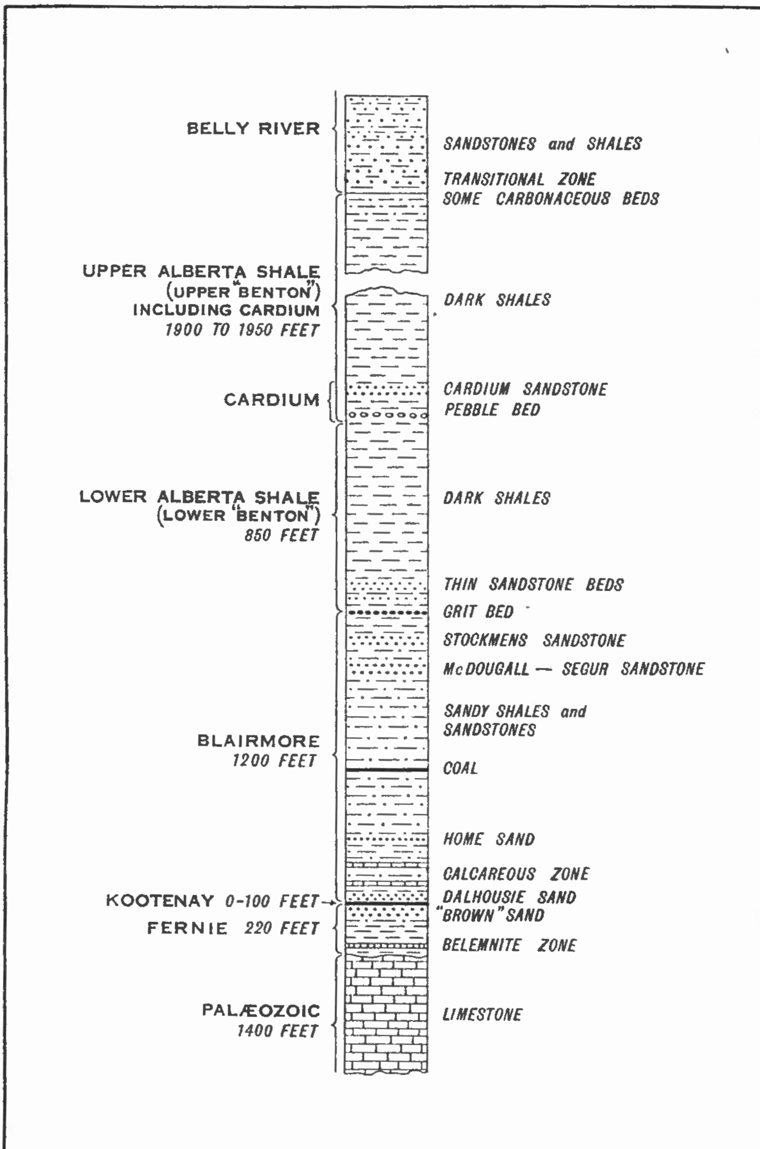

Figure 10. Stratigraphic section, Turner Valley area (partly after J. B. Webb).

to be within the Fernie. J. B. Webb of the Hudson Bay Oil and Gas Company has made a further contribution to the stratigraphy and has shown that a small conglomeratic zone at the top of the Dalhousie sand is probably the equivalent of the heavy conglomerate at the base of the Blairmore in western foothills areas. At the present time, therefore, all strata below the "Grit" zone down to and including the conglomeratic sandstone of the Dalhousie sand are included within the Blairmore, giving the formation in Turner Valley a stratigraphic thickness of about 1,200 feet. Below the Home sand and above the Dalhousie sand are a series of limestone and limy sandstone beds which are well exposed on Elbow River (Hume, 1932, page 48 B) near Moose Mountain. These limestone beds contain gasteropods and pelecypods and where exposed on Fisher Mountain in the Fisher Creek structure an occasional Unio occurs. There is little doubt, therefore, that the Dalhousie sand is the equivalent of the basal Blairmore conglomerate of western sections, since the sequence in Turner Valley can be definitely correlated with exposed sections. In many wells in Turner Valley a small amount of coal occurs below the Dalhousie sand and in certain wells, as for example Model No. 1 in the north end of Turner Valley, there is a considerable thickness of coaly and sandy shales at this horizon. Beneath this is the so-called "brown sand", a granular sandstone of very definite and easily recognizable character. There seems to be some divergence of opinion regarding the age of this "brown sand", but the section at Canyon Creek, Moose Mountain, suggests to the writer that the sandstone is at the top of the Fernie formation. The Kootenay in Turner Valley is, therefore, very thin and in some wells where the "brown sand" appears to directly underlie the Dalhousie sandstone it may be entirely absent. The division between the Kootenay and Fernie, however, may be only an approximation, since in Crowsnest area (McLearn, 1929, page 87) there is a transition zone (passage beds of McLearn) between the two formations. This may indicate continuous sedimentation from marine to non-marine beds. The uppermost Fernie consists of the "brown sand" which in exposed sections is a finely crossbedded, ribboned sandstone. Below this the beds become shaly and glauconite occurs. The main part of the formation consists of dark shales with a glauconitic phosphatic (MacKay, 1932, page 18) belemnite zone 35 to 50 feet above the Palæozoic limestone on which the Fernie rests. The Fernie also contains limestone beds, particularly in the lower part, and these have, in some wells, been confused with the top of the Palæozoic limestone, although as a rule they are darker in colour. This new interpretation of the stratigraphy of Turner Valley brings it into harmony with exposed sections in other parts of the foothills.

The stratigraphy of Turner Valley is well illustrated in the following logs of Royalite No. 14 and Sterling Pacific No. 1 wells. Royalite No. 14 is the shallowest well in Turner Valley producing from the Palæozoic limestone and Sterling Pacific No. 1 well is interesting because after drilling a considerable thickness of Palæozoic limestones it passed through the low-angle fault under Turner Valley into Cretaceous strata.

Log of Royalite No. 14 Well[1]
(L.S. 4, Sec. 7, Tp. 20, Range 3, W. 4th Mer.)

—	Thickness Feet	Depth Feet
Upper Alberta ("Benton") shale		
Dark grey shales	410	410
Cardium (Middle member)		
Dark grey shale, chert pebbles	10	420
Dark grey shale with some sandstone	40	460
Dark grey shale, chert pebbles	10	470
Lower Alberta ("Benton") shale		
Dark grey shale	220	690
Dark grey shale	10	700
Dark grey shale	710	1,410
Dark grey shale with sandstone	10	1,420
Dark grey shale	40	1,460
Blairmore		
Dark grey and green sandstone with grey shales	220	1,680
Sandstone (Stockmens sandstone)	10	1,690
Dark grey shale with sandstone	170	1,860
Sandstone (McDougall-Segur sandstone)	40	1,900
Dark grey and greenish shales and sandstone with carbonaceous materials	500	2,400
Dark grey and green shale with coal	10	2,410
Dark grey and green shale and sandstone with carbonaceous materials and coal	290	2,700
Fine-grained grey to white sandstone (Home sand)	20	2,720
Dark grey shale and sandstone	10	2,730
Lime bands with shale	160	2,890
Light grey sandstone (Dalhousie sandstone)	60	2,950
Kootenay? and Fernie		
Brown sandstone	100	3,050
Dark grey to black shale with belemnites at 3,170–3,180 feet	170	3,220
Top of Palæozoic limestone		3,220

[1] Published by permission of Imperial Oil, Ltd. Compilation from log by J. G. Spratt.

It will be noted that if the brown sandstone listed under Kootenay(?) and Fernie is considered to be Fernie, the Kootenay is either absent or represented by only a few feet of strata not indicated by the samples.

Log of Sterling Pacific Oil Company Well No. 1 [1]
(L.S. 15, Sec. 33, Tp. 18, Range 2, W. 5th Mer.)

—	Thickness Feet	Depth Feet
Upper Alberta ("Benton") shale		
Grey shale	900	900
Cardium?		
Grey shale with considerable brown sandstone	30	930
[2]*Lower Alberta ("Benton") shale*		
Grey shale	2,220	3,150
Grey shale with glauconite	90	3,240
Grey shale	30	3,270

[1] Compilation from log by J. G. Spratt.
[2] This is an unusually thick section of Lower Alberta shale and it may be repeated by faulting. The stratigraphic thickness is considered to be about 850 feet.

Log of Sterling Pacific Oil Company Well No. 1
(L.S. 15, Sec. 33, Tp. 18, Range 2, W. 5th Mer.)—*Concluded*

—	Thickness Feet	Depth Feet
Blairmore		
Greenish and grey shale and sandstone	520	3,790
Grey shale with trace of red shale	100	3,890
Grey and green shale and sandstone	550	4,460
White sandstone and shale (Home sand)	50	4,510
Grey shale and brown limestone	150	4,660
Grey sandstone, limy matrix	60	4,720
Missing	20	4,740
White sandstone (Dalhousie sandstone)	10	4,750
Kootenay		
Black, coaly, and sandy shales	30	4,780
Fernie		
Brown sandstone (brown sand)	70	4,850
Grey-black shale	240	5,090
Grey-black shale and sandstone with black, cherty grains	60	5,150
Palæozoic at	....	5,160
Light and buff-grey limestone	80	5,240
Missing	30	5,270
Light buff-grey limestone	130	5,400
Light buff-grey limestone, slightly porous	10	5,410
Light buff-grey limestone	320	5,720
Dark grey limestone	620	6,340
Light grey limestone	90	6,430
Fault (Low-angle fault under Turner Valley) at	....	6,436
Blairmore		
Grey and green shales and sandstone	70	6,500
Grey and green shales, trace of maroon shale	10	6,510

The type of structure of Turner Valley is illustrated by the cross-section, Figure 11, drawn at right angles to the strike in the vicinity of Sheep Creek. The south end of the general structure, as shown on Geological Survey Map

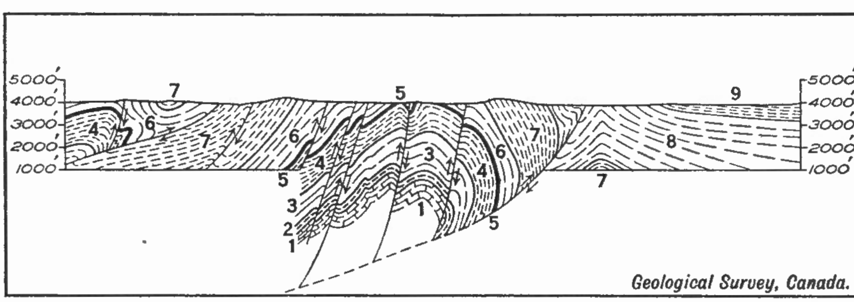

Figure 11. Generalized structure section across Turner Valley from Sec. 34, Tp. 19, Range 3, W. 5th Mer., to east side of Sec. 16, Tp. 20, Range 2, W. 5th Mer. 1, Palæozoic limestone; 2, Fernie and Kootenay; 3, Blairmore; 4, Lower Alberta shale; 5, Cardium; 6, Upper Alberta shale; 7, Belly River; 8, Edmonton; 9, Paskapoo.

257 A, plunges rapidly from Longview Hill southwards and Edmonton rocks occur on Highwood River south of Turner Valley. The fault that outcrops east of Turner Valley in the vicinity of the Black Diamond bridge over Sheep

River has not been traced south of this place, but has been encountered in several wells under southern Turner Valley where there appears to be a low-angle fault of considerable magnitude along which Palæozoic limestones have been thrust over Cretaceous strata. The fault, therefore, may be considered to extend throughout the length of Turner Valley, but possibly dies out or changes trend southward as any extension of it along the strike does not occur on Highwood River. The plunge at the south end of Turner Valley is very steep and suggests that the fault may change in trend southwards and join the important thrust fault in front of the Highwood foothills area on Secs. 9, 16, and 17, etc., Tp. 18, Range 2, W. 5th Mer. At the north end of Turner Valley, south of Quirk Creek (north branch), Sheep River, there is a zone of discordant strikes on Sec. 26, Tp. 20, Range 3. This has been interpreted as indicative of a cross fault (G.S.C., Map 262 A), but this view has been refuted by the geologists of Imperial Oil Company, Limited, because of results obtained by core drilling in the vicinity of the supposed cross fault. In the area north of this supposed fault borings indicate an unusual thickness of Alberta ("Benton") shale and it has been suggested that the Alberta shale of this area is repeated by the low-angle thrust fault outcropping along the western flank of Belly River Ridge in the part of Turner Valley northwest of Section 26, and that the southward continuation of the outcrop crosses Turner Valley in the general vicinity of the at one time postulated cross fault. This thrust may be a continuation of the low-angle fault that outcrops east of the New Black Diamond structure and if so some modification of the Geological Survey's map is required for this area. All wells north of the supposed cross fault seem to have encountered overturned strata at depth, a condition that is in harmony with overturning above a low-angled fault such as suggested above. No well in the extreme north end of Turner Valley has been able to reach the Palæozoic limestone which in central and southern Turner Valley produces gas with naphtha.

PRODUCTIVE HORIZONS IN TURNER VALLEY

Shows of oil are common in Turner Valley in the lower Alberta ("Benton") shale, but no commercial production has been obtained from this formation. There are, however, several producing sands in the Blairmore formation, namely the Stockmens, McDougall-Segur, Home, and Dalhousie sands. The Stockmens sand is about 100 feet below the top of the Blairmore and gave some gas production in the Stockmens well in Sec. 27, Tp. 20, Range 3, W. 5th Mer. It has, however, not yielded extensively. The McDougall-Segur sand, about 200 feet below the top of the Blairmore, has yielded oil in a number of wells, the oil having a gravity of about 54 to 55 degrees Baumé. The Home sand, which is about 875 feet stratigraphically below the top of the Blairmore, was found to be productive in Home No. 1 well at a depth of 4,560 feet and yielded oil of 44 to 45 degrees Baumé. Since this discovery it has yielded oil in a number of wells. Royalite No. 4 obtained an initial flow of 7,000,000 cubic feet of gas at this horizon at a depth of 2,890 feet. The Dalhousie sand, which lies at the base of the Blairmore, was first found to be productive in Dalhousie No. 5 well on Sec. 30, Tp. 19, Range 2, W. 5th Mer., at a depth of 4,810 feet and yielded oil of about 52 degrees Baumé. The main productive zone of Turner Valley, however, is in the upper part of the Palæozoic limestone and was discovered by Royalite No. 4 well at a depth of 3,740 feet. Only one well, i.e. Royalite No. 14, has found the Palæozoic limestone at a less depth than Royalite No. 4 and in several productive wells the depth is in excess of 5,000 feet. This horizon produces gas with naphtha having a gravity as high as 73 degrees Baumé. This productive zone occurs at quite widely varying depths below the top of the Palæozoic limestone. This may be explained by any one or a combination of several conditions, namely: (1) the top of the limestone is an erosion surface; (2) the attitude of the beds, and hence the drilling thickness, may be quite variable; (3) the zone of porosity may not be confined to one horizon.

In McLeod No. 4 well, at a depth of 4,972 feet or more than 1,200 feet below the top of the limestone, a large flow of wet gas was encountered (Bull. Can. Inst. Min. and Met., May, 1929, page 602). This horizon seemed to be quite different from the upper Palæozoic productive zone in that the naphtha had a somewhat different gravity and was more nearly free from sulphur than the upper zone.

The oil production of Turner Valley from 1914 to 1932 has been as follows (*See* schedule, Dept. of Lands and Mines, Alberta).

Year	Naphtha in barrels	Light crude in barrels
1914–21	....	56,599
1922	9,294	6,559
1923	8,060	1,943
1924	13,205	844
1925	165,717	2,926
1926	211,008	2,609
1927	290,270	38,808
1928	410,623	70,734
1929	908,741	73,369
1930	1,314,039	53,917
1931[1]	1,345,689	26,936
1932[1]	854,116	21,694

[1] Information supplied by Metallurgical and Chemical Branch, Bureau of Statistics, Ottawa.

The natural gas production of Turner Valley has been as follows:

Year	[1]Amount of gas in thousands of cubic feet sold, other than for field use	[2]Amount of gas in thousands of cubic feet destroyed by burning	[3]Total amount in thousands of cubic feet produced for all uses and wasted
1922	998,987	....	....
1923	1,371,181	....	....
1924	1,631,337	....	....
1925	1,215,149	5,260,000	8,760,000
1926	4,250,512	4,300,000	8,800,000
1927	5,325,207	6,520,000	13,870,000
1928	7,359,567	13,930,000	21,320,000
1929	12,183,853	45,180,000	61,450,000
1930	14,147,224	97,310,000	114,080,000
1931	12,242,037	156,800,000	169,280,000
1932	9,605,705	....	111,080,000

[1] Information supplied by Met. and Chem. Branch, Bur. of Statistics.
[2] Calder, W.: Can. Inst. of Min. and Met., Nov. 1932, p. 635.
[3] Can. Inst. of Min. and Met., April 1933, p. 258.

NEW BLACK DIAMOND AREA

References: Slipper, S. E.: Geol. Surv., Canada, Mem. 122, 1921, with map.
Hume, G. S.: Geol. Surv., Canada, Sum. Rept. 1929, pt. B, pp. 21-22.
Hume, G. S.: Geol. Surv., Canada, Map 257 A, Pub. No. 2252.

The New Black Diamond area is 1 to 2 miles west of the central part of Turner Valley and is crossed transversely by Sheep River. The structure was formerly thought (*See* G.S.C., Map 1724) to be a faulted anticline, but drilling has revealed that the anticlinal structure which is apparent from the attitude of the Alberta shale ("Benton") exposed along Sheep River is only a superficial structure that in reality is a drag-fold developed above a low-angle fault. The low-angle fault encountered in the wells outcrops west of the Lineham coal seam on Sheep River on the east side of Sec. 2, Tp. 20, Range 3, W. 5th Mer. (Geol. Surv., Map No. 257 A), where the strata have a steep dip taken to indicate a steep westward dip of the fault plane. The crest of the superficial anticline passes through the southeast corner of Sec. 3, Tp. 20, Range 3, and the northwest corner of Sec. 35, Tp. 19, Range 3. The anticlinal structure plunges to the north and on Kew Ridge, Belly River strata are exposed on the strike of the Alberta shale which outcrops along Sheep River. To the west, at the west side of Sec. 34, Tp. 19, Range 3, on Sheep River, a thrust fault occurs and forms the west boundary of the structure. The strata of the west flank of the anticline have a southwesterly dip of 12 to 25 degrees, but are steeper and contorted close to the fault along the west side of the structure. East of the crest of the anticline the Alberta shales dip 50 degrees northeasterly and there is some indication of minor faulting. The anticline is succeeded eastward by a syncline, exposing gently dipping Belly River strata crossing Sheep River on Sec. 2, Tp. 20, Range 3. A short distance east lies the outcrop of the low-angle thrust fault. So far as can be determined there are no overturned beds on the east flank, which might be expected as the beds were presumably dragged against the low-angle fault.

United Oils of Alberta, Limited, in the early boom days of Turner Valley in 1914, drilled a well on the northeast quarter of Sec. 3, Tp. 20, Range 3. This well began in Upper Alberta shale and was abandoned at 3,090 feet in coal-bearing strata at that time considered to be Kootenay but now thought to be Belly River, the well having passed through the low-angle fault underlying the structure and having encountered Belly River strata beneath the fault plane. The log of this well shows the following stratigraphic succession.

Log of United Oils of Alberta, Limited, No. 1 Well[1]
(Sec. 3, Tp. 20, Range 3, W. 5th Mer.; Elevation, 4,175 feet)

—	Thickness Feet	Depth Feet
Upper Alberta ("Benton") shale		
Blue-grey shale	530	530
Cardium		
Blue-grey shale with conglomerate pebbles	10	540
Blue-grey shale	160	700
Sandy shale and sandstone	50	750
Sandy shale with conglomerate pebbles	30	780
Blue-grey shale, partly sandy	140	920
Blue-grey shale, quartz pebbles	20	940
Lower Alberta ("Benton") shale		
Blue-grey shale with some sandstone horizons and becoming quite arenaceous below 1,080 feet, with chert pebbles recorded at 1,190–1,200 feet and 1,260–1,270 feet, below which blue-grey shale occurs	500	1,440
Top of Blairmore at	....	1,440
Grey and green shale and sandstone with maroon shales, from 1,700 to 1,740 feet, followed by lighter coloured sandstones and greenish shales to 2,596 feet, below which there occurred dark shales at	....	2,970
Fault at	....	2,970
Belly River		
Sandstone with coal at 2,995, 3,005, 3,060, 3,065 (2 feet), 3,085–3,090 (4 feet), and dark shale	....	3,090

[1] Published by permission of United Oils, Ltd.

The Cardium sandstone is represented in the sandstone between 700 and 750 feet. The pebble zones probably represent the upper and lower bands of the Cardium in more westerly sections where the stratigraphic thickness is 350 feet and the Cardium consists of three bands. It is possible, however, that some of the strata here included in the Cardium are lower Alberta shales as the thickness of this formation as shown in the well log is too small.

Two wells, namely, Weymarn New Black Diamond No. 1 on L.S. 1, Sec. 2, Tp. 20, Range 3, and Outwest Petroleums No. 1 on L.S. 5, Sec. 35, Tp. 19, Range 3, were drilled in this area in 1929. The summary of the logs is as follows:

Log of Weymarn Oils New Black Diamond No. 1 Well
(Elevation, 4,054 feet)

—	Feet
Grey shale, Alberta shale ("Benton"). Surface to	2,130
Fault at	2,130
Sandstone and greenish and grey shale with coal at 2,156–2,160, 2,190–2,200, 2,230–2,240, 2,290–2,300, and 2,580–2,590 feet. The colour becomes greener below 2,720 feet and the log shows an alternation of sandstones and shales to bottom of hole at	3,910

The coal apparently belongs to the uppermost part of the Belly River formation which in outcrops shows green shales and sandstones in the central part of the formation.

Log of Outwest Petroleums, Limited, No. 1 Well[1]
(Elevation, 4,150 feet)

—	Thickness Feet	Depth Feet
Upper Alberta ("Benton") shale		
Grey to black shale	290	290
Cardium		
Grey to black shale, chert pebbles	20	310
Grey to black shale	170	480
Sandstone and black shale	30	510
Grey to black shale	20	530
Grey shale, conglomerate pebbles	10	540
Lower Alberta ("Benton") shale		
Grey shale with some sandstone and a bentonite layer at 1,640-1,660 feet	1,380	1,920
Grit	40	1,960
Blairmore		
Green and grey shale and sandstone	120	2,080
Stockmens sand	20	2,100
Green and grey shale and sandstone	160	2,260
McDougall-Segur sand	20	2,280
Green and maroon shale	60	2,340
Greenish and grey sandstone and shale	180	2,520
Fault at	....	2,520
Belly River		
Shale and brown, carbonaceous sandstone	100	2,620
Shale and a little coal	10	2,630
Shale and coal	20	2,650
Shale and sandstone with ironstone. Coal at 2,790 feet	1,080	3,730

[1] Summary from log prepared by J. G. Spratt.

The fault at about 2,520 feet is the low-angled fault underlying the structure and has thrust Blairmore over the uppermost part of the Belly River formation.

Knowing the elevations of the three wells, United No. 1, Outwest, and Weymarn Petroleums, and considering that the fault was penetrated at 2,970, 2,520, and 2,130 feet, respectively, the angle of dip of the fault plane can be calculated to be about 22 degrees and the strike to be north 21 degrees west or 314 degrees magnetic. The strike of the formations in this part of the foothills ranges from north 25 degrees west to north 10 degrees west or 310 to 325 degrees magnetic.

The fact that all three wells passed through the low-angle fault into the upper part of the Belly River formation which outcrops along the east side of the outcrop of the fault suggests that the bedding planes of the strata underlying the fault very nearly parallel the plane of the fault. Above the fault, however, lower stratigraphic horizons are encountered in the more westerly wells than in the more easterly one and, therefore, still lower horizons would be expected in wells located still farther west, although it seems highly improbable that the Palæozoic limestone could be reached within the New Black Diamond structure. If this is true the prospects of the New Black Diamond structure are not favourable so far as production from the Palæozoic limestones is concerned.

The low-angle fault underlying the New Black Diamond structure is, as already mentioned, steep at the outcrop. It can be traced southeasterly and becomes the low-angle fault underlying Highwood area. Its position on Highwood River has not been precisely determined, but is considered to lie in the extremely crumpled zone of Edmonton strata that outcrops on the west side of Sec. 16, Tp. 18, Range 2, and on Bull (Coal) Creek near its junction with Highwood River (Geol. Surv., Canada, Map 257 A, note 3). In a northwest direction from the New Black Diamond structure its extension is somewhat questionable. There is a difference of opinion among geologists as to the validity of the transverse fault shown on Geological Survey maps as crossing Turner Valley from Sec. 16 to Sec. 35, Tp. 20, Range 3, and as offsetting eastwards the New Black Diamond fault (*See* Maps 257 A and 262 A). As already explained the continuation of the New Black Diamond fault may cross Turner Valley from west to east and continue thence along the west flank of the eastern Belly River Ridge in the north end of Turner Valley, and if so this fault may continue for a long distance northwestward. Although this fault has not definitely been traced northwestward it is interesting to note that it lies on the strike of a fault that occurs just east of the Two Pine anticline on Elbow River and that is believed to be a low-angle fault under this structure.

HIGHWOOD-JUMPINGPOUND ANTICLINE

Reference: **Hume, G. S.: Geol. Surv., Canada, Sum. Rept. 1927, pt. B, pp. 1-20; 1929, pt. B, pp. 1-20. Geol. Surv., Canada, Maps 257 A, 258 A, and 261 A to 265 A inclusive.**

The Highwood-Jumpingpound anticline is the major anticlinal feature of the eastern foothills between Highwood River and Jumpingpound Creek. On Highwood River, on Secs. 19 and 20, Tp. 18, Range 2, eastward dipping Belly River strata are exposed. On the same river Belly River strata again occur on Sec. 7, Tp. 18, Range 3, but dip westerly. Thus the major structure is anticlinal, but it is broken by thrust faults into a number of fault blocks some of which exhibit considerable folding. This anticline can be traced from Highwood River for 40 miles in a northwesterly direction to Jumpingpound Creek on the south side of Tp. 24, Range 5. So far as can be told from the study of the surface geology it has not, however, the same structural height throughout and the width varies. The apparent high structural areas may be roughly divided into: (1) Highwood anticlinal area extending from south of Highwood River north as far as Sheep River; (2) Fisher Creek area centring around Fisher Creek in Tp. 21, Range 4, and the Birch Ridge structure extending from Sec. 31, Tp. 21, Range 4, to Sec. 2, Tp. 23, Range 5; and (3) Two Pine anticline lying mainly north of Elbow River, in the east side of Tp. 23, Range 5, and extending to the north end of this township south of Jumpingpound Creek. Low structural areas are: (1) Waite Valley in the southwest corner of Tp. 20, Range 3, and the northeast corner of Tp. 20, Range 4; (2) Elbow River area between the Fisher Creek and Two Pine anticlines.

These high and low structural areas result from marked reversals of direction of plunge along the main anticline and, whereas low stratigraphic horizons are exposed in the high structural areas, higher stratigraphic horizons occur at the surface in the low structural areas. The anticline also narrows northward from Highwood to Elbow River. This is due to the occurrence of several synclines that commence in the northwesterly part of Turner Valley map-area (Map 257 A) and continue northwesterly to merge into a large synclinal area west of the Two Pine anticline (Map

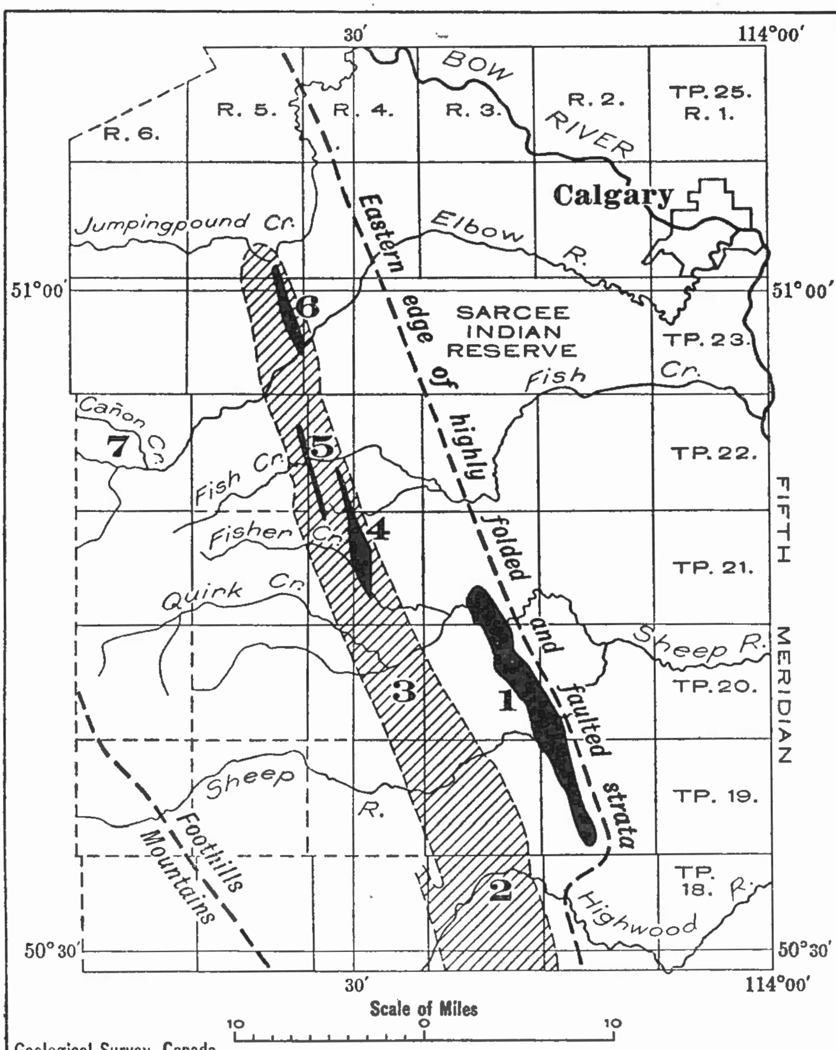

Figure 12. Showing location of Highwood-Jumpingpound anticline (by pattern of ruling) and: 1, Turner Valley area; 2, Highwood area; 3, Waite Valley area; 4, Fisher Creek structure; 5, Birch Ridge structure; 6, Two Pine structure; 7, Moose Mountain area.

258 A). Along the west side of Tp. 24, Range 4, on Jumpingpound Creek, Edmonton strata occur in the central part of this syncline, whereas farther south in Tps. 21 and 22, Range 4, there is a broad belt of faulted Belly River strata lying east of the anticline. The anticline is extensively faulted and folded. Within the high structural areas, i.e., Highwood River, Fisher Creek, Birch Ridge, and Two Pine anticlinal areas, Blairmore strata are exposed, whereas elsewhere Alberta (" Benton ") shales occur over most of the anticlinal area.

HIGHWOOD ANTICLINAL AREA

References: Hume, G. S.: Geol. Surv., Canada, Sum. Rept. 1929, pt. B; Geol. Surv., Canada, Maps 257 A, 261 A.

Within the eastern foothills on Highwood River several fault blocks, mainly dipping westerly and exposing Blairmore rocks, occur. East of the most easterly block, Alberta (" Benton ") shales, Belly River and higher strata occur, mainly dipping east. West of the areas of Blairmore are areas of Alberta shales and Belly River strata dipping westerly. Thus there is, in a general way, an anticlinal structure broken into several fault blocks within which minor faulting and folding occur. It is believed, however, that the whole structure is underlain by a low-angle fault that is the continuation of the New Black Diamond low-angle thrust fault. On Highwood River this fault occurs in the area of intricately folded Edmonton strata in the vicinity of Longview bridge on the west side of Sec. 16, Tp. 18, Range 2. The extreme contortion in proximity to the fault is well illustrated by exposures on the lower part of Bull (Coal) Creek in the east part of Section 8 and the west part of Section 9 in the same township and range. Although it is difficult to locate exactly the outcrop of the major overthrust it is believed that the intricately folded strata occur west of it and that their structures are a resultant of the thrusting along the fault plane which in this locality is relatively close to the surface. Several wells have been drilled in Highwood area, but at a considerable distance west of the outcrop of the major overthrust underlying the structure and for this reason the fault has not been encountered in drilling.

The wells drilled on the Highwood structure are as follows:

Well	L.S.	Sec.	Tp.	Range	Mer.	Depth Feet	Horizon reached
Alberta Associated.......	5	7	16	2	5	2,860	Blairmore
Western Alberta No. 1....	11	7	17	2	5	3,878	Palæozoic limestone
Banner Oils No. 1.........	6	34	17	2	5	630	Alberta shale
H.B. Oil and Gas Co. No. 1.................	8	1	18	3	5	4,087	Palæozoic limestone
Highwood Imperial No. 1[1]	3	36	18	3	5	4,525	Palæozoic limestone
Northwest C and E.......	8	35	18	3	5	3,315	Palæozoic limestone
Warner No. 3[2]...........	3	28	18	3	5	2,800	Blairmore
Cal. Dev. and Prod. No. 1	......	21	19	3	5	5,010	Palæozoic limestone

[1]Highwood Imperial No. 1 well after penetrating a relatively small amount of limestone passed through a fault into higher stratigraphic beds and was abandoned at a depth of 4,525 feet.

[2] Warner Nos. 1 and 2 were abandoned on account of drilling difficulties.

The stratigraphy of this area is shown by the log of Northwest C and E well[1] on L.S. 8, Sec. 35, Tp. 18, Range 3.

—	Thickness Feet	Depth Feet
Drift	30	30
Missing	10	40
Blairmore		
Greenish grey shale and sandstone	50	90
Maroon and green shale	20	110
Greenish grey shale with some sandstone	90	200
Grey sandstone	60	260
Greenish grey shale	150	410
Grey sandstone	10	420
Greenish grey shale	30	450
Coarse sandstone	20	470
Grey shale	50	520
Greenish grey shale with coal 610-620 feet	260	780
Dark grey and greenish shale	170	950
Fine-grained, greenish sandstone and shale	20	970
Sandy shale	20	990
Grey, calcareous sandstone with some ironstone	50	1,040
Missing	40	1,080
Grey sandstone	30	1,110
Dark grey shale	10	1,120
Light grey sandstone	60	1,180
Dark grey shale	30	1,210
Grey sandstone	10	1,220
Dark grey shale and ironstone	110	1,330
White, siliceous sandstone and calcareous sandstone "Crooked hole sandstone"?	50	1,380
Grey, calcareous shale with lime fragments	70	1,450
Light grey sandstone	60	1,510
Sandy, light grey shale	95	1,605
Calcareous, light grey sandstone	25	1,630
Calcareous, sandy shale	35	1,665
Black shale with lime bands	30	1,695
Fine-grained, calcareous sandstone	35	1,730
Dark grey shale	20	1,750
Light grey, calcareous sandstone	10	1,760
Black shale	20	1,780
Shales with brown, calcareous fragments (fossils)	5	1,785
Black and grey shale with sandstone	30	1,815
Calcareous, black shale with pyrites	20	1,835
Dark grey to black shale	45	1,880
Coarse, dark sandstone with dark shale	25	1,905
Dark grey, calcareous shale and sandstone	25	1,930
White, quartzitic sandstone and dark shale	10	1,940
Dark grey sandstone with dark shale	20	1,960
Conglomeratic, coarse grey sandstone	5	1,965
Dark grey, sandy shale	5	1,970
Coarse and conglomeratic sandstone	10	1,980
Kootenay		
Sandstone and dark, carbonaceous shale	5	1,985
Black and brownish shale	10	1,995
Black and grey shale and fine-grained sandstone	15	2,010
Black shale, micaceous and carbonaceous	35	2,045
Brown sandstone with shale	10	2,055
This is the approximate base of the Kootenay		
Fernie		
Brown, granular sandstone with some glauconite	55	2,110
This is the "brown sand"		
Very coarse, conglomeratic, grey sandstone	10	2,120
Granular, brown sandstone, glauconite	35	2,155
Shaly sandstone and brownish to black shale	5	2,160
Grey to black shale with pyrites and glauconites	60	2,220
Grey and black shale, pyrites, and glauconite abundant from 2,235-2,250 feet	55	2,275

[1] Summary of log compiled by J. G. Spratt. Published by permission of Imperial Oil Co., Ltd.

—	Thickness Feet	Depth Feet
Fernie—Conc.		
Dark shale with glauconite 2,285–2,295 feet	35	2,310
Brown limestone band and dark shale	10	2,320
Dark shale—belemnites at 2,360 feet	130	2,450
Buff limestone and sandy shale	20	2,470
Black shale with shaly limestone fragments	24	2,494
This is approximately the base of the Fernie and the top of the Palæozoic limestone.		
Palæozoic		
Light brown to grey limestone	26	2,520
Dark grey limestone	10	2,530
Light buff limestone with chert	15	2,545
Light grey limestone	45	2,590

A small amount of oil was encountered at 2,535 feet, but not in sufficient quantity to be of commercial value.

FISHER CREEK STRUCTURE

References: Hume, G. S.: Geol. Surv., Canada, Sum. Rept. 1929, pt. B; 1931, pt. B; Maps 258 A, 263 A, 264 A, Blue print on scale 10 inches = 1 mile (1931).

The Fisher Creek structure lies 12 miles west and slightly north of the north end of Turner Valley in Tp. 21, Range 4, W. 5th Mer. Within it is a large area of Blairmore strata and on the east side of Fisher Mountain a small area of Kootenay strata comprising the oldest rocks anywhere exposed on the Highwood-Jumpingpound anticline. The topography of the area is rather rugged for this part of the foothills, Fisher Mountain having an elevation of 5,000 feet and rising nearly 700 feet above the adjoining valleys. This topography results from differential erosion, the high hills within the area being capped by the harder and more resistant strata which in this particular area are mainly Blairmore sandstones.

The structure is bounded on the east by an overthrust fault which at its maximum displacement thrusts Kootenay strata eastwards onto Alberta ("Benton") shales, thus indicating a stratigraphic break of possibly as much as 2,500 feet. It is suspected that the Alberta ("Benton") shales east of the fault have a west dip only slightly greater than the dip of the fault plane, and as in the case of other faults of this type, that is, faults that approach bedding plane faults, the total displacement along the fault is probably many times the stratigraphic displacement. Within the structure are a number of eastward dipping faults along which the west sides have moved downward relative to the east sides. If, as assumed, the pressure causing these faults is from the west, the faults are underthrusts. The underthrusts probably originate where the underlying overthrust changes from a fairly steep dipping fault at and near the surface to a fault with a much lower dip at depth. West of the underthrusts are a number of overthrusts that are assumed to be steep dipping throughout and to join the main overthrust at depth. These faults break the structure into a series of fault blocks, but in nearly every case the displacement along these faults is relatively small, that is, never more than a few hundred feet. The dip of the strata in the Fisher Creek structure is more gentle than in some other foothills structures of a similar type and on the west side, where Alberta shales overlie the Blairmore, the dip averages 50 to 55 degrees.

One well drilled by Cottonbelt Mining Company on Sec. 21, Tp. 21, Range 4, has tested this structure. The log of this well is as follows:

—	Thickness Feet	Depth Feet
Surface materials	80	80
Blairmore		
Greenish grey sandstone	60	140
Green and dark grey shale with traces of maroon shale	10	150
Sandstone and greenish shale	10	160
Greenish shale with sandstone. Water reported at 201 feet. Drilling difficulties resulted in this well and the derrick was skidded 10 feet and a new hole started	80	240
Greenish grey shale and shaly sandstone	100	340
Sandstone carrying water at 345 feet	20	360
Greenish grey shale	80	440
Light green-grey shale	50	490
Light grey sandstone with artesian water at 485 feet	50	540
Green-grey shale	60	600
Light grey sandstone and sandy shale	70	670
Light grey sandstone with some shale	80	750
Greenish grey, sandy shale	290	1,040
Grey sandstone with some shale	20	1,060
Greenish grey shale	100	1,160
Grey sandstone and shale	20	1,180
Greenish grey shale	160	1,340
Green sandstone and shale	50	1,390
Greenish grey shale	10	1,400
Dark brownish shale	10	1,410
Dark grey shale	50	1,460
Yellow, siliceous sandstone	10	1,470
Dark grey shale	20	1,490
Siliceous, white and yellowish sandstone	2	1,492
Dark grey shale and sandstone	5	1,497
White, siliceous sandstone underlain by coal. This is the "Crooked hole sandstone." It probably begins at 1,493 feet	5	1,502
Dark, sandy shale, partly calcareous	50	1,552
Grey sandstone, calcareous	25	1,577
Dark, sandy shale becoming brownish	40	1,617
Brownish, limy bands and shales	25	1,642
Dark to brownish shales, calcareous	105	1,747
Grey sandstone with brownish shales, limy	60	1,807
Black shales, calcareous	10	1,817
Dark grey to brownish, siliceous and calcareous shales	350	2,167
Brown, siliceous limestone and calcareous sandstone	70	2,237
White, siliceous sandstone	28	2,265
Kootenay		
Coal and coaly shales	22	2,287
Brownish black shales	40	2,327
Coal, and coaly shales	20	2,347
Brown shales	20	2,367
Coal, and coaly shale	10	2,377
Brown shales	20	2,397
Grey sandstone and brown shales	20	2,417
Brownish, sandy shales	143	2,560
Brown and black shale and coal	10	2,570
Coal, and black, carbonaceous shale	70	2,640
Black shale and coal	40	2,680
Fault		

—	Thickness Feet	Depth Feet
Belly River		
Grey sandstone and dark shale	10	2,690
Dark greenish shale and sandstone	40	2,730
Light grey sandstone and dark greenish shale	20	2,750
Dark greenish shale and sandstone	50	2,800
Light grey sandstone and greenish shale	30	2,830
Dark greenish shale	50	2,880
Light grey sandstone and greenish shale	10	2,890
Dark green, sandy shale and sandstone	50	2,940
Dark greenish shale	60	3,000
Light grey sandstone and greenish shale	70	3,070

As is shown by the log the Cottonbelt No. 1 well encountered a fault at about 2,680 feet, at which depth Kootenay strata are overthrust onto Belly River sandstones and shales. This fault is apparently a low-angle fault underlying the structure. It is inferred to occur on the east side of the structure in Secs. 15 and 22, Tp. 21, Range 4, W. 5th Mer., but is not the northwestward continuation of the low-angle fault assumed to be present under Highwood area. The Fisher Creek structure must, therefore, be regarded as a slice overlying the main Highwood-Jumpingpound structure, below which the limestone must be at a relatively great depth. As already stated, Kootenay strata occur on the east side of Fisher Creek area, above the outcrop of the low-angle fault. As no horizons lower than Kootenay were encountered in the well it is very probable that the fault follows this horizon for some distance and hence the occurrence at any point in the structure of Palæozoic limestone above the low-angle fault is unlikely. This conclusion, if true, completely eliminates the Fisher Creek structure as a possible producer of oil and gas, since productive horizons are not contained in the favourable surface structure.

BIRCH RIDGE STRUCTURE

References: Hume, G. S.: Geol. Surv., Canada, Sum. Repts. 1931 and 1932, pt. B. Geol. Surv., Canada, Maps 258 A, 264 A, and 265 A.

The Birch Ridge structure is a westward dipping fault block. It is named from a prominent hill included in the area and known locally as Birch Ridge. The centre of the structure exposes Blairmore strata that can be traced from south of Whisky Creek in Sec. 31, Tp. 21, Range 4, almost to Elbow River in Sec. 2, Tp. 23, Range 5. As a result of detailed work carried out in 1932 some corrections to Maps 258 A and 265 A are necessary. These maps show the Blairmore extending only to Sec. 25, Tp. 22, Range 5, but owing to an error of identification of one outcrop it is now known that this Blairmore area extends about 1 mile farther north. The Blairmore strata of the Birch Ridge structure are bounded on the east side by a thrust fault along which they are overthrust onto Alberta ("Benton") shales at about the horizon of the Cardium sandstone. As the strata close to the fault have a steep dip it is assumed that the dip of the fault plane is also steep and there is no evidence to show that this condition changes at depth. It was formerly thought that this fault died out along a northwest direction and passed into a simple anticline as shown on Map 265 A. The re-interpretation of the north end of the structure, where there are few outcrops except on Elbow River, indicates that the fault persists at least as far north as Elbow River and that the anticlinal structure shown by the Cardium band on Map 265 A is east of the fault which here thrusts Lower Alberta shales against the anticline. The plunge of the Birch Ridge structure at the north end is indicated by an outcrop of Blairmore east of the centre of Section 2 and the outcrop of Lower Alberta shales on Elbow River farther north along the strike.

The only well drilled on the Birch Ridge structure is that of Elbow Oils, Limited, on Sec. 35, Tp. 22, Range 5. This well was drilled on the west flank of the structure and apparently encountered some faulting in the Lower Alberta shales as the top of the Blairmore was not reached until a depth of 2,220 feet had been made. There is no evidence to indicate any other faults between the top of the Blairmore and the top of the Palæozoic limestone and hence the Elbow well when completed will be a test of the Birch Ridge structure. In the south part of the structure it is believed the Lower Alberta shales are unfaulted and hence slightly less drilling depths would be required than at the Elbow well. In the south end of the structure there is one gas seepage issuing from a spring in the Lower Alberta shales.

TWO PINE ANTICLINE

References: Hume, G. S.: Geol. Surv., Canada, Sum. Rept. 1927, pt. B.; 1931, pt. B. Geol. Surv., Canada, Maps 258 A, 265 A.

The Two Pine anticline lies between Elbow River at Bragg Creek post office and Jumpingpound Creek. It is 4½ miles long and 1 mile wide. Blairmore strata outcrop over the axial part of the anticline where, as in the Fisher Creek structure, certain, hard, sandstone beds that relatively are more resistant to erosion than the surrounding strata form hills and ridges rising to a maximum elevation of 5,000 feet and giving a relief of several hundreds of feet. The anticlinal nature of the fold is well shown on Elbow River where the Blairmore is bounded on the east and west by Lower Alberta ("Benton") shales dipping, respectively, east and west. East of the structure, Upper Alberta ("Benton") shales are thrust along a major overthrust fault onto strata that are Edmonton or belong to the top of the Belly River formation. This fault, like the fault east of the Fisher Creek structure, is apparently steeply dipping at the surface, since its outcrop seems to follow a fairly straight line regardless of topography. It is suspected, however, that as there is a wide zone of disturbed strata with many repetitions of the Cardium band, to the west of the fault outcrop, and as there are a number of underthrust faults within the structure, that the major overthrust changes to a less steeply inclined fault at depth. As has been previously pointed out (Hume, 1932, page 53 B) the underthrusts are thought to originate in the zone of maximum concavity of the major overthrust and either to join or to die out before reaching it. Other overthrusts occur in the Two Pine anticline, but these are considered to be steeply inclined throughout and to be subsidiary to, and to join, the main overthrust at depth. The strata within the Two Pine anticline are more steeply inclined than in the Fisher Creek structure, a condition that appears to be due to more severe compression. Three wells were drilled in the vicinity of the Two Pine structure in 1914, but none of these reached a depth sufficient to give conclusive results, although "shows" of oil were reported. Recent activities have centred around the drilling of Graystone No. 1 (Signal Hill No. 2) well located on the west flank of the Two Pine anticline.

The wells are as follows.

—	Sec.	Tp.	Range	Mer.	Depth Feet	Horizon reached
Moose Mountain No. 1	34	23	5	5	2,410	Blairmore
Moose Mountain No. 2	34	23	5	5	1,350	Alberta shale
Graystone No. 1	34	23	5	5	Drilling	Blairmore

According to Slipper (1921, page 34), Moose Mountain No. 1 well obtained a small quantity of petroleum in upper Blairmore sandstones at a depth of 1,602 feet. The oil had a gravity of 45 to 47 degrees Baumé. The well was torpedoed and as no increase in oil was obtained it was abandoned.

The log of Graystone No. 1 well to the depth reached in 1932 is as follows.

—	Thickness Feet	Depth Feet
Alberta shale		
Dark grey, sandy shale to		685
Dark grey shale, sandstone, and sandy shale with gas reported at 290 to 295, 360 to 370, 530 to 540, 590 to 675, and slight amount of water at 775–800 feet	405	1,090
Dark grey shale with few quartz pebbles	10	1,100
Dark shale with some sandy beds with a little water at 1,235 and an oil show at 1,350 feet	650	1,750
Grit	10	1,760
Blairmore		
Grey sandstone	10	1,770
Mostly grey shale with some sandstone	75	1,845
Greenish and purplish shale and some sandstone	15	1,860
Greenish shale with some sandstone	20	1,880
Light grey sandstone with pyrites	70	1,950
Greenish grey shale	20	1,970
Green and maroon shale	30	2,000
Grey shale	80	2,080
Fine-grained, grey sandstone	10	2,090
Dark grey shale	70	2,160
Fine-grained sandstone and grey shale	20	2,180
Dark green, sandy shale	30	2,210
Greenish grey sandstone and shale	20	2,230
Greenish grey shale with some sandstone	50	2,280
Dark grey sandstone with interbedded shale	50	2,330
Sandy, greenish grey shale	30	2,360
Shaly sandstone	10	2,370

—	Thickness Feet	Depth Feet
Blairmore (Conc.)		
Sandy, greenish grey shale	20	2,390
Greenish grey, shaly sandstone	30	2,420
Fine-grained, grey sandstone	10	2,430
Dark grey, sandy shale, traces of plants	70	2,500
Fine-grained, grey sandstone. Oil reported at 2,520 feet	20	2,520
Dark, carbonaceous shale, badly sheared	20	2,540
Greenish grey shale	30	2,570
Greenish grey sandstone and shales	100	2,670
Dark grey shale with coal	30	2,700
Dark grey shale with some sandstone	100	2,800
Dark, carbonaceous shale	10	2,810
Grey, fine-grained sandstone	30	2,840
Black, carbonaceous shale with coal	40	2,880
Fine-grained sandstone	60	2,940
Dark shale with a little coal	20	2,960
Missing	70	3,030
Dark grey shale with some sandstone	100	3,130
Grey, fine-grained sandstone	30	3,160
Dark grey shale with sandstone	20	3,180
Grey sandstone with shale	30	3,210
Grey to greenish shale and sandstone	110	3,320
Grey, fine-grained sandstone	80	3,400
Grey sandstone and shale	90	3,490
Dark grey, sandy shale	60	3,550
Dary grey, shaly sandstone	40	3,590
Dark grey shale with some sandstone	130	3,720
Grey, calcareous sandstone	40	3,760
Grey to black shale	135	3,895
Sandy, brown limestone	10	3,905
Grey, sandy shale and limy sandstone	5	3,910
Dark shale, partly calcareous	70	3,980
Brownish, limy sandstone and sandy limestone	30	4,010
Dark shale, sandy and calcareous	60	4,070

Some gas was encountered in this well in the Alberta shales and small amounts of oil were reported from the Blairmore at depths of 1,350, 3,905, and 4,120 feet.

WAITE VALLEY STRUCTURE

References: Hume, G. S.: Geol. Surv., Canada, Sum. Rept. 1929, pt. B; Geol. Surv., Canada, Maps 257 A and 262 A.

Waite Valley lies north of Sheep River and south of Fisher Creek area in Tp. 20, Ranges 3 and 4, W. 5th Mer. It is low topographically because it is mainly underlain by Alberta ("Benton") shales which are much more easily eroded than the Blairmore strata that outcrop in Fisher Creek area to the north and in the hills north and south of Highwood River to the south. The strata underlying Waite Valley, although anticlinal, form in reality a low, structural area into which the strata plunge downwards at the two ends. A tongue of Blairmore projects northwards from the south end and extends as far north as Sec. 6, Tp. 20, Range 3, in which section the Innerfold well was commenced. A narrow strip of Blairmore also occurs in the west part of Waite Valley south of Quirk Creek (*See* Map 262 A).

The following wells have been drilled in Waite Valley:

—	L.S.	Sec.	Tp.	Range	Mer.	Depth Feet	Horizon reached
Brock No. 1	2	35	20	3	5	3,712	Alberta shale
Richfield No. 1	4	25	20	3	5	4,765	Blairmore
Gibraltar No. 1	4	18	20	3	5	1,400	Alberta shale
Innerfold No. 1	2	6	20	3	5	4,295	Blairmore
Angus No. 1	5	33	19	3	5	3,100	Blairmore
Anglo-Pacific	4	27	19	3	5	495	Alberta shale

The log[1] of the Richfield well is as follows:

—	Thickness Feet	Depth Feet
No samples	....	40
Cardium		
Grey, fine-grained sandstone and chert pebbles	40	80
Sandy shale	70	150
Grey sandstone—chert pebbles	70	220
Lower Alberta ("Benton") shale		
Grey to black shale, in part sandy, with glauconite at 3,190 feet	3,250	3,470
Grit bed at	....	3,470
Blairmore		
Grey, sandy shale and sandstone	70	3,540
Medium-grained, grey sandstone	10	3,550
Grey to green shale, in part sandy	80	3,630
Green and maroon shale	50	3,680
Light grey sandstone with some shale	70	3,750
Dark greenish grey shale	80	3,830
Medium-grained, grey sandstone	60	3,890
Green and maroon shale	50	3,960
Light green shale	40	4,000
Greenish grey sandstone	100	4,100
Dark grey, sandy shale, trace of maroon shale	120	4,220
Medium-grained, grey sandstone	20	4,240
Greenish grey shale	40	4,280
Greenish and maroon shale	160	4,440
Dark greenish grey shale	95	4,535
Light grey sandstone with maroon and green shale	5	4,540
Light grey sandstone	20	4,560
Light greenish and maroon shale	120	4,680

[1] Published by permission of Richfield Oil Company, Ltd. Summary of log compiled by J. G. Spratt.

OIL PROSPECTS OF THE HIGHWOOD-JUMPINGPOUND ANTICLINE

Oil and gas seepages occur at many places on the Highwood-Jumpingpound anticline and considerable volumes of gas with some oil have been found in a number of wells drilled. So far, however, only wells drilled within what has here been designated the Highwood anticlinal area have reached the Palæozoic limestone. In these wells, namely, Western Alberta No. 1, Hudson Bay Oil and Gas Company No. 1, Northwest C and E, and

Calgary Development and Production No. 1, shows of oil with some gas were encountered in the Palæozoic, but unfortunately in no well were these large enough to provide commercial production and salt water was present in every case. The wells have demonstrated, however, that at properly selected sites the Palæozoic limestone can be reached at reasonable depths and it is thought that, disappointing as the results have been, there remain untested areas that offer good opportunities for obtaining commercial yields of either gas or oil or both.

The Highwood-Jumpingpound anticline evidently originated as a fold that was later faulted as compression proceeded. It is assumed that oil and gas were generated and began to concentrate in this anticline in the early stages of compression, but it is not known to what extent the concentration had proceeded before faulting occurred. In a fairly broad anticline the concentration of oil and gas might be expected to be relatively imperfect and if such an anticline were faulted it would be expected that each fault block would contain only such gas and oil as was present in it prior to the faulting, because the faults would act as barriers to migration. The result would be, therefore, that subsequent to faulting there would be only a rearrangement of the oil and gas in each fault block; little or no migration from one fault block to an adjoining block would take place. It is possible, therefore, that in the Highwood anticlinal area, where the original anticlinal structure was fairly broad, no fault block so far drilled received a sufficient volume of oil or gas to give commercial production, but did receive sufficient to account for the shows of oil and gas obtained in the wells drilled. Not all of the wells that reached the top of the Palæozoic limestone were, however, located on the crest of the structure in which they were drilled. Certain of these structures were, therefore, not fully tested and may contain oil in commercial quantities because the shows of oil were of a very encouraging nature. Other fault blocks may also be worthy of tests but at present it is impossible to reach any definite conclusions regarding them.

If the above deductions in regard to the Highwood anticlinal area are correct it would be inferred that narrower parts of the Highwood-Jumpingpound anticline where concentration may have been more complete prior to faulting, offer still more favourable prospects. The Highwood-Jumpingpound anticline narrows northwestward and within this part are high, structural areas. Some of these may, however, be only superficial structures, as drilling has proved to be the case in Fisher Creek area where, although the surface structure is high, it is cut off at depth by a low-angle fault passing above the Palæozoic limestone. The Two Pine anticline north of Elbow River is, so far as can be told, structurally similar to the Fisher Creek structure and its value will depend on whether areas of Palæozoic limestone are present above the low-angle fault which undoubtedly underlies it. The Birch Ridge structure, also structurally high at the surface, is, so far as known, different from the Fisher Creek and Two Pine structures in that there is no evidence that it is underlain by a shallow, low-angle fault. The Birch Ridge structure is believed, therefore, to be worthy of a test such as is being made by Elbow Oils south of Elbow River. Waite Valley seems to be definitely eliminated as an oil and gas prospect, although the western part where a narrow strip of Blairmore outcrops may be worthy of serious consideration should other more favourably situated parts of the Highwood-Jumpingpound anticline prove productive.

At numerous places throughout the Highwood-Jumpingpound anticline seepages of gas and oil occur. In most of these cases the gas and oil can be definitely traced to either the Lower Alberta (" Benton ") shales or to the Blairmore formation. As there are some very bituminous, black shales in the lower part of the Lower Alberta shales some of this gas and oil may have been derived from this source. But this can hardly be true for seepages that issue from the Blairmore formation such as the large gas flows on Bull (Coal) Creek in the Highwood anticlinal area, the oil shows from the Blairmore formation on Highwood River, and the large gas seep from a Blairmore anticline in the north part of the Two Pine structure. The non-marine beds of the Blairmore formation can scarcely be regarded as probable sources of either oil or gas and the more likely source is Jurassic or Palæozoic beds. The seepages are regarded, therefore, as indicating that large concentrations of oil and gas may be present in Jurassic or Palæozoic strata where structural conditions are favourable, porous reservoir rocks exist, and the cover is sufficiently thick.

JUMPINGPOUND ANTICLINE

Reference: Hume, G. S.: Geol. Surv., Canada, Map 277 A.

The Jumpingpound anticline, locality 11, Figure 8, lies on the eastern edge of the foothills south of Bow River in Tps. 24 and 25, Ranges 4 and 5. Jumpingpound Creek enters the anticlinal area from the southwest and flows for a number of miles along the strike passing eastward out of the anticlinal area near its north end. The major structural features are believed to be similar to those of Turner Valley. Ridges of Belly River strata border the area as far south as the south boundary of Township 25. South of this there is a wide flat with practically no outcrops other than those exposed along Jumpingpound Creek, but it is presumed the structure continues southeast for some distance but plunging southward. The anticline also plunges northward at the north end with the result that Lower Alberta (" Benton ") shales are exposed in the central part of the anticline and are completely surrounded by Upper Alberta shales. The anticline, like that of Turner Valley, is broken by a number of thrust faults and is believed to be underlain by a low-angle thrust fault that outcrops east of the eastern flank of Belly River strata. This low-angle fault may be an extension of the fault that underlies Turner Valley 30 miles to the southeast. The fault continues northwest from the Jumpingpound structure to Bow River, north of which another fault a very short distance east becomes the low-angle fault under the eastern foothills. Two wells drilled by the Imperial Oil Company, Limited, in the Jumpingpound anticlinal area, encountered the low-angle fault. The first, known as Bow River No. 1 well, on Sec. 12, Tp. 25, Range 5, passed through the fault at a surprisingly small depth and in consequence the structure is somewhat difficult to interpret. The second well, Bow River No. 2, on Sec. 31, Tp. 24, Range 4, encountered a small fault that repeated the top of the Blairmore, reached a sandstone that may possibly be the equivalent of the Dalhousie sand at 3,174 feet, passed out of the Fernie at 3,281 feet and there encountered what is presumed to be a low-angle fault below which carbonaceous sandstones and shales of probably Belly River age occurred. The logs[1] of the wells are as follows:

Log of Imperial Jumpingpound Bow River No. 1 Well

—	Thickness Feet	Depth Feet
Drift	70	70
Upper Alberta shale		
Grey and dark shale	170	240
Cardium		
Grey sandstone	70	310
Lower Alberta shale		
Grey and dark shale	1,370	1,680
At 1,680 feet the shales are slickensided and it is believed a fault was encountered.		
Belly River		
Grey sandstone and shale; darker towards the base	1,790	3,470
Upper Alberta shales		
Grey and dark shales	110	3,580
Grey sandstone	50	3,630
Dark and grey shales with glauconite zone 3,700–3,710 feet	1,620	5,250

The well finished in upper Alberta shale without reaching the Cardium sandstone. The glauconite zone at 3,700 to 3,710 feet is very prominent in the upper part of the Upper Alberta shales on Ghost River.

Log of Imperial Jumpingpound-Bow River No. 2 Well
(L.S. 11, Sec. 31, Tp. 24, Range 4, W. 5th Mer.)

—	Thickness Feet	Depth Feet
Lower Alberta shales		
Grey to dark shales with some sandstones	420	420
Grit mixed with dark shale	10	430
Blairmore		
Sandy shale	20	450
Coarse, grey, and fine sandstone	30	480
Dark grey to green shale	10	490
Maroon and greenish shales	10	500
Greenish grey shales	20	520
Grey sandstone	30	550
Light green and grey shale	50	600
Greenish grey sandstone	20	620
Greenish grey shale	20	640
Dark grey shale	10	650
Grey sandstone	60	710
Missing—(fault)	10	720

[1] Published by permission of Imperial Oil Co., Ltd.

Log of Imperial Jumpingpound-Bow River No. 2 Well (L.S. 11, Sec. 31, Tp. 24, Range 4, W. 5th Mer.)—*Concluded*

—	Thickness Feet	Depth Feet
Lower Alberta shales		
Grey shales	50	770
Grit	10	780
Blairmore		
Dark grey to green shale, sandy	30	810
Maroon and greenish shales	10	820
Dark grey and green shale	10	830
Grey sandstone	30	860
Dark green, pasty, sandy shale	90	950
Grey sandstone	50	1,000
Sandy shale and sandstone	10	1,010
Missing	10	1,020
Grey sandstone	50	1,070
Dark grey shale	20	1,090
Grey sandstone	20	1,110
Grey and green shale, partly sandy	90	1,200
Dark green, sandy shale, trace of maroon shale	40	1,240
Green shale	50	1,290
Green and purple shale	20	1,310
Green and grey shale	250	1,560
Greenish grey shale and shaly sandstone	100	1,660
Greenish grey sandstone	120	1,780
Greenish grey sandstone with coal	10	1,790
Black, carbonaceous shale and coal	30	1,820
Greenish grey sandstone	60	1,880
Sandy, grey shale	10	1,890
Grey sandstone	20	1,910
Dark greenish shale	10	1,920
Sandy, green shale with trace of coal	30	1,950
Greenish grey sandstone	20	2,010
Dark grey to green, sandy shale	140	2,150
Grey sandstone	10	2,160
Dark greenish grey shale	10	2,170
Grey sandstone	20	2,190
Dark greenish grey shale	130	2,320
Dark greenish grey shale with sandstone	20	2,340
Dark greenish grey shale	210	2,550
Greenish grey sandstone	20	2,570
Greenish grey shale	80	2,650
Dark grey shale and brownish lime fragments	3	2,653
Sandy, dark grey shale	83	2,736
Limy, grey sandstone	4	2,740
Light grey, limy sandstone and shale	22	2,762
Grey sandstone	4	2,766
Dark grey, calcareous shale, sandy	48	2,814
Dark grey, calcareous shale and sandstone	71	2,885
Light grey to dark grey sandstone	70	2,955
Dark grey, sandy shale	30	2,985
Dark grey sandstone	15	3,000
Sandy shale and sandstone	74	3,174
Grey sandstone—"Dalhousie sand?"	22	3,196
It is not certain that this is the Dalhousie sand. If so the Kootenay is very thin.		
Kootenay (?)		
Sandy, dark grey shale and sandstone	14	3,210
Fernie		
Brown and dark grey sandstone	42	3,252
Grey sandstone and dark shales	29	3,281
Fault at	....	3,281
Belly River		
Missing	22	3,303
Light grey sandstones, dark shales with carbonaceous materials	221	3,524

Apparently only the west side of the Jumpingpound anticline has any prospective value and this is conditional on the presence of Palæozoic limestone within the anticline. There is still some doubt as to whether in structures of this type any considerable body of Palæozoic limestone is involved in the folding above the low-angle faults. If the rate of dip of the strata as observed at the surface over the western part of the anticlinal area continues in depth, the plane of the low-angle fault would intersect these beds and no Palæozoic limestone could be present except possibly in the form of an isolated mass in the central part of the anticline. If, however, the strata on the west flank sufficiently flatten in dip with depth, continuous beds of Palæozoic limestone could lie above the low-angle fault, especially if the dip of the strata in proximity to the fault were less than the angle of the fault. In such a case the Palæozoic limestone would be in the form of a wedge thickening to the west. Data derived from wells drilled in the foothills in general, appear to indicate that except locally, as for example in proximity to a fault, the surface dips continue in depth and this being so there is a reasonable doubt as to whether Palæozoic limestones are present in the Jumpingpound anticline. It should be noted that the Imperial-Jumpingpound No. 2 well was drilled on a site considered to be exceptionally well chosen for a test and failed to reach Palæozoic limestone.

MORLEY AREA

References: Rutherford, R. L.: Geology along the Bow River, Cochrane and Kananaskis, Alberta; Sci. and Ind. Research Council Report 17, 1927.
Hume, G. S.: Geol. Surv., Canada, Map 277 A.

The village of Morley is on Bow River in the Stoney Indian Reserve. Some drilling has been done in this area, but no production has been secured although "shows" of gas have been encountered in a number of wells. A list of the wells drilled in this area is as follows:

- Wabash Oils, Limited, west of Chiniki Lake
- Gold Coin No. 1, 2 miles east of Ozada Siding
- Gold Coin No. 2, about 1 mile west of Gold Coin No. 1
- Norcon No. 1, about 1 mile east of Ozada Siding
- Melbourne Oils (Reserve Oils) No. 1, close to Bow River about one-half mile east of Morley
- Kamorley, north of Bow River north of the mouth of Kananaskis River.

All these wells except Melbourne Oils No. 1 are on the north end of an anticlinal structure that plunges downward from Moose Mountain where the Palæozoic limestones are exposed. Certain faults are believed to occur and the prospects depend on whether concentrations of oil and gas have formed against these faults and that the faults prevented the oil and gas escaping up the dip to the outcrop of the limestones. The area where drilling has been done has not been investigated by the Geological Survey and hence no opinion regarding the oil and gas prospects can be formed. The Wabash Oils, Limited, well commenced drilling in Blairmore strata, all other wells commenced in the Alberta ("Benton") shales.

The log (Evans, 1930, page 29 B) of the Wabash is as follows.

—	Thickness Feet	Depth Feet
Alluvium	106	106
Blairmore		
Alternating sandstone and siliceous shale; 6-inch coal seam reported at 154 feet	69	175
Coal seam 1 inch thick in shale	1	176
Alternating sandstone and shale; the shale dark grey (sandy) to black, some of it quite carbonaceous. Bedding planes in core samples show low dip, some slickensiding	397	573
Mostly sandstone, some shale, and many bands of black, chert pebble conglomerate. Average diameter of pebbles ¼ to ½ inch	88	661
Kootenay		
Alternating sandstone and shale. Many veinlets of calcite. Shales commonly slickensided. Drag-folds indicated by rapid variation in attitude of bedding in core samples. Coal at the following horizons: 3 feet of coal with thin bands of shale at 835 feet; 27 feet of coal with shale or bone partings at about 889 feet; 7 feet of coal at about 894 feet; 5 feet of coal at about 1,036 feet; 4 feet of coal at about 1,049 feet. A fossil plant at 953 feet determined as "probably Kootenay" by W. A. Bell	599	1,260
Fernie		
Black shale with calcareous bands. Hard, limy shale, some pyrite. Belemnite guards at 1,400 feet	150	1,410
Core samples lacking	40	1,450
Black shale, partly calcareous	30	1,480
Fernie (and, or) pre-Fernie		
Limestone. At 1,480 feet a grey, limestone breccia with chert and pyrite. At 1,630-1,635 feet, brecciated limestone. A gas blow at 1,629 feet. Six inches of gypsum at 1,800 feet. Finely porous limestone at 1,924-1,940 feet. One foot of gypsum at 1,985 feet. One foot of gypsum at 2,018 feet	561	2,041

Norcon No. 1 well commenced drilling in Lower Alberta ("Benton") shales. An oil and gas show was reported at 930 feet and the top of the Blairmore was encountered at 1,135 feet with water at 1,152 feet. Further water was reported at 1,515 feet and a strong gas flow at 1,530 feet, apparently in the equivalents of the McDougall-Segur sands. Red and green shales occurred at 1,584 feet. No work has been done on this well since 1929 and water is flowing from the casing head with a considerable gas flow. It is believed that the area at the Norcon well is cut off by a thrust fault from the main mass of Moose Mountain area and hence the gas concentration may be due to accumulation against this fault.

The Melbourne Oils (Reserve Oils) No. 1 well is in an area of complicated faulting and it is believed that the depth to the limestone would be very great. The structure at the well is not regarded as favourable, since on the strike to the southeast the structure is undoubtedly synclinal (*See* Map 277 A).

Crossing Bow River in the vicinity of Jacob Creek east of Morley and extending northwesterly for several miles is a broad belt of folded and faulted Alberta ("Benton") shales that are anticlinal in structure. On Bow River, at Jacob Creek, is a belt of Lower Alberta shales one-half mile broad and separated from another more easterly band by a zone of highly faulted strata in which there are several repetitions of the Cardium.

The structure as a whole plunges southwards and a few miles south of Bow River Belly River strata appear on the strike. In a northwesterly direction the structure rises and on Ghost River on the strike occurs an area of Blairmore strata. The complete structure north of Ghost River has not been mapped by the Geological Survey and the amount of closure to the north, if any, is unknown.

On Bow River east of the broad belt of Alberta shales, above referred to, is a fault that is suspected to be low-angled. It causes the Alberta shales to be overthrust onto Belly River rocks. This fault is thought to be the same as that which occurs east of the Two Pine anticline where detailed studies indicate that it dips at a low angle. Further proof that it has such an attitude is the somewhat sinuous course followed by the fault north of Bow River. It may be that this fault dips at an even lower angle than many others in the foothills whose presence is known from drilling but whose detection at the surface is very difficult because of their straight, line-like outcrop. It is possible this low-angle fault may underlie the anticlinal structure at Jacob Creek at a very shallow depth and hence prohibit the surface structure from persisting deep enough to embrace the possibly productive oil and gas zone. Further detailed work, however, will be needed in this area before the accurate details of the structure can be determined.

MOOSE MOUNTAIN AREA

Reference: Cairnes, D. D.: Moose Mountain District, Southern Alberta (second edition); Geol. Surv., Canada, Mem. 61, 1914, with map.

Moose Mountain is an anticlinal mountain 3 miles wide and 12 miles long, exposing Palæozoic limestone. Two wells have been drilled in this area as follows:

Moose Dome Oils No. 1, on Canyon Creek in the centre of Moose Mountain
Herron Petroleums No. 1, on the east flank of Moose Mountain on Elbow River about 2 miles east of Canyon Creek.

Moose Dome Oils commenced drilling within the Palæozoic limestone below the zone productive of oil and gas in Turner Valley. The well was entirely within Palæozoic strata and encouraging shows of oil and gas were encountered, but at what stratigraphic positions is unknown. Herron Petroleums No. 1 well commenced in the Blairmore formation near the contact with the Lower Alberta ("Benton") shales. The Palæozoic limestone was encountered at a depth of 2,700 feet.

From Moose Mountain where the Palæozoic limestone is exposed there is an eastward dipping succession of strata including Fernie, Kootenay, Blairmore, Lower and Upper Alberta shales, and Belly River (*See* G.S.C. Map 258 A). There is very little minor folding and only very minor faulting. The dip gradually diminishes eastwards from fairly steep in the Lower Blairmore and Kootenay to as low as 5 to 10 degrees within the Upper Alberta shales. The structure, therefore, provides only a very limited amount of closure in small folds east of the outcrop of the Palæozoic limestone. No production is to be expected from horizons that outcrop in Moose Mountain, even where they lie at a considerable depth in the eastern flank of the structure. It would seem that if any productive horizons occur in the flank of the structure they must be horizons lower than any outcropping in the west and it was in such lower horizons that the shows of oil and gas were encountered in Moose Dome Oils No. 1 well. The log[1] of Herron Petroleums, Limited, No. 1 well is as follows.

—	Thickness Feet	Depth Feet
Blairmore		
Alternating shales and sandstones	90	90
Sandstone with water	10	100
Grey to green-grey shale	10	110
Green and maroon shale	10	120
Dark grey and green shale	140	260
Dark grey, medium-grained sandstone	10	270
Greenish grey shale	20	290
Greenish, fine-grained sandstone	30	320
Grey and green shale	20	340
Green and maroon shale	20	360
Green and grey shale	50	410
Greenish grey, fine-grained sandstone	10	420
Greenish grey shale	20	440
Greenish grey shale with some sandstone	40	480
Greenish and dark grey, fine-grained sandstone	70	550
Greenish and dark grey, medium-grained sandstone	60	610
Dark grey, carbonaceous shale with traces of coal	40	650
Dark grey shale and medium-grained sandstone	10	660
Missing	30	690
Greenish grey shale, sandy	30	720
Greenish grey, shaly sandstone	20	740
Dark grey shale	20	760
Coarse, light grey sandstone—calcareous	20	780
Dark grey shale	20	800
Dark grey shale with coal 810–820 feet	90	890
Greenish grey sandstone	30	920
Missing	70	990
Greenish grey shale	40	1,030
Green-grey sandstone	10	1,040
Dark grey shale with a little calcareous sandstone	20	1,060
Dark grey, slightly calcareous shale	80	1,140
Light grey, coarse sandstone with some shale	10	1,150
Missing	10	1,160
Medium-grained sandstone with some shale	10	1,170
Dark grey shale and some sandstone	20	1,190
Missing	10	1,200
Dark grey shale and some sandstone	10	1,210
Missing	10	1,220
Dark grey shale with slight brown tinge	20	1,240
Missing	20	1,260
Grey, sandy, calcareous shale	10	1,270
Missing	10	1,280
Grey, sandy, calcareous shale	30	1,310
Dark, shaly, calcareous sandstone	70	1,380
Dark grey, slightly sandy shale	20	1,400
Dark, fine-grained, calcareous shale	10	1,410
Dark grey, calcareous sandstone	25	1,435
Dark grey, sandy, and carbonaceous shale	10	1,445
Dark grey, calcareous sandstone	20	1,465
Dark grey, carbonaceous shale	15	1,480

[1] Log compiled from log by J. G. Spratt. Published by permission of Herron Petroleums, Ltd.

—	Thickness Feet	Depth Feet
Blairmore—Conc.		
Dark grey, calcareous sandstone and carbonaceous shale	70	1,550
Dark, sandy shale	45	1,595
Grey, fine-grained sandstone	10	1,605
Dark, shaly, limy sandstone	40	1,645
Fine to medium-grained, limy sandstone	50	1,695
Dark shale	10	1,705
Dark, carbonaceous shale	10	1,715
Dark, sandy shale	70	1,785
Medium to coarse-grained sandstone	40	1,825
Fine-grained sandstone	40	1,865
Dark, carbonaceous shale with a little coal	40	1,905
Dark, shaly sandstone	25	1,930
Conglomerate and sandstone	100	2,030
Kootenay		
Coal	....	2,030
Dark shale, shaly sandstone, partly carbonaceous	70	2,100
Coal	....	2,110
Dark, sandy shale	50	2,150
Dark sandstone	30	2,180
Carbonaceous shale and coal	40	2,220
Missing	20	2,240
Dark grey, sandy shale	50	2,290
Dark, shaly sandstone with coal	20	2,310
Dark to brown, fine-grained sandstone	20	2,330
Brownish grey, shaly sandstone	10	2,340
Fine-grained sandstone and dark shale, a little coal	10	2,350
Dark, sandy shale	15	2,365
Carbonaceous shale, coal, and dark sandstone	30	2,395
Dark, sandy shale	5	2,400
Dark, fine-grained sandstone	10	2,410
Brownish grey sandstone and black, coaly shale	30	2,440
Medium-grained, granular, brown sandstone	70	2,510
Fernie		
Grey to black, micaceous sandstone with pyrites	80	2,590
Grey to black shale with glauconite	10	2,600
Grey to black shale with pyrites	30	2,630
Grey to black shale; belemnites, glauconite, and phosphate nodules	30	2,660
Grey to black shale, partly limy	20	2,680
Missing	10	2,690
Grey to black shale	10	2,700
Palæozoic		
Shaly limestone, brownish grey, crystalline	10	2,710
Shaly limestone	10	2,720
Impure limestone with traces of chert	10	2,730
Finely crystalline limestone	65	2,795
Buff, dense limestone	15	2,810
Grey, calcareous sandstone	10	2,820
Buff, dense limestone	70	2,890
White anhydrite	20	2,910
Dark, dense limestone	35	2,945
White anhydrite	20	2,965
Dark, dense limestone	10	2,975
Dark buff limestone with much anhydrite	10	2,985
Dark grey to buff limestone	100	3,085
Dark grey limestone with anhydrite and pyrite	10	3,095
Dark grey, crystalline limestone	45	3,130
Crystalline limestone, porous at 3,140–3,160 feet	40	3,170
Crystalline limestone, free sulphur at 3,190–3,200 feet	30	3,200
Crystalline limestone, porous at 3,200–3,220 feet and with sulphur impregnation	20	3,220

WILDCAT HILLS ANTICLINE

The Wildcat Hills anticline lies north of Bow River on the eastern edge of the foothills in the south part of Tp. 27, Range 5, W. 5th Mer. It is superficially the same general type of structure as Turner Valley and the Jumpingpound anticline, although much less extensive, being less than ½ mile wide and 1 mile long. The central part of the anticline is occupied by Upper Alberta ("Benton") and is completely surrounded by Belly River rocks that form ridges on the east and west flanks and dip to the east and west respectively. The anticline plunges to the north and south. Apparently it is underlain by a low-angle fault that was encountered in drilling at a fairly shallow depth. The outcrop of this fault is presumably east of the eastern Belly River Ridge and it there dips steeply west. As in the case of the Turner Valley and Jumpingpound anticlines, the Wildcat Hills structure is a superficial drag-fold developed above a low-angle thrust. It offers no prospects of producing any oil or gas.

GHOST RIVER AREA

The so-called Ghost River area lies in Tps. 26 and 27, Range 6, W. 5th Mer., and extends north and south of Ghost River several miles northwest of its junction with Bow River. It is flanked by Belly River strata that show quite variable dips to the east of from 15 to 70 degrees on the east flank and a fairly uniform westward dip of 60 to 65 degrees on the west flank. The central part of the structure is occupied by Upper Alberta ("Benton") shales, the lowest horizons being the Cardium bands which are repeated by faulting. There are many faults within the area that repeat the Upper Alberta shales. In fact the faulting as observed along Ghost River and one tributary from the southwest that joins Ghost River in the southwest corner of Sec. 4, Tp. 27, is so excessive that the structure would seem to have little value as an oil and gas prospect on account of the very deep drilling that would be necessary to reach the Palæozoic limestone. The anticlinal structure is only apparent in the flanking Belly River strata, the Upper Alberta shales of the central part having a west dip except in a very narrow area along the eastern side. This general westerly dipping attitude is presumably due to the faults that have thrust the part of the anticline west of the axis against the extreme eastern flank, and as a result the main eastern part of the anticline within the Alberta shale has been replaced by one or more thrust fault blocks.

Two wells have been drilled on the Ghost River structure. These are the Baymar No. 1 well on L.S. 15, Sec. 5, Tp. 27, Range 6, W. 5th Mer., and the Atlantic-Keystone well on L.S. 1, Sec. 19, Tp. 27, Range 6. The Baymar No. 1 well encountered the Cardium sandstone at 768 feet, drilling ceased at a depth of 850 feet. It is quite apparent from the structure that before the Blairmore could be reached in this well, the Cardium band would be again intersected at least once and perhaps several times. The amount of throw of the thrust faults is unknown, but assuming it to be the minimum, the depth to the Palæozoic limestone would be greater than could be reached by the drill.

The Atlantic-Keystone well encountered Cardium sandstones in the Alberta shales at depths of 245, 890, 1,000, 1,260, 1,680, and 2,480 feet. The structure is somewhat difficult to interpret due to the fact that in this area there are three Cardium bands within a stratigraphic thickness of 350 feet. The interpretation suggested is as follows: Upper Cardium sandstone band at 245 feet repeated by faulting at 890; second sandstone band at 1,000 feet; third sandstone band 1,260 to 1,410 feet. The drilling thickness of the Cardium zone would thus be 540 feet. Since the zone is 350 feet thick, the drilling thickness indicates that the strata dip at an angle of about 50 degrees. Such a dip is in harmony with the observed dips of the strata along Ghost River. The third sandstone band is probably repeated by faulting at 1,680 feet and again at 2,480 feet. The well drilled to a depth of 2,930 feet without reaching the Blairmore.

The log of this well confirms the surface evidence of excessive faulting within the structure and also confirms the opinion that the structure has little value as a gas and oil prospect on account of the extreme depth of the possible productive horizons.

RED DEER FOOTHILLS AREA

Within the foothills along Red Deer River, in Tp. 31, Ranges 9 and 10, W. 5th Mer., is an anticlinal structure discovered by R. J. MacLaren and held at the present time by the Hunter Valley Oil Company, Limited, of which Campbell M. Hunter is president. Where the axis of the anticline is crossed by the river, the Cardium sandstone lies in an arch less than a mile wide, but only 1,800 to 2,000 feet across the strike, with dips of approximately 40 degrees on the east side and 50 degrees on the west side, and with a strong northward plunge across the intervening width of the arch. West of the outcrops of the Cardium zone in the west limb of the anticline is a southwest dipping series of beds of which the youngest belong to the Belly River formation. East of the Cardium zone in the east limb of the anticline the strata dip northeasterly and form the west limb of a gentle syncline in the centre of which basal Belly River beds are exposed. The axis of the syncline lies about 2 miles east of that of the anticline. Both the syncline and the anticline plunge rapidly northward and on James River, 6 miles north on the strike of the anticline, only westward dipping strata occur. For about 3 miles southwest of Red Deer River the anticline remains at about the same level structurally. South of this it begins to open up and Blairmore strata occur in the central part. The eastern flank of the anticline, however, becomes faulted and Blairmore strata are thrust first against the east dipping Cardium on the east side of the structure and farther south against the upper part of the Upper Alberta shales close to their contact with Belly River rocks. From the most northerly exposure of Blairmore to the north fork of Burnt Timber Creek, a distance of 3 miles, lower and lower Blairmore beds outcrop until on Burnt Timber Creek the lime series towards the base of the Blairmore occurs. The eastern part of these Blairmore beds is highly contorted and the eastern flank of the anticline seen farther north is wholly replaced by a fault which, as already stated, thrusts lower Blairmore strata almost in contact with Belly River beds. The rapidity with which this displacement takes place along the fault and in many places the relatively low dip of the beds close to the fault lead to the conclusion that this fault dips west at probably not more than 35 degrees. This relatively low dip to the fault plane also explains the extreme contortion of the Blairmore beds on the east side as observed on both the north and south forks of Burnt Timber and Fallen Timber Creeks, since these beds have been greatly disturbed by the low-angle fault close to the surface under them. From the north fork of Burnt Timber Creek southeast for 18 miles to and beyond the north fork of Ghost River this band of Blairmore strata outcrops. Between the north and main branches of Ghost River, in the northeast part of Township 27, Range 8, only a short distance south of Meadow Creek, this Blairmore band ends in the centre of a complex anticline plunging southward.

To the east of the Cardium anticline above referred to on Red Deer River, and its continuance southeastward in the faulted structure exposing Blairmore strata, lies a syncline in the central part of which Belly River strata occur. This syncline opens southward due to the plunge and on Fallen Timber Creek Belly River strata in it occupy a width of 2½ miles. These Belly River beds are exposed from 1 mile south of Red Deer River to Sec. 20, Tp. 27, Range 7, a distance of nearly 20 miles. South of Section 20 the syncline is plunging northward and disappears. East of the syncline westerly dipping strata occur in the normal sequence, namely, Upper Alberta shales, Cardium bands, Lower Alberta shales, Blairmore, and in certain areas more than 100 feet of Kootenay. The westward dipping sequence, however, is bounded by a low-angled thrust fault which along its outcrop thrusts various horizons of Kootenay, Blairmore, or Alberta shales onto Belly River strata. The lowest stratigraphic horizons exposed above the fault plane occur in the vicinity of and north of Red Deer River where the fault follows a highly sinuous outline and is thought to have a westerly dip of not less than 10, and not more than 25, degrees. To the north on James River, as well as south of Red Deer River, the fault plane may have a somewhat steeper dip since the trace of the fault on the surface there appears to be a fairly straight line.

The prospects for oil and gas occurring in the anticline on Red Deer River where the Hunter Valley well is being drilled are dependent on the structure continuing downwards without encountering the low-angled fault above the prospective productive horizons. There is a possibility production might be found in sands in the Fernie formation, although the most prolific productive horizon in the only foothills field so far developed, namely Turner Valley, is in the upper part of the Palæozoic limestone. The Hunter Valley well commenced drilling in Lower Alberta shales about 50 feet below the Cardium and reached the top of the Blairmore formation at about 1,400 feet. The stratigraphic thickness of the Lower Alberta shales in this area is 1,150 feet, so that it is thought the dip of the strata in the well averaged about 38 degrees. This is due to the northward plunge, although the well started in comparatively flat strata. Below the Lower Alberta shales the Blairmore has a stratigraphic thickness of 1,900 feet which on a dip of 40 degrees would give a drilling thickness of about 2,500 feet, making the base of the Blairmore probably 3,900 to 4,000 feet deep. The thickness of the Kootenay under the Blairmore is unknown. West in the mountains it is not less than 1,600 feet (Evans, 1930, page 33 B). East in the foothills, however, as far as known, it has thinned to at most a few hundred feet. The thickness of the Fernie in this area is also unknown, but the exposed section on Ram River, 100 miles distant, shows 490 feet of strata between the base of the Kootenay and a very porous limestone horizon near the top of the Palæozoic. It seems, therefore, improbable that the Palæozoic limestone at the Hunter Valley well could occur at a less depth than 5,000 feet. At this depth the dip of the low-angled fault becomes a serious consideration because a continuous dip of 10 or even 15 degrees from the fault outcrop to the well site will undoubtedly cut above the top of the Palæozoic limestone, whereas a dip of 25 degrees would cause the fault to be at a depth of more than 8,500 feet. It is possible, also, that the fault steepens from a low-angle fault at the outcrop to a higher angled fault at an unknown distance west of the outcrop. The depth to the fault, therefore, at any place cannot be accurately predicted and the test on this structure is considered to be extremely important in reference to further exploration in this part of the foothills.

At the eastern edge of the foothills lower Belly River sandstones and shales dipping southwestward at gentle angles are overthrust onto highly crumpled and steeply dipping, soft, coal-bearing sandstones and shales of the Edmonton formation. The structural break is exceedingly sharp and the Edmonton beds for some distance east are thrown into gentle folds. On one of these folds Monarch Oil Company, Limited, in 1914-15, drilled a well on Sec. 5, Tp. 32, Range 6, W. 5th Mer., to a depth of 3,560 feet. The sediments encountered in drilling consisted entirely of non-marine sandstones and shales of the Edmonton and Belly River formations and shows of both oil and gas were reported (Slipper, 1921, page 34). In this area the Edmonton and Belly River formations are considered to have a combined thickness of not less than 8,000 feet (Evans, 1930, page 31 B). It is unknown at what horizon in the Edmonton drilling commenced.

West of the main fault at the eastern edge of the foothills, Cartier Majestic Oils, Limited, drilled a well in 1931 on Sec. 36, Tp. 31, Range 7, W. 5th Mer., to a depth of 1,135 feet. The well commenced in basal Belly River beds and continued in strata of this age to the bottom of the hole. Since 1931 the well has been deepened somewhat, but the stratigraphic horizon reached is unknown. It seems probable that before any considerable further depth is made the low-angled fault underlying the eastern foothills will be encountered below which Edmonton beds are likely to occur.

COALSPUR-LOVETT ANTICLINE

Reference: MacKay, B. R.: Geol. Surv., Canada, Map 276 A, Pub. No. 2184.

An anticline extends from Lovett to Coalspur, from Tp. 47, Range 19, to Tp. 49, Range 21, W. 5th Mer. It lies about 1½ miles north of the Lovett-Coalspur branch of the Canadian National Railway. The area is wholly covered by the Brazeau formation (*See* table of formations, page 72) and the dip of the strata on the flanks of the anticline ranges from 20 to 40 degrees. The anticline is, however, faulted along the crest with the north side thrust up in respect to the south side. A 10-foot volcanic ash bed in the Brazeau formation occurs about 6,000 feet above the base of the formation and with the commercial coal seams of the area forms a very reliable horizon marker. It can be traced along the flanks of the anticline which is a fairly broad structure (*See* G.S.C., Map 276 A).

Two wells were drilled in this area by the Imperial Oil Company, Limited. The first well was abandoned on account of mechanical troubles, without having passed through the Brazeau formation. The second well, drilled on L.S. 3, Sec. 3, Tp. 46, Range 21, W. 5th Mer., reached a depth of 4,305 feet and at a depth of 2,810 feet passed through the Brazeau formation into the Wapiabi shales in which the well was completed. The Brazeau sediments consisted of light grey to dark grey sandstones alternating with dark shales. A small amount of coal was encountered at a number of horizons and small shows of gas occurred. The Wapiabi formation, as far as it was penetrated, consisted of dark grey shales. The Bighorn sandstone, which is believed to be the equivalent of the Cardium zone of southern foothills areas, was not reached.

From this information it would appear that on account of the very deep drilling required to reach any possible productive horizons, the Coalspur-Lovett anticline has no present value as a prospect for oil and gas.

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CHAPTER V

SOUTHERN PLAINS OF ALBERTA[1]

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STRATIGRAPHY

The stratigraphy of the plains and foothills has already been outlined in Chapter III. A detailed description of the formations outcropping or met in drilling in southern Alberta is given here (For locations of drilling areas *See* Figure 13).

Palæozoic. The Palæozoic of the southern plains of Alberta has been described by Moore (1931) from well logs. It consists of marine strata of Mississippian, Devonian, and Cambrian age. The age of the pre-Devonian rocks is somewhat questionable, but in the Potlatch well in the Kevin-Sunburst field of Montana it is considered (Romine, 1929, page 791) to be Upper and Middle Cambrian. Only one well in southern Alberta, namely the Commonwealth Milk River well, has reached these older rocks which, according to Moore (1931, page 1153), are buff and buff-brown, crystalline limestones underlying a zone of anhydrite tentatively placed at the base of the Devonian.

A number of wells in Alberta have penetrated strata considered to be Devonian. The division between the Devonian and overlying Carboniferous is placed at a black, bituminous shale (oil-shale) zone which in a number of wells is 10 to 30 feet thick and contains (Moore, 1931, page 1149) *Lingula spatula,* a fossil regarded as indicative of highest Devonian. The oil-shale zone with the underlying strata containing anhydrite have been called the Potlatch anhydrite formation by Perry (1929, page 4), but

[1] Mr. C. S. Evans has co-operated with the writer in the preparation of the data concerning southern Alberta.

this is divided into the Three Forks and Jefferson formations by other geologists (Romine, 1929, page 790). According to Moore (1931, page 22), immediately below the black, bituminous shale zone of the Three Forks formation are 20 feet of hard, dense, grey limestones which in the Eyremore well of the Hudson's Bay Oil and Gas Company lie on 310 feet of pure, pale grey anhydrite. The thickness of this anhydrite zone is quite variable and hence if the bottom of the Three Forks formation is drawn at the base of the anhydrite zone this formation is also quite variable in thickness. Below the Three Forks formation in the Commonwealth Milk River well there are nearly 800 feet of dolomitic limestones, including a basal anhydrite zone. Moore assigns these strata to the Jefferson formation, also of Devonian age.

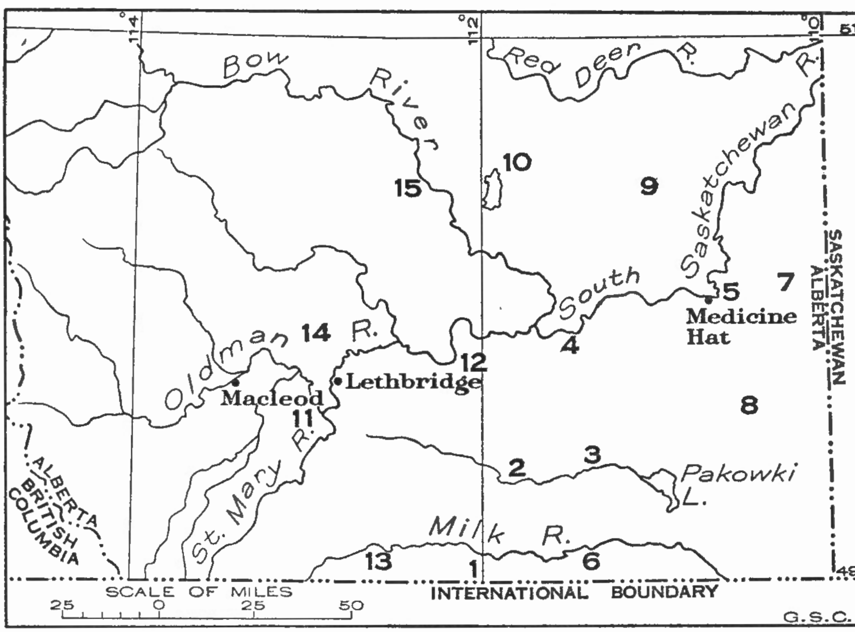

Figure 13. Alberta south of Red Deer River showing locations of areas in southern plains explored by drilling. 1, Red Coulée area; 2, Skiff (Devenish) area; 3, Foremost gas field; 4, Bow Island gas field; 5, Medicine Hat gas field; 6, Milk River area; 7, Many Island Lake area; 8, Cypress Hills area; 9, Suffield area; 10, Brooks area; 11, Blood Indian Reserve-Lethbridge-Spring Coulée area; 12, Taber-Barnwell-Chin Coulée area; 13, Twin River area; 14, Keho Lake area; 15, Eyremore area.

According to Perry the beds immediately overlying the Devonian oil-shale zone consist of shaly and sandy, thin-bedded limestones of Mississippian age. This zone in the Commonwealth Milk River and Erickson Coulée wells is 80 feet thick. It apparently disappears northward and in the Imperial-Burdett well pure limestones rest on the black Devonian shale (Moore, 1931, page 1146). Above the sandy beds in the southern wells and directly succeeding the oil-shale in northern wells is a zone of dark limestones and overlying this a much thicker series of white limestones with some cherty members. According to Moore (1931, page 1145)

"the only variation from the general white crystalline character of the upper part is a red and pink limestone and chert phase that is revealed in Imperial-Burdett No. 1, Roth No. 1, and Drazan No. 1 in the vicinity of the city of Medicine Hat. This zone has sharp upper and lower contacts and ranges in thickness from 250 feet in Imperial-Burdett No. 1 to 370 feet in Roth No. 1 and to 85 feet in Drazan No. 1. Thin phases ranging from a few to 20 feet in thickness in this pink or red zone, are entirely chert."

The thickness of the Mississippian decreases from south to north. In the Commonwealth Milk River well it is approximately 1,100 feet, whereas at Eyremore it is about 750 feet. The thickness, however, is somewhat variable as would be expected since the top of the Mississippian is an erosional surface. Moore also believes there is some thinning in the lower, dark limestone member.

Jurassic. Jurassic strata do not outcrop on the plains of southern Alberta. The following section from Sweet Grass Hills, Montana, has been described by Sanderson (1931, page 1158)

	Thickness Feet
Top of Jurassic	
Black, brown weathering shale	19
Dense, massive, limy, pyritic, black shale with conchoidal fracture and containing Gryphaea and Ammonites	33·5
Fissile, calcareous, light grey shale with a few Gryphaea	24
Black shale with a few thin beds of grey limestone	38·5
Black, fissile shale with beds of grey limestone 4 inches to 1 foot thick	26·5
Dark grey, calcareous shale interbedded with compact, grey, rubbly-weathering limestone at 2 to 4-foot intervals	26·5
Sandy limestone and fissile, grey shale	30·5
Conglomerate with polished, black chert pebbles; coarse sandstone and mud galls	0·5
Fine-grained, thin-bedded, slaby sandstones, laminæ marked by limonitic streaks grey in colour with pinkish tones	42
Siliceous and calcareous sandstone partly oil stained	7·5
Thin-bedded, siliceous limestone alternating with grey and dark grey shales	8·5
Black, massive limestone with corals, bryozoa and ostrea, and other pelecypods	4
Light grey, calcareous shales alternating with dark limestone	12·5
Soft, buff-coloured limestone	2
Fine-grained, siliceous sandstone, grey with pinkish tones. This sandstone is variable in thickness and locally may be absent	30
Total thickness	305·5

These Jurassic strata have been included in the Ellis formation and as the measured section is close to the International Boundary the name Ellis is applied to beds of equivalent age in southern Alberta. In well logs, however, it is not always easy to distinguish the boundary between the Ellis and overlying Lower Cretaceous, nor is it always certain where the division between the Jurassic and the Palæozoic occurs, because of the occurrence of limestones in both the lower Ellis and the Palæozoic beds.

In certain wells in Red Coulée field there are sandy beds at the base of the Ellis and in others, as in the Roth wells at Medicine Hat, there appears to be a well-developed sandstone. At other places, as for example the Eyremore well, the Ellis seems to have lost its typical character and is represented by dark shales with thin limestone bands underlain by sandstones with red, green, and grey shales and chert. In certain Red Coulée wells the base of the Lower Cretaceous appears to be a well-developed sandstone below which are grey, light greenish, and brownish, slightly calcareous shales with glauconite. Glauconite seems to be a particularly characteristic feature of the upper shales of the Ellis and has been noted in many wells in Red Coulée and elsewhere, as for example Commonwealth-Milk River and Erickson Coulée wells. In certain areas outside of Red Coulée the strata below the well-marked sandstone beds appear to be Lower Cretaceous and the division between the Lower Cretaceous and Ellis cannot be sharply defined.

The Ellis seems to show considerable variation in lithology and thickness from place to place. The varying lithology of the lower part may be due to the fact that the Ellis was deposited on an irregular erosion surface formed of the Palæozoic strata. It is possible that an erosion surface also occurs at the top of the Ellis formation, since in the foothills the Kootenay thins so rapidly in an eastward direction as to make it quite doubtful if any Kootenay occurs in the plains area where Kootenay time thus might have been an interval of non-deposition and erosion.

There is evidence to show that the Sweet Grass Arch was a prominent structural feature in pre-Jurassic time. According to Moore (1931, page 1154) there are in the south higher stratigraphic Madison (Mississippian) beds on the limbs of the arch than over its centre. This condition indicates that prior to the pre-Ellis erosion interval, the pre-Jurassic fold was expressed topographically. Furthermore, as Moore points out, the erosion surface developed on the Palæozoic rises northwards and in that direction successively truncates lower and lower Palæozoic horizons. That is, the pre-Jurassic arch appears to have plunged southward. The continued existence of it on into Jurassic time may account in part at least for the variation in thickness that occurs in the Ellis formation. On the present Sweet Grass Arch the Ellis in Red Coulée field (area 1, Figure 13) has a thickness of about 60 to 80 feet. To the west, at the Parco-Nordon well (area 13, Figure 13) it is about 190 feet. Still farther to the west and slightly north at the Spring Coulée well (area 11, Figure 13) the thickness is 323 feet. To the east of Red Coulée, the Ellis has a thickness of 140 feet in the Erickson Coulée well (area 6, Figure 13). This well is on the central part of the present arch and the increased thickness of the Ellis here as compared with its thickness in the Red Coulée area suggests that the pre-Jurassic arch may have been farther west than the present arch. In the boundary well of southwestern Saskatchewan the Ellis is approximately 220 feet thick, whereas to the north in eastern Alberta in the Eagle Butte No. 2 well (area 8, Figure 13) the thickness is 300 feet and still farther north in the Drazan well at Many Island Lake (area 7, Figure 13) the thickness, according to Dyer, is 253 feet. In the Devenish wells (area 2, Figure 13), north and east of Red Coulée, the thickness of the Ellis is 150 to 175 feet. Farther north a pronounced thinning occurs, as at Taber (area 12, Figure 13) where in the Cole-Hunter well the thickness is only 75± feet, and at Eyremore (area 15, Figure 13), still farther north, only 60 to 80 feet of doubtful Ellis strata are present. To the west of Taber, in the Imperial Texas (area 11, Figure 13) well the thickness of the Ellis is 260 feet and north of this, in the

Keho Lake well, it is 180 feet. Evidently these last two wells are on the west flank of the pre-Jurassic arch. It is not known if the Ellis continues to thicken westward. The evidence shows, however, that the Ellis thins and disappears northward, as none of it has been recognized in wells in Central and eastern Alberta.

Lower Cretaceous. The Lower Cretaceous in the southern foothills of Alberta consists of the Kootenay and Blairmore formations, the latter with local developments of volcanics. Within the foothills, the Kootenay in a very short distance from west to east thins markedly and, therefore, probably does not extend for any great distance eastward under the plains of southern Alberta where all the Lower Cretaceous may be equivalent (Irwin, 1931, page 1132) to the Blairmore formation. In view of the absence of evidence permitting an exact correlation it seems advisable, however, to refer to the strata as being Lower Cretaceous. They are non-marine sediments and, as is to be expected, show considerable variation in thickness and lithology. In Red Coulée (area 1, Figure 13) and Milk River (area 6, Figure 13) areas the Lower Cretaceous strata according to Evans (1931, page 12)

"consist of grey, brownish grey, green, and red shales with thin (a few inches to a few feet) sandstone beds and a heavy sandstone bed at the base. . . . They lie above the Ellis and vary in thickness from 580 feet in the western part of the area (Range 16) to 490 feet in the eastern part (Range 12). In general the upper part is predominately shaly, and it is here that grey and green shales predominate, though some red shale is present in most of the well logs. Sandstone is greater in amount and present in thicker beds in the lower part where it is associated with red shales, though grey, green, and brown shales also occur."

According to Yarwood (1931, page 1167) there are three zones of red shales in Red Coulée area.

"The first of these occurs in places as high in the section as the top of the Blairmore but is not persistent. The second red bed, in like manner, is not persistent and where it does appear the interval between it and the top of the Blairmore is not uniform. This marker occurs at an average depth of 236 feet below the top of the formation but the interval ranges from 180 to 300 feet. The third red bed. . . . has been logged in about 75 per cent of the wells. It occurs at an average depth of 345 feet below the top of the Blairmore and is considered the most important horizon in this part of the section."

The lower part of the Lower Cretaceous in Red Coulée field contains several sandstones. According to Erdmann as reported by Evans (1931, page 22) the lower part in the Border oil field of Montana, just south of and continuous with the Red Coulée field of Alberta, is thought to be as follows:

	Feet	
Gas sand	10 to	45
Variegated shale	40	80
Vanalta sand	5	15
Grey, green, pyritic shale	10	15
Cosmos sandstone	30	40

"The gas sand is commonly regarded as the counterpart of the Sunburst sand in the Kevin-Sunburst field, but it probably occupies a slightly higher stratigraphic horizon. The variegated shale is regarded as the westward expansion of the 'yellow shale' horizon of the Kevin-Sunburst field. The Vanalta and Cosmos sandstones occupy the horizon of the 'laminated sandstones' of the Kevin-Sunburst field."

The thickness, as penetrated by various wells, of strata believed to be Lower Cretaceous, is given in the following table.

Area No. (Figure 13)	Well	L.S.	Sec.	Tp.	Range	Mer.	Thickness Feet	Remarks
15	Eyremore...........	1	26	17	18	4	410	
14	Keho Lake...........	2	17	11	22	4	550	
12	Cole-Hunter, Taber..	3	11	10	17	4	400	
6	Commonwealth "Milk River"......	3	9	3	15	4	430	
11	Spring Coulée........	11	15	4	23	4	675	
13	Parco-Nordon........	16	34	1	20	4	610	
1	Vanalta No. 1........	3	4	1	16	4	537	Not drilled through
1	Vanalta No. 2........	3	4	1	16	4	530	" "
1	Vanalta No. 3........	3	4	1	16	4	545	" "
1	Alta. Pac. Con. "Red Coulée"...........	2	4	1	16	4	540	" "
1	Southern Alta. Exp..	8	3	1	16	4	519	" "
1	Commonwealth "Red Coulée".....	10	3	1	16	4	573	
1	Celtic...............	4	17	1	16	4	540	
1	Scottish United......	1	3	1	16	4	553	" "
1	Urban..............	2	4	1	15	4	500	
6	Erickson Coulée......	13	8	1	12	4	490	
6	Range No. 2.........	6	21	1	11	4	380	
2	Devenish No. 1......	5	27	5	14	4	410	
2	Dauntless...........	9	36	6	15	4	420	" "
4	Imperial Burdett.....	......	8	11	11	4	330	
5	Roth and Faurot No. 1...................	SW.	6	13	5	4	250	
8	Eagle Butte No. 2....	4	30	7	3	4	210+	60 feet of samples missing at top
	Boundary...........	4	9	1	27	3	620	Partly missing

The contact of the Lower Cretaceous with the overlying Alberta shales is placed where green or red shale or greenish sandstones give way to overlying, drab-grey shales or grey sandstones. In some wells the grey shales and sandstones are fairly carbonaceous, whereas in other wells little carbonaceous material is found and the beds contain small amounts of glauconite. Since no exposure of the Lower Cretaceous occurs in this area the position of the contact is regarded as being somewhat arbitrary.

Alberta Shale. In the southern plains of Alberta, Upper Cretaceous, grey and dark grey marine shales overlie the Lower Cretaceous and underlie the Milk River sandstone. These shales have as a rule been called Colorado, but in certain areas (Evans, 1931, page 13) it is known that the upper part contains marine Montana fossils. The name Benton, which also has been used to designate these shales, is also not applicable and as the shale group is believed to be a correlative of the Alberta shales of the foothills the name Alberta shales is here used for the plains areas to designate the marine shales of both Colorado and Montana age that lie above Lower Cretaceous and below non-marine Montana beds. McLearn (1929, page 95) states that in the vicinity of Lundbreck in the Crowsnest area "the basal sandstones of the Belly River . . . are followed below by about 80 feet of banded sandstone and shale and by several hundred feet of shale." In the basal part of this shale there occurs a fauna including a species (*Inoceramus lundbreckensis*) that is stated to be very similar to a species found in the basal part of the

Allison farther west. The basal part of the Allison and the basal part of the Belly River in this general district must be the same or nearly the same age. The *Inoceramus lundbreckensis* fauna which McLearn (1929, pages 98 and 106) considers to be Montana in age is " probably close in time to the Eagle fauna " so that it is apparent that the so-called Colorado shale of Crowsnest area contains strata of Montana age, as does the Alberta shale of Turner Valley area where the upper part carries large *Baculites ovatus* of Montana age. Similar large *Baculites ovatus* have been found (Evans, 1931, page 13) in Buckley Coulée, Montana, just south of Coutts, Alberta. It thus seems logical to use the name Alberta shale in the plains areas of southern Alberta.

In the south, in Milk River district, the Alberta shales are overlain by the Milk River (Eagle) sandstone. To the north and east the Milk River disappears and the marine Montana shales at the top of the Alberta shale pass upward into other marine Montana beds called Pakowki, which overlie the Milk River sandstone where it is present. The Alberta shale does not include the strata of Pakowki age and where, as in central Alberta, well samples show a continuous shale series from the top of the Pakowki to the Lower Cretaceous, no formational name is available to designate the whole group. Farther north, in Wainwright-Ribstone area, the Lea Park is at least in part the equivalent of the Pakowki, but here again no lithological division can be made between the Lea Park and underlying shales which presumably are also equivalents of the Alberta shale formation.

The Alberta shales in southern Alberta have been described by Spratt (1931, pages 1171-79). The upper part consists of about 1,200 feet of dark grey shales with bentonite horizons and some thin, very fine-grained sandstone beds. Ironstone and impure limestone horizons are present, presumably in the form of nodular layers. The lower part, about 500 feet thick, consists of dark shales with alternating grey sandstones, particularly toward the base. In southern Alberta, according to Wickenden (1932, page 203), foraminifera occur in the upper part of the Alberta shale in a zone about 200 feet thick and whose upper limit is about 300 feet below the top of the formation. Two species, namely, *Clavulina* sp. and *Bullopora leavis*, occur in an horizon about 420 feet below the top of the Alberta shale and this zone can be used for correlation purposes. The two species have been found in wells as far west as Lethbridge and as far east as Skiff but are not known to be present in eastern central Alberta or Saskatchewan. They occur in samples from wells in Red Coulée field (Evans, 1931, page 22) as follows.

Well	L.S.	Sec.	Tp.	Range	Mer.	Depth in well Feet
Top of Bullopora zone						
Alta. Pac. Cons. No. 1	2	4	1	16	4	610
Dalco No. 2	7	19	2	17	4	1,040
Top of Clavulina zone						
Alta. Pac. Cons. No. 1	2	4	1	16	4	640
Southern Alberta Exp. No. 1	8	3	1	16	4	580
Commonwealth "Red Coulée" No. 1	10	3	1	16	4	630
Devonshire No. 1	4	10	1	16	4	580
Dalco No. 2	7	19	2	17	4	1,070

In certain wells small, black chert pebbles or coarse, chert sandstone occur in the lower part of the Alberta shale. The data relating to these occurrences is given in the following table.

Well	L.S.	Sec.	Tp.	Range	Mer.	Depth to chert pebbles Feet	Depth to top Lower Cretaceous Feet	Height of chert pebbles above Lower Cretaceous Feet
Roth No. 2	9	17	13	6	4	2,330	2,705	375
Commonwealth Milk River No. 1	8	9	3	15	4	1,650–80	2,160	510
Erickson Coulée No. 1	13	8	1	12	4	1,350	1,870	520
Parco-Nordon Twin River	16	34	1	20	4	2,560	3,060	500
Keho Lake	2	17	11	22	4	3,770	4,190	420
Eyremore	1	26	17	18	4	3,190	3,540	350
Burdett	......	8	11	11	4	2,010–30 2,070–90	2,500	490
Cole-Hunter "Taber"	3	11	10	17	4	2,220–60	2,720	500
Imperial Texas	14	22	8	22	4	3,240–60	3,715	475
Taylor "Red Coulée" Vanalta No. 3	3	4	1	16	4	1,470	1,960	490
Commonwealth Red Coulée	10	3	1	16	4	1,460	1,980	520
Capitol Red Coulée	3	21	1	16	4	1,550–70 (S.S.)	2,030	480
Vanalta No. 2	3	4	1	16	4	1,380	1,950	570
Scottish United	1	3	1	16	4	1,370	1,880	510
Dalco No. 2	7	19	2	17	4	1,900	?	?

Note. In the Keho Lake well, cherty sandstone occurs at a depth of 3,860 feet and at 1,550 to 1,570 feet in Capitol Red Coulée well.

The occurrence of these pebble zones over such a wide area is very remarkable and indicates very uniform conditions of sedimentation. Although the data given in the above table is not entirely conclusive, it suggests the presence of a pebble zone in the Alberta shale at approximately 500 feet above the top of the Lower Cretaceous. The several occurrences at other heights and the seemingly rather persistent zone at 500 feet are as a whole strongly suggestive of the Cardium zone of the eastern foothills where this zone consists of three conglomeratic and sandstone horizons with a total thickness of 350 feet and marks the base of the Upper Alberta shale. In Turner Valley area of the eastern foothills the Lower Alberta shale is about 850 feet thick. A thinning eastward would be expected.

In certain wells, particularly in Battle River (Wainwright-Ribstone) area in the north, small, smooth chert pebbles occur at or near the base of the Alberta shales. It is probable, however, that this zone is not the same as that occurring 500 feet above the base of the Alberta shale in southern Alberta, but more probably correlates with another zone which shows chert pebbles at or near the contact of the Alberta shale and Lower Cretaceous (*See* logs of Roth No. 2, Ontario Alberta No. 1, Alberta Pacific Consolidated Spring Coulée wells, etc.). According to Evans (1931, page 13) in southern Alberta the upper 200 feet and the lower 600 feet of the Alberta shales are more sandy than the middle part. The lower 600 feet are more sandy than the upper part and contain a fairly persistent sandstone horizon which, according to Spratt (1931, page 1174), occurs 350 to 400 feet above the base and produces gas in Bow Island field. Other sands, carrying water in Red Coulée field, occur near the base of the formation. It was formerly thought that in Medicine Hat field the gas horizon was in the Milk River sandstone. Spratt (1931, page 1179), however, is of the opinion that the productive sandstone is in the upper part of the Alberta shales. He places it 300 feet below the base of the Milk River formation, but Wickenden[1] considers it to be less than 100 feet below this horizon. The difference of opinion is due to the difficulty of recognizing the exact division between the Milk River and Alberta shale formations.

Milk River Formation. In southern Alberta the Milk River formation is the oldest continental deposit of the Upper Cretaceous. It is well developed in Milk River area, from which it obtains its name. It thickens to the west and is apparently the equivalent of the lower part of the Allison formation of the foothills. It is recognizable (Spratt, 1931, page 1178) at least as far north as Bow Island, but loses its identity both to the north and to the east and at Medicine Hat it is thought (Slipper and Hunter, 1931, page 1196) to be only 10 feet thick. It consists of two main divisions known respectively as the Upper and Lower (Virgelle) Milk River. It is overlain by marine Pakowki shales from which it is separated by a thin, chert conglomerate. The Upper Milk River consists (Evans, 1931, page 15)

"for the most part, of shales and sandy shales with several thick (8 to 20 feet) beds of sandstone. The shales and sandy shales are grey, dark grey (usually lignitic), yellowish, and greenish grey. Weathered exposures are characterized by light grey, yellowish grey, black, purplish grey, and brownish bands. The succession varies both in lithology and thickness from place to place but in general is as follows.

	Feet
Pebble bed at base of Pakowki	
Grey and yellowish shales and sandy shales; some bentonite and selenite	20 to 30
Coarse and medium-grained, yellowish sandstone	8 " 24
Shales, carbonaceous and sandy, with thin sandstone beds, and beds and layers of nodules of iron carbonate, and greenish sandstone cemented with iron carbonate. These layers and nodules weather dark brown	45
Medium and coarse-grained, yellowish sandstone	8 " 22
Grey, greenish grey, and dark grey, sandy shales with two to four, thin, lignitic bands	45 " 50
Top of Lower Milk River."	

The Upper Milk River formation, as shown on an isopach map by Slipper and Hunter (1931, page 1193), decreases in thickness from 200 feet west of Lethbridge to zero slightly west of Bow Island.

The Lower Milk River consists (Evans, 1931, page 15)

"of thick (70 to 100 feet), massive, fine to medium sandstone, composed chiefly of quartz grains (with minor black and brown mica) rather loosely cemented with a calcareous and shaly matrix. At its base, the massive sandstone gives way to alternations of sand and shale, and in the well logs the base is usually placed where sand first becomes subordinate to dark shale. . . Towards the top of the Lower Milk River the sandstones are markedly crossbedded and there are many large (up to 10 feet diameter) ovoid concretions of sandstone cemented with ferruginous carbonate, which characteristically form the cappings of ledges and pillars or 'hoodoos'."

[1] Wickenden, R. T. D.: Personal communication.

The thickness of the Milk River as determined in a few wells is as follows.

Well	L.S.	Sec.	Tp.	Range	Mer.	Thickness Feet
Spring Coulée	11	15	4	23	4	530
Parco-Nordon	16	34	1	20	4	490
Keho Lake	2	17	11	22	4	300
Cole Hunter "Taber"	3	11	10	17	4	280
Commonwealth "Milk River"	8	9	3	15	4	420(?)
Devenish No. 1	5	27	5	14	4	295
Range No. 2	6	21	1	11	4	420(?)

The sandstones at the top of the Lower Milk River outcrop on Milk River Ridge, on Sweet Grass Arch. To the north, east, and west they pass under younger strata. Water entering the formation on Milk River ridge provides the water of the artesian basin outlined by Dowling (1916, page 104; 1917, page 79; 1923, page 104).

Pakowki. In southern Alberta the Pakowki formation overlies the Milk River sandstone and underlies the Foremost beds. North of Bow Island where the Milk River is no longer recognizable the Pakowki is not easily distinguished from the underlying Alberta shales. It is a marine formation of shales and sandstone and thickens markedly from west to east. In Milk River district the section is as follows (Slipper and Hunter, 1931, page 1189).

	Thickness Feet
Interbedded, dark, blue-grey shales with fine-grained sandstones	23
Dark, blue-grey shale (some cone in cone calcite near the top)	25
Greenish to grey, fine-grained sandstone	25
Dark, blue-grey shales, sandy shale, and fine-grained sandstone. This horizon varies laterally, the shales and sandstones replacing one another	25
Greenish to grey, fine-grained sandstone	25
Dark, blue-grey, sandy shale	10
Dark, blue-grey shale	40
Dark, blue-grey shale and sandy shale	10
Total thickness	183

. . . "In the eastern part of the plains area the Pakowki is composed almost entirely of shale; in the southwest a sandstone phase occurs near the middle. In localities west of the town of Milk River it is possible that the formation consists entirely of sandstone, this being a further development of the middle sandstone phase."

The thickness of the Pakowki, as measured in wells in various localities, is as follows (Slipper and Hunter, 1931, pages 1189-91).

Locality	Thickness Feet
Milk River ridge	183
Monarch	100
Lethbridge	130
Barnwell	110
Grassy Lake	190
Burdett	195[1]
Foremost	220
Medicine Hat	290

[1] Approximate.

The westward thinning of the formation is indicated by the fact that only 40 feet of strata equivalent to the Pakowki occur in the Spring Coulée well (Yarwood, 1931, page 1266).

In some localities the base of the Pakowki is marked by a fine chert conglomerate and in certain areas the top part contains sandy shale with thin, coaly, and carbonaceous shale layers.

Foremost Beds. In southern Alberta a series of brackish water beds overlying the marine Pakowki formation are known as the Foremost beds. On Oldman River the top of the formation is placed at the Taber coal seam, but according to Dowling (1917, page 37) this seam occupies a higher place in the series in the west than it does in the east. To the west and northwest of Taber it loses its identity, passing into a coal series 100 feet thick (Slipper and Hunter, 1931, page 1185). To the southwest the base of the overlying Pale Beds is marked by a massive, buff-weathering sandstone and where this or the Taber coal seam can be recognized the division between the Pale and Foremost Beds is readily made, but elsewhere the division is somewhat arbitrary. There is a general difference, however, in that the Foremost consists of darker beds than occur in the overlying Pale Beds, the name of which indicates the lighter colour of the sediments included in it. The base of the Foremost is marked (Slipper and Hunter, 1931, page 1186) by a very persistent sandstone which on account of its good outcrops on Verdigris Coulée has been named the Verdigris sandstone. The base of this member, however, is not sharply marked, but instead the sandstone grades downward into the marine Pakowki shales. This sandstone is not recognizable at Medicine Hat, Lethbridge, and elsewhere (Slipper and Hunter, 1931, page 1186), but in general is more prominent in the south and southwest where it has the greatest thickness. The Foremost consists of lenticular beds mostly of dark grey shales and sandstones. Ostrea beds are very prominent in some sections in the central part of the formation (Slipper and Hunter, 1931, page 1185), but they too are lenticular. A coal zone known as the McKay coal horizon, in the lower part of the formation, is commonly accompanied by prominent seams of bentonite (Powers, 1931, page 1209). A generalized section of the Foremost beds is as follows (Slipper and Hunter, 1931, page 1183).

	Feet
Carbonaceous shale, coal seams, and ferruginous limestone (Taber coal horizon)	100
Sandstones and shales in thicker units than below	120
Thinly bedded, carbonaceous shales, sandstones, sandy shales, ferruginous limestones, and ostrea beds	100
Colloidal clays and coal seams (McKay coal horizon) and sandstones	60
Basal sandstone (Verdigris sandstone)	60
Total thickness	440

The thickness of the Foremost formation at various localities is given in the following table.

	Thickness Feet
Milk River Ridge (Hake and Addison, 1931, page 1219)	350
Lethbridge (Imperial-Texas well) (Powers, 1931, pages 1204-6)..	410
Monarch (Powers, 1931, pages 1204-6)	395
Keho Lake (" " ")	390
Champion (" " ")	400
Eyremore (" " ")	420
Taber (Hake and Addison, 1931, page 1219)	326
Brooks (Powers, 1931, pages 1204-6)	375
Medicine Hat (Williams and Dyer, 1930, page 29)	350

Pale Beds. The Pale Beds overlie the Foremost. The base, particularly in the southwestern part of the southern plains, is a fairly persistent sandstone. At the top of the formation is a series of coal measures (Link and Childerhose, 1931, pages 1229-30) in which there are four seams of coal, three of which range from 6 inches to 2 feet in thickness and the fourth is 4 to 7 feet thick and is the main commercial seam of the area. Above the uppermost seam of coal is an *Ostrea coquina* bed a few inches to 3 feet thick, but not present everywhere. Above it are a few feet of grey shales or sandy shales overlain by a brown, ferruginous sandstone 8 inches to 2 feet thick and regarded by Link (Link and Childerhose, 1931, page 1229) as forming the top of the Pale Beds.

The Pale Beds are freshwater sediments consisting of grey and greenish grey sandstones, shaly sandstones, and dark shales (Powers, 1931, page 1201). Crossbedding, concretions, and lenticular beds are characteristic of this formation. On Milk River Ridge the formation consists (Hake and Addison, 1931, page 1220) of four groups of sediments as follows: an upper zone, 280 feet thick, containing more sandstones than shales; a second zone, 175 feet thick, predominantly of shales but containing numerous thin limestones; a third zone, 220 feet thick, consisting of alternating sandstones, shales, and thin limestones; and a fourth zone, 200 feet thick, bearing many thin limestones but only a few sandstones and characterized by the occurrence of thin, carbonaceous beds which decrease in number, thickness, and carbon content from top to bottom. The total thickness varies markedly from place to place as is shown by the following table.

	Thickness feet
Milk River Ridge (Hake and Addison, 1931, page 1220)........	875
Lethbridge (Powers, 1931, pages 1204-6)	740
Monarch (" " ")	760
Keho Lake (" " ")	680
Champion (" " ")	600
Eyremore (" " ")	550
Brooks (" " ")	605
East of Medicine Hat at Rapid Narrows, South Saskatchewan River (Williams and Dyer, 1930, page 29)	350

The Pale and Foremost beds constitute (Williams and Dyer, 1930, page 16) the Belly River formation which according to various authors is equivalent to the Judith River beds of Montana. The thickness of the two formations decreases considerably from west to east, the thinning amounting to 600 feet in 125 miles between Macleod and Medicine Hat (Powers, 1931, page 1210). To the north, in Battle River area, the Belly River was formerly thought to include all strata between the top of the Pale Beds and the base of the Ribstone Creek. It is probable that the Pale and Foremost formations of southern Alberta are equivalent to the Pale, Variegated, and Birch Lake formations of eastern central Alberta, and that the Pakowki and Milk River of southern Alberta are equivalent to the Grizzly Bear, Ribstone Creek, and Lea Park formations of the more northerly areas. Belly River is a lithologic rather than a time term and the Belly River in the foothills probably includes the equivalents of the Pakowki and Milk River as well as the Pale and Foremost beds of southern Alberta. To the east, in Saskatchewan, the Belly River disappears as a recognizable formation and there its equivalent is a marine shale constituting part of what has been called Pierre.

Bearpaw Formation. The Pale beds are overlain by a series of marine shales and sandstones of Montana age included in the Bearpaw formation. In the southwest part of the plains these shales are overlain by the so-called Fox Hills sandstone or Blood Reserve formation, which, however, disappears northward and there the Bearpaw shales are overlain by non-marine beds of the Edmonton formation. The stratigraphy of the Bearpaw is shown (Russell 1932, pages 28-30) by the following section from St. Mary River in Tps. 6 and 7, Ranges 22 and 23, W. 4th Mer.

Remarks	Material	Thickness Feet
Base of Blood Reserve sandstone	Interbedded sandstone and shale	4
Top of Bearpaw	Shale, somewhat sandy, grey and grey-brown	8
	Shale, fissile or friable, grey	10
	Shale, bentonitic, light greenish grey	0·1
	Shale, friable, grey	3
	Shale, sandy, soft, grey-brown	1·5
	Shale, friable, grey, with concretions	6·5
	Concealed	10
	Shale, somewhat carbonaceous, fissile, grey brown	12
Ryegrass member	Shale, somewhat sandy, friable, grey-brown and grey, with calcite veins	11
Ryegrass member	Shale, concretionary, grey-brown	0·5
Ryegrass member	Shale, grey and brown, somewhat sandy, friable	8
Ryegrass member	Shale, concretionary, grey-brown	0·5
Ryegrass member	Shale, sandy, friable, grey-brown, with concretions	7
Bentonite No. 14	Shale, bentonitic, friable, grey-green	0·2
	Shale, friable, grey	12·5
Bentonite No. 13	Shale, bentonitic, friable, grey-green	0·3
	Shale, rather compact, dark grey	3
	Shale, yellow-streaked	0–0·1
	Shale, friable, grey, with thin concretionary bands	40
	Concretions, hard, crossbedded, grey-brown	0·5
	Shale, friable, grey	8
	Concretions, rusty brown	0–3
	Shale, grey, with concretions	55
Bentonite No. 12	Shale, bentonitic, friable, greenish grey	0·5
	Shale, fissile, grey	11
	Shale, bentonitic, greenish grey	0·04
	Shale, friable, grey	4
	Shale, somewhat sandy, friable, grey-brown, with concretions	5
	Shale, bentonitic, friable, pale yellow	0–0·1
	Shale, friable, grey-brown, somewhat sandy in places	8·5
	Concretions, grey-brown	0–2
	Shale, friable, grey and grey-brown	15·5

Remarks	Material	Thickness Feet
Bentonite No. 11	Shale, very bentonitic, pale buff	0·2
	Shale, friable, grey and grey-brown	5
	Concretions, grey-brown	0–2
	Shale, friable, grey and grey-brown	21
	Shale, bentonitic, light grey	0–0·05
	Shale, sandy, soft, friable, grey-brown	3–4
	Shale, friable, grey and grey-brown, somewhat sandy at top	5
	Shale, bentonitic, pale buff	0–0·1
	Shale, friable, grey, somewhat sandy and brown in places	14
Bentonite No. 10	Shale, bentonitic, light greenish grey	0·2
	Shale, grey, friable	1·5
	Shale, somewhat bentonitic, grey-green	0–0·2
	Shale, friable, grey	4
Bentonite No. 9	Shale, bentonitic, friable, light greenish grey	0·5
	Shale, rather sandy, grey and brownish grey, with fossiliferous concretions	12
Bentonite No. 8	Bentonite, friable, light greenish grey	0·7
	Shale, friable or fissile, fossiliferous, grey	15
Bentonite No. 7	Bentonite, pale greenish grey	0·5
	Shale, fissile, grey, with fossils and concretions	5
Kipp member	Shale, sandy, friable, grey-brown	2·5
Kipp member	Concretions, rusty brown	0·5
Kipp member	Shale, sandy, friable, grey-brown	5
Kipp member	Concretions, rusty brown	1–2
Kipp member	Shale, sandy, rather soft, friable, brownish grey, with fossiliferous concretions and scattered nodules; transitional below	20
	Shale, friable, brownish grey to grey, somewhat sandy in places; fossiliferous concretions	62
Bentonite No. 6; "D" of Link and Childerhose	Bentonite, light greenish grey	0·3
	Shale, friable, grey	1
	Bentonite, light greenish grey	0·2
	Shale, fissile or friable, grey, with concretions	22
	Shale, bentonitic, light grey	0–0·2
	Shale, fissile, grey, with concretions	13
	Fossil bed, *Arctica ovata*	0·1
	Shale, fissile, grey, fossiliferous	15
Magrath member	Shale, sandy, soft, grey-brown	3·5
Magrath member	Concretions, rusty brown, fossiliferous	0–0·5
Magrath member	Shale, sandy, soft, grey-brown	3
Bentonite No. 5	Shale, bentonitic, especially in lower portion, light greenish grey	2
	Shale, fissile or friable, grey, fossiliferous, with concretions	55
	Concretions, rusty brown	0–2
	Shale, fissile or friable, grey, with concretions	18
	Concretions, rusty brown	0–1
	Shale, sandy, grey, friable	2
Bentonite No. 4; "B" of Link and Childerhose	Shale, bentonitic, pale greenish grey	0·5
	Shale, fissile or friable, grey	12
	Concretions	0–1
	Shale, bentonitic, pale grey-buff	0·1
	Shale, grey	7
	Concretions	0–1
	Shale, fissile, grey	5
Bentonite No. 3	Bentonite, pale greenish grey, usually with shale parting in lower portion	0·2
	Shale, friable, grey	3
	Shale, bentonitic, grey and yellow	0·05
	Shale, fissile or friable, grey, with concretions	7
	Shale, bentonitic, light greenish grey	0·1
	Shale, fissile or friable, grey, with concretions and fossils	38
	Concretions, rusty yellow	0–2
	Shale, grey	1

Remarks	Material	Thickness Feet
Bentonite No. 2	Bentonite, light grey	0·1
	Shale, fissile or friable, grey	19
	Concretions, dark reddish brown	0–1
	Shale, fissile, grey	7
	Shale, bentonitic, yellowish	0·05
	Shale, fissile, grey	3
Bentonite No. 1; "A" of Link and Childerhose	Bentonite, pale greenish grey	0·7
	Shale, fissile, grey	10
	Concretions, rusty brown	0–1
	Shale, fissile, grey	11
	Concretions	0–1
	Shale, fissile, grey, with concretions	10
	Concretions, dark reddish brown	0–1
	Shale, grey	6·5
	Shale, friable, brownish grey, with thin, rusty, concretionary bands	5
	Shale, friable, grey	1·5
	Shale, sandy, friable, brownish grey	1·5
Base of Bearpaw	Shale, fissile, grey	4·5
Top of Belly River	Coal	0·3

The sandy shales that occur in the Bearpaw formation in Lethbridge area are probably local developments. In the area to the north, at Keho Lake, three sandstones are still recognizable (Clarke, 1931, page 1246), but in other areas only one prominent sandstone occurs and it lies in the lower third of the formation. This lowest sandstone is underlain by shale which according to Clarke has a thickness of 220 feet at Keho Lake, 230 feet in Little Bow River area (Tp. 14, Range 20), 250 feet at Champion, 180 feet at Eyremore, and 180 feet on Bow River (Tp. 19, Range 18). The thickness of the sandstone member is also variable, being 35 feet at Keho Lake, 70 feet at Little Bow River, 10 feet at Champion, 35 feet at Eyremore, and 40 feet on Bow River. The thickness of the sandy shales above the lowest sandstone member is somewhat variable, being 380 feet at Champion, 360 feet at Eyremore, and 335 feet on Bow River (Tp. 19, Range 18). In the shales above the lowest sandstone there are, in various areas, thin sandstones and in Keho Lake area there are two well-marked sandstones, each 40 feet thick. The top of the upper of these sandstones is 95 feet below the top of the Bearpaw and, therefore, occupies the same stratigraphic position as the Ryegrass sandstone. The top of the intermediate sandstone is 325 feet below the top of the formation.

Farther to the north, in Neutral Hills area, brown, massive sandstones called the Bulwark beds (Slipper, 1918, page 8) occur in the Bearpaw formation. The stratigraphical position of the Bulwark sandstone within the Bearpaw is not definitely known.

The total thickness of the Bearpaw as measured in various areas is as follows.

Locality	Thickness Feet
Lethbridge (Tp. 8, Range 22) (Link and Childerhose, 1931, page 1229)	726
Keho Lake (Tp. 11, Range 22) (Clarke, 1931, page 1246)	740
Little Bow River (Tp. 14, Range 20) (Clarke, 1931, page 1246)	600
Eyremore (Tp. 17, Range 18) (" " ")	575
Bow River (Tp. 19, Range 18) (" " ")	575
Bassano (Tp. 21, Range 18) (" " ")	510

The Bearpaw formation was deposited in a sea that advanced from the south and southeast. It is represented in the eastern part of the southern foothills by sandy shales. It thins northward and is not definitely recognizable north of Highwood River. It thickens eastward and presumably at one time covered all the southern plains region of Alberta. To the east, in Saskatchewan, strata equivalent to the Bearpaw occur, but since the Belly River is absent they form part of a continuous series of shales of Colorado and Montana age.

Blood Reserve Formation. In the southwestern plains of Alberta a series of sandstones overlying the Bearpaw and formerly called Fox Hills has been named Blood Reserve formation by Russell (1932, page 32) who states that this formation is the northward continuation of the Horsethief sandstone of Montana and that he believes (1932, page 130) it to be of pre-Fox Hills age. The sandstones are in general massive with a calcareous or argillaceous cement. According to Russell the thickness on St. Mary River in Tp. 6, Range 23, is 70 to 80 feet and at Monarch 40 feet. Sanderson (1931, page 1251) includes still higher beds in the "Fox Hills" and states that there is an increasing amount of carbonaceous detritus toward the top, the upper part containing thick beds of Ostrea, in places preceded by a thin coal seam although more commonly succeeded by a thick coal seam which is regarded as the base of the overlying St. Mary River formation. Sanderson also points out that the normal sandstone section is interrupted in some places by dark shales in thin beds containing marine fossils, although Russell regards the formation as of brackish water deposition. Sanderson gives the following thickness for various localities: Del Bonita, 121 feet; St. Mary River, 1 mile north of International Boundary, 327 feet with the main sandstone bed 225 feet thick; canyon of Belly River near Hillspring, west of Cardston, about 186 feet; Pothole Creek, south of Magrath, 80 feet; St. Mary River, south of Lethbridge, Sec. 24, Tp. 6, Range 23, 62 feet; drill hole No. 11, Commonwealth Petroleum, Limited, Sec. 25, Tp. 8, Range 23, 142 feet; Monarch, Sec. 32, Tp. 9, Range 23, 80 feet, of which 40 feet is sandstone and constitutes the whole of the Blood Reserve formation of Russell; Little Bow River, near Travers, Sec. 32, Tp. 14, Range 21, 21 feet, of which 15 feet is sandstone. On Geological Survey Map 204 A the Blood Reserve ("Fox Hills") sandstone is shown as extending north of Bassano. Russell, however, is of the opinion that the sandy beds exposed on Bow River south of Bassano at the top of the Bearpaw do not belong to the Blood Reserve sandstone, but are a part of the Bearpaw formation which he calls the Bassano member (Russell, 1932, page 126).

St. Mary River Formation. The St. Mary River formation overlies the Blood Reserve sandstone in southwestern Alberta and consists of alternating grey to buff, massive sandstones with grey, somewhat arenaceous shales. Seams of coal or carbonaceous shale are present in the base of the formation according to Russell, but some or all of these are included in the "Fox Hills" of Sanderson. Freshwater fossils occur abundantly within the formation with brackish water fossils in the lower beds. The formation according to Williams and Dyer (1930, page 54) is 1,600 feet thick, but thickens westward to perhaps as much as 3,000 feet in the foothills (Stewart, 1919, page 40). According to Russell (1932, page 132) the St. Mary River formation is a correlative of the Edmonton which in north-central Alberta occupies a similar stratigraphic position.

The St. Mary River-Edmonton formations constitute the upper divisions of the Cretaceous. In the north-central part of Alberta the Edmonton is overlain by the Paskapoo formation, from which it is separated by an erosional interval that, according to Sanderson, produced erosion of a maximum depth of 450 feet. In the south the St. Mary River formation is overlain by the Willow Creek formation, overlain by the Porcupine Hills formation. No erosional break is apparent between the St. Mary River and Willow Creek formations and on Waterton River in the foothills, according to Russell (1932, page 139), a thick transitional series of strata is exposed.

The Paskapoo, Willow Creek, and Porcupine Hills formations are post-Cretaceous and as all are non-marine and do not seem to offer prospects for oil and gas they are not described in detail.

STRUCTURE

East of the complicated zone of folding and faulting in the foothills belt there is in Alberta a relatively large synclinal area extending from the International Boundary to Lesser Slave Lake. The central part of this syncline is occupied by post-Cretaceous beds. The syncline is narrow in the south where it is bordered on the east by the Sweet Grass Arch which is a fairly wide, anticlinal area plunging northwards and dying out north of Oldman and South Saskatchewan Rivers. In Canada the Sweet Grass Arch has no closure to the south, but on it and on the east flank of the Alberta syncline subsidiary folds have developed and are being prospected for oil and gas with some success. The gas fields of this area are the Bow Island, Foremost, and Rogers-Imperial fields; the oil fields are the Red Coulée and Skiff, and developments of a promising nature are carried on at Twin River and Keho Lake. East of the Sweet Grass Arch a gas field occurs on a local fold at Medicine Hat and gas has been struck in considerable quantities in other areas of the southern plains and in one well in Cypress Hills.

OIL AND GAS HORIZONS

Several productive horizons have been found in southern Alberta. These are as follows. (1) Medicine Hat gas sands which occur about 100 feet (Wickenden, personal communication) below the Milk River sandstone, with shows of gas in higher horizons. It was formerly thought the gas sands at Medicine Hat belonged to the Milk River sandstone, but later studies (Spratt, 1931, page 1178) have shown that they are in the upper part of the marine shales underlying the Milk River horizon. (2) Gas-producing sands in the lower part of the Alberta shales in a sandstone and shaly sandstone zone the top of which is about 350 to 400 feet (Spratt, 1931, page 1174) above the Lower Cretaceous in Bow Island and Foremost gas fields. This zone also gave a show of oil in the Keho Lake well of the Hudson's Bay Oil and Gas Company, but so far has yielded no commercial oil production. (3) Oil and gas in the lower part of the Lower Cretaceous strata in the Vanalta sandstone (Evans, 1931, page 21) in Red Coulée oil field, and gas in the basal sandstone of the Lower Cretaceous in Rogers-Imperial No. 1 well (Williams and Dyer, 1930, page 123). (4) Oil in the Jurassic (Ellis) in Devenish Nos. 1 and 3 wells in Skiff field. (5) Oil and oil shows at the Jurassic-Palæozoic contact and in the top of the Palæozoic limestone in a number of wells, as for example Fuego No. 1, Parco-Nordon No. 1, Twin River No. 1, Imperial-Texas No. 1, and Keho Lake No. 1. The Parco-Nordon No. 1 well yields a small amount of oil at this horizon, whereas the Texas-Imperial and Keho Lake have had encouraging showings. In the Rogers-Imperial No. 1 well, in addition to the gas encountered at the base of the Lower Cretaceous, a large flow was struck either in the base of the Ellis or at the Jurassic-Palæozoic contact.

Oil and Gas Fields and Prospected Areas

RED COULÉE FIELD

Red Coulée field is in Tp. 1, Range 16, W. 4th Mer., 5 miles west of the town of Coutts (Figure 14). It lies on the Sweet Grass Arch which plunges northward, but the dip is not uniform and the accumulation of oil occurs in a structural nose that apparently extends only a short distance into Canada so that the main fold lies in United States, where it is known as the Border field. The first test in Red Coulée field was made by the Northwest Company in 1922-23. This first well obtained a fair show of oil at a depth of 2,525 feet, but gave no commercial production. In 1929, Vanalta No. 1 was drilled and oil was obtained at a depth of 2,470-2,477 feet in the basal part of the Lower Cretaceous in the Vanalta sand. Other wells showed that Vanalta No. 1 is on the crest of a narrow plunging arch and close to the foot of a fairly steep terrace slope (Evans, 1931, page 24). Two other wells, namely, Vanalta Nos. 2 and 3 on the same small arch close to No. 1 well, produced oil and Alberta Pacific Consolidated "Red Coulée" No. 1 well, drilled on the east flank of this small arch, produced oil for several months before being abandoned. Vanalta No. 4 well, drilled 1,100 feet north of the International Boundary and down the dip of the structure from the other Vanalta wells, obtained no commercial production from the Vanalta sand. On the other hand, the Southern Alberta Exploration

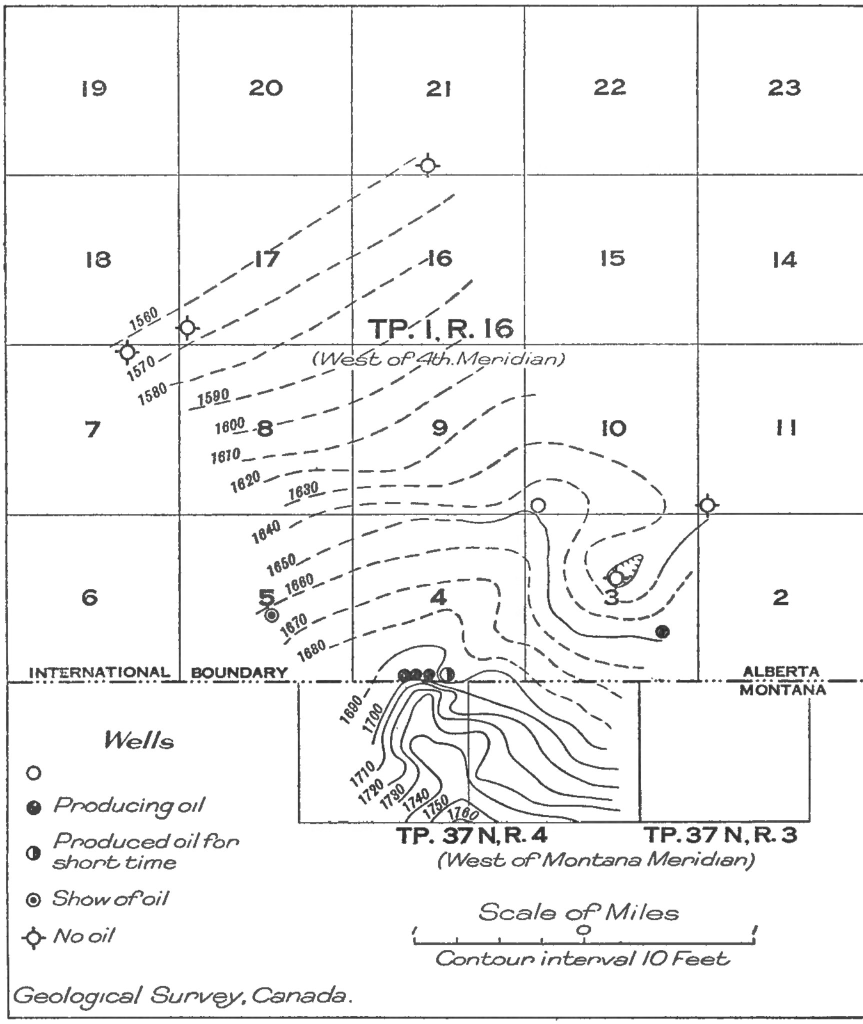

Figure 14. Structural contour map of Red Coulée field, west of 4th Meridian, Alberta, contours represent surface of Colorado water sand.

well, slightly more than a mile east of the Vanalta wells, obtained oil at a depth of 2,429-2,439 feet in the Vanalta sand. At this location there are indications of another structural nose, but the data are somewhat limited and the details not definitely known. The structure of Red Coulée field is shown in Figure 14, reproduced from a report by Evans (1931).

According to Evans (1931, page 21)

"In most of the wells a fine white sandstone occurs with its base 47 to 60 feet above the Vanalta oil sand. This sandstone seems to be less than 10 feet thick, since from 10 to 70 per cent of the samples from the 10-foot interval in which it occurs consist of shale. It is probable that there are several beds of this sandstone, since it is present as fragments in two or three of the 10-foot samples. Small flows of gas were encountered at this horizon in several of the wells."

In many of the wells at an horizon 65 to 75 feet above the top of the Lower Cretaceous, there occurs a water sand which according to Yarwood (1931, page 1167) has a thickness of 30 feet, but which may be an alternation of sandstone and sandy shales.

The stratigraphy of Red Coulée area is shown by the logs of Commonwealth " Red Coulée " No. 1, and Dalco No. 2, wells.

Log of Commonwealth " Red Coulée " Well (Evans, 1931, page 28)
(L.S. 10, Tp. 1, Range 16, W. 4th Mer.; Elevation, 3,527 feet)

—	Thickness Feet	Depth Feet
Drift	20	20
Lower Milk River		
Yellowish, medium-grained sandstone	70	90
Fine to medium, light grey sandstone	70	160
Fine, light grey, shaly sandstone	40	200
Alberta ("Benton") shale		
Dark shale and sandy shale, little grey sandstone, some beds limy	470	670
Dark shale	510	1,180
Dark, sandy shale and fine, grey sandstone	40	1,220
Dark shale, bentonitic	60	1,280
Dark shale	30	1,310
Dark shale and sandy shale, some fine, grey sandstone	60	1,370
Dark shale, some bentonite	80	1,450
Sandy shale and 40 per cent medium quartz, and black chert sandstone	20	1,470
Dark shale, a little sandstone	50	1,520
Dark shale and bentonitic, medium sandstone	10	1,530
Dark shale, some bentonite	150	1,680
Dark shale and bentonitic, fine to medium sandstone	20	1,700
Dark shale	40	1,740
Dark shale and fine to medium sandstone with some glauconite	80	1,820
Grey shale, some bentonite	30	1,850
Grey shale and bentonitic, sandy shale	40	1,890
Dark shale and fine, grey sandstone	20	1,910
Medium-grained sandstone and dark shale; a little glauconite; water	10	1,920
Dark grey shale, some sandy and some bentonitic beds	60	1,980
Lower Cretaceous		
Grey and greenish grey shale, some greenish, bentonitic sandstone	40	2,020
Dark grey, light grey, green, and red shale	80	2,100
Grey and greenish grey sandstone	50	2,150
Grey, green, and red shale	10	2,160
Grey, green, and red shale, minor grey and greenish sandstone, little coal	110	2,270
Missing	10	2,280
Grey, green, and red shale	10	2,290
Grey, green, and red shale, 20 per cent white sandstone	20	2,310
Grey and green shale	60	2,370
Red shale	20	2,390
Light grey sandstone	10	2,400
Grey, greenish, and red shale, some sandstone	30	2,430
Medium, light grey sandstone	20	2,450

Log of Commonwealth " Red Coulée " Well (Evans, 1931, page 28)
(L.S. 10, Tp. 1, Range 16, W. 4th Mer.; Elevation, 3,527 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Lower Cretaceous—Conc.		
Brownish shale	45	2,495
Brownish shale and medium to coarse, grey sandstone	10	2,505
Medium to coarse, quartz and black chert sandstone, pyrite, and coal fragments; Vanalta sand; water at 2,535 feet	48	2,553
Ellis		
Light greenish grey shale and shaly limestone; pyrite, some calcareous and glauconite beds at base	57	2,610
White, sandy dolomite, 30 per cent sand; water at 2,614 feet	4	2,614
Sandy dolomite and grey shale	11	2,625
Palæozoic limestone		
White limestone, some grey shale 2,689-2,695 feet	107	2,732

Log of Dalco No. 2 Well (Evans, 1931, page 30)
(L.S. 7, Sec. 19, Tp. 2, Range 17, W. 4th Mer.; Elevation, 3,630 feet)

—	Thickness Feet	Depth Feet
Missing	....	50
Foremost		
Drift, grey sandstone, dark carbonaceous shale, a few coal fragments	70	120
Pakowki		
Grey and slightly greenish grey, fine sandstone, shaly sandstone, and sandy, grey shale. Foraminifera present at 130-150 and 280-290 feet	170	290
Milk River		
Grey shale and grey sandstone	20	310
Light grey, shaly sandstone, a little greenish sandstone and white "mud"	30	340
Mostly white, sandy "mud", some greenish and brown shale	40	380
Light grey and greenish grey shale, some brown shale	20	400
Fine, light grey, shaly sandstone	20	420
Fine, light grey sandstone, brown shale, and coal fragments	10	430
Grey, sandy shale and shaly, medium-grained sandstone	10	440
Light grey, medium-grained sandstone	20	460
Light grey, medium-grained sandstone, some brown shale	10	470
Light grey, sandy shale and brown shale	10	480
Light grey, fine and medium sandstone and shaly sandstone	60	540
Light grey, medium-grained sandstone and shaly sandstone	110	650
Alberta shale		
Dark grey shale, some sandy shale. Top of Bullopora zone at 1,040 feet and top of Clavulina zone at 1,070 feet	1,240	1,890
Dark shale and some light grey, medium-grained sandstone, a little bentonite	30	1,920
Dark shale, a little bentonite	50	1,970
Grey shale, and shaly sandstone	130	2,100
Grey, shaly sandstone, and quartz and chert sandstone	10	2,110
Grey shale and shaly sandstone	130	2,240
Grey, sandy shale and grey sandstone	20	2,260
Grey shale and fine, shaly sandstone	30	2,290
Missing	270	2,560
Lower Cretaceous		
Grey and green shale	10	2,570
Grey and green shale, some red shale	40	2,610

Log of Dalco No. 2 Well (Evans, 1931, page 30)
(L.S. 7, Sec. 19, Tp. 2, Range 17, W. 4th Mer.; Elevation, 3,630 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Lower Cretaceous—Conc.		
Grey and greenish shale	60	2,670
Grey, greenish, and red shale	30	2,700
Grey, greenish, and red shale, minor grey sandstone	40	2,740
Mostly white sandstone, some red and green shale	20	2,760
Grey, green, and red shales, a little white sandstone	70	2,830
Grey and greenish shale	60	2,890
Grey, green, and red shales with grey sandstone	50	2,940
Grey and green shale	10	2,950
Light grey sandstone	10	2,960
Grey, green, and red shale and sandstone	30	2,990
Cherty sandstone and chert	20	3,010
Ellis		
Light grey, dense, calcareous shale	70	3,080
Lime and chert with shale and sandstone	40	3,120
Mississippian limestone		
Mostly limestone	20	3,140

SKIFF FIELD

The area where drilling has been done in the vicinity of Skiff lies south of the Canadian Pacific Railway and north of Etzikom Coulée. No exposures of rocks occur in the immediate vicinity of the wells. Foremost beds outcrop east of Crow Indian Lake and in Range 15, in Etzikom Coulée. The details of the structure are unknown, but a northwesterly dip is indicated by the elevation of the top of the Lower Cretaceous in the wells drilled (*See* Figure 15).

		Feet
Devenish No. 2 well:	Elevation of top of Lower Cretaceous....	541
Devenish No. 1 well:	Elevation of top of Lower Cretaceous....	510
Devenish No. 4 well:	Elevation of top of Lower Cretaceous....	470
Dauntless No. 1 well:	Elevation of top of Lower Cretaceous....	369

The top of the Palæozoic limestone was reached in three wells and shows that the dip is in the same direction but at a slightly different angle, as would be expected since the top of the Palæozoic is an erosion surface.

	Feet
Devenish No. 2 well: elevation of top of Palæozoic............	+ 6
Devenish No. 1 well: elevation of top of Palæozoic............	− 90
Dauntless No. 1 well: elevation of top of Palæozoic..........	−269

Development in Skiff area commenced in 1926 with the drilling of Devenish No. 1 well which, at a depth of 3,080 feet, encountered in Ellis strata oil of 18·2 degrees Baumé, that rose to a level of 800 feet below the surface. The well was deepened, but encountered water which was shut off by plugging. The well when tested in January and February, 1928, produced only 22 barrels of oil a day. Later the well produced 40 barrels a day, but by May, 1930, production had dropped to 25 barrels a day. The success of this first well encouraged further exploration and arrangements were made between the Devenish Oil Company and Imperial

Oil Company, Limited, to have the latter drill several wells. No oil or gas in any quantity was encountered in No. 2 well which was drilled to a depth of 3,171 feet. This well was south of, and higher structurally than, No. 1. No. 3 well was drilled close to No. 2 well and encountered oil at 3,054 feet. Pumping tests carried out between August 1 and 10, 1929, under the direction of the Supervisory Engineer, Department of the Interior, gave 37·86 barrels of oil of 19·5 degrees Baumé a day, with some water. Later, by the use of a compressor pump, the well produced 30 to 40 barrels a day for a time. Devenish No. 4 well, drilled by the Devenish Oil Company to a depth of 3,148 feet, showed that the well was lower structurally than Nos. 1 and 3 and no commercial quantity of oil or gas was encountered. Dauntless No. 1 well, drilled in 1929, encountered oil shows, but like Devenish No. 4 well gave no commercial production.

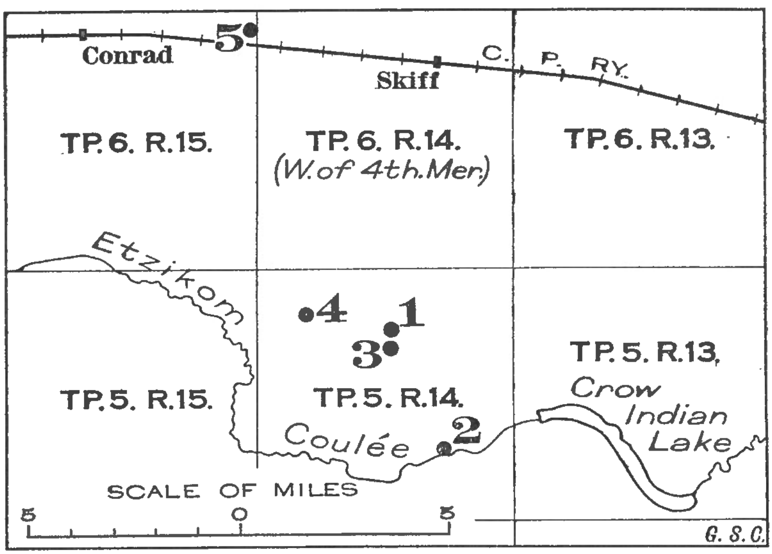

Figure 15. Skiff field wells. 1, Devenish No. 1; 2, Devenish No. 2; 3, Devenish No. 3; 4, Devenish No. 4; 5, Dauntless No. 1.

The Geological Survey has little exact information regarding the structure in this area other than that provided by the deep wells. It is apparent that there is a rise from west to east from Devenish No. 4 to Devenish Nos. 1 and 3 wells. Devenish No. 1 well is 170 feet higher structurally than Foremost No. 7 well, 4½ miles north and 20 miles east of Devenish No. 1 well. It is apparent, therefore, that in the area east of Devenish No. 4 and west of Foremost No. 7 anticlinal conditions exist. The position of the crest of the structure is unknown, but it is highly improbable that the crest coincides with the location of Devenish No. 1 well. If it does not, the crest lies east of Devenish No. 1 well and the production from Devenish Nos. 1 and 3 wells seems to warrant assuming that larger flows would be encountered by drilling farther east. So far as known there is no southward closure to the anticline since Devenish No. 2 situated south of No. 1 was higher structurally. It may be that the oil is confined to a lens of sandstone the extent of which can only be determined by drilling, but as a southward flattening of dip might provide the necessary conditions for accumulation if closure is absent, it is thought more likely that the occurrence of the oil is directly related to the structure rather than to irregularities of sedimentation. The area east of the present Devenish wells, therefore, seems worthy of serious consideration as an oil prospect.

Log of Devenish No. 1 Well

(L.S. 5, Sec. 27, Tp. 5, Range 14, W. 4th Mer.; Elevation, 3,050 feet)

—	Thickness Feet	Depth Feet
Samples to a depth of 345 feet contain much intermixed surface materials		
Foremost		
Missing	....	35
Buff, sandy shale with coaly materials	60	95
Missing	10	105
Grey, sandy shale, some coal	30	135
Grey, sandy shale	40	175
Grey, sandy shale	165	335
Pakowki?		
Grey shale	140	475
Grey shale with a little sandstone	10	485
Grey shale	30	515
Missing	10	525
Milk River		
Dark grey and light grey shale	20	545
Dark grey and light grey shale with lignite	30	575
Dark grey shale	20	595
Light grey, sandy shale	70	665
Grey, sandy shale with carbonaceous materials	20	685
Grey sandstone with carbonaceous materials	30	715
Grey, sandy shale with carbonaceous materials	55	770
Alberta shale		
Dark grey shale	10	780
Missing	10	790
Grey shale, somewhat sandy	20	810
Missing	50	860
Dark grey shale	220	1,080
Dark grey shale with sandstone	20	1,100
Dark grey shale	110	1,210
Dark grey shale with some bentonite	240	1,450
Dark grey shale	50	1,500
Dark grey shale with bentonite	10	1,510
Dark grey shale	30	1,540
Dark grey shale with bentonite	10	1,550
Dark grey shale, traces of bentonite	130	1,680
Dark grey shale	60	1,740
Missing	10	1,750
Dark grey shale	70	1,820
Dark grey shale with sandstone	10	1,830
Missing	10	1,840
Dark grey shale with some sandstone and bentonite	50	1,890
Missing	10	1,900
Dark grey shale, sandstone, and bentonite	90	1,990
Dark grey shale, a little sandstone	70	2,080

Log of Devenish No. 1 Well
(L.S. 5, Sec. 27, Tp. 5, Range 14, W. 4th Mer.; Elevation, 3,050 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Alberta shale—Conc.		
Grey, sandy shale and sandstone	10	2,090
Grey sandstone (water)	10	2,100
Grey sandstone and shale	20	2,120
Grey sandstone	13	2,133
Grey shale and sandstone, carbonaceous	12	2,145
Grey shale and sandstone	15	2,160
Grey shale and sandstone, carbonaceous	10	2,170
Bentonite	10	2,180
Missing	20	2,200
Grey shale, sandy shale, and sandstone with a little bentonite	110	2,310
Missing	30	2,340
Grey shale and sandstone	40	2,380
Missing	10	2,390
Grey shale and sandy shale	60	2,450
Dark grey sandstone (oil and gas show 2,458 feet)	25	2,475
Dark grey shale and greenish sandstone	10	2,485
Dark grey, sandy shale	20	2,505
Dark grey shale with some bentonite	35	2,540
Lower Cretaceous		
Grey and greenish shale, sandy	30	2,570
Grey and greenish shale and grey sandstone	40	2,610
Fine, light grey, shaly sandstone	10	2,620
Green and grey shale	40	2,660
Green shale and sandstone	60	2,720
Green shale with carbonaceous materials	10	2,740
Grey and green shale with sandstone	30	2,770
Grey and green shale with sandstone and little red shale	150	2,920
Grey sandstones	40	2,960
Ellis		
Dark grey shale	30	2,990
Dark grey, calcareous shale	10	3,000
Dark grey shale with light grey sandstone	10	3,010
Dark grey shale slightly greenish	60	3,070
Dark grey and greenish shale with limestone and sandstone containing oil	10	3,087
Dark grey and greenish shale and limestone	9	3,096
White sandstone	24	3,140
Mississippian		
Grey limestone	42	3,182

FOREMOST FIELD

In 1916 United Oils of Alberta, Limited, drilled a well to the depth of 3,716 feet in Etzikom Coulée on the southwest quarter of Sec. 31, Tp. 5, Range 10, W. 4th Mer. The well is reported to have encountered a small amount of gas at 960 and 1,663 feet, salt water at 1,940 feet, a flow of 10,000,000 cubic feet of gas a day at 2,015 feet, a further flow of 2,000,000 cubic feet a day at 2,070 feet, salt water at 2,240 and 2,910 feet, and an oil show at 2,990 feet. As the water had not been properly shut off the well was later plugged and abandoned.

The results obtained by this well led to the development of the Foremost gas field by the Canadian Western Natural Gas, Light, Heat, and Power Company. Operations on Foremost No. 1 well commenced in April, 1923. The well was drilled to a depth of 2,191 feet and penetrated three gas sands that gave a combined flow of 26,000,000 cubic feet a day. In all, nine wells (including one by United Oils of Alberta) were drilled in a limited area extending from Sec. 24, Tp. 6, Range 11, to Sec. 29, Tp. 5, Range 10.

The gas from the Foremost field was piped to Calgary, but after the development of the Turner Valley field following the completion of Royalite No. 4 well in the autumn of 1924 the Foremost field has not been extensively drawn upon and constitutes a very important reserve supply of gas which can be utilized as necessity arises.

The gas in the Foremost field is derived from sandstones in the lower part of the Alberta shales at a depth of 2,070 to 2,250 feet in depth. According to Williams and Dyer (1903, page 121) the structure is a northward plunging anticline that flattens southward without providing actual closure. The dip on the east and west flanks is said to be 30 to 50 feet a mile.

Log of Foremost No. 7 Well

(L.S. 4, Sec. 24, Tp. 5, Range 11, W. 4th Mer.; Elevation, 2,968 feet)

—	Thickness Feet	Depth Feet
Missing	....	20
Foremost		
Grey shale, fragments of coal	70	90
Light greenish shale	40	130
Lignitic shale and grey sandstone	80	210
Light grey sandstone	20	230
Light greenish and dark lignitic shale and sandstone	110	340
Light grey sandstone	40	380
Pakowki		
Grey shale with small amount fine sandstone	190	670
Milk River		
Grey and lignitic shale with coal fragments; pebbles at 690–700 feet.	30	700
Light grey sandstone with some coal	30	730
Grey and carbonaceous shales and grey sandstones	50	780
Fine, light grey, shaly sandstone	40	820
Grey shales with sand	40	860
Alberta shales		
Grey shales, in part sandy	1,292	2,152
Grey sandstone	5	2,157

Although the base of the Pakowki is commonly marked by a fine chert conglomerate the samples from 670 to 690 feet resemble Upper Milk River.

BOW ISLAND FIELD

(*See* Figure 16)

The first well in Bow Island gas field was drilled by the Canadian Pacific Railway Company, but the Canadian Western Natural Gas, Light, Heat, and Power Company have done the major part of the development work. In 1911 they acquired the first well from the Canadian Pacific and since then have completed twenty-four others. In addition to those owned by the company there are two other wells in the field, one of them owned by the village of Bow Island, and the other by the Southern Alberta Land Company. A tabulated list of the wells with locations, open flow measurements, etc., follows.

Gas Wells in Bow Island Gas Field

No.	L.S.	Sec.	Tp.	Range	Elevation above sea-level	Depth to top of gas sand	Elevation of top of gas sand	Initial open flow, cubic feet a day
					Feet	Feet	Feet	
1	6	15	11	11	2,300	1,866	434	8,500,000
2	15	15	11	11	2,273	1,849	424	Abandoned
3	14	9	11	11	2,273	1,849	434	13,000 000
4	3	17	11	11	2,273	1,843	430	29,000,000
5	9	22	11	11	2,270	1,867	403	Abandoned
6	1	16	11	11	2,286	1,881	405	4,200,000
7	8	18	11	11	2,283	1,856	427	7,000,000
8	13	18	11	11	2,314	1,891	423	12,000,000
9	2	24	11	12	....	....	414	Abandoned
10	8	23	11	12	....	....	415	Abandoned
11	1	7	11	11	....	....	....	7,300,000
12	13	7	11	11	2,467	1,958	409	16,000,000
13	3	9	11	11	2,521	....	....	18,000,000
14	1	1	11	12	2,548	2,100	448	7,000,000
15	13	12	11	12	2,581	2,170	411	4,000,000
16	4	4	11	11	2,554	2,134	420	Abandoned
17	1	25	11	12	2,594	2,207	387	Abandoned
18	4	1	11	12	2,663	2,230	433	Abandoned
19	16	25	10	12	2,531	2,076	455	3,000,000
20	16	30	10	11	2,550	2,100	450	Abandoned
21	1	30	10	11	2,564	2,127	437	Abandoned
22	14	31	10	11	2,544	2,100	444	1,300,000
23	16	17	11	11	2,396	1,981	415	2,300,000
26	15	33	10	11	2,559	....	....	Abandoned
27	4	20	11	11	2,496	2,092	404	1,300,000
28	12	4	11	11	2,275	....	....	7,000,000
29	9	24	11	12	....	....	....	12,000,000

28=Village of Bow Island well: 29=Southern Alberta Land Company well.

No outcrops of rock occur in the immediate vicinity of the field. The gas occurs in a porous sandstone band 35 feet thick, in the Alberta shales about 1,300 feet below the base of the Milk River sandstone. The structure of the field is represented in Figure 16 which is based on the data given in the preceding table. That the irregular-shaped dome with a closure of only 50 feet has been large enough to hold the large quantity of gas obtained in the field is surprising. Undoubtedly the reason is that the small dome is situated on the crest of the Sweet Grass Arch.

Bow Island field[1] was discovered in 1909 and by 1914 the total open flow of all the producing wells amounted to 184,000,000 cubic feet. The original rock pressure was 745 pounds and in 1927 after the withdrawal of about 38,000,000,000 cubic feet of the estimated content of 45,000,000,000 cubic feet of gas, the pressure had fallen to 256 pounds with a daily

[1] Information supplied by P. D. Mellon, Can. West. Nat. Gas, Light, Heat, and Power Company, Calgary.

capacity of all the wells of 16,000,000 cubic feet. As it was recognized by the officials of the Canadian Western Natural Gas, Light, Heat, and Power Company that further withdrawal of gas would accentuate the encroachment of edge water it was decided to experiment with re-pressuring to determine if such was feasible and if so to introduce waste gas from Turner Valley. In the preliminary experiments gas from the Foremost field was used and beginning the latter part of September, 1927, approximately 37,000,000 cubic feet of gas was introduced through eight wells. This caused a rise in the rock pressure from 256 to 286 pounds, or at a rate slightly less than 1

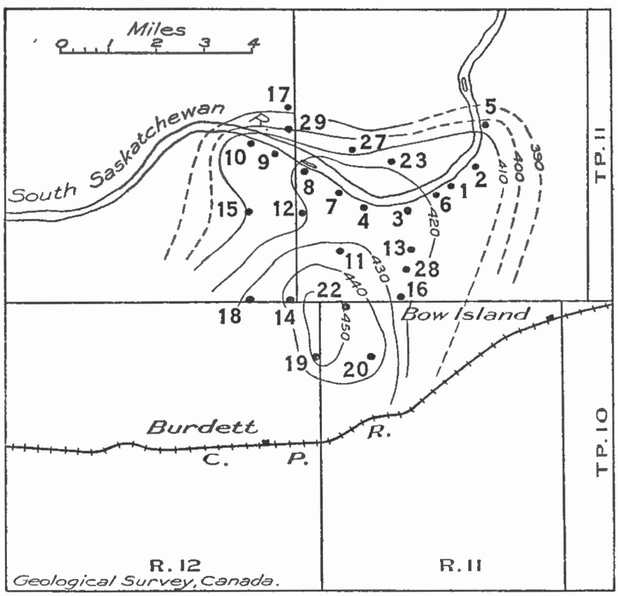

Figure 16. Bow Island gas field (after Dyer); structure contours represent top of the gas sand; numbers designate the wells as given in the table, page 145.

pound a million cubic feet of gas stored. As the preliminary experiment was successful the necessary repairs were made to pipe-lines and wells and high-pressure compressors installed. The actual work of pumping Turner Valley gas into the field began on August 4, 1930, at the rate of 3,500,000 cubic feet a day and was continued until December 31, during which time 623,000,000 cubic feet had been stored. In the beginning only three wells, Nos. 4, 7, and 8, were used, but later gas was also introduced through wells Nos. 11 and 12. The storage of gas was continued through 1931 and on August 19, 1,555,650,000 cubic feet of gas had been stored with an increase of pressure[1] in the field to 335·2 pounds which is equivalent to a rise of one pound in rock pressure for 17,984,000 cubic feet stored. It is estimated that perhaps 20,000,000,000 cubic feet can be stored.

[1] Measurement of ten wells after being shut in 11 days.

Log of Northwest Company, Burdett No. 1 Well[1]
(Sec. 8, Tp. 11, Range 11, W. 4th Mer.; Elevation, 2,580± feet)

—	Thickness Feet	Depth Feet
Drift	....	140
Foremost		
Light grey, sandy shale with traces of coal	40	180
Grey, sandy shale	70	250
Grey, sandy shale, a little coal	20	270
Grey, sandy shale	130	400
Pakowki?		
Grey shale	....	420
Grey shale, traces of coal	130	550
Grey shale	40	590
Milk River		
Grey shale, sandy	200	790
Alberta shale		
Dark grey shale	50	840
Dark grey, sandy shale	70	910
Dark grey shale	140	1,050
Dark grey shale, in part sandy	140	1,190
Dark grey shale, chert pebbles	10	1,200
Dark grey shale	170	1,470
Dark grey shale, chert pebbles	10	1,480
Dark grey shale, somewhat sandy	70	1,650
Dark grey shale, bentonite	20	1,670
Dark grey shale	100	1,770
Dark grey, sandy shale	40	1,810
Dark grey shale	30	1,840
Dark grey shale, with bentonite	20	1,860
Dark grey shale, somewhat sandy and with a little bentonite	270	2,130
Dark grey shale, with chert pebbles	10	2,140
Grey sandstone, somewhat shaly	40	2,180
Grey, sandy shale, some bentonite and sandstone	130	2,310
Grey shale, a little sand	190	2,500
Lower Cretaceous		
Light green, grey, and red shale	10	2,510
Grey and greenish shale	10	2,520
Variegated shale	20	2,540
Grey shale	10	2,550
Light green and reddish shale	20	2,570
Grey shale	20	2,590
Greenish and reddish shale with bentonite	10	2,600
Grey and greenish shale with traces of coal	10	2,610
Light grey sandstone, some coaly shale	20	2,630
Dark shale and sandstone	20	2,650
Grey, green, and reddish shale with sandstone	40	2,690
Black, carbonaceous shale	10	2,700
Dark shale	10	2,710
Dark and greenish shale	20	2,730
Missing	10	2,740
Variegated shale with grey sandstone	30	2,770
Dark grey and greenish shale	30	2,800
Dark grey shale, trace of maroon shale	10	2,810
Dark grey shale with sand	10	2,820
Dark grey to black shale	30	2,850
Dark grey, green, and maroon shale	10	2,860
Ellis?		
Blue-grey shale and sandstone	40	2,900
White, sandy lime and dark grey shale	70	2,970
Mississippian		
White limestone	90	3,060
Pink limestone	50	3,110
Brown limestone	120	3,220
Pink and brown limestone	10	3,230
Grey to brown limestone	160	3,390
Dark grey limestone	190	3,580

[1] Published by permission of Imperial Oil Co., Ltd. Log compiled in part from log by J. G. Spratt.

Log of Northwest Company, Burdett No. 1 Well
(Sec. 8, Tp. 11, Range 11, W. 4th Mer.; Elevation, 2,580± feet)—*Concluded*

—	Thickness Feet	Depth Feet
Devonian?		
Black shale	10	3,590
Grey, sandy limestone	20	3,610
Black shale	10	3,620
Grey limestone	10	3,630
Grey and dark grey shale	10	3,640
Grey, sandy limestone	100	3,740
Greenish, calcareous shale	60	3,800
Greenish, calcareous shale with anhydrite	20	3,820
Greenish grey shale and limestone	120	3,940
Grey, calcareous sandstone with shale	50	3,990
Grey shale, little limestone	50	4,040
Missing	10	4,050
Grey shale and limestone	10	4,060

MEDICINE HAT FIELD

According to Dyer (Hume, 1928, page 50)

"Attention was first directed to the gas possibilities of Medicine Hat area by the seepages of gas in South Saskatchewan River; these are made evident by a continuous stream of bubbles rising to the surface of the water. The first wells were drilled in 1901, but penetrated only to a shallow gas sand 700 feet deep, from which a very small production was obtained. In 1908 the Canadian Pacific Railway Company drilled to 1,000 feet and penetrated the Medicine Hat Gas sand which has proved the principal gas horizon in the field. From that time on, all wells have been drilled to the deeper horizon and the shallow wells have been abandoned. The following table contains a list of the wells drilled in Medicine Hat, with data concerning open flow measurements, depth of the gas sand, etc.

Gas Wells in Medicine Hat Field

	Name of well	Sec.	Tp.	Range	Elevation of well	Depth to Medicine Hat gas sand	Elevation Medicine Hat sand above sea-level	Open flow cub. ft. a day
					Feet above sea-level	Feet	Feet	
1	Main St.	SW. ¼ 31	12	5	2,202·95	....	....	2,225,000
2	Armory	NE. ¼ 31	12	5	2,145·05	....	....	3,000,000
3	Rosary	NW. ¼ 32	12	5	2,132·65	....	....	2,000,000
4	Balmoral	SW. ¼ 32	12	5	2,128·95	905	1,224	2,500,000
5	Electric Plant	NW. ¼ 35	12	6	2,167·75	....	....	4,000,000
6	Craft	SW. ¼ 36	12	6	2,148·15	918	1,230	3,264,000
7	S. Industrial	NW. ¼ 18	12	5	2,346·95	1,094	1,253	2,300,000
8	W. Industrial	NE. ¼ 22	12	6	2,312·82	1,065	1,247·82	2,100,000
9	Stella	SW. ¼ 28	12	5	2,147·65	938	1,209·65	2,500,000
10	Hargrave	NW. ¼ 31	12	5	2,165·65	....	....	2,500,000
11	Cousins and Sissons	NE. ¼ 25	12	6	2,269·44	1,075	1,194	2,800,000
12	Central Park	NW. ¼ 30	12	5	2,262·87	1,030	1,232·87	3,000,000
13	Maple St.	NW. ¼ 29	12	5	2,131·35	....	....	2,500,000
14	Powell	SE. ¼ 30	12	5	2,139·55	....	....	2,900,000
15	Huckvale	NE. corner 6	13	5	2,336·53	1,080	1,256·53	3,625,000

Gas Wells in Medicine Hat Field—Concluded

	Name of well	Sec.	Tp.	Range	Eleva-tion of well	Depth to Medicine Hat gas sand	Eleva-tion Medicine Hat sand above sea-level	Open flow cub. ft. a day
					Feet above sea-level	Feet	Feet	
16	Big Chief..........................	....	12	5	2,133·55	....	....	2,800,000
17	Ogilvie............................	NE. ¼ 30	12	5	2,137·16	904	1,233·16	3.000,000
18	Marlborough........................	SW. ¼ 30	12	5	2,151·65	915	1,236·65	1,850,000
19	Wellington.........................	SW. ¼ 28	12	5	2,171·05	975	1,196·05	2,225,000
20	C.P.R. No. 1.......................	SE. ¼ 31	12	5	2,178·65	....	....	....
21	C.P.R. No. 2.......................	SE. ¼ 31	12	5	2,179·54	970	1,209·54	2,800,000
22	C.P.R. No. 3.......................	NE. ¼ 36	12	6	2,236·98	979	1,257·98	2,995,000
23	Purmal.............................	NW. ¼ 28	12	5	....	....	....	....
24	No. 1 Canada Cement Co.............	Dauntless Sta.	....	....	2,360	....	....	2,000,000
25	No. 2 " "	NE. ¼ 28	12	6	2,330·96	1,095	1,235·99	2,338,000
26	No. 3 " "	SE. ¼ 22	12	6	2,306·37	1,057?	1,249·37?	2,117,000
27	No. 4 " "	NE. ¼ 14	12	6	2,223·33	965?	1,258·33	1,500,000
28	No. 5 " "	SE. ¼ 28	12	6	2,291·86	1,058	1,240	2,600,000
29	Golden Valley Irrig. Co............	NW. ¼ 33	12	5	2,171·22	940	1,231·22	....
30	Roth and Faurot No. 1..............	SW. ¼ 6	13	5	2,329·76	1,081	1,248·76	2,600,000
31	Redcliff, South....................	NE. ¼ 5	13	6	2,450·88	1,187	1,263·88	....
32	Redcliff, East.....................	NE. ¼ 9	13	6	2,413·04	1,150	1,263	4,000,000
33	Redcliff, West.....................	NE. ¼ 7	13	6	2,434·47	1,183	1,251·47	4,000,000
34	Redcliff Pressed Brick Co..........	SW. ¼ 9	13	6	2,443·28	....	1,195 ??	1,800,000
35	Redcliff Brick and Coal No. 2......	NW. ¼ 5	13	6	2,421·32	....	1,250·3	4,000,000
36	Redcliff Brick and Coal No. 3......	NW. ¼ 5	13	6	2,247·04	....	1,224	2,000,000
37	Dom. Glass Co......................	SW. ¼ 17	13	6	....	....	....	3,147,000
38	Redcliff Broadway..................	SW. ¼ 17	13	6	....	....	....	5,000,000
39	Dunmore Junc.......................	NE. ¼ 9	12	5	....	....	....	....
40	Dunmore............................	Townsite...	....	....	....	....	....	....
41	Roth and Faurot No. 2..............	8	13	6	2,490	1,252	1,238	....

The best wells in the field have open flows of nearly 5,000,000 cubic feet a day. Those under 2,000,000 cubic feet are considered poor. The original total open flow capacity of the field was about 80,000,000 cubic feet a day, but it is reported that by 1922 this had decreased to 50,000,000 cubic feet. The rock pressure in the early history of the field was 550 pounds a square inch; this had declined to 425 pounds in 1925. The open-flow capacity is, therefore, falling more rapidly than the rock pressure. The rock pressure in Redcliff has always been higher than in Medicine Hat; in 1925 it was about 475 pounds. Abount one-half the wells are owned by the municipalities of Medicine Hat and Redcliff; the remainder, for the most part, are owned and used by industrial concerns.

The structure of the field as represented in Figure 17 is largely based on the data contained in the preceding table, but additional information was obtained by determining the strike and dip of the overlying rocks (Foremost beds) in the coal mines in the western part of the field and along the river valley opposite Redcliff. The structure which causes the accumulation of the gas is low and broad with about 50 feet closure, and extends northward from the structurally higher land on the south. It is divided into two parts by an east-west trough that roughly parallels the river. The southern part of the field was developed first and has received most attention. A few good wells have been obtained in the trough. The northern part, however, holds most promise for the future. It is higher than the southern part and the rock pressure also is greater. Some of the best wells have been drilled on it, including the Huckvale well and the Broadway well at Redcliff.

How far the gas-field extends beyond the present proved area has not been determined. The Canada Cement Company's well at Dauntless is a very poor one, and the field probably does not extend south at this point. Some gas was obtained at Dunmore, but the gas sand was thin and the field probably does not extend farther east. Nothing is known of the western extent of the field, but possibilities of obtaining good flows outside the structure shown on the map are not considered good. Future drilling may show that the field extends a considerable distance farther north, and it is even possible that the rocks may rise in that direction.

The manner in which the rock pressure has kept up is remarkable and augurs well for the continued life of the field. Edge water has appeared in but few of the wells in the central part of the city, namely in the Power Plant well and in Canada Cement well No. 2. With the wise conservation measures that have been, and are being, taken and with proper care in avoiding water troubles, the field should last for a number of years, and there is always the hope of extending the area to the north or of finding new fields sufficiently close at hand for the gas to be piped to Medicine Hat.

In the summer of 1925 the drilling firm of Roth and Faurot, by agreement with the city council of Medicine Hat, commenced a search for oil in the rocks below the Medicine Hat gas sand within the limits of the Medicine Hat gas field. For their first well they chose a location in the northern part of the city—L.S. 4, Sec. 6, Tp. 13, Range 5, W. 4th Mer."

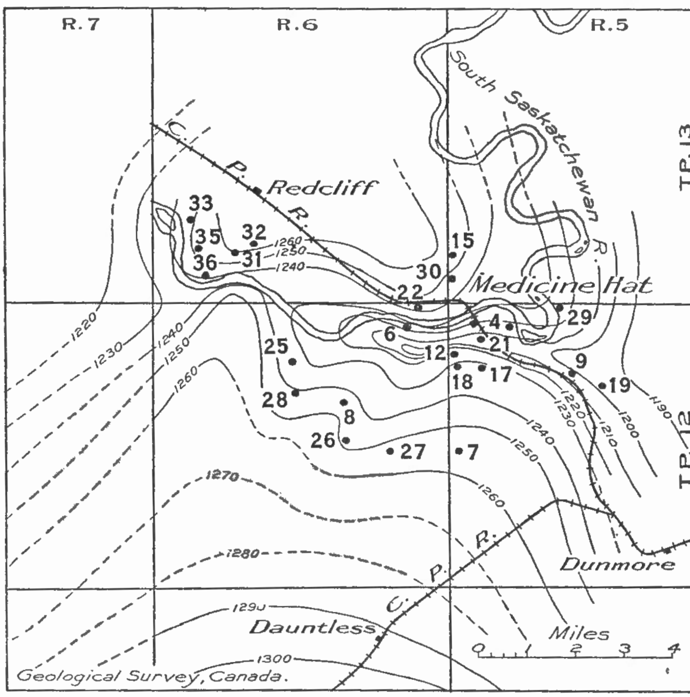

Figure 17. Medicine Hat gas field; structure contours represent top of Medicine Hat gas sand; numbers designate the well as given in the table, pages 148 and 149.

This well did not find oil in commercial quantity. The Medicine Hat gas sand where penetrated was 39 feet thick and was reached at a depth of 1,081 feet, the Alberta shale-Lower Cretaceous contact is at approximately 2,525 feet, the top of the Ellis at about 2,760, and the top of the Palæozoic, although difficult to determine from the samples, is thought to be at approximately 2,980 feet. A flow of 2,600,000 cubic feet of gas a day under a pressure of 400 pounds a square inch was struck in the Medicine Hat gas sand and a flow of 10,000,000 cubic feet of gas which turned to water in one day was obtained at a depth of 2,845 feet.

Dyer considered the Medicine Hat gas sand to be an eastward extension of the Milk River sandstone. Spratt (1931, page 1178) has shown that this is probably not the case. According to determinations made by Wickenden (personal communication) the top of the Alberta shale in Roth No. 1 well occurs between depths of 990 and 1,000 feet and since the Medicine Hat gas sand was reported to occur at a depth of 1,081 feet it must lie within and near the top of the Alberta shale.

Log of Roth and Faurot Well No. 2

(Sec. 8, Tp. 13, Range 6, W. 4th Mer.; Elevation, 2,490 feet)

—	Thickness Feet	Depth Feet
Foremost beds		
Buff-coloured and grey shale	....	100
Grey, sandy shale and sandstone	25	125
Grey sandstone	15	140
Light grey shale with sandstone	20	160
Sandy, grey shale, carbonaceous	40	200
" " trace of coal	10	210
Coal bed	10	220
Grey to brown, coaly shale	10	230
Grey shale with traces of coal	10	240
" " carbonaceous materials	20	260
" " lignite	70	330
Pakowki formation		
Light grey, sandy shale	10	340
Grey shale, darker	120	460
Very fine, light grey shale	30	490
Fine, grey shale	20	510
Grey shale, slightly darker	10	520
Grey shale	50	570
" , darker	20	590
Brownish grey shale	70	660
Grey, sandy shale and calcareous sandstone	30	690
Dark grey shale	100	790
Grey shale, darker	10	800
Grey shale with a little bentonite	30	830
Grey shale	40	870
Samples missing	400	1,270
Alberta shales		
Grey shale	400	1,670
" " with sandy shale and sandstone	20	1,690
" " " pyrite	20	1,710
" "	50	1,760
" " with bentonite	10	1,770
" "	10	1,780
" " with pyrite	10	1,790
" "	200	1,990
Dark grey shale with sandstone bands	210	2,200
" brown to grey shale with sandy partings and sandstone	120	2,320
Dark grey shale with tiny, black chert pebbles	10	2,330
Sandy, grey shale with chert pebbles	130	2,460
" " with some pyrite and bentonite	245	2,705
Lower Cretaceous		
Fine-grained sandstone with quartz grains and black, grey, and green chert pebbles	35	2,740
Red shale with a little green shale	20	2,760
Lighter red shale	30	2,790
Light green to bluish shale with some maroon to reddish shale	40	2,830

Log of Roth and Faurot Well No. 2

(Sec. 8, Tp. 13, Range 6, W. 4th Mer.; Elevation, 2,490 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Lower Cretaceous—Conc.		
Light green to bluish shale; a little coal	10	2,840
Light green to purplish red shale; a little coal	20	2,860
Grey, green, and reddish shale	55	2,915
Grey sandstone	20	2,935
Ellis formation		
Sandstone with some shale and dolomite	5	2,940
Reddish brown and light greenish shale with some sandstone and dolomite	10	2,950
Very fine sand	20	2,970
Buff and brown, clay shale, calcareous and in part limy	60	3,030
Grey sandstone with dark grey shale (oil show)	10	3,040
Grey, calcareous shale with pyrites	20	3,060
Fine, white quartz sand; water at 3,065 feet	10	3,070
Grey and reddish stained sandstones	80	3,150

It is reported that the top of the Medicine Hat gas sand was struck at 1,252 feet and hence the top of Alberta shale should be in the 400-foot interval between 870 and 1,270 feet unrepresented by samples. This well did not reach the Palæozoic limestone, although it must have been very close to it at 3,150 feet. The top of the Palæozoic was encountered at Roth No. 1 well at approximately 2,980 feet. A log of the Palæozoic section in No. 1 well is as follows:

—	Thickness Feet	Depth Feet
White and pinkish, cherty limestone	630	3,610
Dark shale	80	3,690
Greenish shale	60	3,750
Samples very poor and indeterminate	110	3,860
White and pinkish anhydrite and limestone	60	3,920
Grey limestone and black shale	140	4,060

The dark shale corresponds, according to Moore (1931), to the top of the Three Forks formation, i.e., the top of the Devonian, whereas the overlying, cherty limestone is Mississippian.

MILK RIVER AREA

Milk River area (Figure 13, No. 6), as here considered, includes the sites of the Commonwealth Milk River well, Erickson Coulée well, and the structure on which the Rogers-Imperial (Range No. 1 and Range No. 2) wells have been drilled. There are also a number of other wells in the area.

Milk River, Pakowki, and Foremost beds are exposed along Milk River which flows eastward across the area, turning southward in Range 5. The river lies in a comparatively deep valley showing some bad land topography in the eastern part where the higher beds are exposed. Drainage from Sweet Grass Hills has cut many deep coulées in the south side of the valley from Range 13 to Range 7. The most prominent valley joining Milk River Valley on the north side is Verdigris Coulée which trends in a southeast direction and contains a number of small lakes. It is cut deeply below the general level of the plains and exposes successively higher beds to the northwest. On a small branch of it in Tp. 3, Range 15, the Commonwealth Milk River well was drilled.

Structurally the Milk River area is part of the Sweet Grass Arch which, as already stated, plunges northward. The rate of dip varies considerably, but in Range 15 is about 40 feet to the mile. West Butte lies south of Range 12 and close to the International Boundary. From it the strata dip steeply northward and the structure along the International Boundary seems to be a series of plunging anticlines on the Sweet Grass Arch. The Rogers-Imperial gas field is on one of these folds northeast of West Butte. Dykes radiating from the intrusive mass of West Butte are known in the Rogers-Imperial field and may occur elsewhere. They may have considerably influenced the concentration of oil and gas, as apparently seems to have been the case in the Rogers-Imperial field. The Geological Survey has little information regarding the details of the structure.

Log of Commonwealth Milk River Wells

(L.S. 8, Sec. 9, Tp. 3, Range 15, W. 4th Mer.; Elevation, 3,157 feet)

—	Thickness Feet	Thickness Inches	Depth Feet	Depth Inches
Missing	....		20	0
Milk River				
Brown weathering shale	20	0	40	0
Grey shale and sandy shale	40	0	80	0
Missing	10	0	90	0
Dark grey, carbonaceous, and lignitic shale	10	0	100	0
Grey shale with a little sandstone	10	0	110	0
Light grey sandstone	30	0	140	0
Dark grey shale with plant remains	60	0	200	0
Light grey sandstone	90	0	290	0
Light grey, sandy shale, sandstone, traces of lignite	170	0	460	0
Alberta shale				
Dark grey shale with occasional sandstones. Traces of bentonite at 830–840 feet	540	0	1,000	0
Dark grey shale, partly sandy	570	0	1,570	0
Dark grey shale with some bentonite	60	0	1,630	0
Dark grey shale	40	0	1,670	0
Grey sandstone and shale (water)	10	0	1,680	0
Grey shale and sandstone	50	0	1,730	0
Light grey sandstone (water)	10	0	1,740	0
Dark grey shale and sandstone	40	0	1,780	0
Grey, fine-grained sandstone	10	0	1,790	0
Dark grey, sandy shale and sandstone	40	0	1,830	0
Grey sandstone (water)	10	0	1,840	0
Grey shale and sandstone with bentonite	10	0	1,850	0
Missing	10	0	1,860	0
Grey sandstone, some shale and bentonite	20	0	1,880	0
Grey shale and sandstone with bentonite	80	0	1,960	0
Grey sandstone (water at 1,974–1,980 feet)	40	0	2,000	0
Grey shale and sandstone	20	0	2,020	0
Grey sandstone	10	0	2,030	0
Grey shale alternating with grey sandstone	130	0	2,160	0

Log of Commonwealth Milk River Wells

(L.S. 8, Sec. 9, Tp. 3, Range 15, W. 4th Mer.; Elevation, 3,157 feet)—*Continued*

—	Thickness		Depth	
	Feet	Inches	Feet	Inches
Lower Cretaceous				
Grey and greenish shale and sandstone	10	0	2,170	0
Grey sandstone	10	0	2,180	0
Green and maroon shale, some sandstone	10	0	2,190	0
Grey sandstone	10	0	2,200	0
Grey, green, and red shale and sandstone	20	0	2,220	0
Red shale	10	0	2,230	0
Red and green shale	10	0	2,240	0
Grey sandstone with some shale	40	0	2,280	0
Grey, green, and maroon shale	30	0	2,310	0
Grey sandstone	20	0	2,330	0
Grey, green, and maroon, sandy shale	90	0	2,420	0
Grey and green shale; ironstone at 2,500 feet	80	0	2,500	0
Grey and green shale, trace of maroon shale	10	0	2,510	0
Light grey, shaly sandstone	40	0	2,550	0
Grey, green, and maroon shale	10	0	2,560	0
Light grey, shaly sandstone and shale	10	0	2,570	0
Light grey sandstone "Sunburst" sand	30	0	2,600	0
Ellis				
Grey and brown shales with glauconite	50	0	2,650	0
Light grey, calcareous shale	60	0	2,710	0
Light greenish grey, calcareous, and sandy shale, pyritic	20	0	2,730	0
Light greenish shale, some white limestone and chert	10	0	2,740	0
Mississippian				
Granular, white limestone, oil stained	40	0	2,780	0
Light-coloured limestone	160	0	3,540	0
Cherty limestone	110	0	3,650	0
Dark grey, calcareous shale	10	0	3,660	0
Dark grey, shaly limestone	90	0	3,750	0
Light grey limestone	90	0	3,840	0
Devonian				
Black, bituminous shale	30	0	3,870	0
Dark grey limestone and shale	30	0	3,900	0
Missing	70	0	3,970	0
Light grey limestone	50	0	4,020	0
Grey to brown limestone and anhydrite	20	0	4,040	0
Grey limestone	30	0	4,070	0
Light buff limestone, a little anhydrite	50	0	4,120	0
Grey to brownish limestone with anhydrite at 4,170–4,180 and at 4,220–4,230 feet	110	0	4,230	0
Dark buff and grey limestone	440	0	4,670	0
Missing (may be the lower anhydrite zone of the Devonian)	65	0	4,735	0
Pre-Devonian, probably all Cambrian				
Grey to light brownish limestone	91	0	4,826	0
Missing	46	0	4,872	0
Light brownish limestone	78	0	4,950	0
Very dark brown limestone, silty	145	0	5,075	0
Missing	65	0	5,140	0
The log of rest of well from core samples.				
Interbedded buff and grey, sugary-textured and hard, dark grey, dolomitic limestone, all with paper-thin partings of black, fine-grained bituminous shale. The coarsely crystalline parts bear small vugs filled with white anhydrite. The porous, buff limestone at 5,144 feet gave a small show of oil in chloroform	9	5	5,149	5
Fine-grained, hard, black, calcareous shale	1	0	5,149	6
Core lost, probably all shale	2	0	5,151	6
Dark brownish grey, medium to coarse, crystalline dolomitic limestone with partings of black, bituminous shale	2	8	5,153	8

Log of Commonwealth Milk River Wells

(L.S. 8, Sec. 9, Tp. 3, Range 15, W. 4th Mer.; Elevation, 3,157 feet)—*Concluded*

—	Thickness Feet	Thickness Inches	Depth Feet	Depth Inches
Pre-Devonian, probably all Cambrian—Concluded				
Dense, medium grey, dolomitic limestone with thin, dark and white bands	3	6	5,157	2
Grey, subtranslucent anhydrite banded with dark, calcareous shale in thin stringers	0	10	5,158	0
Hard, dense, dolomitic limestone with inclusions of anhydrite	1	3	5,159	3
Dark grey, thin-bedded, platy, fine-textured anhydrite	0	9	5,160	0
Brownish grey, coarse-grained, dolomitic limestone with some inclusions of anhydrite	2	3	5,162	3
Denser, closer grained, light grey, dolomitic limestone with small anhydrite inclusions. At 5,163 feet a small band of pure, fine-grained, dense anhydrite interbedded with small amounts of black, bituminous shale	2	3	5,164	6
Brownish grey, sugary-textured, crystalline, dolomitic limestone with thin films of dark, bituminous matter	1	7	5,166	1
Core lost, probably coarse-grained dolomite	1	11	5,168	0
Brownish grey, medium-textured, crystalline, dolomitic limestone. Gave a small oil show with chloroform	1	8	5,169	8
Light grey, fine-grained, crystalline, dolomitic limestone	0	10	5,170	6
Brownish grey, medium-textured, crystalline, dolomitic limestone with partings of black, bituminous shale	1	4	5,171	10
Light grey, dense, fine-grained anhydrite with thin films of black shale and some grey, dolomitic limestone	2	1	5,173	11
Core lost	5	1	5,179	0
Dark brown, coarse-textured, crystalline, dolomitic limestone, some brownish oil. Rock is of low porosity	2	0	5,181	0
Dark grey, dense to coarse-grained anhydrite containing small percentage of lime	6	0	5,187	0
Coarse-grained, crystalline, pearly anhydrite	2	0	5,189	0
Hard, fine-grained dolomite interbedded with coarse, crystalline anhydrite	1	6	5,190	6
Dark grey, limy dolomite and anhydrite with a few partings of dark, fine shale	2	0	5,192	6
Core lost	2	6	5,195	0
Light brown, soft, crystalline, medium-grained, dolomitic limestone. Probably water-bearing	1	6	5,196	6
Dark grey to black chert	0	2	5,196	8
Light buff, sugary-textured, crystalline, limy dolomite	0	10	5,197	6
Dark grey, fine-grained, dense, limy, hard dolomite at top grading to dense, blue, siliceous, limy dolomite	2	8	5,200	2
Dark steel-grey, limy sericite, coarse-grained, siliceous shale	0	2	5,200	4
Core lost, all shale	5	8	5,206	0
Dark steel-grey, sericitic shale with *Lingula* sp.? at 5,206 feet 6 inches and at other lower horizons in shale. Shale has patches, spots, and thin beds of deep maroon (hematite) colouring. Has some crystals suggestive of pyrite. Parts of shale extremely flaky, other parts deep greenish grey and very fissile, other parts hard, more siliceous, and of deep maroon colour. More fossils at 5,230 feet	36	0	5,242	0

The log of the upper part of the Commonwealth Milk River is by J. G. Spratt. The log of the lower part is by J. O. G. Sanderson who places the strata from 4,950 to 5,205 feet in the Meagher limestone (Cambrian), and the strata below this, in the Barker shale formation.

Log of Erickson Coulée Well

(L.S. 13, Sec. 8, Tp. 1, Range 12, W. 4th Mer.; Elevation, 3,216 feet)

—	Thickness Feet	Depth Feet
Missing	....	760
Alberta shale		
Grey shale	120	880
Grey shale with bentonite	110	990
Grey shale	210	1,200
Grey shale, very bentonitic	20	1,220
Grey shale, with grey, calcareous sandstone	40	1,260
Grey shale, with sandstone with bentonite, chert pebbles, 1,260-1,270, 1,340-1,350 feet	170	1,420
White bentonite	20	1,440
Dark grey shale and grey sandstone, some chert pebbles and bentonite	120	1,560
Dark grey shale and sandstone with bentonite	90	1,650
Dark grey shale and sandstone, chert pebbles at 1,670-1,680 feet	60	1,710
Dark grey shale and bentonite	10	1,720
Dark grey shale and shaly sandstone	60	1,780
Dark grey shale	10	1,790
Dark grey shale and bentonite	30	1,820
Dark grey shale	40	1,860
Lower Cretaceous		
Dark grey and green shale, and sandstone	20	1,880
Light grey and greenish sandstone, grey, green, and red shale	60	1,940
Light grey and greenish sandstone, and grey shale	60	2,000
Grey, green, and red shale, and greenish sandstone	90	2,090
Green shale, and grey and greenish sandstone, some red shale and bentonite	150	2,240
Light green shale, some red shale	10	2,250
Grey and greenish sandstone, some red shale	60	2,310
Missing	8	2,318
Light grey sandstone	2	2,320
Missing	50	2,370
Ellis, top of, probably at about 2,360 feet		
Grey, sandy, slightly calcareous shale with glauconite	10	2,380
Calcareous shale, much glauconite	20	2,400
Calcareous shale, less glauconite	40	2,440
Missing	10	2,450
Light grey, calcareous shale, a little red shale	20	2,470
Greenish grey, shaly limestone with some glauconite	20	2,490
Greenish grey, shaly limestone with calcareous sandstone	20	2,510
Mississippian		
Grey limestone with chert and sandstone	10	2,520
Grey limestone with chert	10	2,530
Grey limestone, cherty, 3,330-3,360 feet	830	3,360
Grey limestone	90	3,450
Grey limestone and quartz sand	80	3,530
Devonian		
Black, bituminous shale	10	3,540
Grey limestone	10	3,550
Greenish, calcareous shale with anhydrite	40	3,590
Mostly anhydrite and gypsum	60	3,650

Log of Range Oil and Gas Company Well No. 2

(L.S. 6, Sec. 21, Tp. 1, Range 11, W. 4th Mer.; Elevation, 3,361 feet)

—	Thickness Feet	Depth Feet
Missing	....	110
Pakowki		
Shale with sand, chert pebbles 120-130 feet	20	130
Upper Milk River		
Shale and grey sand, carbonaceous	20	150
Light grey sandstone	10	160
Light grey sandstone with a little grey shale	40	200
Grey shale	10	210
Sand and shale	20	230
Grey shale, traces of lignitic materials	20	250
Lower Milk River		
Light grey sandstone	120	370
Light grey sandstone with shale	10	380
Grey, clayey sand	30	410
Greenish grey, sandy shale	140	550
Some of the sandy shale may belong to the Alberta shale. There is, however, a very distinct colour change at 550 feet.		
Alberta shale		
Grey to dark grey shale	510	1,060
Grey to dark grey shale with bentonite	10	1,070
Grey to dark grey shale	650	1,720
Grey sandstone	20	1,740
Sandstone with shale	100	1,840
Sandstone	40	1,880
Dark grey shale	30	1,910
Grey sandstone with shale and bentonite	40	1,950
Dark grey shale with bentonite	40	1,990
Sandstone and shale	20	2,010
Grey sandstone	50	2,060
Grey to black shale, shaly sandstone, and bentonite	170	2,230
Grey to black shale	60	2,270
Coarse grey sandstone	50	2,320
Lower Cretaceous		
Green and grey shale	120	2,440
Green shale, trace of coal 2,520 feet	100	2,540
Green and maroon shale	45	2,585
Sandstone and vari-coloured shale	25	2,610
Limestone and grey shale	10	2,620
Grey shale	20	2,640
Grey shale and light buff limestone	10	2,650
Coarse sandstone	10	2,660
Vari-coloured shale	20	2,680
Light grey sandstone	30	2,710
Green and reddish shale	30	2,740
Ellis		
Grey, limy shale, slightly greenish	70	2,810
Brownish grey, limy shale	20	2,830
Light buff, grey, limy sandstone	10	2,840
Limy sandstone and light and dark shale	30	2,870
White sandstone	10	2,880
Green-grey, calcareous shale; fossil fragment	20	2,900
Buff limestone and green, calcareous shale	12	2,912
Green, calcareous shale	3	2,915
Palæozoic (Mississippian) limestone		
Cherty limestone, bluish grey	3	2,918

In the above log the descriptions are by J. G. Spratt, the divisions into formations by the writer.

MANY ISLAND LAKE AREA

(Figure 13, No. 7)

Many Island Lake area is 20 miles northeast of Medicine Hat. Attempts have been made by several companies to drill wells, but only two holes reached any considerable depths. These were the Community Oil Company's well which reached a depth of 2,500 feet, and the well of the Many Islands Oil and Gas Company, Limited, which attained a depth of 3,540 feet and penetrated 350 feet of Palæozoic limestone. The upper 1,870 feet of this well was drilled by jetting machine and consequently the information regarding this part is not very reliable. The lower part, however, was drilled by diamond drill and furnished an excellent log.

Log of Many Islands Oil and Gas Company, Limited, Drazan No. 1[1] Well

(L.S. 13, Sec. 34, Tp. 13, Range 2, W. 4th Mer.; Elevation, 2,368 feet)

—	Thickness Feet	Depth Feet
Recent	0	55
Foremost		
Light-coloured clay and sandy clay	68	123
Grey sand, clay bands	36	159
Light grey and greenish clay, thin beds of sand	35	194
Brown, carbonaceous shale and coal	11	205
Missing	14	219
Shale and clay, light grey, slightly sandy at intervals	70	289
Shale, grey, darker	46	335
Shale, grey and brown, coal seams and oyster beds	22	357
Shale, blue-grey	18	375
Sandstone, greenish grey	15	390
Pakowki and Milk River equivalents		
Shale, blue-grey	50	460
Sandstone, hard	2	462
Shale, blue-grey	368	830
Shale, brown	12	842
Sandy shale, black	9	851
Shale, grey, dark, fissile	14	865
Shale, grey, dark, slightly sandy	20	885
Shale, blue-black, compact, and fairly hard, containing some fine sand, thin bunch of bentonite	100	985
Shale, blue-black, and fine sand, steel grey	130	1,115
Shale, blue-grey, fissile, laden with iron pyrites	57	1,172
Shale, dark, compact	23	1,195
Shale, blue-grey, iron-stained from pyrites	25	1,220
Shale, dark, compact, with fine sand partings yielding gas	55	1,275
Shale and fine sand	45	1,320
Alberta shale		
Shale and sandy shale. A speckled shale zone occurs at this horizon with fossil shells and columnar calcite	20	1,340
Sandy shale	35	1,375
Shale, dark; bands of bentonite	48	1,427
Shale and fine sand, gas? This is probably the equivalent of the Medicine Hat gas sand	13	1,440
Shale, dark bands of bentonite	36	1,476
Dark, hard shale	54	1,530
Soft, dark shale	20	1,550

[1] This log is slightly modified from a log prepared by W. S. Dyer and published in Geol. Surv., Canada, Ec. Geol. Ser. No. 5, pp. 54-55. The main change made here is in the position of the top of the Alberta shale.

Log of Many Islands Oil and Gas Company, Limited, Drazan No. 1 Well (L.S. 13, Sec. 34, Tp. 13, Range 2, W. 4th Mer.; Elevation, 2,368 feet)—*Continued*

—	Thickness Feet	Depth Feet
Alberta shale—Conc.		
Soft, dark shale	20	1,570
Hard, dark brown shale	5	1,575
Soft, and dark brown shale	16	1,591
Hard, dark brown shale with fossils	1	1,592
Hard, dark, sandy shale	38	1,630
Grey, soft shale	30	1,660
Hard ironstone nodule?	2	1,662
Dark brown shale	8	1,670
Hard ironstone nodule	1	1,671
Soft, dark brown, sandy shale	9	1,680
Hard ironstone nodule	0·5	1,680·5
Dark brown, coarse, sandy shale	39·5	1,720
Dark brown, hard and tough shale, and fine sand	86	1,806
Hard, dark brown shale and sand	4	1,810
Light brown sand and shale	50	1,860
Hard, brown sand and ironstone	10	1,870
Hard, grey sandstone	12	1,882
Shale and sandy shale	43	1,925
Shale	37	1,962
Shale, part of core only	48	2,010
Sand and shaly sand, part of core only	23	2,033
Missing	7	2,040
Shale	43	2,083
Shale grading to sandy shale	20	2,103
Shale, only a few inches recovered	18	2,121
Shale, a few inches of sandstone at 2,160 feet	39	2,160
Shale	24	2,184
Core lost except a few inches of shale	24	2,208
Shale	86	2,294
Sandy shale to sandstone	4	2,298
Sandstone and sandy shale	37	2,335
Sandstone	25	2,360
Sandstone and sandy shale	65	2,425
Shale	5	2,430
Missing except a little shale and bentonite?	11	2,441
Sandstone and shaly sandstone. Bentonite reported at 2,456 feet	47	2,488
Sandy shale	32	2,520
Only one foot of shale recovered. Some bentonite? at 2,530 feet	12	2,532
Shale, part recovery	50	2,582
Shale, dark	85	2,667
Lower Cretaceous		
Yellowish grey, crossbedded sandstone	87	2,754
Shale, green	7	2,761
Shale, grey, green, and reddish	32	2,793
Sandstone, grey	15	2,808
Shale, black	8	2,816
Sandstone, grey	2	2,818
Shale, red, oil show 2,808 to 2,822 feet	4	2,822
Shale, grey, sandy	13	2,835
Shale, chocolate-red	5	2,840
Shale, grey	9	2,849
Shale, black	1	2,850
Shale, red	8	2,858
Shale, grey	12	2,870
Shale, black, carbonaceous in places	3	2,873
Shale, grey, sandy	16	2,889
Sandstone, grey	15	2,904
Coarse, grey sandstone	33	2,937

Log of Many Islands Oil and Gas Company, Limited, Drazan No. 1 Well
(L.S. 13, Sec. 34, Tp. 13, Range 2, W. 4th Mer.; Elevation, 2,368 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Ellis		
Light-coloured, hard, sandy limestone	5	2,942
Grey shale	21	2,963
Grey, arenaceous limestone and some shale	8	2,971
Hard, grey shale	5	2,976
Grey shale with streaks of limestone and sandstone	10	2,986
White or light grey, argillaceous limestone very like Jurassic of Sweet Grass Hills but somewhat lighter colour. Show of oil between 3,005 and 3,018 feet	50	3,036
Grey, fine-grained, argillaceous limestone. Fossils	9	3,045
Grey, fine-grained sandstone	13	3,058
Light grey, hard, argillaceous limestone	7	3,065
Very hard, grey, sandy shale	2	3,067
Pale grey, argillaceous limestone	2	3,069
Black shale	2	3,071
Grey, argillaceous limestone	5	3,076
Shale and limestone, grey, hard	4	3,080
Dark grey, soft shale	3	3,083
Grey limestone, hard	3	3,086
Grey, and dark shale	5	3,091
Grey, sandy shale	8	3,099
Black shale	4	3,103
Green, sandy shale and pyrite	7	3,110
Light grey, argillaceous limestone with crystalline quartz	3	3,113
White, rather hard limestone, very porous with show of heavy black oil between 3,113 and 3,123 feet	27	3,140
White, chalky limestone, porous toward top	15	3,155
Green, soapy shale	8	3,163
Hard, white limestone	2	3,165
Green shale	1	3,166
Hard limestone	8	3,174
Softer limestone	2	3,176
Hard, white limestone	2	3,178
Soapy, green shale	5	3,183
Grey limestone	1	3,184
Greenish grey, soft shale	6	3,190
Palæozoic (Mississippian)		
Light grey limestone, crystalline	3	3,193
Somewhat mottled, brown and grey, very hard limestone	2	3,195
Grey and white, crystalline limestone	26	3,221
Cherty limestone, not crystalline, grey and brown mottled	2	3,233
Grey, sandy shale	1	3,234
Cherty, mottled limestone, grey and brown	6	3,240
Grey limestone, crystalline in places	18	3,258
Grey, non-crystalline limestone, with crinoid stems	11	3,269
Grey limestone, more crystalline	3	3,272
Grey limestone with crinoid stems	18	3,290
Hard, grey limestone. Spirifer at 3,292 feet	34	3,324
Hard, grey limestone, more crystalline. Large, brachiopod-like Productus at 3,325 feet	4	3,328
Grey limestone with very numerous crinoid stems and sections of brachiopods	13	3,341
Grey, sandy limestone	4	3,345
Grey limestone full of crinoid stems and with some brachiopods; black chert from 3,353 to 3,354 feet	29	3,374
Dark, hard limestone with fossils	9	3,383
Dark grey shale, hard	7	3,390
Calcareous shale, hard	11	3,401
Calcareous shale, streaked with sandstone layers	34	3,435
Dark brown limestone	10	3,445
Grey, fine-grained, sandy limestone with black chert	95	3,540

According to Dyer (Hume, 1928, page 56) the top of the Lower Cretaceous in this well is 100 feet lower than in Roth No. 1 well at Medicine Hat, giving a low regional dip of 5 feet a mile to the east or northeast. Dyer states that

"the elevation of the contact between the Bearpaw shales and the Pale beds at several points around Many Island Lake and Medicine Hat illustrates well the nearly horizontal attitude of the strata. Thus, in an outcrop in Sec. 34, Tp. 16, Range 8 (30 miles northwest of Medicine Hat), the elevation of this contact is 2,580 feet; in Sec. 30, Tp. 15, Range 2 (15 miles north of the Drazan well and 20 miles north of Many Island Lake), it is 2,547 feet; in Sec. 13, Tp. 11, Range 3 (4 miles south of Irvine), it is 2,631 feet; in Sec. 18, Tp. 11, Range 29, W. 3rd Mer. (5 miles southeast of Walsh, Sask.), it is 2,539 feet. This shows a dip of 5 feet a mile to the east."

No local structure is known in Many Island Lake area and hence prospects for gas and oil are questionable. The equivalent of the Milk River sandstone in Drazan No. 1 well carried a little gas. Apparently the Medicine Hat gas sand about 100 feet below the top of the Alberta shale is very thin.

CYPRESS HILLS AREA

By Loris S. Russell

Cypress Hills of southeastern Alberta and southwestern Saskatchewan constitute a large erosion remnant of the Tertiary plains of western Canada. The summit, at an elevation of about 4,800 feet above sea-level, is an extremely flat plateau, interrupted in many places by stream dissection. At the western end of the hills certain outliers, such as Eagle Butte, are cut off from the main upland by a large valley known as Medicine Lodge Coulée. The presence of geological structures suitable for the accumulation of oil and gas in the western Cypress Hills was first suggested by W. S. Dyer (1928, pages 15-29). This was followed by the drilling of the two Eagle Butte wells. During 1931 the writer visited this area and conducted detailed surveys of the geology in the vicinity of Eagle Butte and Thelma. This investigation confirmed the observations of Dyer, but showed that his interpretations were open to some modification.

The stratigraphy of southern Saskatchewan has been investigated critically by F. H. McLearn (1927, 1928, 1929, 1930). The results of this work have necessitated a revision of the stratigraphy in the western Cypress Hills. One notable change is that the strata formerly divided into the Fox Hills and Estevan formations are now grouped in the Eastend formation. The stratigraphic succession in the western Cypress Hills is now considered to be as follows.

Tertiary	Lower Oligocene	Cypress Hills
	Upper? Paleocene	Ravenscrag
Mesozoic	Upper Cretaceous	Whitemud
		Eastend
		Bearpaw

Only the upper part of the Bearpaw formation is exposed within Cypress Hills. These upper beds consist mostly of the typical dark grey shale, but also contain thin bands of silt that become more numerous toward the top of the formation.

The overlying Eastend formation is best exposed on Willow Creek, near Thelma. Here the writer has subdivided (Russell, 1932, page 132) the section into the following members.

	Feet
Uppermost member: silt and fine sand, pale buff, transitional above to the Whitemud formation	± 30
Carbonaceous member: alternating sand and clay, with carbonaceous beds and at least one lignite seam	49
Upper sandstone member: sandstone, soft, massive, crossbedded, grey, buff, or brown	37
Shale member: shale, friable or fissile, grey-brown, sandy or bentonitic in places; some clayey sandstone; marine fossils	95
Lower sandstone member: sandstone, soft, massive, crossbedded, grey and grey-buff, finely banded with brown	±172

The lower sandstone and the shale member together are the Fox Hills formation as recognized by Williams and Dyer (1930, pages 62-74), and the remainder is the Estevan formation of those authors. In the writer's interpretation the shale member represents the uppermost part of the Bearpaw formation of Saskatchewan, and the upper sandstone and uppermost member are the approximate equivalents of the type Eastend in Frenchman River Valley, Saskatchewan. Both the lower sandstone and the carbonaceous member apparently disappear to the east.

A somewhat thicker section of the Eastend formation was measured in Medicine Lodge coulée, about 6 miles to the northwest. Here the shale member appears to be represented by less than 20 feet of sandy shale, with brackish-water fossils in places.

The Whitemud formation belongs to the same sedimentary phase as the underlying Eastend, as shown by the transitional nature of the contact. As the Whitemud formation is the most conspicuous geological horizon in the area, a detailed section is given below. This was measured in Medicine Lodge coulée, Sec. 31, Tp. 7, Range 3, W. 4th Mer.

	Feet
Argillite or tuff, siliceous, hard, compact, light grey	0·5
Clay, friable, plastic, dark grey-brown	27
Clay, somewhat kaolinized, friable, white to light grey	4
Clay, friable, plastic, dark grey-brown	5·5
Clay, light grey, white-weathering	1
Clay, friable, black, refractory	1
Clay, friable, light greenish grey	1·5
Silt, kaolinized, white	6

These Whitemud beds are correlated by the writer with the type Whitemud of Saskatchewan, and, following Sanderson (1932, page 67), with certain beds in the upper part of the Edmonton formation. Most students of the geology in the western Cypress Hills have limited the Whitemud formation to the white clay and silt. The writer follows McLearn in including also the dark clays, up to the base of the overlying Ravenscrag.

The upper limit of the Whitemud beds is an erosional unconformity, and in many places the formation appears to be removed completely. This possibility must be kept in mind when using the Whitemud horizon for structural mapping. The overlying formation, the Ravenscrag, consists mostly of medium- to coarse-grained, buff-coloured sandstone, especially in the lower part. It is considered by the writer to be similar in lithology and age to the Paskapoo formation of central Alberta, and to represent only the upper part of the type Ravenscrag of Saskatchewan.

The Cypress Hills formation is the uppermost unit in the section, and underlies the summit of Cypress Hills. In the western end of the hills, near Medicine Lodge Coulée, the formation is about 40 feet thick, and is composed almost entirely of quartzite and chert conglomerate, with coarse sandstone matrix.

Cypress Hills, Alberta, are situated on the eastern limb of the Sweet Grass anticline, so that the general dip of the area is a slight one to the east. In places, however, the Whitemud beds and other horizons occupy anomalous elevations, as noted by all recent observers in the area. Dyer (1927, pages 18, 21) made numerous observations on the position of these horizons and from the data so obtained plotted a subsurface contour map for the region of Eagle Butte and Bullshead Creek. The disturbed condition of the Whitemud beds was noted by this author, but apparently not considered as a significant feature. In contrast, some of the petroleum geologists who have worked in this area appear to have interpreted all the anomalous elevations as the result of large-scale slumping. The great extent to which Whitemud beds may be slumped without destruction of the bedding is well shown in Frenchman River Valley, between Eastend and Ravenscrag, Saskatchewan. In Eagle Butte area the Whitemud formation in many cases shows unmistakable evidence of such dislocation. The geologist here must decide to what extent slumping is to be invoked as an explanation of the apparent structural irregularities displayed by the Whitemud beds. It is the writer's opinion that sharp changes in level at this horizon cannot be accepted as indications of subsurface structural features unless corroborated by other evidence. As a check on the Whitemud the most useful horizon is the carbonaceous member of the Eastend formation, also employed by Dyer. With this viewpoint the writer plotted his observations in the form of structure sections. The sections are described from south to north, so that the more regular conditions may be examined first.

One section lies in a north-south direction and follows closely the valley of Willow Creek. The beds here have a very slight dip to the north, with small subsidiary folds. M. Y. Williams (G.S.C., Map 204 A, 1928) has recorded dips as high as 49 degrees in Sec. 23, Tp. 6, Range 3, W. 4th Mer., just south of the end of this section. These dips appeared to the writer as the results of Pleistocene or Recent slumping in the Bearpaw beds.

In two east-west sections the regional eastward dip appears, as determined from both the Whitemud beds and the carbonaceous member of the Eastend. This inclination is slight on the east side of Medicine Lodge Coulée, but on the west side there is an increase in the dip, resulting in the unusually high elevations of the Whitemud beds in Sec. 25, Tp. 7, Range 4, W. 4th Mer., and at the west end of Eagle Butte, Sec. 9, Tp. 8, Range 4, W. 4th Mer. In another section the eastward dip increases from Fly Lake to the east side of Medicine Lodge Coulée. At the latter place Bearpaw beds outcrop about 150 feet above the valley floor. These were not seen on the west side, and probably decrease rapidly in elevation toward the northwest. The western portion of this section passes through the uplands between Eagle Butte and Bullshead Creek. As noted above, the Whitemud beds are exposed near the western summit of Eagle Butte. The next outcrop to the north is about 2,000 feet distant and 218 feet lower in elevation, and from this point as far north as Sec. 21, Tp. 8, Range 4, W. 4th Mer., the Whitemud formation is exposed at decreasing elevations. However, as the beds in all these outcrops are inclined or otherwise distorted the marked decrease in the elevation of this horizon north of Eagle Butte may be ascribed in part to slumping. The presence, also, of a true northerly dip in this vicinity is shown by the occurrence of the Eastend coal in Sec. 28, Tp. 8, Range 4, W. 4th Mer., 50 to 75 feet above Bullshead Creek.

Another section involves the supposed fault described by Dyer on Bullshead Creek. Near the east end of the section in Sec. 4, Tp. 9, Range 4, W. 4th Mer., traces of Whitemud beds were found at about the same elevation as the disturbed outcrops south of Bullshead Creek. Slumping may have occurred here also, but its moderate extent is shown by the presence of the coal on Bullshead Creek, as mentioned above. Proceeding eastward no outcrops are encountered until the valley of Bullshead Creek is reached(Sec. 2, Tp. 9, Range 5, W. 4th Mer.). The conditions here have been well described by Dyer. Near the northwest corner of Section 2 there is a large outcrop of typical Bearpaw beds. Southeast or upstream from here the bedrock is covered for a short distance, but near the centre of Section 2 there are several small coal mines and some outcrops of disturbed Whitemud beds. The coal seam here dips slightly to the southeast, but shows no evidence of slumping. The position of the Whitemud beds relative to the seam indicates that the former have slumped down 50 to 75 feet. However, owing to the relatively undisturbed appearance of the coal seam the writer concurs with Dyer in ascribing the conditions here to the presence of a fault zone, which has a displacement of at least 400 feet. It is possible, however, that the fault does not persist at depth.

In conclusion, it is evident that certain horizons in the western Cypress Hills vary greatly in elevation within rather short distances, and that these variations can not be completely explained as the results of large-scale slumping. However, the structural features so indicated are very complex and do not appear to have definite trends, as represented in Dyer's subsurface contour map. Such complex, irregular structures might result from the unequal settling of underlying sediments. If this is the true explanation, the structural features at depth may be expected to differ considerably from those near the surface.

The presence of natural gas in western Cypress Hills has been demonstrated by Eagle Butte well No. 1, which encountered large flows at depths of 1,175 and 3,340 feet. The negative results of the No. 2 well indicate that the reservoirs tapped by No. 1 are of limited extent. There is, as yet, no evidence in this region of petroleum in commercial quantities.

The area in the vicinity of Eagle Butte appears worthy of further investigation. Structural features are visible in the surface geology here, but may not correspond to the structure at depth. It is recommended that any further deep drilling be preceded by shallow test-well investigations. The areas immediately east and south of Eagle Butte particularly merit study in this manner. Excellent key horizons may be encountered here at moderate depths.

Log of Eagle Butte No. 2 Well[1]

(L.S. 4, Sec. 30, Tp. 7, Range 3, W. 4th Mer.; Elevation, 3,854 feet)

—	Thickness Feet	Depth Feet
Sand, gravel, etc	50	50
Bearpaw		
Grey shale with sandy streaks	800	850
Grey shale, a little sandstone	30	880
Pale beds?		
Grey shale, carbonaceous streaks	170	1,050
Grey shale, coal fragments	50	1,100
Yellowish grey, sandy shale	110	1,210
Yellowish grey sand	10	1,220
Yellowish grey, shaly sandstone	10	1,230
Yellowish grey, calcareous sandstone	20	1,250
Yellowish grey sandstone	30	1,280
Grey sand	10	1,290
Dark grey sandstone and carbonaceous shale	10	1,300
Grey sand	10	1,310
Grey, shaly sand	50	1,360
Foremost		
Dark grey shale	70	1,430
Dark grey shale, with coal	10	1,440
Dark grey shale	50	1,490
Dark grey shale with coal	10	1,500
Dark grey shale with coal and fossil shells	10	1,510
Dark grey shale with coal	10	1,520
Dark grey shale in part carbonaceous	40	1,560
Dark grey shale with coal	10	1,570
Pakowki		
Yellowish grey shale, slightly bentonitic	540	2,110
Milk River		
Grey, sandy shale, black and yellowish, chert pebbles	30	2,140
Sandy shale	45	2,185
Light grey, calcareous sandstone	5	2,190
Grey shale and sandstone, water at 2,200 feet	10	2,200
Grey shale in part sandy	220	2,420
Alberta shale		
Grey shale (speckled shale zone)	20	2,440
Grey shale	220	2,660
Grey, bentonitic shale	30	2,690
Grey shale	430	3,120
Grey, bentonitic shale	10	3,130
Grey shale, some bentonite	180	3,310
Grey shale, very bentonitic	10	3,320
Grey shale, bentonitic (much at 3,420 feet)	100	3,420
Grey shale	150	3,570
Grey shale and sandstone, bentonitic	10	3,580
Grey shale, a little sandstone	50	3,630
Lower Cretaceous (marine)?		
Grey sandstone, a little shale	10	3,640
Grey sand	40	3,680

[1] Log of well and conclusions based on comparison of the two wells by G. S. Hume.

Log of Eagle Butte No. 2 Well

(L.S. 4, Sec. 30, Tp. 7, Range 3, W. 4th Mer.; Elevation, 3,854 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Grey sandstone, in part shaly	60	3,740
Dark grey shale	60	3,800
Dark grey shale, bentonitic	20	3,820
Dark grey shale	250	4,070
Missing	40	4,110
Lower Cretaceous (non-marine)		
Brown and greenish shale	60	4,170
Grey and greenish shale and sandstone	30	4,200
Missing	20	4,220
Grey sandstone with maroon and green shale	10	4,230
Greenish shale, some sandstone	10	4,240
Greenish and maroon shale	10	4,250
Grey sand	20	4,270
Grey dolomite and sand	20	4,290
Grey sand	30	4,320
Grey sandstone	10	4,330
Grey sand	10	4,340
Brownish, sandy shale	20	4,360
Ellis		
Greenish grey shale, calcareous	170	4,530
Greenish grey shale, and sandstone	10	4,540
Greenish grey shale, with limestone	30	4,570
Greenish grey shale, a little limestone	30	4,600
Light buff limestone and grey shale	40	4,640
Greenish grey shale	20	4,660
Limestone	10	4,670
Greenish grey shale	10	4,680

The uppermost 220 feet of beds assigned to the Pale Beds are so classed although dark of colour. The contact of the Bearpaw and Pale beds is not well marked although quite distinct in No. 1 well at 600 feet. The coal at the top of the Foremost occurs at the same height above sea-level in Nos. 1 and 2 wells. It is believed the well did not penetrate the Palæozoic limestone, but finished in the Jurassic (Ellis).

A comparison of the log of No. 1 well on L.S. 9, Sec. 31, Tp. 7, Range 4, with No. 2 well on L.S. 4, Sec. 30, Tp. 7, Range 3, is as follows:

—	Well No.	Depth Feet	Elev. of horizon	Difference
Coal at top of Foremost	1	1,210	2413	− 1
	2	1,440	2414	
Top of Milk River	1	1,880	1743	− 1
	2	2,110	1744	
Top of Alberta shale	1	2,130	1493	+59
	2	2,420	1434	
Top of marine Lower Cretaceous	1	3,330	293	+69
	2	3,630	224	
Top of non-marine Lower Cretaceous	1	3,805	−182	+74
	2	4,110	−256	

Thus although these two wells are 6 miles apart the higher horizons are at approximately the same elevation. The Alberta shale in each well is also about the same thickness and the main difference in the elevations of corresponding horizons at depth is apparently due to the Milk River formation being 60 feet thicker in No. 2, than in No. 1, well. A thickening of the Milk River formation within a local area might be accounted for by a lensing of certain sandstone beds, but since the top horizons are practically horizontal it follows that both the top of the Alberta shale and the top of the Lower Cretaceous show an eastward slope between the two wells of about 10 feet to the mile. This suggests tilting of the strata below the base of the Milk River formation prior to the deposition of the Milk River beds, a condition not known to occur elsewhere. This tilting is also suggested by the concentration of gas encountered in No. 1 well and the absence in No. 2 well. A tilting or warping, however, assumes a time interval between the top of the Alberta shale and the beginning of the deposition of the Milk River formation. Such a time interval seems improbable in the light of evidence from other areas and it seems certain there was no erosion of the Alberta shales since the thickness in the two wells is about the same. There does not appear, therefore, to be any obvious explanation of the tilting at depth and the horizontal character of the strata at the higher horizons.

SUFFIELD AREA

The Geological Survey has no information regarding the local structure in the vicinity of Suffield.

Log of Ontario-Alberta Oil Development Company, Limited, Well No. 1
(L.S. 15, Sec. 34, Tp. 17, Range 8, W. 4th Mer.; Elevation, 2,475± feet)

—	Thickness Feet	Depth Feet
Drift	....	80
Pale beds		
Light grey, argillaceous sandstone	50	130
Light grey sand with water at 141 feet	30	160
Ironstone band	2	162
Pale grey sandstone and shale	18	180
Light grey shale	10	190
Grey shale with carbonaceous partings	20	210
Pale, yellowish grey shale	10	220
Soft, light grey sandstone with shale	20	240
Light grey shale with plant remains	10	250
Foremost beds		
Grey to dark brown shale with coal fragments	10	260
Fine-grained, light grey sandstone	10	270
Grey to dark brown shale with coal fragments	20	290
Coal and dark brown, carbonaceous shale	10	300
Grey shale and coal fragments	90	390
Grey, sandy shale	30	420
Grey, sandy shale with coal fragments	70	490
Grey, sandy shale with sandstone	10	500

Log of Ontario-Alberta Oil Development Company, Limited, Well No. 1 (L.S. 15, Sec. 34, Tp. 17, Range 8, W. 4th Mer.; Elevation, 2,475± feet)—*Concluded*

—	Thickness Feet	Depth Feet
Fine-grained, light grey sandstone, some shale and coal	10	510
Light grey, argillaceous sandstone	10	520
Fine-grained sand with traces of coal	10	530
Fine-grained sand	10	540
Fine, sandy shale	10	550
Fine-grained, grey sand	10	560
Sandy shale with plant remains	10	570
Fine-grained, grey sand with sandstone	20	590
Missing	70	660
Pakowki and Milk River equivalents?		
Dark grey shale, in part sandy (Foraminifera)	80	740
Dark grey shale, with sandstone	20	760
Fine-grained, grey sandstone (water)	10	770
Fine-grained, grey sandstone with ironstone and coal fragments	10	780
Fine-grained sandstone with shale	10	790
Grey shale with some sand	130	920
Grey shale with bentonite	50	970
Grey shale	40	1,010
Grey shale with sandy partings (gas show reported at 1,108 feet)	190	1,200
Grey shale, partly sandy. Gas show reported at 1,210-1,215 feet	20	1,220
Grey shale containing traces of pearly shell fragments and sandy layers. Gas show at 1,300-1,315 feet	90	1,310
Grey shale	60	1,370
Alberta shale		
Grey shale, a few shell fragments (speckled shale at 1,370-1,400 feet). Gas show reported at 1,430-1,450 feet	110	1,480
Grey shale	70	1,550
Grey shale with bentonite and sandstone	160	1,710
Grey shale, darker, trace coal at 1,770 feet	250	1,960
Grey shale, darker and more fissile below 1,980 feet	150	2,100
Dark grey shale with sandstone and glauconite	20	2,120
Sandy shale with traces of shells of columnar calcite	30	2,150
Grey to black shale with traces of bentonite	60	2,210
Missing	60	2,270
Dark grey shale	160	2,430
Sandstone with glauconite and chert pebbles (water)	10	2,440
Lower Cretaceous? and Ellis?		
Sandstone	50	2,490
Dark grey shale with sandstone	40	2,530
Grey, fine-grained sandstone, some shale	110	2,640
Dark grey shale	40	2,680
Sandstone with chert pebbles	20	2,700
Dark grey shale with some sandstone	60	2,760
Sandstone with chert pebbles at 2,780 feet. Water at 2,797 feet	40	2,800
Shale and sandstone, traces of red shale	40	2,840
Grey shale with brown and reddish shale	50	2,890
Grey sandstone	20	2,910
Grey shale	150	3,060
Grey shale with dark brown oil sand	20	3,080
Grey shale	10	3,090
Grey shale, little pyrites and sandstone. Water at 3,097 and 3,105 feet	10	3,100
Grey shale	20	3,120
Missing	50	3,170
Palæozoic		
Limestone with chert	40	3,210
Limestone with shaly fragments	110	3,220

Foraminifera were found by Wickenden in the sample from a depth of 670 feet, thus indicating that the strata of this horizon are marine and, probably, of Pakowki age. By this interpretation, however, the equivalents of the Pakowki and Milk River formation would be 710 feet thick, which seems excessive since there appear to be only 490 feet of strata of the same age in the Brooks No. 1 well, 40 miles to the northwest. The position of the top of the Lower Cretaceous in this well is also debatable, but if placed at a depth of 2,440 feet the thickness of the Alberta shale is 1,070 feet and agrees with the thickness of 1,075 feet assigned to this series at Brooks. The elevations of the top and bottom of the Alberta shale in, respectively, the Brooks No. 1 and Ontario-Alberta wells indicates a southeasterly dip of 285 to 290 feet in 40 miles, or about 7¼ feet a mile. This is probably not the true dip since the regional dip is supposed to be northeasterly.

BROOKS AREA

Prior to 1913 the Canadian Pacific Railway drilled two wells for gas at Brooks, Alberta (Figure 13, No. 10), and in each obtained a small flow of natural gas. These wells were later taken over by the Canadian Western Natural Gas, Light, Heat, and Power Company, Limited, who have also drilled three new wells.

Well	L.S.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet	Year drilled	Results
No. 1...	SE.	32	18	14	4	2,487	2,795	Prior to 1913	20,000 cub. ft. of gas a day
No. 2...	NW.	31	18	14	4	2,495	1,379	1913	Gas at 855, 1,233, and 1,353 feet. Small flow
No. 3...	15	32	18	14	4	2,500	1,625	1928	Gas at 585, 1,240, and 1,540 feet. 68,000 cub. ft. a day
No. 4...	12	33	18	14	4	....	1,370	1931	Gas at 1,198, 1,329-1,332 feet. 200,000 cub. ft. a day
No. 5...	4	33	18	4	4	....	1,297	1932	Gas at 1,191 feet and at lower depths. 160,000 cub. ft. a day

The gas obtained in No. 1 well at 855 feet was struck in a coal horizon in the base of the Foremost beds. In other wells a small amount of gas seems to have been encountered in sandstone beds that are the equivalents of the Pakowki and Milk River. The gas found at 1,540 feet in No. 3 well appears to be in a sand about 140 feet below the top of the Alberta shale. It is possible that this last horizon is the equivalent of the Medicine Hat gas sand.

The Geological Survey has no information regarding the details of the structure (if any) at Brooks.

Log of Brooks No. 1 Well
(S.E. Sec. 32, Tp. 18, Range 14, W. 4th Mer.)

—	Depth Feet	Thickness Feet
Glacial material	....	35
Missing	20	55
Pale beds		
Light grey sand	10	65
Light grey, argillaceous sand and shale	9	76
Missing	10	86
Grey shale, coal fragments	10	96
Dark grey shale, bentonite and coal	10	106
Missing	10	116
Greenish grey shale	10	126
Light grey, sandy shale with ironstone	10	136
Light grey sandstone	20	156
Light grey, argillaceous sandstone	10	166
Greenish grey shale	10	176
Light grey, argillaceous sandstone	10	186
Grey sand and argillaceous sand	10	196
Missing	29	225
Light grey, argillaceous sand	5	230
Missing	10	240
Dark grey shale	7	247
Light grey sand	4	251
Missing	49	300
Light grey (salt and pepper) sand	25	325
Greenish grey, sandy shale with ironstone	25	350
Fine, grey sand	30	380
Grey (salt and pepper) sand	33	413
Foremost beds		
Dark grey shale, sand and coal	15	428
Dark grey shale, sand and much coal	111	439
Dark grey shale, sand and coal	10	449
Dark grey shale and sand	11	460
Grey sand and coal	11	471
Grey shale, sand, and coal	20	491
Grey shale, and much coal	10	501
Mostly coal, a little grey shale	10	511
Grey shale	10	521
Grey shale and coal	10	531
Grey shale	9	540
Grey sand	10	550
Grey sand and shale	10	560
Grey shale	40	600
Dark grey shale and sandy shale	20	620
Greenish grey shale, ironstone and fossil shells	20	640
Grey shale	50	690
Grey sand	15	705
Greenish grey shale	15	720
Dark grey shale	50	770
Dark grey shale with coal	10	780
Dark grey shale	20	800
Dark grey shale with coal and fossil shells	46	846
Mostly coal, 20,000 cubic feet of gas	4	850
Dark grey shale, sand, and coal	15	865
Dark grey shale, sand, coal and fossil shells	15	880
Light grey, fine sand	15	895
Light grey, fine sand and shale	5	900
Light grey sand	10	910
Equivalent of Pakowki and Milk River		
Greenish grey shale (a few coal fragments at 930-935 feet)	145	1,055
Dark grey shale	25	1,080
Grey shale with fine sand	5	1,085
Grey shale with a few coal fragments	5	1,090
Grey shale	30	1,120

Log of Brooks No. 1 Well

(S.E. Sec. 32, Tp. 18, Range 14, W. 4th Mer.)—*Continued*

—	Depth Feet	Thickness Feet
Equivalent of Pakowki and Milk River—Concluded		
Fine, grey sand	15	1,135
Fine, grey sand and shale	20	1,155
Grey shale	10	1,165
Fine, grey sand	5	1,170
Grey shale and fine sand	5	1,175
Grey shale	20	1,195
Grey shale and fine sand	25	1,220
Fine, grey sand	40	1,260
Fine, grey sand and shale	15	1,275
Fine, grey sand	10	1,285
Fine, grey sand and shale	25	1,310
Fine, grey sand, shale, and coal fragments	5	1,315
Fine, grey sand and shale	10	1,325
Fine, grey sand	10	1,335
Fine, grey sand and shale	5	1,340
Grey shale and fine, grey sand	5	1,345
Fine, grey sand and grey shale	15	1,360
Grey shale	10	1,370
Fine, grey sand	5	1,375
Fine, grey sand and shale	15	1,390
Grey shale	5	1,395
Alberta shale		
Grey and fine sand; speckled shale with columnar calcite and shell fragments	5	1,400
Grey, sandy shale, fossils, etc	70	1,470
Grey shale and sandy shale	10	1,480
Grey sand	10	1,490
Grey sand and shale with brown, chitinous fish remains	5	1,495
Grey, sandy shale	10	1,505
Grey shale and sandy shale	30	1,535
Grey sand, fossil shells	5	1,540
Grey sand	15	1,555
Grey shale and sandy shale	20	1,575
Grey shale and sandy shale, a few small coal fragments	5	1,580
Grey shale and sandy shale with fossil fragments	10	1,590
Grey sand and shale	10	1,600
Very fine, grey sand	15	1,615
Grey sand and shale	5	1,620
Grey sand	30	1,650
Grey sand and shale	20	1,670
Grey shale and sand	25	1,695
Grey, sandy shale	10	1,705
Grey shale	710	2,415
Grey shale with quartz sandstone	10	2,425
Grey sandstone and sandy shale	20	2,445
Grey sandstone with carbonaceous streaks and sandy shale	5	2,450
Grey sandstone and sandy shale	15	2,465
Dark shale, partly sandy	5	2,470
Lower Cretaceous?		
Dark shale, quartz sandstone, and bentonite	5	2,475
Dark shale	10	2,485
Dark shale and quartz sandstone	5	2,490
Grey sandstone and sandy shale	25	2,515
Grey sandstone and sandy shale (columnar calcite of fossil shell attached to sandy, shale fragment)	5	2,520
Grey sandstone and sandy shale	10	2,530
Mostly dark grey shale	15	2,545
Dark, sandy shale and light grey sandstone	40	2,585
Dark, sandy shale and light grey sandstone with bentonite	5	2,590
Light grey sandstone with a little dark grey shale and bentonite	25	2,615
Light grey sandstone and dark grey shale	5	2,620

Log of Brooks No. 1 Well

(S.E. Sec. 32, Tp. 18, Range 14, W. 4th Mer.)—*Concluded*

—	Depth Feet	Thickness Feet
Lower Cretaceous?—Concluded		
Light grey, quartz sand	8	2,628
Mostly dark grey, sandy shale	7	2,635
Light grey, quartz sand	5	2,640
Light grey, quartz sand and dark shale	10	2,650
Light grey, quartz sand, dark grey shale, and bentonite	10	2,660
Dark grey shale and light grey sandstone	10	2,670
Dark grey shale, light grey sandstone, and bentonite	5	2,675
Light grey sandstone, dark shale, and bentonite	5	2,680
Light grey sandstone	5	2,685
Light grey sandstone, dark shale, and bentonite	20	2,705
Light grey sandstone and sandy shale	5	2,710
Light grey sandstone and much bentonite	5	2,715
Light grey sandstone and some bentonite	5	2,720
Light grey sandstone, dark sandy shales, and bentonite	25	2,745
Dark shale, light grey sandstone, and bentonite	10	2,755
Dark, sandy shale	5	2,760
Dark, sandy shale, light grey sandstone, and bentonite	15	2,775
Light grey sandstone	10	2,785
Dark shale, light grey sandstone, and bentonite	5	2,790
Light grey sandstone and bentonite	5	2,795

The lower part of the strata in this well from 2,475 feet to the bottom contains much sandstone and the age is somewhat in doubt. The material resembles the sediments in Fuego No. 1 well in Oyen area, eastern Alberta, below 2,890 feet and above the Palæozoic limestone. These sediments in the Fuego well are thought to be Lower Cretaceous since they contain foraminifera that are believed to be of this age.

BLOOD INDIAN RESERVE AND ADJOINING AREA

The Blood Indian Reserve (Figure 13, No. 11) lies north of Cardston and west of Lethbridge. It is bounded on the northeast by Oldman River, and on the west and east respectively by Belly and St. Mary Rivers, both tributaries of Oldman River. Strata outcropping along these river valleys belong to the following succession, listed in descending order from west to east: Willow Creek, St. Mary River, Blood Reserve sandstone (Russell, 1932, pages 26-38 B), and Bearpaw formations.

The Blood Indian Reserve is on the west flank of the Sweet Grass Arch and the east flank of the Alberta syncline. The prevailing dip is thus westerly, but modifications of this dip give rise to local anticlines and synclines. The following description by Russell (1932, pages 35-38 B) gives all the information available regarding structure.

"An anticlinal axis crosses St. Mary River somewhere between Secs. 7 and 10, Tp. 5, Range 23, W. 4th Mer. Outcrops are small and few in number here, so that the exact position and magnitude of the structure were not determined. Presumably it is the southward continuation of this fold that has been tested by the Spring Coulée well of the Alberta Pacific Consolidated Oils, Limited, in Sec. 15, Tp. 4, Range 23, W. 4th Mer.

Eastward-dipping St. Mary River beds may be observed in Secs. 10, 15, and 27, Tp. 5, Range 23, W. 4th Mer., forming the west limb of a low syncline, which is seen to cross St. Mary River near the quarter corner north of Section 22. The east limb of this structure outcrops in Secs. 22 and 34, Tp. 5, Range 23, W. 4th Mer., and the westerly dip apparently persists in the remaining St. Mary River strata traversed by the river.

In Sec. 24, Tp. 6, Range 23, W. 4th Mer., the Blood Reserve sandstone and the upper part of the Bearpaw formation appear, and from here to the mouth of Pothole Creek the exposure is almost continuous. This condition, together with the presence of numerous determined horizons in the Bearpaw beds, permits a very detailed determination of the structure. Normal faults are very numerous here, but as they seldom exceed 10 feet in throw they are not recorded.

The structure contours show a relatively steep westward dip in Sec. 24, Tp. 6, Range 23, and Secs. 19 and 30, Tp. 6, Range 22, W. 4th Mer. There is evidence of a slight reverse dip in Sec. 33, Tp. 6, Range 22, W. 4th Mer., and the direction of strike changes to considerably east of north. In Sec. 12, Tp. 7, Range 22, W. 4th Mer., a distinct eastward dip may be measured, but this changes to westward in the adjacent Sec. 7, Tp. 7, Range 21, W. 4th Mer. These observations are interpreted as indicating an anticlinal axis crossing the river in Sec. 12, Tp. 7, Range 22, W. 4th Mer., and a synclinal axis crossing near the west boundary of Range 21.

In the general vicinity of Pothole Creek the base of the Bearpaw formation is well exposed, and shows a persistent westerly dip. To the west of here, in the central part of Tp. 7, Range 22, W. 4th Mer., the beds are nearly horizontal as shown by test borings.

From Pothole Creek to the mouth of St. Mary River the principal feature to be observed is the northwesterly direction of the strike. A low anticline may be observed in Sec. 24, Tp. 7, Range 22, W. 4th Mer., and there is probably a very shallow syncline in the northwest quarter Sec. 34, Tp. 7, Range 22, W. 4th Mer., suggested by the log of Commonwealth Petroleums test-hole No. 3.

The structure of the remaining part of the area is determined from scattered outcrops on Oldman River and from the logs of test-holes. Data from these sources indicate a general westerly dip, which is quite pronounced in the northern part of Township 8, but which becomes gentler toward the north. The very strong westward dip in the northeast quarter Sec. 25, Tp. 8, Range 23, W. 4th Mer., and the pronounced nose in Secs. 30 and 31, Tp. 8, Range 22, W. 4th Mer., are noteworthy. These features may indicate large-scale faulting, but no evidence of this was observed. It is quite possible that easterly dips are present in the northern part of the area, but if so, they must be of rather limited extent. This will be determined by further drilling.

The most striking structural feature of the area appears in the northwest corner, 3 miles north of the Indian Reserve boundary. This is here designated as the Monarch fault zone. It is well exposed in two large outcrops and a number of smaller ones on Oldman River, in Secs. 31 and 32, Tp. 9, Range 23, and Sec. 6, Tp. 10, Range 23, W. 4th Mer. Essentially, the Monarch fault zone consists of a series of blocks, separated by thrust faults of rather steep inclination, and involving, in almost every case, portions of the St. Mary River, Blood Reserve, and Bearpaw formations.

In spite of the intense deformation visible in this zone, it does not seem to be a major structural feature. This is suggested by the apparent lack of continuity along the strike. No fault zone is visible in Sec. 26, Tp. 8, Range 23, W. 4th Mer., where the same horizons outcrop. Furthermore, in the fault zone itself the stratigraphic displacement is not great. In only one case was it observed to exceed 100 feet, and it is usually much less. The horizons exposed at river level in the most westerly of the visible fault blocks are the same as those seen in the most easterly block. If we assumed that the faults disappear in the more competent rocks at depth, their place must be taken, not by one or more large folds, but by a series of small undulations.

The localization of this zone of intense deformation probably is dependent on the stratigraphic relationships. As noted above, almost every fault block consists of relatively hard, sand beds (St. Mary River, Blood Reserve), overlying softer, more argillaceous strata (Bearpaw). In reconstructing the history of the deformation, we may postulate a slight dip to the west prior to the development of faults. This dip would bring the Bearpaw-Blood Reserve contact to the surface near the site of the present fault zone. Further stresses from the west, transmitted by the relatively competent St. Mary River formation, found expression in the development of shear zones and faults along the top of the less competent Bearpaw shale. The release would be most pronounced near the surface. Continued pressure steepened the earlier breaks and developed additional thrusts. This would account for the different inclination of various existing fault planes. Cessation of pressure was followed by relaxation, developing a few normal faults, as in other parts of the area. As a corollary of this interpretation, we may imagine that the fault zone is not continuous for any great distance downward, but that it may extend somewhat westward beneath the rather gently dipping St. Mary River formation."

Two wells, namely Monarch Nos. 1 and 2, have been drilled near Monarch by the Canadian Western Natural Gas, Light, Heat, and Power Company, Limited. The first of these reached a depth of 1,775 feet and the second 2,813 feet. Showings of gas were reported in No. 1 well and a flow of about 10,000 cubic feet a day was encountered in No. 2 at a depth of 1,245 to 1,249 feet, with salt water at 2,540 feet.

Log of Alberta Pacific Consolidated "Spring Coulée" No. 1 Well [1]
(L.S. 11, Sec. 15, Tp. 4, Range 23, W. 4th Mer.; Elevation, 3,702 feet)

—	Thickness Feet	Depth Feet
Surface materials	....	60
St. Mary River		
Green shale with trace of gypsum	20	80
Dark grey shale with less green shale and grey sandstone	110	190
Green shale with less dark brown to grey and a few sandstone beds	110	300
Grey sandstone with a little coal	20	320
Carbonaceous shale containing coal	20	340
Grey-black shale with fragments of grey sandstone	25	365
Blood Reserve sandstone		
Grey, micaceous sandstone	15	380
Grey sandstone with a few coal fragments	100	480
Grey sandstone containing water	20	500
Bearpaw		
Lead-grey shale	50	550
Shale containing bentonite	10	560
"Rye grass sandstone", 65 per cent dark grey sandstone and 35 per cent lead-grey shale	40	600
Lead-grey shale and minor dark grey sandstone	40	640
Lead-grey shale with ironstone	10	650
Lead-grey shale	100	750
Lead-grey shale with shell fragments and coal	10	760
Lead-grey shale	30	790
"Kipp" sandy member, 50 per cent dark grey sandstone and 50 per cent lead grey	60	850
Lead-grey shale with sandstone fragments	50	900
Lead-grey shale with ironstone	10	910
Lead-grey shale containing Nucula (probably)	26	936
Lead-grey shale containing bentonite	24	960
"Magrath" sandy member containing bentonite	50	1,010
Lead-grey shale	20	1,030
Lead-grey shale containing bentonite and ironstone	40	1,070
Lead-grey shale containing *Dentalium gracile*	20	1,090

[1] Yarwood, 1931, pp. 1267-77.

Log of Alberta Pacific Consolidated "Spring Coulée" No. 1 Well
(L.S. 11, Sec. 15, Tp. 4, Range 23, W. 4th Mer.; Elevation, 3,702 feet)—*Continued*

—	Thickness Feet	Depth Feet
Bearpaw—Conc.		
Lead-grey shale containing ironstone and bentonite	10	1,100
Lead-grey shale	50	1,150
Lead-grey shale with *Placenticeras meeki*, *Inoceramus*, *Ostracoda*, and *Corbula perangulata*	40	1,190
Pale beds		
Grey sandstone with coal and brown, carbonaceous coal, *Viviparus conradi?*, *Unio danae*, and *Anodonta?* sp.	10	1,200
Lead-grey and grey-green shale containing coal in upper part	65	1,265
Grey-green shale with beds of grey sandstone *Viviparus?* sp., *Sphaerium* sp. (1,337 feet), fish scale (1,356 feet)	117	1,382
Pellet conglomerate, *Campeloma multilineata?*, *Velatella baptista?*	1	1,383
Grey-green shale with thin sandstone beds containing plant remains. *Campeloma multilineata* (1,400 feet)	58	1,441
Pellet conglomerate	1	1,442
Pale green shale with thin, grey, sandstone beds	35	1,477
Pellet conglomerate	1	1,478
Pale green shale	7	1,485
Grey, micaceous sandstone	7	1,492
Pale green shale	3	1,495
Pellet conglomerate and grey sandstone	1	1,496
Pale green sandstone	4	1,500
Olive-green shale; *Goniodiscus?* sp. (1,516 feet)	18	1,518
Grey sandstone	20	1,538
Grey-green shale, *Campeloma* sp. (1,638 feet), *Sphaerium* cf. *formosum*, *Campeloma* cf. *limnaeiformis*, *Campeloma* sp. (1,678 feet)	172	1,710
Grey sandstone	20	1,730
Grey-green shale	90	1,820
Grey sandstone	10	1,830
Grey-green shale containing *Physa copei* at 1,954 feet	130	1,960
Greenish brown shale	20	1,980
Greenish brown shale containing pebbles	1	1,981
Grey-green shale *Sphaerium* cf. *formosum* (1,938 feet)	153	2,134
Blue-grey, conglomeratic sandstone	11	2,145
Grey to green shale *Viviparus reynoldsanus*, *Physa copei* (2,160 feet)	25	2,170
Foremost beds		
Dark brown to grey-green shale containing beds of grey sandstone, *Sphaerium* sp., *Campeloma* sp.	18	2,188
Unio bed containing *Unio danae* and *Unio mclearni*	1	2,189
Dark grey to brown shale containing coal and a little amber, *Martesia* sp.?, *Sphaerium* sp.?, and *Viviparus* cf. *conradi*	16	2,205
Dark brown to green shale; *Campeloma* sp., *Physa?* sp., and *Sphaerium formosum*	9	2,214
Grey, micaceous sandstone	5	2,219
Dark grey to green shale characterized by large specimens of *Unio* sp.?	12	2,231
Dark grey to green shale	44	2,275
Grey sandstone	5	2,280
Dark brown to grey-green shale	19	2,299
Grey sandstone, fine grained, hard	13	2,312
Grey-green, soft, friable shale	9	2,321
Grey sandstone containing petrified wood	9	2,330
Dark grey shale	22	2,352
Dark brown and grey-green shales with coal. *Unio* sp.? and *Viviparus reynoldsanus*	21	2,373
Dark grey shales with thin beds of grey sandstone	19	2,392
Bentonite	2	2,394
McKay coal: dark brown, carbonaceous shales containing coal	20	2,414
coal	1	2,415
Bentonite	1	2,416

Log of Alberta Pacific Consolidated "Spring Coulée" No. 1 Well

(L.S. 11, Sec. 15, Tp. 4, Range 23, W. 4th Mer.; Elevation, 3,702 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Foremost beds—Conc.		
Coal, bentonite, and lignitic shale	2	2,418
Dark brown shale, with 6-inch bentonite at 2,421 feet and grading to sandstone in lower 2 feet	11	2,429
"Verdigris" sandstone	101	2,530
Pakowki equivalent		
Brown to grey, carbonaceous shale containing coal and *Unio mclearni*	40	2,570
Milk River		
Light grey, limy sandstone with about 25 per cent dark grey shale and 25 per cent grey-green shale	300	2,870
Light grey sandstone with 25 per cent dark grey shale and minor amounts of grey-green shale	230	3,100
Alberta shales		
Transition zone; contains 60 per cent grey-black shale and 40 per cent grey sandstone	60	3,160
Grey-black shale with some sand, bentonite, and ironstone	140	3,300
Medicine Hat (?) gas sand: shaly sandstone containing oil trace	60	3,360
Grey-black shale with sandy lenses, traces of bentonite, pyrite, aragonite, calcite, chert, and ironstone	840	4,200
Grey-black shale 75 per cent; dark grey sandstone 25 per cent	190	4,390
Grit bed	20	4,410
Grey-black shale 70 per cent; dark grey to grey sandstone 30 per cent	70	4,480
Gas sand	10	4,490
Grey-black shale with green shale at 4,520 feet	165	4,655
Bow Island gas sand (?): grey, indurated, medium-grained sandstone	15	4,680
Grey-black shale with green shale at 4,706 feet and 4,711 feet	35	4,715
Grey, coarse-grained sandstone	28	4,743
Grey-black shale	15	4,758
Grey sandstone	38	4,796
Grey-black shale with thin sand lenses	54	4,850
Dark grey sandstone	11	4,861
Grey-black shale with thin sand lenses and a few fragments of green shale	106	4,967
Lower Cretaceous		
Green shale with grey sand lenses	133	5,100
Medium grey sandstone 50 per cent; grey shale 25 per cent; green shale 25 per cent	60	5,160
Green and dark grey shale	52	5,212
Grey sandstone	28	5,240
Black, carbonaceous shale containing coal	10	5,250
Green shale 60 per cent; dark grey shale 15 per cent; grey sandstone 20 per cent; red shale 5 per cent	305	5,555
Dark grey, sandy shale containing fish scales (Cycloides) and light grey limestone containing volcanic ash or sponge spicules (?) probably marine	50	5,605
Variegated shale with *Unio hamili* and *Corbula onestae?* bed at 5,625 feet, fresh water	35	5,640
Chert conglomerate	2	5,642
Jurassic		
"Brown ribbon" sandstone	25	5,667
Dark grey shale, containing sporadic belemnites; thin, grey limestone bands, total 3 per cent of section; glauconitic shale at 5,687 and 5,810-5,817 feet; coal and bentonite at 5,687 feet; traces of red shale and pyrite; fish scale at 5,750 feet; *Astarte?* at 5,796 feet; *Pleuromya* cf. *obtusiporata* at 5,818 feet	244	5,911
Grey-black shale containing belemnites, pyrite, and glauconite	7	5,918
Grey, massive limestone containing belemnites, glauconite, and oolitic pyrite	8	5,926
Grey-black shale containing pyrite	2	5,928
White to brown, sandy, cherty, mottled limestone with rhynchonellid brachiopods at top	37	5,965

The top of the Palæozoic is placed by Yarwood at 5,965 feet, but by Mellen and Rohwer (1931, page 1280) it is placed at 5,935 feet. According to these authors the limestone at 5,940 feet is reported by A. J. Goodman to contain secondary silica interpreted as occurring within a leached zone formed during the period of erosion prior to the deposition of the Jurassic strata.

The Palæozoic section according to Mellen and Rohwer is as follows.

—	Thickness Feet	Depth Feet
Light grey limestone, chert bands, secondary silica	4	5,939
Brown, sandy limestone, cherty, heavy oil saturation	4	5,943
No core recovered	3	5,947
Light grey, crystalline limestone with chert, iron sulphide, and pyrobitumen	9	5,956
Sandy limestone	1	5,957
Sandy limestone, only part of core recovered	9	5,966
Grey limestone with 3 inches black, limy shale and 3 inches dark grey, shaly limestone	4	5,970
Light grey, crystalline limestone, crinoid and Mississippian bryozoa	2	5,972
No core recovered	4	5,976
Light grey, crystalline limestone, styolitic structure, pyrobitumen	8	5,984
No core recovered	16	6,000
Light grey limestone, cherty, styolitic, iron sulphide and trace of pyrite; 2 inches dark grey, limy shale and hard, dense limestone, cherty, styolitic, Mississippian bryozoa	12	6,012
Light grey, compact, crystalline limestone	4	6,016
Dark grey limestone, very porous, coral Diphyphyllum. Good oil saturation, dark colour due to pyrobitumen	5	6,021
Soft, light grey to white, crystalline limestone, dolomitic with almost pure dolomite at base. Porosity due to dolomitization increases with depth. Fossiliferous, mainly Bryozoa with crinoid stems. Styolitic structure at 6,177 feet. Sulphur water increasing toward bottom, 2,200 pounds pressure per square inch. Harder beds at 6,033 to 6,038 feet. Dense limestone with chert 6,059-6,065 feet. About 15 per cent of core recovered	170	6,191

The best saturation of oil (31·2 degrees Baumé), according to Mellen and Rohwer, was found between 5,946 and 5,955 feet with sulphur water below 6,055 feet.

Yarwood correlated a grit bed at 4,410 feet with the base of the Alberta shales of Turner Valley. If this correlation is correct and if the beds below it are Upper Cretaceous they may be of Dakota age as suggested by Irwin (1931, page 1133).

Log of Monarch No. 2 Well [1]

(Sec. 12, Tp. 10, Range 24, W. 4th Mer.; Elevation, 3,092·6 feet)

—	Thickness Feet	Depth Feet
Missing	......	20
Light grey, sandy clay	30	50
Fragments of boulders	5	55
Dark and light grey clay	50	105
Light grey, fine-grained, argillaceous sandstone	10	115
Dark, brownish grey shale	10	125
Light grey shale	20	145
Light grey, fine-grained, argillaceous sandstone	10	155
Light grey shale	15	180
Light grey, sandy shale	10	190
Light grey shale	25	215
Dark brown shale	10	225
Brown to grey shale	10	235
Light grey shale	15	250
Light grey, fine-grained, argillaceous, calcareous sandstone	15	265
Grey shale	50	315
Brown shale	5	320
Dark grey shale	10	330
Light grey shale	10	340
Dark brown shale	10	350
Dark grey shale	10	360
Dark grey, sandy shale	5	365
Dark grey shale	35	400
Missing	100	500
Dark grey shale	5	505
Coal	10	515
Dark grey shale and sandy shale	610	1,125
Pale and Foremost beds		
Dark grey shale with coal	5	1,130
Dark grey shale	65	1,195
Light grey sandstone and brown, carbonaceous shale	5	1,200
Shale	5	1,205
Light grey, argillaceous sandstone, slightly calcareous	5	1,210
Grey, sandy shale	30	1,240
Light grey, argillaceous sandstone	15	1,255
Grey shale	20	1,275
Light grey, sandy shale	30	1,305
Grey, sandy shale	15	1,320
Light grey, sandy shale	95	1,415
Light grey, argillaceous, calcareous sandstone	50	1,465
Light grey, sandy shale	40	1,505
Light grey, argillaceous, calcareous sandstone	15	1,520
Light grey, sandy shale	5	1,525
Light grey, argillaceous, calcareous sandstone	5	1,530
Light grey, sandy shale	10	1,540
Brownish grey, sandy shale	10	1,550
Light grey shale	10	1,560
Light grey, argillaceous, calcareous sandstone	10	1,570
Light grey, sandy shale	20	1,590
Light grey shale	25	1,615
Light grey, argillaceous, calcareous sandstone	10	1,625
Light grey shale	35	1,660
Grey, fine-grained, argillaceous sandstone	15	1,675
Light grey shale	15	1,690
Grey, argillaceous, calcareous sandstone	25	1,715
Grey shale	25	1,740
Grey sandstone	5	1,745
Dark grey to brown shale	15	1,760
Grey, calcareous sandstone	40	1,800
Light grey shale	120	1,920
Grey sandstone	35	1,955

[1] Log supplied by S. E. Slipper.

Log of Monarch No. 2 Well

(Sec. 12, Tp. 10, Range 24, W. 4th Mer.; Elevation, 3,092·6 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Pale and Foremost beds—Conc.		
Dark grey shale	45	2,000
Grey, sandy shale	10	2,010
Light grey, very fine-grained, argillaceous sandstone	10	2,020
Dark grey shale	25	2,045
Grey shale	15	2,060
Light grey, calcareous, argillaceous sandstone and grey shale	10	2,070
Grey, argillaceous sandstone	10	2,080
Grey sandstone	20	2,100
Grey, soft shale	45	2,145
Grey sandstone, a little coal	5	2,150
Sandstone and coal	10	2,160
Coal, black, carbonaceous shale and sand	5	2,165
Dark grey sandstone	5	2,170
Dark grey shale and sandstone	10	2,180
Dark grey shale	20	2,200
Grey sandstone with dark grey shale	5	2,205
Dark grey shale with a little sandstone	5	2,210
Dark grey shale with carbonaceous shale	15	2,225
Coal, black, carbonaceous shale, dark grey shale, and bentonite	25	2,250
Black, carbonaceous shale, bentonite, and a little sand	20	2,270
Sandstone and black, carbonaceous shale	10	2,280
Pakowki shale		
Dark grey shale	20	2,300
Dark grey shale with sand	40	2,340
Dark grey shale	40	2,380
Upper Milk River		
Grey sandstone	30	2,410
Light grey, argillaceous, calcareous sandstone	5	2,415
Dark grey shale and sandstone	10	2,425
Sandstone with dark grey shale	45	2,470
Sandstone and shale	20	2,490
Light grey sandstone	15	2,505
Sandstone and black, carbonaceous shale	10	2,515
Light grey sandstone	25	2,540
Light grey sandstone and black, carbonaceous shale	15	2,555
Dark grey shale, black, carbonaceous shale, and light grey sandstone	10	2,565
Lower Milk River		
Light grey sandstone	90	2,655
Light yellowish grey, argillaceous sandstone	20	2,675
Alberta shale		
Sandstone and dark grey shale	25	2,700
Sandstone and dark grey shale	40	2,740
Dark grey shale	73	2,813

TABER-BARNWELL-CHIN COULÉE AREA

Oldman River Valley from the mouth of Little Bow to the mouth of Bow River (Figure 13, No. 12) is pre-Glacial in age (Williams and Dyer, 1930, page 105) and it is suspected that the drainage has been influenced by the local structure. A U-shaped bend in Oldman River northwest of Taber suggests local anticlinal conditions in an east-west direction, although data at hand are indicative of a terrace rather than an anticline. The Taber coal seam, which is considered to be the top of the Foremost beds in this locality, is understood to have a west dip and this dip seems to be shown in the Chin Coulée wells drilled by the Canadian Western Natural Gas, Heat, Light, and Power Company in the vicinity of Elcan. No known closure occurs to the south, although closure to the north is almost certain since the regional dip from the Sweet Grass Arch is in this direction and successively higher beds occur to the northwest of Taber.

Chin Coulée No. 1 well, drilled on L.S. 14, Sec. 31, Tp. 9, Range 17, W. 4th Mer., obtained a flow of gas of about 4,000,000 cubic feet a day at a depth of 2,151 to 2,166 feet, but other wells drilled in the immediate vicinity yielded only small flows or shows. The Cole-Hunter "Taber" No. 1 well, drilled on L.S. 3, Sec. 11, Tp. 10, Range 17, W. 4th Mer., was drilled into the Palæozoic limestone and obtained a show of oil at 3,317 feet in what is thought to be Ellis strata. So far as known no other wells in the area penetrated this formation. The Lethalta (Chinalta) well drilled some distance south of the others in L.S. 5, Sec. 23, Tp. 8, Range 18, W. 4th Mer., did not reach the base of the Alberta shales.

Log of Cole-Hunter "Taber No. 1" Well

(L.S. 3, Sec. 11, Tp. 10, Range 17, W. 4th Mer.; Elevation, 2,567 feet)

—	Thickness Feet	Depth Feet
Drift	....	70
Foremost and Pakowki		
Dark grey shales, sandstone, and coal	330	400
Grey and greenish shales	180	580
Milk River		
Grey, sandy, lignitic shales	140	720
Grey sandstone, carbonaceous	80	800
Grey sandstone and carbonaceous shale	70	870
Alberta shales		
Grey, sandy shales	240	1,110
Grey shales with few sandy layers	1,140	2,250
Grey shales and grey sandstone	450	2,700
Lower Cretaceous		
Grey shales and sandstone, trace maroon shale	70	2,770
Dark, carbonaceous shale, light grey sandstone with green and red shale	210	2,980
Grey and greenish shale and sandstone	60	3,040
Grey and greenish shale, sandstone more prominent	80	3,120
Dark grey, carbonaceous, light green and red shale	90	3,210
Ellis		
Pale green and brown shale	60	3,270
Fine-grained, calcareous sandstone	20	3,290
Light greenish, calcareous shale with some sandstone; oil reported at 3,317 feet	30	3,320
Dark grey and greenish, calcareous shale and coarse, chert sandstone	17	3,337
Mississippian		
White chert, few fragments of white lime	23	3,360
Light grey limestone	190	3,550
Light grey, sandy limestone	52	3,602

According to Slipper (Slipper and Hunter, 1931, page 1189) the Pakowki has been completely cored at Barnwell and shows a total thickness of 110 feet. "The base is distinctly marked, in some places by a thin chert conglomerate, in others by a green shale, and in others by a light grey sandstone of the Upper Milk River". According to the same author it is difficult to determine the top of the formation owing to the presence of 50 to 100 feet of beds transitional to the Foremost. For these reasons, and also because the Cole-Hunter "Taber" No. 1 well was drilled with a rotary, the Pakowki can not be separated in the log of this well.

Log of the Lethalta Oils, Limited, (Chinalta) Well [1]

(L.S. 5, Sec. 23, Tp. 8, Range 18, W. 4th Mer.)

—	Thickness Feet	Depth Feet
Drift	....	50
Pale and Foremost		
Grey shale and sandstone with lignitic fragments	440	490
Light grey sandstone	20	510
Grey shale and sandstone	60	570
Grey sandstone	10	580
Missing	25	605
Pakowki?		
Grey shale and sandstone	155	760
Milk River?		
Shaly sandstone and shale with carbonaceous materials	100	860
Grey sandstone, a little shale	165	1,025
Grey, fine-grained sandstone	70	1,095
Alberta shale		
Grey shale and sandy shale	1,155	2,245

[1] Log compiled from log by J. G. Spratt and published by permission of Lethalta Oils, Ltd.

The Clavulina zone occurs at 1,475-1,485 feet and is considered to be about 400 feet below the base of the Milk River formation. The well was drilled with rotary equipment and hence the contacts are poorly defined in the samples.

TWIN RIVER AREA

The Twin River area (Figure 13, No. 13) lies west of Red Coulée field and on the east flank of the Alberta syncline. The Nordon Corporation outlined the structure by shallow test wells and geophysical methods. The Geological Survey, however, has no detailed information regarding the structure.

Log of Parco-Nordon Companies Well No. 1

(L.S. 16, Sec. 34, Tp. 1, Range 20, W. 4th Mer.; Elevation, 3,962 feet)

—	Thickness Feet	Depth Feet
Missing	....	100
Mostly surface cavings or drift	30	130
Pale Beds		
Light grey to yellowish sandstone and shale	310	440
Foremost		
Dark grey and carbonaceous, sandy shale	70	510
Grey sandstone	10	520
Grey shale and sandstone, partly carbonaceous	70	590
Light grey shale and grey, carbonaceous sandstone	20	610
Light grey and dark grey shale with sandstone	60	670
Grey shale and sandstone, coal fragments	80	750

Log of Parco-Nordon Companies Well No. 1

(L.S. 16, Sec. 34, Tp. 1, Range 20, W. 4th Mer.; Elevation, 3,962 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Pakowki?		
Grey shale	70	820
Milk River		
Dark grey and greenish shale and sandstones with lignitic material	10	830
Medium-grained, grey sandstone	20	850
Grey sandstone and grey and greenish shale	20	870
Grey and green shale	20	890
Grey and green shale and sandstone	20	910
Grey and brownish sandstone	30	940
Grey and greenish shale and sandstone	30	970
Light grey sandstone	50	1,020
Grey and black shale and some sandstone	20	1,040
Light grey sandstone, some grey shale	150	1,190
Grey and greenish, sandy shale	40	1,230
Grey and green shale with carbonaceous sandstone	70	1,300
Alberta shale		
Dark grey shale, sandy	30	1,330
Dark grey shale	790	2,120
Dark grey shale with bentonite	10	2,130
Dark grey shale	140	2,270
Dark grey sandstone with shale	80	2,350
Dark grey shale	10	2,360
Dark grey sandstone and shale	10	2,370
Dark grey shale and grey sandstone	70	2,440
Dark grey shale; grey, coarse sandstone	60	2,500
Dark grey shale and sandstone, chert pebbles at 2,560 feet	130	2,630
Dark grey shale and sandstone, a little bentonite	40	2,670
Dark grey shale and sandstone	30	2,700
Dark grey sandstone, some shale	50	2,750
Dark grey shale and sandstone	30	2,780
Dark grey shale with very coarse sandstone	20	2,800
Dark grey, shaly sandstone	30	2,830
Grey sandstone	30	2,860
Dark grey, shaly sandstone	20	2,880
Dark grey shale	30	2,910
Dark grey shale and grey sandstone with glauconite 2,950-2,960 and 3,040-3,050 feet	150	3,060
Lower Cretaceous		
Light greenish sandstone and grey, partly carbonaceous shale	40	3,100
Greenish sandstone and shale	10	3,110
Grey, green, and red shale, greenish sandstone	40	3,150
Grey, brown, green shale and greenish sandstone	30	3,180
Missing	10	3,190
Grey and greenish sandstone	30	3,220
Red and green shale and greenish sandstone	20	3,240
Red shale	10	3,250
Grey, green, and red shale and greenish sandstone with prominent red shale at 3,440-3,450 feet	230	3,480
Medium to coarse sandstone, a little variegated shale with prominent coal at 3,510-3,520 feet	50	3,530
Coarse, grey sandstone	80	3,610
Fine, shaly sandstone	20	3,630
Red shale	10	3,640
Variegated shale	30	3,670
Ellis		
Grey shale with glauconite and white, cherty limestone	20	3,690
Grey, calcareous shales with glauconite and limestone	70	3,760
Grey, calcareous shales and shaly limestone, some chert and belemnite fragments	100	3,860
Mississippian		
White limestone	285	4,145

KEHO LAKE AREA

Keho Lake (Figure 13, No. 14) lies north of Scabby Butte which on the west face shows a prominent scarp 50 feet high exposing the lower part of the Edmonton-St. Mary River[1] formation. Shallow test drilling by the Hudson's Bay Oil and Gas Company led to the drilling of a deep well in this area. The Geological Survey has no detailed information regarding the structure.

Log of Hudson's Bay Oil and Gas Company Well[2]

(L.S. 2, Sec. 17, Tp. 11, Range 22, W. 4th Mer.; Elevation, 3,270 feet)

—	Thickness Feet	Deoth Feet
Drift	....	60
Edmonton		
Sandy shale and grey sandstone with plant remains	60	120
Bearpaw?		
Dark grey shale and sandy shale	50	170
Dark grey shale	60	230
Bentonite and bentonitic shale	20	250
Grey shale, sandstone, and bentonitic shale	50	300
Dark grey shale	30	330
Grey, limy sandstone	20	350
Dark grey shale	50	400
Dark shale and bentonite	20	420
Dark grey shale	50	470
Dark, shaly sandstone, traces of glauconite	30	500
Dark grey shale	140	640
Dark, glauconitic sandstone	20	660
Dark grey shale, sandy	110	770
Dark shale with trace of ironstone	10	780
Dark grey shale, traces of bentonite	10	790
Dark grey shale with ironstone	30	820
Dark grey shale	60	880
Dark grey shale with traces of coal	20	900
Pale Beds		
Grey, shaly sandstone with coal	20	920
Grey, shaly sandstone with coal	20	940
Grey shale and sandstone	70	1,010
Light yellowish sandstone	20	1,030
Light yellowish, sandy shale and sandstone	70	1,100
Light yellowish sandstone	20	1,120
Light yellowish, sandy shale and sandstone	130	1,250
Grey, carbonaceous sandstone and yellowish shale	30	1,280
Grey and yellowish, sandy shale and sandstone	130	1,410
Grey shale and sandstone with plant remains	60	1,470
Foremost		
Grey, carbonaceous shale with coal fragments	40	1,510
Light grey sandstone with carbonaceous materials	40	1,550
Grey shale with plant remains and ironstone	30	1,580
Light grey, sandy shale, carbonaceous	10	1,590
Light grey, carbonaceous sandstone	10	1,600
Light grey, carbonaceous sandstone with coal	10	1,610
Dark grey shale with iron carbonate	50	1,660
Grey, carbonaceous shale with coal	10	1,670
Grey shale with carbonaceous materials and ironstone	210	1,880
Grey shale with coal	70	1,950

[1] Russell, L. S.: Personal communication.
[2] Log from 0 to 2,480 feet, by J. G. Spratt.

Log of Hudson's Bay Oil and Gas Company Well

(L.S. 2, Sec. 17, Tp. 11, Range 22, W. 4th Mer.; Elevation, 3,270 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Pakowki		
Dark shale with some sandstone and traces of glauconite. Traces of chert and light grey sandstone at 2,040–2,050 feet	100	2,050
Milk River		
Grey sandstone	10	2,060
Shale and grey, sandy shale with sandstone	80	2,140
Dark grey shale with coal	10	2,150
Light grey sandstone	130	2,280
Light grey sandstone with some shale	60	2,340
Alberta shale		
Dark grey shale, in part sandy	70	2,410
Dark grey shale	30	2,440
Dark grey, shaly sandstone	10	2,450
Dark grey shale	700	3,150
Dark grey, sandy shale	30	3,180
Dark grey shale	50	3,230
Dark grey, shaly sandstone	10	3,240
Dark grey shale	70	3,410
Dark grey, sandy shale	50	3,500
Dark grey, sandy shale, traces of bentonite	20	3,520
Dark grey, sandy shale	150	3,670
Dark grey, sandy shale and sandstone	160	3,830
Dark grey shale, greenish shale, and sandstone	20	3,850
Greenish and brownish shale and sandstone	10	3,860
Grey sandstone, greenish and dark grey shale	20	3,880
Greenish and dark grey shale, and sandstone	40	3,920
Dark grey shale and sandstone	90	4,010
Grey sandstone and dark shale	20	4,030
Dark grey shale and sandstone, pyrite	160	4,190
Lower Cretaceous		
Grey and greenish sandstone	20	4,210
Grey and greenish sandstone and dark, carbonaceous, sandy shale	10	4,220
Grey and greenish sandstone and grey, green, and red shale	70	4,290
Grey sandstone, coarse	30	4,320
Grey sandstone, not so coarse	10	4,330
Grey, green, and red, sandy shale and sandstone	60	4,390
Green and grey shales and sandstone	100	4,490
Grey sandstone	60	4,550
Dark grey shale and sandstone	10	4,560
Dark grey shale and sandstone with coal	20	4,580
Dark grey and green shale and sandstone	40	4,620
Dark grey and red shale	10	4,630
Dark grey and green shale with coal fragments	10	4,640
Missing	10	4,650
Dark grey and green shale and sandstone	40	4,690
Dark grey and red, sandy shale	10	4,700
Dark grey and red, sandy shale and sandstone	20	4,720
Missing	10	4,730
***Jurassic* (Ellis)?**		
Dark grey, small amount of red and green shale	20	4,750
Dark grey and brown, limy shale	10	4,760
Dark grey, limy shale	100	4,860
Dark grey, limy, slightly bituminous shale	50	4,910
Dark grey, limy shale and cherty limestone	10	4,920

EYREMORE AREA

As a result of geological mapping and structural test drilling, the Hudson's Bay Oil and Gas Company located a structure favourable for the accumulation of oil and gas in what has come to be known as Eyremore area (Figure 13, No. 15). A deep well was drilled which, according to Powers (1931, page 1205), commenced in an inlier of Pale Beds. The Geological Survey has no information regarding the details of the structure.

Log of Hudson's Bay Oil and Gas Company[1] *Wells No. 1 and No. 1-S*
(L.S. 1, Sec. 26, Tp. 17, Range 18, W. 4th Mer.; Elevation, 2,700 feet)

—	Thickness Feet	Depth Feet
Pale and Foremost beds		
Dark grey shale	....	80
Pale grey, argillaceous sand	10	90
Pale grey shale with coal fragments	50	140
Coal and carbonaceous shale	10	150
Pale grey shale, traces of coal	90	240
Coal	10	250
Pale grey shale	30	280
Light grey, argillaceous sandstone	10	290
Pale to dark grey shale, slightly sandy and carbonaceous in places, fragments of coal becoming more abundant from 880 feet to base	290	920
Light grey, argillaceous sandstone, coal fragments	30	950
Coal and shaly sandstone	10	960
Light grey, fine-grained sandstone	20	980
At this depth the rig was skidded 230 feet north and 30 feet east and redrilled as No. 1-S, but no samples taken to 930 feet.		

Log of Well No. 1-S from 960 feet to bottom of hole

Coal, and brown to grey, ferruginous shale	20	980
Light grey, fine-grained sandstone with coal and carbonaceous, brown shale	20	1,000
Missing	50	1,050
Grey to greenish, shaly sandstone with coal and carbonaceous shale	30	1,080
Grey shale with plant impressions and traces of coal	20	1,100
Grey shale and sandy shale	200	1,300
Dark grey, carbonaceous shale and light grey sandstone. A little bentonite	10	1,310
Medium-grained, light grey sandstone	10	1,320
Pakowki		
Dark grey shale, chert pebbles at 1,400 feet	80	1,400
Milk River		
Fine-grained, grey sandstone and dark shale	40	1,440
Fine-grained, grey sandstone and shale with ironstone and glauconite	50	1,490
Missing. The top of the Alberta shale occurs in this interval	500	1,990
Alberta shale		
Grey to black shale with thin sandstones	30	2,020
Grey to black shale	130	2,150
Grey to black shale with bentonite	10	2,160
Grey to black shale	80	2,240

[1] Published by permission of Hudson's Bay Oil and Gas Co., Ltd. Log compiled by R. M. S. Owen.

Hudson's Bay Oil and Gas Company Wells No. 1 and No. 1-S

(L.S. 1, Sec. 26, Tp. 17, Range 18, W. 4th Mer.; Elevation, 2,700 feet)—*Continued*

—	Thickness Feet	Depth Feet
Alberta shale—Concluded		
Grey to black shale with ironstone	10	2,250
Grey to black shale	550	2,800
Grey to black shale with bentonite	20	2,820
Grey to black shale	230	3,050
Grey to black shale with sandstones	70	3,120
Grey to black shale with coarse sandstones	60	3,180
Sandstone with black and brown, chert pebbles	10	3,190
Fine-grained, shaly sandstone	20	3,220
Fine-grained sandstone with dark shale	20	3,240
Dark to grey shale and sandy shale	10	3,250
Grey to black shale	70	3,320
Coarse sandstone and shale; water at 3,340 feet	20	3,340
Missing	110	3,450
Grey-black shales, traces of fibrous calcite believed to be fossil *Inocerami*	90	3,540
Lower Cretaceous		
Fine-grained, grey sandstone and shale, 5 feet missing	10	3,550
Maroon and dark green, sandy shale	10	3,560
Maroon, grey, and green shale and grey sandstone	10	3,570
Grey to green sandstone	10	3,580
Sandstone and shale with ironstone	10	3,590
Green and grey shale with plant remains	20	3,610
Grey to green shale and shaly sandstone with ironstone	10	3,620
Grey to green, sandy shale	20	3,640
Grey to green shale	10	3,650
Fine-grained, grey sandstone and shale	40	3,690
Grey to green and carbonaceous shale	10	3,700
Grey to green sandstone and shale	10	3,710
Grey to green and brown shale	10	3,720
Shaly sandstone and shale	30	3,750
Grey shale	10	3,760
Coal and carbonaceous shale	10	3,770
Fine-grained sandstone	40	3,810
Medium-grained sandstone	40	3,850
Brown and dark grey shale	10	3,860
Shale and sandstone	10	3,870
Vari-coloured shale	20	3,890
Dark shale	20	3,910
Fine-grained sandstone, a little ironstone, and grey shale	20	3,930
Jurassic (Ellis)?		
Dark to grey, sandy, and calcareous shale	10	3,940
Buff limestone and grey shale	20	3,960
Sandstone with white and red chert matrix	30	3,990
White, siliceous sandstone	10	4,000
Coarse sandstone with chert and siliceous sandstone	20	4,020
Palæozoic		
Chert with white to grey and brown, porous limestone or dolomite and pyrite	10	4,030
Chert and pale green shale	10	4,040
Limestone with pale green shale and shaly limestone	10	4,050
White to pale green, sandy limestone	15	4,065
NOTE. At this point hole was accurately measured and found to be 4,037 feet deep.		
Show of oil at 4,032 feet.		
White to buff limestone	....	4,041
Missing	179	4,220
White to buff limestone	110	4,430
Light buff chert	20	4,450
Cherty limestone	20	4,470
Limestone and light buff chert	70	4,540
Dark grey to light limestone, partly shaly	10	4,550

Hudson's Bay Oil and Gas Company Wells No. 1 and No. 1-S
(L.S. 1, Sec. 26, Tp. 17, Range 18, W. 4th Mer.; Elevation, 2,700 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Palæozoic—Conc.		
Dark limestone	160	4,710
Dark grey, shaly limestone	40	4,750
Dark grey limestone with glauconite	10	4,760
Black shale	10	4,770
Shaly limestone and black shale	10	4,780
Black shale	20	4,800
Light grey to buff limestone	30	4,830
Brownish grey anhydrite	50	4,880
Olive-green shale and anhydrite	10	4,890
Brownish grey anhydrite or gypsum	230	5,120
Buff, dolomitic limestone	20	5,140
Buff, dolomitic limestone with anhydrite	20	5,160
Buff, dolomitic limestone	50	5,210
Missing	10	5,220
Dark grey, dense limestone	260	5,480
Dark grey, shaly limestone	10	5,490
Dark grey, dense limestone	100	5,590

As shown by Moore (1931, page 1150) the Palæozoic section in this well closely resembles that of the Potlatch-Adams well in the Kevin-Sunburst field of Montana, although the thicknesses of the various members are somewhat different. The Carboniferous (4,020 to 4,760 feet) is about 740 feet thick and is divisible into a light grey top part 500 to 550 feet thick and a darker, lower part. The Devonian, the top of which was encountered at 4,760 feet, includes the anhydrite-bearing beds.

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CHAPTER VI

CENTRAL PLAINS OF ALBERTA

STRATIGRAPHY

As here used the term central plains of Alberta designates the area between Red Deer and North Saskatchewan Rivers. The stratigraphy is shown in the following table.

Table of Formations

	Age	Formation	Thickness Feet	Description	—
		Bearpaw..........	600 to 700	Dark grey shale containing large quantities of selenite and ironstone nodules. Within these shales is the Bulwark sandstone which is hard, massive, and brown. Marine	
		Pale beds	About 500	Pale, incoherent, crossbedded sandstone and green clays. Ironstone bands and coal seams occur. Contains fresh-water fossils	
		Variegated beds	200	Interlayered sands and shales with thin coal seams	
	Montana	Birch Lake	60 to 100	Massive, crossbedded, buff sandstone with some shales. At Birch Lake a marine member has been reported. Mainly brackish water deposits	
Cretaceous		Grizzly Bear	100 to 40	Dark blue-grey shale containing ironstone and sandstone nodules; some sand beds present. Marine	
		Ribstone Creek	225	Greenish yellow, massive, soft sands with some hard sandstone beds. Green and carbonaceous shale with coal. To the east in Saskatchewan it contains a marine horizon. Mainly brackish water deposits	Unimportant gas showings have been found in wells in this formation
		Lea Park	Lea Park and Alberta shale 1,500-1,650	Blue-grey shale and sandy shale with selenite and ironstone nodules. Fossils. Marine.	Gas showings
	Colorado	Alberta shale		Grey shale with some sandstone beds and nodules. Marine	Oil and gas
	Lower Cretaceous		150	Mostly sands with some shale. Continental deposit	Oil and gas
Palæozoic				Limestones, marine	Oil showings

Palæozoic. The Palæozoic has been penetrated by several wells in various localities within the central plains of Alberta. The writer formerly thought that the upper part was Devonian, but there is now reason to believe that a small thickness of Mississippian may be present. The Duvernay well of the Alberta-Pacific Consolidated Oil Company, drilled north of Vegreville on the bank of North Saskatchewan River, encountered black, bituminous shales at some distance below the top of the Palæozoic. These black shales are similar to those that in southern Alberta occur at the top of the Devonian and, therefore, the Palæozoic strata above the bituminous shales in the Duvernay well may be Mississippian. A small thickness of bituminous shales was also found within the Palæozoic in one of the Ribstone wells and it is inferred that Mississippian strata underlie the whole area. In Wainwright area, in some wells, green or vari-coloured, calcareous shales occur at the top of the Palæozoic and are underlain by light grey limestones. A small amount of anhydrite occurs in the Devonian in Ribstone area and a 1-foot bed of rock salt was reported from one of the Unity Valley wells in Saskatchewan, 25 miles east of the Alberta boundary.

Lower Cretaceous. The Lower Cretaceous in the central plains area consists of grey and dark shales and light grey to whitish sandstones. So far as known, red or maroon beds such as are present in southern Alberta are lacking. Coal occurs at several horizons. In Athabaska (McMurray) area the Lower Cretaceous consists of alternating marine and non-marine formations and one marine formation, the Clearwater shales, is 275 feet thick. Possibly there are some marine strata in the Lower Cretaceous of Battle River area since fragmentary shells have been noted in samples from some of the Ribstone wells.

In Battle River area, smooth, polished chert pebbles commonly occur at what has been considered to be the division between the Lower and Upper Cretaceous. In McMurray area the top of the Pelican sandstone of Upper Cretaceous age is conglomeratic (McLearn, 1917, page 148). A correlation made on lithology alone may not have any real significance, but if the conglomerate at the top of the Pelican sandstone is equivalent to the pebble bed in Battle River area then it follows that Upper Cretaceous strata occur below the pebble bed in Battle River area. However, because of the doubtful value of the correlation of the two pebbles horizons, the division between the Lower and Upper Cretaceous in Battle River area is assumed to be marked by the pebble bed. The Pelican sandstone although partly marine and containing *Inoceramus* is mainly composed of non-marine sandstones. In well samples a division between it and the non-marine beds of the Lower Cretaceous would be impossible.

Alberta Shales. In former reports the shales between the Lower Cretaceous and the Lea Park formation were designated Colorado shales, but presumably, as in the case of the marine shale series of southern Alberta, they are in part of Montana age. They are the equivalents of the Alberta shales of the Central Plains area and should also be called Alberta shales. The equivalent strata of Athabaska area are the LaBiche shales with, possibly, the Pelican sandstone. The upper part of the LaBiche shales contains the *Inoceramus lundbreckensis* fauna which occurs in the upper part of the Alberta shale in the southern foothills and presumably this Montana fauna or an equivalent occurs in the Alberta shale of Battle River.

The Lea Park has been defined as including the Montana shales in Battle River area but, as already stated, Montana horizons are included in the Alberta shale. In well samples the division between the Lea Park and Alberta shales is somewhat indefinite because of continuous shale deposition, but the contact is tentatively placed just above a peculiar speckled shale whose speckled appearance is due to white or yellowish flakes of carbonate of lime in a dark, soapy-like shale. A peculiarity of this speckled shale is that it invariably holds shell fragments and thick prisms of calcite (aragonite?) and these make the zone easily recognizable, although small amounts of the same kind of speckled shale may occur at other horizons. It is possible the speckled shale-fossil shell zone may not mark the exact contact between the Lea Park and Alberta shale, although Wickenden (personal communication) has noticed a change in the micro-faunas (Foraminifera) at this same horizon. At any rate this zone provides a valuable key horizon in the central part of a continuous shale series and its widespread occurrence leads to the belief that it is of more than local significance.

In the Central Plains area, assuming that the speckled shale-fossil shell zone marks the contact between the Lea Park and Alberta shales, it will be noticed from the following table that the Lea Park thickens and the Alberta shale thins from east to west, from Ribstone area to Viking area. Also, that the Lea Park thins and the Alberta shale thickens southward.

—	L.S.	Sec.	Tp.	Range	Mer.	Elev. of well Feet	Depth to: Ribstone Creek-Lea Park contact Feet	Depth to: Speckled shale zone Feet	Depth to: Top of Lower Cretaceous Feet	Thickness: Lea Park Feet	Thickness: Alberta shale Feet	Thickness: Lea Park and Alberta shale Feet	Notes
Ribstone Area													
Meridian No. 1....	4	16	45	1	4	1,938	80[1] (approx.)	930 and 1,030	1,668	950	638	1,588	Chert pebbles at 1,668 feet. Speckled shale prominent at 1,030 feet
Meridian No. 2....	4	16	45	1	4	1,912	20[1] (approx.)	990–1,000	1,630	970	640	1,610	From 1,630–1,640 feet samples are 50 to 75 per cent smooth chert pebbles
Meridian No. 3....	4	16	45	1	4	1,994	130[1] (approx.)	1,100–1,110	1,750?	970	650	1,620	Sand with shells at 1,740 feet. Greenish shale at 1,750 feet. No chert pebbles
Imperial Ribstone No. 1	......	5	45	1	4	1,851	?	1,000–1,010	1,623?	....	623?	....	Rotary samples. Top of Lower Cretaceous not definite
Imperial Ribstone No. 2	14	9	45	1	4	1,796	90[1] above top well	840–860	1,500	930	660	1,590	Chert pebbles at 1,500 feet
Algonquin No. 1...	1	20	45	1	4	2,051	160 (approx.)	....	1,780	....	....	1,620	Chert pebbles 1,780–1,800 feet Samples missing where speckled shale should occur
Algonquin No. 2...	5	16	45	1	4	2,011	100[1] (approx.)	1,050–1,100	1,610–or 1,750	950	560 or 700	1,510 or 1,650	Chert pebbles in sandstone at 1,610 and 1,750 feet; samples 1,610–1,720 dark shale
Ribstone Oils, No.1	1	1	46	1	4	1,921	20[1] (approx.)	980–1,000	1,630	960	650	1,610	Sand 1,610 to 1,630 feet. Greenish shale 1,630–1,640 feet. No chert pebbles
Ribstone Oils, No.2	5	25	46	1	4	2,087	140	1,090–1,110	1,754	950	664	1,614	Chert pebbles at 1,754 feet
Oxville No. 1......	14	10	46	2	4	2,046	130	1,100–1,130	1,776	970	676	1,646	Top of Lower Cretaceous not definite. Sand at 1,776 feet
Wainwright Area													
Admiral No. 1.....	16	36	44	7	4	2,226	535	1,530–1,560	2,054	995	524	1,519	The speckled shale zone well marked. Chert pebbles at 2,054 feet. Rotary samples
Wainwell No. 3....	9	36	44	7	4	2,216	500	1,480–1,500	?	980	....	....	Speckled shale zone poorly marked in samples
Sasko Wainwright.	1	19	45	6	4	2,314	585	1,590	2,116	1,005	526	1,531	Rotary samples
Wainwright Petroleums No. 1	6	30	45	6	4	2,328	?	1,570–1,580	2,100	?	530	....	Pebbles at 2,100 feet. Base of Ribstone Creek indefinite. Rotary samples
Imperial Fabyan No. 1	16	18	45	7	4	2,044	350	1,360	1,889	1,010	529	1,539	
Beaumont No. 1...	1	10	45	7	4	2,193	490	1,510–1,550	2,035	1,020	525	1,545	Chert pebbles at 2,035 feet (Spratt, J. G.). Rotary samples
Montreal Alberta No. 1	2	15	45	7	4	....	640	1,650–1,740	?	1,010	....	....	Rotary samples
Fabyan Petroleums No. 1	8	24	45	8	4	1,927	285 (approx.)	1,310–1,360	1,770+	1,025	460+	1,485+	Shale at 1,750–1,760 feet. Sand 1,760–1,770 feet, a marked change in lithology, but top of Lower Cretaceous probably slightly deeper. Rotary samples

[1] The Lea Park contains a sand the base of which is thought to be 180 feet below the Ribstone Creek-Lea Park contact. In many of the wells in Ribstone area, glacia materials rest on Lea Park shales and in these cases the position of the Ribstone Creek-Lea Park contact is calculated with reference to the base of the sand in the Lea Park.

—	L.S.	Sec.	Tp.	Range	Mer.	Elev. of well Feet	Depth to: Ribstone Creek-Lea Park contact Feet	Depth to: Speckled shale zone Feet	Depth to: Top of Lower Cretaceous Feet	Thickness: Lea Park Feet	Thickness: Alberta shale Feet	Thickness: Lea Park and Alberta shale Feet	Notes
Maple Leaf No. 2..	1	24	45	8	4	1,937	200+	1,220–1,240	1,769?	1,020–	549?	1,569?	Horizons not well marked. Rotary samples
Viking Area													
C.W.N.G.L.H. and P. Co. Viking No. 14	4	4	49	12	4	2,310	830	1,915–1,925	....	1,085	....	....	Lower Cretaceous not reached
C.W.N.G.L.H. and P. Co. Viking No. 23	10	31	48	12	4	....	780 (approx.)	1,870–1,890	....	1,190	....	....	Lower Cretaceous not reached
Hudson's Bay Oil and Gas Company Viking No. 1	5	18	49	12	.....	2,278	770 (approx.)	1,850–1,860	2,255	1,080	405	1,485	Chert pebbles at 2,260 feet
Kinsella Area													
Duluth Syndicate (MacDonald Well)	3	29	48	10	4	2,305	700	1,760–1,770	....	1,060	....	....	Lower Cretaceous not reached
Other Areas													
Alberta Pacific Con. Duvernay No. 1	5	34	55	12	4	....	....	1,050–1,100	1,491	....	440	....	Lea Park forms bedrock surface. Change from shale to grey sandstone at 1,491 feet
London Ribstone No. 1	14	10	43	3	4	2,080	303?	1,322–1,343	1,965	1,019?	643	1,662	Samples taken at very irregular intervals so that position of horizons only approximate
Northwest Co. "Czar" or "Tit Hills" well	10	17	39	7	4	2,267	1,100	1,710	2,450?	610	740	1,350?	Top of Lower Cretaceous somewhat doubtful
Northwest Co. Misty Hills well	NE.	29	32	4	4	2,451	1,290	1,790 1,880–1,900	2,830	590	950	1,540	Speckled shale at 1,790 feet and with fossil shells and prismatic calcite at 1,880–1,900 feet
							Base of Belly River	Speckled shale zone	Top of Lower Cretaceous	Between base of Belly River and Alberta shale	Alberta shale	Between base of Belly River and base of Alberta shale	
Fuego..............	16	34	25	4	4	2,200±	840	1,740–1,760	2,870?	900	1,130?	2,030?	Top of Lower Cretaceous doubtful. Rotary samples
Ontario Alberta (Suffield)	15	34	17	8	4	....	670	1,370–1,400	2,430	700	1,060	1,760	Small, round, smooth chert pebbles in sand and shale at 2,430–2,440 feet
Eagle Butte No. 1....	9	31	7	4	4	3,623	....	2,130	3,800	....	1,670	....	

Assuming that the speckled shale-fossil shell zone occurs everywhere at the same horizon and also marks the top of the Alberta shale, certain correlations are suggested. The Lea Park has been recognized in well samples as far south as Tp. 32, Range 4, and decreases in thickness from about 1,000 feet in the north to 590 feet in the south. Presumably it continues to decrease in thickness south from Township 32. In Tp. 25, Range 4, the Lea Park has not been recognized in the Fuego well samples, but the Belly River strata have been identified. In this well the thickness from the base of the Belly River (base of the Foremost beds) to the speckled shale horizon at the top of the Alberta shale is 900 feet. This interval of 900 feet must include more than the horizons representing the Lea Park because this formation to the north in Township 32 is only 590 feet thick and, furthermore, the available evidence indicates that the thickness of the Lea Park decreases southward and in Township 25 would be considerably less than 590 feet. It is suggested, therefore, that the base of the Foremost is the approximate equivalent of the base of the Birch Lake sandstone and that the Milk River and Pakowki in southern Alberta are equivalent to the Lea Park, Ribstone Creek, and Grizzly Bear of Battle River area. The Birch Lake sandstone may be a sedimentation phase similar to that occurring at the base of the Foremost in parts of southern Alberta.

This explanation, if correct, clarifies the problem of what constitutes Belly River in Battle River area. Adopting the interpretation of Williams and Dyer restricting Belly River in southern Alberta to the Foremost and Pale beds, the Belly River of Battle River would be the Birch Lake, Variegated, and Pale beds. If, however, the older interpretation of Dowling is followed, whereby in southern Alberta all beds from the top of the Pale beds to the base of the Milk River are considered to constitute the Belly River, then in Battle River area the Belly River would include all beds from the top of the Pale beds to the base of the Lea Park. The Belly River according to Williams and Dyer is restricted almost wholly to non-marine beds and it is possible to make this division throughout the plains area of Alberta, although it is a lithologic and not a time unit.

The Alberta shale of the Central Plains area consists of dark marine shales with sandstones near the base. These lower sandstones contain gas and oil in various localities. It is possible that some part of these sandstones is equivalent to the Pelican sandstone of the Athabaska (McMurray) River section, although as has already been pointed out the division between the Lower and Upper Cretaceous is rather uncertain and certain sandstones placed in the Lower Cretaceous may in reality belong in the Upper Cretaceous.

Lea Park Formation. The type section of the Lea Park formation is at Lea Park, Alberta, on North Saskatchewan River. At this place the formation consists of dark shales and sandy shales with nodules and discontinuous ironstone layers. Fossils of Montana age are quite plentiful in some localities. The base of the formation is not exposed and, therefore, the thickness of the formation has not been definitely determined. Slipper (1918, page 8) estimated the thickness to be 700 feet, but as indicated in the table, page 191, this figure appears to be too small.

Ribstone Creek Formation. The Ribstone Creek formation is named from Ribstone Creek, a tributary of Battle River in Alberta near the Saskatchewan boundary. At this locality it is readily separated from the underlying Lea Park formation as the lower beds of the Ribstone Creek formation are soft, greenish yellow, crossbedded sands, whereas the upper beds of the Lea Park are dark grey, marine shales. The thickness of the sand beds at the base of the Ribstone Creek varies from only a few feet to more than 20 feet, and several hard sandstone beds occur in outcrops within this sand zone. In many of the wells these sands are water-bearing and where the sands outcrop along stream or river valleys springs are common. Most of the information regarding the character of the middle part of this formation has been derived from well records, outcrops are rare because the formation consists of easily weathered, soft shales. Where outcrops occur the shale is not easily distinguishable from the higher Grizzly Bear shales or the lower beds of the Lea Park formation. The Ribstone Creek shales, so far as known, however, carry no fossils and the formation is considered to be predominantly non-marine, at least in Alberta. Above these shales there is another sand zone at the top of the formation, which also carries in outcrops a number of hard bands and nodules. It is thought that these hard bands are largely a surface feature due to cementation of the sand by circulating waters carrying minerals in solution, since in well logs not many hard sandstone bands are encountered. In certain localities carbonaceous layers and even small coal seams occur in the upper part of the formation. On the banks of Battle River near the mouth of Buffalo Coulée a coal seam has been mined to a slight extent for local use. The thickness of the whole formation is approximately 200 to 225 feet, thinning eastwards.

Grizzly Bear Formation. The Grizzly Bear formation consists of dark grey, marine shale and carries Montana fossils. It is thought that the Ribstone Creek non-marine beds grade upwards into the Grizzly Bear marine beds and although in a general way a division can be made, owing to the fact that the top of the Ribstone Creek formation is sand, whereas the base of the Grizzly Bear is predominantly shale, there is a 10 to 15-foot zone in which shale and sand beds alternate and carry marine fossils as well as an abundance of selenite in crystals and flakes. This zone is thought to represent the change from non-marine to marine sedimentation. It seems very probable that the seas depositing the Grizzly Bear shales were very shallow, since the formation in various places carries small nodules made up almost entirely of selenite crystals, and in one well at least, a very thin seam of carbonaceous or coaly material was encountered in shales that were thought to belong to this formation, although the formation is considered to be predominantly marine.

Birch Lake Formation. The Birch Lake formation, named from Birch Lake, Alberta, consists mostly of massive, crossbedded, brownish, and grey sandstones with some softer sand and shales. The contact with the underlying Grizzly Bear shale has not been observed by the writer, but at what is considered to be approximately the base of the formation a bed of oyster shells, in places 3 feet thick, occurs. This oyster shell bed has been found over a wide area and is considered to represent the change from marine conditions in Grizzly Bear time to brackish water conditions in Birch Lake time. It is probable that the brackish water beds of the Birch Lake were deposited almost at sea-level, since the presence of marine fossils (Warren, 1926, page 9) in this formation at Birch Lake attests to at least one invasion of the sea.

Variegated and Pale Beds. Although it has been found impossible in the field to make a sharp division between the Variegated and Pale beds, yet in a general way the two formations are dissimilar, the Pale beds being light grey and whitish sands interbedded with darker shales, whereas the Variegated beds are somewhat darker. Both formations contain thin, unimportant coal seams and carbonaceous layers and the Pale beds are characterized by numerous bentonitic layers. Ironstone nodules are common in both formations. The total thickness as given by Slipper (1918, page 8) is 700 feet, but from well logs in Monitor area, where the top of the Pale beds is exposed, the thickness is believed to be somewhat greater.

Bearpaw Formation. The Bearpaw overlies the Pale beds and consists of dark marine shale with a sandstone member (Bulwark sandstone) in the area south and southwest of Wainwright. Shales of this age occur on Battle River southwest of Hardisty, but not within the area under consideration. The Bearpaw represents the top of the Montana series of rocks and in central Alberta is overlain by the non-marine beds of the Edmonton.

STRUCTURE

Eastward from the edge of the Alberta syncline west of Viking, the strata dip southwesterly, but at angles decreasing in size eastward. In the vicinity of Wainwright a regional southwesterly dip is still recognizable, although it is modified in places by small folds superimposed on the major structure; but east of the Alberta-Saskatchewan boundary, in the vicinity of Battle River, the dip changes to a southeast direction. The major structure between Viking, Alberta, and Battleford, Saskatchewan, is a broad anticline, the highest point of which is somewhere in the vicinity of the mouth of Ribstone Creek. On this major structure a number of minor folds are known and although the accumulations of oil and gas may in a general way have resulted from the larger structure, they occur on the minor folds. The locating of these minor folds, therefore, is the most important consideration in locating drilling sites, for past experience has proved beyond doubt that wells not located on the minor folds have small chances of striking commercial supplies of oil or gas. The major structure, which embraces a very large area in an east-west direction, may be taken as roughly outlining the territory in which oil and gas may occur, but it is only the much smaller areas of local folding that may be expected to be productive.

VIKING GAS FIELD

References: Slipper, S. E.: Geol. Surv., Canada, Sum. Rept. 1917, pt. C, pp. 6-7.
Elworthy, R. T.: "Gas in Alberta"; Mines Branch, Dept. of Mines, Canada, Pub. No. 616 A, p. 17 (1924).

Viking gas field lies north of the town of Viking on the Canadian National Railway main line. The country is for the most part flat or gently rolling and covered by a mantle of glacial drift. No large streams cut through the area and consequently outcrops are relatively scarce. Such as do occur belong to the Pale and Variegated beds.

The Viking field lies on the eastern edge of the Alberta syncline and, therefore, the regional dip is westward. There is, however, a local structure forming Viking gas field with closure both to the south and to the northwest, but so far as known less closure has been demonstrated in a northeast direction. The trend of the structure appears to be northeast-southwest with the highest part of the field centring around Secs. 6 and 8, Tp. 49, Range 12. Shows of oil have been found in some of the wells but no commercial oil production has been developed. The gas is dry. The gas pressure varied between 600 and 660 pounds. The wells are listed in the following table.

Well	L.S.	Sec.	Tp.	Range	Mer.	Elev. of well Feet	Depth of well Feet	Depth to gas sands Feet	Initial open flow in 1,000 cub. ft.
Hudson's Bay Oil and Gas Co., Ltd. (Hudson Bay Marland Oil Co., Ltd.)									
Viking No. 1.......	5	8	49	12	4	2,278	3,040	2,122–30 2,376–87 2,460–65 2,580–85	6,500
Viking No. 2.......	8	8	49	12	4	2,298	2,150	2,140	7,680

NOTE. In Viking No. 1 well there were oil shows (22·2° Bé.) at 2,522–2,524 feet and water at 2,625–2,635 feet. The hole was plugged back to conserve gas sand at 2,122–2,130 feet. Flow of gas increased somewhat from initial flow. Initial pressure 660 pounds.

Well	L.S.	Sec.	Tp.	Range	Mer.	Elev. of well Feet	Depth of well Feet	Depth to gas sands Feet	Initial open flow in 1,000 cub. ft. a day
Northwestern Utilities, Ltd.,									
No. 1	13	24	48	13	4	2,285	2,430	2,180 2,340–45	9,000
No. 2	5	19	48	12	4	2,289	2,373	2,213 2,283	1,750
No. 3	10	25	48	2	4	2,290	2,365	2,176–85 2,197–2,201 2,337–40	5,000
No. 4	3	30	48	12	4	2,307	2,343	2,215–19	2,000 Plugged back to 2,221 feet
No. 5	8	36	48	13	4	2,290	2,220	2,148–50 2,166–87	5,000
No. 6	5	6	49	12	4	2,283	2,203	2,154–76	8,190
No. 7	1	6	49	12	4	2,300	2,215	2,180–95	6,269
No. 8	2	18	48	12	4	2,270	2,430	2,209 2,215–21	 2,000
No. 9	8	24	49	13	4	2,259	2,318	2,158–65	4,500 Salt water at 2,299 feet
No. 10	16	29	48	12	4	2,316	2,245	2,200–06 2,211–13	 5,000
No. 11	16	6	48	12	4	2,279	2,152	2,122–42	9,246
No. 12	9	12	49	13	4	2,254	2,125	2,116–25	7,500
No. 13	1	18	49	12	4	2,239	2,105	2,085–2,105	8,115
No. 14	4	4	49	12	4	2,310	2,198	2,180 2,192–5	 5,217
No. 15	16	2	49	13	4	2,266	2,165	2,153–65	5,054
No. 16	6	7	49	12	4	2,256	2,140	2,127–40	8,418
No. 17	1	31	48	12	4	2,299	2,215	2,203–11	4,930
No. 18	8	17	49	12	4	2,263	2,118	2,107	3,251
No. 19	13	12	49	13	4	2,255	2,145	2,130–43	7,000
No. 20	12	18	49	12	4	2,248	2,110	2,095–2,110	7,000
No. 21	13	4	49	12	4	2,310	2,228	2,193	200 Abandoned
No. 22	10	31	48	12	4	2,283	2,188	2,176–87	4,200
No. 23	10	31	48	12	4	2,307	2,215	2,200–03	3,200

Log of Hudson's Bay Oil and Gas Company, Limited, Viking No. 1 Well [1]
(L.S. 5, Sec. 8, Tp. 49, Range 12, W. 4th Mer.; Elevation, 2,273 feet)

—	Thickness Feet	Depth Feet
Pale, Variegated, Birch Lake, and Grizzly Bear		
Missing	....	25
Light yellowish grey clay	20	45
Sandy clay	45	90
Sandstone	35	125
Grey-brown, sandy shale	10	135
Light grey, sandy shale	65	200
Light grey, sandy shale and sandstone with traces of lignite at 205-210 feet	15	215
Light yellowish grey shale	5	220
Grey-brown, sandy clay	5	225
Grey sandstone and carbonaceous shale	35	260
Grey clay shale with lignite traces	80	340
Grey clay shale with a little sandstone 385–390 feet	125	465
Grey clay shale	55	520

[1] Log by J. G. Spratt; published by permission Hudson's Bay Oil and Gas Company, Limited.

Log of Hudson's Bay Oil and Gas Company, Limited, Viking No. 1 Well (L.S. 5, Sec. 8, Tp. 49, Range 12, W. 4th Mer.; Elevation, 2,273 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Ribstone Creek		
Grey shale and sandstone	25	545
Light grey sandstone	5	550
Grey and grey-brown, sandy shale with lignite at 625 feet	95	645
Grey sand	35	680
Grey shale with coal	10	690
Grey sand and sandstone	85	775
Lea Park		
Light grey shale	45	820
Darker grey shale	35	850
Dark grey shale	1,000	1,850
Alberta shale		
Dark grey shale	255	2,105
Grey sandstone with a few chert pebbles; gas sand	25	2,130
Dark grey shale with fossil fragments	125	2,255
Lower Cretaceous		
Dark grey shale with coal fragments	36	2,291
Grey sandstone	1	2,292
Grey, sandy shale with coal	48	2,340
Coal, grey shale, and sandstone	5	2,345
Grey, sandy shale with coal	20	2,365
Sandstone with coal fragments	14	2,379
Missing	33	2,412
Grey sandstone	5	2,417
Grey, sandy shale and coal fragments	8	2,425
Light grey, carbonaceous shale	84	2,509
Missing	13	2,522
Grey shale	13	2,535
Palæozoic		
Buff limestone with a little white sandstone and pale green shale	9	2,544
White sand and limestone	5	2,549
Buff limestone and pale green shale	26	2,575
Red and green, arenaceous shale	10	2,585
Buff limestone and pale green shale	25	2,610
Buff limestone and red, arenaceous shale	10	2,620
Buff sand with a little green shale	12	2,632
Pale green and red, arenaceous shale and limestone	23	2,655
Reddish sandstone	5	2,660
Buff limestone with red and green shale	25	2,685
Brown limestone	2	2,687
Buff limestone	3	2,690
Buff sandstone and limestone	1	2,691
Buff limestone	34	2,725
Buff sandstone	10	2,735
Light grey limestone	5	2,740
Buff sand	3	2,743
Buff and grey limestone	63	2,806
Grey shale	50	2,856
Brown shale	11	2,867
Grey, calcareous shale	168	3,035

KINSELLA AREA

Kinsella lies about 13 miles southeast of Viking on the main line of the Canadian National Railway. In 1929 the McDonald well of the Duluth syndicate, drilled on Sec. 29, Tp. 48, Range 10, W. 4th Mer., about 11 miles north and 3 miles east of Kinsella, came in at about 2,080 feet with a gas flow of approximately 29,000,000 cubic feet a day. The details of the structure in this area are unknown to the Geological Survey, but the gas sand is said to be the same as that which yields gas in Viking area 12 miles west of this well.

During 1932 Northwestern Utilities, Limited, drilled two wells in Kinsella area. The first on Sec. 17, Tp. 47, Range 11, about 8 miles south, and 5 miles west, of the Duluth syndicate well, is reported to have obtained a flow of 7,000,000 cubic feet of gas a day and the second, on Sec. 25, Tp. 47, Range 11, 3 miles northeast of the first, obtained a gas flow of 19,000,000 cubic feet a day. These developments are of great importance as indicating that a large area is likely to be highly productive, thus affording a reserve supply of gas for Edmonton district.

BATTLE RIVER AREA

References: Allan, J. A.: Geol. Surv., Canada, Sum. Rept. 1917, pt. C.
Dowling, D. B., Slipper, S. E., and McLearn, F. H.: "Investigations in the Gas and Oil Fields of Alberta, Saskatchewan, and Manitoba"; Geol. Surv., Canada, Mem. 116 (1919).
Hume, G. S.: "Oil and Gas Prospects of the Wainwright-Vermilion Area, Alberta"; Geol. Surv., Canada, Sum. Rept. 1924, pt. B.
"Oil Prospects in the Vicinity of Battle River at the Alberta-Saskatchewan Boundary"; Geol. Surv., Canada, Sum. Rept. 1925, pt. B.

INTRODUCTION

Battle River area, as the name is here used, includes an area extending from Irma east to the Saskatchewan boundary. The country is flat or rolling, with a covering of glacial till which obscures most of the underlying rocks except along stream valleys where erosion subsequent to the Glacial period has removed part of the glacial deposits.

The drainage is toward the east, Battle River and tributaries providing the main drainage channels. North of the area the drainage is to North Saskatchewan River which also flows eastwards. Both North Saskatchewan and Battle Rivers have wide valleys which in many places are several hundred feet deep and, considering the low relief of the remainder of the country, are marked topographic features. It can be proved that parts of both valleys antedate the Glacial epoch and probably this is the case throughout most of their length within this area. They have been cut in Cretaceous strata and at least some of the bends of Battle River have been controlled by structural features in the underlying rocks, a condition that could be possible to any considerable degree only in an area where the river valley antedated the Glacial age.

Hawkins Fold

A cross-section of this fold appears on Map 2058 which accompanies Summary Report 1924, part B. If the writer's interpretation of the stratigraphy is correct, the Birch Lake formation forms the crest of an anticline whose axis is assumed to extend in a southeast-northwest direction. Gratton No. 1 well in Sec. 4, Tp. 45, Range 6, W. 4th Mer., was drilled on the southwestern flank of this fold and gave a fair flow of gas. Since it is assumed that gas fills the crest of the fold and that oil, if present, occurs down the flanks, any well drilled nearer the crest of this fold would be a gas well. As the Gratton well is a considerable distance down the southwestern flank of the fold it is, therefore, assumed that the fold contains only gas. If the fold extends northwest, the axis will pass east of Irma and the well of the Irma Oil Holdings, Limited, drilled on Sec. 28, Tp. 45, Range 9, is believed to be on the western flank of the anticline.

FABYAN FOLD

By running lines of levels in connexion with known stratigraphic horizons along Battle River it was found that an anticline, known as the Fabyan fold, corresponds roughly with a southward bend of the river east of Fabyan No. 1 well. The Hawkins, Fabyan, and Battle River-Wainwright folds all show structural control over the course of Battle River and in each case the anticline is indicated by a southward bow in the river valley. This is due to the fact that the river valley is pre-Glacial and hence the structure in part determined the course of the river. The axes of the Fabyan fold cannot be accurately determined because of the scarcity of outcrops and the difficulties of stratigraphic interpretation. The bend in the river valley seems to indicate that the crest of the Fabyan fold lies slightly east of the Imperial Fabyan No. 1 well. The trend of the anticline is presumed to be northwest and southeast and the axis is thought to pass through a group of wells located about a half mile west of the town of Wainwright. The fold is thought to be quite broad with gentle dips on the flanks. Imperial Fabyan No. 1 well was the first well to be drilled on this fold and at 1,870 feet encountered a flow of 10,000,000 cubic feet of gas a day with a small amount of heavy, dark oil and, at other horizons, salt water. Maple Leaf No. 1 well, drilled on the west flank of the fold, encountered a gas flow of 2,500,000 cubic feet a day at a depth of 1,705 to 1,720 feet. The horizon is believed to be stratigraphically higher than the gas zone in Imperial Fabyan No. 1 well. Imperial No. 2 well, drilled on L.S. 2, Sec. 14, Tp. 45, Range 8, reached a depth of 2,015 feet with gas shows at 1,565 and 1,585 feet. The well is believed to be in a syncline separating the Hawkins and Fabyan folds.

Wainwell No. 1, formerly Interior Oil Company No. 1, well, drilled on L.S. 9, Sec. 36, Tp. 44, Range 7, is on the southeast extension of the Fabyan fold. This well, at a depth of 2,068 to 2,075 feet, encountered oil of a gravity of 15·25 degrees Baumé and estimated initial flow of 250 barrels a day with a flow of gas of 5,577,000 cubic feet. The well was drilled to a depth of 2,225 feet and more gas was encountered near the bottom of the hole, the total volume being 8,500,000 cubic feet with a closed pressure of 390 pounds. Water troubles subsequently developed in this well and it was plugged back to the oil horizon. The results of this well led to considerable drilling activity and Wainwell No. 2 A well drilled only a short distance west of No. 1 well came in at 2,025 feet with an initial gas flow of 33,000,000 cubic feet a day and a closed pressure of 350 pounds. Wainwell No. 3 well, drilled south of No. 1, obtained a very poor sand at the productive horizon and was a failure so far as commercial production was concerned. Wainwell No. 4, drilled west of No. 2 well, obtained oil in the productive horizon, but later encountered water troubles. Admiral

Oils drilling northeast of Wainwell No. 1 encountered a tight sand at the oil and gas horizon, and although shows of oil were obtained the well yielded no commercial production. So far as the available information goes Beaumont No. 1 is the only other well on this fold that obtained oil in any quantity, although small amounts were encountered in some other wells.

Log of Imperial Fabyan No. 1 (now Fabyan Petroleums No. 2) Well
(L.S. 16, Sec. 18, Tp. 45, Range 7, W. 4th Mer.; Elevation, 2,040 feet)

—	Thickness Feet	Depth Feet
Birch Lake		
Light grey sand	40	40
Grizzly Bear		
Grey shale with sandy streaks	100	140
Ribstone Creek		
Sandstone and shale	30	170
Shale with a little sandstone and carbonaceous layers	20	190
Hard sandstone (5 feet) and shale	10	200
Grey shale	20	220
Sand and shale	20	240
Grey shale and sandy shale	100	340
Grey shale with sandstone and coal	10	350
Lea Park and Alberta shales		
Grey shale with sandy streaks. Dark, fissile shale 1,810–1,870 feet	1,545	1,890
Lower Cretaceous		
Sandstone with some shale	17	1,907
Sand with grey shale with coal at 1,970–1,980 and 2,000–2,010 feet	43	2,050
Dark, carbonaceous shale and sandstone	60	2,110
Dark, carbonaceous shale and coal	20	2,130
Dark shale and sand	10	2,140
Palæozoic		
Green shale and limestone	50	2,190
Dark grey limestone with some shale	540	2,730

Gas was struck at 1,720-1,732 feet. The principal gas horizon was at 1,870 feet and yielded a flow of about 10,000,000 cubic feet a day. A heavy black oil occurred at 1,892 feet with further shows reported at 1,934-1,947 feet, at 1,962 feet, and minor indications in the Palæozoic rocks. It will be noted that both gas sands lie in the basal part of the Upper Cretaceous.

The thickness of Lower Cretaceous strata in this well is unusually small. At 1,907 feet a conglomeratic, black sandstone was reported. In various wells in Wainwright and Ribstone areas chert pebbles occur at what appears to be the contact between the Upper and Lower Cretaceous.

The correlation of the strata from well to well is extremely difficult, possibly because most of the wells were drilled with rotary equipment and, therefore, poor samples resulted. If it be assumed that the upper gas sand in Imperial Fabyan No. 1 well is to be correlated with the gas sand in Maple Leaf No. 1 well then the same gas sand is about 40 feet higher in Imperial Fabyan No. 1 well than in Maple Leaf No. 1 well. But Maple Leaf No. 2 well, which is very close to No. 1 well, struck gas sand that yielded 4,000,000 cubic feet a day and lies about 110 feet below the horizon of the gas sand in No. 1 well. If this lower gas sand is correlated with the lower gas sand in Imperial Fabyan No. 1 well, then the same gas sand is only about 8 feet higher in Imperial Fabyan No. 1 well than in Maple Leaf No. 2 well. Thus, between Maple Leaf Nos. 1 and 2 wells and Imperial Fabyan No. 1 well, the amount of rise of the two gas sands would differ by 30 feet or more and would take place in a distance of a mile. The data secured from studies of outcrops seem to indicate that the strata rise from west to east and it may be that the 30-foot difference in the intervals separating the two gas sands is not to be regarded as in opposition to the correlations suggested above.

The oil sands of the Wainwell wells have not been definitely correlated with the gas sands of the Imperial Fabyan No. 1 and Maple Leaf wells, but it appears that the oil comes from sands close to the bottom of the Upper Cretaceous. Wainwell Oils, Limited, has a small refinery at Wainwright, but at present it is not operating.

So far as known the oil and gas horizons of Battle River area are confined to sands in the basal part of the Upper Cretaceous and to sandstones in the Lower Cretaceous. Oil shows have been encountered in the Palæozoic limestone, but as yet no commercial production has been obtained from them. In Ribstone field a small amount of gas has been found in the Ribstone Creek formation and flows of gas up to 500,000 cubic feet have been encountered in what is thought to be Lea Park shales.

Wells Drilled on the Fabyan Fold

——	L.S.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet	Notes
Imperial Fabyan No. 1	16	18	45	7	4	2,040	2,730	10,000,000 cub. ft. of gas, small amount of oil
Maple Leaf No. 1	1	24	45	8	4	1,992	1,775	Producing gas
Maple Leaf No. 2	1	24	45	8	4	1,938	1,775	Producing gas
Fabyan Petroleums No. 1	8	24	45	8	4	1,927	1,833	Small shows of oil
Fabyan Petroleums No. 2	16	18	45	7	4	....	2,730	This is the Imperial Fabyan No. 1 well
Admiral Oils No. 1	16	36	44	7	4	2,226	2,698	Dry hole. Finished in Palæozoic limestone
Beaumont Oils No. 1	1	10	45	7	4	2,193	2,182	Shut in
Beaumont Oils No. 2	10	30	45	7	4	2,207	668	Closed down
Bethwain Oils No. 1	13	6	45	7	4	2,247	2,485	Closed down. Finished in Palæozoic limestone
Lloyd Petroleums No. 1	12	6	45	7	4	....	323	Closed down
Wainwell No. 1	9	36	44	7	4	2,219	2,225	Oil and gas at 2,068-2,075 feet. Gas at 2,215 feet
Wainwell No. 2	15	36	44	7	4	2,194	525	Abandoned
Wainwell No. 2A	15	36	44	7	4	2,194	2,033	Initial flow of 33,000,000 cub. ft. of gas
Wainwell No. 3	9	36	44	7	4	2,216	2,072	Never productive
Wainwell No. 4	15	36	44	7	4	....	2,052	Produced some oil, water troubles
Wainwright Oil Dev. Co., No. 1	15	36	44	7	4	2,211	218	Abandoned
Montreal-Alberta Oil Co. No. 1	2	15	45	7	4	....	2,650	Shut down. Finished in Palæozoic limestone

Battle River-Wainwright Fold

The Battle River-Wainwright fold crosses Battle River at the northeast corner of Range 7, Tp. 45, and is roughly outlined by the southward bow of Battle River. It is thought to extend in a northeast and southwest direction, but the character of the fold and the plunge, if any, is unknown. Presumably the crest is flat and the dips on the flanks are very gentle. To the west between the Battle River-Wainwright fold and the Fabyan fold there is a syncline of unknown magnitude. On the northeast flank the dip is less than one degree and probably the northeast dip does not continue for any great distance as the regional southwest dip becomes apparent along Battle River before the mouth of Buffalo Coulée is reached.

Nearly all the wells on this fold have been drilled by rotary methods and as a result logs are unsatisfactory and the correlation of the strata penetrated is uncertain. Apparently the wells commence in the Variegated beds and reach the base of the Ribstone Creek formation at depths of 500 to 600 feet. In many of the wells some gas was found at horizons in sandy shales struck at depths of from 1,200 to 1,400 feet but all of which lie at an elevation of 850 to 1,000 feet. In some wells gas occurs near the base of the Alberta shales. The greatest potential producer of gas on this fold is the National Exploration well on L.S. 1, Sec. 30, Tp. 45, Range 6. It had an initial gas flow of more than 15,000,000 cubic feet a day and in this case the gas comes from the Lower Cretaceous at a depth of 2,237 feet. In a few wells chert pebbles were found at what is supposed to be the contact between the Upper and Lower Cretaceous. In most of the producing oil wells the oil sands occur a few feet below a coal seam in the Lower Cretaceous. It was formerly thought (Hume, 1926, page 15) that the oil sand in British Petroleums Nos. 2 and 4 wells, drilled on L.S. 13, Sec. 30, Tp. 45, Range 6, was in the Upper Cretaceous. There is no doubt the oil horizon in these wells is higher than in British Petroleums No. 3, Sasko-Wainwright No. 1, Edmonton-Wainwright No. 1, etc., but if the chert zone represents the contact of the Upper and Lower Cretaceous it is possible that the oil horizon of British Petroleums Nos. 2 and 4 is in the top of the Lower Cretaceous, although the boundary between Lower and Upper Cretaceous has not been satisfactorily determined in either well.

An analysis of the oil from British Petroleums No. 4 well, by the Fuel Testing Division, Mines Branch, is as follows:

Sample taken at well, September, 1924
Specific gravity at 60°F.= 0·973
" " =13·9° Bé.
Water..........7·4 per cent (volume)
Sulphur ....1·98 per cent

Distillation range—	Per cent
Up to 150° C. (Naphtha)	
150° to 300° C. (Illuminants)	12·9 (vol.)
300° C. and up (Lubricants)	68·2 (vol.)
Coke and residue oil	14·1 (wt.)

An analysis of oil from British Petroleums No. 3B well, made by P. V. Rosewarne, Fuel Testing Division, Mines Branch, is as follows:

Sample taken from initial production of well

Specific gravity at 60° F.= 0·940
" " =18·9° Bé.

	Per cent
Water	0·7
Sulphur	1·6
Distillation range—	
Up to 150° C. (Naphtha)	2·1 (vol.)
150° to 300° C. (Illuminants)	21·3 (vol.)
300° C. and up (Lubricants)	69·0 (vol.)
Coke and residue oil	10·9 (wt.)

Log[1] of British Petroleums No. 3 Well

(L.S. 4, Sec. 29, Tp. 45, Range 6, W. 4th Mer.; Elevation, 2·304·3 feet: Method of drilling: Rotary rig with core barrel used for part of log)

	Feet
Surface material	0 to 130
Shale, dark grey	130 to 210
Sandstone, with hard layer on top	210 to 230
Shale, soft, grey	230 to 251
Sandstone, hard, grey	251 to 285
Shale sand, grey	285 to 302
Shale, grey, sticky, sandy in part	302 to 343
Shale, grey	343 to 370
Shale, blue	370 to 383
Sandstone, hard, grey	383 to 386
Shale, coal fragments	386 to 412
Shale, grey, hard	412 to 479
Sandstone, hard	479 to 480
Shale, blue, soft	480 to 501
Limestone, hard. (Probably ironstone bands or sandstone)	501 to 504
Shale, grey	504 to 507
Limestone, hard. (Probably ironstone bands)	507 to 509
Shale, sandy, dark grey	509 to 580
Shale, grey, soft	580 to 588
Limestone, blue. (Probably ironstone)	588 to 589
Shale, blue	589 to 624
Shale, blue, hard	624 to 784
Shale, grey, hard	784 to 897
Limestone, hard. (Probably ironstone band)	897 to 898
Shale, grey, soft	898 to 997
Shale, blue	997 to 1,045
Shale, blue, hard	1,045 to 1,073
Limestone. (Probably ironstone band)	1,073 to 1,074
Shale, grey, hard	1,074 to 1,189
Shale, sandy, grey	1,189 to 1,239
Shale, black, pyrite	1,239 to 1,277
Shale, black, hard streaks	1,277 to 1,300
Shale, black, sandy. Gas	1,300 to 1,352
Shale, black, soft	1,352 to 1,427
Shale, sandy, dark grey. Gas	1,427 to 1,481
Shale, black, hard and soft alternating	1,481 to 1,657
Shale, dark grey. Glauconitic sand, 1,800 to 1,804 feet	1,657 to 1,804
Limestone. (Probably ironstone band)	1,804 to 1,804·5
Shale, black, sandy	1,804·5 to 1,820

[1] Log supplied by British Petroleums, Ltd.

Log of British Petroleums No. 3 Well—Continued

Shale, sandy, with pyrite	1,820 to 1,836
Shale, black, hard	1,836 to 1,838
Limestone, hard. (Probably ironstone band)	1,838 to 1,838·5
Shale, grey, hard	1,838·5 to 1,852
Lime, sandy, hard, grey	1,852 to 1,852·5
Shale, black	1,852·5 to 1,879
Lime, sandy, hard	1,879 to 1,879·5
Shale, black, soft	1,879·5 to 1,895
Sand, hard	1,895 to 1,896
Shale, black, hard	1,896 to 1,903
Shale, black, sandy	1,903 to 1,931
Sand, blue-grey, hard	1,931 to 1,931·5
Shale, sandy, black	1,931·5 to 1,939
Sand, brown, soft, with shale partings. All saturated with oil. Gas	1,939 to 1,942
Shale, sandy, soft, brown, containing oil and gas	1,942 to 1,953
Sand, brown, soft, saturated with oil and gas	1,953 to 1,956
Shale, black, sandy layers	1,956 to 2,008
Lime, grey, very hard. (Probably ironstone band)	2,008 to 2,009
Shale, hard, dark	2,009 to 2,021
Lime, grey, very hard. (Probably ironstone band)	2,021 to 2,022
Shale, black, hard	2,022 to 2,038·5
Lime, grey, hard. (Probably ironstone band)	2,038·5 to 2,039·5
Shale, black	2,039·5 to 2,056
Sand, coarse, white, soft. Bentonite band	2,056 to 2,058
Shale, black	2,058 to 2,074
Sand, blue	2,074 to 2,075
Shale, black	2,075 to 2,085
Shale, with streaks of soft, brown sand impregnated with oil. Gas	2,085 to 2,093
Shale, black, hard	2,093 to 2,096
Lime, grey, hard, with pyrite. (Probably ironstone bands)	2,096 to 2,096·5
Shale	2,096·5 to 2,098
Sand, soft, brown, impregnated with oil. Gas	2,098 to 2,106
Shale, sandy. Oil and gas	2,106 to 2,109
Sand, brown, soft. Oil and gas	2,109 to 2,111
Shale, brown, sandy	2,111 to 2,113
Shale, brown, sandy	2,113 to 2,118
Sand, showing oil	2,118 to 2,120
Sand, hard, showing oil	2,120 to 2,151
Sand, hard, shale partings	2,151 to 2,152
Shale, grey	2,152 to 2,155
Shale, grey, with some sandy streaks	2,155 to 2,157
Sand, hard, coarse	2,157 to 2,158
Shale, grey, sandy	2,158 to 2,160
Shale, grey, sticky	2,160 to 2,161
Sand, hard and coarse, grey	2,161 to 2,165
Sand, grey, with streaks of asphaltic material	2,165 to 2,166
Shale, brown, with streaks of asphaltic material	2,166 to 2,171
Shale, grey, sandy	2,171 to 2,178
Asphaltic material	2,178 to 2,183
Shale, grey, sandy, asphaltic material	2,183 to 2,188
Sand, hard, coarse	2,188 to 2,190
Sand, grey, with streaks of shale	2,190 to 2,200
Shale, grey	2,200 to 2,208
Coal	2,208 to 2,217
Shale, sticky, grey	2,217 to 2,222
Shale, black, with sand partings. Oil and gas	2,222 to 2,223·8
Lime. (A part of this was tested by the Borings Division, Geological Survey, showing it to be ironstone)	2,223·8 to 2,224·8

NOTE. The glauconitic horizon at 1,800 to 1,804 feet in this well correlates with a similar horizon at 1,684 to 1,688 feet in No. 1 B.P. well and at about 1,705 feet in Maple Leaf No. 1 well.

It is difficult to divide the logged strata into stratigraphic horizons, but the following division is approximately correct for No. 3 well.

	Feet
Glacial material	0 to 130
Variegated beds and Birch Lake formation	130 to 285
Grizzly Bear formation	285 to 383
Ribstone Creek formation	383 to 580
Lea Park and Alberta shale	580 to 2,100 (?) (approximately)
Lower Cretaceous	2,100 to (bottom of well)

Wells Drilled on Battle River-Wainwright Fold

——	L.S.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet	Notes
Bethwain No. 2....	16	4	45	6	4	2,347	2,286	Some oil and gas
British Wainwright No. 1............	13	20	45	6	4	2,296	2,238	Closed down
British Petroleums No. 1............	1	36	45	7	4	2,187	2,017	Abandoned
British Petroleums No. 2............	13	30	45	6	4	2,251	2,038	Some oil and gas
British Petroleums No. 3............	4	29	45	6	4	2,304	2,296	Abandoned
British Petroleums No. 3B...........	4	29	45	6	4	2,305	2,259	Oil
British Petroleums No. 4............	13	30	45	6	4	2,251	2,036	Closed down
Edalta No. 1.......	15	19	45	6	4	....	2,225	Closed down
Edmonton-Wainwright No. 1.....	4	29	45	6	4	2,318	2,275	Oil
Emerald No. 1.....	8	30	45	6	4	2,326	2,425	Dry hole
Mid Canada No. 1..	7	13	45	6	4	....	175	Closed down
National Exploration No. 1........	1	30	45	6	4	2,316	2,268	Gas
Onalta No. 1.......	8	20	45	6	4	2,270	2,232	Oil
Peninsular Petroleums No. 1......	16	30	45	6	4	....	234	Closed down
Sasko-Wainwright No. 1............	1	19	45	6	4	2,314	2,246	Oil
Senator Oils No. 1.	1	23	44	6	4	....	710	Closed down
Western Consolidated No. 2......	11	30	45	6	4	2,301	2,233	Abandoned
Wainwright Dome (Anwood Dome) No. 1............	7	31	45	6	4	2,349	2,308	Closed down
Wainwright Petroleums No. 1......	6	30	45	6	4	....	2,252	Oil, closed down

Ribstone-Blackfoot Anticline

Outcrops indicating the Ribstone-Blackfoot anticline occur along the banks of Battle River and its tributaries Ribstone and Blackfoot Creeks. Elsewhere the country is covered by a heavy mantle of drift which conceals the underlying sediments. The Ribstone-Blackfoot anticline appears to occupy the crest of a regional anticlinal structure on which minor folds are superimposed. Originally it was thought the trend of the structure was northeast and southwest, but this view has been modified somewhat by the results obtained from a number of structural test wells drilled by Ribstone Oils, Limited. The Ribstone-Blackfoot anticline is now thought to consist of a number of domes as is indicated on Figure 18. The structural contour lines of this figure represent the attitude of the contact between the sands constituting the lower part of the Ribstone Creek formation and the marine shales of the Lea Park formation. This contact is exposed on Ribstone Creek, 2 miles from Battle River, at an elevation of 1,900 feet. In the Imperial Muddy Lake well, 50 miles southeast, the contact is thought to lie at an elevation of 1,340 feet. This indicates a southeast regional dip of about 10 feet a mile, but this dip may not be uniform as other folds may possibly intervene between the two areas. The southerly regional dip is indicated by a succession of higher and higher formations occurring along a southeast direction from Ribstone area. At the mouth of Ribstone Creek Lea Park strata outcrop. To the southeast, at the south end of Manitou Lake in the vicinity of Zumbro and eastward to Vera, there is an extensive area of sand dunes, the sand of which is thought to have been derived from the top of the Ribstone Creek formation. Manitou Lake is probably underlain by shales of the central part of the Ribstone Creek formation, although so far as known there are no outcrops. Farther southeast around Unity and Muddy Lake the Variegated and Pale beds outcrop and these can be traced westward to Macklin and on westward to Czar which lies southwest of Ribstone area. Southeast of Unity, Sask., marine shales outcrop on Tramping Lake. It was formerly thought (Hume, 1926, page 6) these shales might belong to the Grizzly Bear formation, but the southeasterly regional dip indicates that probably they are Bearpaw shales. Coal is washed up on the shores of Tramping Lake. It is probable that it is derived from the Pale beds.

West of Ribstone area there is, on Battle River, in Tp. 45, Range 3, W. 4th Mer., a small syncline exposing Grizzly Bear shales. Their presence indicates a westward dip of about 275 feet in the 12 miles from the mouth of Ribstone Creek west to the outcrops of Grizzly Bear shale. The nature of the Ribstone-Blackfoot anticline along its continuation northwest or northeast is unknown. Along these directions, a considerable distance north, Lea Park shales are present along North Saskatchewan River from Lea Park, Alberta, to Battleford, Saskatchewan. A certain amount of closure has been demonstrated, however, by drilling (*See* Figure 18).

East of Ribstone area, the general dip appears to be southeast. It is thought that the Ribstone Creek formation changes from a non-marine to a marine formation east and north of Ribstone area. Marine sandstones outcrop along Big Gully in Tps. 49 to 51, Ranges 23 to 27, W. 3rd Mer. Similar sandstones carrying marine fossils also occur on Battle River in Tps. 46 and 47, Ranges 24 to 26, W. 3rd Mer. Levels carried on these sandstone beds on the north bank of Battle River show that the strata are so nearly horizontal that the elevation of what was considered to be the same horizon varied only within about 8 feet, that is within the limits of the thickness of the beds measured. No definite dip in any one direction could be recognized. Along Big Gully what are believed to be the same beds showed—principally in Tp. 49, Ranges 24 and 25—a slightly wider variation in elevation, but again no definite dip for any distance in one

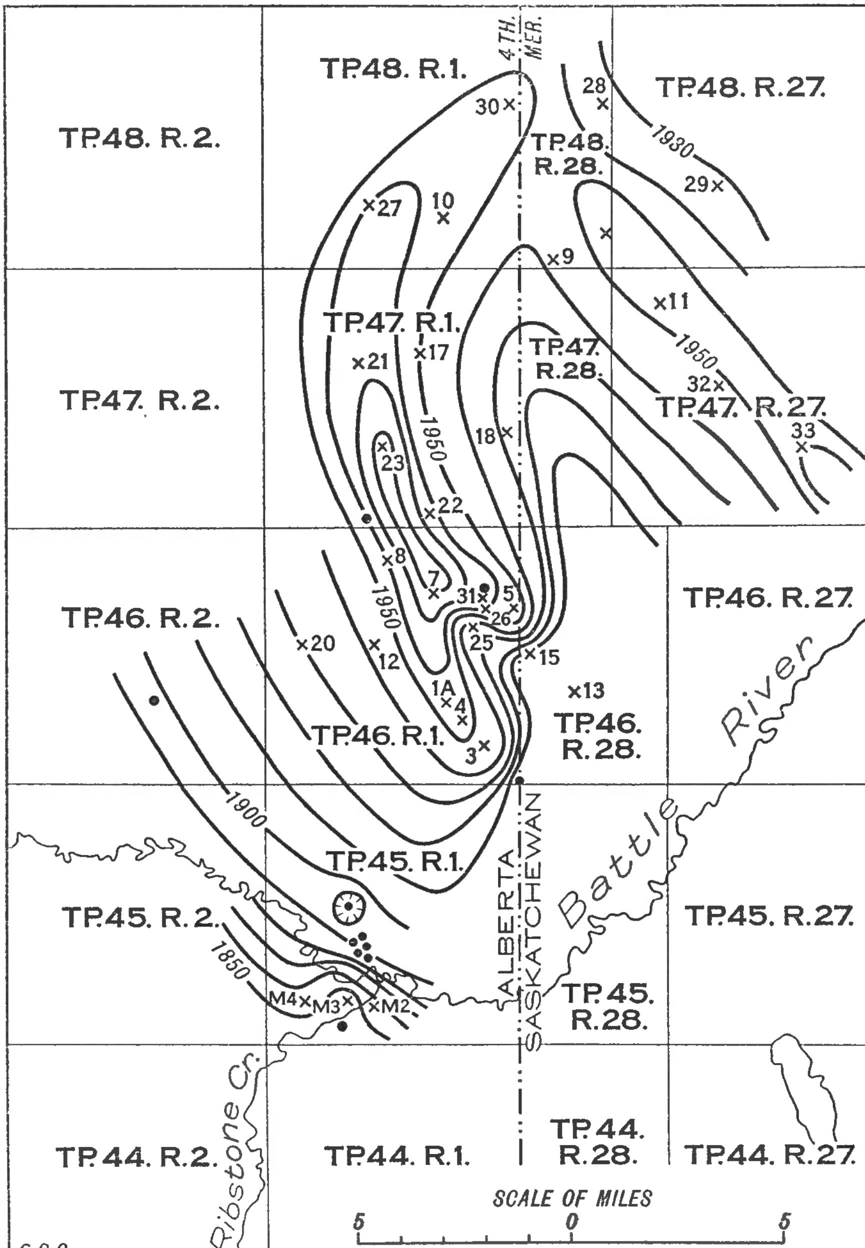

Figure 18. Structural contour map of Ribstone-Blackfoot anticline, contours represent Ribstone Creek-Lea Park contact; deep wells are represented by solid black circles, structural test wells by numbered crosses.

direction. On the other hand, all elevations measured along Big Gully are somewhat higher than those on Battle River, indicating a southward dip of a few feet a mile. These sandstone beds are not entirely satisfactory horizons for the measuring of accurate elevations, because the exposures consist mainly of hard nodules not always at exactly the same horizon, but sufficient outcrops were obtained to show that no marked dip is continuous for any considerable distance.

On Battle River, east of Range 24, there are a series of sand hills in which no outcrops occur. Farther east, at the mouth of Cutknife Creek, in Tp. 45, Range 21, coal has been reported to occur. Still farther east, in the vicinity of Prongua in Tps. 43 and 44, Range 18, W. 3rd Mer., Ribstone Creek sandstones outcrop at elevations that indicate a regional eastern dip which, in all probability, extends as far east as Battleford. In the north, a southward dip is shown by the occurrence of coal presumably belonging to the Ribstone Creek formation, in a shallow water well in Tp. 53, Range 22, near St. Wallburg, at an elevation slightly greater than outcrops of these beds south of North Saskatchewan River. A southerly dip is also shown by the occurrence of Ribstone Creek strata in the Unity Valley wells in Tp. 41, Range 24, at a lower elevation than outcrops of this formation on Battle River in Township 47. From these data, therefore, it seems safe to conclude that east of Ribstone area the dip is southeasterly.

In Ribstone-Blackfoot area drilling has demonstrated the existence of two distinct sandstone horizons separated by marine shales. The upper sandstone horizon is at the base of the Ribstone Creek formation. The lower is within the Lea Park formation, has a thickness of 50 to 70 feet, and its base is 180 to 190 feet below the base of the upper or Ribstone Creek sandstone. Both sandstones carry water, but apparently the positions of the water horizons vary. The water well on the farm of Mr. Garton in Sec. 24, Tp. 46, Range 1, W. 4th Mer., from which gas was escaping for many years prior to the discovery of the Ribstone structure, obtains both water and gas from the Lea Park sandstone. It was reported that the gas occurred at a depth of 290 feet and the water at 315 feet. If the water comes from near the base of the sandstone, the Ribstone Creek-Lea Park contact would be about 180 feet higher or 135 feet below the surface and the elevation of the contact would be 1,965 feet. Ribstone Oils, Limited, drilled structural test well No. 25 on Sec. 25, Tp. 46, Range 1, W. 4th Mer., about 100 yards west of Mr. Garton's farm buildings. This well reached the Ribstone Creek-Lea Park contact at an elevation of 1,960 feet. Evidently, therefore, the water in the Garton well was struck a few feet above the base of the Lea Park sandstone. In a well on the farm of Mr. Sands on northwest Sec. 30, Tp. 45, Range 1, water was struck at a depth of 312 feet. The elevation of this well is not exactly known, but is approximately 2,060 feet. The elevation of the water horizon would, therefore, be 1,748 feet. The structural contours (Figure 18) indicate that in the vicinity of this well the elevation of the Ribstone Creek-Lea Park contact is between 1,890 and 1,900 feet and, therefore, that the base of the Lea Park sandstone lies at an elevation of 1,700 to 1,720 feet. It follows that the water horizon is 30 to 50 feet above the base of the sandstone.

The Ribstone-Blackfoot structure was discovered by the Geological Survey in 1924. It was further investigated in 1925 when the highest part of the structure along Battle River was found to be in the vicinity of the present Meridian wells and in fact Meridian No. 1 (Advance) well owes its location to this fact. The three Meridian wells in Sec. 16, Tp. 45, Range 1, and the nearby Imperial Ribstone No. 2 well in Sec. 9, Tp. 45, show very slight differences of elevation of the oil sand and Algonquin Nos. 1 and 2 wells only a relatively short distance to the north failed to find production. Apparently in Meridian No. 3 well the productive sand is split by a shale member that rapidly thickens northward, replacing the productive sand, so that at the horizon where oil should have been encountered in the Algonquin wells only shales occur. By inference, therefore, the sand should thicken southward. In order to examine the structure southward Meridian Oil Company drilled several shallow test wells. The results were disappointing because they showed that the structure was very flat. A well, Imperial-Ribstone No. 1, drilled to the south on Sec. 5, Tp. 45, struck an oil sand that gave 3 to 4 barrels a day. This sand is lower than the productive sand in the Meridian and Imperial-Ribstone No. 2 wells to the north and it is concluded that the concentration of oil in this area depends more on the presence of favourable sand lenses than on the local structure.

The first productive well to be drilled was Meridian No. 1. At a depth of 1,820 feet it struck a gas flow that originally measured 30,000,000 cubic feet a day. When the well was allowed to flow both the amount and pressure of the gas fell rapidly and much oil sand was blown from the well. The well was subsequently deepened to 1,833 feet where oil was encountered. Considerable oil of 14·5 degrees Baumé was taken from the well, but owing to market conditions and the lack of storage facilities production was not continuous. The indicated production was, however, believed to justify further drilling and three other wells, Meridian Nos. 2 and 3 (also in Section 16) and Imperial-Ribstone No. 2 (in Section 9) were drilled, all of which were productive. A power plant was installed and the four wells were put on the pump. Initially the wells were capable of a production of 75 barrels a day, but with continuous pumping this decreased rapidly to about 10 barrels each a day, which seems to be about the rate the heavy oil may flow through the sand to the wells. Pumping was continued during the summer of 1931 and several thousand barrels of oil were produced and sold for fuel to the Canadian Pacific Railway Company. The failure to get larger production seems to be due to the small thickness of the oil sand, as well as to the heavy character of the oil which as a result does not flow as readily as would a lighter oil. As production could not be maintained on a profitable commercial basis all wells were abandoned.

As is shown by the following log of Meridian No. 1 well, the oil was obtained in sands of Lower Cretaceous age.

Log of Meridian No. 1 Well[1]

(L.S. 4, Sec. 16, Tp. 45, Range 1, W. 4th Mer.)

—	Thickness Feet	Depth Feet
Glacial drift	60	60
Lea Park and Alberta shale		
Grey shale, a little sand	10	70
Grey shale, fossil shells at 80 feet	100	170
Grey, shaly sand	30	200
Fine, grey sand	30	230
Grey shale, ironstone at 750 feet	780	1,010
Dark grey, in part paper, shales highly bituminous, gas at 1,275 feet and at 1,440-1,470 feet (250,000 cub. feet). Sandy shale towards bottom	630	1,650
Chert pebbles in shale	20	1,670
Lower Cretaceous		
Sandstone, fine-grained, water at 1,670-1,684 feet	10	1,680
Shale	10	1,690
Sandstone and shale, carbonaceous	30	1,720
Shale, ironstone, and coal fragments	5	1,725
Shale	5	1,730
Sandstone	10	1,740
Shale	10	1,750
Sandstone, shale, and carbonaceous materials	40	1,790
Shale	8	1,798
Carbonaceous shale and coal	8	1,806
Shale and carbonaceous materials	9	1,815
Sandstone with carbonaceous partings, gas sand at 1,820 feet; initial flow 30,000,000 cubic feet	12	1,827
Oil sand	2	1,829
Fine-grained, white sand, no oil	5	1,834

[1] Compiled from log by J. G. Spratt; published by permission of Meridian Oils, Ltd.

A mechanical analysis of the Meridian Oil sand by F. J. Fraser, Geological Survey, shows the following composition.

	Per cent
Sand with a grain diameter over 0·2 mm	7·2
Sand with a grain diameter between 0·1 and 0·2 mm	66·8
Silt grade; particles between 0·01 and 0·1 mm	6·0
Clay grade and oil left after extraction with cold benzol—by difference	20·0

The main structure of the Ribstone-Blackfoot fold (*See* Figure 18) lies north of the Meridian wells. It has been outlined by shallow test wells. Two deep wells, namely, Ribstone Oils No. 2 and Rayco Oils No. 1, drilled on this part of the structure, found no commercial gas or oil flows. This is surprising in view of the fact that the structure is much higher than at the Meridian wells. Two other deep wells, Ribstone Oils No. 1 on the east flank of the structure and Oxville Oil and Gas Company's No. 1 well on the west flank, gave encouraging shows of oil but no commercial production. The prospects for oil in this higher part of the Ribstone-Blackfoot fold do not seem very promising, although it is possible that if more wells were drilled local areas of production might be found because of the lens-like character of the Lower Cretaceous sands that provide the productive zones.

An interesting feature of Ribstone Oils No. 2 well (L.S. 5, Sec. 25, Tp. 45, Range 1, W. 4th Mer.) was the presence in the Palæozoic limestone, at a depth of 3,010 feet, of salt water carrying a high concentration of calcium, magnesium, and sodium chlorides. An analysis of this brine by the Mines Branch, Department of Mines, gave the following results.

Specific gravity at 60 degrees F.	1·194	
Solid matter in 100 cc.	26·98	grs.
Percentage of solid matter to weight of brine	22·59	
Composition of solid matter		
Sodium chloride	43·62	per cent
Potassium chloride	2·48	"
Calcium chloride	40·36	"
Magnesium chloride	12·97	"
Calcium sulphate	0·21	"
Calcium carbonate	0·30	"
	99·94	

Composition of brine a barrel (35 gallons)
26·98 grs. of solid matter in 100 cc.
2,698 lbs. of solid matter in 1,000 imp. gals.
94·43 lbs. of solid matter in 1 barrel (35 gals.)

Pounds of salt constituents recoverable from one barrel (35 gals.):

	Pounds
Sodium chloride	41·19
Potassium chloride	2·34
Calcium chloride	38·11
Magnesium chloride	12·25
Calcium sulphate	0·20
Calcium carbonate	0·28
	94·37

In 1932 a test was made of the rate of production of brine. It amounted to about 150 barrels a day. As this was considered to be too low to be of value the well was abandoned.

Log of Ribstone Oils No. 2 Well

(L.S. 5, Sec. 25, Tp. 45, Range 1, W. 4th Mer.; Elevation, 2,087 feet)

—	Thickness Feet	Depth Feet
Glacial drift	90	90
Sandy clay	20	110
Sand; water at 120 and 140 feet	30	140
Lea Park and Alberta shale		
Shale	110	250
Lea Park sand		
Fine sand	10	260
Sandstone, sand, and a little shale	50	310
Fine sand	10	320
Grey shale with shell fragments, ironstone, and sandstone bands. Gas at 1,372-1,392, 1,462, and 1,600 feet	1,413	1,733
Lower Cretaceous		
Chert pebbles in shale	....	1,733
Shale	6	1,739
Sandstone: flow of 750,000 cubic feet of gas a day at 1,740 feet and salt water at 1,743 feet	4	1,743

Log of Ribstone Oils No. 2 Well

(L.S. 5, Sec. 25, Tp. 45, Range 1, W. 4th Mer.; Elevation, 2,087 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Shale and sandstone; pebbles	11	1,754
Sandstone with a little carbonaceous material	123	1,877
Carbonaceous shale and coal	12	1,889
Sandstone, ironstone	1	1,900
Dark shale and coal	6	1,906
Sandstone; salt water at 1,908 and 1,953 feet	50	1,956
Shale, a little sandstone, coal at 1,983 feet	64	2,020
Sand; oil show; water at 2,023 feet	5	2,025
Sandstone, fine grained	2	2,027
Shale, a little ironstone	6	2,033
Sandstone, grey, fine grained	17	2,050
Shale, grey to dark grey	1	2,051
Sandstone, light grey, pyrite	6	2,057
Shale, grey to dark grey, pyrite	12	2,069
Sandstone, fine grained, grey, pyrite	47	2,116
Shale, grey to dark grey	3	2,119
Sandstone, fine grained, light grey	14	2,133
Shale, grey to dark grey, carbonaceous	4	2,137
Sandstone, fine grained, light grey	23	2,160
Sandstone, sulphur water at 2,166 feet	10	2,170
Sand, white, coarse	101	2,271
Palæozoic		
Limestone, light buff-grey	27	2,298
Sandstone	8	2,306
Limestone, light grey-buff	824	3,130
Greenish shale	5	3,135
Limestone, bluish grey and buff	95	3,230

Wells Drilled on the Ribstone-Blackfoot Anticline

—	L.S.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet	Notes
Algonquin No. 1	1	20	45	1	4	2,051	2,100	Abandoned
Algonquin No. 2	5	16	45	1	4	2,011	2,206	"
Imperial Ribstone No. 1	......	5	45	1	4	1,851	3,489	Abandoned. Shows of oil and gas
Imperial Ribstone No. 2	14	9	45	1	4	1,796	1,685	Produced oil, abandoned
Meridian No. 1	......	16	45	1	4	1,938	1,834	" "
Meridian No. 2	4	16	45	1	4	1,912	1,803	" "
Meridian No. 3	4	16	45	1	4	1,994	1,889	" "
Oxville No. 1	14	10	46	2	4	2,046	2,260	Abandoned. Shows of oil and gas
Rayco Oils No. 1	3	4	47	1	4	2,194	2,510	Abandoned
Ribstone Oils No. 1	1	1	46	1	4	1,921	2,056	Abandoned
Ribstone Oils No. 2	5	25	46	1	4	2,087	3,230	Shows of oil and gas. High concentration of salts at depth of 3,010 feet

Structural Test Wells

	Ribstone[1] Oils, Ltd.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth of Ribstone Creek-Lea Park contact Feet	Elev. of contact Feet
1A	Northwest corner	11	46	1	4	2,075	124	1,951
3	340 feet east and 600 feet south of northwest corner	1	46	1	4	1,975	28	1,947
4	Centre	11	46	1	4	2,054	100	1,954
5	Southeast quarter	25	46	1	4	2,040	86	1,954
6	Southwest quarter	25	46	1	4	2,086	105	1,981?
7	East half, about middle of	27	46	1	4	2,093	110?	1,980?
8	Southeast corner	33	46	1	4	2,153	180–190	1,960-1,970
9	70 feet north and 205 feet east of north quarter of corner of	35	47	28	3	2,096	155	1,941
10	125 feet north and 200 feet east of northeast corner	3	48	1	4	2,100	146	1,954
11	100 feet east and 100 feet north of northeast corner	30	47	27	3	2,163	210	1,953
12	50 feet north of south quarter corner of	21	46	1	4	2,135	193	1,942
13	Southeast quarter	15	46	28	3	2,047	190	1,857
14	Auger hole, east bank of coulée 125 yards north of road	13	47	1	4	2,003	Not reached	Below 1,947
15	Auger hole, west bank of coulée in south part	21	46	28	3	1,942	"	" 1,910
16	1,650 feet east and 80 feet north of southwest corner	1	47	1	4	2,034	....	....
17	Southeast quarter	27	47	1	4	2,065	115	1,950
18	Southeast quarter	13	47	1	4	2,041	112	1,929
19	Northeast quarter	9	47	1	4	2,189	....	....
20	Southeast quarter	19	46	1	4	2,173	242	1,930
21	Northwest quarter	21	47	1	4	2,068	100	1,968
22	Southeast quarter	3	47	1	4	2,124	159	1,965
23	120 feet northwest of No. 19	9	47	1	4	2,190	209	1,981
24	Northwest quarter	1	47	28	3	2,096	162	1,934
25	Northwest quarter	23	46	1	4	2,100	167	1,933
26	100 yards east of southwest corner	25	46	1	4	2,092	130	1,962
27	Near centre	9	48	1	4	2,056	96	1,960
28	Northeast quarter	24	48	28	3	2,112	181	1,931
29	Near north quarter corner of	9	48	27	3	2,140	208	1,932
30	Near northeast corner	24	48	1	4	2,109	154	1,955
31	300 feet south of Ribstone Oils No. 2 well	25	46	1	4	2,080	115	1,965
32	½ mile east and ¼ mile north of southwest corner	21	47	27	3	2,085	137	1,948
33	915 feet south and 1,727 feet east of northwest corner	11	47	27	3	2,125	165	1,960
34	Northwest corner	16	45	1	4	....	Glacial drift to Lea Park shale	

[1] Published by permission of Ribstone Oils, Ltd.

—	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth to base of Ribstone Creek sand Feet	Depth to base of Lea Park sand Feet	Elevation of base of Lea Park sand Feet	Elevation of Ribstone Creek-Lea Park contact (actual or calculated) Feet	Remarks
Meridian Oils, Ltd.										
1 East side of Ribstone Creek near Battle River	9	45	1	4	1,788	....	....	....	....	Depth 114 feet. No results
2 On northwest quarter..	4	45	1	4	1,965	....	297	1,678	1,858	Total depth, 299 feet
3 On northeast corner...	5	45	1	4	1,953	....	291	1,662	1,842	Total depth, 297 feet
4 1 mile west of No. 3...	6	45	1	4	1,997	142	....	....	1,855	Total depth, 148 feet

Lone Rock Anticline

To the east of Ribstone area, structural test drilling has revealed some evidence of a dome-like structure in the vicinity of Lone Rock in Saskatchewan close to the Alberta boundary. This anticline is in part roughly parallel to the Ribstone-Blackfoot fold, but at the northwest end seems to curve a little to the west to join the north end of the Ribstone-Blackfoot fold. The south end of the Lone Rock anticline has not been located by drilling and no evidence of it could be obtained from outcrops along Battle River. There is no doubt, however, of a regional southerly dip and hence closure is to be expected in this direction. As already pointed out, marine sandstones at the base of the Ribstone Creek formation outcrop along Battle River in Tps. 46 and 47, Ranges 25 and 26, W. 3rd Mer. Levels run by the Geological Survey in 1931 along these sandstones indicate that the strata are very nearly horizontal, although the regional distribution of the strata seems to indicate an easterly dip between the 4th Meridian and Battleford. No conclusions regarding the prospects of the Lone Rock anticline may be safely drawn, particularly as the results of drilling on the higher part of the Ribstone-Blackfoot fold have been very disappointing.

Oil and Gas Horizons

Apparently two zones have produced gas and oil in Battle River area. One zone is the sandstones at the base of the Upper Cretaceous. These have yielded gas in the Viking field and in the Fabyan fold, and oil in the Fabyan and Battle River-Wainwright folds. The second zone is in the Lower Cretaceous and has yielded oil with some gas in the Battle River-Wainwright fold and in the Ribstone field.

The conditions of sedimentation are instructive. In the Athabaska (McMurray) River area the Lower Cretaceous consists of an alteration of marine and non-marine beds as follows:

	Thickness Feet
Pelican shale	
Black marine shale	90
Grand Rapids	
Mostly continental sandstones with thin coal seams in the upper part; lower part concretionary and marine	280
Clearwater	
Grey and black shales and grey and green sandstones with some concretionary layers	275
McMurray	
Massive, crossbedded sandstone partly impregnated with bitumen; a deltaic formation	100 to 180

To the south in the Ribstone and Wainwright area the Lower Cretaceous consists mainly of non-marine sandstones and shales, indicating that the shore-line of the seas that deposited the marine beds in McMurray area lay between McMurray and the Wainwright-Ribstone areas. These shore-lines with their embayments and lagoons are regarded as being very favourable places for the deposition of source materials for oil and gas, and it is suspected that a great part of the oil that now occurs as bitumen in the McMurray formation was derived from this source. The shore-lines, in addition, ought to have provided sands that would form reservoir rocks, and it is interesting to note that the Duvernay well, drilled on the bank of North Saskatchewan River north of Vegreville, penetrated an oil-stained sand 50 feet thick in which the sand grains are much coarser than any known in the Lower Cretaceous of the Wainwright-Ribstone areas. Apparently, therefore, any favourable structure north and west of Battle River area should offer excellent oil prospects. The presumed conditions of sedimentation also indicate that the oil in the Lower Cretaceous of the Wainwright-Ribstone areas is indigenous. The absence of red and maroon-coloured strata from the Lower Cretaceous of Battle River area may signify non-oxidation conditions, and hence more favourable conditions for the preservation of source materials for oil than is the case in southern Alberta where maroon and red shales occur and indicate exposure to atmospheric conditions with the attendant opportunities for decomposition of source materials. Thus it seems that the Lower Cretaceous of the more northern parts of Alberta was more favourable for the formation of oil than the Lower Cretaceous of the southern plains. This conclusion is supported by the distribution of the known oil occurrences in strata of this age. In southern Alberta where the oil occurs in the basal sands of the Lower Cretaceous (Vanalta sand of Red Coulée), it is possible the oil originated in the Ellis formation which is not present in northern Alberta.

In addition to the two main oil and gas zones in, respectively, the Lower Cretaceous and the basal part of the Upper Cretaceous of Battle River area, a certain amount of gas has been found at the base of the Lea Park or in the upper part of the Alberta shales. So far no commercial production has been obtained from this horizon but the Alberta shales are so highly bituminous in certain areas, as at Ribstone, that gas and oil can be distilled from them. There is little doubt, therefore, that the failure to obtain a large gas production at this horizon is due to the lack of suitable reservoir rocks rather than the absence of potential source beds. In the Ribstone area small flows of gas have also been noted in the Ribstone Creek formation and in a fairly prominent sand in the Lea Park about 180 feet below the base of the Ribstone Creek formation. These horizons in the Ribstone area are water-bearing.

DUNN AREA

Two wells have been drilled by London-Ribstone Oils, Limited, in Tp. 43, Range 3, W. 4th Mer., south of Dunn on the Canadian National Railway. These wells are a considerable distance south of Ribstone area. The country in their vicinity is largely occupied by sand dunes and, due to lack of outcrops, no structural information is available. The sand area seems to be an extension of that at the south end of Manitou Lake where the sand is thought to have been derived from the top of the Ribstone Creek formation.

The interpretation of the logs of the London-Ribstone wells presents difficulties owing to the fact that the wells were drilled by rotary methods. A tentative interpretation of the log of No. 1 well is here given.

Log of London-Ribstone Oils Well No. 1[1]

(L.S. 14, Sec. 10, Tp. 43, Range 3, W. 4th Mer.; Elevation, 2,080 feet)

—	Thickness Feet	Depth Feet
Sand	30	30
Clay and sandy clay	30	60
Ribstone Creek		
Sand, water at 75 feet	15	75
Shale, water at 172 and 231 feet	146	231
Sand	39	270
Shale	10	280
Sand with water	23	303
Lea Park and Alberta shale		
Shale	97	400
Shale with fine-grained sandstone. Gas show at 405 feet	30	430
Shale with gas shows at 1,055, 1,125 feet. Core sample 1,322–1,343 shows fossil shells. Fossils also at 1,590, 1,610, 1,650–1,660, 1,700–1,710, 1,740, 1,780, 1,810–1,840 feet. Speckled shale 1,322–1,343 feet	1,530	1,965
Lower Cretaceous		
Sandstone, 2 feet with fine shale and sandy, carbonaceous layers	22	1,987
Carbonaceous shale and fine, grey sand	18	2,005
Sandstone, light grey and carbonaceous	5	2,010
Shale and sandy layers	10	2,020
Ironstone layers 4 inches thick		
Sandstone alternating with thin, carbonaceous shale bands	20	2,040
Sandstone with slight amount of shale; ironstone band 2 inches thick at 2,046 feet	13	2,053
Sandstone with 1 foot coal at 2,054 feet underlain by 1·6 inch shale	27	2,080
Shale with ironstone and coaly material	5	2,085
Shale	13	2,098

[1] Log from samples examined by J. G. Spratt. Published by permission of London-Ribstone Petroleums, Limited.

Log of the London-Ribstone Oils Well No. 1

(L.S. 14, Sec. 10, Tp. 43, Range 3, W. 4th Mer.; Elevation, 2,080 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Sandstone, 1 foot	1	2,099
Shale and coaly material, ironstone. Gas at 2,112-2,118 feet	19	2,118
Shale; coal at 2,121 feet	3	2,121
Oil sand with thin, coaly shale layers	11	2,132
Shale with a little sand	5	2,137
Oil sand	1	2,138
Sandstone	5	2,143
Sandy shale	2	2,145
Sandstone	2	2,147
Shale	2	2,149
Oil sand	9	2,158
Sandy shale; water?	2	2,160
Sandstone with carbonaceous partings	34	2,194
Shale and shaly sandstone	2	2,196
Sandstone	11	2,207
Ironstone	1	2,208
Sandy shale, carbonaceous	9	2,217
Sandstone	13	2,230
Shale and ironstone	8	2,238
Sandstone with thin shale bands	4	2,242
Shale; show of oil	6	2,248
Sandstone with pyrite; show of oil	4	2,252
Sandy shale	6	2,258
Sandstone with pyrite	6	2,264
Shale and sandy shale, all carbonaceous	18	2,282
Sandstone	2	2,284
Shale with a little coal	14	2,298

The fine-grained sandstone with shale occurring between depths of 400 and 435 feet may be the Lea Park sand, but if it is the thickness of the Lea Park appears to be only 127 feet instead of 180 feet as it is in the Ribstone area. The top of the Lower Cretaceous seems to be at about 1,965 feet and, therefore, according to the log, the combined thickness of Lea Park and Alberta shale is 1,657 feet instead of 1,600 feet as in the Ribstone-Blackfoot area. The Dunn area is only about 10 miles south of the Ribstone area and, therefore, a closer agreement between the thicknesses of the formations in the two areas would be expected. If the combined thickness of Alberta shale and Lea Park is the same in the two areas, then the top of the Lea Park would be at an horizon about 60 feet lower than as given in the above log and the sand and shale between depths of 400 and 430 feet would not be the Lea Park sand at the base of that formation. On the other hand, if the Ribstone Creek-Lea Park contact is at 303 feet as given in the log then this well is approximately 100 feet lower structurally than Imperial Ribstone No. 1 well on Sec. 5, Tp. 45, Range 1, W. 4th Mer. The local structure at the London-Ribstone location is not known.

MONITOR-CZAR-CASTOR AREA

Monitor-Czar-Castor area is in eastern Alberta and extends north of Sullivan Lake and east to the Saskatchewan boundary. It lies south of Battle River area and at a considerable distance north of Red Deer River. It is on the east side of the Alberta syncline and due to a relatively gentle west or southwest dip of the strata the succession of formations from west to east is Edmonton, Bearpaw, and Belly River, the latter comprising what are believed to be the equivalents of the Pale, Variegated, and Birch Lake formations of Battle River area and the Pale and Foremost beds of southern Alberta.

Drilling has been done in three localities, namely, in the vicinity of Monitor, Czar, and Castor.

Monitor and Misty Hills Area

Misty Hills south of Monitor, in Townships 32 of Ranges 4 and 5, rise to a height of 2,800 feet or 500 to 600 feet above the plains on the northeast. Unlike most other hills in this general area these hills are not composed of morainic materials but are erosion remnants of Cretaceous strata (Williams and Dyer, 1930, page 98). These strata belong to the Bearpaw and older horizons and are highly contorted and folded, the result of slumping or distortion by glacial action (Hopkins, 1923, pages 419-30) as in Czar area where beds of the same formations are exposed but where the contorted strata are, so far as known, confined to the Pale beds which in places are highly bentonitic. As at Czar, the disturbance exhibited by the beds in the Misty Hills area is believed to be entirely superficial and to have no relation to any oil or gas accumulations that may possibly exist at depth.

Two deep wells have been drilled in this area. Of these the West Regent Oil Company's Monitor well on Sec. 19, Tp. 34, Range 4, elevation 2,210 feet, encountered the Palæozoic limestone at a depth of 3,050 feet. The log of the second well is given below.

Log of Northwest Company's Misty Hills Well

(NE. ¼ Sec. 29, Tp. 32, Range 4, W. 4th Mer.; Elevation, 2,451 feet)

—	Thickness Feet	Depth Feet
Missing		49
Pale and Variegated beds		
Light grey sandstone with coal fragments	6	55
Light grey sandstone with grey shale	40	95
Grey sand with much argillaceous material	15	110
Light grey shale, in part sandy	150	260
Dark grey, sandy shale	200	460
Dark grey, sandy shale with coal	20	480
Dark grey, sandy shale	10	490
Grey, argillaceous sandstone	80	570
Light grey shale	10	580
Grey sand with carbonaceous material	80	660
Light grey shale with coal and sand	10	670

Log of Northwest Company's Misty Hills Well

(N.E. ¼ Sec. 29, Tp. 32, Range 4, W. 4th Mer.; Elevation, 2,451 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Light grey sandstone with coal	30	700
Dark grey, argillaceous sandstone with some coal	20	720
Grey, argillaceous sand	30	750
Grey, sandy shale	120	870
Grey, sandy shale with coal	10	880
Dark grey, sandy shale	10	890
Birch Lake formation equivalents?		
Dark grey, fine-grained sand	40	930
Grizzly Bear formation equivalents?		
Grey, sandy shale	30	960
Dark greyish brown, sandy shale	30	990
Dark grey, sandy shale with a little coal at 1,030–1,040 feet	50	1,040
Grey, sandy shale	20	1,060
Ribstone Creek formation equivalents?		
Light to dark grey, sandy shale	60	1,120
Dark grey shale	20	1,140
Light grey shale with sand	20	1,160
Light grey shale with coal	10	1,170
Light grey sand and sandy shale	40	1,210
Dark grey shale	30	1,240
Dark grey, sandy shale	40	1,280
Dark grey, sandy shale with coal	10	1,290
Lea Park and Alberta shale		
Finely laminated, grey shale	70	1,360
Dark grey, sandy shale	10	1,370
Dark grey shale	100	1,470
Dark grey shale with traces of fossils	10	1,480
Dark grey shale	1,160	2,640
Dark grey, sandy shale	10	2,650
Dark grey, sandy shale with chert pebbles	10	2,660
Dark grey, sandy shale	170	2,830
Lower Cretaceous		
Dark grey and greenish shale	10	2,840
Light grey shale	60	2,900
Brownish, sandy shale	30	2,930
Brownish, sandy shale with coal	10	2,940
Brownish, sandy shale with red tinge	10	2,950
Brownish, shaly sandstone	50	3,000
Sandstone, sandy shale, and coal	10	3,010
Light grey, fine sandstone	10	3,020
Chocolate brown, shaly sandstone	20	3,040
Brown, sandy shale	10	3,050
Black, carbonaceous shale with coal	10	3,060
Dark brown shale	20	3,080
Dark brown shale with coal	10	3,090
Dark shale and sandstone	10	3,100
Brown sandstone	10	3,110
Dark grey, coaly shale	10	3,120
Dark grey, sandy shale	40	3,160
Light grey, sandy shale	30	3,190
Brown, sandy shale	10	3,200
Grey, sandy shale	10	3,210
Very fine sandstone	10	3,220
Dark carbonaceous shale with coal	50	3,270
Light brown, sandy shale	10	3,280
Very fine sand	24	3,304

In the above log, descriptions of strata are by Imperial Oil Company, Limited; division into formations are by the writer.

Czar Area

South of Czar, in Tp. 39, Range 7, W. 4th Mer., the Pale Beds outcrop in various places and particularly in Tit Hills in Township 39, Range 7. The Pale beds continue to the west end of Neutral Hills in Township 37, Range 7, where apparently they are overlain by Bearpaw shales (Dowling, 1920, page 23). In Neutral Hills, which rise 300 or more feet above the general plains level, there are outcrops of massive sandstone evidently the Bulwark member of the Bearpaw formation. A peculiar feature of some sections of Pale beds even where these outcrop on the flat plains country is their disturbed character due to slumping or to distortion by glacial action (Hopkins, 1923, pages 419–430), and which is similar to features exhibited by outcrops that occur in Misty Hills in Township 23, Range 4. There is little doubt the movement has been caused or facilitated by the presence of bentonite horizons in the Pale beds. These when wet swell to several times their thickness when dry and become exceedingly slippery. The structures indicated by these beds are superficial and have no relation to possible oil and gas accumulations.

A deep well was drilled by the Northwest Company, Limited, on northwest quarter Sec. 17, Tp. 39, Range 7, W. 4th Mer., in the vicinity of Tit Hills. The elevation of the well is 2,267 feet and its log, published by permission of Imperial Oil Company, Limited, is as follows.

—	Thickness Feet	Depth Feet
Missing		20
Pale and Variegated beds equivalents		
Light grey sandstone with coal	½	20½
Missing to		70
Light grey, sandy shale with coal fragments	20	90
Fine-grained, argillaceous sandstone with coaly materials with some shale	120	210
Light grey sand; shale with coal fragments	10	220
Fine, grey sand (fresh water) with shale	5	225
Light grey, sandy shale	35	260
Light grey sandstone	10	270
Light and dark grey, sandy shale	10	280
Dark grey, sandy shale with coal fragments	7	287
Light grey, sandy shale	83	360
Dark grey to brown, sandy shale, coal fragments	60	420
Dark grey sandstone	25	445
Dark grey, sandy shale	5	450
Grey, argillaceous sandstone with some coal, possibly the base of the Pale beds	90	540
Brown-grey shale with some sandstone	40	580
Light grey, sandy; fissile shale with coaly streaks	50	630
Light grey, argillaceous sandstone with thin coal streaks	20	650
Light grey, sandy shale with some fine sandstone and carbonaceous materials	130	780
Birch Lake formation equivalents?		
Dark grey, argillaceous sandstone and shale	40	820
Grizzly Bear formation equivalents?		
Dark grey shale, a little carbonaceous material	100	920
Ribstone Creek formation equivalents?		
Light grey, sandy shales and sandstone	50	970
Dark grey shales	70	1,040
Light grey shales with coal	60	1,100
Lea Park and Alberta shale equivalents?		
Dark grey shales	1,230	2,340
Grey shales, bentonitic	20	2,360
Dark grey shales	90	2,440

—	Thickness Feet	Depth Feet
Lower Cretaceous		
Reddish and greenish shales	10	2,450
Grey and greenish shales	50	2,500
Grey and greenish shales with coal	20	2,520
Greenish shale	10	2,530
Grey and greenish shale	30	2,560
Grey and greenish shale with coal	10	2,570
Grey and greenish shale	10	2,580
Grey sandstone	40	2,620
Grey shale	20	2,640
Grey shale with coal	10	2,650
Grey shale	20	2,670
Grey shale with coal	20	2,690
Dark and grey shale	30	2,720
Coal	10	2,730
Grey shale with coal fragments	30	2,760
Dark grey to black shale	50	2,810
Light sandstone with black shale	30	2,840
Missing	10	2,850
Palæozoic?		
White sandstone becoming calcareous at 3,120 feet and with chert fragments	390	3,240
Light grey limestone	110	3,360
Very sandy, dark grey limestone	40	3,400
Hard, greyish white limestone	50	3,450
Sandy, white limestone	40	3,490

It is difficult to state where the top of the Palæozoic should be drawn. The sand below 2,850 feet is sharply marked from the sediments above, but grades downwards into sandstone that is highly calcareous and contains chert fragments. It is possible that this sandstone to a depth of 3,240 feet, where it is sharply divided from undoubted Palæozoic limestone, is an erosion product deposited on the Palæozoic floor prior to the deposition of the Lower Cretaceous from which it is so sharply divided. If this is so the age of the sandstone might be Lower Cretaceous or possibly it might have been deposited in the interval between the Mississippian and the Lower Cretaceous. A similar sandstone, but not nearly so thick, occurs underlying Ellis (Jurassic) strata in Roth No. 2 well at Medicine Hat between the depths of 3,060 feet and the bottom of the hole at 3,158 feet.

Castor Area

A well drilled by the town of Castor some years ago is reported[1] to have obtained a flow of gas with a pressure of 300 pounds a square inch in a 38-foot gas sand between depths of 1,392 and 1,430 feet in beds thought to be the equivalents of the Foremost. More recently a deep well, known as the Paintearth well, has been drilled by the Hudson's Bay Oil and Gas Company, Limited, on L.S. 5, Sec. 27, Tp. 39, Range 14, W. 4th Mer. The Geological Survey has no data on the details of the structure in this area and the rotary samples from the Hudson's Bay Oil and Gas Company well are very difficult of interpretation. It would seem, however, that the well penetrated 160 to 180 feet of Edmonton strata, followed below by approximately 400 feet of Bearpaw shales and sandy shales extending to a

[1] Geol. Surv., Canada, Mem. 116, pp. 4, 24, 59 (1919).

depth of 570 feet. The Bearpaw is underlain by light grey sandstones and shales, presumably the Pale beds, and a prominent sand occurs at a depth of 1,200 to 1,220 feet. It is thought this sand represents the base of the Pale beds. Below this are grey, sandy shales with some coal with another fairly prominent sandstone at 1,720 to 1,740 feet. It is thought that this lower sandstone may be the equivalent of the basal sand of the Ribstone Creek formation. The speckled shale zone is not well marked but apparently occurs at a depth of 2,630 to 2,650 feet which according to the above interpretation would give a thickness of 890 feet to the Lea Park. The top of the Lower Cretaceous is not recognizable in well samples. The top of the Palæozoic occurs at 3,650 feet. A gas show was reported in this well at a depth of 1,450 feet.

Oil and Gas Prospects

The writer is of the opinion that the oil prospects of the Monitor-Czar-Castor area are relatively poor although some oil and gas might occur in favourable structures in sands in the basal part of the Alberta shales. In southern Alberta there seems to be evidence that oil and gas source beds occur in the Ellis formation of Jurassic age, but the Ellis thins northward and is entirely absent from the Monitor-Czar-Castor area. The Lower Cretaceous of the Monitor-Czar-Castor area in all probability does not contain source beds for oil or gas because the strata appear to be non-marine deposited south of the edge of the Lower Cretaceous sea in which were laid down the marine strata of McMurray area. So far drilling has revealed little indications of oil and gas in the Palæozoic of northern or eastern central Alberta and, therefore, it is inferred that in the Monitor-Czar-Castor area the only possible source of oil and gas would be in the lower, dark strata of the Upper Cretaceous. Thus it would seem that any oil or gas that may be present will be confined almost wholly to the sands of the Alberta shales which in places are dark and bituminous and on distillation yield small amounts of gas and oil. In the Czar well the speckled shale zone that is the approximate base of the Lea Park occurs at 1,710 feet. A small amount of gas was reported at 2,100 feet, apparently from the Alberta shales. So far as known there is, however, no local structure in the Czar area that would give a concentration of gas. In the Misty Hills well the speckled shale zone occurs at 1,888 to 1,900 feet and a small show of gas was reported at 1,894 to 1,900 feet, that is at the approximate base of the Lea Park. A further small show of gas occurred at 2,670 feet in the basal Alberta shales, the top of the Lower Cretaceous being placed in this well at 2,830 feet. As in the Czar area no local structure is known to occur in the vicinity of the Misty Hills well. It is concluded that gas fields could occur in the Monitor-Czar-Castor area in the lower Upper Cretaceous strata provided suitable structures are present. Gas occurs in Belly River sands at various localities in central Alberta and hence the occurrence of small amounts of gas in these sands in the Castor area is not unusual. The origin of this gas is unknown, but there appears to be no reason why it could not have been generated in the marine sediments that alternate with the non-marine strata in the Upper Cretaceous beds overlying the Lea Park formation.

WETASKIWIN-PONOKA-PIGEON LAKE AREA

Wetaskiwin-Ponoka-Pigeon Lake area lies within the Alberta syncline and such wells as have been drilled commenced in upper Edmonton or Paskapoo strata. Small amounts of gas have been encountered and have been used locally, but there is no reason to expect large flows in the higher formations. No well has been drilled deep enough to reach the base of the Alberta shales and unless some definite structure suitable for accumulation is demonstrated no such drilling is warranted. The Geological Survey has no definite information regarding the structural details, and the information that can be obtained from the samples from wells already drilled is so unsatisfactory that no correlation between different wells is at present possible. The data in regard to the wells drilled are summarized in the following table.

Well	L.S.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet	
Wetaskiwin No. 1..	NE.	14	46	24	4	2,491	1,511	Drilled in 1912. 240 M cub. ft. of gas at 1,210 to 1,216 feet with small amounts at other horizons. Fresh water at 70, 110, and 160 feet. Salt water at 1,460–1,470 feet.
Wetaskiwin No. 2..	NW.	13	46	24	4	2,486	1,470	Drilled in 1914. 110 M cub. ft. of gas at 1,216 feet with small amount at other horizons. Fresh water at 70, 110, and 960 feet.
Wetaskiwin No. 3..	NE.	14	46	24	4	2,507	3,185	Drilled in 1914–15. 20 M cub.ft. of gas at 1,740 feet, 50 M. cub.ft. of gas at 1,780, small amounts at 600 and 2,010–2,020 feet. Fresh water at 90, 130, and 800 feet and salt water at 1,700, 1,835, 1,860, and 1,915 feet.
Ponoka Asylum No. 1.	NW.	29	42	25	4	....	2,485+	Drilled in 1916. 100 M cub. ft. of gas at 2,275 to 2,300 feet with shows and small amounts at other horizons. Water encountered at shallow depths and at 2,100 feet. Abandoned.
Ponoka Asylum No. 2	4	32	42	25	4	....	2,890	Drilled in 1919–20. 50 M cub.ft. of gas at 1,115 ft. Flows of gas at 1,522, 1,730–1,743, 1,767, 2,604 ft. No water reported.
Globe Drilling Co. No. 1.	13	14	47	27	4	2,900	1,200	Well begun by Mutual Oil and Gas Dev. Co., Ltd., in 1921. Taken over by Globe Drilling Co. in 1924 and operations resumed in 1929. 250 M. cub.ft. of gas at 370–381 feet with small amounts at 480 and 900 feet. Fresh water at 90, 160, and 650 feet.

A well drilled at Camrose on Sec. 2, Tp. 47, Range 20, W. 4th Mer., gave a flow of gas of 149,200 cubic feet a day, which was insufficient for commercial purposes. According to Rutherford (1928, page 36)

"the gas horizons penetrated by wells at Ponoka, Wetaskiwin, and Camrose are all in Edmonton or older beds. The upper horizons are in Edmonton and cannot be expected to be prolific producers at any time or place owing to the nature of the formation. . . . The gas from the lower horizons in these wells is very probably from Belly River beds and there is a greater likelihood of these horizons being more productive, in some districts, although to date, where they have been tested, they have not been very productive. Some shallow wells produce gas which has been used by individual householders for domestic purposes. Mr. E. F. Bresee, residing in Sec. 33, Tp. 43, Range 27, about 14 miles northwest of Ponoka, has been using gas for heating purposes from water wells 180 to 190 feet deep for the past eight years (since 1920). The life of a gas well here is two or three years until the well becomes flooded with water and new wells have to be drilled to obtain gas. The writer is of the opinion that the gas is coming from basal Paskapoo beds."

OYEN AREA

Oyen area is in eastern Alberta north of Red Deer River. In this part of the plains outcrops are relatively scarce except along the major streams or rivers and hence information in regard to the local structure is very limited or entirely lacking.

So far as known only one well, namely, Fuego No. 1 on L.S. 16, Sec. 34, Tp. 25, Range 4, W. 4th Mer., has been drilled in this area. The log of this well is as follows:

Log of Fuego No. 1 Well

—	Thickness Feet	Depth Feet
Sand and clay		12
Dark clay shale with glacial pebbles and sand	118	130
Pale and Foremost beds		
Light yellowish clay	10	140
Dark shale, sandy	20	160
Light greenish or yellowish clay	117	377
Fine, white sand	8	385
Dark grey and light grey shale	130	515
Sand and sandstone	45	560
Grey shale	20	580
Light grey sand	46	626
Dark grey shale	84	710
Dark grey shale with sand	10	720
Greenish yellow shale with sand	20	740
Light grey sand	10	750
Dark grey shale	40	790
Dark grey shale and sandstone	50	840
Pakowki and Milk River equivalents		
Dark grey shale	910	1,750
Alberta shale		
Dark grey shale; speckled shale at 1,750-1,760 feet. Chert pebbles at 2,620 feet. Small amount of bentonite in various horizons	1,110	2,860
Very dark shale with sandstone	20	2,880

Log of Fuego No. 1 Well—Concluded

—	Thickness Feet	Depth Feet
Lower Cretaceous?		
Very dark shale with increasing amount of sandstone	50	2,930
Sandstone with carbonaceous streaks	20	2,950
Grey shale with sandstone	40	2,990
Grey, carbonaceous shale	70	3,060
Missing	20	3,080
Grey shale, a little sandstone	10	3,090
Grey shale, and sandstone	10	3,100
Palæozoic (Mississippian)		
Chert and siliceous limestone	33	3,133
Light grey limestone and chert	32	3,165
Bottom of hole		3,182

At 3,136 feet a heavy gas flow with some oil was encountered. The initial gas flow was about 5,750,000 cubic feet. This flow diminished quite rapidly and may have been drowned out by salt water, as salt water accompanied by oil flowed from the well for a time. The oil had a gravity of 10·2 degrees Baumé.

The Geological Survey has no information regarding the local structure and, consequently, no conclusions can be reached in regard to the prospects for oil and gas. Test drilling to determine the structure may be difficult since at present no definite key horizons are known. It is possible, however, that the structure could be outlined by geophysical methods.

DUVERNAY AREA

Duvernay area is on North Saskatchewan River north of Vegreville. The river has cut a fairly deep valley across the strike of the formations and in Alberta east of Edmonton exposed sections of strata from the Edmonton to the Lea Park. Bearpaw shales were not definitely recognized by Allan (1918), but their equivalents are undoubtedly present. Below the Bearpaw and above the Lea Park is a series of formations that Allan (1918, page 12) correlates with formations in more southerly districts as follows.

Section in Duvernay Area

—	Thickness Feet	Equivalent formations
Bearpaw formation	?	Bearpaw formation
Myrtle Creek formation	425+	Pale beds
Pakan formation	225	Variegated beds
Victoria sandstone	95	Birch Lake sandstone
Shandro shales	70	Grizzly Bear shales
Brosseau formation	325+	Ribstone Creek formation
Lea Park formation	....	Lea Park formation

In 1897 to 1899 a well (Victoria well) was drilled by the Geological Survey near Pakan in Sec. 12, Tp. 58, Range 17, W. 4th Mer. This well reached a depth of 1,840 feet, but obtained only small shows of gas. According to Dowling[1] it began in the Victoria sandstone and finished in the equivalents of the Clearwater shales (Lower Cretaceous). Small amounts of gas were encountered at 156 and 495 feet in what from present knowledge of the stratigraphy would be inferred to be the upper and lower sandstones of the Brosseau or Ribstone Creek formations. A small amount of gas was also obtained between 1,500 and 1,565 feet in what Dowling believed to be Lower Cretaceous strata.

More recently Alberta Pacific Consolidated Oils, Limited, drilled a well, known as Duvernay No. 1, on L.S. 5, Sec. 34, Tp. 55, Range 12, W. 4th Mer. The log of this well, published by permission of Alberta Pacific Consolidated Oils, Limited, is as follows:

Log of Duvernay No. 1 Well

—	Thickness Feet	Depth Feet
Samples missing		190
In this interval the contact of the Brosseau (Ribstone Creek) and the Lea Park probably occurs.		
Lea Park		
Grey shale	280	470
Light grey sandstone	10	480
Dark grey shale	570	1,050
Alberta shale		
Dark grey shale	328	1,378
Sandstone alternating with shale	12	1,390
Dark grey to black shale	100	1,490
Brown oil sand	1	1,491
Grey shale and bentonite	9	1,500
Grey sandstone, bentonite	7	1,507
Lower Cretaceous		
Fine grey sandstone, bentonite, and shale	18	1,518
Brown sandstone	15	1,533
Grey shale	7	1,540
Brown sandstone	10	1,550
Coal and black, coaly shale	10	1,560
Grey sandstone	3	1,563
Grey shale	7	1,570
Dark shale and coaly shale	13	1,583
Fine-grained sandstone, shale, and coal	10	1,593
Dark grey shale	2	1,595
Black shale and coal	1	1,596
Grey, carbonaceous sandstone, oil stained	4	1,600
Grey, carbonaceous shale	9	1,609
Grey shale	7	1,616
Grey sandstone, oil stained at 1,617 feet	4	1,620
Grey sandstone, and shale	4	1,624
Fine sandstone, oil stained	16	1,640
Grey shale	1	1,641
Black shale, sandy	8	1,649
Carbonaceous sandstone	1	1,650
Dark grey, sandy shale	2	1,652
Fine sandstone, oil stained	3	1,655
Dark grey to black shale, in part sandy	18	1,683
Coarse sandstone, oil stained	37	1,720
Grey sandstone, slightly shaly	5	1,725
Grey sandstone, oil stained in part	9	1,734

[1] For log *See* Geol. Surv., Canada, Mem. 116, p. 63 (1919).

Log of Duvernay No. 1 Well—Concluded

—	Thickness Feet	Depth Feet
Lower Cretaceous—Conc.		
Sandstone and shale	3	1,737
Light grey sandstone	31	1,768
Sandstone, partly oil stained	12	1,780
Dark shale	10	1,790
Sandstone, oil stained in part	50	1,840
Light grey sandstone	10	1,850
Shale with sandstone partings	10	1,860
Light grey sandstone, oil streaks	50	1,910
Dark, carbonaceous shale	10	1,920
Brown sandstone, partly oil stained	10	1,930
Dark shale	50	1,980
Shaly sandstone, slightly oil stained	30	2,010
Shaly sandstone	60	2,070
Pyrite and marcasite	1	2,071
Grey to white, calcareous sandstone	4	2,075
Mississippian		
Limy shale, slightly green-grey	65	2,140
Limy shale, harder	20	2,160
Limestone, buff to grey	40	2,200
Greenish grey, limy shales	30	2,230
Devonian		
Brown to black oil-shale	50	2,280
Dense, buff limestone	20	2,300
Brown to black oil-shale	10	2,310
Dense, buff limestone	10	2,320

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CHAPTER VII

NORTHERN PLAINS OF ALBERTA

The area here included in the northern plains of Alberta extends from North Saskatchewan River to the north boundary of Alberta and includes the Peace River block, British Columbia. Much open country with small areas of trees is found in the southern part of this area, whereas the northern part is extensively covered by forest and muskeg. At present farming is carried on much farther to the north in the west or Peace River section than in the east or McMurray section.

McMURRAY-ATHABASKA AREA

References: McConnell, R. G.: Geol. Surv., Canada, Ann. Rept., vol. V, pt. D (1893).
McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1916 (1917).
Dowling, D. B., Slipper, S. E., and McLearn, F. H.: Geol. Surv., Canada, Mem. 116 (1919).
Ells, S. C.: "Bituminous Sands of Northern Alberta"; Mines Branch, Dept. of Mines, Canada, Pub. No. 632 (1926).

(*See* Figure 19)

Athabaska River is the largest of the southern members of the Mackenzie River system. It rises in the mountains to the west, in the region of Yellowhead Pass, and flows northeastward across the plains area almost to the eastern edge of the Cretaceous rocks in the vicinity of McMurray, and from there northward to Athabaska Lake. From the town of Athabaska to McMurray, the river flows through a valley 300 to 500 feet deep, and is marked by a number of rapids. Below McMurray the valley is broad with gentle slopes and a low gradient, but above McMurray the valley is narrower with more abrupt slopes and in part is gorge-like. Away from the river the region as a whole, according to McLearn (1917, page 146), consists of " a number of plateau-like surfaces which, along the river, become lower in altitude northward. They are underlain by gravel, sand, and clay, and are poorly drained, with large areas of swamp and muskeg." The country as a whole is wooded and rock exposures occur only where streams or rivers have cut valleys through the surface drift.

Table of Formations[1]

			Thickness in feet	
Drift				Gravels, sand, and clay
Cretaceous	Montana	LaBiche formation	1,100	Grey and black shales with layers of concretions at various horizons. Marine
	Colorado	Pelican sandstone	35	Crossbedded sandstone, conglomeratic at top. Central part continental. Top and base marine
	Lower Cretaceous	Pelican shale	90	Black shale. Marine
		Grand Rapids formation	280	Sandstone. Upper part continental with thin coal seams. Lower part concretionary, carrying marine fossils
		Clearwater formation	275	Soft, grey shale, black shales, grey and green sandstones with some concretionary layers. Marine
		McMurray formation	110 to 180	Sandstone, massive and crossbedded. In certain places conglomerate and more rarely clay and shale are found at the very base. Parts are highly impregnated with bitumen. Continental
Unconformity				
Devonian			220+	Limestones

[1] McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1916, p. 146.

The structure is described by McLearn (1917, page 148) as follows:

"The structure from Athabaska to Point Brûlé is simple, consisting of a half-fold or homocline with a low south dip. From Grand Rapids to Pelican Rapids the rate of dip is about 5½ feet a mile, and north of Grand Rapids the dip flattens considerably. But south of Pelican Rapids to carry the strata to their position in the Athabaska bore-hole requires a dip of about 10 feet a mile. This greater dip below may be due, in part, to the southwest course of the river near Athabaska. Indeed the true dip is probably west of south, rather than directly south, and hence steeper on sections in the former than in the latter direction.

The section exposed between Point Brûlé and McMurray is almost at right angles to the above and shows a low anticlinal structure (Athabaska anticline). The axis lies near Crooked Rapids and the dips on either side are exceedingly low, only about 3 or 4 feet a mile.

Below McMurray the land on either side of the valley is low, so that the top of the McMurray formation soon ceases to be exposed in the cliffs. Since the bedding of this formation is not reliable for structural purposes, the dip cannot be accurately determined there. It probably does not depart very far from the horizontal, but may have a slight north or northeast dip. This section is best adapted for demonstrating the structure of the limestone and the nature of the unconformity.

In addition to sharing with the Cretaceous sediments of the above-described Athabaska anticline and the long half-fold to the southwest, as a major structure, the limestone is warped into low domes of much smaller magnitude."

Drilling has been done on some of these minor warpings, but the structures are too small to be important as structures suitable to contain commercial amounts of oil or gas.

The McMurray formation, composed of massive and crossbedded sandstones, is to a considerable extent impregnated with bitumen. The bituminous content varies from place to place and even in different layers of the same exposure. The richest parts contain more than 20 per cent bitumen, but the average bituminous content is considerably less. The bituminous sands outcrop in thick sections in many places along Athabaska River from Boiler Rapids to some distance below McMurray, and on many of the tributary streams. Southward the dip carries them below younger deposits. At Pelican, about 70 miles southwest of McMurray, they were encountered in a drill-hole at a depth of approximately 750 feet.

It has been assumed (McConnell, 1893, page 66) that the bituminous sands represent "an upwelling of petroleum to the surface . . . . . but the more volatile and valuable constituents of the oil have long since disappeared." On such an assumption it was considered that oil might be found away from the outcrop and under suitable cover. To test this idea several wells were drilled, but in the central and southwest part of the district, as stated by McLearn (1917, page 149), "no liquid oil has so far been found, nothing more than the asphaltum or at best semi-liquid maltha content of the tar sands." According to Dawson (1901, page 28) in a well drilled by the Geological Survey in 1897, at the mouth of Pelican River on the Athabaska, a strong flow of gas was encountered at the bituminous sand horizon and tarry-like material filled the bottom of the hole to such an extent that further drilling was impossible. Other evidence of natural gas in this area is afforded by gas seepages, and according to McConnell (1893, page 64):

"The most important natural gas spring in the district occurs on the Athabaska at the mouth of Little Buffalo River (Point Brûlé). The gas here forces its way up through the tar sands, through 250 feet of the Clearwater shales, and issues from the surface in numerous small jets distributed over an area 50 feet or more in diameter. Some of the jets burn steadily when lighted until extinguished by heavy rains or strong winds, and afford sufficient heat to cook a camp meal.

A second spring was noticed on the left bank of the Athabaska about 13 miles below the mouth of Pelican River. The volume of gas escaping here is less than at the mouth of Little Buffalo River and in order to reach the surface it is obliged to penetrate 570 feet of shales and sandstones which here overlie the tar sands."

McLearn (1917, page 151) states

"explorations to date indicate that the McMurray formation (tar sands) is the only source of gas that promises to be of commercial importance."

The most prominent structure, according to McLearn (1917, page 148), is the low, broad Athabaska anticline and the long half-fold (homocline) to the southwest. Evidence from gas seepages and drilled wells led McLearn to conclude that:

"The anticline and half-fold as far down the dip as Pelican are gas-bearing rather than oil-bearing" (Only liquid oil is here considered). . . . . "As far as the homoclinal structure is effective, ... the possibilities for the occurrence of oil southwest of Pelican (i.e. down the dip) are better than for its occurrence north or northeast of Pelican (i.e. up the dip.)"

In the northeastern part of the district, according to McLearn:

"The wells of the Athabaska Oils, Limited, opposite the mouth of Dover River, ... record the presence of oil, although of low gravity. The wells are all shallow and the tar sands themselves outcrop so that the conditions of cover do not exist."

The oil at this place has collected

"In a hollow of the Cretaceous-Devonian unconformity. This depression is 12 miles long in the direction of the river and opposite the mouth of Dover River, at the wells of the Athabaska Oils, Limited, has a depth of about 85 feet below the river and about 140 feet below the limestone rim."

This is an interesting occurrence of oil since it records the presence of oil in a syncline, the strata being "dry" so far as the presence of water is concerned.

A sample of gas collected from the Pelican well by Elworthy (1924, page 21) in 1916 and analysed by the Mines Branch, gave the following analysis:

		Per cent
Methane	CH_4	83·5
Carbon dioxide	CO_2	1·0
Oxygen	O_2	2·9
Nitrogen	N_2	12·6
Calorific value per cub. ft. at 60° F. and 760 mm.		850 B. Th. U.

As will be noted from the above analysis the gas is dry, i.e. contains no gasoline.

The discovery in other areas of oil in Lower Cretaceous sands occupying the same position stratigraphically as the Lower Cretaceous of the Athabaska area has led to the hope that sands comparable in thickness with the McMurray formation will be found over a large area at some distance from Athabaska River. According to McLearn (1919, page 127) "the Lower Cretaceous includes . . . . . in the Athabaska section the McMurray tar sands, Clearwater formation, and Grand Rapids formation." Later studies have shown that the Pelican shale is also Lower Cretaceous. These formations hold the same stratigraphic position in the Athabaska section as do the sands between the base of the Alberta shale and the top of the Palæozoic limestones in Wainwright area. Other than that both are of Lower Cretaceous age no definite correlation is at present possible. In Athabaska area the Clearwater formation, 275 feet thick, the Pelican shale, 90 feet thick, and the lower concretionary member of the Grand Rapids sandstone, are marine, whereas the upper part of the Grand Rapids sandstone is subaerial as demonstrated by the presence of small coal beds. In Wainwright area the Lower Cretaceous sediments have been considered to be entirely non-marine, although no proof of this is available. The non-marine character is inferred from the presence of a number of coal seams logged in various wells. Coal and carbonaceous shale 9 feet thick were found in British Petroleums No. 3 and No. 3B wells, not far below what is considered to be the base of the Colorado shale. It is possible the coal is of about the same age as the coal seams in the upper part of the Grand Rapids formation, but such a correlation is questionable and unreliable. If there are no marine shales in the Lower Cretaceous of Wainwright area, then the marine phases represented by the Clearwater formation, the Pelican shale, and the lower part of the Grand Rapids formation on Athabaska River must thin out entirely before reaching Wainwright area. If this is the situation, the marine phase in Athabaska area must have a shore phase toward the southeast where there would be some alternation of marine shales and sands, and such a place under suitable structural conditions would be a very favourable location for oil accumulations. It has already been demonstrated in Wainwright area, that the Lower Cretaceous contains oil of economic importance, so that the area northwestward should offer equally as favourable, if not more favourable, opportunities for oil, provided, of course, other conditions, such as structure, etc., are equally as good as in Wainwright area.

In Athabaska area the Colorado group includes the Pelican sandstone and the Lower LaBiche formation, whereas the Upper LaBiche shales are Montana in age. The Pelican sandstone and Lower LaBiche sediments are thus of the same general age as the Alberta shale in Wainwright area. The Lea Park formation in Wainwright area is Montana in age (Lower Pierre) and possibly is a correlative to the Upper LaBiche, since both are marine shales. The combined thickness of the Pelican sandstone and LaBiche formation is less than the thickness of the Lea Park and Alberta shale in Wainwright area, and part of the Pelican sandstone in Athabaska area is non-marine. Subaerial conditions seem to have prevailed farther west as the Pelican sandstone only 35 feet thick on Athabaska River, is correlated (McLearn, 1919, page 4) with the Dunvegan sandstone in Peace River area, 530 feet thick. Thus, westward from Athabaska area there is an appreciable thickening of the subaerial deposits, whereas southeastward there is an increase in the thickness of marine deposits. The situation thus suggests that possibly during Colorado time a sea continuously occupied Wainwright area, with a shore-line for part of the time southeast of Athabaska area, where subaerial deposits were formed, and hence it is possible that somewhere between Athabaska and Wainwright areas there may be alternations of marine shales and sands, as should occur towards the shore-line which represents the southeastern edge of the subaerial deposits of the Pelican sands. Oil and gas have already been found in Wainwright-Viking area in sands near what is considered to be the base of the Alberta shales. These sands, however, are believed to be marine and, therefore, were deposited under entirely different conditions from the subaerial Pelican sandstone. It is probable, owing to the character of the deposition, that the marine sands will be found to be much more widespread than the subaerial sands, but either of these sandstone horizons under favourable structural conditions would offer reservoir horizons for oil and gas accumulations.

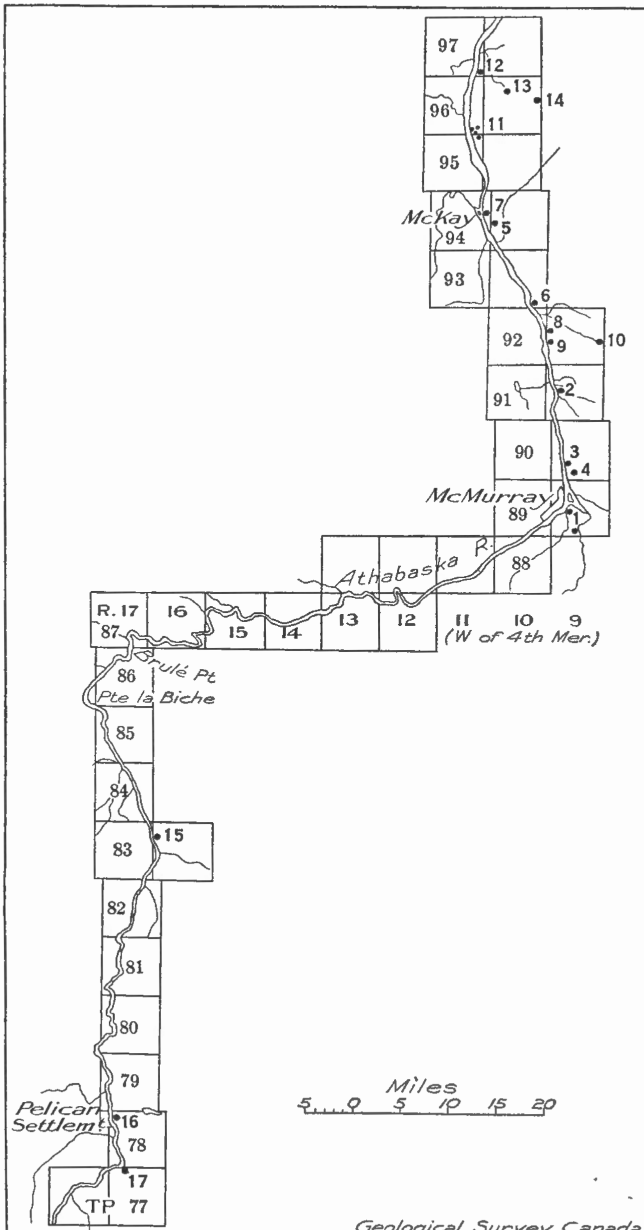

Figure 19. McMurray-Athabaska area, showing positions of wells drilled for oil and gas: 1, Northern Alberta Explorations Co.; 2, 3, and 4, Athabaska Oil and Asphalt Co.; 5 and 6, Fort McKay Oil and Asphalt Co.; 7, 8, 9, and 10, A. von Hammerstein; 11, Athabaska Oils, Ltd. (8 wells); 12, Spokane-Athabaska Oil Co.; 13 and 14, Alcan Oil Co.; 15, Edmonton Athabaska Oil Co., Ltd. (2 wells); 16 and 17, Pelican Oil and Gas Co., Ltd.

As indicated above it is possible that two oil horizons may underlie large areas between Athabaska and Wainwright districts. One horizon is in the Alberta shales and the other in the Lower Cretaceous. At any location in this area there is a possibility that both horizons may be present, but the thickness and oil content are likely to vary widely. Drilling to test the possibilities of the region should be done only where there is a local structure of sufficient magnitude to cause oil or gas accumulations.

The McMurray, a non-marine formation, is not likely to maintain over a wide extent the thickness displayed on Athabaska River, for part of this formation at least is a delta deposit that apparently thins to the southwest to a very small thickness, as is shown by the log of the Pelican well. Its extension in other directions is unknown. It is believed that the oil that gave rise to the bituminous sands migrated to the sands in which it is now found. There is a much greater development of marine beds in the Lower Cretaceous in Athabaska area than in Wainwright field and a location on a favourable structure at some distance from Athabaska River would seem to offer the best possibilities to test what is considered to be the better of the two horizons in which oil has been found and which have been developed to some extent in Wainwright field. Wells located where there is no local structure are not likely to be successful in finding oil or gas in commercial quantities.

The presence of oil in the bituminous sands of the McMurray formation is well known. McConnell (1893, page 65) regarded the bitumen as derived from the underlying Devonian limestones, as is shown by the following sentence from his report: "The amount of petroleum which must have issued from the underlying limestones . . . . . cannot now be estimated, as the conditions of oxidation and the original composition of the oil are unknown."

The contact of the Palæozoic limestones with the overlying McMurray formation is an erosion surface and many cracks and joints in the limestone are filled with bitumen. This has been interpreted as meaning that the bitumen came from below, but it seems more reasonable to suppose the cracks and joints were filled by seepages from above. The limestone as a whole is dense, white, and free from bitumen. It is difficult to understand how such a great migration of oil could take place unless along fissures. If a migration from below did take place then there must be a reservoir in the limestones or below them from which the oil was derived and of which evidence should still be available. In the vicinity of McMurray two wells, of which cores were obtained, were drilled through the limestones in the search for salt.[1] The records of two wells drilled to the granite at the mouth of Horse Creek at McMurray are also available. In none of these wells was there any indication of an oil reservoir from which the oil in the bituminous sands could have been derived. In the log of the salt well at McMurray there is a sharp change at a depth of 500 feet, from massive, mottled limestone to gypsum and anhydrite, which, with salt and thin interbedded shales, continue for 185·5 feet (depth of 685·5 feet), at

[1] Second Ann. Rept. of the Min. Res. of Alberta, 1920, pp. 111-112.

which point drilling was stopped. No indications of oil were found. In the log of salt well No. 2 drilled at Waterways the limestone-anhydrite[1] contact was found at a depth of 415 feet. An alternation of gypsum, anhydrite, and a slight amount of salt with dolomite beds continued to a depth of 782 feet and at 785 feet the Precambrian was encountered. As in No. 1 well no indications of oil were found. Thus it is highly improbable that the oil now found in the bituminous sands came from a reservoir either in the limestones or below them.

As indications of oil occur in Lower Cretaceous strata in Wainwright and other areas it is much more reasonable to assume that the bitumen in the bituminous sands originated in the Lower Cretaceous strata of which the McMurray formation forms a part and that any bitumen now filling cracks and joints in the upper part of the Devonian limestones is due to downward seepage under gravitational influences. Such a conception of origin implies that the Lower Cretaceous strata have been capable of forming a very large amount of petroleum and that the bituminous sands are the residue left as a result possibly of evaporation of the lighter constituents of the oil at the outcrop, the oxidation of the oil, and changes due to contact with sulphate waters, etc.

In a well drilled at the mouth of Horse Creek the top of the limestone has an elevation of about 800 feet above sea-level,[2] whereas at Pelican, 75 miles southwest, the elevation of the top of the limestone is about 400 feet. The dip of the surface of the limestone is, thus, about 400 feet in 75 miles, or slightly more than 5 feet a mile. This is not the dip of the Palæozoic strata, since the top of the limestone is an erosion surface. In the Pelican well the part of the McMurray formation represented by sands is very thin, whereas it is 110 to 180 feet in the Athabaska section. The dip of the Cretaceous beds would be the dip of the limestone surface, i.e. about 5 feet a mile, if the sands at Pelican in which heavy oil was found were equivalent to the basal beds of the McMurray formation at McMurray. If, however, the oil-bearing beds at Pelican are equivalent to the highest beds of the McMurray formation at McMurray the dip would be about 8 feet a mile. It may be safely concluded, therefore, that the regional dip between McMurray and Pelican is a southwest dip at a rate of between 5 and 8 feet a mile. Such a regional dip could cause the migration of oil toward the outcrops if there were any movement of water up the dip. Assuming that the hydraulic theory is applicable, water would enter Lower Cretaceous rocks in the foothills area and move slowly toward the lower elevations of the outcrops of these formations in the plains area. The movement would be eastward or northeastward toward the outlet at the outcrops of the Lower Cretaceous on Athabaska River and any oil and gas in the water-bearing horizons would be flushed towards the outcrop and the bituminous sands would result from the alteration of oil at the outcrop due to the loss of the lighter constituents by evaporation, to oxidation of the

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[1] Fourth Ann. Rept. of the Sci. and Ind. Res. Coun. of Alberta, 1923, p. 50.

[2] "Investigations in the Gas and Oil Fields of Alberta, Saskatchewan, and Manitoba"; Geol. Surv., Canada, Mem. 116, p. 83.

oil, and, possibly, to changes resulting from the contact of the oil with sulphate-bearing waters. It should be remembered, also, that a migration in Athabaska region would be up the dip, that is in the direction that oil and gas would tend to move on account of their buoyancy and any effect from this cause would aid the flushing effect due to moving waters. Huntley (1915, page 343) explained the bituminous sands as due to oil produced in the " Dakota " formation as a result of deformation and caused to migrate by the flushing effect of water. No flora of the typical Dakota formation has yet been found in Canada, McLearn (1923, page 6), so that all Huntley's contentions may not necessarily hold, but it is interesting to note that he regards the concentration of oil at the outcrops on Athabaska River as having resulted from the flushing effect of underground water movement.

EASTERN PEACE RIVER AREA

References: McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1917, pt. C.; Geol. Surv., Canada, Sum. Rept. 1918, pt. C.
Dowling, D. B., Slipper, S. E., and McLearn, F. H.: Geol. Surv., Canada, Mem. 116 (1919).

(*See* Figure 20)

Peace River flows from the British Columbia-Alberta boundary eastward to the town of Peace River and from there northward to Vermilion. At the town of Peace River the river valley is about 800 feet below the level of the bordering plateau country, but the depth of the valley gradually decreases northward, until at Vermilion Chutes where limestones of Devonian age form ledges in the river the banks are quite low. Along the part of the river between the towns of Peace River and Vermilion, the " Ramparts of the Peace " occur, the steep valley walls being formed of beds of sandstone. West of Dunvegan, sandstone beds of the Dunvegan formation form high cliffs which in places weather into castellated forms, but in other parts the valley sides are more rounded, and in places terraces occur. The country away from the river is plateau-like, part of it is open prairie, but the larger part is wooded. At some distance from Peace River the tributary streams flow on the prairie level, but close to the river they have cut deep valleys.

Table of Formations[1]

				Description
Cretaceous	Montana	Wapiti	900 feet +	Thick, massive, crossbedded sandstone, with some grey to dark carbonaceous shales. Thin coal seams, one of which is 180 feet, and another 580 feet above the base of the formation. Continental
Cretaceous	Colorado	Smoky River 300 feet	Upper shale	Dark, friable shale with thin beds of sandstone near the top. Ironstone concretionary bands
Cretaceous	Colorado	Smoky River 300 feet	Bad Heart sandstone	Coarse sandstone weathering reddish brown, 10 to 25 feet thick. Marine
Cretaceous	Colorado	Smoky River 300 feet	Lower shale	Thin-bedded sandstone and shale at the top, below which are dark, friable shales and paper-thin carbonaceous shales with concretions. Marine
Cretaceous	Colorado	Dunvegan	440 feet in the Smoky River section (estimated) 530 feet in the Peace River section	Massive, concretionary, and crossbedded sandstone, with shale, alternating with thick zones of thin-bedded sandstone and shale. Some thin coal seams in the continental deposits. Subaerial and marine
Cretaceous	Lower Cretaceous	St. John	560 feet (estimated) on Smoky River, much thicker in the western sections of Peace River	Dark, friable, and paper-thin carbonaceous shale, with some ironstone bands and concretions
Cretaceous	Lower Cretaceous	Peace River	Upper sandstone 130 feet (max.)	Massive, white to cream-coloured, crossbedded sandstone with a discontinuous lignite seam. The upper sandstone thins northward on Peace River, where the upper part is replaced by bedded sandstone and shale of marine origin
Cretaceous	Lower Cretaceous	Peace River	Middle shale 30 feet	Blue-black, friable shale. Marine (?)
Cretaceous	Lower Cretaceous	Peace River	Lower sandstone 160 feet (max.) Thins northward	Top is massive and crossbedded with large, spherical concretions passing downwards into bedded sandstones and shales which are marine. The top may be subaerial
Cretaceous	Lower Cretaceous	Loon River	1,100 feet below town of Peace River. May be thicker on Smoky River	Dark blue to dark grey, friable shale with some ironstone concretions. Where penetrated by wells near town of Peace River sediments are arenaceous near the base of formation. Where exposed the shale is marine

Palæozoic limestone series

[1] McLearn, F. H.: Geol. Surv., Canada, Sum. Rept. 1918, pt. C, p. 2.

The structure within Peace River area has been described by McLearn (1918, pages 18, 19), as follows:

"Eastward to several miles below St. John the structure seems to be almost flat. Near North Pine River and downstream the structure steepens with an east dip, so as to bring the Dunvegan sandstone almost to river-level a few miles below the mouth of Kiskatinaw River. From here to the bend at Montagneuse River the structure is flat. The section is east-west to this point. From the mouth of Montagneuse River southward a north-south section is cut and here a small south dip is revealed. Where the river turns east past Dunvegan an east-west section is again exposed and flat structure indicated. Beyond the mouth of Burnt River the Peace turns to the northeast and so continues to Peace River. Here the strata rise downstream and the inclination near Peace River amounts to some 40 feet per mile to the south.

From Peace River northward a north-south section is exposed and at first reveals a south dip of 10 feet a mile. In the vicinity of No. 2 well and extending to Tar Island the structure is practically flat, although there is probably a slight rise of 1 or 2 feet a mile. Downstream from here there is a slight dip north of a few feet a mile to a point about 10 miles below the mouth of Cadotte River. Beyond this there is a gentle rise and a final flattening out. The above structure applies to that observed above river-level. It is possible, however, owing to the thinning of the Loon River shales northward and the consequent rise of the limestone contact, that the lower strata below river-level, which would be reached by drilling, would be slightly tilted southward as compared with the overlying strata above river-level. This applies particularly to the section north of Tar Island."

To the south of Peace River, on Smoky River, McLearn (1919, page 5) describes the major structure as:

"A south dipping homocline or half-fold, the north side of a large synclinal basin whose axis is south of Bezanson. No undulating structure of anticline and syncline is superposed on the major structure. There is considerable change of dip, however, and a few miles above the mouth of the river a rather poorly defined terrace. Details of the dip are given in the table below. Attention is called to the almost flat structure revealed by the east-west section from Bad Heart River to the great bend one mile east of the east boundary on Range 25; this shows that the general strike is practically east-west."

	Dip to south Feet a mile
Mouth (Smoky River) to 1 mile south of north boundary of Tp. 81	12
Latter to south boundary of Tp. 81	Flat
" middle of Tp. 79	25
" south of Smoky River	50
" south boundary of Tp. 77	20
" within one mile east boundary Range 25	12
Mouth Bad Heart River to Puskwaskau River	60
Latter to horseshoe bend above Puskwaskau River	15
" 2 miles below Kleskun Creek	30
" middle of Tp. 72	45
" ferry below Bezanson	60
	Dip to east Feet a mile
Mouth Bad Heart River to 1 mile east of east boundary Range 25	1

From this it would appear that the structure in Smoky River area, as well as along Peace River, is very gentle and nowhere has a dip of as much as one degree been noted. Since from the town of Peace River northwards the dip is southward this southward dip is probably a continuation of the southward dip noted in Smoky River area. North of Tar Island, on Peace River, there is a northward dip of a few feet a mile, so that the crest of this broad structure is somewhere in the vicinity of Tar Island, although the strata at this place are practically flat. The crest of the structure is, thus, probably quite broad, but it is interesting to note its occurrence in this locality in view of the fact, according to Camsell (1917, page 148):

"A spring of natural gas is situated at Tar Island on Peace River about 25 miles below Peace River crossing. The gas rises with salt water and some tar among the gravel and boulders at the upper end of the island. The flow of gas was roughly calculated to be about 3 or 4 cubic feet per minute."

The occurrence of gas and tar at this point may be due to the broad structure already described.

OIL AND GAS HORIZONS

In 1917 oil was struck in No. 2 well of the Peace River Oil Company, about 15 miles below Peace River. The oil, according to McLearn (1918, page 19), occurs in two sandstone horizons "near the base of the Loon River and not far above the limestone contact." The upper sandstone was encountered from 842 to 948 feet in the drill hole.

"Above 852 feet this bed yielded gas; from 852 to 905 feet it contained a highly viscous oil; from 905 to 910 feet it carried salt water; and from 910 to 948 feet was firmly cemented and barren of oil, gas, or water. Below this is a 14-foot shale bed, followed below from 962 to 1,032 feet by a second oil sand. This is impregnated with oil of a somewhat better quality. This horizon would produce a few barrels per day."

Also, according to McLearn:

"Oil of similar gravity was found at the corresponding horizons in the No. 1 well 1½ miles downstream. The two sandstones are of less thickness here and the shale between thicker. The thinning of these oil sands northward no doubt limits the possibilities of exploration in that direction, since with their disappearance there would be no reservoir to contain oil."

In the Smoky River section McLearn (1919, page 6) found no structure especially favourable for oil. He described a terrace in Township 81, Range 23, but with low dip on the north side. This is the only structure in this area that approaches a suitable structure for oil or gas accumulation, but the dips are so gentle that its value is rather doubtful.

Since the drilling of the wells by the Peace River Oil Company, a well was completed in 1923 by H. L. Williams and Company, Limited, on SE. ¼ Sec. 11, Tp. 85, Range 21, W. 5th Mer., and a depth of 2,810 feet was reached. The Devonian limestone is reported to have been encountered slightly above a depth of 1,400 feet and below this limestone and shale of Palæozoic age occurred to the bottom of the hole. No flows of oil or gas were reported from the Palæozic rocks. In 1916, according to Camsell (1917, pages 144, 145):

"At Vermilion Chutes a drill hole was driven to a depth of 860 feet, but at that depth an accident happened to the stem of the drill which prevented the hole being driven any farther and drilling ceased without having struck oil. The rocks cut in this drill hole are Devonian limestones and shales which have a slight dip to the westward. The upper beds are porous and impregnated with bitumen, and at two or three points in the neighbourhood heavy black oil comes to the surface in springs."

Thus, drilling to date in Peace River area has shown the presence of oil in sandstone beds at the base of the Loon River formation of Cretaceous

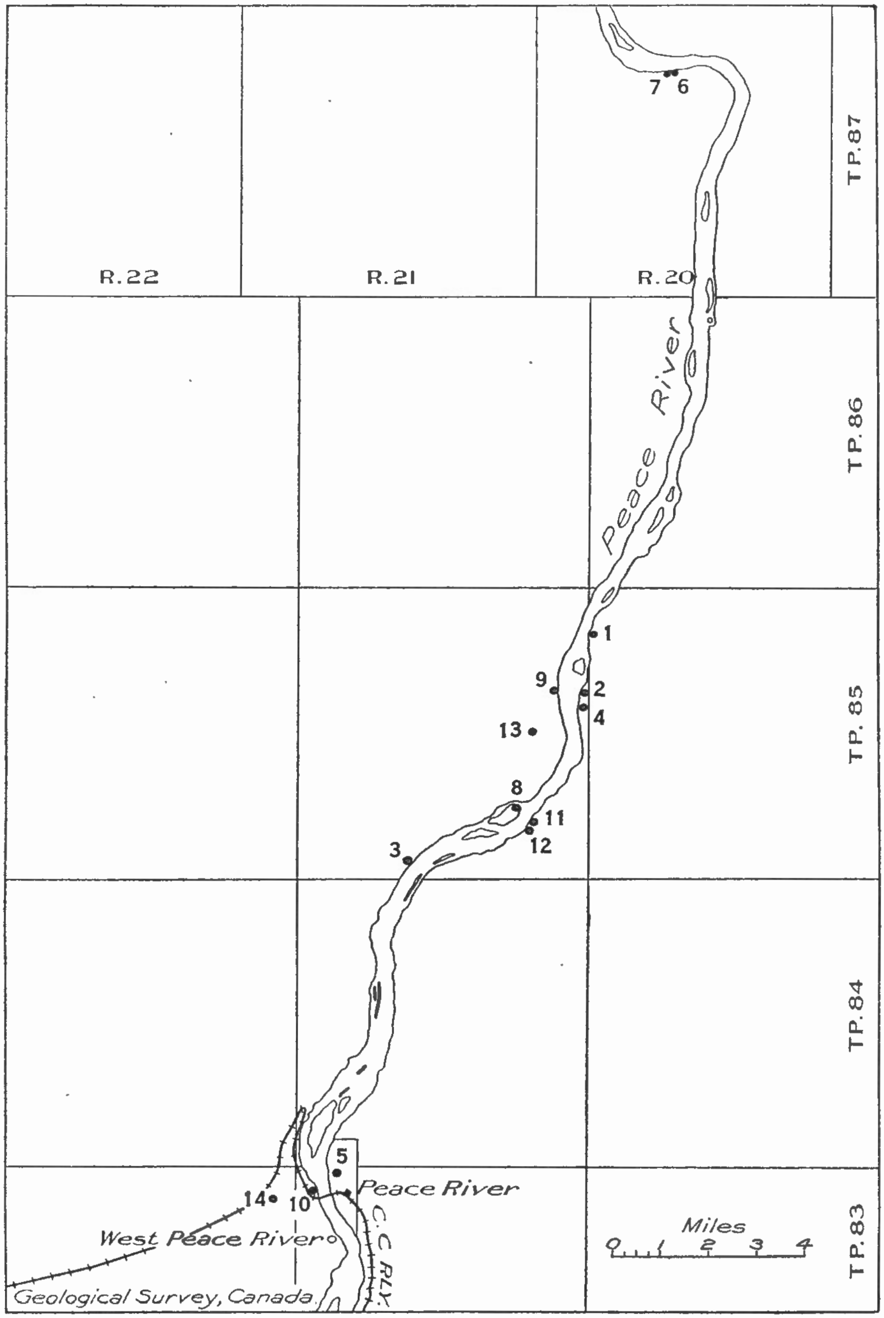

Figure 20. Eastern Peace River area, Alberta, showing positions of wells drilled for oil and gas; numbers designate the wells as given in the table, page 242.

age and also the presence of oil has been recorded in certain places in the upper part of the Devonian. No well so far drilled has, however, found oil in commercial quantities.

A sample of oil from well No. 2 Peace River Oil Company, collected by F. H. McLearn and analysed by the Mines Branch, gave the following results (McLearn, 1918, page 19):

Specific gravity at 60° F.	981
Distillation test—	
Below 150° C.	2% by volume naphtha
150° to 200° C.	4·87
200° to 250° C.	5·3
250° to 300° C.	56·2
300° to 325° C.	5·2
Residue and loss.	26·5%

According to McLearn (1919, page 6), "the oil from Peace River 'cracks' at abnormally low temperatures. This phenomenon begins at 200 degrees and is particularly active between 250 and 300 degrees."

The crest of a broad structure occurs in the vicinity of Tar Island and it is surely more than a coincidence that a seepage of tar and gas occurs on Tar Island and that some oil was found in suitable sandstone horizons in the Loon River formation in wells drilled in this area. McLearn (1918, page 19) has pointed out:

"As far as structure is . . . effective (in concentrating oil) it should be noted that it is of a gentle nature north of the wells (Peace River Oil Company), with very low dips. The conditions obtaining at the wells, therefore, might be expected to prevail over a considerable area from the wells north, limited in that direction more particularly by the wedging out of the sandstones."

Since, however, the structure is so gentle the results from the wells already drilled may be taken as a fair indication of what might be expected to be found by drilling over a much wider area. From what is at present known of the structure no area more favourable than the one that has been tested can be outlined. It is unfortunate that more pronounced folding does not exist in this area, for, excepting the structure, other conditions appear favourable for oil.

No.	Well	Location					Depth
		L.S.	Sec.	Tp.	Range	Mer.	Feet
1	Peace River Oil Co., No. 1	4	31	85	20	5	1,136
2	Peace River Oil Co., No. 2	16	24	85	21	5	1,125
3	Peace River Oil Co., No. 3	6	4	85	21	5	1,282
4	Peace River Oil Co., No. 4	9	24	85	21	5	305
5	Peace River Petroleum, Ltd., No. 1	R.L. 9	31	83	21	5	1,162
6	Peace River Petroleum, Ltd., No. 2	9	28	87	20	5	897
7	Peace River Petroleum, Ltd., No. 3	9	28	87	20	5	890
8	North Pacific Oil Co.	10	11	85	21	5	850
9	Tar Island Oil and Gas Co.	14	24	85	21	5	1,087
10	Victory Oil Co., No. 1	11	31	83	21	5	1,807
11	Canadian Petroleum, Ltd., No. 1	SE. ¼	11	85	21	5	1,275
12	Canadian Petroleum, Ltd., No. 2	SE. ¼	11	85	21	5	3,008
13	H. L. Williams	SE. ¼	23	85	21	5	—
14	P. M. Oil Co.	7	36	83	22	5	130

WESTERN PEACE RIVER AREA

References: McLearn, F. H.: "Peace River Section, Alberta"; Geol. Surv., Canada, Sum. Rept. 1917, pt. C, pp. 14-21 (1918).

McLearn, F. H.: "Cretaceous, Lower Smoky River, Alberta"; Geol. Surv., Canada, Sum. Rept. 1918, pt. C, pp. 1-7 (1919).

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Gwillim, J. C.: "Report of Oil Survey in the Peace River District"; Dept. of Lands, B.C., 1919, pt. M.

Dresser, J. A.: "Report of Oil Surveys in the Peace River District"; Dept. of Lands, B.C., 1920, pt. R, pp. 1 to 10.

Spieker, E. M.: "Report of Oil Surveys in the Peace River District"; Dept. of Lands, B.C., 1920, pt. K, pp. 10 to 27.

Allan, J. A., and Cameron, A. E.: "Pouce-Coupé Area, Alberta"; Min. and Eng. Rec., Sept., 1921.

McLearn, F. H.: "Mesozoic of Upper Peace River, B.C."; Geol. Surv., Canada, Sum. Rept. 1920, pt. B, pp. 1-5 (1921).

McLearn, F. H.: "Peace River Canyon Coal Area, B.C."; Geol. Surv., Canada, Sum. Rept. 1922, pt. B, pp. 1-47 (1923).

Spieker, E. M.: "The Petroleum Geology of a Part of the Western Peace River, B.C."; Am. Ass. Pet. Geol., vol. 6, pp. 112-138 (1922).

(*See* Figure 21)

The following account is based wholly on published information, a bibliography of which is given above. The "Western Peace River Area" includes the country north and south of Peace River and extending eastwards from the "disturbed belt" east of the mountains in British Columbia, to the plateau country of Alberta. Within this area is the Peace River block of British Columbia and, to the south of the Peace River block, the country east of the "disturbed belt" drained by Moberly, Pine, Kiskatinaw, and Pouce-Coupé rivers. The area includes a belt of moderately folded rocks, which lies east of the disturbed belt and passes eastward into the plateau area in which the rocks are relatively little disturbed.

Peace River, according to Spieker (1920), occupies a valley about 800 feet deep, which in the vicinity of Hudson Hope, on the western edge of the Peace River block, is 2 to 3 miles wide. The higher land adjacent to the valley is more or less flat, but from Moberly Lake southeastwards the surface is broken by hills and dissected by river valleys. According to Stewart (1920) this part of the area:

> "Is well timbered, rough and hilly. A relief of 1,500 feet is common and in places the higher ridges rise over 3,000 feet above the adjacent river valleys. Peace River being the main waterway to which all the streams of the region are tributary has the lowest elevations, the higher altitudes are attained by the most westerly ridges. Eastwards the uplands gradually become less irregular and blend into a high level plateau. The main streams flow for the most part in deep, narrow, V-shaped valleys and except in a few places, at time of low water, are too deep to be forded."

Table of Formations[1]

System	Group	Formation	Character	Thickness Feet
Upper Cretaceous	Montana	Wapiti	Subaerial sandstone, massive, cross-bedded, with shales and lignite	900+ (Top not exposed)
		Smoky River	Dark, friable shales, marine with median sandstone member	1,100±[2]
	Colorado	Sukunka member	Coarse, subaerial sandstones, hardened continental muds, green shales, lignite	1,000+
		Dunvegan	Massive to thin-bedded sandstones, varying in origin from littoral to subaerial, with some shale and a few thin seams of lignite	1,000+
Lower Cretaceous		St. John	Black marine shales, usually arenaceous with intercalated sandstone bands and marine sandstone locally	1,400 to 2,200
		Bullhead Mountain	Hard, green-grey conglomerates, coarse-grained massive sandstones and shales, with many seams of high-grade coal	1,500 to 4,400+
Jurassic?		Pine River	Blue-black marine shales with intercalated limestone and some sandstone	300+ (Base not exposed)
Triassic		Schooler Creek (In foothills)	Purple limestones and fine-grained sandstones; limestones vesicular near top	3,000 in the foothills

[1] From Spieker (1920) and various reports by McLearn.
[2] Russell, L. S.: Personal communication.

Triassic. Rocks of Triassic age have not been observed in the plains area, but it is presumed they occur underlying younger formations, since they were seen by McLearn (1918) on Peace River west of Peace River Canyon where they consist of limestones, hardened sandstones, and shales, all of which are marine. The total thickness is approximately 3,000 feet (McLearn, 1921), but since the Cretaceous rests on the Devonian in the eastern Peace River area the Triassic must wedge out eastwards.

Jurassic (?). Spieker (1920) found blue-black clay shales interbedded with bands of limestone and sandstone, on Pass Creek, a tributary of Pine River. To this series Spieker applies the name Pine River formation and assumes it belongs to the Jurassic, although the few fossils found are not sufficient to indicate a definite age.

Bullhead Mountain Formation. The Bullhead Mountain formation, according to McLearn (1923), consists of an upper and a lower member in Peace River Canyon and westwards. The upper member is composed of conglomerates, grits, and coarse sandstones, with smaller amounts of medium to fine sandstones and shales. Large-scale crossbedding is present

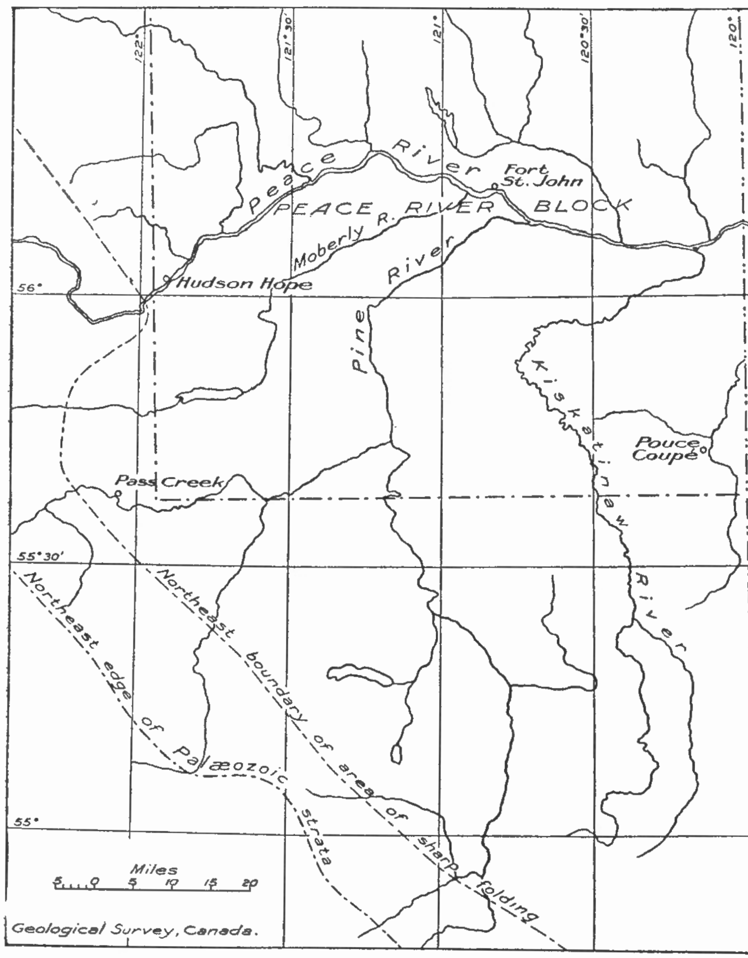

Figure 21. Western Peace River area, British Columbia.

in some of the grits and sandstones and some layers are ripple-marked. The lower or Gething member consists of medium to fine sandstone, shale, clay ironstone, and a number of coal beds. The thickness of the upper member is over 3,000 feet, and the lower member is more than 1,400 feet.

On Pine River, at the mouth of Commotion (Boulder) Creek, Spieker (1920) found the top of the Bullhead Mountain formation to consist of

130 feet of extremely hard, resistant conglomerate, the pebbles of which are almost uniformly one-eighth to one-quarter of an inch in diameter and are flint, chert, and quartz. Below the 130 feet of conglomerate are 600 feet of sandstone, which decreases in hardness downwards. The bottom part, also 600 feet thick, consists of less massive sandstones and possibly shales with coal. The total thickness is thus only 1,300 feet, although the area examined by Spieker on Pine River is only 20 miles almost directly south of the area at Peace River Canyon and westwards where the formation is more than 4,400 feet thick. McLearn (1918) correlated the Bullhead Mountain formation "with the Peace River and probably also the Loon River formation of the eastern succession" on Peace River.

St. John Formation. According to McLearn (1918) the St. John formation where seen on Peace River consists of two, thick, shale members separated by a thin sandstone member. The lower shale member in the vicinity of Peace River Canyon is 800 feet thick and consists of dark, thin-bedded, slightly arenaceous shale. The middle sandstone in the same locality consists of 50 to 80 feet of massive, crossbedded sandstone representing subaerial conditions of deposition. The upper member in the vicinity of Cache Creek, a tributary of Peace River, is 1,300 feet thick; the bottom part is dark, friable shales with concretions overlain by black, paper-thin shales, above this are thin-bedded, arenaceous shales with several large sandstone lenses, and higher still are thin-bedded sandstones and shales. The series contains fossils which according to McLearn indicate marine conditions of deposition.

Outcrops of St. John shales are widely distributed over the area under consideration. They form the valley slopes of Peace River in the vicinity of Hudson Hope and of many of the tributaries including Moberly, North and South Pine, Halfway, Kiskatinaw, and Pouce-Coupé Rivers for long distances from Peace River. Some of the lower plateau surfaces to the east expose these shales, but mostly the plateaux are capped by the harder, more resistant, Dunvegan sandstone.

On Smoky River the St. John shales have an estimated thickness of 560 feet (McLearn, 1919). In Moberly River area the thickness is placed by Stewart (1920) in excess of 2,200 feet. This indicates a thinning eastwards of about 1,640 feet in about 150 miles.

Dunvegan Formation. On Peace River (McLearn, 1919) the top of the St. John formation grades upwards into the Dunvegan by an increase in thickness of the sandstone layers, thus giving a gradation to the massive sandstones at the base of the Dunvegan. The Dunvegan formation outcrops on Peace River in the vicinity of Dunvegan and westwards and the sandstone weathers into peculiar castellated forms in the cliffs along the river. To the south of Peace River on the Sukunka branch of Pine River, Spieker (1920) found a series of shales, hardened muds, and sandstones overlying the Dunvegan. These beds have not been observed elsewhere and according to Spieker may represent the westward phase of the lower Smoky River formation, but he classified them tentatively under the name Sukunka formation, as the upper member of the Dunvegan. According to Spieker (1920) the Dunvegan formation on Sukunka River, including the Sukunka beds, is 2,000 feet thick, although the Dunvegan as measured by McLearn (1918) near the mouth of Cache Creek and eastwards is only 530 feet thick, representing a very considerable increase in thickness in about 50 miles in a north and south direction.

Smoky River Formation. On Smoky River (McLearn, 1919) the Smoky River formation is composed of marine shales with thin bands of sandstone near the top. The formation appears on Peace River at and west of Dunvegan where shales underlie the adjacent plateaux. According to Allan and Cameron's map (1921) these shales form the plateau surface some distance east of Pouce-Coupé River, although the plateau in the vicinity of the river exposed the Dunvegan formation. The Smoky River formation does not appear in the area examined by Spieker just east of the " disturbed belt."

Wapiti Formation. The Wapiti formation does not occur in the area under consideration, but has been described (McLearn, 1919) from Wapiti River, a tributary of Smoky River. In that locality it is composed of cross-bedded sandstones and shales with coal seams. It is thus non-marine in origin. The thickness is about 900 feet.

To the east of the " disturbed belt " bordering the mountains there is an area of moderately folded rocks in which a number of possible oil and gas structures have been outlined. Since the lower formations occur in the west and the higher in the east it may be assumed that there is a general eastward or southeastward dip. Such a conclusion, however, may be erroneous because of the thinning eastwards of such formations as the St. John and the equivalents of the Bullhead Mountain. Allan and Cameron (1921) describe an eastward and northeastward dip for Pouce-Coupé area. In the vicinity of Smoky River, McLearn (1919) has shown that the dip is southward towards the synclinal area to the south of Wapiti River, although in Township 81, on Smoky River, there is a poorly defined terrace. The structure along Peace River is indicated by McLearn (1918) as follows:

"The transition from foothills to plains structure is very abrupt and takes place where the Portage Mountain anticline is succeeded by an area of gentle undulation and overthrust faulting extending as far as the Gates. From there to Cache Creek there is a low east dip, under one-half degree, with a local west dip equally low near the mouth of Cache Creek. Eastwards to several miles below St. John the structure seems to be almost flat. Near North Pine River and downstream the structure steepens with an east dip, so as to bring the Dunvegan sandstone almost to river-level a few miles below the mouth of Kiskatinaw River. From here to the bend at Montagneuse River the structure is flat. The section is east-west to this point. From the mouth of Montagneuse River southward a north-south section is cut and here a small dip is revealed. Where the river turns east past Dunvegan an east-west section is again exposed and flat structure indicated. Beyond the mouth of Burnt River, the Peace turns to the northeast and so continues to Peace River. Here the strata rise downstream and the inclination near Peace River amounts to some 40 feet per mile to the south."

Thus the structure as indicated by a study of the Peace River section is exceedingly flat for the plains area and the prospects for finding suitable structural reservoirs for oil and gas are not bright.

To the south, in Pouce-Coupé area, Allan and Cameron (1921) believe there is a terrace structure on the west side of the Alberta syncline. According to them:

"The high land just east of Kiskatinaw River shows a very flat tableland capped by the Dunvegan formation, while east of Pouce-Coupé River valley a gentle easterly dip causes the appearance of the Smoky River formation. The dip in the strata is in all cases very gentle and nowhere has been observed to exceed 25 feet to the mile."

According to Dresser (1920):

"Two broad anticlines appear on the banks of Peace River in the first 15 miles east of the foothills. The first is near Hudson Hope and the second at the 'Gates' of the Peace, a rock-enclosed narrows some 7 miles east of Hudson Hope. In these the dip, which elsewhere is commonly less than 5 degrees, rises very perceptibly on both limbs of the folds."

According to Spieker (1922), the Hudson Bay anticline is a low fold of small extent and although little is known of the axial extent of the fold it is presumed to be continuous with a faulted fold exposed in the west fork of Maurice Creek, and dies out southward. The lower member of the St. John shale is exposed at the crest of the fold and the top of the Bullhead Mountain formation is supposed to be 600 to 700 feet in depth. Spieker (1922) thinks:

"The Hudson Hope anticline is hardly pronounced enough to have been thoroughly effective as a reservoir structure and the comparatively small thickness of hopeful beds beneath it within ordinary drilling depth emphasizes the decision that it is not to be considered with the best anticlines of the region."

On Red River, about 20 miles northwest of Hudson Hope, Dresser (1920) found a well-marked anticline.

In the area of gently folded rocks south of Peace River and east of the "disturbed belt" Stewart (1920) and Spieker (1920) both noted a number of local folds. These are outlined in detail on the map issued with Spieker's report.

OIL AND GAS HORIZONS

In eastern Peace River area, north of the town of Peace River, several wells have been drilled (*See* Figure 20) and indications of oil and gas have been obtained. According to McLearn (1918) the oil in No. 2 well of the Peace River Oil Company "occurs at two horizons, beds of sandstone in both cases, near the base of the Loon River and not far above the limestone contact." The Loon River formation lies on the Devonian limestone at this locality, but west in the western Peace River area Triassic beds occur in part or all of the area. The Peace River sandstone and probably also the Loon River formation of the eastern succession are, according to McLearn (1918), to be correlated with the Bullhead Mountain formation of the western succession. In a later report McLearn indicates a doubt as to the validity of this correlation, but if it is correct it indicates a change from marine conditions in the eastern area to non-marine conditions in the localities where the Bullhead Mountain formation occurs. The thick, heavy, massive sandstone beds of the Bullhead Mountain formation do not give much promise of holding oil and gas, but if there was an interfingering of marine beds, conditions would be much more favourable. In the area under consideration no evidence of the existence of marine beds in the Bullhead Mountain formation has been noted at any point and, therefore, the chances of finding an oil horizon equivalent to that in the Loon River formation are not considered good.

In Pouce-Coupé area the Imperial Oil, Limited, drilled a well on Sec. 26, Tp. 80, Range 13, W. 6th Mer., to a depth of 3,057 feet. The well began in the Upper Dunvegan formation.[1] On Smoky River the St. John shales are estimated by McLearn (1919) to be 560 feet thick, whereas in Moberly River area Stewart (1920) estimated the thickness to be at least 2,200 feet, and on Peace River near Cache Creek McLearn (1918) estimated the thickness to be 2,150 to 2,180 feet. The thickness in Pouce-Coupé area would, therefore, be between 560 and 2,180 feet. In the Pouce-Coupé well a gas flow estimated at 10,000,000 cubic feet a day was struck at 1,675 feet, with other insignificant gas shows at 2,000, 2,372, and 2,736 feet, respectively. Salt water was encountered at 1,730 to 1,740 feet. The interpretation of the Pouce-Coupé well log is very difficult, but it is possible the large gas flow was struck near the base of the St. John formation and that the lower small flows of gas are in strata equivalent to the Peace River and Loon River formations of the eastern succession. These strata are not the same as the Bullhead Mountain formation farther west. In Pouce-Coupé area Allen and Cameron (1921) report a terrace structure. It is considered that such a structure may be sufficient to cause gas accumulation, whereas oil accumulations would, it is thought, demand a much more pronounced structural trap. The fact that an oil seepage is reported by Allan and Cameron (1921) on Pouce-Coupé River suggests that the St. John formation might be oil-bearing if more favourable structural conditions existed. According to Spieker (1922) an oil seepage occurs near Rolla, B.C., on Pouce-Coupé River; this is probably the seepage referred to by Allan and Cameron. Gas seepages are common, according to Spieker, in the vicinity of the oil seepage and another oil seep is known on Moose Creek about 4 miles north of Peace River.

If, as has been assumed, the Bullhead Mountain formation is entirely non-marine west of Pouce-Coupé, this formation would not appear to offer favourable opportunities for oil accumulation even if proper structures were present, and the only formation within the Cretaceous worthy of prospecting would be the St. John which contains considerable sands as well as shales. There is, however, the possibility that rocks below the

[1] Russell L. S.: Personal communication.

Cretaceous, i.e. Triassic, may be suited to act as oil and gas reservoirs. As these rocks have been seen only on Peace River west of Peace River Canyon nothing is known regarding them except that they probably are all marine. Where seen they are in part arenaceous limestone and calcareous sandstones containing numerous geode cavities. To the eastward they probably would be less metamorphosed than where seen. The thickness diminishes eastwards from a maximum of 3,000 feet (McLearn, 1921) in the foothills to zero in the eastern succession of Peace River where the Cretaceous rests on Devonian limestones.

LESSER SLAVE LAKE AREA

Reference: Allan, J. A.: "Geology of the Swan Hills in Lesser Slave Lake District, Alberta"; Geol. Surv., Canada, Sum. Rept. 1918, pt. C, pp. 7-13 (1919).

Lesser Slave Lake area is southeast of Peace River and southwest of Athabaska River at McMurray. The lake covers an area of 485 square miles, has a length of 60 miles, and a width of from 3 to 12 miles. The drainage is to Athabaska River. The shores, especially on the south, are low and marshy but 20 to 30 miles south of the lake the country rises abruptly to the Swan Hills Plateau with an elevation of 4,000 to 4,320 feet or 2,100 to 2,420 feet above the level of Lesser Slave Lake. The plateau is dissected by streams with the formation of, in places, mesas or buttes. Muskeg occurs at all levels even on the tops of the hills, but the greater part of the country is forest.

Rock exposures are few and consist of consolidated sediments ranging in age from Colorado to early Tertiary. The tops of some of the hills are capped by unconsolidated gravels up to 15 feet in thickness, Allan (1919, page 12) thinks it possible these gravels are to be correlated with similar conglomerates on Cypress and Hand Hills. Underlying the gravels are sandstones and shales of the Paskapoo formation about 1,000 feet thick. These are in turn underlain by about 650 feet of Edmonton beds. No Bearpaw has been definitely recognized and if present it is probably not more than 100 feet thick according to Allan. Lower down in the section non-marine coal-bearing beds occur. These have been called the Sawbridge formation and are believed to represent some part of the Belly River series. They are underlain by the LaBiche shales, in which commenced the two wells drilled in this area.

—	LS.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet
International Oils No. 1	11	14	74	6	5	1,910	2,845
International Oils No. 2	......	30	75	6	5	1,980	3,105

In well No. 1 at a depth of 1,855 feet a flow of gas estimated at 7,000 M cubic feet a day was encountered. This gas was subsequently drowned out by water. Shows of oil were reported between 1,862 and 1,960 feet with further shows in limestone, the top of which was encountered at 1,902 feet. So far as known only slight shows of gas were encountered in No. 2 well. The stratigraphy is illustrated by the log of No. 2 well as follows:

Log of International Oils No. 2 Well

—	Thickness Feet	Depth Feet
Drift	....	100
La Biche		
Grey shale	120	220
Dark grey shale	410	630
Dark grey, sandy shale	100	730
Dark grey shale	150	880
Very dark grey shale	200	1,080
Dark grey shale with sand	30	1,110
Dark grey shale	40	1,150
Pelican sandstone and Lower Cretaceous		
Conglomerate	40	1,190
Light grey sandstone	20	1,210
Grey shale	10	1,220
Conglomerate	10	1,230
Grey sandstone	40	1,270
Grey shale	20	1,290
Grey sandstone	30	1,320
Conglomerate	10	1,330
Grey sandstone	40	1,370
Grey shale	50	1,420
Grey sandstone	50	1,470
Grey shale	50	1,520
Grey sandstone	70	1,590
Grey shale	140	1,730
Grey sandstone	10	1,740
Grey shale	60	1,800
Brown sand with oil	30	1,830
Grey shale	150	1,980
Missing	2	1,982
Palæozoic		
Brownish sandstone, chert, etc	8	1,990
Very dark grey shale	10	2,000
Brown limestone	60	2,060
Grey limestone	140	2,200
Brown-grey limestone	10	2,210
Grey limestone	60	2,270
Brown limestone	10	2,280
Brown to grey limestone	20	2,300
Grey limestone	10	2,310
Grey shale	100	2,410
Grey limestone	30	2,440
Dark grey shale, yields oil on distillation	30	2,470
Grey to brown-grey limestone	460	2,930
Grey to brown dolomite and dolomitic limestone	40	2,970
Grey to brown limestone	135	3,105

In McMurray area the Pelican sandstone consists, according to McLearn (1917, page 148) "of crossbedded sandstone, conglomeratic at the top". It is possible, therefore, that the conglomerate from 1,150-1,190 feet in No. 2 well represents the top of the Pelican sandstone. In Athabaska area the Pelican sandstone is the basal Upper Cretaceous formation and as the Pelican shale of Lower Cretaceous age grades upward into it the division between the Upper and Lower Cretaceous is difficult to determine in well samples. In Wainwright-Ribstone area, as has been pointed out, the division between the Upper and Lower Cretaceous is drawn at a pebble bed below which sandstones become predominant and above which shales form the maximum part of the sediments. This arbitrary division is also applicable here and is inaccurate only to the extent of the thickness of the Pelican sandstone, which in McMurray area is 35 feet but which probably decreases southward.

The top of the Palæozoic is somewhat difficult to determine. Hard, dense limestones occur at 2,000 feet but above this are a series of beds containing very dark shales, some sand, and white chert that may represent the erosion products of the Palæozoic, and if so the top should properly be placed at 1,982 feet in this well. The age of the upper part of the Palæozoic is unknown. In the main the sediments of this part are calcareous shales with a very distinct contact with limestone at 2,470 feet. At this contact are some black, bituminous shales that yield oil on distillation. These black shales suggest a correlation with the oil-shales that in southern Alberta represent the top of the Devonian. If this is so the upper part of the Palæozoic in Lesser Slave Lake area may be Mississippian. Caution should be exercised, however, in postulating the existence of Mississippian strata in this area since none is apparently present in either Peace River or McMurray areas.

International Oils No. 2 well is reported to be 70 feet higher than No. 1 well. The following horizons in the two wells can be correlated.

—	No. 1	No. 2
	Depth to	
	Feet	Feet
Top of Pelican sandstone (conglomerate)	1,110	1,150
Top of Palæozoic (erosion surface)	1,902	1,982
Contact between Palæozoic shales and limestones	2,420	2,470

If No. 2 well is 70 feet higher than No. 1 well then No. 1 well is only 20 to 30 feet structurally higher than No. 2 well although the distance between the two wells is about 4 miles, representing a dip of about 5 feet to the southeast. If, as would be expected in this area, the regional dip is to the southwest then the apparent dip between the wells is not the actual dip of the formation but might be due to the fact that the wells are on a line that approaches the strike of the formation.

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CHAPTER VIII

THE PLAINS OF MANITOBA AND SASKATCHEWAN

PHYSICAL FEATURES

West of the edge of the Canadian Shield in eastern Manitoba there is a lowland underlain by Palæozoic rocks. Lake Winnipeg, with its southern end 100 miles north of the International Boundary and stretching northwest for 250 miles, lies along the Precambrian-Palæozoic contact. It has a variable width up to 65 miles and a surface area somewhat greater than Lake Ontario, but unlike Lake Ontario it is very shallow being only 40 to 60 feet deep. To the south of the lake there is a wide depression through which Red River drains northward, bringing with it the waters of the Assiniboine which joins it at Winnipeg. The Assiniboine is the principal river of southern Manitoba and is the union of Souris River, which drains southwest Manitoba and southeast Saskatchewan, Qu'Appelle River, which originates in Saskatchewan northeast of Regina, and the upper part of Assiniboine River, which has its source in eastern Saskatchewan north of Yorkton but for most of its course flows through western Manitoba. Near the north end of Lake Winnipeg Saskatchewan River enters by a series of rapids in which the descent is 70 feet in the last 4 miles. The Saskatchewan is the largest river of the prairies receiving the waters of North and South Saskatchewan Rivers which join at Prince Albert, the former originating in the eastern mountains southwest of Edmonton and the latter being the union of many rivers such as Red Deer, Bow, Oldman, Belly, St. Marys, etc., which have their sources in southwestern Alberta. Both Red and Saskatchewan Rivers carry large quantities of sediment. Saskatchewan River, however, before reaching Lake Winnipeg flows through a low, swampy area and several small lakes, which act as settling basins for sediments held in suspension, and, in consequence, although Lake Winnipeg in the vicinity of the mouth of the river is quite shallow there is no extensive delta. In the case of Red River there is a delta at its mouth at least 12 miles wide and 10 miles long, through part of which dredging has to be done every summer in order that navigation may be maintained from Selkirk on Red River to points on Lake Manitoba. It has been estimated (Wallace, Baker, Ward, 1926, page 163) that Red River in a single year carries past Winnipeg 1,771,500 tons of soluble matter and 888,500 tons of suspended matter. The northern part of Lake Winnipeg has clear blue water so that the suspended matter is dropped at the mouth of the river and in the southern part of the lake.

West of Lake Winnipeg and parallel with it are a number of lakes which with Lake Winnipeg are remnants of an earlier, much larger, Pleistocene lake, Lake Agassiz. The most southerly of the larger lakes is Lake Manitoba which extends northwest for 119 miles and is separated by a narrow neck of land from Lake Winnipegosis which stretches 122 miles farther northwest. East of these two larger lakes are the smaller bodies of water known as Shoal Lake, Dog Lake, Lake St. Martin, and Waterhen Lake, and west of them are Dauphin, Swan, Pelican, and Red Deer Lakes.

The west edge of the Manitoba lowland is delimited by the Manitoba escarpment, which is a cuesta capped by Cretaceous strata and rising 1,000 feet or more to an elevation of 2,000 to 2,500 feet. The escarpment is broken by the valleys of a number of streams that flow eastward, into plateau-like areas that from south to north are known as Pembina Mountain, Riding Mountain, Duck Mountain, Porcupine Mountain, and Pasquia Hills. All are south of Saskatchewan River. Very little is known concerning the area adjacent to the edge of the Canadian Shield in northern Saskatchewan where the border of the Precambrian follows a westerly course to Clearwater River, a tributary of the Athabaska in Alberta. It is known (McInnes, 1913, page 66 and Map 58 A), however, that east of Lac la Ronge, in the vicinity of Wapawekka Lake, the Cretaceous strata overlap the Palæozoic and rest on the Precambrian, and the high escarpment that bounds the Manitoba lowland does not occur in this part of Saskatchewan.

West of the Manitoba escarpment the country is plateau-like, gradually rising in elevation westward and more rolling in the north than in the south. In southwestern Saskatchewan there are a series of butte-like hills including Missouri Coteau, Wood Mountain, and Cypress Hills. Missouri Coteau forms a hilly country west of Moose Jaw, has a width of 25 to 30 miles, rises fairly abruptly several hundred feet above the prairie level on the east and falls away again on the west with a less abrupt slope. Unlike Wood Mountain and Cypress Hills it was an area of morainic deposition (Johnston and Wickenden, 1931, page 31). East of it at McLean Station the drift was not penetrated in a well 495 feet deep and northeast of Regina, Qu'Appelle Valley is 300 feet deep and borings 180 feet deep in its valley bottom did not reach bedrock. In contrast with this the top of Wood Mountain and Cypress Hills, which rise to elevations of 4,600 to 4,800 feet, are not glaciated. Wood Mountain Plateau extends (McConnell, 1886, pages 13-14C) west from the third meridian. It consists of two parts each about 40 miles long. The surface is channelled in all directions by deep, wide, dry coulées, but where it is not broken the surface is smooth and only slightly undulating except in the western part where there is a rolling, hilly area resembling the coteau country. In the highlands on the southwest side of the eastern part some "badlands" occur.

Cypress Hills are partly in western Saskatchewan and partly in eastern Alberta. In the east the rise above the prairie level is 600 to 700 feet, whereas in Alberta it is much greater (Williams, 1929, page 64). The top is a plateau surface but is dissected, especially near the edges, by deep gorges and coulées. The drainage from Cypress Hills area is by Frenchman River which passes into United States east of Wood Mountain. Near

Cypress Hills the valley of the river is canyon-like, $\frac{3}{4}$ mile wide and 500 feet deep in many places (Williams, 1929, page 74). Farther southeast it is 1 to 2 miles wide and 200 to 300 feet deep (Rose, 1916, page 17) and the river meanders in a very crooked course through a silt plain. The southern part of Saskatchewan is mostly treeless, except in sheltered river valleys. The same is true of central Saskatchewan, which is a fairly level country devoted mostly to wheat growing. Farther north poplar trees grow in small groves and north of Saskatchewan River the country is quite extensively forested.

STRATIGRAPHY

Palæozoic strata underlie all of the Manitoba lowland and along its eastern border rest on Precambrian rocks. The floor of the early Palæozoic sea appears to have had considerable relief. North of St. Martin and Partridge Crop Lakes, which lie east of Lake Manitoba, there are several outcrops of Precambrian igneous rocks that according to Wallace (1927, page 39) represent the tops of hills or a high plateau that rose at least 800 feet above the average level of the Precambrian surface. Presumably the relief of the Precambrian floor on which the early Palæozoic sediments were deposited was not unlike that now exhibited by the Canadian Shield.

As the Palæozoic sea advanced, the weathered materials on the Precambrian surface were washed into it and deposited as the Winnipeg sandstone. In the southern part of Manitoba this consists of a white, in many places very pure, quartz sandstone overlain by shaly beds. It is not everywhere present in the north but is fairly persistent in the south, although here it shows a considerable variation in thickness even within a limited area, presumably due to the irregularity of the floor on which it was deposited. Outcrops occur (Wallace, 1925, page 16) on Lake Winnipeg at Elk Island, Grindstone Point, Little Grindstone Point, Black Island, and Punk Island, and on Simonhouse Lake south of Cranberry Lake on Grassy River. At Black Island there is an exposed section of 33 feet of sandstone. In the Commonwealth Manitou No. 2 well, drilled on Sec. 26, Tp. 2, Range 9, W. 1st Mer., it is represented by 110 feet of dull green shale underlain by, in descending order, 2 feet of quartz sand, 2 feet of green-grey " arkose," and 1 foot of green shale. Below the green shale the rocks are Precambrian. In the Stony Mountain well on Sec. 29, Tp. 12, Range 2, E. Principal Mer., there are 85 feet of green to green-grey shales underlying which are 13 feet of light grey sandstones which in turn rest on Precambrian beds. In the Winnipegosis well, drilled on Sec. 29, Tp. 30, Range 17, W. 1st Mer., 70 feet of shales are underlain by 48 feet of sandstones, with one thin streak of shale and another thin streak of kaolin or clay containing fragments of weathered igneous material. The basal part of the sandstone rests on weathered igneous rock. In the Mafeking well, drilled on Sec. 2, Tp. 43, Range 26, W. 1st Mer., the Winnipeg sandstone consists of 50 feet of fairly pure quartz sand.

In the shales at the top of the Winnipeg sandstone member a few fossils have been found that indicate a Black River age (Wallace, 1925, page 16). The age of the underlying sandstone probably varies from place to place, as would be the case as the result of deposition in an advancing sea. No fossils have been found in the sandstone but probably it is also Ordovician. So far as known no Cambrian occurs in Manitoba. In southern Alberta, Cambrian strata were penetrated in the Commonwealth Milk River well, but their easterly limit is unknown. There are, however, 800 feet of Cambrian beds in the Little Rocky Mountain area of Montana (Reeves, 1924, page 75 C) 75 miles south of the International Boundary and east of longitude 109, and hence it is quite possible Cambrian strata occur, deeply buried, in southwestern Saskatchewan.

In Manitoba the Palæozoic strata above the Winnipeg sandstone are of Silurian and Devonian age, and are mainly limestones and dolomites with a few shale horizons and gypsum beds. As the Palæozoic strata dip gently southwest from the edge of the Canadian Shield the Ordovician, Silurian, and Devonian appear as successive bands underlying the Manitoba lowland and trending northwest with the oldest rocks on the east and the youngest on the west. The succession is as follows:

	Thickness Feet
Devonian	
Manitoba limestone	185
Winnipegosan dolomite	165
Elm Point limestone	25
Silurian	
Stonewall formation	250 – 610
Ordovician	
Stony Mountain formation	330
Selkirk (upper mottled limestone)	130
Cat Head limestone	70
Dog Head (lower mottled) limestone	70
Winnipeg sandstone	..

The Dog Head limestone overlies the Winnipeg sandstone on Lake Winnipeg where its principal outcrops are at Grindstone Point, Bull Head, Dog Head, Black Bear Island, Tamarack Island, and Jack Head Island. To the northwest of Lake Winnipeg, in the vicinity of Wekusko, Reed (Alcock, 1920, pages 28-30 and Map No. 1801), Cranberry, Athapapuskow, and Amisk (Bruce, 1918, pages 47-49 and Map No. 1726) Lakes, Ordovician limestones mostly lie directly on the Precambrian, although locally there is a slight amount of basal clastic material or reddish limestones showing that the weathered material on the surface of the Precambrian was incorporated into the sediments of the advancing sea. It is not by any means certain that these limestones all belong to the same formation and there is some evidence suggesting that proceeding northwesterly progressively higher horizons occur in contact with the Precambrian.

The Cat Head limestone is exposed (Wallace, 1925, page 17) at Cat Head, McBeth Point, Inmost Island, Outer Sturgeon Island, Howell Point, and Robinson Point on Lake Winnipeg. It is easily recognized according to Wallace (1925, page 17) "by chert nodules, some of them of large size, which are found throughout the beds but particularly at the base of the formation. The cherts are distributed in horizontal bands flattened along the bedding planes."

The Selkirk limestone is exposed on the west shore of Lake Winnipeg, near the mouth of Saskatchewan River, and on Selkirk Island and at a number of places on the west shore south of this. It is also exposed at Lower Fort Garry, East Selkirk, and Tyndall, the latter place being the site of extensive quarries of building stone that have largely replaced the quarries formerly operated at East Selkirk.

The Dog Head, Cat Head, and Selkirk formations were formerly assigned to the Galena Trenton and correlated with strata carrying similar fossils in Minnesota. Faunas of the same age occur in the Arctic on Baffin Island and elsewhere and recent studies (Foerste, 1928, and Wilson, 1928, page 124) have shown that the age of these beds is Richmond. They are overlain in Manitoba by the later Richmond beds of the Stony Mountain formation, the upper part of which at Stony Mountain is a buff limestone that is quarried. The section at Stony Mountain, according to Wallace, consists of the following beds in descending order: 14 feet buff-coloured limestone; 15 feet argillaceous limestone full of fossil casts; 12 feet red shales; 60 feet speckled, reddish limestone, at the base of which is a harder limestone only known from cores and which may be the top of the Selkirk limestone.

The extent of the Ordovician under the plains of Manitoba and Saskatchewan is unknown. It is believed that the Devonian rests on the Cambrian in southern Alberta, but 350 feet of Ordovician beds are present in the Little Rocky Mountain area of Montana 75 miles south of the International Boundary and east of longitude 109. The Ordovician beds in Montana are apparently of the same age as the Lower Ordovician beds in Manitoba and may signify that Ordovician beds underlie, at least, southeastern Saskatchewan and southwestern Manitoba. They probably do not extend into northwest Saskatchewan for they are not present on Clearwater River in northeastern Alberta.

The Silurian of Manitoba is composed (Kindle, 1913, page 248) of the following succession of beds, arranged in descending order:

	Thickness Feet
Hard, light grey or drab, dolomitic limestone (*Leperditia hisingeri* zone)	100
Gypsum	150
Buff dolomitic limestone (*Conchidium decussatum* zone)	135

These beds are well exposed at Grand Rapids near the mouth of Saskatchewan River, in quarries at Stonewall, Gunton, and Inwood, at Cedar and Moose Lakes, and at the northeast end of Lake Manitoba. Formerly they were considered to be Niagaran (Tyrrell, 1893, page 153 E) in age, but it has been shown (Savage, 1918, page 340) that strata that carry similar fossils are pre-Niagaran or about the age of the Cataract of southwestern Ontario.

The gypsum beds are exposed and quarried at Gypsumville northwest of Lake St. Martin. At this locality, according to Wallace (1925, page 21), their stratigraphic position is somewhat doubtful as they lie on or near a Precambrian outlier. Very little limestone is associated with the gypsum beds and drilling at Gypsumville has revealed 150 feet of gypsum and anhydrite. In one quarry the gypsum passes laterally into reddish brown beds containing a large amount of argillaceous material and it is believed by Kindle (1913, page 250) that this may grade into red magnesium shale or limestone. In other localities where gypsum has been found it rests on red shales. At Dominion City, 50 miles south of Winnipeg, Wallace (1925, page 23) reports 60 feet of gypsum underlain by 110 feet of red clay and sand. To the north of this locality the gypsum is 25 feet thick and the red clay 135 feet.

No limestones have been seen in actual superposition with the gypsum, but 8 miles west of Gypsumville unfossiliferous limestones outcrop on Fairford River. If, as assumed, the regional dip is westward then these limestones overlie the gypsum beds. The limestones are believed to be correlatives of limestones that elsewhere carry *Leperditia hisingeri*, although this correlation has not been definitely established. At the top of these limestones is an unknown thickness of red, argillaceous limestone which Tyrrell (1893, page 200 E) placed in the Devonian but which Kindle (1913, page 251) believes is Silurian.

The extent of the Silurian under the plains of Manitoba and Saskatchewan is conjectural, since no wells in Saskatchewan or southwestern Manitoba have been drilled deep enough to penetrate this horizon, if present. It is probable, however, that the Silurian is absent over a great part of the southern plains, since it does not occur in either southeastern Alberta or northern Montana. Its presence in central Saskatchewan is doubtful.

In Manitoba Middle Devonian strata rest on early Silurian beds, the Middle and Upper Silurian and the Lower Devonian being absent. The Middle Devonian consists of the Elm Point limestone, the overlying Winnipegosan dolomite, and, possibly, the still younger Manitoban limestone which, however, may be Upper Devonian. The Elm Point limestone is exposed at a few places on Lake Manitoba, whereas both the Winnipegosan and Manitoban formations are best exposed on Lake Winnipegosis, especially on the shore of Dawson Bay. Manitoban limestone also occurs on Red Deer River and the shores of Red Deer Lake. Salt springs issue from the Winnipegosis dolomite and the Manitoban limestone along the west sides of Lakes Winnipegosis and Manitoba and gypsum has been known for many years in bore-holes drilled at Vermilion River, Neepawa, and Rathwell. More recently a continuous bed of gypsum 38 feet thick was found (Brownell, 1931, page 274) at a depth of 92 feet in the vicinity of Amaranth, west of the southern end of Lake Manitoba. The Amaranth deposit has been opened by a shaft and the surface of the gypsum is reported to be glaciated (Brownell, 1931, page 276) so that no rock has been found above it by which its age might be determined. Limestone is found with the gypsum suggesting a replacement origin for the anhydrite from which the gypsum has formed. Below the gypsum beds are green clay beds only a few feet thick underlain by red shale. Thus although these gypsum and anhydrite beds are thought to be Devonian their age is by no means very definite.

Devonian rocks presumably underlie the whole of the Great Plains west of the Manitoba escarpment. They have been encountered in a number of wells in Saskatchewan where strata, presumably of this age, carry salt as in the Simpson area 75 miles north of Moose Jaw, or thin bands of anhydrite or salt as in the Unity Valley area in western central Saskatchewan northwest of Unity.

No Carboniferous rock outcrops in Manitoba and none is believed to be present. This is also assumed to be true for eastern and northern Saskatchewan, although it is probable some Mississippian limestones occur in southwestern Saskatchewan because strata of this age have been encountered in a well in Cypress Hills area, a few miles west of the Saskatchewan boundary, and in Oyen area of Alberta, 150 miles north of the International Boundary and 20 miles west of the Saskatchewan border.

The Mesozoic is represented in Manitoba and Saskatchewan by Jurassic and Cretaceous strata. The Jurassic is definitely known (Wickenden, 1932, pages 179,184) from the Moose Jaw and Boundary (Tp. 1, Range 27, W. 3rd Mer.) wells in Saskatchewan where it consists of marine shales with limestone bands. Non-marine Jurassic beds have been identified from the Pilot Butte well drilled 9 miles east of Regina. In the Commonwealth Manitou No. 2 well (Tp. 2, Range 9, W. 1st Mer.) and the Dauphin No. 1 well (Tp. 24, Range 20, W. 1st Mer.) in Manitoba green, grey, and red shales carrying chara seeds are overlain by shales that contain foraminifera and are thought to be Jurassic. In the Neepawa well (Tp. 14, Range 15, W. 1st Mer.) 480 feet of shales were thought by Dowling (1919, page 37) possibly to be Jurassic. There is evidence to show that in pre-Jurassic time the Palæozoic was uplifted in central Saskatchewan in an area east of Regina and extending northwest to Hanley. The extent of the uplift is very imperfectly known. Simpson area seems to have remained above sea-level in Jurassic time, and in the Regina area during part of Jurassic time there may have been a barrier between the Jurassic sea on the west and the Manitoba area on the east where the earlier of the Jurassic beds appear to be non-marine, but their age relationships with the Jurassic of the west are unknown.

The Jurassic is overlain by Lower Cretaceous beds. In McMurray area on Athabaska River, Alberta, marine and non-marine beds of Lower Cretaceous age alternate. The sea in which the oldest marine beds (Clearwater shales) of Athabaska area were deposited had, according to McLearn (1932, page 173), a shore-line trending northwest across Alberta from the International Boundary at the southwest corner of Saskatchewan. To the southwest of this shore-line non-marine Lower Cretaceous beds occur as in southern Alberta, but northeast of it marine Lower Cretaceous beds were deposited and hence presumably occur over the whole of western Saskatchewan south of the Canadian Shield. The eastern margin of this sea is not known. Beds doubtfully referred to the Lower Cretaceous have been penetrated by a few wells in Manitoba, and the sediments suggest non-marine deposition although it is possible some marine horizons are also present.

The Upper Cretaceous of Manitoba, with the exception of a basal sandstone member, is entirely marine and consists of 1,000 to 1,100 feet of shales with a few thin limestone beds. It has been subdivided (Kirk, 1930, page 114 B) as follows:

Pembina Mountain section	Riding Mountain section
Odanah beds 250 feet+	Odanah beds 300 feet
Riding Mountain beds 50–80 feet	Riding Mountain beds 200 feet
Pembina beds 80 feet	
Boyne beds 140 feet Morden beds 200 feet	Vermilion River beds 250–300 feet
Assiniboine beds 70 feet	Assiniboine beds 70 feet
Keld beds 90 feet Ashville beds 100–150 feet (unexposed)	Keld beds 60–65 feet Ashville beds 170 feet
Basal beds 90 feet	Basal beds 19–90 feet

The basal beds on account of their stratigraphic position have been called Dakota, but their age has not been definitely established. Exposures occur in Swan River area and on Red Deer River and on the shores of Wapawekka Lake north of Saskatchewan River where they overlap (McInnes, 1913, page 66) onto the Precambrian.

The Ashville beds are dark grey or black shales, essentially non-calcareous, and containing carbonaceous materials and fish remains. Interbedded with the shales are thin limestone bands, one of which holds abundant oysters.

According to Kirk (1930, page 119) the section of Keld beds overlying the Ashville on Vermilion River in Sec. 2, Tp. 24, Range 20, W. 1st Mer., is as follows, arranged in descending order:

Limestone; 4-8 inches; grey, speckled, weathering white. *Metoicoceras* sp., *Anomia* sp., etc.
Shale and limestone; 17 feet; alternating bands, grey to buff with prominent 6-inch band of limestone at base. *Inoceramus labiatus* abundant
Shale; 9 feet; grey, speckled, calcareous; *Inoceramus labiatus* abundant
Clay; 41 inches; bentonitic, weathering white
Shale; 35 feet; grey, speckled, calcareous; with several white clay bands
Clay 6 inches; bentonitic, weathering white

The presence of *Inoceramus labiatus* in these beds seems definitely to correlate them with at least part of the Lower Alberta shales of the foothills.

The Assiniboine beds overlie the Keld and outcrop on several streams and rivers north of Assiniboine River. On Vermilion River, in Sec. 35, Tp. 23, Range 20, there is a complete section of 72 feet consisting, in descending order, of the following beds (Kirk, 1930, page 121):

Limestone and shale; 3 feet; then, alternating layers; strongly iron-stained
Shale 20 feet; dark grey, calcareous, with several thin bands of hard limestone
Limestone; 4 to 5 feet; hard, grey, weathering buff; highly fossiliferous
Shale; 45 feet; grey, speckled, calcareous

The fossils of the Assiniboine do not permit exact correlation with the Alberta sections, but it may be significant that a large *Inoceramus* occurs with oysters in all sections and that large, flat specimens of *Inoceramus* with oysters occur in many sections of the Upper Alberta shales of the foothills belt. The lower part of the Upper Alberta shales of the foothills area contains the *Scaphites ventricosus* or Niobrara fauna, whereas the upper part contains *Baculites ovatus* and is Montana in age. In Manitoba *Baculites ovatus* does not occur below the Vermilion River beds which overlie the Assiniboine and no occurrence of *Scaphites ventricosus* has been reported. Thus although the Assiniboine beds are about Niobrara age, their precise age is unknown.

The Assiniboine beds are overlain by the Vermilion River beds best known from Vermilion River. The following complete section (Kirk, 1930, page 123), expressed in descending order, is exposed between Sec. 35 and Sec. 17, Tp. 23, Range 20, W. 1st Mer.:

Shale; 32 feet; dark grey, non-calcareous with bands of clay ironstone and septaria containing Pierre fossils
Shale; 80 feet; dark grey, non-calcareous, weathering to lighter pinkish grey containing some brown fish scales, etc.
Shale; 36 feet; dark grey, mainly non-calcareous, but including bands of grey, speckled, calcareous shale within the lower 12 feet; numerous, thin, lenticular bands of clay ironstone and septarian concretions containing Pierre fossils
Shale; 45 feet; dark grey to black, non-calcareous, with calcareous concretions and a few lenticular bands of grey, crystalline limestone showing "cone-in-cone"
Shale; 70 feet (?); no exposure; "soft dark grey clay shale" of Vermilion River well record
Shale; 8 feet; dark grey, non-calcareous

In Pembina Mountain area in the southern part of Manitoba, beds believed to be equivalent to the Vermilion River of the more northerly section have been divided into, from lowest to highest, the Morden, Boyne, and Pembina beds. They consist entirely of shales. Those composing the Morden are dark grey and carbonaceous and grade upwards into speckled, calcareous shale forming the Boyne, which in turn are overlain by the Pembina dark shales with interbeds of bentonitic clay in the lower part.

The Vermilion River beds in the north and the Pembina beds in the south are, according to Kirk (1930, page 124), overlain by the Riding Mountain beds consisting of light grey to greenish grey shales with nodular and irregular bands of ironstone. Exposures are not plentiful but the presence of these beds can be recognized by the fragments of weathered ironstone on the slopes of rounded hills or buttes whose sides are generally bare of vegetation. They are overlain by the Odanah beds, which consist of hard, highly siliceous shale well exposed along the edge of Pembina and Riding Mountains. The Odanah beds seem to disappear to the north and west. Like the underlying Riding Mountain beds they are Pierre[1] in age. According to Kirk (1930, page 127) it is probable that the Odanah is merely a local lithological facies of the Pierre assemblage and that the Riding Mountain beds, though generally earlier than the Odanah, are partly equivalent and thicken westward and pass into the Bearpaw of Saskatchewan.

In Alberta, marine Bearpaw shales lie above non-marine Belly River beds and below non-marine late Cretaceous (Edmonton, St. Mary River, Eastend, etc.) strata. Russell (1932, page 134) believes that the Bearpaw in Cypress Hills area includes younger strata than in western Alberta. The Belly River non-marine strata thin eastward from Alberta and disappear in western Saskatchewan, their equivalent being marine Montana shales inseparable lithologically from the overlying shales that farther west are called Bearpaw. Wickenden (1932, page 196) has shown that the Riding Mountain beds of eastern Saskatchewan and Manitoba are probably the equivalent of the Lea Park of Alberta which there underlies the Belly River. In eastern Saskatchewan, therefore, there is a great group of marine shales of Montana age including beds which in age are equivalent to the strata in Alberta that range from the Lea Park to the top of the Bearpaw as it occurs in Cypress Hills area, and perhaps even higher horizons.

In southwestern Saskatchewan in the vicinity of Cypress Hills and Frenchman River, the Bearpaw is overlain by the Eastend formation of non-marine beds and this by the Whitemud formation of sands and refractory clays. The Eastend formation at Eastend, the type locality, consists of about 100 feet of buff to brown, fine-grained, argillaceous sandstone, but thickens westward and in the Cypress Hills area its equivalents are sandstones, shales, and carbonaceous shales with at least one lignite seam. Locally the Eastend beds seem to grade into marine shales like the Bearpaw. The Whitemud is 35 to 40 feet thick. Above the Whitemud is the Ravenscrag, but the two periods of deposition were separated by an interval of erosion and in places part or even all of the beds down to the Bearpaw were eroded away so that in certain sections in southwestern Saskatchewan the Ravenscrag directly overlies the Bearpaw. The Ravenscrag formation consists of sandstones, silts, and clays with coal seams. The basal part of the Ravenscrag contains fossil bones of the reptile *"Triceratops"* and hence is Lance in age. The upper part is Paleocene, that is early Tertiary. More than 400 feet above the base of the formation is the Willowbunch member (McLearn, 1930, page 58) of refractory clays, 20 to 30 feet thick. Above it are cream or buff-weathering, fine-grained sandstones, silt, and clays with coal seams, as for example south of Big Muddy Lake and south of the town of Willowbunch. The Estevan and Bienfait coal seams are evidently in the upper Ravenscrag formation. A section of the Ravenscrag described by MacLean (1919,

[1] The name Fort Pierre group was introduced by Meek and Hayden in 1861 (*See* Proc. Acad. Nat. Sci., Phil., 1861, p. 419) to designate beds that in Nebraska overlie their Niobrara division and underlie Fox Hills beds.

page 4 A) from the vicinity of the coal fields of Estevan and Bienfait in southeastern Saskatchewan is as follows. The beds are enumerated in descending order.

	Thickness Feet
Light yellow sands overlying sandy clays	70
Lignite	5
Sandy clays	40
Buff sandstone	15
Lignite with banded clays	2
Grey clay	3
Lignite	5
Sand and silt	20
Lignite at Estevan and Bienfait 7 to 10 feet	4
Stiff blue-grey clay or in some cases incoherent sand 20 to 50 feet.	25
Lignite, Taylorton seam	6
Dark grey clays and sands	130
Lignite	2
Sands and clays	207
Lignite	4
Clays and sands with streaks of lignite	209
Lignite	4
Blue clays and sands	186
Shales amounting to at least 500 feet	..
Total thickness above the shales	937

The shales at the base of the sands and clays are probably Bearpaw. The Willowbunch refractory clay member is not recognizable in this section nor is it known what relationship the coal seams farther west bear to the coal seams of this section. Still farther east in Manitoba on Turtle Mountain there are non-marine strata above the Odanah beds. These consist of a basal sandstone called the Boissevain and overlying non-marine beds not known from exposures. The age of these strata is questionable and they may be Cretaceous, although generally regarded as Tertiary. Like the Ravenscrag farther west they carry lignite seams. They occupy an area which, according to Dowling (1914, page 60), does not exceed 48 square miles.

As already noted, the upper Ravenscrag in southwestern Saskatchewan is Paleocene. Younger Tertiary deposits are represented by gravels found near Swift Current, Saskatchewan, and believed (Russell, 1932) to be of late Eocene age, by the Cypress Hills conglomerate of Alberta and Saskatchewan of Lower Oligocene age, and by the Miocene gravels (Sternberg, 1930, page 29) of Wood Mountain area. The Eocene gravels of Swift Current area rest unconformably on Cretaceous strata. The Cypress Hills conglomerate, according to Williams and Dyer (1930, page 69), "is co-extensive with the upland surface of Cypress Hills and caps several small plateau remnants south of Frenchman River." It rests on an erosion surface of beds that range in age from Bearpaw to Ravenscrag. The Wood Mountain gravels are a few feet to 50 feet thick and rest unconformably on the upper part of the Ravenscrag formation. They occur on the higher parts of Wood Mountain.

The plains of Saskatchewan and Manitoba are for the most part covered by thick deposits of glacial drift and over extensive areas the bedrock is several hundred feet below the surface. The higher parts of Cypress Hills and Wood Mountain, however, have little or no drift

(Johnston and Wickenden, 1931, page 39), but the eastern edge of the Missouri Coteau was an area of drift deposition. In front of it was the broad basin of Lake Regina northeast of which is another broad, morainic belt. Other glacial lakes existed in various parts of the plains and deposited wide areas of clays. The greatest of these lakes was Lake Agassiz in Manitoba which at its greatest height covered almost the whole of southern Manitoba and adjoining parts of United States. The different stages of its history can be traced in beaches, particularly along the foot of the Manitoba escarpment which formed its western boundary. Lakes Winnipegosis, Manitoba, and Winnipeg are the present day remnants of this former, much more extensive, body of water whose deposits of sand and clay have become the arable land of southern Manitoba.

STRUCTURAL FEATURES

The Palæozoic strata of the Manitoba lowland dip gently southwest from the edge of the Canadian Shield. West of the Manitoba escarpment they are covered by Mesozoic strata, the escarpment representing a true cuesta in which the beds dip away from the escarpment face. In the western part of southern and central Saskatchewan the dip is east or northeast so that in southern Saskatchewan there is a broad basin in which the Mesozoic strata are overlain by Tertiary beds. Apparently the top of the marine Montana shales in Turtle Mountain area, southern Manitoba, is at least 500 feet higher than the same horizon in Estevan area which may be about the centre of the basin. From the vicinity of Estevan the strata apparently rise gradually to the west and in some areas the rise amounts to as much as 10 feet to the mile.[1] At Big Muddy Valley the top of the marine shales is about 700 feet higher than at Estevan and at Willowbunch Lake, to the northwest, the estimated elevation of the same horizon is about 300 feet higher still. This shows what is thought to be a southward plunge of the basin. On Morgan Creek in Range 5, W. 3rd Mer., at the International Boundary, the elevation of the top of the marine shales is calculated to be about 1,600 feet higher than in Estevan area, 165 miles away. At Eastend, in Range 21 and 35 miles north of the International Boundary, the elevation of the top of the same marine horizon is 2,000 feet higher than at Estevan and at the west end of Cypress Hills in Alberta its height has increased by 700 feet more. Such evidence as is available, therefore, points to a broad basin steeper in the east than in the west and with a southward plunge. Apparently this basin originated later than the deposition of the Ravenscrag formation of Paleocene age. Within the wide basin very few local folds have been found. Geophysical research first by electrical surveys and later by reflection seismograph methods are reported to have outlined an anticline in Dirt Hills area south of Moose Jaw, but the Geological Survey has not sufficient information to indicate the extent of the fold (Warren, 1930, page 45). Dirt Hills are on the northeast edge of the Coteau where the Upper Cretaceous beds are highly disturbed by slumping and a fault of some magnitude with downthrow to the northeast may occur in front of the escarpment.

[1] Personal communication from F. H. McLearn.

There is evidence from bore-hole records to show that prior to the Cretaceous the Palæozoic rocks were uplifted in an area east of Regina and extending northwest to Hanley. The top of the Lower Cretaceous in a well drilled at Moose Jaw is 470 feet lower than in the Pilot Butte well, 9 miles east of Regina, and 400 feet lower than in the Simpson well, 72 miles north of Moose Jaw. As the distance from Moose Jaw to the Pilot Butte well is 49 miles, the westward component of the dip of the Lower Cretaceous surface is nearly 10 feet to the mile, whereas the southward component from Simpson to Moose Jaw is slightly more than 5 feet to the mile. This appears to indicate post-Cretaceous folding. The top of the Palæozoic in the Moose Jaw well is 800 to 1,000 feet lower (Wickenden, 1932, page 195) than in the Pilot Butte and Simpson wells, so that the slope of the Palæozoic erosion surface is nearly twice as steep as that of the Lower Cretaceous. This is not readily accounted for except on the assumption that there was pre-Cretaceous folding involving the Palæozoic surface. It cannot be a Palæozoic erosion feature since there does not appear to be any important difference in the stratigraphic horizon at the top of the Palæozoic surface between the Moose Jaw and Pilot Butte wells. It would appear, therefore, that in Regina area two periods of folding have occurred, one in pre-Cretaceous, and one in post-Cretaceous, time.

The presence of the Palæozoic ridge is suggested by positive gravity anomalies obtained by Miller (1927, pages 175-187), although the ridge is not known from geological information to be so extensive as the gravity anomalies appear to indicate. There does not seem to be any reason to assume that a buried Palæozoic ridge exists in the vicinity of the Muddy Lake well (Sec. 7, Tp. 39, Range 22, W. 3rd Mer.). At this well the elevation of the top of the Lower Cretaceous is 104 feet above sea-level. Fifteen miles northwest at Unity Valley No. 3 well the same horizon[1] has an elevation of 180 feet, and 40 miles still farther northwest at Ribstone Oils No. 2 well (Sec. 25, Tp. 46, Range 1, W. 4th Mer.) the elevation is 354 feet. Thus it appears as if this horizon has a fairly consistent southeast dip of 4 to 5 feet to the mile between Ribstone and Muddy Lake areas. The thickness of the Lower Cretaceous in both Ribstone Oils No. 2 and Muddy Lake wells is approximately 340 to 350 feet so that the Palæozoic surface, although it is an erosion surface, is approximately parallel to the top of the Lower Cretaceous. This being so there is no evidence that a Palæozoic ridge existed in this area at the time of deposition of the Lower Cretaceous strata. The top of the Palæozoic in Ribstone area is probably Carboniferous, whereas in Muddy Lake area the top is Devonian. It is not impossible, therefore, that the Palæozoic was broadly folded and bevelled off prior to the deposition of the Lower Cretaceous strata. The southeast regional dip of the Mesozoic strata continues for some distance southeast beyond Muddy Lake area, but toward the Pike Lake well, 100 miles away, there is a reversal of dip. If this is so a syncline occurs between Muddy Lake and Pike Lake areas. The top of the Palæozoic at Muddy Lake is 215 feet higher than at Pike Lake, but this does not necessarily imply a uniform dip in one direction in the intermediate area.

[1] Determination based on chert pebbles recorded in log by J. G. Spratt.

East of Saskatoon no data are available concerning the regional dip except that the strata dip southwestward away from the Canadian Shield, which lies to the north and east.

Thunder Hill in Manitoba, in Swan River Valley, appears to be of structural origin. Kirk (1930, p. 133) has shown that the strata on Thunder Hill are some 300 to 400 feet higher than the same horizons where they occur in the surrounding district and that the strata are flat-lying near the summit. According to this author " it appears to be necessary to postulate a direct and very much local uplift, but the cause of such uplift can only be guessed at."

According to Wallace (G.S.C. unpublished manuscript) a peculiar feature of the Devonian on Lakes Winnipegosis and Manitoba is dome structures of small extent. North of Bell River on the shore of Dawson Bay, Lake Winnipegosis, one of these structures is 100 yards wide and shows 26 feet of closure in the exposed section. Other small folds of this type occur on Snake Island at the south end of Lake Winnipegosis and on Monroe and Onion Points in the northwest part of Lake Manitoba. No evidence exists that these domes are due to swelling produced during the change of anhydrite to gypsum, although it seems that the stresses that caused the folding must have been developed locally since the folds do not seem to follow any definite lines of deformation and, therefore, have not the appearance of being of tectonic origin.

REGIONAL DIPS IN SASKATCHEWAN AS DEDUCED FROM WELL RECORDS
(*See* Figure 22)

Top of Lower Cretaceous 470 feet higher in Pilot Butte well than in Moose Jaw well; distance 49 miles; slope 9 to 10 feet a mile.

Top of Lower Cretaceous 400 feet higher in Simpson well than in Moose Jaw well; distance, 72 miles, slope 5 to 6 feet a mile.

Top of Lower Cretaceous 400 feet higher in Moose Jaw well than in Rush Lake well. Probably a syncline between these two areas, as a syncline is known to be present southeast of Riverhurst.

Top of Lower Cretaceous calculated to be 250 to 300 feet higher at Simpson than at Riverhurst; distance 75 miles; slope 3 to 4 feet a mile.

Top of Lower Cretaceous 145 feet higher in Hanley well than in Simpson well; distance 45 miles; slope slightly more than 3 feet a mile.

Top of Alberta shale 120 feet higher in Eden Valley well at Outlook than at Simpson. From this it is calculated that same strata at Hanley are about 25 feet higher than at Outlook. Distance 24 miles; slope 1 foot a mile.

Top of Alberta shale 170 feet higher in Pike Lake well than at Outlook; distance 33 miles; slope slightly more than 5 feet a mile.

Top of Lower Cretaceous 164 feet higher in Muddy Lake well than in Pike Lake well; distance 100 miles. Probably a syncline between the two areas.

Top of Lower Cretaceous 48 feet higher in Pike Lake well than in Herschel well; distance 66 miles. Probably a syncline between the two areas.

Top of Lower Cretaceous 282 feet higher in Herschel well than in Rush Lake well; distance 77 miles; slope 3·66 feet a mile.

Top of Lower Cretaceous 212 feet higher in Muddy Lake well than in Herschel well; distance 59 miles; slope 3·59 feet a mile.

Top of Alberta shale 345 feet higher in Muddy Lake well than in Fusilier well; distance 40 miles; slope 8·5 feet a mile.

Top of Lower Cretaceous 76 feet higher in Unity Valley No. 3 well than in Muddy Lake well; distance 15 miles; slope 5 feet a mile.

Top of Lower Cretaceous 174 feet higher in Ribstone Oils No. 2 well (Alberta) than in Unity Valley No. 3 well; distance 42 miles; slope 4 to 5 feet a mile.

PROSPECTS OF OIL AND GAS OCCURRING IN COMMERCIAL QUANTITIES

Only small flows of natural gas have been obtained in Saskatchewan and Manitoba and have no commercial significance, although gas produced in southwestern Manitoba has supplied fuel for several farm houses. No oil in commercial quantities has been found. There does not appear to be any reason, however, why both natural gas and oil should not occur provided structures suitable for their accumulation exist.

The Palæozoic has not been proved to be a source rock for oil or gas over a great part of the plains, but the overlying Mesozoic contains a number of probable source beds. It is known that marine Jurassic occurs in southwestern Saskatchewan and although the sediments of this age are quite variable from place to place yet their occurrence with oil in Alberta suggests that if favourable structures exist, they might also yield oil in southwestern Saskatchewan. It is also known that the Lower Cretaceous in western Saskatchewan contains some marine beds and these probably alternate with non-marine beds, thus indicating sedimentation conditions that could give rise to oil and gas source beds. In Alberta the close association of the older beds of Colorado age with numerous gas fields suggests that these Colorado beds are probably the source of the gas. These strata continue across Saskatchewan into Manitoba and although over such a vast area the conditions governing the entombment of organic life in the sediments may have been quite divergent, yet there is nothing to suggest that the strata of Colorado age might not also be source rocks for gas in the eastern as well as the western prairies. They are overlain in Saskatchewan and Manitoba by marine shales of Montana age in which at a few places small flows of gas have been encountered. Shales of Upper Cretaceous age in Pasquia Hills, Manitoba, have been shown by Ells (1923, page 40) to be capable of yielding 3 to 10 gallons of oil a ton on distillation. It is probable that shales of this character, if subjected to the proper dynamic conditions under adequate cover, would afford both oil and gas. It would appear, therefore, that source rocks for oil and gas are probably present in many parts of Saskatchewan and Manitoba and drilling is warranted at any place where the reservoir rocks are under an impervious cover and are folded sufficiently to cause an accumulation.

Drilling has been done in a number of places in Saskatchewan (Figure 22) and Manitoba (Figure 23) and in other places certain structures that may have prospective values are thought to exist. These areas are described in the following pages.

BOUNDARY AREA

The Boundary or Woodpile Coulée area in southwestern Saskatchewan was tested by a well drilled on L.S. 4, Sec. 9, Tp. 1, Range 27, W. 3rd Mer. The beds (Williams and Dyer, 1930, page 85) in Woodpile Coulée north of Sec. 3, Tp. 1, Range 24, are tilted to the south at an average angle of 45 degrees and are a series of sandstones, shales, and lignite beds of the non-marine Pale and Foremost beds. North of them are flat-lying Bearpaw strata apparently in faulted contact with the non-marine beds to the south. The well was commenced on the tilted strata, but apparently the

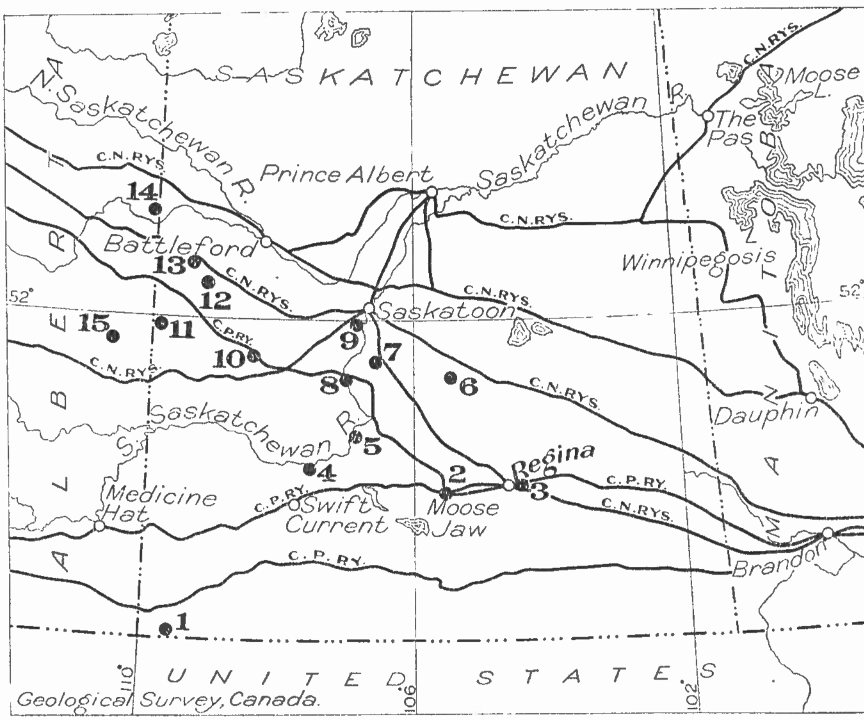

Figure 22. Index map of portion of Saskatchewan showing areas of drilling. 1, Boundary; 2, Moose Jaw; 3, Pilot Butte; 4, Rush Lake; 5, Riverhurst; 6, Simpson; 7, Hanley; 8, Outlook (Eden Valley); 9, Pike Lake; 10, Herschel; 11, Fusilier; 12, Muddy Lake; 13, Unity Valley; 14, Ribstone (Alberta); 15, Misty Hills (Alberta).

tilting was only superficial and flat-lying beds were encountered at no great depth. The drilling yielded neither oil nor gas. The log of the Boundary well as given by Wickenden (1932, page 179) follows:

Log of Boundary Well

(L.S. 4, Sec. 9, Tp. 1, Range 27, W. 3rd Mer.; Elevation, approximately 2,800 feet)

—	Thickness Feet	Depth Feet
Pale and Foremost beds		
Missing	40	40
Shale, medium grey, coal fragments, and sand	60	100
Coal and a little grey shale	10	110
Shale, brown and grey; a little coal and shell fragments	30	140
Sand, fine, brown, and shale	20	160
Sand, fine, and buff shale	20	180
Sand, fine, and buff shale; coal	10	190
Shale, grey	10	200
Shale, grey, and coal	110	310
Shale, grey	30	340
Shale, brown	20	360
Shale, light grey, occasional coal fragments	180	540
Shale, grey, slightly sandy	10	550
Shale, grey	20	570
Shale, grey, with coal	30	600
Shale, grey, sandy	10	610
Shale, grey, with coal	10	620
Shale, grey	60	680
Shale, grey, with coal	10	690
Shale, grey, sandy	10	700
Shale and sand, grey	60	760
Shale and sandstone	20	780
Shale, grey, and some sandstone	110	890
Sandstone, very bentonitic	40	930
Pakowki and marine equivalents of Milk River		
Shale, grey to dark grey	130	1,060
Shale, grey to dark grey, foraminifera	140	1,200
Shale, light grey	10	1,210
Shale, medium to dark grey	240	1,450
Shale, light grey	30	1,480
Shale, medium grey; *Epistomina caracolla* at about 1,500 feet	130	1,610
Missing	140	1,750
Shale, medium grey	50	1,800
Alberta shale		
Shale, grey, with calcareous specks	270	2,070
Shale, dark grey, bentonite	10	2,080
Shale, dark grey; Clavulina and Bullopora zone at 2,090 feet	220	2,300
Bentonite	10	2,310
Shale, dark grey	70	2,380
Shale, dark grey; bentonite	10	2,390
Shale, dark grey	130	2,520
Shale, dark grey; bentonite	20	2,540
Shale, dark grey	130	2,670
Shale, dark grey; bentonite	30	2,700
Shale, dark grey; fine grey sand and chert pebbles near base; show of gas at 2,700 feet, foraminifera at 2,960 feet	390	3,090
Sand, fine, grey	20	3,100
Lower Cretaceous (marine and non-marine)		
Shale, medium to light grey	70	3,170
Sand, fine, grey	20	3,190
Shale, dark grey	10	3,200
Shale, medium to light grey	10	3,210
Shale, dark grey; foraminifera (marine)	30	3,240
Shale, dark grey, and bentonite	10	3,250
Shale, dark grey, foraminifera	90	3,340
Bentonite	10	3,350
Shale, medium and dark grey	90	3,440
Shale, black, carbonaceous; last Lower Cretaceous foraminifera at 3,470 feet	80	3,520

Log of Boundary Well

(L.S. 4, Sec. 9, Tp. 1, Range 27, W. 3rd Mer.; Elevation, approximately 2,800 feet.)—*Concluded*

—	Thickness Feet	Depth Feet
Lower Cretaceous (marine and non-marine)—*Concluded*		
Shale, light grey	20	3,540
Shale, maroon and grey	20	3,560
Shale, greenish grey and mauve	20	3,580
Shale, grey	30	3,610
Shale, grey and reddish purple	20	3,630
Shale, dark red	10	3,640
Shale, grey and brownish red	10	3,650
Shale, brownish red	10	3,660
Shale, greenish grey	50	3,710
Sand, grey	20	3,730
Jurassic		
Shale, medium grey	30	3,760
Shale, dark grey; Jurassic foraminifera at 3,780 feet	30	3,790
Shale, calcareous, medium grey, many Jurassic foraminifera	90	3,880
Shale, light to medium grey	30	3,910
Shale, very calcareous, medium grey	30	3,940

Epistomina caracolla found at a depth of about 1,500 feet is, according to Wickenden, typical of the Milk River formation of Alberta. The Milk River sandstone thins eastward and is replaced by marine shale as in this well.

DIRT HILLS AREA

Dirt Hills area is south of Moose Jaw, on the northeast edge of Missouri Coteau. The Geological Survey has little information regarding the structure. Geophysical methods have been used in this area and it is claimed that by means of them there has been found a structure said to be favourable for oil and gas. The beds outcropping in Dirt Hills area are the Whitemud and other non-marine Cretaceous beds above the Bearpaw. The drilling depth to the Palæozoic cannot be precisely stated, but is not likely to be less than 3,000 feet and may be almost 4,000 feet.

REGINA-MOOSE JAW AREA

(Figure 22, Nos. 2 and 3)

It is believed that a ridge of Palæozoic limestone developed as a result of folding in pre-Jurassic time in Regina area and extended northwest to Hanley. The outline of the ridge is very imperfectly known. Its existence is deduced from the fact that an oolite horizon at the top of the Palæozoic is 800 to 900 feet higher in the Pilot Butte well, drilled 9 miles east of Regina, than in a well drilled at Moose Jaw 49 miles to the west, whereas the difference in elevation of the top of the Lower Cretaceous in the two wells amounts to only 470 feet. Not only was the Palæozoic folded prior to the deposition of the Lower Cretaceous sediments but since the top of the Lower Cretaceous is inclined, post-Lower Cretaceous folding also occurred.

The pre-Lower Cretaceous folding cannot be precisely dated. Jurassic strata of unknown thickness occur in the Pilot Butte well (Wickenden, personal communication) and Jurassic strata at least 250 feet and perhaps 440 feet thick (Wickenden, 1932, page 192) occur in the Moose Jaw well. No Jurassic beds are known to have been encountered in the Simpson well and none would be expected since the Jurassic is known to thin and disappear northward. In Alberta, although the evidence is not conclusive, there are some data that suggest that the thinning of the Jurassic strata northeastward is due to non-deposition and hence the Jurassic shore-line is believed to have crossed southern Alberta, but at some distance north of the International Boundary. In Saskatchewan this shore-line must be south or southwest of Simpson and north of Pilot Butte and Moose Jaw wells. Owing, also, to the presence of a pre-Cretaceous Palæozoic ridge extending northwest from Regina area, the Lower Cretaceous in the Moose Jaw well is 155 feet thicker than in the Simpson well and perhaps is also thicker than in the Pilot Butte well, although the thickness in the Pilot Butte well is uncertain due to the difficulty of interpreting the rotary samples from this well. In regard to the oil and gas prospects the southwest dip is important because if any oil or gas occurs in the area it is likely to be found in the sands of the shore-line of the former Jurassic sea or in the sands of the Lower Cretaceous where these end against the Jurassic or overlap onto the Palæozoic ridge. It is thought that in southern Alberta Jurassic shales are source beds of oil. If so they are possible source rocks in southwestern Saskatchewan. Also the Lower Cretaceous of western Saskatchewan contains marine as well as non-marine beds, a condition quite favourable for the occurrence of source beds of oil and gas as well as for the probable presence of reservoir rocks. It is unfortunate that there is no method except drilling by which the shore-line of the former Jurassic sea can be located and tested. The Pilot Butte well is too far south and the Moose Jaw well with its considerable thickness of Jurassic strata is too far southwest. The Simpson well is also on the Palæozoic ridge and an unknown distance north of the former Jurassic seashore. A well drilled at Estlin about 13 miles south of Regina did not reach the top of the Lower Cretaceous, according to an interpretation of the log by Dowling (1919, page 40), although it reached a depth of 2,425 feet or 500 feet below sea-level. As the top of the Lower Cretaceous in the Pilot Butte well is at approximately 320 feet below sea-level it is apparent that in the 16 miles between the Pilot Butte and Estlin wells there is a dip of more than 11 feet to the mile. Another well drilled at Wilcox (Dowling, 1919, page 41) southwest of Estlin did not reach sufficient depth to give any information on the position of the shore-line of the former Jurassic sea, and hence was not a satisfactory test. The Moose Jaw well reached the top of the Jurassic at slightly less than 3,000 feet and hence in any attempt to find the position of the Jurassic shore-line it would be necessary to drill to about as great a depth. The stratigraphic succession encountered by the Moose Jaw well as interpreted by Wickenden (1932, page 182) is as follows:

Log of Moose Jaw Well

(Near power house in Moose Jaw; Elevation, 1,778 feet)

—	Thickness Feet	Depth Feet
Missing	400	400
Marine shale (Montana)		
Shale, medium grey; foraminifera	180	580
Shale, greenish grey; foraminifera	20	600
Missing	20	620
Shale, medium grey; foraminifera	30	650
Missing	25	675
Shale, medium grey; foraminifera	215	890
Missing	10	900
Sand, grey	10	910
Shale, sandy	10	920
Missing	20	940
Shale, sandy	10	950
Missing	30	980
Sand, grey	30	1,010
Shale, medium grey	150	1,160
Missing	440	1,600
Alberta shale		
Shale, dark grey, with white calcareous specks	10	1,610
Missing	50	1,660
Shale, dark grey, with white calcareous specks	10	1,670
Missing	100	1,770
Shale, dark grey, with white calcareous specks	10	1,780
Missing	30	1,810
Shale, dark grey	10	1,820
Missing	50	1,870
Shale, dark grey, calcareous	10	1,880
Missing	40	1,920
Shale, dark grey	10	1,930
Missing	10	1,940
Shale, dark grey	10	1,950
Missing	40	1,990
Shale, dark grey	10	2,000
Missing	40	2,040
Shale, dark grey	20	2,060
Missing	30	2,090
Shale, dark grey	10	2,100
Missing	30	2,130
Shale, dark grey	20	2,150
Missing	40	2,190
Shale, dark grey	10	2,200
Missing	40	2,240
Shale, very dark grey	10	2,250
Missing	20	2,270
Shale, very dark grey	10	2,280
Missing	10	2,290
Shale, dark grey	10	2,300
Missing	15	2,315
Shale, dark grey	10	2,325
Missing	30	2,355
Shale, dark grey	10	2,365
Missing	40	2,405
Shale, dark grey	10	2,415
Missing	45	2,460
Shale, dark grey	10	2,470
Missing	10	2,480
Shale, dark grey	10	2,490
Missing	40	2,530
Shale, dark grey	10	2,540
Missing	30	2,570

Log of Moose Jaw Well
(Near power house in Moose Jaw; Elevation, 1,778 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Lower Cretaceous (marine and non-marine)		
Shale, dark grey, and sand, light grey, trace of coal	10	2,580
Missing	10	2,590
Shale, dark grey	10	2,600
Shale, dark grey, and fine, light grey sand; foraminifera	35	2,635
Shale, dark grey; foraminifera	45	2,680
Shale, medium grey	10	2,690
Shale, medium grey, and fine, light grey sand	40	2,730
Sand, fine, light grey	10	2,740
Shale, dark grey, and fine, light grey sand	30	2,770
Missing	30	2,800
Shale, sandy, dark grey	5	2,805
Sand, medium grained	15	2,820
Shale, dark grey, and medium-grained sand	30	2,850
Shale, light grey	10	2,860
Missing	20	2,880
Shale, light grey	15	2,895
Shale, light grey and greenish grey	30	2,925
Sand, fine grained	10	2,935
Jurassic		
Shale, medium grey, calcareous; Jurassic foraminifera at 2,990–3,000 feet	90	3,125
Missing	35	3,160
Shale, medium grey	25	3,185
Shale, red, with a little grey	10	3,195
Shale, medium grey, calcareous	3	3,198
Limestone, white, and shale, grey	10	3,208
Shale, medium grey	2	3,210
Missing	45	3,255
Sand, medium grey	10	3,265

The well was deepened in 1931, but the samples taken look as if much material has caved in from above. A series of cores, however, shows an oolitic limestone at 3,380 feet and underlying this, a fine-grained, grey limestone. The oolitic limestone at 3,380 feet is believed by Wickenden (1932, page 185) to mark the top of the Palæozoic.

In the Rush Lake well, drilled 85 miles west and slightly north of Moose Jaw, the top of the Lower Cretaceous is 400 feet higher (1932, page 191) than in the Moose Jaw well. Since between the Moose Jaw well and the Pilot Butte well, 49 miles to the east, the same horizon rises 470 feet, it is obvious the Moose Jaw well lies in a basin in which unless there is local anticlinal folding, such as is not known to exist, no concentration of oil and gas would be expected to exist except, as already stated, towards the eastern edge.

SIMPSON AREA
(Figure 22, No. 6)

In the account of Regina-Moose Jaw area, reference has already been made to a well drilled at Simpson, 72 miles north of Moose Jaw. The top of the Lower Cretaceous in this well is 400 feet higher than in the Moose Jaw well and if the depth of 3,380 feet be considered to be at the top of the Palæozoic in the Moose Jaw well then this horizon is 1,026 feet higher at Simpson than at Moose Jaw. As already pointed out, the Simpson well enters the top of the Palæozoic ridge. No evidence has been found to indicate that the Palæozoic limestone in this area is a source rock of oil or gas and since the basal part of the Lower Cretaceous is non-marine there are no strata in contact with the limestone that are possible source rocks, and, therefore, no grounds exist for expecting the limestone to be productive of oil or gas. Higher horizons in the Cretaceous are possible source rocks, but there is no reason to believe any local structure exists in this area that would cause oil and gas to accumulate even if a source for these materials existed. The log of the Simpson well as interpreted by Wickenden (1932, page 186) is as follows:

Log of Simpson Well

(L.S. 2, Sec. 9, Tp. 29, Range 25, W. 2nd Mer.; Elevation, 1,768 feet)

—	Thickness Feet	Depth Feet
Drift	360	360
Lea Park		
Shale, medium grey, somewhat sandy; foraminifera	644	1,004
Shale, medium grey, darker than above; *Epistomina caracolla*	46	1,450
Alberta shale		
Shale, dark grey with white, calcareous specks	120	1,570
Shale, very dark grey, almost black; show of oil at 1,612 feet	140	1,710
Shale, dark grey; gas at 1,720 feet	155	1,865
Bentonite	10	1,875
Shale, dark grey	60	2,035
Sand, light grey, fine grained	25	2,060
Shale, dark grey, some nearly black; show of oil about 2,116 feet	60	2,120
Lower Cretaceous		
Shale, medium to light grey, sandy	10	2,130
Shale, dark grey	10	2,140
Shale, mauve-grey	5	2,145
Shale, dark grey and salt water and gas at		2,161
Shale, mauve-grey at		2,170
Shale, light grey at		2,180
Shale, medium grey, much pyrite	20	2,200
Shale, medium grey	60	2,260
Sand, fine grained	5	2,265
Shale, dark grey	15	2,280
Shale, medium grey	30	2,310
Shale, light grey, calcareous	20	2,342
Palæozoic		
Anhydrite and grey shale	68	2,410
Missing	190	2,600
Shale, red	10	2,610
Missing	20	2,630
Shale, red	10	2,640
Missing	50	2,690
Shale, red	20	2,710
Missing	10	2,720
Shale, grey	11	2,731
Oolite, white, at		2,735
Shale, red, at		2,743
Limestone, cream coloured, at		2,746
Limestone, white and buff dolomite, at		2,776
Limestone, white; buff dolomite	4	2,780
Limestone, cream coloured	80	2,860
Limestone, cream coloured; grey shale	50	2,910
Dolomite, buff and white limestone, at		2,938
Limestone, grey-white	22	2,960
Dolomite and limestone, buff coloured, at		2,983
Limestone, white	17	3,000
Missing	15	3,015
Limestone and dolomite, buff coloured	20	3,035
Limestone, white and light buff, some dolomite	40	3,075
Dolomite and limestone, light buff	53	3,128
Dolomite, dark buff	22	3,150

The total depth of the well was 3,445 feet and a rock salt bed, said to be 12 feet thick, was encountered between 3,420 and 3,432 feet.

RUSH LAKE-RIVERHURST-OUTLOOK-HANLEY AREA
(Figure 22, Nos. 4, 5, 7, and 8)

In 1920 a well was drilled on the south side of South Saskatchewan River north of Rush Lake. The top of the Lower Cretaceous was encountered at an elevation 400 feet higher than that of the same horizon in a well at Moose Jaw 85 miles to the east and slightly south. The dip in Moose Jaw area is probably to the southwest and if so the area between Rush Lake and Moose Jaw may be synclinal. East of South Saskatchewan River and 32 miles northeast of the Rush Lake well is Riverhurst, southeast of which an artesian water basin has been developed (Maddox, 1932, page 75). The water-bearing horizon is a sandstone in the base of the Bearpaw or underlying Belly River beds. It rises to the south at a rate of 7 to 14 feet a mile and to the west at 5 to 6 feet a mile. Evidently, therefore, the dip is to the north rather than to the east. A flow of gas of considerable but not commercial volume was struck at a depth of 518 feet in a well drilled at Riverhurst (Warren, 1927, page 41). The gas occurs in a sandstone that Warren considered to be Belly River, but data more recently secured suggest that it may be in the Bearpaw. Belly River sandstones and shales outcrop on South Saskatchewan River in Tp. 21, Range 18, W. 3rd Mer., disappearing below the river-level about Range 13, and the Bearpaw-Belly River contact occurs near the top of the Rush Lake well in Range 11. From these outcrops Warren calculated the northeast dip to Riverhurst to be 6·5 feet a mile, assuming that the gas-producing sandstones in the Riverhurst well are Belly River. If they are Bearpaw the dip is somewhat steeper. It is not known how far the northeast dip continues beyond Riverhurst, but there is a very pronounced rise before Simpson, Hanley, or Outlook are reached. The top of the Lower Cretaceous at Simpson is probably 250 to 300 feet higher than at Riverhurst, 75 miles southwest of Simpson, and the top of the same horizon is 145 feet higher still at Hanley, 45 miles northwest of Simpson. At Outlook, 24 miles southwest of Hanley, in a well drilled by Eden Valley Oil and Gas Company on L.S. 14, Sec. 35, Tp. 28, Range 8, W. 3rd Mer., the top of the Alberta shale occurs at a depth of 1,310 feet or about 120 feet higher than at Simpson. The above data indicate that Riverhurst area is in a pronounced basin on the west flank of which the Rush Lake well was drilled. The Outlook well is apparently only 25 feet lower structurally than the well at Hanley drilled on L.S. 9, Sec. 28, Tp. 30, Range 5, W. 3rd Mer., to a depth of 2,134 feet, and abandoned in Lower Cretaceous strata. The Hanley well is considerably higher than the Simpson well. The structurally high Hanley well did not obtain commercial supplies of oil and gas and, therefore, the prospects of this whole general area do not appear very promising unless there is a more pronounced local anticlinal area in the vicinity of Hanley than now appears probable.

The log of the Rush Lake well as interpreted by Wickenden (1932, page 185) is as follows:

Log of Rush Lake Well

(L.S. 2, Sec. 20, Tp. 19, Range 11, W. 3rd Mer.; Elevation, approximately 1,750 feet)

—	Thickness Feet	Depth Feet
Drift	20	20
Bearpaw, Birch Lake? or Belly River?		
Shale, medium grey	20	40
Missing	10	50
Sand, grey, pepper and salt	20	70
Grizzly Bear and Ribstone Creek		
Shale, medium grey; gas at 318 feet; *Haplophragmoides rugosa* (found in the Grizzly Bear formation)	230	340
Sand, medium grey; little shale	10	350
Sandy shale, brownish grey	50	400
Sand, fine grained	20	420
Lea Park		
Shale, somewhat sandy, medium grey	490	910
Shale, medium grey, darker than previous, somewhat sandy with buff shale and glauconite; much gypsum at 1,450 feet; *Epistomina caracolla*, typical of the Milk River in eastern Alberta	650	1,560
Alberta shale		
Shale, dark grey with white, calcareous specks, foraminifera	50	1,610
Bentonite	10	1,620
Shale, dark grey; foraminifera	520	2,140
Lower Cretaceous		
Sandy shale, medium grey, chert pebbles and coal	10	2,150
Shale, medium to dark grey (marine)	120	2,270

This well is reported to have reached a depth of 2,325 feet, at which depth salt water was encountered.

The Eden Valley Oil and Gas Company's well at Outlook did not reach the Lower Cretaceous. Wickenden has compiled the log, as follows, from samples submitted to the Geological Survey.

Log of Outlook Well

(L.S. 14, Sec. 35, Tp. 28, Range 8, W. 3rd Mer.; Elevation, 1,750 feet)

—	Thickness Feet	Depth Feet
Missing	390	390
Upper Lea Park		
Shale, medium grey	50	440
Missing	20	460
Shale, sandy; some glauconite	10	470
Missing	20	490
Shale, sandy; some glauconite	10	500
Missing	40	540
Shale, sandy; some glauconite	10	550
Missing	40	590
Shale, grey, sandy; some glauconite	10	600
Missing	20	620
Shale, grey, sandy; some glauconite	10	630

Log of Outlook Well

(L.S. 14, Sec. 35, Tp. 28, Range 8, W. 3rd Mer.; Elevation, 1,750 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Upper Lea Park—Concluded		
Missing	30	660
Shale, grey	10	670
Missing	20	690
Shale, grey	10	700
Missing	20	720
Shale, grey	10	730
Missing	10	740
Shale, grey and greenish grey	10	750
Missing; show of gas reported at 780 feet	40	790
Shale, medium grey	10	800
Missing	20	820
Shale, medium grey	10	830
Missing	10	840
Bentonite	10	850
Missing	10	860
Lower Lea Park		
Shale, medium grey, darker than above	10	870
Missing	20	890
Shale, medium grey	30	920
Missing	50	970
Shale, medium grey	10	980
Missing	10	990
Shale, medium grey	320	1,310
Alberta shale		
Shale, dark grey with white calcareous specks	90	1,400

The well was not deep enough to test the possibly productive horizons.

PIKE LAKE AREA

(Figure 22, No. 9)

The Pike Lake well was drilled on L.S. 8, Sec. 13, Tp. 34, Range 7, W. 3rd Mer., west of Pike Lake and 16 miles southwest of Saskatoon. It is 33 miles north and slightly east of the Eden Valley Oil and Gas Company's well at Outlook. It is thought that similar horizons are 170 feet higher at Pike Lake than at Outlook, indicating a rise of slightly more than 5 feet a mile. The Muddy Lake well drilled 100 miles northwest of Pike Lake entered the top of the Lower Cretaceous at an elevation only 164 feet higher than the elevation of this horizon in the Pike Lake well. This southeast slope of 1·64 feet a mile seems to be somewhat low, as indicated by the following considerations. At Tramping Lake, 80 miles west of Pike Lake, coal from Belly River strata is frequently washed up on the shores of the lake and it is believed that shales[1] outcropping along the west shore of the lake in Township 35 belong to the basal part of the Bearpaw. The elevation of the base of the Bearpaw would, therefore, be about that of Tramping Lake or 2,018 feet. The Muddy Lake well,

[1] Formerly it was thought that these beds might belong to the Grizzly Bear formation; *See* Hume: Geol. Surv., Canada, Sum. Rept. 1925, pt. B, p. 6.

25 miles northwest of Tramping Lake, was commenced in the Pale and Variegated beds. These horizons as developed southwest of Muddy Lake are 700 to 800 feet thick, but it is known that they decrease in thickness from west to east. If it be assumed that their thickness is 500 feet in Muddy Lake area then, since the Muddy Lake well penetrated the base of this horizon at an elevation of 1,729 feet, the elevation of the top of the Pale and Variegated beds, i.e., the base of the Bearpaw, would have been 1,729 plus 500 feet, that is 2,229 feet. The elevation of the base of the Bearpaw at Tramping Lake 25 miles to the southeast being 2,018 feet, the dip in a southeast direction is at the rate of about 8 feet a mile, whereas, as already stated, the rate of dip as established by comparing the elevations of the top of the Lower Cretaceous at Muddy Lake and Pike Lake, respectively, amounts to only 1·64 feet a mile. It may be, therefore, that the dip between Muddy Lake and Pike Lake is not uniformly southeast but changes to a westerly or possibly southwesterly dip at an unknown distance west of Pike Lake. Otherwise the calculated dip of 1·64 feet a mile between Muddy Lake and Pike Lake cannot be explained by the present data. A southwest dip would be in harmony with the southwest dip between Hanley and Riverhurst to the southeast of Pike Lake and would suggest that the Riverhurst synclinal basin extends northwestward so as to lie between Muddy Lake and Pike Lake.

Log of Pike Lake Well (By J. G. Spratt)

(L.S. 8, Sec. 13, Tp. 34, Range 7, W. 3rd Mer.; Elevation, 1,715± feet)

—	Thickness Feet	Depth Feet
Drift	90	90
Sand, fine grained	50	140
Shale, grey, organic remains	60	200
Shale, grey	50	250
Sand, grey; water	5	255
Shale, olive-grey, and fine-grained sandstone	10	265
Sandstone, very fine grained, and shale, grey	35	300
Sand, mostly white, black, and green; water at 315 feet	15	315
Shale, grey or green	25	340
Sandstone, fine grained, grey	30	370
Sandstone, coarser, greenish	10	380
Sandstone with some shale and ironstone	10	390
Sandstone and some shale	110	500
Shale, grey, sandy	690	1,190
Shale, grey, with a little bentonite	35	1,225
Shale, dark grey	375	1,600
Shale, dark grey, with pyrite, at	....	1,635
Shale, dark grey	140	1,775
Lower Cretaceous		
Shale with fine-grained sandstone	5	1,780
Sandstone, oil show and salt water, at	....	1,790
Sandstone and shale, grey and dark grey, at	....	1,795
Shale and little sandstone, at	....	1,810
Sandstone, fine grained, a little shale, at	....	1,855
Sandstone, light grey, with carbonaceous materials	....	1,870 to 1,925
Sand, white, medium fine	....	1,940 to 1,950
Sand, white, at	....	1,960

Log of Pike Lake Well (By J. G. Spratt)

L.S. 8, Sec. 13, Tp. 34, Range 7, W. 3rd Mer.; Elevation, 1,715± feet)—*Concluded*

—	Thickness Feet	Depth Feet
Lower Cretaceous—Concluded		
Sandstone, medium grained, light grey, at	....	1,975
Shale, dark, carbonaceous, at	....	1,990
Shale, grey, at	....	2,010
Shale, black, carbonaceous, with sandy streaks, at	....	2,030
Sand, fine grained, grey	....	2,090 to 2,115
Shale, dark and light grey	....	2,115 to 2,125
Pyrite, at	....	2,130
Shale, black, carbonaceous, and light grey, at	....	2,165
Palæozoic (top at)	....	2,165
Limestone, sandy, and pale green shale	....	2,190 to 2,220
Limestone, grey; shale, calcareous, grey to green, at	....	2,315
Limestone, grey, and shale, at	....	2,390
Limestone, buff-grey, at	....	2,425
Limestone, buff-grey, at	....	2,535
Limestone, buff-grey, at	....	2,550
Limestone, buff-grey, at	....	2,605
Limestone, buff-grey, at	....	2,650
Salt water	....	2,655
Limestone, buff-grey	....	2,725 to 2,745
Limestone, light grey	....	2,755 to 2,770
Limestone, light grey, at	....	2,860
Limestone, light grey, at	....	2,875
Limestone, light grey	....	2,950 to 2,970
Limestone, shaly, grey, at	....	2,985
Gypsum, white to brownish, translucent	....	3,020 to 3,060
Limestone, buff	....	3,105
Limestone, buff to grey, at	....	3,170

HERSCHEL AREA

(Figure 22, No. 10)

A well drilled at Herschel, by the Rosetown Lease Holding Company, on Sec. 4, Tp. 31, Range 17, W. 3rd Mer., is 58 miles west and north of the well at Outlook and 66 miles west and south of the Pike Lake well. This well was drilled by rotary methods and the samples are difficult to interpret. According to Warren (1930, page 41) Belly River strata outcrop in the vicinity of Herschel and it is probable that the well commenced in these beds. It appears also probable from a log of the well compiled by Spratt that the top of the Lower Cretaceous occurs at 2,028 feet. The total depth represented by samples (the lowest being core samples) is 2,031 feet, and is assumed to be the depth of the well. The elevation of the top of the Lower Cretaceous (elevation of well 1,920 feet) is 48 feet lower than in the Pike Lake well, but if the synclinal basin of Riverhurst area extends northwest, as seems possible, it probably passes between Herschel and Pike Lake and a comparison of the elevations of the same horizon at the two places does not show the true dip.

The Herschel well is almost on a straight line joining the Rush Lake and Muddy Lake wells. It lies 77 miles northwest of Rush Lake and 59 miles southeast of Muddy Lake. The top of the Lower Cretaceous shows a rise of 282 feet or 3·66 feet a mile between Rush Lake and Herschel and a rise of 212 feet or 3·59 feet a mile between Herschel and Muddy Lake. This suggests an extraordinarily uniform slope to the southeast.

The Fusilier well (Sec. 23, Tp. 34, Range 28, W. 3rd Mer.) is about 65 miles west and 22 miles north of the Herschel well and in it the top of the Lower Cretaceous is somewhat lower than in the Herschel well. It is somewhat difficult to fit this data in with what is known of regional dips, but it can be explained by assuming a westerly or southwesterly dip west of Herschel. As has already been stated in the account of Pike Lake area, a syncline possibly occurs east of Herschel between it and Pike Lake and if such a structure is present there must be an anticlinal structure plunging to the southeast, somewhere in the general area around Herschel. With present information it is impossible to state whether this structure, if present, is sufficiently pronounced locally to cause any accumulation of oil or gas.

FUSILIER AREA

(Figure 22, No. 11)

A well was drilled in 1916 about 7 miles northwest of Fusilier on Sec. 23, Tp. 34, Range 28, W. 3rd Mer. This well began in strata probably the equivalent of the Pale and Variegated beds and encountered the top of the Lea Park shale at 1,320 feet and the top of the Alberta shale at 2,135 feet. The top of the Lower Cretaceous is not exactly known on account of the lack of samples, but Dowling (1919, page 48) placed it at 2,716 feet. The well is 65 miles west and 22 miles north of the Herschel well and slightly lower structurally as should be if there is a southwest dip in this area. A southwest dip seems to be proved by the fact that the dip of the top of the Lea Park or Alberta shale horizons from the Muddy Lake well, 40 miles to the northeast of the Fusilier well, is at the rate of slightly more than 8½ feet a mile and this southwest dip apparently continues through Fusilier to the Misty Hills well of Alberta, 25 miles away, on Sec. 29, Tp. 32, Range 4, W. 4th Mer., although the slope seems to be lower than farther to the northeast. No available evidence indicates any local anticlinal conditions in Fusilier area and, therefore, no oil or gas production is to be expected, although the Fusilier well is reported to have encountered small flows of gas at 2,473 and 2,560 feet.

The log of the Fusilier well, described in part by Dowling but interpreted by the author as a result of the examination of the available samples, is as follows:

Log of Fusilier Well

—	Thickness Feet	Depth Feet
Drift	138	138
Equivalents of the Pale?, Variegated, Birch Lake, Grizzly Bear, and Ribstone Creek formations		
Sand, soft	7	145
Clay, blue, with some sand	145	290
Clay, soft, blue	126	416
Shale, brown; some coal at 425 to 490 feet	29	445
Clay, light blue	15	460
Shale, brown	4	464

Log of Fusilier Well—Concluded

—	Thickness Feet	Depth Feet
Equivalents of the Pale?, etc.—Concluded		
Shale, sandy, brown. At 478 feet a thin sand gave water which rose 100 feet	21	485
Shale, sandy, brown	30	515
Shale, sandy, brown, with blue shale mixed with sand	25	540
Shale, blue, and sand	48	588
Shale, brown, with some sand	29	617
Water sand, somewhat less than 1 foot thick	1	618
Clay, blue, very hard	99	717
Sand	11	728
Clay, blue, sticky	22	750
Shale, brown	3	753
Shale, blue, sticky	10	763
Shale, sandy, blue	12	775
Clay and sand	4	779
Clay, blue, sticky	15	794
Shale, blue	128	922
Sand, possibly carrying water	1	923
In part quite sandy and grey	397	1,320
Lea Park		
Shale, grey to black	815	2,135
Alberta shale		
Shale, grey to black and speckled with white, calcareous spots	65	2,200
Shale, dark grey	425	2,625
Sand, streaks in shales	17	2,642
Sand, fine, brown and white with streaks of grey shale	74	2,716
Alberta shale or Lower Cretaceous		
Sandstone, streak of grey in shales	46	2,762
Lower Cretaceous		
Coal and ironstone	4	2,766
Sandstone, very hard, and streaks of shale	48	2,814
Sandstone, fine, and shales; some coal	10	2,824

Dowling considered that the sand at a depth of 923 feet formed the base of the Ribstone Creek formation. The beds below are in part quite sandy and grey to 1,320 feet and the present writer believes the base of the Ribstone Creek should be placed at 1,320 feet. The elevation of the top of the Lower Cretaceous is not known, as no samples are available between 2,545 and 2,762 feet; it may be 2,716 feet or may be at 2,762 feet.

MUDDY LAKE AREA
(Figure 22, No. 12)

Extensive outcrops of Pale and Variegated beds occur in the vicinity of Muddy Lake and in the area to the south and east. About 25 miles southeast marine shales outcrop on the west side of Tramping Lake. They are probably Bearpaw shales close to the base of this formation since coal washed ashore indicates Belly River beds at about lake-level. If the condition is as interpreted, then, as explained in the section dealing with Pike Lake area, the regional dip is probably about 8 feet to the mile in a southeast direction. A well drilled at Muddy Lake on L.S. 11, Sec. 7, Tp. 39, Range 22, W. 3rd Mer., reached the top of the Lower Cretaceous at an elevation of 104 feet above sea-level. In Unity Valley No. 3 well 15 miles northwest of Muddy Lake well, the same horizon as determined by Spratt by the presence of chert pebbles occurs at an elevation of 180 feet, thus indicating a slope of 5 feet to the mile to the southeast between Unity Valley No. 3 and the Muddy Lake wells. Thus there appears to be a fairly uniform dip southeast through Muddy Lake area and no local structure that would cause any accumulation of oil or gas is known to occur. The log of the Muddy Lake well, as given by Wickenden (1932, page 188), is as follows:

Log of Muddy Lake Well

(L.S. 11, Sec. 7, Tp. 39, Range 22, W. 3rd Mer.; Elevation, 1,894 feet)

—	Thickness Feet	Depth Feet
Missing	40	40
Pale and Variegated beds		
Shale, sandy, light grey; coal fragments	30	70
Missing	10	80
Coal, little shale	10	90
Shale, medium to light grey, some sand and coal	60	150
Missing	15	165
Grizzly Bear		
Shale, medium grey, *Haplophragmoides rugosa*	85	250
Ribstone Creek		
Shale, sandy, medium grey; glauconite	50	300
Missing	40	340
Upper Lea Park		
Shale, medium grey	210	550
Shale, dark buff and grey; *Verneuilina* sp	10	560
Shale, medium grey	10	570
Shale, dark buff and grey	90	660
Shale, medium grey	190	850
Lower Lea Park		
Shale, medium grey, but darker than above; *Epistomina caracolla*	300	1,150
Alberta shale		
Shale, dark grey with white, calcareous specks; Upper Alberta foraminifera fauna at 1,280 feet	300	1,450
Shale, dark grey; Lower Alberta foraminifera fauna	320	1,770
Sand, fine, white quartz	10	1,780
Missing	10	1,790
Lower Cretaceous		
Shale, dark grey	10	1,800
Shale, medium to light grey	20	1,820
Missing	30	1,850
Shale, medium to light grey	30	1,880
Shale, grey and reddish buff; coal at 1,910-1,920 feet	40	1,920
Shale, sandy, medium grey	40	1,960
Shale, medium grey and black; *Haplophragmoides gigas*	10	1,970
Shale, medium grey	60	2,030
Shale, reddish buff	20	2,050
Shale, dark grey	10	2,060
Shale, medium grey to reddish buff	30	2,090
Shale, light grey	20	2,110
Shale, light and dark grey	10	2,120
Shale, red and dark grey	10	2,130
Devonian and other Palæozoic horizons		
Shale, grey; limestone and dolomite	20	2,150
Dolomite, white, some bituminous matter, at	....	2,152
Shale, grey, and dolomite	35	2,185
Shale, grey, calcareous, and grey limestone; fossils	25	2,210
Limestone, buff	10	2,220
Shale, grey, and limestone	50	2,270
Dolomite, buff	10	2,280
Limestone, buff	140	2,420
Shale, grey, and limestone	30	2,450
Dolomite and limestone, buff	90	2,540
Dolomite, buff	40	2,580
Limestone and dolomite, buff to grey	60	2,640
Dolomite, buff; very little limestone	135	2,775
Limestone, white and grey; smooth ostracoda	55	2,830
Dolomite, buff	70	2,900

UNITY VALLEY AREA

(Figure 22, No. 13)

Three wells have been drilled by the Unity Valley Oil Company in Tp. 41, Range 24, W. 3rd Mer. The samples are from rotary cuttings and except for cores the interpretation is somewhat difficult. Sand dunes cover the area in the vicinity of the wells and a large area covered by sand hills occurs to the west and south of Lake Manitou. Some of this sand may be derived from the Birch Lake formation but undoubtedly a large part of it comes from the top of the Ribstone Creek formation. It was formerly assumed (Hume, 1926, page 7) that the Unity Valley wells began in the Birch Lake formation. This may not be correct because it is known that the Birch Lake formation thins eastward and may have disappeared west of this area. An examination of the samples from the wells seems to indicate that the wells commenced in the top of the Ribstone Creek formation. The thickness of the marine shales that lie between the Ribstone Creek and Birch Lake formations is unknown, but presumably is less than 100 feet. The shales are not known to outcrop in the immediate vicinity of the wells. The nature of the samples does not permit correlating the strata from well to well except in a very general way. A peculiar feature is that the top of the Palæozoic limestone was reported in No. 1 well at 1,770 feet, but was not reached until a depth of 2,140 feet had been drilled in No. 2 well. The elevation of the two wells is only slightly different and the distance between them less than a mile. This would seem to indicate a knob of Palæozoic limestone under the Mesozoic sediments of this area. No. 3 well, intermediate between No. 1 and No. 2 wells, did not reach the Palæozoic at a depth of 1,850 feet, where drilling was discontinued. In No. 2 well the top of the Alberta shale apparently occurs at 1,140 feet (elevation 810±feet), whereas the same horizon in the Muddy Lake well 15 miles southeast is at an elevation of 744 feet and in Ribstone Oils No. 2 well, 42 miles northwest, it has an elevation of 997 feet. This indicates a southeast slope from Ribstone to Muddy Lake of 4 to 5 feet a mile.

LONE ROCK AREA

(*See* Figure 18, page 208)

The Lone Rock area lies north of Battle River in western Saskatchewan close to the Alberta boundary. It is believed to be a part of the Ribstone-Blackfoot fold of Alberta and has been described in Chapter VI of this report, in the section dealing with Battle River area.

MANITOBA

Gas in quantities sufficient to be used by farmers has been found in shallow wells in southwestern Manitoba (Wallace, 1927, page 71). In Treherne area a well on NE. ¼ Sec. 28, Tp. 7, Range 10, W. 1st Mer., supplied gas for a farm house for fifteen years. The depth to the gas-producing horizon is 150 feet. In a well near Rathwell, on SE. ¼ Sec. 21, Tp. 7, Range 8, W. 1st Mer., gas was produced for several years from an horizon 170 feet deep. Farther west, on NW. ¼ Sec. 14, Tp. 6, Range 22, W. 1st Mer., a well 190 to 210 feet deep when capped built up a gas pressure of 48 pounds a square inch. At Waskada four wells drilled many years ago produced gas from depths of 190 to 240 feet. South of Sourisford, on SE. ½ Sec. 10, Tp. 2, Range 27, W. 1st Mer., a well 212 feet deep gave a gas pressure of 19 pounds a square inch. Many years ago gas from the

Figure 23. Index map of portion of Manitoba showing areas of drilling. 1, Deloraine; 2, Commonwealth (Pembina River); 3, Morden; 4, Dominion City; 5, Treherne-Rathwell area; 6, Stony Mountain; 7, Neepawa; 8, Vermilion River-Dauphin area; 9, Winnipegosis; 10, Mafeking.

same shallow horizon was used in Melita. This gas is produced from marine shales but in areas where there is no evidence of local structures to cause any large accumulations. It is, therefore, improbable any extensive commercial yields could be obtained, although it is quite practicable to produce sufficient quantities for the lighting of farm houses.

Several wells (Figure 23) have been drilled in southern Manitoba, but no commercial supplies of either oil or gas have been discovered.

Log of Commonwealth Manitou No. 2 Well[1]

(L.S. 8, Sec. 26, Tp. 2, Range 9, W. 1st Mer.; Elevation, approximately 1,260 feet)

	Thickness Feet	Depth Feet
Drift	100	100
Boyne and Morden beds (Upper Cretaceous)		
Missing	40	140
Shale, dark grey	40	180
Missing	20	200
Shale, dark grey	100	300
Missing	20	320
Shale, dark grey	20	340
Assiniboine and Keld beds (Upper Cretaceous)		
Shale, dark grey	10	450
Limestone, dark grey	10	460
Shale, dark grey	140	600
Ashville (Upper Cretaceous) and basal Upper Cretaceous beds		
Shale, dark grey	70	670
Missing	30	700
Shale, medium grey	5	705
Sand, light grey to white	30	735
Lower Cretaceous (?)		
Shale, medium grey	20	755
Shale, light grey	9	764
Shale, light grey and reddish brown	16	780
Shale, light grey	40	820
Shale, medium grey	35	855
Shale, reddish brown and grey	5	860
Shale, medium grey	10	870
Shale, reddish brown	10	880
Shale, medium grey	10	890
Shale, reddish brown and grey	5	895
Sand, light grey to white	5	900
Jurassic		
Shale, medium grey	70	970
Shale, variegated, reddish brown, green, white, and yellow	120	1,090
Shale, light grey and white, some gypsum	30	1,120
Devonian		
Dolomite, light grey	20	1,140
Shale, light grey	60	1,200
Missing	10	1,210
Shale, cream colour	10	1,220
Shale, reddish brown and white with much gypsum	50	1,270
Shale, grey and reddish brown	10	1,280
Shale, reddish brown	110	1,390
Sand, reddish stained quartz	10	1,400
Shale, reddish brown	30	1,430
Silurian (?)		
Limestone, dirty cream	20	1,450
Shale, reddish brown	20	1,470
Shale, brick-red	20	1,490
Dolomite	10	1,500
Limestone, pinkish	10	1,510
Limestone, light grey	20	1,530
Dolomite, pink	10	1,540
Dolomite, cream	10	1,550
Dolomite, pink	20	1,570
Limestone, cream	10	1,580
Dolomite, pink, at	....	1,590
Limestone, pink, at	....	1,595
Dolomite, pink, at	....	1,600
Limestone, cream	20	1,620
Limestone, pink, at	....	1,630

[1] Log by R. T. D. Wickenden and F. J. Fraser in Geol. Surv., Canada, Sum. Rept. 1932, pt. B, pp. 91-93.

Log of Commonwealth Manitou No. 2 Well

(L.S. 8, Sec. 26, Tp. 2, Range 9, W. 1st Mer.; Elevation, approximately 1,260 feet)—*Concluded*

—	Thickness Feet	Depth Feet
Silurian (?)—Concluded		
Dolomite, pink	75	1,705
Dolomite, cream	85	1,790
Shale, brick-red, and sand	10	1,800
Dolomite, pink	50	1,850
Dolomite, brown and grey	20	1,870
Dolomite, sandy grey	20	1,890
Sandstone, dolomitic	10	1,900
Stony Mountain (Ordovician)		
Dolomite, sandy, and calcareous shale	10	1,910
Missing	15	1,925
Limestone, medium grey, fossils	8	1,933
Sand, light grey	2	1,935
Missing	5	1,940
Dolomite, light grey	40	1,980
Dolomite, medium grey	20	2,000
Dolomite, buff and grey	17	2,017
Selkirk, Cat Head, and Dog Head formations (Ordovician)		
Dolomite, cream at	....	2,030
Dolomite, medium grey, at	....	2,040
Dolomite, buff and grey, at	....	2,045
Dolomite, light buff, at	....	2,055
Dolomite, cream	25	2,080
Limestone, cream	50	2,130
Limestone, cream	45	2,290
Dolomite, cream	50	2,340
Calcareous mud, at	....	2,350
Limestone, cream, at	....	2,360
Calcareous mud, at	....	2,370
Dolomitic mud, at	....	2,380
Calcareous mud, at	....	2,390
Limestone, cream, at	....	2,400
Dolomitic mud, light grey	30	2,430
Calcareous mud, at	....	2,440
Dolomitic mud, at	....	2,450
Calcareous mud	20	2,480
Missing?	10	2,490
Winnipeg sandstone		
Shale, dull green	110	2,600
Quartz sand	2	2,602
Missing	8	2,610
"Arkose", green-grey	2	2,612
Shale, dull green	1	2,613
Missing (?)	2	2,615
Precambrian		
"Granite", brown stained	24	2,639

Wells have been drilled at other places in southern Manitoba as follows: Rosenfeld, Deloraine (For log *See* Dowling, 1919, page 38), Dominion City, Morden (For log *See* Dowling, 1919, page 35), and in Winnipeg district at Stony Mountain (For log *See* Maddox, 1930, page 177), etc. None of these wells obtained commercial quantities of either gas or oil and in no place is there known to be any local anticlinal structure sufficient to cause an accumulation.

North of the latitude of Winnipeg in the western part of Manitoba wells have been drilled at Winnipegosis (For log *See* Maddox, 1930, pages 178-180), Dauphin, Mafeking, Neepawa (For log *See* Dowling, 1919, page 37), Vermilion River (For log *See* Dowling, 1919, page 38), and Hudson Bay Junction.

The following log has been prepared by R. T. D. Wickenden of the Geological Survey:

Log of Dauphin Well

(SE. ¼ Sec. 14, Tp. 24, Range 20, W. 1st Mer.)

—	Thickness Feet	Depth Feet
Drift	10	10
Keld and Ashville beds (Upper Cretaceous)		
Shale, dark grey	10	20
Shale, medium grey	70	90
Shale, dark grey	10	100
Shale, medium grey	30	130
Lower Cretaceous (?)		
Shale, medium grey, with sand and pyrite	30	160
Shale, sandy, light grey	40	200
Jurassic		
Shale, mottled red	10	210
Shale, light grey	20	230
Shale, red	10	240
Shale, light grey	90	330
Devonian		
Dolomite, grey to white, cherty	40	370
Missing	10	380
Dolomite, brown, grey	10	390
Shale, red, with gypsum	100	490
Dolomite, cream, shaly	20	510
Dolomite, pink	10	520
Missing	10	530
Dolomite, pink	20	550
Dolomite, brown, grey	40	590
Dolomite, pink	20	610
Dolomite, light grey	40	650
Dolomite, grey	20	670
Dolomite, brown-grey	10	680
Missing	10	690
Dolomite, grey	20	710
Dolomite, dirty white	10	720
Missing	10	730
Dolomite, dirty white	10	740
Dolomite, brown-grey	50	790
Dolomite, pink	10	800
Dolomite, brownish grey	90	890
Missing	30	920
Dolomite, brown	20	940
Dolomite, medium grey, some limestone fossils	50	990
Limestone, medium grey	20	1,010
Dolomite, medium grey	20	1,030
Missing	10	1,040
Dolomite, medium grey	10	1,050
Missing	10	1,060
Dolomite, reddish brown	10	1,070
Silurian		
Missing	30	1,100
Dolomite, light grey	30	1,130
Dolomite, brown-grey	100	1,230
Shale, brownish grey	10	1,240
Shale, red, at	....	1,256

Besides wells that commenced in Cretaceous strata, there have been a number of wells drilled wholly within Palæozoic strata. No evidences of gas or oil sufficient to justify drilling in the Palæozoic of Manitoba have been found at any place. Nothing yet known gives any grounds for supposing oil or gas would originate in the Palæozoic rocks and nowhere, so far as known, are there any folds of a magnitude sufficient to cause an accumulation of oil or gas, even assuming oil or gas could originate in these strata. As already described, the Devonian in certain places shows small local domes, but these are not of sufficient size to be of importance as oil or gas structures. Thunder Hill in Swan River Valley, as already pointed out, is a structure in which certain Cretaceous strata occur 300 to 400 feet (1930, pages 132-3) above similar horizons on the surrounding plains. The reason for this apparently isolated structure is not obvious, but it seems to offer the most favourable prospects for oil or gas of any known structure in Manitoba. Undoubtedly the structure exhibited at the surface in Cretaceous beds also affects the underlying Palæozoic strata, but the prospects of finding oil or gas would seem to be confined to the Cretaceous beds of which the basal Upper Cretaceous sandstone is the most likely reservoir rock. The beds exposed on the upper part of Thunder Hill belong to the Ashville and Keld, so that it is improbable that the depth to the basal Upper Cretaceous would be more than 200 feet.

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CHAPTER IX

NORTHWEST TERRITORIES

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Maps of Mackenzie River and Great Slave Lake are published by the Department of the Interior, Topographical Surveys, Ottawa.

Within the Northwest Territories, a large lowland area in the vicinity of Great Slave Lake and Mackenzie River Valley is underlain by Palæozoic and younger strata. The lowland is sharply defined from the mountains to the west and from the Canadian Shield to the east. Its continuity is broken, however, by such mountains as the Franklin and Norman Ranges on the east side of Mackenzie River south and north of Great Bear River. Throughout this great area the predominant structural feature is flat-lying or folded strata with a conspicuous absence of extensive faulting. In front of the Cordillera, which flanks the west side of the Mackenzie lowland from Simpson northward, there is no foothills belt as in southern Alberta and gently folded rocks of the lowland occur up to the base of the front range of the mountains from which they are separated by a fault scarp or steeply tilted strata of the mountain folds. Both the Franklin and Norman Ranges are broad, anticlinal folds and between them and the Cordillera on the west the Mackenzie flows through a basin or synclinal structure. South of Franklin Mountains and also north of the Norman Range the strata are much less folded than in the intervening area and gentle undulations without sharply tilted strata are the predominant structural features. The lowland area, therefore, falls into three major divisions: (1) the west end of Great Slave Lake in which the strata are very gently folded; (2) the basin structure of the Mackenzie extending south and north of Norman and in which extensive folding occurs; (3) the Arctic Red River area north of the folded Norman Range in which, as in Great Slave Lake area, gentle folding predominates.

GREAT SLAVE LAKE AREA

Great Slave Lake is the fourth largest lake on the North American continent, being exceeded only by Superior, Huron, and Michigan Lakes. At no place, however, is it more than 70 miles wide and it is divided into three major divisions, a northern, eastern, and western. The longer axis of the lake passes through the eastern and western arms in a northeast-southwest direction. The main part of the lake is between latitudes 61 and 62, but a large part of the north and east arms lies to the north. The lake reaches from longitude 117° 30′ to 109°.

The eastern part of the lake, the east arm, is within the area of Precambrian rocks of the Canadian Shield; the rest of the lake lies within an area of Palæozoic sediments. The boundary between the Precambrian and Palæozoic follows the north arm in a northwesterly direction, with Palæozoic strata forming the west shore and patches of Palæozoic lying on Precambrian along the east shore.

The shore of the western arm of Great Slave Lake is for the most part low and is described by Cameron (1922, page 10) as follows:

"The south shore from Stoney Island west to Little Buffalo River is formed of delta deposits from Slave River . . . . At Resolution a low range of hills rises above the silts and extends west into the lake, forming Mission and Moose Islands and, still farther west, Burnt Islands.

From the mouth of Little Buffalo River, which marks the western limit of the delta deposits, the shoreline is characterized by wide, shallow bays separated by low, gravelly, or rocky points. Usually each bay has a gravelly or sandy beach behind which lies a narrow stretch of low, swampy muskeg or shallow, open lagoon. South of Pine Point the ground rises gently inland until at a distance of some 10 miles it reaches an elevation of 300 feet above the present lake-level . . . . West of the mouth of Buffalo River the shoreline is generally low-lying and swampy with few pronounced points.

West of a line drawn from Hay River to Slave Point on the north shore, the shores of the lake are formed presumably of soft shales, and the adjacent land is low-lying and swampy. Long stretches of spruce and tamarack muskegs reach inland from the lake. These are bounded on the south by Eagle Mountains. . . . .

From Slave Point the [north] shore runs north for about 40 miles and then east for 25 miles and then swings in a wide circle to the north arm . . . . Many deep, narrow bays stretch inland approximately parallel to one another . . . . The heads of the bays are in most cases low and swampy, like those on the south shore . . . . Wide marshes, in many cases containing large, open sloughs, stretch inland from the bays. On the broader points low, wave-cut cliffs in the limestone occur, though frequently the cliffs are situated some distance inland from the present lake shore . . . . The inland country north of the lake is a low spruce and tamarack muskeg slightly higher than the lake, with numerous, long, narrow hills rising 100 to 150 feet above lake-level . . . . One of the pronounced features in this region is the absence of drainage towards the lake. Throughout the entire 136 miles of shoreline between Mackenzie River and the North Arm only one small stream was found entering the lake."

South of Great Slave Lake lies the Alberta Plateau, marked by north-facing escarpments extending from near Fort Smith on Slave River northwesterly and giving rise to falls on Hay and Kakisa Rivers. The falls on Hay River are 40 miles south of the lake. On the north side of Great Slave Lake, as pointed out by Cameron, no large streams enter. To the northwest lies Horn Mountain rising, according to Whittaker (1922, page 47), to a height of 2,000 feet above the monotonous plain of muskeg and lake to the southeast. On the North Arm, Ordovician and Silurian rocks form an eastward-facing cuesta rising in the north directly from the plateau surface of the Canadian Shield, whereas in the south the escarpment is close to or at the lake shore.

The following table of formations is taken from reports by Cameron (1922, page 13), and Whittaker (1922, page 51):

Table of Formations

	Formation	Description	Thickness Feet
Cretaceous	....	Soft, greenish shales with sandstone beds and concretions, on Hay River. Thin, fissile, brown-black shales, which weather yellow, on Horn Mountain	
Upper Devonian	Hay River limestones	Hard, dolomitic limestones, shaly limestones, limy shales	300
	Hay River shales	Shaly limestones, soft clay shales with limestone, sandstone, and ironstone bands	400
	Simpson shales	Greenish grey clay shales weathering to fissile shale	150 to 250
Middle Devonian	Slave Point limestone	Grey, shaly limestone	200
	Presqu'ile dolomites	Hard, crystalline dolomites, dolomitic limestones, thin-bedded, grey, shaly limestone	375
	Pine Point limestone	Soft, grey, shaly limestones, blue to black, thin-bedded, hard limestones, grey to brown, shaly limestones	100 to 595
	Horn River shales	Brown-black, fissile shales	100
Silurian	Fitzgerald dolomites	Grey, dolomitic limestones with gypsum and anhydrite	275
Ordovician (at least in part)		Red, calcareous shale, red gypsum, salt, and red, arenaceous shale	595
Precambrian		Hard, red sandstones, granite	

Over the whole of Great Slave Lake area the strata depart only slightly from the horizontal, though there is a regional southwesterly dip. The lower Palæozoic beds outcrop along the North Arm and in the vicinity of Resolution and southward on the south side of the lake. The higher Devonian strata lie to the west and Cretaceous beds occur in Horn Mountain at a considerable elevation above the lake-level. On the south shore, " at Pine Point and in Resolution Bay," according to Cameron (1922, page 34) " the exposures indicate a gentle anticlinal tendency, the apex of the anticline being in the vicinity of the point itself." This anticline is shown by the presence of Pine Point limestones for some distance on both sides of Pine Point, but flanked both to west and east by the higher Presqu'île dolomites. It is probable that the anticline trends in a northwest direction to the north shore, where, in the vicinity of Sulphur Bay, the Presqu'île formation is exposed with the higher Slave Point limestones to the east and west. This anticline is of the nature of a broad warp with gentle dips and is made apparent only by the distribution of the several formations and not by observed dips. It seems probable that even this broad anticline has had an appreciable influence tending to cause the migration of oil toward the axis, for on Pine Point, which is presumably on the axis on the south shore, the Pine Point limestones have a high bituminous content; and on the north shore, seepages of oil occur in the Presqu'île dolomites in the vicinity of Windy (Nintsi) Point, again presumably on the crest of the anticline.

From geological work done by J. J. O'Neill,[1] geologist for the White Beaver Oil Company, it appears there is local folding in the vicinity of Hay River some distance south of Great Slave Lake. The fold on which the White Beaver Oil Company's well was located strikes, according to O'Neill, about northeast and southwest, or at about right angles to the large fold crossing Great Slave Lake from Pine to Windy Points. The closure from crest to trough on this fold is approximately 300 feet, but there may be a southwest plunge since the regional dip of the strata at this locality is in this direction. The position of the apex of the anticline is unknown and it is possible the well was at a considerable distance away from it, in which case the anticline has oil possibilities toward the apex if there is closure to the northeast. Cameron (1918, page 27) also reports gentle anticlinal folding in the Devonian above Alexandra Falls on Hay River, but the extent and magnitude of these folds are unknown.

Seepages of oil are known in only two formations in Great Slave Lake area, namely the Pine Point and the Presqu'île formations. The Fort Creek shales in Norman area have proved to be oil-bearing in the Northwest Oil Company's Nos. 1 and 2 wells and are believed to be equivalent in age to the Simpson shales of Great Slave Lake area. The Simpson shales are not exposed, so far as known, anywhere on Great Slave Lake, but are presumed to underlie the country at the western end of the lake in the vicinity of the Mackenzie, and according to Whittaker (1922, page 52) are exposed on Mackenzie River 5 miles above Rabbitskin River and at intervals to Simpson. No seepages of oil are known from these

[1] Personal communication.

shales, but as they weather easily and rarely outcrop, knowledge regarding them is very limited. At Pine Point, on Great Slave Lake, the Pine Point formation is, in part, highly bituminous, but the sediments exposed there lack the appearance of being such as would act as reservoirs for large quantities of oil and they were barren in the Windy Point well.

The seepages at Windy Point and on Sulphur Bay on the north shore of the lake are from the Presqu'île formation. According to Cameron (1922, page 23) the rocks of this formation where exposed are " massive, bedded, generally coarsely crystalline, porous, and cavernous dolomites. Large caverns and pores are numerous and are frequently lined with dolomite crystals and filled with semi-liquid bituminous matter." This formation, both on account of its oil content and its porosity, is considered to be the best prospective oil horizon in Great Slave Lake area. The Slave Point limestones are also slightly bituminous in certain areas, but lack the porosity that characterizes the Presqu'île dolomite and no seepages of oil are known from them.

The Northwest Oil Company (Imperial Oil, Limited) in 1921-22 drilled a well at Windy (Nintsi) Point on the north shore of Great Slave Lake. The well began in the Presqu'île dolomites and penetrated the total thickness of the Palæozoic below. No oil was found. The well is abandoned. The White Beaver Oil Company in 1922 drilled a well 15 miles south of Great Slave Lake in the vicinity of Hay River. The depth of the well is 712 feet. A strong flow of salt water was struck in the Presqu'île formation. The well is abandoned.

The well of the Northwest Oil Company was drilled on the crest of the broad anticline in the vicinity of Windy Point and, as already stated, began in the Presqu'île dolomite from which oil seeps at that place. Since at this locality the Presqu'île formation has no cover there hardly could be sufficient pressure, within a formation of such high porosity, to cause oil to flow in commercial quantities into a well. No oil was found in the underlying Palæozoic formations. The broad, anticlinal structure that occurs at this locality apparently has influenced the oil to flow toward the crest of the anticline, since that is where the seepages occur. Any oil that might otherwise have been concentrated at the crest of the anticline is escaping by seepage and no commercial production is to be expected at this locality. The conditions under which the oil occurs lead to the hope that if, at the western end of Great Slave Lake where the Presqu'île formation is presumably overlain by the Simpson shales, other anticlines, preferably not so broad, exist, the prospects for oil wells on such anticlines would be very good. On such structures the Simpson shales would form an effective cover to retain the oil in the Presqu'île formation which, as it is sufficiently porous over a wide area where exposed, would probably be porous in the west also. The only exploration so far attempted, on the north side of Mackenzie River at the western end of Great Slave Lake, was the survey of Horn River and Horn Mountain by

E. J. Whittaker. Mr. Whittaker found no exposed Devonian rocks younger than the Pine Point limestones and no evidence of structure suitable for oil accumulations. Cretaceous strata form Horn Mountain, but since the Devonian is separated from the Cretaceous by an erosional unconformity it is not known if the whole Devonian succession is present; however, as the Simpson shales outcrop on Mackenzie River it is inferred that they are present and hence there would be a suitable cover for an oil field. Since east of Horn River there are no large streams, the possibility of finding suitable outcrops by which to determine local structure is rather remote and search for structures within this promising area would have to be undertaken by shallow drillings.

There appears to be little prospect of finding oil in the broad anticline at Pine Point. No great thickness of Palæozoic sediments is present and as the Pine Point formation outcrops it scarcely could act as a reservoir rock.

At the location of the White Beaver Oil Company's well on Hay River, 15 miles south of Great Slave Lake, there is some local folding. Drilling, however, as already stated, yielded a strong flow of salt water from the Presqu'île formation. If there is any movement of underground water through the Presqu'île formation, the presence of sulphur springs and oil seepages on the north shore of Great Slave Lake would point to a northward flow, but the regional dip of the rocks is apparently southwestward and there is no known place where the Presqu'île outcrops at an elevation sufficient to give a hydrostatic head great enough to cause the strong flow of salt water at the White Beaver Oil Company's well. Thus, the only probable explanation for this strong flow is that the well was drilled on the flank of an anticline, or dome, in the central part of which gas exists under pressure sufficient to cause the water to flow when the proper horizon was reached by the drill. If such is the case some oil may be present below the gas and above the salt water, but the amount of gas and oil in this structure, if such are present, depends on the size of the structure, i.e. the closure above the salt water. If the well location is high up on the flank of the fold the amount of structure that can possibly be occupied by oil and gas will be relatively small, whereas if the well is at a considerable distance down the flank there is a possibility that commercial supplies of gas and oil may be found. Since the details of the structure and the relation of the well to it are not known no predictions can be made.

The following log of the Windy Point well, as given by Cameron (1922, page 16), illustrates the thickness and character of the various formations at this place. The top of the well is 15 feet above Great Slave Lake.

Log of Windy Point Well

Age	Formation	Description	Thickness Feet	Depth Feet
Middle Devonian		Sand and broken rock	6	0 to 6
	Presqu'île dolomites	Light grey dolomite	15	6 to 21
		Dark brown, dolomitic limestone	15	21 " 36
		Light brown, dolomitic limestone	50	36 " 86
		Soft, grey, shaly limestone	15	86 " 101
		Mottled, partly recrystallized, dolomitic limestone	25	101 " 126
		Soft, grey, shaly limestone	5	126 " 131
		Mottled, partly recrystallized, dolomitic limestone	25	131 " 156
		Soft, grey, shaly limestone	5	156 " 161
		Mottled, partly recrystallized, dolomitic limestone	14	161 " 175
	Pine Point limestones	Grey, shaly limestone	165	175 " 340
		Hard, grey limestone	157	340 " 497
		Brown, shaly limestone	33	497 " 530
		Hard, black limestone	20	530 " 550
		Brown, shaly limestone	30	550 " 580
		Hard, grey limestone	20	580 " 600
		Dark grey limestone	30	600 " 630
		Grey, shaly limestone	50	630 " 680
		Dark grey limestone	50	680 " 730
		Light grey, shaly limestone	40	730 " 770
Silurian	Fitzgerald dolomites	Light brown, dolomitic limestone	20	770 " 790
		Grey, dolomitic limestone with gypsum	110	790 " 900
		Gypsum	10	900 " 910
		Grey, dolomitic limestone with gypsum	70	910 " 980
		Gypsum and anhydrite	65	980 " 1,045
[1]Ordovician (at least in part)	Red beds	Red shale with gypsum and salt	25	1,045 " 1,070
		Reddish stained salt	20	1,070 " 1,090
		Salt	30	1,090 " 1,120
		Red shale with salt and gypsum	20	1,120 " 1,140
		Gypsum	40	1,140 " 1,180
		Dark shale with gypsum and salt	20	1,180 " 1,200
		Salt	20	1,200 " 1,220
		Red shale with gypsum	40	1,220 " 1,260
		Red shale with gypsum and salt	120	1,260 " 1,380
		Reddish stained salt	10	1,380 " 1,390
		Gypsum and anhydrite	10	1,390 " 1,400
		Red shale with gypsum and salt	240	1,400 " 1,640
Precambrian		Red sandstone	20	1,640 " 1,660
		Brownish red sandstone	90	1,660 " 1,750
		Granite	56	1,750 " 1,806

[1] An Ordovician fauna was found in these red beds on the southern part of the North Arm. *See* report "Ordovician and Silurian Fossils from Great Slave Lake"; Geol. Surv., Canada, Mus. Bull. No. 44, pp. 59-64.

NORMAN AREA

(*See* Figure 24)

Norman area lies north of latitude 65 and in the vicinity of longitude 127. Norman is at the junction of Great Bear and Mackenzie Rivers and the area tested by drilling lies approximately 50 miles northwest.

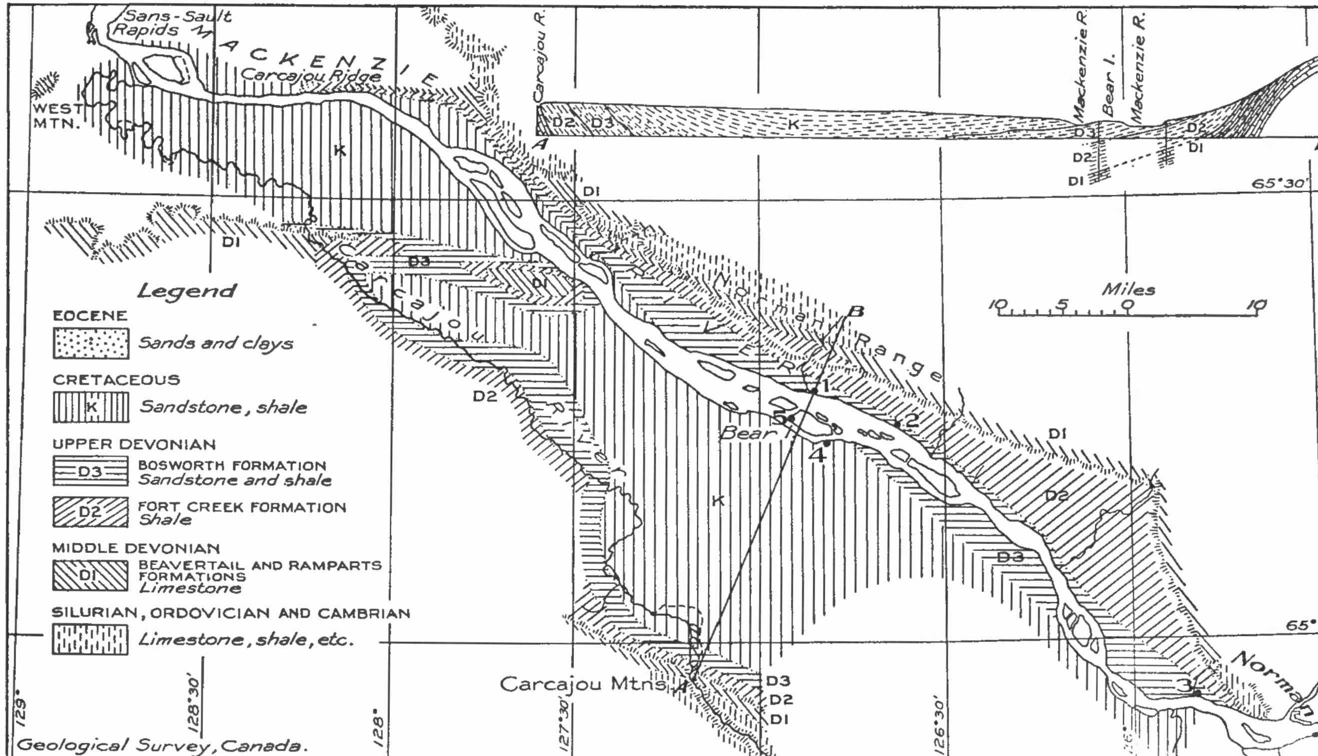

Figure 24. Norman area, District of Mackenzie: 1, Northwest Oil Co., No. 1 and No. 2; 2, Fort Norman Oil Co.; 3, Northwest Oil Co., Bluefish well; 4, Northwest Oil Co., "O" location; 5, Northwest Oil Co., "D" location (on Bear Island).

The Mackenzie lowland through which Mackenzie River flows has a general northward slope. In the vicinity of Norman oil area the lowland is a relatively narrow strip of country between the Norman Range on the east and Carcajou Mountains on the west. The Norman Range rises approximately 2,500 feet above Mackenzie River, whereas Carcajou Mountains are higher and much more rugged. The country between the mountains is heavily forested with spruce, poplar, and alder, and is covered by muskeg in which there are innumerable small lakes. Looking north-eastward from Carcajou Mountains the country appears to be rather flat and one-quarter to one-fifth of the whole area is occupied by lakes and sloughs from which in many cases there are but poorly developed drainage channels. At a few feet below the muskeg surface, even in summer, a layer of ice is encountered in many places and presumably the ground at a slight depth below the surface is permanently frozen.

Rock exposures are almost entirely absent except along the larger streams and rivers and in the mountains. The following table of formations indicates the stratigraphic succession so far as it is known.

<table>
<tr><th>Age</th><th>Formation</th><th>Description</th><th>Thickness Feet</th></tr>
<tr><td>Eocene</td><td></td><td>Imperfectly consolidated sands and clays</td><td></td></tr>
<tr><td colspan="4">Erosional unconformity</td></tr>
<tr><td>Cretaceous</td><td></td><td>Black, soft, fissile shales and greenish sandstones. Lower members with coal in some localities. Upper member marine, carrying ammonites</td><td></td></tr>
<tr><td colspan="4">Erosional unconformity</td></tr>
<tr><td rowspan="2">Upper Devonian</td><td>Bosworth</td><td>Greenish sandstones and shales</td><td>1,600+</td></tr>
<tr><td>Fort Creek</td><td>Mostly black shales</td><td>1,000 to 1,500</td></tr>
<tr><td rowspan="2">Middle Devonian</td><td>Beavertail and Ramparts</td><td>Limestones</td><td>400 (?)[1]</td></tr>
<tr><td>Hare Indian River</td><td>Shales</td><td>300+</td></tr>
<tr><td rowspan="3">Silurian</td><td rowspan="3">Bear Mountain</td><td>Brecciated limestones</td><td>400 to 450</td></tr>
<tr><td>Well-bedded limestone</td><td>1,000</td></tr>
<tr><td>Red, gypsiferous shales</td><td rowspan="3">770</td></tr>
<tr><td>Ordovician (?)</td><td></td><td>Red shales, no fossils</td></tr>
<tr><td>Cambrian</td><td></td><td>Red and greenish shales and sandstone. Bottom not seen</td></tr>
</table>

[1] In Geol. Surv., Canada, Sum. Rept. 1922, pt. B, p. 55, it was shown that the Beavertail limestone was only 60 feet thick at the Wolverine anticline. It is probable that in the measurements by Kindle and Bosworth part of the Ramparts limestone (*Stringocephalus burtoni* zone) was included in the Beavertail. The thickness of the Beavertail-Ramparts limestone is given by the log of Northwest Company's No. 2 well, but it is not known to what formation the shales under the limestones belong.

Norman Mountains are anticlinal in form. The mountains east of the Northwest Company's No. 1 well represent the western half of a great fold, the axis of which has been eroded, leaving a deep valley with abrupt, eastward-facing cliffs. The mountains are composed of westward-dipping Silurian rocks, on the flanks of which, toward the Mackenzie, lie Devonian formations in ascending order, with the Bosworth formation outcropping at the east side of Mackenzie River at the Northwest Company's No. 1 well. On the west side of the river these beds are overlain by Cretaceous, and it is presumed the westward dip continues for some distance west. On the west slopes of the valley, Devonian limestones again appear at the surface at the eastern edge of Carcajou Mountains, and westward in the mountains Silurian and Cambrian rocks occur, indicating an eastward dip. The structure between Norman and Carcajou Mountains in a section through the Northwest Company's No. 1 well is thus a large basin in the central part of which Cretaceous rocks occur with the lower formations on both flanks. To the northwest, a cross-fold trending almost east and west brings Middle Devonian rocks to the surface at Mackenzie River and forms a distinct ridge which crosses Carcajou River about 50 miles above its junction with the Mackenzie. The north slope of this ridge is very steep west of Carcajou River where the beds dip northward at 80 degrees and it is probable that to the west the fold passes into a fault. Farther down Mackenzie River, another cross-fold parallel to that just described forms Wolverine anticline or Carcajou Ridge on the northeast side of the Mackenzie and may continue as far west as West Mountain, although in the intervening area Cretaceous rocks showing only small dips are exposed near the mouth of Carcajou River. Eastward the Wolverine anticline abuts against a mountain of the Norman Range. Between this mountain and the Mackenzie, in a southwest direction, the country is flat and dotted with small lakes and sloughs lying in a muskeg that conceals all underlying rock. Thus, in the northern part of the basin between Norman and Carcajou Mountains there are cross-folds that modify the basin structure, but since these cross-folds are such that they bring the Middle Devonian rocks to the surface they do not appear to offer favourable structures for oil. The details of the structure in the southern part of this basin are unknown, but it may be that other minor folds occur either parallel to the main mountain ranges or parallel to the cross-folds already described. Such minor folds, if present, would be the most favourable locations for test wells, but since the country is almost completely covered by a thick deposit of muskeg the location of such folds would be extremely difficult.

Northwest Company (Imperial Oil Company) No. 1 Well was drilled in 1920 on the east side of Mackenzie River at the mouth of Bosworth Creek. This is the " discovery " well in which oil estimated at 100 barrels a day was obtained at a depth of 783 feet. The oil came from the Fort Creek shales and cavings caused the cessation of the flow. In 1922 the well was deepened to 951 feet and a flow of 60 to 70 barrels of oil was secured. In 1923 the well was further deepened to 1,025 feet and the flow of oil increased to about 100 barrels. It is understood the well has a potential capacity at the present time of about 100 barrels a day. The well is now capped.

Fort Norman Oil Company well was drilled in 1921 about 8 miles up Mackenzie River from the Northwest Company's No. 1 well, on the east bank of the river. The well was drilled to a depth of 1,512 feet. A flow of gas estimated at 300,000 cubic feet a day was obtained between depths of 385 and 500 feet. No commercial supply of oil was secured.

Northwest Oil Company. Bluefish Well. This well is located on the east bank of Mackenzie River at the mouth of Bluefish Creek, a short distance down the Mackenzie from Bear rock at the mouth of Great Bear River. The well was abandoned because of drilling troubles.

Northwest Oil Company " C " location well was drilled in 1921-1922. It is located on the west side of Mackenzie River south and slightly east of the Northwest Oil Company's No. 1 well. It was drilled to a depth of 3,057 feet and finished in the Beavertail limestone. It is a dry hole.

Northwest Oil Company "D" location well is on Bear Island, Mackenzie River, south and slightly west of the Northwest Oil Company's No. 1 well. The well was drilled in 1921 to a depth of 2,304 feet. A small show of oil was obtained at about 1,945 feet and a flow of salt water at 2,060 feet. The flow of oil occurred at the contact of the Fort Creek and Beavertail formations. The salt water flow occurred in the Beavertail-Ramparts limestone.

Northwest Oil Company No. 2 well was drilled in 1924-25, 150 feet from No. 1 well. A production of oil was obtained at 936 and 1,063 feet, amounting to about 110 barrels a day. Also " shows " of oil were found at other depths. The main flow is believed to be from the Fort Creek shales. The well was drilled to 1,602 feet, but without any further results.

The Northwest Oil Company's No. 1 well was drilled on a seepage of oil issuing from the Bosworth formation. A number of other seepages from this formation are known east of the Mackenzie, but so far as the writer is aware no seepages have been reported in this area west of the Mackenzie. The Bosworth formation consists of alternating beds of shale and sandstone and is considered the most favourable for oil accumulations of any of the Devonian formations, since the proportion of sand in it is much higher than in any other Devonian horizon.

As proved by the Northwest Company's Nos. 1 and 2 wells the Fort Creek formation contains oil. The shales of this formation in many exposures are highly bituminous.

The brecciated limestones that are tentatively placed in the Silurian Bear Mountain formation are in places so highly bituminous that a strong odour is emitted on breaking the rock. These brecciated limestones are, in places, quite dolomitic and are sufficiently porous to act as an oil reservoir. At other places, however, they contain much gypsum and it is possible the brecciation has resulted from the change of anhydrite to gypsum. It is possible in certain localities these rocks might be found to be oil-bearing, but in the mountains where they are exposed no seepages of oil from them were seen.

The basal Cretaceous beds are largely sandstones with some shale and as they lie in certain localities on the Bosworth formation, which is undoubtedly oil-bearing, they might under favourable structural conditions act as oil reservoirs. The basal sandstones are overlain by fissile black shales, capable, on account of their fineness, of acting as a suitable cap rock to retain the oil. In certain localities, however, the black, Cretaceous shales rest directly on the Devonian and as the Cretaceous is separated from the Devonian by an erosional unconformity the Cretaceous rests on the Bosworth formation in some localities, whereas in other localities, as for example at the Ramparts of the Mackenzie, the Cretaceous shales rest on the Ramparts limestone. The most favourable localities, therefore, for oil in the Cretaceous, would be where the basal sandstones rest on the Bosworth formation under cover of the higher Cretaceous shales and where there is sufficient local structure to concentrate the oil. There are certain portions of country in the vicinity of Little Bear River where such conditions are fulfilled, but nothing is known regarding the details of local folding.

Nos. 1 and 2, Bear Island and "C" wells of the Northwest Oil Company, and the well of the Fort Norman Oil Company, were drilled on westward-dipping beds on the west flank of the anticlinal fold that forms the Norman Range. The Bear Island and "C" wells are down the dip from Nos. 1 and 2 wells and seem to indicate that no oil may be expected in that direction along the dip slope. It is very difficult to understand how the oil has been accumulated at Nos. 1 and 2 wells of the Northwest Oil Company in a shale formation (Fort Creek) which with the associated formations dips uniformly westward and comes to the surface only a few miles east of the wells. In the Fort Creek formation on Canyon and Vermilion Creeks, a sandstone horizon 50 to 70 feet thick was found about 800 feet above the base of the formation. In a former report it was suggested that the accumulation of oil in the vicinity of the wells might be due to the presence of the sandstone horizon that occurs on Canyon Creek, but this sandstone is not present in No. 2 well. No local folding with which the concentration of oil might be associated has been detected in the vicinity of the oil wells.

As already stated two large cross-folds are known at the north end of the basin structure, but since in each erosion has revealed the core of Middle Devonian rocks, their value as oil structures is very doubtful and depends only on the possibility that oil might be present in the brecciated limestones underlying the Devonian rocks. As already stated, these in places are sufficiently porous to act as oil reservoirs and are known to be somewhat bituminous.

It has been stated that some seepages on the east side of Mackenzie River come from the Bosworth formation which outcrops over large areas. As there is no cover to prevent the free escape of the oil at the outcrop no production could be hoped for from this formation over the area where it is exposed at the surface. If, however, local structures could be located in the areas to the west where the Bosworth is overlain by Cretaceous shales, the prospects for oil accumulations in the Bosworth would seem to be good. Since the Bosworth formation is thinner at " C " well than on Carcajou River to the west, the strata of the uppermost part of " C " well were at first considered to belong to the Bosworth formation, but are now confidently believed to be Cretaceous shales. Thus at " C " well there is a cover of Cretaceous shales which would prevent the escape of the oil upwards, but since " C " well is down the dip from Nos. 1 and 2 wells of the Northwest Oil Company and no local structure is known, there is no apparent reason why any oil originally present in the Bosworth formation should not have migrated up the dip and escaped at the outcrops on the eastern side of Mackenzie River. That such a process is taking place seems to be indicated by seepages at the outcrop. The structural conditions at Bear Island well are similar to those at " C " well and the conclusion to be drawn from these two wells seems to be that no accumulation of oil is likely to occur on the west side of Mackenzie River except where there is a local structure superimposed on the basin structure such as would prevent the migration of the oil to the outcrop.

The migration of the oil up the dip in an eastward direction assumes, on the basis of the hydraulic theory of oil migration, an underground flow of water in the basin structure from west to east, and this seems to be borne out by the springs and seepages on the east side of Mackenzie River. The relative elevations of the outcrops of the Devonian on the east and west sides of this basin are imperfectly known, but the country in the vicinity of Carcajou Mountains where the Bosworth beds outcrop is somewhat higher than the territory occupied by the Bosworth formation on the east side of Mackenzie River. This difference in elevation may provide the hydrostatic head necessary to cause the eastward migration of the underground waters, as a result of which the oil would be flushed toward the eastern side of the basin and would appear at the outcrop in seepages such as do occur. By such a theory the most favourable prospects for oil would lie toward the eastern outcrop, where local folds on the main fold are of such a nature that the eastward flow is prevented and the oil caused to accumulate. If such local folds are not present the oil would be flushed to the outcrop, would be lost, and no commercial production could be expected. It is unfortunate that the conditions causing the accumulation of oil at Nos. 1 and 2 wells of the Northwest Oil Company are not understood, but since in those wells the oil occurs in shales that on account of their texture offer very little opportunity for the migration of liquids, the conditions are not comparable with those involving movement through sandstones, such as are present in the Bosworth formation. It seems almost necessary to assume a certain amount of fracturing of the shales to allow an accumulation of oil in them at any point on a scale sufficient to give an oil well, and, if such is the case, the wells when freely drawn upon would not be expected to yield oil for any great length of time.

From what is known of Norman oil field, the prospects for a large production of oil do not seem very favourable, unless local structures superimposed on the basin structure can be located. If the hydraulic theory of accumulation of oil be accepted the best prospects should occur toward the eastern side of the basin in such local anticlines as exist. It would seem unreasonable to assume in the downwarping of a basin such as that between Norman and Carcajou Mountains, that the movement was so regular as to cause only one, large, regular downfold without a certain amount of local crumplings. That such was not the case is shown at the northern end of the basin where cross-folds have been developed. Other small folds, either parallel to the mountains or to the cross-folds, should occur elsewhere. The writer is of the opinion that the value of the Norman oil field as a large producer of oil depends on the extent to which minor folds have been developed and can be located in areas favourably situated.

It is well established that oil-bearing beds are present and that there are a number of horizons which, given proper conditions, are of sufficient porosity to act as oil reservoirs.

An analysis of the oil from the Northwest Oil Company's No. 1 well, made by J. A. Kelso, University of Alberta, and published in Geological Survey, Summary Report 1920, Part B, page 58, is as follows:

Specific gravity	0·845 (36° Baumé)	
Distillation—		
70 to 150 degrees C.	22·5 per cent	(Gasoline)
150 " 300 "	38·5 "	(Illuminants)
300 " 350 "	33·9 "	(Light lubricants)
350 " 375 "	4·1 "	(Medium lubricants)
Loss	1·0 "	

The following log, supplied and published with the permission of the Imperial Oil Company, illustrates the character of the sediments in Norman area.

Log of Northwest Oil Company's No. 2 Well, Norman

	Depth Feet
Surface materials	0 to 30
Light grey, slightly calcareous, clay shale with a little fine sand	30 " 120
Light grey, non-calcareous, clay shale. Showing of oil at 122 feet	120 " 130
Light grey, non-calcareous, clay shale with a little fine sand	130 " 200
Light grey, calcareous, clay shale with a little fine sand	200 " 220
Light grey, non-calcareous, clay shale with a little fine sand	220 " 230
Bluish grey shale with grey sandstone	230 " 240
Harder, bluish grey shale, sandy	240 " 270
Bluish grey shale, sandy. Gas at 272 feet	270 " 280
Bluish grey shale	280 " 290
Bluish grey shale, sandy	290 " 310
Bluish grey shale, calcareous	310 " 320
Bluish grey shale, sandy	320 " 390
Bluish grey shale, soft	390 " 400
Bluish grey shale	400 " 430
Bluish grey shale, sandy and hard	430 " 440
Bluish grey shale, sandy	440 " 450
Bluish grey shale, very little sand	450 " 460
Bluish grey shale	460 " 490
Bluish grey shale, fairly hard	490 " 500
Bluish grey shale	500 " 700
Dark grey, soft, calcareous shale with some bluish grey shale	700 " 710
Bluish grey shale, calcareous and harder than above	710 " 720
Bluish grey shale, fairly hard, non-calcareous	720 " 770
Bluish grey shale, fairly hard, calcareous	770 " 790
Bluish grey shale, non-calcareous. Showing of oil at 792 feet	790 " 810
Bluish grey shale	810 " 850
Bluish grey shale, fairly hard, calcareous	850 " 860
Bluish grey shale, slightly calcareous	860 " 880
Bluish grey shale, fairly hard, calcareous. At 895 feet 25 bbls. of oil, which decreased to 2 bbls. a day	880 " 900
Bluish grey shale, fairly hard, slightly calcareous	900 " 920
Bluish grey shale, fairly hard, non-calcareous	920 " 950
Blue-black shale, hard, non-calcareous, some pyrite	950 " 960
Blue-black shale, with some pyrite and calcite in veins	960 " 970
Blue-black shale	970 " 980
Dark, greyish black shale, soft	980 " 1,030
Dark, greyish black shale with brownish tinge	1,030 " 1,040
Dark, greyish black shale, harder	1,040 " 1,050
Dark, greyish black shale, very hard, with much pyrite	1,050 " 1,060
Dark, greyish black shale	1,060 " 1,070
Dark, brownish black shale, hard, with pyrite. This is evidently the base of the Fort Creek shales	1,070 " 1,086

Log of Northwest Oil Company's No. 2 Well, Norman—Continued

	Depth Feet
Hard, brown limestone with petroleum odour	1,086 " 1,095
Hard, brown limestone	1,095 " 1,130
Hard, brown limestone, petroleum odour	1,130 " 1,140
Hard, brown limestone	1,140 " 1,190
Hard, brown limestone, becoming darker with depth	1,190 " 1,200
Hard, brown limestone	1,200 " 1,240
Hard, dark brown limestone	1,240 " 1,250
Hard limestone, lighter colour than above	1,250 " 1,260
Hard, brown limestone	1,260 " 1,290
Hard, light brown limestone	1,290 " 1,450
Hard, light brown limestone, becoming more shaly	1,450 " 1,460
Hard, light brown limestone	1,460 " 1,470
Hard, light brown limestone with some dark shale	1,470 " 1,480
Dark grey, calcareous shale	1,480 " 1,600

It is not definitely known what horizon is represented by the shales in the bottom of this well. The Beavertail and Ramparts limestone from sections measured in other parts of Norman area are considered to have a thickness exceeding that of the limestones in this well, but it is possible that the thickness in outcrops was over-estimated. Outside Norman area the Ramparts limestone overlies the Hare Indian River shales, and, possibly, these may be partly represented by the shales in the bottom of the well. Kindle and Bosworth (1921, page 44) state that the thickness of the Hare Indian River shales exceeds 300 feet, so that it is possible the well stopped in these shales. The objection to this interpretation of the lower shales of the well is that the Hare Indian River shales are not known to be present elsewhere in Norman area and since in the mountains both to the east and the west the Ramparts limestone rests directly on brecciated limestones and dolomites of the top of the Bear Mountain formation, the Hare Indian River shales have been presumed absent. It is possible, therefore, that the calcareous shales reported in the well, from 1,480 to 1,600 feet, are a shaly phase of the Ramparts limestone, or possibly are a phase of the Bear Mountain brecciated limestones. However, in view of what is known of the stratigraphy of Norman area, neither of these possibilities seems logical and it is much more reasonable to assume the shales belong to the Hare Indian River formation. This would mean a considerable erosional interval between the Silurian and the Devonian in order to account for the absence of these shales in Carcajou Mountains where in the cliffs along the gorge of Carcajou River the contact between the Devonian and Silurian can be observed for long distances.

ARCTIC RED RIVER AREA

The Geological Survey has no detailed information about the Arctic Red River area, but it is known from reconnaissance studies that there is a large area in the vicinity of Arctic Red and Peel Rivers where Cretaceous overlies Upper Devonian strata. The character of the Devonian is not well known but is assumed to be somewhat like that of the Devonian of Norman area, 250 to 300 miles to the south. The rocks where exposed along Mackenzie River have gentle dips quite in contrast with the sharp folds along the Mackenzie at the Sans Sault rapids south of the Ramparts.

The country back from the river is a broad plateau. The prospects for oil and gas depend on the presence of petroliferous strata which may be assumed to be present, and the presence of local folds. It is believed the Cretaceous would form an adequate cover for the retention of any oil that may have accumulated in local structures. No information is available regarding the presence of reservoir rocks, but regional studies from Norman south to Great Slave Lake seem to point to a northward increase of sandstones in Upper Devonian strata, and hence reservoir rocks might reasonably be expected. It should be remembered, however, that the Devonian is unconformably overlain by the Cretaceous and there may be areas, as at the Ramparts of the Mackenzie, where the Upper Devonian has been wholly eroded prior to Cretaceous deposition.

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CHAPTER X

BRITISH COLUMBIA

FLATHEAD AREA

Flathead area is in southern British Columbia a few miles west of the Alberta boundary. From Waterton Lake in Alberta to the east side of Flathead River Valley is a belt of Precambrian strata the structure of which is broadly synclinal (*See* Chapter IV, Waterton Lake and Cameron Brook Area). The central part of this syncline is occupied by Cambrian and later Palæozoic rocks, part of which from included fossils are assigned to the Silurian. The west limb consists of Precambrian argillites, quartzites, and limestones with lava flows and sills dipping in a northeasterly direction and consisting of successively lower beds to the west. Along the east side of Flathead Valley, however, at the western margin of the area of Precambrian rocks, there is a reversal of dip, but east and west cross-folds so modify the structure that instead of a continuous anticline there is a series of domes. Three domes were seen by the writer during a reconnaissance trip in 1932 and others are said to occur. Only one of the three seen was studied in detail. This dome (*See* Figure 25) is in the valley of Sage Creek, a tributary of Flathead Valley. To the south of it lies a somewhat smaller dome at the head of Fisher Creek. This dome is at a much higher elevation than the Sage Creek dome and is less deeply eroded. South of it in the valley of Kishinena Creek is another dome of apparently the same type as that at Sage Creek. Another dome is said to occur on Starvation Creek south of the Kishinena dome and only a short distance north of the International Boundary. Other domes have also been reported from the area north of Sage Creek.

Seepages of oil were seen by the writer on the Sage Creek and the Kishinena domes. On the Kishinena dome the oil issues from joints and bedding planes in dense and hard argillites of the Appekunny formation. The beds do not appear to be fractured at the point of seepage and the oil slowly accumulates in small pockets in the gently dipping strata on the edge of a beaver dam lake. In Sage Creek area there are a number of seepages of both oil and gas. All issue from gravel overlying bedrock and the flow is said to be partly dependent on the amount of water flowing through the gravel and thus carrying the oil to the outlets. In August, 1932, during a period of occasional rains, one seepage in which a steel barrel had been sunk with both ends open produced steadily over a period of days, by bailing twice a day, 1¼ to 1½ gallons of light yellowish oil a day. Several other seepages in the immediate vicinity were not tested, but an astonishing amount of oil was in evidence and although the oil seepages were not actually seen issuing from the rock at any place owing to the gravel cover, yet it seemed reasonable to attribute the seepages to known fracture zones that could be seen and outlined on the mountain at the valley edge. The dense, hard rocks of the Precambrian are totally unsuited to act as a source for oil or gas and hence it is a logical conclusion that the oil and gas issuing from them comes up through cracks and fissures

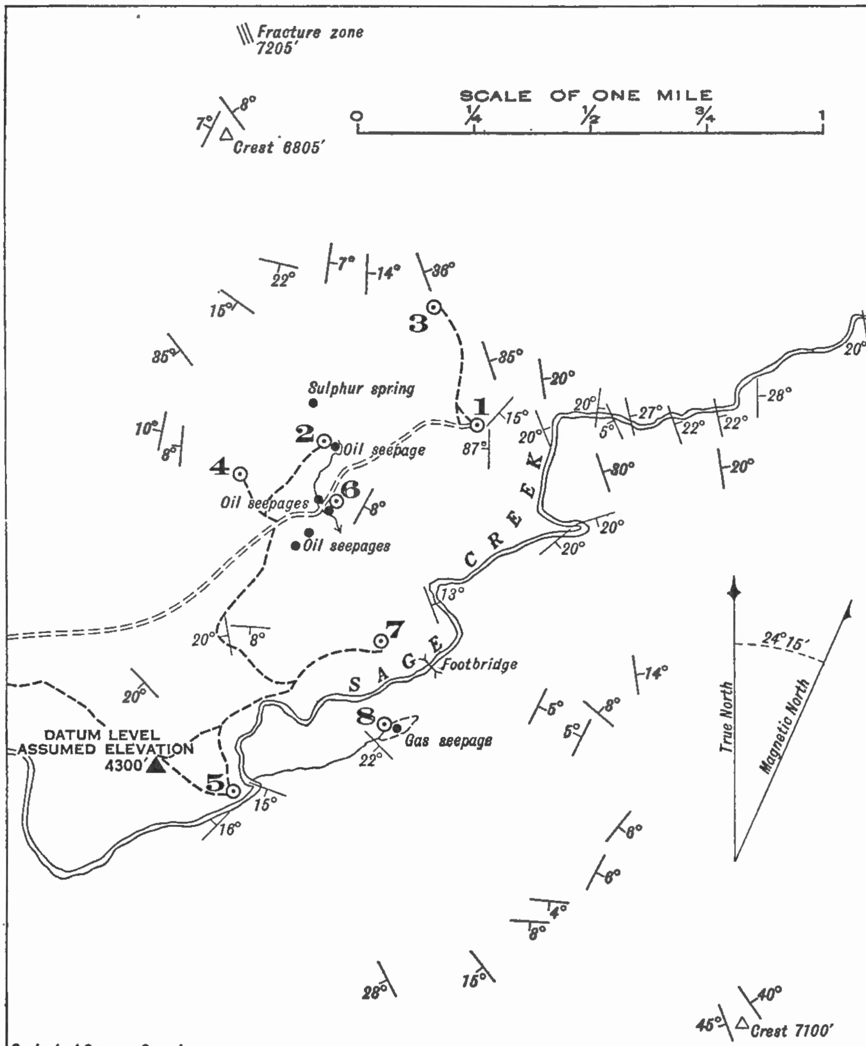

Figure 25. Sage Creek dome—wells: 1, Crowsnest Glacier No. 1; 2, Crowsnest Glacier No. 2; 3, Crowsnest Glacier No. 3; 4, Crowsnest Glacier No. 4; 5, Flathead No. 1; 6, Flathead No. 2; 7 and 8, British Columbia Oil and Coal Development Company.

from underlying Mesozoic or Palæozoic rocks separated by a fault from the Precambrian above. Such an origin is quite in harmony with the known occurrences of oil and gas elsewhere in Mesozoic and Palæozoic beds. Thus it would seem that the prospects for production of oil and gas by drilling on these domes would be dependent on two factors: (1) the presence of suitably porous horizons in the Mesozoic or Palæozoic strata underlying the Precambrian; (2) a favourable structure to cause an accumulation of oil and gas in the Mesozoic or Palæozoic strata under the fault plane.

As already mentioned in Chapter IV in discussing the Waterton Lake-Cameron Brook area, the Lewis fault has been studied in a number of places along the eastern margin of the Precambrian area in Alberta. The amount of disturbance exhibited by the beds immediately underlying the fault plane is very great. Large masses of Palæozoic rocks have been torn from their roots and carried along the fault plane (or zone) under the Precambrian strata and thrust into soft, coal-bearing Kootenay strata that lie below the fault, are overturned, and lie on Blairmore rocks. Under such conditions any brittle rocks in and close to the fault zone must necessarily have been highly fractured, and it is thought that such a fracture zone might possess the degree of porosity requisite for large oil and gas reservoirs. It is believed, as already stated, that the Precambrian strata of Flathead area lie on younger strata from which they are separated by a fault, perhaps a continuation of the Lewis thrust, and it may be that this fault zone is the reservoir from which arise the seepages on Sage Creek and elsewhere. Possibly porous horizons in either the Mesozoic or the Palæozoic beneath the fault are the sources of the seepages, but what horizons these might be and how far below the fault they may lie are unknown.

There is no apparent reason why oil and gas seepages should be connected with a dome in Precambrian rocks unless the concentration of oil and gas is also due to the dome structure. The Precambrian rocks are too dense to act as reservoir rocks except where greatly fractured so that any large accumulation, if present, must be in the underlying fractured fault zone or in the younger strata underlying it. Neither the fault zone nor the underlying Palæozoic or Mesozoic strata would be expected to contain commercial supplies of oil unless they also have a domed structure favourable for its concentration. This implies that the domed structure exhibited in the Precambrian rocks at the surface persists downwards across the fault plane into the younger, underlying beds and that warping or folding took place subsequent to faulting. It is peculiar that isolated domes occur along the western edge of the Precambrian area. This edge is a pronounced fault and, therefore, anticlinal folds continuous over considerable distances might more logically be expected, especially if the fault is an underthrust as it has been thought to be by Link (1932, page 786). The breaking up of the anticlinal condition into domes could result, however, from east-west folds subsequent to faulting. To the east, in Waterton Lake-Cameron Brook area, a major fault occurring on Mount Crandell is distinctly folded (*See* account in Chapter IV) and there are reasons for believing that the Lewis fault is also folded. Such conditions support the probability that the dome structure of the Precambrian of Sage Creek area persists downwards across the fault into the Mesozoic or Palæozoic strata and on this being actually the case the oil and gas prospects to a large extent depend.

The depth to the fault in Sage Creek and Kishinena areas is unknown. In each area the lowest strata exposed belong to the base of the Appekunny formation below which in Waterton Lake area there is thought to be 4,000 to 4,500 feet of strata above the Lewis thrust. The dome at the headwaters of Fisher Creek is less deeply eroded and the lowest beds there exposed are a series of quartzites that are estimated to be at least 2,000 feet above the base of the Appekunny formation. It is unknown whether there are more or less beds above the fault in Sage Creek-Kishinena Creek area than in Waterton Lake-Cameron Brook area, but if it be assumed that the thickness is about the same then a well on the Sage Creek dome, such as is now being drilled by the Crows Nest Glacier Oil Company, Limited, could hardly reach the fault plane at a depth of less than 4,000 to 4,500 feet or even deeper if the dip of the beds is considerable in any part of the section. Evidences of oil and gas have not been lacking in a number of wells drilled in Sage Creek area and numerous oil and gas seepages occur. It seems, therefore, that the area is worthy of being tested by drilling a deep well, but that the test may be conclusive the well must be drilled through the overthrust Precambrian mass into the younger strata below the fault plane.

A certain amount of drilling has been done in Akamina Valley 17 miles west of Waterton Lake and 6½ miles west of the boundary between Alberta and British Columbia. This area is almost in the centre of the great synclinal area between Waterton Lake and Flathead Valley. In this area there are probably not less than 11,000 feet of Precambrian sediments, lava flows, and sills, and as these are too thick to be drilled and the structure is wholly unfavourable for accumulations of oil and gas in quantity the prospects are negative. It is said that seepages occur in this area at certain times when water conditions are favourable. If this is so, it would seem that the seepages must consist of oil carried by surface waters to the central part of the basin structure and hence are not an indication of a large supply at depth in this particular area.

A limited amount of drilling has also been done within Flathead Valley west of the Precambrian area. The southern part of Flathead Valley is underlain by freshwater Tertiary strata resting on the bevelled edges of Mesozoic and Palæozoic sediments and overlapping onto the Precambrian. North of Sage Creek, and on Commerce Creek close to the edge of the Precambrian, occurs a ridge of Mississippian strata extending northward for several miles.

West of Flathead River the edges of Mesozoic formations are exposed and Mississippian strata are overthrust onto them from the west. Since the horizons within these formations that elsewhere are productive of oil and gas are thus exposed at the surface there are no prospects of them affording oil and gas. The Tertiary, where seen on the west side of Flathead Valley, has in general an eastward dip of 15 to 25 degrees. It is certain that the lowest horizons occur under the gravel on the west side of Flathead Valley. Massive conglomerates that occur on the east side of the valley are highly suggestive of basal beds. Although there is some doubt about the structure across the whole valley, due to the lack of outcrops, it is possible that the Tertiary strata lie in a syncline and with the edges of all beds exposed on the west side and perhaps on the east side as well. If this is the situation then there is no reason why any oil or gas accumulations should occur in the syncline. There is, however, a possibility that small folds may occur within the syncline, but the freshwater character of the Tertiary beds would not be favourable for the generation of large amounts of either oil or gas, although small amounts derived from carbonaceous and lignitic materials are undoubtedly present and will give shows of gas in wells drilled into them but without any prospect of sustained or commercial production.

FRASER RIVER AREA[1]

By W. A. Johnston

Drilling Operations and Their Results

The first deep drilling in Fraser River Delta area was done about 1875 in search of workable seams of coal. The first bore-hole was located on the south shore of Burrard Inlet. About 1887 the Canadian Pacific Railway Company drilled a number of holes at Kitsilano and Port Haney in search of coal, but no logs of these holes are available. A great number of shallow borings in the drift deposits, especially in the Nicomekl-Serpentine Valley, and one deep boring by the P. Burns Company, have been made in search of Artesian water. The first well drilled for oil and gas was located at Steveston and was put down about 1906. The recent drilling operations began in 1913 and have continued to the present.

The Steveston well was drilled by Mr. H. C. Fritts, to whom the writer is indebted for the following information regarding the well. A rotary drilling rig was used and a 13-inch hole was carried through sand to a depth of 700 feet, at which point a large boulder was encountered. The boulder was drilled for 6 feet and the 10-inch casing set. A 10-inch hole was carried to a depth of 860 feet, where the first shale bed was encountered and a flow of gas obtained. A gas pressure of 88 pounds to the square inch was obtained by bushing the 10-inch pipe to ½-inch and using a steam gauge. From 800 feet to 1,000 feet, where the first hard shale was encountered, the formation varied from fine sand to shale. The 8-inch casing was set at a depth of 1,000 feet. Drilling was continued with a 6-inch stem to a depth of 1,200 feet, when operations ceased because of lack of capital. A part of the casing still remains in the hole.

The Pitt Meadows well, the location of which is shown on Map 1965, was begun by the Pitt Meadows Oil Wells, Limited, in December, 1913. The well is located on the tidal floats about one mile northeast of Sheridan Hill. The first well was put down at this point by the Cosset Development Company, of which Mr. W. T. Patterson was manager, and reached a depth of about 1,200 feet, but owing to difficulties it was then abandoned. The drilling was done with a standard drilling rig. A second hole reached a depth of 1,990 feet on January 1, 1919, only about 100 feet in depth having been made in three years owing to the loss of tools in the hole. A depth of 2,026 feet was reached in 1921, when it was decided to put down a diamond-drill hole in the bottom of the hole already drilled. The diamond-drill hole was carried to a depth of 2,724½ feet, the first 100 feet being two and three-eighths core and the remainder two and a quarter core.

The unconsolidated surface deposits in the Pitt Meadows well apparently extended to at least 1,047 feet. The upper part consisted of recent alluvium and the lower part of glacial deposits. Glaciated pebbles are stated to have been brought up from a depth of over 1,000 feet. The character of the upper part of the bedrock is not definitely known as the plant was burnt in January, 1914, and the samples were lost. . . . . . It is stated by Mr. C. A. McRae, manager for the company, that salt water containing oil with a paraffin base was struck at 1,148 feet and that a small quantity of oily material was obtained from between 1,855 and 1,875 feet. Some gas was also struck. Salt water (density 1·016 and temperature 59° F.) was flowing from the top of the casing in September, 1921, and bubbles of gas were rising through the water. The

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[1] Extracted from "Geology of Fraser River Delta Map-area," by W. A. Johnston; Geol. Surv., Canada, Mem. 135, pp. 60-72 (1923).

temperature of the water indicates that it comes from a depth of several hundred feet, for it is 10 degrees warmer than the spring waters in the area, which are very nearly the same as the mean annual air temperature.

The Port Haney Oilfields Company drilled a well in the bed of Kanaka Creek about 3 miles east of Port Haney and 1 mile east of the eastern boundary of Map 1965. The hope of finding natural gas or oil at this locality was based on a reported occurrence of gas in a diamond-drill hole put down about 1890 by the Canadian Pacific Railway. The present drill hole is located near the southeast corner of Sec. 15, Tp. 12, W. 7th Mer., and is about 10 feet from where the old hole is supposed to have been. The well was drilled 1,254 feet with a small keystone drilling rig. Small flows of gas are said to have been struck at 193 feet and at 262 feet. No oil was found. Fresh water issues in a small stream from the top of the casing, a part of which remains in the hole, and bubbles of gas rise through the water.

The Spartan Oil Company, of which Mr. S. W. Miller is manager, was organized in 1918 with a capitalization of $500,000 and took up oil rights over 260 acres comprised in lots 120 and 131 in the municipality of Vancouver, 3 miles east of the boundary of the city. Hopes of obtaining oil were based largely on a supposed oil spring or seepage near the company's holdings. The occurrence is described elsewhere. On the advice of Mr. Wm. Jewell, a geologist who examined the area in 1918, a test hole was put down 2,000 feet. It is stated that oil and gas were encountered at different levels and at 1,669 feet a sand was encountered that the company's geologist believed would prove commercially productive. He recommended that a well be drilled to 3,000 feet, or lesser depth if oil were met in satisfactory quantity. Well No. 2 was put down and reached a depth of 2,875 feet early in 1922. Drilling operations were then discontinued. The caving of soft clay shales, especially in the lower part of the well, caused considerable difficulty. The elevation of well No. 1 is 131 feet and of well No. 2, 216 feet above sea-level. . . . . .

The Boundary Bay Oil Company, Limited, of which Mr. S. A. Thompson is managing director, was organized in 1918 with a capitalization of $500,000, increased to $1,000,000 in 1920. The company holds leases on the tidal flats at Boundary Bay, 16 miles south by east of Vancouver. Drilling began in 1919, four test holes being put down to about 350 feet. A new drilling plant was purchased and well No. 2 was drilled to 2,473 feet when the tools were lost and all efforts to recover them failed. No. 3 well (*See* Map 1965) was started on April 6, 1921, and on June 3 was down 2,300 feet. . . . . . Below 2,300 feet considerable difficulty was caused by sand partly filling the casing. The sand apparently came from some point above the end of the 10-inch casing, but may have come, in part, from beds lower down. . . . . . The boring reached a depth of 4,112 feet in March, 1922 . . . . . the bottom 350 feet of which contains perforated button screen casing set opposite six sand horizons. An attempt to test the well by bailing was then made. Considerable difficulty was experienced in lowering the water in the well, but it was finally bailed to a depth of 3,600 feet when the casing collapsed. The casing was reinforced with cement, the bridged-over part was drilled through, and bailing resumed. The test showed no commercial quantities of gas or oil. It is proposed by the company to put down a diamond-drill hole in the bottom of the boring to determine definitely the character of the lower strata. The well was drilled by Mr. C. E. Milburn. It is stated that during the drilling thousands of barrels of water were absorbed by the sands, some of which were dry and contained gas, whereas others were water saturated. It was impossible to tell because of the effect of the heavy mud fluid used in drilling, just what sands were dry and what were water bearing. Water which was somewhat saline was struck at about 2,200 feet and possibly again at a lower level, but most of the water was fresh or nearly so. Small flows of gas were also struck at several horizons. Colours of oil are said to have been observed in the bailings and in the waste water from various depths, and samples of sandstone and shale from near the bottom of the well showed, when treated with chloroform, some light-coloured, oily material. This may be petroleum or an oil derived from fossil resin, the quantity obtained being not sufficient for determination. Samples of material from the well cuttings, which were reported to be gilsonite or solidified petroleum, were found on examination to be lignite.

The Empire Oil and Natural Gas Company, of which Mr. R. H. Wright is manager and Mr. Roy Widney, driller, has been engaged since 1918 in sinking a well in Sec. 27, Tp. 10, Range 4, W. 7th Mer. The well is about one-quarter mile south of the Yale road and about one mile east of the eastern border of Map 1965. The elevation is about 325 feet above the sea. A standard drilling rig is used. The first hole was put down 350 feet without reaching bedrock, and was then abandoned owing to boulders in the drift. A second hole reached 140 feet and was also abandoned. A third hole was begun November 27, 1918, and in December, 1922, had reached a depth of 3,980 feet. . . . A test of the hole by bailing, at about 3,600 feet, showed small quantities of highly saline water, but no commercial quantities of oil or gas. The bailings from the well in many cases showed a brownish scum of froth, apparently an emulsion formed by the water, and finely divided carbonaceous and resinous material derived from the cuttings. Several small seams or lenses of lignite were passed through, and some of the lignite contains considerable quantities of fossil resin. The resinous material when treated with chloroform gives a colour somewhat resembling that of petroleum. A sample of material brought up by the bailer from about 3,600 feet was obtained by skimming the surface of the sludge. The sample was examined by R. T. Elworthy, chemist of the Mines Branch, Department of Mines, who reports that:

"The material was treated with the following solvents, with the results noted: (1) Chloroform. The substance was thoroughly shaken with chloroform in a separatory funnel. After standing, the chloroform was run off and carefully evaporated on the water bath. A dark brown, sticky residue remained, which had the distinctive smell of a bitumen. It was readily soluble in ether and carbon bisulphide. Petroleum would be very different from the sticky residue obtained. (2) Ether. Ether had little solvent action on the material. (3) Carbon bisulphide, shaken with the material, extracted a dark brown substance similar to that obtained with chloroform. The material when heated at first darkened and fumed slightly, but with no noticeable smell of mineral oil. On further heating to dull redness it became greyish. Chloroform extracted nothing from the heated material. Under the microscope the clay suspension was seen to be impregnated with small, yellow particles which closely resemble ground-up fossil resin. The clay residue, after extraction with chloroform, still contained similar yellowish material, but to a smaller degree. These experiments confirm Mr. Johnston's belief that the soluble material is most probably derived from bituminous shale. The sample was too small for many observations to be made."

A depth of 4,200 feet was reached in June, 1923. . . . Colours of oil showed in the bailings from 4,200 feet and are said to have been obtained at several horizons in the marine series of rocks below 3,540 feet, but no commercial quantities of oil have been obtained. Drilling is being continued in an attempt to thoroughly test the rocks at a greater depth.

Oil and Gas Possibilities

Gas springs occur in the Recent delta of the Fraser at Steveston, at Boundary Bay, on the north arm of the Fraser near the entrance, and at other places. They also occur along Still Creek near the head of Burnaby Lake, at Pitt Meadows near Pitt Lake, and at various places in the low swamp ground along the Fraser and tributary streams. They are probably all or nearly all springs of swamp gas. The abundance and volume of the springs at Steveston—on account of which the first boring in search of oil or gas was made at this locality—may possibly indicate that the gas comes in part from the bedrock, but the great thickness of the Recent deposits . . . . seems to show that this is not the case. A sample of the gas from Steveston was analysed by Mr. F. C. Phillips (1894, page 406) in 1894, who found it consisted of: nitrogen, 6·30 per cent; carbon dioxide, 0·14 per cent; and paraffins (chiefly methane, with traces of the higher hydrocarbons of the series), 93·56 per cent. The gas, whatever its source, is a dry gas and, therefore, is probably not a petroleum gas. A gas spring in Still Creek near the Douglas Road bridge is said to bring up, at times, small globules of oil along with the gas bubbles. It is doubtful, however, whether the oil comes from the bedrock, as there is probably a considerable thickness of surface deposits at this point. It is possible, also, that the oil may have been lost during lumbering, or other operations, and become included in the mud in the bottom of the creek. Wet mud or clay has a remarkable affinity for oil and will retain oil for long periods unless it is disturbed, or water is made to circulate through it freely. No gas springs coming from the solid rock are known to occur in the area, though such springs would be difficult to detect and may occur.

Gas flows have been struck in several of the wells drilled in the area. The gas is derived partly from the unconsolidated surface deposits and partly from the bedrock. Probably all or nearly all from the surface deposits is swamp gas. A sample from a considerable depth in the Boundary Bay well was analysed by G. S. Eldridge and Company of Vancouver and was found to consist mainly of methane with only a trace of ethane. The gas, therefore, is probably not associated with petroleum. Gas that is high in nitrogen was struck in the Pitt Meadows well and in the Port Haney well. The gas from the Pitt Meadows well yielded about 99 per cent of nitrogen with 0·5 per cent of oxygen and 0·5 per cent of carbon dioxide. The helium content was found to be 0·003 per cent (McLennan, 1920, page 15). An analysis of the gas from the Port Haney well, by G. S. Eldridge and Company, showed: oxygen, 7·5 per cent; carbon dioxide, 1·2 per cent; olefines, 0·15 per cent; paraffins, 22·5 per cent; nitrogen, 68·3 per cent. The helium content was only 0·013 per cent. Water flows from both wells and the gas bubbles up through the water. The samples of gas were obtained by immersing a funnel in the water and filling a bottle by displacement of the water from it. The gas from the Pitt Meadows well—which is almost entirely nitrogen—is probably derived from the dissolved air of the rain and snow water that supplies the flow of water from the well. "The oxygen of this dissolved air, during the underground passage of the water, is used up in chemical processes such as the oxidation of iron pyrites and of organic matter with which it comes in contact. Nitrogen being chemically inactive passes on unaffected, and thus becomes relatively more concentrated in the gases which finally emerge." This theory of the source of the nitrogen springs in Banff area, British Columbia, has been put forward by R. T. Elworthy (1918, page 143), and is applicable in the present case. The head which causes the flow water from the wells is evidently derived from the high mountainous area in the wells, and the rocks are well jointed, so that the surface waters containing dissolved air are probably carried down to considerable depths. The gas from the Port Haney well is apparently a mixture of dry natural gas and nitrogen. The natural gas is probably derived from thin coal seams in the rock, and the nitrogen in the manner already described. The gas does not indicate the presence of oil in the rocks, for it is dry gas. The nitrogen is of no value for the manufacture of nitrates, for the flows are small, and it is improbable that reservoirs could be formed in the rocks. At depth the gas is dissolved in the water and it appears at the surface as gas bubbles when the pressure is removed. Nitrogen is detrimental to natural gas as an illuminant or as fuel, for it dilutes the hydrocarbon content and lowers the calorific value. The general question of the occurrence in commercial quantities of natural gas—which depends on the structure of the rocks of the area—is described under "structure."

Oil seepages are reported to occur at several points in the area. The first definitely reported and the only one said to come from bedrock is that already referred to, in the woods of north Vancouver. The correct location is probably in the bed of a small creek on district lot 815, in west Vancouver. A search for the seepage, in 1920, however, failed. There are several places in this general neighbourhood where oil occurs on the surface waters, but it evidently comes from the greasing of skids in lumbering operations. The basal sandstone and conglomerate of the Tertiary series outcrop in places near the supposed location of the seepage and if a seepage occurs it probably comes from these rocks. In 1914 the west Vancouver Hollyburn Oil Company was organized to drill at this locality, but no drilling was done.

The best known and most important of the supposed seepages is known as the Burnaby, and is located in a peat bog just south of the Great Northern Railway about 2,000 feet west of Sperling avenue (Pole-line road), near the west end of Burnaby Lake. It is said to have been discovered in 1917 by Thomas Hannah who fell through a hole in the peat and found that his legs were covered with crude oil. It is also stated that the occurrence was known for several years previous to 1917, but this seems to be in doubt. Large quantities of oil have been obtained from the locality and oil could still be seen on the surface of the water in 1922. A small stream of water flows into the bog near where the oil occurs, but the water in the bog is nearly stagnant except after heavy rain. Several square yards of the surface peat is saturated with the oil, which oozes from the peat in periods of high water and appears on the surface of the water in pools beneath and between the stumps of large trees that have been killed by fires or removed in lumbering operations. It is again absorbed by the peat when the water falls. The peat has a maximum depth of 27 feet and is underlain by silty clay interbedded with thin, peaty layers. The depth of the peat decreases rapidly towards the north, the bog extending only about 100 feet in this direction. The peat—which is in reality only slightly altered vegetable material—showed no signs of oil except in the upper part, nor did the underlying silty beds. No appreciable quantities of gas occur. In the spring of 1922 borings were made, pits were sunk, and a pump was installed, under the direction of Mr. C. Estlin, to obtain the oil and determine whether a true seepage existed. Mr. Estlin states that 10 barrels of oil were recovered. The oil came with the water and ceased when the water was pumped out. Channels in the peat, one foot or even more in diameter, were found. The oil occurred chiefly in the channels and on the under side of logs in the peat. No oil was found in the clay under the peat.

A sample of the oil from the Burnaby peat bog, collected by the writer in 1920, was analysed by Mr. P. V. Rosewarne, chemist of the Mines Branch, Department of Mines, who reports on it as follows:

Specific gravity at 15·6° C. (60° F.) = 0·974

Distillation test—

Water distillate, 6 per cent at 100° C.

Oil distillate (straight run)

1st drop	at 275° C.	40 per cent	at 370° C.
5 per cent	at 305° C.	50 "	" 380° C.
10 "	" 322° C.	60 "	" 386° C.
20 "	" 341° C.	62 "	" 388° C.
30 "	" 355° C.		

Cracking began at 388° C.

Water distillate obtained	6·0	per cent
Oil, straight run distillate	62·0	"
Oil, after cracking had begun	19·0	"
Residue	10·5	"
Loss	2·5	"
	100.0	
Total bitumen in residue, soluble in carbon bisulphide..	11·9	"
Paraffin base in residue	4·5	"
Asphalt base in residue	7·4	"

Unsaturated hydrocarbons

16 cc. sample of crude oil was shaken up with sulphuric acid (sp. gr. 1·84) and repeatedly cooled in ice water.

The whole mass became thick, black, and viscid. No line of separation could be detected, even after the sample had stood for several days.

Saponification of crude oil

Duplicate tests showed no saponifiable matter present.

Summary

(a) Results which suggest that oil is a crude oil
  (1) Comparatively wide distillation range
  (2) Ease of cracking
  (3) Relatively large residue on distillation
  (4) Both paraffin and asphalt bases present
  (5) No saponifiable matter
  (6) A similar oil to above was sent to this laboratory for analysis from the same locality in 1917

(b) Results which suggest that oil has been previously refined
  (1) No low boiling fraction
  (2) High specific gravity

Conclusion

(a) If sample is an oil not native to the locality it seems likely that it is either crude oil from some other oil field or an unfiltered stock oil from a refinery.

(b) The weight of evidence seems in favour of declaring sample to be a crude oil, since it must be remembered that crude oils have been obtained which contain no fraction boiling at a low temperature and which have a high specific gravity, but whether the sample is native or not to the locality in which it was collected, it is impossible to state from results of laboratory tests.

The source of the oil is not definitely known. Granting that it is a crude oil, as seems probable, it is difficult to understand how it can be derived from the bedrock.

At the diamond-drill hole of the Spartan Oil Company, about 1,000 feet north of the occurrence and about 75 feet higher, the surface deposits are 110 feet thick and they are probably as thick or thicker beneath the bog. The surface deposits consist in part of silt and clay and if the oil has passed through this material, as it must have done if it comes from the bedrock, it would probably be filtered and appear at the surface as a light-coloured oil, or would form an emulsion with the water and clay and appear at the surface as impure asphalt, and not as a heavy, dark oil. It has been suggested that a fault occurs along Burnaby Valley and that the oil comes from it, but there is no direct evidence of a fault. Even if a fault does occur it would not affect the surface deposits. It has been suggested that a tank car of oil was at one time lost in a sink-hole in the bog along the Great Northern Railway a short distance west of this locality, but this has been denied by railway officials. It is at least not evident that the oil comes from the bedrock and, therefore, the occurrence cannot be considered as proof that the rocks are oil bearing.

An oil seepage was reported to occur on the property of Mr. P. W. Thomas, on Imperial Street, in Point Grey municipality. A strong odour of gasoline, and some oil, were noted by Mr. Thomas in digging a drain there. A small, undrained depression occurs in the surface deposits and the oil may at one time have been lost and remained on the surface of the groundwater until brought to the surface by the rise of the groundwater during an exceptionally wet season. Oil, if spilled, will sink into the ground and remain on the surface of the groundwater for long periods unless the ground has sufficient slope to cause the groundwater to flow. The surface deposits are of considerable thickness at the locality, so that it is not evident that the oil comes from the bedrock. The reported occurrences of oil in water wells in the surface deposits at several places in the area are probably due to oil that has been lost and is slowly moving down slopes on the surface of the groundwater.

Sand or sandstone impregnated with fir pitch has been noted at several places in the region, but is not an indication of the presence of petroleum. The material is partly soluble in chloroform, to which it gives a colour somewhat resembling that of petroleum, and, therefore, may readily be mistaken for it. It, however, has not the odour or general appearance of petroleum.

Salt water is generally met with in oil wells, but its occurrence in the rocks does not necessarily indicate the presence of petroleum. Fresh water is in many cases encountered at shallow depths in oil wells and deep-seated salt water below the oil, but in some cases the waters met with above the oil horizons are even more salty than the under waters (Neal, 1920, page 565). The under water is usually a brine and may be considered as the sea water that remained in the sediments after they were formed (Rogers, 1919, page 66). In many places, however, salt water unaccompanied by oil has been struck in deep wells. Salt or brackish water occurs in many of the wells in Fraser Delta area. The water met with in many of the wells in the surface deposits, particularly in the Nicomekl-Serpentine Valley, is brackish. The salt is evidently derived from the surface deposits, which are in part marine. The salt water that flows from the Pitt Meadows well may be derived from these deposits at a considerable depth. A qualitative analysis of a sample of water from the Empire well at a depth of about 3,600 feet was made by Mr. R. T. Elworthy of the Mines Branch, who states:

"The water had a strong saline, bitter taste. It was faintly alkaline in its reaction with methyl orange. The specific gravity at 70 degrees F. was 1·032. The total dissolved saline matter, dried at 110 degrees C., amounted to 43,590 parts in 1,000,000 parts by weight of water, which is equivalent to 3,148·94 grains per imperial gallon. This mineral matter consisted, principally, of sodium chloride, together with smaller quantities of chlorides and traces of sulphates of calcium and magnesium."

The density of the water is greater than that of normal sea water, which at 60 degrees F. is 1·027. It is apparently a brine. Its chief significance is that it indicates that strata of marine origin occur at about this depth, most of the strata passed through above 3,540 feet being freshwater in origin. It does not indicate the presence of petroleum, but on the other hand does not preclude the possibility of petroleum at greater depths. No salt water was struck in drilling the Spartan wells, the strata passed through being all freshwater in origin. The water flowing from the diamond-drill hole was analysed by G. S. Eldridge and Company and found to contain only 132 parts a million of total solids, which consist mainly of calcium carbonate, with small amounts of silica, alumina, chlorine, sulphates, and alkalis. Water that was brackish, if not salty, was obtained in the Boundary Bay well at a depth of about 2,200 feet and possibly again near the bottom of the well. A sample of water from about 3,600 feet contained only 226 parts per million of solids, consisting mainly of sodium chloride. The sample, however, may have been diluted with fresh water coming in from a higher level. The salt or brackish water indicates the presence of marine horizons, but signifies little regarding the presence of petroleum.

The temperature gradient, which is believed by some investigators to be abnormally high in oil fields, and, therefore, to be of some significance, is not definitely known. The water bailed from the Empire well at a depth of 2,670 feet had a temperature of 81 degrees F. Taking the ground temperature at the surface as 49 degrees (the mean annual temperature), the temperature gradient to a depth of 2,670 feet is one degree increase for each 84 feet in depth. A Negretti and Zambra thermometer was let down in the bailer to a depth of 4,200 feet and showed a maximum temperature of only 88 degrees F. The temperature gradient is not abnormally high and is apparently less in the lower part of the well than in the upper, but sufficient data are not available accurately to determine the gradient.

The rock outcrops, the cores of the Spartan diamond-drill hole, and rock samples from other wells, indicate that the Tertiary sedimentary rocks of the map-area are mostly of freshwater origin. They contain in places thin seams and lenses of lignite. Geologists are generally agreed that petroleum and natural gas must originate from organic life, either directly or indirectly. As stated by White (1921, page 183) "The fact that no commercial accumulations of either are found outside of marine beds, except where these accumulations have clearly come up from marine beds below, would point to the sea as the ultimate source of the organisms or raw material from which these hydrocarbons were derived." The fact that the strata underlying Fraser Delta map-area are mostly freshwater in origin, therefore, indicates that they are not likely to be oil or gas-bearing unless they are underlain by marine beds from which the oil or gas may have migrated. The numerous thin lenses and seams of coal also show that the vegetable material which the beds originally contained was altered to form coal and not petroleum. Petroleum as a rule does not occur in coal-bearing beds, but in many cases occurs in marine strata beneath the coal-bearing beds and occasionally in lignite-bearing beds; probably in such latter cases because of migration of the oil (Emmons, 1921, page 88). Because of lateral variation, also, such as might be expected in alluvial and deltaic beds like those of Fraser Delta region, the same geological horizons may be coal-bearing in the landward part and petroleum-bearing in the seaward part. There is little definite evidence, however, regarding the character of the marine phase of the Tertiary deposits in Fraser Delta region. The salt water struck in the Empire well at a depth of about 3,600 feet indicates that the beds penetrated below that depth are probably marine. The beds are mostly shale, which are probably Tertiary in age. Cretaceous beds may occur in places beneath the Tertiary beds, but there is no evidence that they do. The Tertiary rocks are seen in places to rest on the granitic rocks of the Coast Range batholith. They probably have a maximum thickness of at least 5,000 feet, so that even if Cretaceous rocks do occur they can hardly be regarded as an available source of oil. Moreover, the Cretaceous rocks as exposed on the east side of Vancouver Island are in part coal-bearing and are not known to be oil-bearing (Clapp, 1914, page 51).

Oil-shales or rocks of somewhat similar character, from which material resembling petroleum can be obtained by distillation or by the use of solvents such as chloroform or ether, have been obtained in small quantities from two of the wells. But oil-shales do not indicate the presence of petroleum. They contain a series of substances, generally classified as "kerogen," from which oil can be distilled. Occasionally they contain some free oil or material resembling petroleum which is soluble in chloroform, but the soluble material is usually small. Ziegler (1920, pages 114-115) states that "Oil and gas in small quantities may be disseminated through all marine shales, and may be localized occasionally in small, porous streaks under conditions where no commercial quantities could be expected. A showing of small quantities of either oil or gas in a well is, therefore, not a necessary proof of the existence of, or of approach to, an oil pool." The small showings of oil found in marine shales in the lower part of the Empire well, for example, are, therefore, only what might be expected.

The answer to the first question, whether or not the rocks of the area are gas- or oil-bearing, is that they are gas-bearing to some extent, but there is little or no definite evidence that they are oil-bearing, except possibly to some slight extent in the lower marine parts of the rock series. The freshwater origin of most of the sediments shows that oil is not likely to have formed in the rocks. The reasons why oil had not been formed in the freshwater deposits may be, as suggested by Johnson and Huntley (1916, page 21) that bacterial decay of organic material in fresh water differs from that which takes place in salt water. A considerable part of the Tertiary deposits also consists of continental, subaerial deposits, and Schuchert (1919) has pointed out that during the formation of such deposits oxidation is so active that commercial supplies of petroleum cannot be formed. The marine phases of the rock series are deeply buried and it is not clear from the results of drilling that they are oil-bearing, at least to any great extent.

The structure of the Tertiary rocks of the northern part of the area—the only part in which bedrock outcrops—is a gentle monocline. The strata have a fairly uniform dip of 10 to 15 degrees towards the south, with only slight variations from this general direction. The dip becomes less towards the south and in the most southerly outcrop at South Westminster is only 4 or 5 degrees. The structure of the rocks in the central and southern parts of the area is not known, but it is unlikely that the southward dip continues as far as the International Boundary, and rocks of similar age are known to be folded in the adjacent state of Washington. The strata penetrated in the Boundary Bay well are, for the most part, younger than the Tertiary beds exposed in the northern part of the area. It is probable, therefore, that a deep downwarping of the basin has taken place and that a great thickness of Tertiary rocks exists in the central and southern parts of the area. The existence of folds that might bring the lower Tertiary beds or older formations within reach of the drill is problematical. The Tertiary rocks are probably down-faulted against the Coast Range batholithic rocks in the eastern part of Burrard Inlet and small faults occur at other places. They may be extensively faulted in the central part of the area. Dykes of igneous rocks cut the Tertiary sediments in the vicinity of Vancouver, but are not known to occur in other parts of the area.

The monoclinal structure of the rocks is not necessarily unfavourable, for in such a structure terraces (places where the general dip is flattened or reversed) may occur, and lensing of the strata or sealing of the outcrops by faulting or cementation may produce reservoirs for accumulation of oil or gas. But such structures are usually considered as less favourable than dome or anticlinal structures. There is no evidence of dome or anticlinal structure in the map-area, but such structures may be concealed beneath the drift and alluvial deposits. The dykes of igneous rocks in part of the area are not necessarily an unfavourable feature, for oil fields are known in which dykes of igneous rock occur. The rocks contain many porous sandstone and sand lenses which would form good reservoir rocks and many shale beds which might form impervious covers to prevent the escape of the oil or gas. But the rock exposures and the well logs show clearly that both the sandstone and the shale occur in lenses. This is exactly what is to be expected from the fact that they are mostly freshwater in origin and are mainly alluvial plain deposits. A part is apparently marine and there the individual beds should be thicker and of greater lateral extent. But the marine beds are mostly shale which do not form good reservoir rocks, that is rocks suitable for containing oil-pools. The lens-like character of the freshwater strata and the small extent of the lenses are unfavourable features; for the size of the possible reservoirs is thus restricted and because of the disconnected character of the sand lenses and the presence of numerous shale lenses, opportunity for migration of the oil or accumulation of gas in reservoirs would not be possible to any great extent, even if considerable quantities of oil or gas were present in the rocks. The presence of natural gas in the rocks at considerable depths, and under considerable pressure, as was found in the Boundary Bay well, might be taken as evidence that a favourable structure for gas accumulation exists. But the gas pressure that caused blow-outs at the well was probably due to the fact that the gas was under the pressure of the column of water and mud in the hole, and that the blow-out was caused by the sudden relief of pressure on removal of the tools or by the action of the bailer. Flows of gas that continued violently for short periods have been struck in several of the wells. But the lens-like character of the freshwater strata and the fine-grained character of the marine strata seem to show that there is little chance of accumulations of natural gas in reservoirs of sufficient size to be of commercial importance.

The answer to the second question, therefore, whether or not the structure of the rocks is favourable for the accumulation of oil or gas into pools of sufficient size to be of commercial importance, is that the general structure of the Tertiary rocks may not be unfavourable, but their internal structure is such that important reservoirs of oil or gas are not likely to occur. It is hopeless to drill for oil in the igneous rocks of the Coast Range batholith; they are not a possible source of oil and are not sufficiently porous to act as reservoir rocks. It is not definitely known whether older sedimentary rocks underlie the Tertiary rocks in places in the area, but even if they do they are probably beyond the reach of the drill. It must be concluded, therefore, that the prospects of obtaining commercial supplies of oil or gas in Fraser Delta area are not very bright.

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APPENDIX

LISTS OF WELLS DRILLED

Information for these lists, except that of wells in British Columbia, has been supplied through the courtesy of the Dominion Lands Branch, Department of the Interior, from records collected in part by the Supervisory Engineer prior to the return of the natural resources to the Prairie Provinces. The wells are listed in alphabetical order except those of Alberta. These are presented in groups corresponding to the 3 miles to 1 inch sheets of the Topographical Survey, Department of the Interior (Figure 26). The information in regard to the wells is complete to the end of the year 1931 unless otherwise stated.

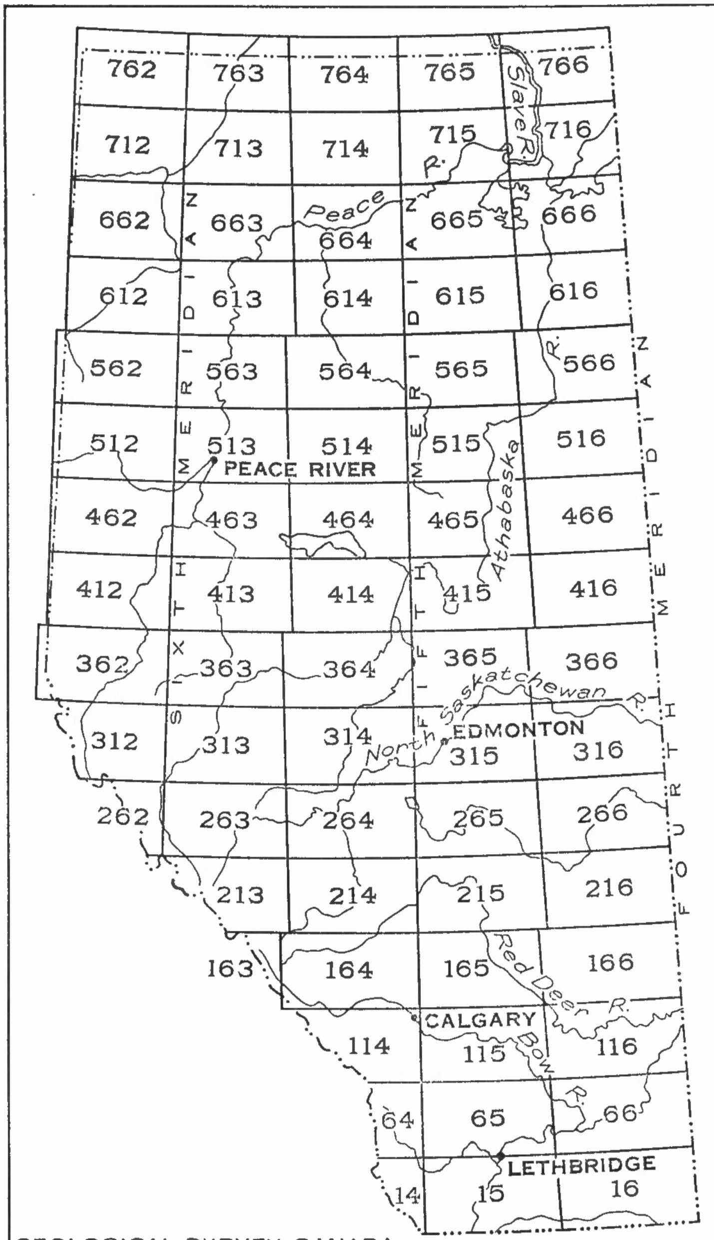

Figure 26. Index to sectional sheets of Alberta.

Manitoba

—	L.S.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet	Remarks
Agassiz Oil Dev. Co.	SW.	26	23	20	1	....	320	Drilled in 1921. No oil or gas
C.P.R. Rosenfeld Station	....	9	1	3	1	770	1,037	Large flow of salt water encountered at 875 feet
Commonwealth Petroleums, Ltd., No. 1	4	23	2	9	1	....	1,120	Drilled in 1930-31. Slight shows of gas
Commonwealth Petroleums, Ltd., No. 2	8	26	2	9	1	....	2,626	Drilled in 1931-2
Daugherty, E., and associates	5	25	43	26	1	....	235	Test hole for geological information drilled in 1925
Daugherty, E., and associates	4	23	43	26	1	....	807	Drilled in 1925-26
Dauphin Oil Syndicate, Ltd	SE.	14	24	20	1	....	1,256	Drilled in 1929-30. Small shows of gas and oil reported
Deloraine	SE.	10	3	23	1	1,644	1,943	Drilled in 1888-92. Sulphur water
Fitzsimmon Gas Co.	....	14	12	30	1	....	1,500	No record
Grandview Oils, Ltd., No. 1	11	18	26	23	1	....	?	Drilled in 1926-27. Oil reported but this was subsequently proved to be incorrect
Grandview Oils, Ltd., No. 2	11	18	26	23	1	....	126	Drilled in 1927
Gurton, H. E., and Prov. of Manitoba No. 1	9	29	30	17	1	....	113	Drilled in 1920. Abandoned
Gurton, H. E., and Prov. of Manitoba No. 2	9	29	30	17	1	....	40	Drilled in 1920. Abandoned
Gurton, H. E., and Prov. of Manitoba No. 3	9	29	30	17	1	....	57	Drilled in 1920. Abandoned
Gurton, H. E., and Prov. of Manitoba No. 4	7	29	30	17	1	....	1,473	Drilled in 1921. No oil or gas. Abandoned
Holmes, J. W., and Co., No. 1	10	30	22	17	1	....	1,487	Drilled in 1926-27. Abandoned
Irro Oil and Gas Co., Ltd	....	....	....	....	....	....	....	*See* Grandview Oils, Ltd.
Jukes, H. A.	....	12	20	6	1	....	98	Drilled in 1926
Lindsay and Thompson	12	30	22	17	1	....	540	Drilled in 1921. Taken over by Mack Oil Co. in 1927. Show of gas encountered
Mack Oil Co.	....	....	....	....	....	....	....	*See* Lindsay and Thompson
Manitoba Mutual Oil Co.	9	34	7	10	1	....	....	Drilled in 1925. Shallow depth
Manitoba Oil Co. No. 1	....	....	23	20	1	....	292	Drilled in 1887. Abandoned
Manitoba Oil Co. No. 2	....	....	23	20	1	....	743	Drilled in 1888. Abandoned
Manitou well	....	23	2	9	1	....	925	Drilled in 1915-16. Gas encountered
Mann, George	NW.	6	20	4	1	....	....	Drilled in 1921. Abandoned
Martin and Rothwell	NW.	35	19	6	1	....	28	Drilled in 1921. Abandoned
Martin and Rothwell	9	34	19	6	1	....	267	Drilled in 1921. No results
McGuckin, R. J., No. 1	....	....	31	1	E. of 1	....	232	Drilled in 1928. Water encountered. Test hole
McGuckin, R. J., No. 2	....	....	33	1	E. of 1	....	141	Drilled in 1928. No water encountered. Test hole
McGuckin, R. J., No. 3	....	....	31	1	E. of 1	....	258	Drilled in 1928. No water encountered. Test hole

Manitoba—Concluded

—	L.S.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet	Remarks
Morden		5	3	5	1	978	601	Drilled in 1889-90 by the town of Morden in search for water. Salt water obtained
Neepawa		33	14	15	1		1,798	Drilled previous to 1919
Northern Manitoba Oil Co. No. 1	2	33	42	26	1			Drilled in 1921 to a shallow depth
Northern Manitoba Oil Co. No. 2	2	33	42	26	1		996	Drilled in 1921. Abandoned 1923
Northern Manitoba Oil Co. No. 3		33	42	26	1		1,380	Drilled in 1923-4-5. Suspended
Ochre River								*See* Holmes, J. W., and Company
Pembina Valley Gas and Oil Co								*See* Commonwealth Petroleums, Ltd.
Porcupine Mt. Oil and Gas Co., Ltd., No. 1	2	3	42	26	1	1,063	350	Drilled in 1923. Abandoned
Porcupine Mt. Oil and Gas Co., Ltd., No. 2	2	3	42	26	1	1,063	977	Drilled in 1923. Abandoned. Small shows of gas
Rathwell		7	8	9	1		1,885	Drilled previous to 1913. Abandoned
Riding Mountain		9	18	15	1	1,214	351	Drilled previous to 1914. *See* log Geol. Surv., Canada, Mem. 116, p. 37
Riding Mountain Oil and Dev. Co								*See* Agassiz Oil and Dev. Co.
Rosenfeld well								*See* C.P.R.
Stony Mountain Oil and Gas Co	7	29	12	2	E. 1	800	1,009	Drilled in 1922. No oil or gas. Abandoned
Vermilion River								*See* Manitoba Oil Co

Saskatchewan

—	L.S.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet	Remarks
Abray and Patterson		13	15	19	2	1,926	2,425	Drilled in 1909-10. Abandoned
Aladdin Oil and Gas Co., Ltd., "Pilot" Butte		33	17	18	2		2,160	Drilled in 1931
Associated Securities No. 1	16	18	29	2	3		154	Drilled in 1927 by Big Six Oil Co.; taken over by Associated Securities
Associated Securities, "Olmen" No. 1	4	33	22	7	3	1,700	527	Drilled in 1926. Water and gas encountered
Associated Securities, "Olmen" No. 2	6	23	22	7	3		523	Drilled in 1930. Water and gas encountered
Associated Securities, "Olmen" No. 3	15	29	22	7	3		290	Drilled in 1930. Suspended
Battleford Oil and Gas Co			44	18	3		940	Drilled in 1913. Abandoned
Beattie Bros. and Hinton	13	30	11	28	2		692	Drilled in 1925. Abandoned
Belle Plaine C.P.R		31	16	23	2	1,874	1,551	Drilled prior to 1886. Some gas at 1,106 feet. Abandoned
Big Six Oil Co								*See* Associated Securities
Bigger Oil and Gas Co	SW.	5	36	14	3			Drilled in 1930. Suspended
C.W.N.G.L.H. and P. Co., "Hanley"	8	28	30	5	3		2,134	Drilled in 1929. Abandoned. No oil or gas

Citizens Oil and Gas Co., Ltd., No. 1	SE.	22	41	24	3	1,890	2,925	Drilled in 1926. Small gas flow. Suspended
Citizens Oil and Gas Co., Ltd., No. 2	12	14	41	24	3	1,890	3,195	Drilled in 1927-28. Suspended
Citizens Oil and Gas Co., Ltd., No. 3	13	14	41	24	3	....	2,056	Drilled in 1929-30. Shows of oil and gas reported. Suspended
Donovan, John	....	18	29	25	2	....	452	Drilled in 1923. Abandoned
Eastend Gas Co., Ltd., No. 1	....	31	6	21	3	3,000	1,245	Drilled in 1924. Small show of gas. Abandoned
Eastend Gas Co., Ltd., No. 2	7	31	6	21	3	3,000	1,615	Drilled in 1925-26. No oil or gas. Abandoned
Eden Valley Oils, Ltd	14	35	28	8	3	1,725	1,400	Drilled in 1929-30. Slight show of gas. Suspended
Estlin well	....	....	....	....	....	....	....	*See* Abray and Patterson
Fort Pelly	....	....	32	32	1	....	501	Drilled in 1874-75. *See* Geol. Surv., Canada, Mem. 116, p 39
Gas Prod. and Trans. Co., "Hanley"	....	....	....	....	....	....	....	*See* C.W.N.G.L.H. and P. Co. "Hanley" No. 1
Gessell and Delta Oil Co., Ltd	. 15	26	21	29	2	....	563	Drilled in 1928. Show of gas reported at 433 feet. Suspended
Great West Nat. Gas Corp., Ltd	....	....	....	....	....	....	....	*See* Northwest Co.
Hanley Development Co., Ltd	1	6	31	4	3	....	2,069	Drilled in 1914-17. Water flowing from well
Herschel well	13	4	31	17	3	2,020	2,034	Drilled in 1927-28. Small shows of gas. Show of oil, 2,026 feet. Abandoned. Artesian water at 190 feet
Kakwa (C.N.R.)	....	....	41	4	2	....	....	Drilled in 1930 by C.N.R. while drilling for water. Flow of gas at 272 feet in No. 1 well. No. 2 hole drilled 212 feet where gas again was struck
Kamsack	....	....	29	32	1	1,445±	775	Drilled in 1909. *See* Geol. Surv., Canada, Mem. 116, p. 39
Keithville	12	35	18	16	3	....	414	Drilled in 1910. No gas or oil. Abandoned
Langham (Mackenzie and Mann) No. 1	....	24	39	7	3	1,400	1,358	Drilled in 1905. Abandoned
Langham (Mackenzie and Mann) No. 2	....	....	....	....	....	....	1,600+	Drilled in 1906
Man River Oil and Gas Co., Ltd	....	....	....	....	....	....	....	*See* North Battleford Oil and Gas Co., Ltd., No. 2
Maple Creek Gas, Oil, and Coal Co	....	15	11	26	3	2,507	1,860	Drilled in 1909. Abandoned
McLean Station	....	13	18	16	2	2,248	495	Drilled previous to 1913. Abandoned
Moose Jaw City	....	....	....	....	....	....	....	*See* National Light, Heat, and Power Co.
National Light, Heat, and Power Co	....	32	16	26	2	1,778	3,302	Drilled in 1913-14. *See* Geol. Surv., Canada Mem. 116, p. 43, 1919.
Northwest Co., "Boundary" or "Woodpile Coulée" well	4	9	1	27	3	....	3,963	Drilled in 1920-2. Small show of gas at 2,700 feet. Abandoned
Northwest Co., "Muddy Lake"	11	7	39	22	3	1,897	2,900	Drilled in 1920-22. Small flow of gas. Abandoned
North Battleford Oil and Gas Co., Ltd., No. 1	....	1	50	5	2	....	....	Very shallow, drilled in 1922

Saskatchewan—Concluded

—	L.S.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet	Remarks
North Battleford Oil and Gas Co., Ltd., No. 2.	....	....	50	5	2	....	300	Drilled in 1924. Abandoned
North Battleford Oil and Gas Co., Ltd., No. 3	....	15	50	5	2	....	268	Drilled in 1930. Suspended
Perkins Syndicate	7	6	4	7	2	....	347	Drilled in 1930. Suspended
Pike Lake Oil and Gas Dev. and Exp. Co., Ltd.	8	13	34	7	3	....	3,170	Drilled in 1929. Slight show of oil reported 1,780–1,790 feet
Pilot Butte well	....	....	....	....	....	....	....	*See* Aladdin Oil and Gas Co., Ltd.
Rambler Exp. Co	....	....	....	....	....	....	....	*See* North Battleford Oil and Gas Co., Ltd., No. 1
Ribstone-Wainwright Oils, Ltd	11	7	8	27	2	....	365	Drilled in 1927. Suspended
Riverhurst Oil Co	....	....	....	....	....	....	....	*See* Associated Securities "Olmen" Nos. 1, 2, and 3
Rosetown Lease Holding and Dev. Co., Ltd.	....	....	....	....	....	....	....	*See* Herschel well
Sask. Exp. and Dev. Co., Ltd. "Ralph well"	SE.	28	7	13	2	....	1,515	Drilled in 1917-18. Abandoned
Simpson Oil Co. "Roycroft"	2	9	29	25	2	1,768	3,500±	Drilled in 1926. Shows oil and gas. Rock salt at 3,410 feet
Souris Valley Oil Fields Co	6	24	1	7	2	....	266	Drilled in 1914-15. Suspended
Spruce Lake Petroleums, Ltd	1	27	53	21	3	....	112?	Drilled in 1931
Unity Valley Oil and Gas Co	....	....	....	....	....	....	....	*See* Citizens Oil and Gas Co.
Vermilion Hills Oil and Gas Assoc	14	25	20	7	3	....	458	Drilled in 1929. Suspended
Weyburn Exploring Co	....	21	4	15	2	....	1,155	Drilled in 1926. No results
Wilcox	NE.	24	13	20	2	....	1,450	Drilled previous to 1913. Abandoned
Williams, H. L. (Saskatoon)	SW.	22	35	27	3	2,534	2,824	Drilled in 1916. A little gas at 2,473 and 2,560 feet. Abandoned

Alberta

Pincher Creek Sheet No. 14
(Tps. 1 to 8, W. 5th Mer.)

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Pincher Creek Oil and Refining Co	....	8	24	1	1	....	....	Four holes from 300 to 800 feet deep. Abandoned
Pincher Creek Oil and Refining Co	....	9	25	1	1	....	....	Abandoned
Weymarn Petroleums, Ltd., "Mount Royal"	1	3	7	6	1	....	975	Drilled in 1929. Suspended
Weymarn Petroleums, Ltd., "Pincher Creek"	2	5	7	6	1	....	3,900	Drilled in 1930. Suspended
Alberta Gas and Fuel, "Castle"	1	2	11	6	1	....	3,310	Drilled in 1928. Abandoned

Note: For other wells of Alberta Gas and Fuel Co. *See* Lethbridge sheet No. 16.

LETHBRIDGE SHEET No 15

(Tps. 1 to 8, Ranges 16 to 30, W. 4th Mer.)

Northwest Co., "Red Coulée"	1	7	5	1	16	3,545	2,695	Drilled in 1922–23. Oil in small quantity at 2,525 feet. Abandoned
Alberta Pacific Consolidated Oils, Ltd., "Red Coulée"	1	2	4	1	16	3,585	2,549	Drilled in 1930. Oil at 2,445 to 2,500 feet. Abandoned
Capitol Oil and Natural Gas Co., Ltd., "Red Coulée"	1	3	21	1	16	3,545	2,752	Drilled in 1930. Oil shows at 2,480 to 2,520 and 2,687 feet
Celtic Oils, Ltd	1	4	17	1	16	3,534	2,705	Drilled in 1930. Show of gas at 2,523 feet. Abandoned
Commonwealth Petroleums, Ltd	1	10	3	1	16	3,534	2,761	Drilled in 1930. Shows of gas. Abandoned
Dalco Oil Co., Ltd	1	4	11	1	16	3,505	2,640	Drilled in 1930. Abandoned
Devonshire Oil Co., Ltd	1	4	10	1	16	3,503	1,930	Drilled in 1930. Suspended
Dixie Oil Company	1	15	7	1	16	....	220	Drilled in 1930. Water well
Dixie Oil Company	1A	15	7	1	16	3,549	2,525	Drilled in 1930. No oil or gas reported
Southern Alberta Exploration Co., Ltd	1	8	3	1	16	3,502	2,442	Drilled in 1930. Oil well
Vanalta Oils, Ltd	1	3	4	1	16	3,571	2,477	Drilled in 1929. Oil well
Vanalta Oils, Ltd	2	3	4	1	16	3,574	2,494	Drilled in 1929–30. Oil well
Vanalta Oils, Ltd. (Taylor No. 1)	3	3	4	1	16	3,584	2,507	Drilled in 1930. Oil well
Vanalta Oils, Ltd	4	3	4	1	16	3,580	2,489	Drilled in 1930–31. Abandoned
Vanalta Oils, Ltd	5	4	4	1	16	....	2,517	Drilled in 1932. Oil
Scottish United Petroleums, Ltd	1	1	3	1	16	3,505	2,433	Drilled in 1930–31. Oil well
Ko-Top Oils, Ltd	1	1	2	1	17	3,637	1,665	Drilled in 1929–30. Abandoned
Ko-Top Oils, Ltd	1A	1	2	1	17	3,640	345	Drilled in 1930. Not completed
Dalco Oil and Gas Co	1	4	11	1	16	3,505	2,640	Drilled in 1930. Abandoned
Dalco Oil and Gas Co	2	7	19	2	17	3,630	3,140	Drilled in 1930–31. Abandoned
Anglo Western Oils, Ltd	1	1	12	4	17	....	....	Drilled in 1930–31. Suspended
Gas Production and Transportation Co. (Warner)	1	14	21	4	18	3,414	4,157	Drilled in 1927–28. Small amount of gas. Abandoned
Chinalta Petroleums, Ltd. (Lethalta Oils, Ltd.)	1	5	33	8	18	....	2,261	Drilled in 1928. Show of gas at 2,066 to 2,082 feet. Suspended
Lethbridge	....	....	31	8	21	....	2,220	Abandoned. Log in Geol. Surv., Canada, Mem. 116, p. 65
Parco-Nordon "Twin River"	1	16	34	1	20	3,962	4,145	Drilled in 1931–2. Oil on top of Palæozoic limestone
Nordon-Roney "Twin River"	2	12	2	2	20	4,028	3,940	Drilled in 1932–33. Oil in Palæozoic limestone
Macdonald Syndicate	....	12	26	3	22	....	....	Drilled in 1924 to very shallow depth. Abandoned
Northwest Co. (Imperial-Texas)	1	14	22	8	22	3,077	4,578	Drilled in 1931–32. Oil show on top of Palæozoic limestone. Abandoned
Lethbridge Breweries	1	NE. ¼	36	8	22	....	1,802	Drilled in 1929. Abandoned
Alta. Pac. Con. Oils, Ltd. (Spring Coulée)	1	11	15	4	23	3,702	6,191	Drilled in 1916. Show of oil. Abandoned

Alberta—Continued

Lethbridge Sheet No. 15—*Concluded*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Lethberta Oil Co. (Weeks)	1	1	1	2	26	....	1,380	Drilled in 1916. Abandoned
Lethberta Oil Co.	2	9	36	1	26	....	2,000	Drilled in 1916. Abandoned
Dominion Oil Co.	1	14	4	1	25	....	660	Drilled in 1915. Abandoned
Weeks, Alberta Oil Associates	1	16	5	1	25	....	1,900	Drilled in 1917. Abandoned
Weeks, Alberta Oil Associates	2	....	5	1	25	....	2,780	Drilled in 1919. Abandoned
McFarlane Oil Co.	....	11	14	2	26	....	2,090	Drilled in 1915–16. Abandoned
Original Discovery Oil Co., Rocky Mt. Dev. Co., "Lineham"	1	16	30	1	30	....	1,020	Drilling commenced 1902. Oil at 1,020 feet. Taken over by Patrick Oils, Ltd., in 1930
Original Discovery Oil Co.	2	16	30	1	30	....	1,900	Drilled in 1919–1920, a little gas, no oil
Western Oil and Coal Co.	1	W. ½	23	1	30	....	1,920	Drilled between 1902–1907. A little oil at 1,920 feet
Western Oil and Coal Co.	2	....	23	1	30	....	......	Drilled in 1907. Shallow depth reached
Western Oil and Coal Co.	3	....	4	2	30	....	......	Drilled in 1907. Shallow depth reached
Pincher Creek Oil and Refining Co.	4	NW. ¼	29	1	30	....	400	*See* Pincher Creek Sheet No. 14
Northwest Co. (Twin Butte)	1	15	14	4	30	....	2,780	Drilled in 1920. No oil or gas. Abandoned
Northwest Co. (Twin Butte)	2	1	20	3	29	....	4,392	Drilled in 1920–22. Small amount of gas. Abandoned
Alberta Gas and Fuel Co., "Waterton" or "Jenkins"	1	3	34	2	29	4,150	4,605	Drilled in 1928. Trace of gas, no oil. Abandoned
Alberta Gas and Fuel Co., "Yarrow"	1	16	34	3	30	4,624	4,157	Drilled in 1930–31. Small amount of oil at 4,100 feet. Abandoned
Alberta Gas and Fuel Co., "Drywood"	1	16	14	4	30	....	4,095	Drilled in 1928–29. Trace of oil and gas at 1,125 feet. Abandoned
Western Oil and Coal Co.	4	SE.	27	6	30	....	1,510	Drilled in 1907–8. Abandoned

Note: Alberta Gas and Fuel Company drilled seven diamond drill test holes as follows:

	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
	1	2	27	2	29	....	1,685	
	2	11	14	4	30	4,545	1,108	
	3	12	13	4	30	4,524	300	
	4	7	13	6	30	4,428	538	
	5	8	13	4	30	4,430	534	
	6	11	14	4	30	4,491	350	
	7	7	13	4	30	4,448	1,012	

Milk River Sheet No. 16

(Tps. 1 to 8, Ranges 1 to 15, W. 4th Mer.)

Eagle Butte Oil Co., Ltd.	1	9	31	7	4	3,623	4,002	Drilling commenced Sept., 1927. Abandoned May, 1929. Gas at 3,340 feet
Eagle Butte Oil Co., Ltd.	2	4	30	7	3	3,854	4,120	Drilling commenced Nov., 1929. Suspended Nov., 1930. Small gas flow
United Oils of Alberta, Ltd. (Etzikom Coulée)	3	SW.	31	5	10	2,825	3,716	Drilled in 1916. Three gas horizons penetrated at 960, 1,663, and 2,015 feet. Log in Geol. Surv., Canada, Mem. 116, p. 50
Canadian Oil and Refining Co., Range Oil and Gas Co. "Rogers-Imperial"	1	16	29	1	11	3,270	2,797	Drilling commenced Nov., 1922. Completed Aug., 1925. 20,000 M cub. ft. of gas encountered at 2,526 to 2,530 feet and further gas at 2,720 feet. Pressure 1,080 pounds a square inch
Range Oil and Gas Co.	2	6	21	1	11	3,361	2,918	Drilling commenced Nov., 1928. Completed Sept., 1930. Abandoned
Northwest Co., Ltd., Dead Horse Coulée.	2	5	32	1	11	2,999	2,580	Drilling commenced Sept., 1924. Completed Nov., 1925. Gas at 500 to 600, 1,005, 2,355 feet. Well abandoned
Beaver Oils, Ltd.	1	8	24	2	11	....	3,055	Drilling commenced April, 1915. Completed Aug., 1916. Gas at 1,645 feet. Abandoned
Foremost C.W.N.G.L.H. and P. Co.	1	8	1	6	11	3,013	2,191	Well completed 1923. Three gas sands penetrated giving 26,000 M cub. ft.
Foremost C.W.N.G.L.H. and P. Co.	2	13	29	5	10	3,002	2,215	Drilled in 1923. 7,538,800 cub. ft. of gas. Original pressure 600 pounds.
Foremost C.W.N.G.L.H. and P. Co.	3	2	36	5	11	2,876	2,070	Drilled in 1923. 1,741,824 cub. ft. at 2,015-2,019 feet
Foremost C.W.N.G.L.H. and P. Co.	4	8	12	6	11	3,071	2,252	Drilled in 1924. 14,410 M cub. ft. at 2,235 and 2,250 feet
Foremost C.W.N.G.L.H. and P. Co.	5	1	14	6	11	3,038	2,215	Drilled in 1925. 9,952 M cub. ft. at 2,200, 2,207 to 2,212 feet
Foremost C.W.N.G.L.H. and P. Co.	6	8	2	6	11	3,048	2,221	Drilled in 1925. 1,240 M cub. ft. at 2,195 to 2,196 feet. Abandoned
Foremost C.W.N.G.L.H. and P. Co.	7	4	24	6	11	2,968	2,157	Drilled in 1926. 3,500 M cub. ft. at 2,153 to 2,154 feet
Foremost C.W.N.G.L.H. and P. Co.	8	12	5	6	10	....	2,325	Drilled in 1927. Abandoned
Mutual Holdings, Ltd. (Madison Oil, Ltd.)	2	10	24	2	11	....	....	Drilling commenced June, 1928. Abandoned in 1931
Dreamfield Oil Co.	1	13	28	3	11	....	675	Diamond drill hole. Drilled in 1919-20. No results
Dreamfield Oil Co.	2	12	28	3	11	3,342	1,000	Drilling commenced 1921. Show of gas at 700 feet. Abandoned

Alberta—Continued

Milk River Sheet No. 16—*Concluded*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Fortymile Coulée	....	4	23	8	11	2,621	2,079	Drilled in 1919. Artesian water at 500 feet. Abandoned
Grand Trunk Pacific Development Co.	1	....	1	1	12	3,660	2,900	Drilled in 1914–15. Log in Geol. Surv., Canada, Mem. 116, p. 49
Northwest Co., Ltd., "Erickson Coulée"	1	13	8	1	12	3,612	3,650	Drilling commenced April, 1926. Completed June, 1927. Gas at 2,376 (7,300 M), 2,488, and 2,531 feet
Capitol Oil and Natural Gas Co., Ltd.	1	4	4	2	12	....	660	Drilled in Oct.–Nov., 1928. Abandoned
Capitol Oil and Natural Gas Co., Ltd.	1A	16	32	1	12	2,960±	3,581	Drilling commenced May, 1929. Suspended. Small amount of gas
Border Oil Co.	1	1	6	1	14	....	2,001	Drilling commenced Aug., 1922. Showing of oil and gas reported
Devenish Petroleum, Ltd	1	5	27	5	14	3,050	3,190	Drilling commenced Aug., 1926. Completed in 1927. Oil at 3,080 feet
Devenish Petroleum, Ltd	2	11	11	5	14	2,906	3,171	Drilling commenced June, 1928. Completed Oct., 1928. Abandoned. No oil or gas reported
Devenish Petroleum, Ltd	3	4	27	5	14	3,008	3,067	Drilling commenced Nov., 1928. Oil encountered in April, 1929, at 3,054 feet
Devenish Petroleum, Ltd	4	13	29	5	14	3,030	3,148	Drilling commenced April, 1930. Abandoned Aug., 1930. Gas show at 3,107 feet
Urban Oil Co. (Moodie Dundas No. 1)	1	2	4	1	15	3,465	3,427	Drilling commenced June, 1923. Abandoned May, 1927
Coutts-Sweetgrass Oils, Ltd., "McLean"	1	1	1	1	15	....	2,852	Drilling commenced July, 1922. Completed Aug., 1923. Abandoned. Shows of gas and oil
Oil Lands Exploration Co. (Somerville Co.)	1	1	2	1	15	....	210	Drilling commenced July, 1922. Abandoned
Oil Lands Exploration Co. (Somerville Co.)	2	8	2	1	15	....	200	Drilling commenced June, 1923. Abandoned
Boundary Oil Co. (McCulloch well)	1	1	3	1	15	....	670	Drilling commenced May, 1923. Abandoned
T. M. Huff (Livingstone Maughan)	....	1	11	1	15	....	310	Drilled in summer of 1922-23. Abandoned
Lethbridge Oils, Ltd	1	1	12	1	15	3,475	2,030	Drilling commenced July, 1922. Abandoned
Anglo-Indian Oils, Ltd	....	1	14	1	15	....	225	Drilling commenced June, 1923. Abandoned
Foster Oil and Gas Syndicate	....	1	15	1	15	....	220	Drilling commenced July, 1922. Abandoned
Commonwealth, "Milk River"	1	8	9	3	15	3,157	5,301	Drilling commenced Nov., 1928. No commercial production. Abandoned in 1933
Dauntless Oils, Ltd	1	9	36	6	15	3,019	3,295	Drilling commenced July, 1929. Shows of oil at 2,999 and 3,079 feet

PORCUPINE SHEET No. 64
(Tps. 9 to 16, W. 5th Mer.)

Willow Creek Oils, Ltd	1	12	21	9	2	....	1,385	Drilled in 1914. No results. Abandoned
Willow Creek Oils, Ltd	2	1	4	8	2	....	1,686	Drilled in 1914-15. No results. Abandoned
Source Rock Petroleums	1	13	21	9	2	....	160	Drilled in 1930
Northwest Co., Ltd. (Rice Creek)	....	13	4	14	2	....	5,747	Drilling commenced Aug., 1924. Completed Dec., 1926. Abandoned. No oil
Northwest Co., Ltd. (Willow Creek)	....	14	29	14	2	....	3,602	Drilling commenced Oct., 1919. Abandoned May, 1923. Shows of gas
Northwest Co., Ltd. (Alta. Assoc. Oil Fields, "Christie")	....	5	7	16	2	....	2,860	Drilled in 1920-21. Some oil. Abandoned
Gap Oil Concessions, Ltd	1	....	33	10	3	....	770	Drilled in 1917-18. Abandoned 1923. No oil or gas

MACLEOD SHEET No. 65
(Tps. 9 to 16, Ranges 16 to 29)

Taber	....	SW. ¼	5	10	16	2,671	2,350	Diamond drill hole drilled in 1911. No results. Log in Geol. Surv., Canada, Mem. 116, p. 56
Chin Coulée C.W.N.G.L. H. and P. Co.	1	14	31	9	17	2,708	2,255	Drilled in 1918. Gas at 2,151 to 2,166 feet. Initial flow 4,000,000 cub. ft.
Chin Coulée	2	3	1	10	18	2,700	2,617	Drilled in 1919-20. Shows of gas. Abandoned
Chin Coulée	3	14	6	10	17	2,709	2,254	Drilled in 1919-20. No gas. Abandoned
Chin Coulée	4	8	36	9	18	2,705	730	Drilled in 1919. No gas. Abandoned
Chin Coulée	6	5	32	9	17	2,723	2,508	Drilled in 1923. Some shallow gas. Abandoned
Chin Coulée	7	15	32	9	17	2,693	2,183	Drilled in 1923. Gas at 2,150 to 2,168 feet. Initial flow 500 M cub. ft.
Chin Coulée	8	16	29	9	17	2,721	2,470	Drilled in 1923. No gas. Abandoned
Barnwell	1	14	31	9	17	2,670	932	Drilled in 1928. A structural test well
Cole English Syndicate, "Taber"	1	3	11	10	17	2,567	3,319	Drilled in 1929-30. Shows of gas and oil. Deepened by Alberta Pac. Con. Oils, Ltd., in 1931. Suspended
Hudson's Bay Oil and Gas Co., Keho Lake	1	2	17	11	22	3,270	4,920	Drilling commenced June, 1930. Not completed Dec. 31, 1931. Some oil
West Canadian Coal Mining Co., "Kipp"	....	....	35	9	23	....	658	Drilled in 1910. No results. Abandoned
Alberta Gas and Fuel Co., Ltd., "Champion"	1	9	9	16	23	3,334	2,750	Drilled in 1929. No gas or oil. Abandoned
Monarch C.W.N.G.L.H. and P. Co.	1	10	1	10	24	2,950	1,775	Drilled in 1920. Abandoned
Monarch C.W.N.G.L.H. and P. Co.	2	5	12	10	24	3,093	2,813	Drilling commenced 1920. Resumed in 1922. Small show of gas at 1,245-1,249 feet. Suspended Nov., 1922

NOTE. Chin Coulée No. 5—Location only.

Alberta—Continued

MEDICINE HAT SHEET No. 66

(Tps. 9 to 16, Ranges 1 to 15)

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Canadian American Oil Co. (Many Islands Oil and Gas Co.)	1	12	31	13	1	....	1,315	Drilled in 1923, 750 M cub. ft. of gas at 1,300 feet
Medicine Hat Development Co...........	1	4	19	14	1	....	1,550	Drilled in 1921-22, 3,000 M cub. ft. of gas at 1,535 feet
Medicine Hat Development Co...........	2	SW.	20	14	1	....	70	Drilled in 1922
Community Oil Wells, Ltd...............	1	7	19	14	1	2,490	2,850	Drilled between 1922-28. Some gas
Many Islands Oil and Gas Co., "Drazan" No. 1	1	13	34	13	2	2,368	3,540	Drilled in 1923-26. Some gas and oil shows at 3,005-3,018, and 3,110-3,123 feet
W. B. Nicholson........................	....	14	12	15	4	....	1,306	Drilled in 1917. 40 M cub. ft. of gas at 1,270 feet
Medicine Hat Petroleum Co.............	1	5	14	11	6	....	365	Drilled in 1922. Abandoned on account crooked hole
Medicine Hat Petroleum Co.............	2	5	14	11	6	....	800	Drilled in 1922-3. Abandoned
Medicine Hat Petroleum Co.............	3	5	14	11	6	....	550	Drilled in 1924. Suspended
Medicine Hat, City, "Main St.".........	1	5	31	12	5	2,203	1,010	Drilled in 1903-4. Initial open flow 2,225 M cub. ft.
Medicine Hat, City, "Armory"..........	2	10	31	12	5	2,145	1,200	Drilled in 1905. Initial open flow 3,000 M cub. ft.
Medicine Hat, City, "Rosary"...........	3	12	32	12	5	2,133	1,000	Drilled in 1911. Initial open flow 2,000 M cub. ft.
Medicine Hat, City, "Balmoral".........	4	6	32	12	5	2,129	1,984	Drilled in 1911. Initial open flow 2,500 M cub. ft. Log in Geol. Surv., Canada, Mem. 116, p. 47
Medicine Hat, City, "Electric Plant"....	5	11	35	12	6	2,168	1,134	Drilled in 1911-13. Initial open flow 4,000 M cub. ft.
Medicine Hat, City, "Craft".............	6	6	36	12	6	2,148	1,075	Drilled in 1913. Initial open flow 3,264 M cub. ft.
Medicine Hat, City, "S. Industrial"......	7	13	18	12	5	2,347	1,203	Drilled in 1913. Initial open flow 2,300 M cub. ft.
Medicine Hat, City, "W. Industrial".....	8	16	22	12	6	2,313	1,202	Drilled in 1913. Initial open flow 2,100 M cub. ft.
Medicine Hat, City, "Stella"............	9	6	28	12	5	2,148	1,002	Drilled in 1913. Initial open flow 2,500 M cub. ft.
Medicine Hat, City, "Hargrave".........	10	13	31	12	5	2,166	1,042	Drilled in 1913. Initial open flow 2,500 M cub. ft.
Medicine Hat, City, "Cousins and Sissons"	11	15	25	12	6	2,269	1,108	Drilled in 1913. Initial open flow 2,800 M cub. ft.

Medicine Hat, City, "Central Park"	12	12	30	12	5	2,263	1,126	Drilled in 1913. Initial open flow 3,000 M cub. ft.
Medicine Hat, City, "Maple St."	13	12	29	12	5	2,131	980	Drilled in 1913. Initial open flow 2,500 M cub. ft.
Iron Rolling Mills, "Powell"	14	7	30	12	5	2,140	1,100	Drilled in 1911. Initial open flow 2,900 M cub. ft.
Alberta Clay Products No. 1, "Big Chief"	15	15	29	12	5	2,134	1,100	Drilled in 1911. Initial gas flow 2,750 M cub. ft.
Ogilvie Milling Co. No. 1	16	9	30	12	5	2,137	1,050	Drilled in 1912. Initial gas flow 2,800 M cub. ft.
Maple Leaf Milling Co.	17	6	30	12	5	2,152	1,000	Drilled in 1913. Initial gas flow 1,850 M cub. ft.
C.P.R. No. 1	18	1	31	12	5	2,179	900	Drilled in 1908. Produced gas for some years. Abandoned
C.P.R. No. 2	18A	1	31	12	5	2,179	1,013	Drilled in 1914. Initial gas flow 2,800 M cub. ft.
Medicine Hat Brick and Tile Co. No. 1, "Purmal"	19	13	28	12	5	2,163	953	Drilled in 1914. Initial gas flow 2,250 M cub. ft.
Canada Cement No. 1, "Dauntless"	20	14	36	11	6	2,360	1,434	Drilled in 1913. Initial gas flow 2,000 M cub. ft.
Canada Cement No. 2, "Reservoir"	21	16	28	12	6	2,331	1,187	Drilled in 1913. Initial gas flow 2,338 M cub. ft.
Canada Cement No. 3, "Smeltzer"	22	15	14	12	6	2,306	1,040	Drilled in 1913-14. Initial gas flow 2,117 M cub. ft.
Canada Cement No. 4, "Ditcher"	23	1	22	12	6	2,223	1,075	Drilled in 1914. Initial gas flow 1,500 M cub. ft.
Canada Cement No. 5	24	1	28	12	6	2,292	1,150	Drilled in 1914. Initial gas flow 2,600 M cub. ft.
Redcliff Gas Co., "South side"	25	10	5	13	6	2,451	1,187	A gas well. No data available
Redcliff Brick and Coal No. 3	26	14	5	13	6	2,247	1,027·5	Drilled in 1921. A gas well
Redcliff Gas Co., "West side"	27	9	7	13	6	2,434	1,171	Drilled in 1913? Initial gas flow 4,000 M cub. ft.
Redcliff Gas Co., "Broadway"	28	3	17	13	6	2,459	1,187	Drilled in 1913? Initial gas flow 5,000 M cub. ft.
Dominion Gas Co. No. 1, "East well"	29	3	17	13	6	2,452	1,181	Initial gas flow 3,147 M cub. ft.
Redcliff Gas Co. No. 2, "East side"	30	10	9	13	6	2,413	1,155	Initial gas flow 4,000 M cub. ft.
C.P.R. Dunmore Junc.	31	NE.	9	12	5	2,250	1,325	Drilled in 1908-9. Initial gas flow 1,500 M cub. ft.
Alberta Clay Products No. 2	32	13	29	12	5	....	985	Drilled in 1924. Initial gas flow 1,365 M cub. ft.
Dunmore Development Co. No. 1	33	4	2	12	5	....	1,175	Drilled in 1911-12. A gas well
Medicine Hat City, "Wellington"	34	R.A.	27/28	12	5	2,171	996	Drilled in 1917-18 on road allowance between Secs. 27 and 28. Initial gas flow 2,225 M cub. ft.
Medicine Hat City, "Crescent Heights or Huckvale"	35	13	6	13	5	2,336	1,118	Drilled in 1924. Initial gas flow 2,900 M cub. ft.

Alberta—Continued

Medicine Hat Sheet No. 66—*Continued*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Dominion Glass Co. No. 2, "West well"	36	4	17	13	6	2,438	1,187	A gas well
Roth No. 1	37	4	6	13	5	2,330	3,940	Drilled in 1925-26. Gas at 1,080 feet. Initial open flow 2,635 M cub. ft.
Roth No. 2	38	9	8	13	6	2,490	3,150	Drilled in 1926-27. Gas at 1,252 feet. Initial open flow 1¼ to 2 million cub. ft.
Ogilvie Milling Co. No. 2	39	9	30	12	5	....	1,000	Drilled in 1927. A gas well
Medicine Hat, City, "Uberheim"	40	8	5	13	5	2,171	1,925	A gas well
Medicine Hat, City, C. H. Pratt	41	16	30	12	5	....	....	No record
C.P.R. No. 3	42	14	36	12	6	2,237	1,014	Drilled in 1924-25. Initial open flow 3,000 M cub. ft.
Redcliff Pressed Brick Co. No. 1	43	5	9	13	6	2,443	1,291	Drilled in 1924. Initial open flow 1,800 M cub. ft.
Redcliff Pressed Brick Co. No. 2	44	4	9	13	6	2,421	1,200	Drilled in 1927. A gas well
Redcliff Brick and Coal No. 2	45	1	7	13	6	2,421	1,234	Drilled in 1912. Initial open flow 4,000 M cub. ft.
Medicine Hat, City, "Fox Farm"	46	15	26	12	6	2,269	1,120	Drilled in 1928. Initial open flow 1,170 M cub. ft.
Medicine Hat, City, "Manyberries" or "Bullivant"	47	16	18	12	5	2,326	1,200	Drilled in 1929. Initial open flow 1,000 M cub. ft.
C.P.R. No. 4	48	3	2	13	6	2,288	1,098	Drilled in 1929. A gas well
Medicine Hat, City, "Shepherd"	49	11	35	12	6	2,177	1,012	Drilled in 1929. Initial open flow 1,500 M cub. ft.
Medicine Hat Brick and Tile No. 2	50	4	33	12	5	....	1,025	Drilled in 1929. Initial open flow 1,500 M cub. ft.
Alberta Clay Products No. 3 } Yuill No. 3 }	51	14	29	12	5	....	986	Drilled in 1930. Initial open flow 1,100 M cub. ft.
Alberta Clay Products No. 4	52	14	29	12	5	....	1,006	Drilled in 1930. Initial open flow 800 M cub. ft.
Medicine Hat, City, "Canneries"	....	16	31	12	5	....	....	Drilled previous to 1904. No record
Medicine Hat, City, "Old Power House"	....	5	31	12	5	....	....	Drilled previous to 1904. Did not reach producing horizon
Medicine Hat, City, "Methodist Church"	....	6	31	12	5	....	....	Drilled previous to 1904. Did not reach the producing sand
Medicine Hat, City, "Alberta Stables"	....	10	31	12	5	....	....	Drilled previous to 1904. Did not reach the producing sand
Medicine Hat, City, "Montreal Street"	....	9	31	12	5	....	....	Drilled previous to 1904. Did not reach the producing sand

Medicine Hat, City, "Coulter"		9	31	12	5	....	....	Drilled previous to 1904. Did not reach the producing sand
Medicine Hat, City, "New Edinburgh"		8	36	12	6	....	....	Drilled previous to 1904. Did not reach the producing sand
Redcliff Premier Brick Co., No. 1	53	13	9	13	6	2,426	1,231	Drilled in 1930. Initial open flow 2,400 M cub. ft.
Medicine Hat, City	54	14	34	13	5	2,436	1,243	Drilled in 1930. Initial open flow 2,750 M cub. ft.
Gold Valley Irrigation Co		SW.	4	13	5	2,171	940	Drilled in 1914. A gas well
James Mitchell		3	3	14	5	....	684	Drilled in 1917. Initial open flow, 34,500 cub. ft.
Drowning Ford Ranch		NE.	21	15	5	....	668	Drilled previous to 1919. Initial open flow 50,000 cub. ft.
								Log in Geol Surv., Canada, Mem. 116, p. 47
Raymond C. Porter		3	24	12	7	....	1,155	Drilled in 1920. Good flow of gas
George S. Worthy		15	12	13	7	....	785	Drilled in 1924. Initial open flow 150,000 cub. ft.
Sanctuary Oil Co. (Pakowki Lake well)		10	10	5	8	....	2,845	Drilled in 1922–4. Abandoned 1925
C.P.R. Suffield		....	4	13	9	2,220	1,200	Small show of gas
Village of Suffield No. 1		12	34	14	9	....	900	Drilled in 1911. Produced some gas
Village of Suffield No. 2		13	34	14	9	....	715	Drilled in 1922–23. Abandoned on account of drilling trouble
C.P.R. Alderson (Langevin)	1	SW. ¼	29	15	10	2,471	1,155	Drilled in 1883. Some gas
C.P.R. Alderson	2	....	30	15	10	2,471	1,426	Drilled in 1884. Initial gas flow 50,000 cub. ft.
Bow Island C.W.N.G.L.H. and P. Co.	1	6	15	11	11	2,300	1,916	Drilled in 1909. Initial gas flow 8,500 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co.	2	15	15	11	11	2,273	1,907	Abandoned on account of water
Bow Island C.W.N.G.L.H. and P. Co.	3	14	9	11	11	2,273	1,887	Drilled in 1911. Initial gas flow 13,100 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co.	4	3	17	11	11	2,273	1,879	Drilled in 1911. Initial gas flow 29,000 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co.	5	9	22	11	11	2,270	1,896	Drilled in 1911. Abandoned
Bow Island C.W.N.G.L.H. and P. Co.	6	1	16	11	11	2,286	1,918	Drilled in 1911. Initial gas flow 4,190 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co.	7	8	18	11	11	2,283	1,900	Drilled in 1911. Initial gas flow 1,080 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co.	8	13	18	11	11	2,314	1,930	Drilled in 1911. Initial open flow 12,160 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co.	9	2	24	11	12	2,283	1,911	Drilled in 1912. Some gas with water
Bow Island C.W.N.G.L.H. and P. Co.	10	8	23	11	12	2,281	1,904	Drilled in 1912. Some gas
Bow Island C.W.N.G.L.H. and P. Co.	11	1	7	11	11	2,534	2,159	Drilled in 1912. Initial open flow 7,300 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co.	12	13	7	11	11	2,467	2,085	Drilled in 1912. Initial open flow 16,000 M cub. ft.

Alberta—Continued

Medicine Hat Sheet No. 66—*Concluded*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Bow Island C.W.N.G.L.H. and P. Co....	13	3	9	11	11	2,521	2,141	Drilled in 1912. Initial open flow 18,500 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co....	14	1	1	11	12	2,548	2,148	Drilled in 1912. Initial open flow 7,000 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co....	15	13	12	11	12	2,581	2,218	Drilled in 1913. Initial open flow 4,000 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co....	16	4	4	11	11	2,554	2,218	Drilled in 1913. Abandoned
Bow Island C.W.N.G.L.H. and P. Co....	17	1	25	11	12	2,594	2,166	Drilled in 1914. Abandoned
Bow Island C.W.N.G.L.H. and P. Co....	18	4	1	11	12	2,663	2,563	Drilled in 1916–17. Abandoned
Bow Island C.W.N.G.L.H. and P. Co....	19	16	25	10	12	2,531	2,146	Drilled in 1917. Initial open flow 3,000 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co....	20	16	30	10	11	2,550	2,167	Drilled in 1917. Abandoned
Bow Island C.W.N.G.L.H. and P. Co....	21	1	30	10	11	2,564	2,415	Drilled in 1917. Abandoned
Bow Island C.W.N.G.L.H. and P. Co....	22	14	31	10	11	2,544	2,151	Drilled in 1918. Initial gas flow 1,300 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co....	23	16	17	11	11	2,396	2,028	Drilled in 1918–19. Initial open flow 2,300 M cub. ft.
Bow Island C.W.N.G.L.H. and P. Co....	25	16	12	9	12	2,568	2,122	Drilled in 1919. Abandoned
Bow Island C.W.N.G.L.H. and P. Co....	26	15	33	10	11	2,559	2,220	Drilled in 1919. Abandoned
Bow Island C.W.N.G.L.H. and P. Co....	27	4	20	11	11	2,496	2,130	Drilled in 1919. Initial open flow 1,300 M cub. ft.
Bow Island Town..........................	....	12	4	11	11	2,275	2,150·5	Drilled in 1913–14. Initial open flow 7,000 M cub. ft.
Northwest Co., Ltd., Burdett............	1	....	8	11	11	....	4,060	Drilled in 1926–27. Abandoned
Southern Alberta Land Co..............	1	9	24	11	12	....	2,177	Drilled in 1912. Initial gas flow 14,143 M cub. ft.
Southern Alberta Land Co...............	2	12	34	14	9	....	900	This is Suffield No. 1 well

Calgary Sheet No. 114

(Tps. 17 to 24, W. 5th Mer.)

Turner Valley								
Advance Oil Co..........................	5	16	19	19	2	4,230	3,451	Drilled in 1927. Abandoned
Advance Oil Co..........................	5A	16	19	19	2	....	6,515	Drilled in 1929–30. Producing from Palæozoic limestone

Alberta Federated	1	10	1	20	3	4,021	5,374	Drilled in 1930. Producing. *See* Freeman Lundy Syn.
Alberta Pacific Consolidated	1	5	20	19	2	4,245	5,796	Drilled in 1929-30. Producing from Palæozoic limestone
Alberta Pacific Consolidated	2	5	20	19	2	4,271	5,840	Drilled in 1929-30. Producing from Palæozoic limestone
Anaconda (Model 2)	1	16	22	20	3	4,083	6,539	Taken over by Model Oils. Producing from Palæozoic limestone
Baltac	1	13	20	19	2	4,215	5,874	Drilled in 1929-30. Producing from Palæozoic limestone
Big Chief Oil Co	1	4	5	20	2	3,993	4,370	Drilled in 1925-27. Abandoned
British Dominion Oil and Dev. Corp	1	4	5	20	2	3,986	6,600	Drilled in 1926-28. Abandoned
British Dominion Oil and Dev. Corp	2	6	12	20	3	4,046	5,180	Drilled in 1928-29. Producing from Palæozoic limestone
British Dominion Oil and Dev. Corp	3	6	12	20	3	4,060	5,316	Drilled in 1930. Producing from Palæozoic limestone
Calmont Oils, Ltd	1	2	1	20	3	4,015	5,877	Drilled in 1926-30. Producing from Palæozoic limestone
Calmont Oils, Ltd	2	11	20	19	2	4,200	4,927	Drilled in 1929-30. Producing from Palæozoic limestone
Calmont Oils, Ltd	3	2	1	20	3	3,961	1,587	Drilled in 1929. Suspended
Calmont Oils, Ltd	4	11	20	19	2	4,209	5,084	Drilled in 1929-30. Producing from Palæozoic limestone
Calmont Oils, Ltd	5	3	34	20	3	4,014	4,082	Drilled in 1929. Suspended
Calmont Oils, Ltd	6	11	20	19	2	4,206	3,770	Drilled in 1929. Suspended
Calmont Oils, Ltd	7	11	20	19	2	4,200	5,414	Drilled in 1929-30. Producing from Palæozoic limestone
Calmont Oils, Ltd	8	11	20	19	2	4,213	1,602	Drilled in 1929-30. Suspended
Calmont Oils, Ltd. (Seneca No. 1)	9	1	34	20	3	3,987	4,930	Drilled in 1926-29. Suspended
Calmont Oils, Ltd	10	11	20	19	2	4,207	1,604	Drilled in 1930. Suspended
Calmont Oils, Ltd	11	11	20	19	2	4,236	463	Drilled in 1930. Suspended
Canada Southern Oil and Refining Co	1	9	1	20	3	3,996	2,510	Drilled in 1914-15. Oil encountered at 2,384 and 2,510 feet
Commonwealth Petroleums, Ltd	1	7	9	19	2	....	5,000	Drilled in 1929-31. Producing from Palæozoic limestone
Cooper Nanton Oils, Ltd	1	2	7	20	2	3,901	4,830	Drilled in 1926-27. Abandoned
Dalfin Petroleums, Ltd	1	12	34	20	3	4,024	3,319	Drilled in 1929. Suspended
Dalhousie Oil Co. (Southern Alberta)	1	4	18	20	2	4,002	4,565	Drilled in 1914-15 by Southern Alberta Oil Co. Deepened by Dalhousie Oil Co. 1926-28. Producing from Palæozoic limestone
Dalhousie Oil Co	2	4	18	20	2	4,015	3,600	Drilled in 1916-17. Abandoned
Dalhousie Oil Co. (Alberta Southern)	3	10	13	20	3	4,046	3,340	Drilled in 1916. Deepened 1926 and abandoned. Produced oil for several years
Dalhousie Oil Co	4	8	13	20	3	4,006	3,600	Drilled in 1916-17. Abandoned
Dalhousie Oil Co	5	16	30	19	2	4,036	4,901	Drilled in 1926-28. Producing oil from 4,527 and 4,810 feet

Alberta—Continued

Calgary Sheet No. 114—*Continued*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Dalhousie Oil Co	6	10	13	20	3	4,056	5,593	Drilled in 1926-28. Small production
Dalhousie Oil Co	7	9	30	19	2	4,061	5,339	Drilled in 1929-30. Producing from Palæozoic limestone
Dallas Oil Co., Ltd	1	11	20	19	2	4,204	3,100	Drilled in 1926. Abandoned
Dome Oils, Ltd	1	2	24	20	3	4,044	6,005	Drilled in 1929-30. Abandoned
Dome Oils, Ltd	2	16	36	19	3	4,036	5,612	Drilled in 1930-31
East Crest Oil Co., Ltd	1	5	16	19	2	4,133	4,675	Drilled in 1928-30. Producing from Palæozoic limestone
East Crest Oil Co., Ltd	2	4	16	19	2	4,124	3,203	Drilled in 1929-30. Abandoned
East Crest Oil Co., Ltd	2A	4	16	19	2	4,125	4,637	Drilled in 1930. Producing from Palæozoic limestone
East Crest Oil Co., Ltd	3	4	16	19	2	4,005	4,845	Drilled in 1930-31. Producing from Palæozoic limestone
Foothills Oil Co., Ltd	1	4	26	20	3	4,001	5,915	Drilled in 1927-28. Producing from Palæozoic limestone
Foothills Oil Co., Ltd. (Dolomite No. 1)	2	8	1	20	3	3,971	4,940	Drilled in 1926-30. Producing from Palæozoic limestone
Foothills Oil and Gas Co., Ltd. (Southwest Petroleums, Ltd.)	3	16	8	9	2	4,080	6,054	Drilled in 1929-30. Producing from Palæozoic limestone
Foothills Oil and Gas Co., Ltd	4	1	26	20	3	4,023	4,559	Drilled in 1929. Abandoned
Freehold Oil Corp	1	4	3	21	3	3,993	4,825	Drilled in 1928-29. Suspended
Freehold Oil Corp	2	8	20	19	2	4,205	4,440	Drilled in 1929-30. Producing from Palæozoic limestone
Freehold Oil Corp	3	8	20	19	2	4,202	140	Drilled in 1930. Suspended
Freeman-Lundy Synd. (Alberta Federated)	1	10	1	20	3	4,020	5,374	Drilled in 1929-30. Producing from Palæozoic limestone
Great West Oils, Ltd	1	2	7	20	2	3,903	5,400	Drilled in 1926-27. Abandoned
Hargal Oils, Ltd	1	10	20	19	2	4,192	5,348	Drilled in 1929-30. Producing from Palæozoic limestone
Highland Oil Co., Ltd	1	5	5	20	2	3,985	3,020	Drilled in 1926-27. Abandoned
Home Oil Co., Ltd	1	10	20	19	2	4,198	5,280	Drilled in 1926-29. Producing from Palæozoic limestone
Home Oil Co., Ltd. (Advance No. 1)	1A	14	20	19	2	4,201	3,160	Drilled in 1915. Suspended
Home Oil Co., Ltd. (Advance No. 2)	2	14	20	19	2	4,204	5,507	Drilled in 1926 (Advance). Completed 1929 (Home). Producing from Palæozoic limestone
Home Oil Co., Ltd	3	10	20	19	2	4,206	5,139	Drilled in 1928-29. Producing from Palæozoic limestone

Home Oil Co., Ltd.	4	14	20	19	2	4,213	5,601	Drilled in 1928-30. Producing from Palæozoic limestone
Home Oil Co., Ltd.	5	7	20	19	2	4,228	4,898	Drilled in 1929-30. Producing from Palæozoic limestone
Home Oil Co., Ltd.	6	2	20	19	2	4,251	4,689	Drilled in 1929-30. Producing from Palæozoic limestone
Home Oil Co., Ltd.	7	1	20	19	2	4,263	2,280	Drilled in 1930. Suspended
Homestead Oils, Ltd.	1	6	16	19	2	4,144	4,798	Drilled in 1929-30. Producing from Palæozoic limestone
Hylo Oils, Ltd.	1	12	14	19	2	4,051	5,665	Drilled in 1929-32. Producing from Palæozoic limestone
Illinois-Alberta Oil Co., Ltd.	1	14	12	20	3	4,008	3,862	Drilled 1914. Deepened 1927. Producing from Palæozoic limestone
Illinois-Alberta Oil Co., Ltd.	2	14	12	20	3	4,012	3,681	Drilled in 1927-29. A diamond drill hole
Invaders Petroleum, Ltd.	1	10	9	21	3	3,972	4,763	Drilled in 1929-30. Abandoned
Livingstone	....	5	34	18	2	....	330	Drilling commenced Dec., 1930. Not completed
Lowery Petroleums, Ltd.	1	14	17	19	2	4,316	5,473	Drilled in 1929-30. Producing from Palæozoic limestone
Lowery Petroleums, Ltd.	2	11	17	19	2	4,249	6,594	Drilled in 1930-31. Producing from Palæozoic limestone
Lundy Petroleums, Ltd.	....	4	3	19	2	....	100	Drilled in 1930. Suspended
Mayland Oil Co., Ltd.	1	10	17	19	2	4,215	6,242	Drilled in 1928-30. Producing from Palæozoic limestone
Mayland Oil Co., Ltd.	2	8	17	19	2	4,136	5,017	Drilled in 1929-30. Producing from Palæozoic limestone
Mayland Oil Co., Ltd.	3	2	17	19	2	4,105	6,177	Drilled in 1929-30. Producing from Palæozoic limestone
Mayland Oil Co., Ltd.	4	16	17	19	2	4,283	2,290	Drilled in 1930. Hole lost
Mayland Oil Co., Ltd.	6	1	17	19	2	4,117	4,935	Drilled in 1930-31
Mar-Jon Freehold	1	9	28	18	2	....	5,854	Drilled in 1931-33. Producing from Palæozoic limestone
McLeod Oil Co., Ltd.	1	16	1	20	3	4,012	3,940	Drilled in 1923. Produced crude oil from 2,390 feet. Deepened to Palæozoic limestone 1927-28. Producing
McLeod Oil Co., Ltd.	2	16	1	20	3	4,005	4,420	Drilled in 1925-26. Producing from Palæozoic limestone
McLeod Oil Co., Ltd.	3	15	1	20	3	4,029	4,973	Drilled in 1927. Produced crude oil from 3,170-3,200 feet. Deepened to Palæozoic limestone 1929. Producing
McLeod Oil Co., Ltd.	4	16	1	20	3	4,007	7,740	Drilled in 1928-29. Producing from Palæozoic limestone. Deepened 1932. Drilling
McLeod Oil Co., Ltd.	5	15	1	20	3	4,034	5,188	Drilled in 1929-30. Producing from Palæozoic limestone
McDougall Oil Co.	1	SE. 16	16	21	3	3,971	3,900	Drilled in 1912-14. Abandoned
Mercury Oil Co., Ltd. (Dutch-America 2)	1	13	4	19	2	4,009	5,365	Drilled in 1928-30. Producing from Palæozoic limestone

Alberta—Continued

CALGARY SHEET No. 114—*Continued*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Mercury Oil Co., Ltd.	2	11	4	19	2	4,056	5,432	Drilled in 1929-30. Producing from Palæozoic limestone
Mercury Oil Co., Ltd. (Sunlight Oils, Ltd.)	3	2	4	19	2	4,202	5,275	Drilled in 1929-30. Producing from Palæozoic limestone
Mercury Oil Co., Ltd.	5	2	4	19	2	4,168	5,998	Drilled in 1929-31. Abandoned
Mercury Oil Co., Ltd.	6	12	4	19	2	....	2,000	Drilled in 1931. Suspended
Mercury Oil Co., Ltd.	7	2	4	19	2	4,146	1,930	Drilled in 1930. Suspended
Merland Oil Co., Ltd.	1	13	27	18	2	4,274	5,543	Drilled in 1929. Production secured at 4,410 feet. Well deepened at a later date to Palæozoic limestone
Midfield Oil Co., Ltd.	1	9	1	20	3	3,980	4,205	Drilled in 1929-30. Producing from Palæozoic limestone
Mid-West Oil Co., Ltd.	1	8	31	19	2	4,028	3,740	Drilled in 1914 (N.W. Pac. Oil Co.). Deepened (Mid-West Oil Co.) 1917. Work ceased 1922. Abandoned
Mid-West Oil Co., Ltd.	2	3	24	20	3	4,024	3,750	Drilled in 1914 (N.W. Pac. Oil Co.). Deepened (Mid-West Oil Co.) 1917. Abandoned
Midroyal Oil Co., Ltd.	1	4	31	19	2	....	2,175	Drilled in 1929-30. Not completed
Mill City Petroleums, Ltd.	1	14	4	19	2	....	430	Drilled in 1929. Abandoned
Mill City Petroleums, Ltd.	1A	14	4	19	2	4,025	5,065	Drilled in 1929-30. Production at 4,515 feet
Miracle Oils, Ltd.	1	11	4	19	2	4,030	5,585	Drilled in 1929-30
Miracle Oils, Ltd.	2	16	5	19	2	4,074	6,723	Drilled in 1930-33. Producing oil 55° Bé. from Palæozoic limestone
Miracle Oils, Ltd.	3	11	4	19	2	....	6,150	Drilled in 1931-32
Model Oils, Ltd.	1	8	22	20	3	4,093	5,905	Drilled in 1928-30. Producing from Palæozoic limestone
Model Oils, Ltd.	2	....	....	....	....	....	....	*See* Anaconda No. 1
Mount Stephen Oil and Gas Co., Ltd.	1	13	7	20	2	3,989	2,150	Drilled in 1916-17. Abandoned
Mount Stephen Oil and Gas Co., Ltd.	2	13	7	20	2	3,992	1,400	Drilled in 1917-18. Abandoned
New McDougall-Segur Oil Co., Ltd.	1	14	12	20	3	4,013	2,495	Drilled in 1926-27. Oil in McDougall-Segur sands at 2,470 feet
New McDougall-Segur Oil Co., Ltd.	2	14	12	20	3	4,018	5,665	Drilled in 1927. Produced oil from 2,620 feet. Deepened in 1928-29 to Palæozoic limestone. Producing
New McDougall-Segur Oil Co., Ltd.	3	14	12	20	3	4,028	5,834	Drilled in 1928-31. Producing from Palæozoic limestone

New McDougall-Segur Oil Co., Ltd.	4	14	12	20	3	4,015	5,108	Drilled in 1929-30. Producing from Palæozoic limestone
Northwest Associated Oil Co., Ltd.	1	6	20	19	2	4,224	5,410	Drilled in 1928-29. Producing from Palæozoic limestone
Northwest Associated Oil Co., Ltd.	2	6	20	19	2	4,265	5,423	Drilled in 1929-30. Producing from Palæozoic limestone
Okalta Oils, Ltd.	1	1	1	20	3	3,956	5,040	Drilled in 1926-28. Producing from Palæozoic limestone
Okalta Oils, Ltd.	2	8	1	20	3	3,955	5,141	Drilled in 1914 (Alberta Pet. Con., Ltd.) oil at 2,774 feet. Taken over by Sheep Riv. Oil Co. in 1920 and production restored. In 1924 taken over by Indiana Alberta Oil Co. and again put on production. In 1926 taken over by Okalta Oils, Ltd., and drilling resumed in 1928. Deepened to 3,058 feet where oil secured. Deepened and completed Jan., 1931. Producing from Palæozoic limestone
Okalta Oils, Ltd.	3	9	1	20	3	3,984	4,563	Drilled in 1928-29. Producing from Palæozoic limestone
Okalta Oils, Ltd.	4	8	1	20	3	3,986	1,664	Drilled in 1929. Suspended
Okalta Oils, Ltd.	5	7	1	20	3	4,003	1,623	Drilled in 1929. Suspended
Regent Oil Co., Ltd.	1	16	1	20	3	4,001	3,908	Drilled in 1927-29. Producing from Palæozoic limestone
Regent Oil Co., Ltd.	2	16	1	20	3	4,010	1,978	Drilled in 1929
Regent Oil Co., Ltd.	3	16	1	20	3	3,999	4,192	Drilled in 1929-32. Reached Palæozoic limestone
Regina Progress	....	7	32	19	2	4,010	2,000	Drilled in 1914. Abandoned
Richfield Petroleums, Ltd. (Turner Valley No. 1)	2	12	13	20	3	4,034	5,070	Drilled in 1930-31. Producing from Palæozoic limestone
Royalite Oil Co., Ltd. (Dingman No. 1)	1	14	6	20	2	3,931	3,924	Drilled in 1913 (Cal. Pet. Prod. Co., Ltd.). Oil at 2,718 feet. Deepened in 1918 to 3,924 feet. Taken over by Royalite Oil Co., Ltd., in 1921
Royalite Oil Co., Ltd. (Dingman No. 2)	2	11	6	20	2	3,964	3,175	Drilled in 1914 (Cal. Pet. Prod. Co., Ltd.). Suspended 1917 at 3,175 feet
Royalite Oil Co., Ltd. (Dingman No. 3)	3	14	6	20	2	3,916	2,830	Drilled in 1919 (Cal. Pet. Prod. Co., Ltd.). Taken over by Royalite Oil Co. in 1921
Royalite Oil Co., Ltd.	4	12	7	20	2	3,975	3,740	Drilled in 1922-24. This is the discovery well in the Palæozoic limestone in Turner Valley
Royalite Oil Co., Ltd.	5	13	7	20	2	3,984	3,527	Drilled in 1925-26. Hole lost
Royalite Oil Co., Ltd.	6	16	31	19	2	4,000	4,531	Drilled in 1925-29. Producing from Palæozoic limestone
Royalite Oil Co., Ltd.	7	3	13	20	3	4,013	4,285	Drilled in 1927. Deepened 1930. Producing from Palæozoic limestone

Alberta—Continued

CALGARY SHEET No. 114—*Continued*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Royalite Oil Co., Ltd	8	15	12	20	3	4,005	3,753	Drilled in 1927-28. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	9	6	13	20	3	4,031	5,593	Drilled in 1927-28. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	10	10	12	20	3	4,010	2,333	Drilled in 1927. Oil at 2,268-2,278 feet
Royalite Oil Co., Ltd	11	10	12	20	3	4,013	4,047	Drilled in 1928. Oil at 2,470-2,472 feet. Deepened 1930 and producing from Palæozoic limestone
Royalite Oil Co., Ltd	12	3	13	20	3	4,025	5,638	Drilled in 1928-30. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	13	6	13	20	3	4,001	4,946	Drilled in 1928-29. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	14	4	7	20	2	4,006	3,792	Drilled in 1928-29. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	15	1	12	20	3	4,022	3,047	Drilled in 1928. Production at 3,003-3,035 feet. Completed 1929
Royalite Oil Co., Ltd	16	2	12	20	3	4,046	6,224	Drilled in 1928-30. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	17	13	6	20	3	3,994	4,034	Drilled in 1928-29. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	18	15	12	20	3	3,995	3,887	Drilled in 1928-29. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	19	5	6	20	2	3,951	5,020	Drilled in 1928-30. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	20	7	12	20	3	4,036	5,180	Drilled in 1928-30. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	21	1	13	20	3	4,002	5,034	Drilled in 1928-29. Produced oil at 3,862 feet. Completed Jan., 1930. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	22	8	12	20	3	4,019	2,250	Drilled in 1928. Storage well, not successful
Royalite Oil Co., Ltd	23	13	31	19	2	4,036	5,331	Drilled in 1929-30. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	24	3	29	19	2	4,043	5,555	Drilled in 1930-31. Producing from Palæozoic limestone
Royalite Oil Co., Ltd	25	11	31	19	2	4,031	4,690	Drilled in 1930-31. Producing from Palæozoic limestone
Sioux City Oils, Ltd	1	16	1	20	3	4,019	6,194	Drilled in 1929-30. Producing from Palæozoic limestone

Southern Lowery	1	3	9	19	2	3,985	4,857	Drilled in 1929-31. Producing from Palæozoic limestone
Southern Lowery	2	13	9	19	2	....	4,632	Drilled in 1930-31. Producing from Palæozoic limestone
Southern Lowery	3	4	9	19	2	....	5,622	Drilled in 1931. Producing from Palæozoic limestone
Southwest Petroleums, Ltd	1	....	....	....	....	....	....	*See* Foothills No. 3
Southwest Petroleums, Ltd. (Foothills No. 5)	2	15	8	19	2	4,116	5,407	Drilled in 1930-31. Producing from Palæozoic limestone
Spooner Oils, Ltd	1	12	13	20	3	4,060	5,230	Drilled in 1926-28. Producing from Palæozoic limestone
Spooner Oils, Ltd	2	14	13	20	3	4,023	5,983	Drilled in 1928-29. Producing from Palæozoic limestone
Spooner Oils, Ltd	3	6	24	20	3	4,047	3,240	Drilled in 1929. Abandoned
Spooner Oils, Ltd	4	14	13	20	3	4,019	5,444	Drilled in 1930-31. Producing from Palæozoic limestone
Spray Oils, Ltd	1	9	5	19	2	4,133	3,065	Drilled in 1929-30. Deepened 1932. Drilling
Sterling Pacific Oil Co., Ltd	1	15	33	18	2	4,214	6,525	Drilled in 1929-30. Producing from Palæozoic limestone
Sterling Pacific Oil Co., Ltd	2	10	33	18	2	....	5,748	Drilled in 1931-32. Producing from Palæozoic limestone
Stockmens Oils, Ltd. (Turner Basin No. 1)	1	1	27	20	3	4,042	5,300	Drilled in 1926-27. Gas at 1,760 feet
Stockmens Oils, Ltd. (Turner Basin No. 2)	2	7	27	20	3	4,041	2,980	Drilled in 1928. Suspended
Structure Oil and Gas Co., Ltd	1	7	31	19	2	4,044	5,212	Drilled in 1929-31. Producing from Palæozoic limestone
Turner Basin Oil Co., Ltd	3	2	27	20	3	4,055	4,040	Drilled in 1929-30. Suspended. Stockmens Nos. 1 and 2 are now Turner Basin Nos. 1 and 2
United Oils, Ltd	4	2	24	20	3	4,043	6,115	Drilled in 1928-31. Oil in Dalhousie sand
Vanberta Oils, Ltd	2	5	34	18	2	4,210	115	Drilled in 1930. Suspended
Vimy Oils, Ltd	1	7	24	20	3	4,056	3,550	Drilled in 1929. Abandoned
Vulcan Oil Co., Ltd	1	11	13	20	3	4,012	5,030	Drilled in 1925-26. Deepened 1930. Producing from Palæozoic limestone
Vulcan Oil Co., Ltd	2	11	13	20	3	4,031	4,850	Drilled in 1927-28. Abandoned
Vulcan Oil Co., Ltd	3	12	13	20	3	....	3,100	Drilled in 1931. Producing crude oil
Wellington Oil and Gas Co., Ltd	1	1	20	19	2	4,248	4,965	Drilled in 1929-30. Producing from Palæozoic limestone
Widney Oils, Ltd	1	11	12	20	3	4,023	5,420	Drilled in 1929. Produced crude oil at 3,160 feet. Deepened 1930-31. Producing from Palæozoic limestone
Wells East of Turner Valley								
Anglesey Oil Co. (Lakeview)	1	1	22	21	1	3,650	4,500	Drilled 1927-28. No results
Calgary Natural Gas Co	2	....	11	24	1	3,415	3,414	Drilled 1909? Small gas well at 2,772 feet
New Valley Oil Co., Ltd	1	4	6	21	2	3,873	2,218	Drilled 1926-28. Small gas at 1,360 feet
Sentinel Oils, Ltd	1	15	8	20	2	3,858	5,850	Drilled 1926-30. Suspended
Calgary Natural Gas Co. (Sarcee Reserve)	1	....	5	24	3	....	3,365	Drilled previous to 1909. No results

Alberta—Continued

Calgary Sheet No. 114—*Concluded*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Wells in New Black Diamond Area								
Black Diamond Oil Co.	1	16	34	19	3	....	1,430	Drilled in 1914-15. Abandoned
Black Diamond Oil Co.	2	1	3	20	3	....	1,380	Drilled in 1914-15. Abandoned
New Black Diamond Oil Co. (Weymarn Petroleums, Ltd.)	1	1	3	20	3	4,054	4,003	Drilled in 1926. Taken over by Weymarn Petroleums, Ltd., and drilled in 1929-30. Suspended
Outwest Petroleums, Ltd.	1	5	35	19	3	4,150	3,702	Drilled in 1929. Small gas flow at 1,240 feet
Vanberta Oils, Ltd.	1	4	35	19	3	....	846	Drilled in 1929. Suspended
United Oils, Ltd.	1	11	3	20	3	4,175	3,150	Drilled in 1914. Abandoned
Highwood Area								
Western Alberta Oil Co., Ltd.	1	11	7	17	2	....	3,878	Drilled in 1929-30. Small amount of oil with water in Palæozoic limestone
Banner Oils, Ltd.	1	6	34	17	3	....	630	Drilled in 1929. Suspended
Sterling Oil and Refining Co.	1	4	15	17	3	....	226	Drilled in 1914. Abandoned
Calgary Alberta Oil Co.	....	6	34	17	3	....	232	Drilled in 1914. Abandoned
Northwest Co., "Highwood"	1	3	36	18	3	4,074	4,525	Drilled in 1926-29. Abandoned
Northwest Co., "C and E"	1	8	35	18	3	....	3,315	Drilled in 1929-30. Show of oil in Palæozoic limestone
Hudson's Bay Oil and Gas Co. "Highwood"	1	8	1	18	3	4,194	4,074	Drilled in 1929-30. Suspended
Warner Oils, Ltd.	1	3	28	18	3	....	120	Drilled in 1928. Suspended
Warner Oils, Ltd.	2	3	28	18	3	....	1,310	Drilled in 1929. Abandoned
Warner Oils, Ltd.	3	3	28	18	3	....	2,800	Drilled in 1929-30. Suspended
Waite Valley								
Angus Oils, Ltd.	1	8	33	19	3	4,159	3,060	Drilled in 1929-30. Suspended
Anglo-Pacific Oils, Ltd.	1	4	27	19	3	....	495	Drilled in 1929. Suspended
Calgary Dev. and Prod., Ltd.	1	10	21	19	3	....	5,010	Drilled in 1929-31. Some gas and shows of oil
Gibraltar Oils, Ltd.	1	4	18	20	3	....	1,430	Drilled in 1929-30. Suspended
Innerfold Oils, Ltd.	1	2	6	20	3	4,417	4,280	Drilled in 1929-30. Suspended
Brock Petroleums, Ltd.	1	2	35	20	4	....	3,710	Drilled in 1929-30. Suspended
Richfield Petroleums, Ltd.	1	4	25	20	4	....	4,785	Drilled in 1929-30. Abandoned
Other Foothills Wells								
Paramount Oils, Ltd.	1	1	28	19	4	....	2,297	Drilled in 1929-30. Suspended
United Oils, Ltd.	2	....	23	20	4	....	1,500	Drilled in 1914. Abandoned
Cottonbelt Mining Co., Ltd.	1	5	21	21	4	4,317	248	Drilled in 1930. Abandoned
Cottonbelt Mining Co., Ltd.	1A	5	21	21	4	4,317	3,140	Drilled in 1930-32. Abandoned

Elbow Oils, Ltd.	1	11	35	22	5	....	3,620	Drilled in 1929-32. Not completed
Bragg Creek Oil Co., Ltd. (Cherokee).	1	SE.	33	23	5	....	1,894	Drilled in 1915. Taken over by Cherokee Oil and Refining Co. in 1926
British Alberta Oil Co., Ltd.	....	SE.	11	23	5	....	3,148	Drilled in 1914-15. Abandoned
Moose Mountain Oil Co., Ltd.	....	1	34	23	5	....	2,410	Drilled in 1914. Produced some oil at 1,634 feet. Abandoned
Signal Hill Oil Co., Ltd. (Moose Mt. No. 2)	1	9	34	23	5	4,225	2,040	Drilled in 1915 (Moose Mountain Oil Co.). Taken over by Signal Hill Oil Co. in 1925. Suspended 1926. Abandoned 1927
Graystone Oil Co. (Signal Hill No. 2).	1	9	34	23	5	4,240	4,200	Drilled in 1926 (Signal Hill Oil Co.). Taken over by Graystone Oil Co. in 1931. Drilling
Indian Oil, Ltd.	1	2	24	19	6	....	1,130	Drilled in 1929. Suspended
Herron-Petroleums, Ltd.	1	3	24	22	6	....	3,590	Drilled in 1929-30. Water in Palæozoic limestone
Moose Oils, Ltd.	1	16	29	22	6	5,300	2,834	Drilled in 1929-31. Suspended

Blackfoot Sheet No. 115

(Tps. 17 to 24, Ranges 16 to 29)

Bassano.	....	12	8	21	18	....	1,500	Initial gas flow 80,000 cub. ft. a day
H.B. Oil and Gas Co., Eyremore.	1	1	26	17	18	2,700	5,768	Drilled in 1929-30. Abandoned. Some shows of oil
Twin Dome Oil Co., Ltd.	1	10	16	21	28	3,000±	1,400	Drilled in 1929. Suspended
T. E. Forester.	....	11	6	19	28	....	220	Drilled in 1917. Abandoned
William Murray.	....	....	6	19	28	....	770	Drilled in 1921. A little gas. Abandoned
High River Oil Fields, Ltd.	....	11	6	19	28	....	717	Drilled in 1913-14. 200 M cub. ft. of gas at 504 feet
Federal Oil and Gas Co.	....	NE.	22	20	28	....	2,300	Drilled in 1913-15. Small amount of gas. Abandoned
High River Oil Fields, Ltd.	....	6	34	18	29	3,460	269	Drilled in 1929. Suspended
Sam Drumheller Oil Co.	....	....	13	20	29	....	930	Drilled in 1921. Shows of gas. Abandoned
Ranchmens Oil and Gas Co., Ltd.	....	16	13	20	29	....	5,300	Drilled in 1927-31. Not completed

Rainy Hills Sheet No. 116

(Tps. 17 to 24, Ranges 1 to 15, W. 4th Mer.)

Ontario Alberta Oil Dev. Co.	1	15	34	17	8	2,475±	3,592	Drilled in 1928-30. Shows of gas and oil
Steveville.	1	8	4	22	12	....	....	Spudded in 1932
C.W.N.G.L.H. and P. Co., "Brooks".	3	15	32	18	14	2,500	1,625	Drilled in 1928. Gas at 1,240 and 1,540 feet. Producing to 1913. Small amount of gas

Alberta—Continued

RAINY HILLS SHEET No. 116—*Concluded*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
C.W.N.G.L.H. and P. Co., "Brooks"	5	4	33	18	14	....	1,297	Drilled in 1932. Gas
C.P.R., Brooks	....	SE.	32	18	14	2,487±	2,795	Drilled prior to 1913. Small amount of gas
C.P.R., Brooks	....	....	31	18	14	....	....	No record
C.P.R., Cassils	1	....	5	19	15	2,493	700	Drilled in 1883. Small amount of gas. *See* Geol. Surv., Canada, vol. 4, 1888-89, pt. S, p. 75
C.P.R., Cassils	2	....	5	19	15	2,493	1,000	Drilled in 1884. Small amount of gas

BANFF SHEET No. 164

(Tps. 25 to 32, Ranges 1 to 15, W. 5th Mer.)

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Northwest Co., "Bow River"	1	15	12	25	5	....	5,330	Drilled in 1926-27. Shows of gas. Abandoned
Northwest Co., "Bow River"	2	11	31	24	5	....	3,530	Drilled in 1928-29. Gas at several horizons amounting to 1,900 M cub. ft. Gas used locally
Janse Bros., Ltd. (Dome wells)	....	14	12	25	5	....	2,990	Drilled in 1914-15. Gas at 1,500 feet=25,000 cub. ft.
Purity Oils, Ltd	....	9	34	25	5	....	1,255	Drilled in 1914. A little oil and gas at 563 and oil at 863 feet
Frontier Developments, Ltd	1	2	9	27	5	4,600	2,240	Drilled in 1928-30. Abandoned
Ottawa Petroleum Products, Ltd	1	7	7	32	5	....	150	Drilled in 1914. Abandoned
Baymar Oils, Ltd	1	15	5	27	6	....	853	Drilled in 1929. Suspended
Atlantic Keystone Petroleum Co	1	1	19	27	6	4,400	2,930	Drilled in 1929-30. Suspended
Union Pacific Consolidated	2	SW.	4	31	6	....	1,342	Drilled in 1914-15. Shows of oil. Abandoned
London Canadian Petroleums, Ltd	....	8	36	30	6	....	1,200	Drilled in 1914-15. Abandoned
Monarch Oil Co	....	NW.	5	32	6	....	3,608	Drilled in 1914-15. Some gas (100,000 cub. ft.). Abandoned
Cartier Majestic Oils, Ltd	1	6	36	31	7	....	....	Drilled in 1931. No results
Melbourne Oil Co., Ltd. (Reserve Oils, Ltd.)	....	11	25	25	7	....	2,203	Stony Indian Reserve. Drilled in 1926-28 (Reserve Oils, Ltd.). Taken over by Melbourne Oils in 1928. Suspended

Gold Coin Oils, Ltd. (Rockland Oils, Ltd.)	1	Stony Indian Reserve				....	3,928	Drilled in 1926-27. A little show of gas. Abandoned
Gold Coin Oils, Ltd. (Rockland Oils, Ltd.)	2	Stony Indian Reserve				....	1,037	Drilled in 1929. Suspended
Sinclair-Morley Oil Structures Syndicate, Ltd., "Norcon"	1	Stony Indian Reserve				....	1,594	Drilled in 1928-29. Considerable gas. Suspended
Wabash, "Norcon"	1	Stony Indian Reserve				....	3,056	Drilled in 1926-30. Considerable gas. Suspended
Kamorley Oils, Ltd	....	Stony Indian Reserve				....	30	Spudded in 1929. No drilling. Suspended
Mount Stephen Oil and Gas Co	....	8	25	32	7	....	4,500	Drilled in 1914-16. Abandoned

ROSEBUD SHEET No. 165

(Tps. 25 to 32, Ranges 16 to 29, W. 4th Mer.)

Prairie Nat. Gas Co	1	4	36	32	17	....	400	Drilled in 1920, 45 M cub. ft. of gas at 400 feet at pressure of 45 lbs.
Prairie Nat. Gas. Co	2	4	36	32	17	2,750	477	Drilled in 1923. Gas at 450 feet amounting to 100,000 cub. ft.
Prairie Nat. Gas Co	3	5	36	32	17	2,800	480	Drilled in 1924
Gleichen	....	....	13	23	22	2,926	502	No record. Abandoned
Carbon Exploration Co	1	7	18	29	22	....	660	Drilled in 1930. Some gas shows

SOUNDING CREEK SHEET No. 166

(Tps. 25 to 32, Ranges 1 to 15, W. 4th Mer.)

Fuego Oil Co., Ltd	1	16	34	25	4	2,200±	3,182	Drilled in 1924-29. Gas and oil with salt water at 3,133-3,136 feet
Northwest Co., Ltd., "Misty Hills"	....	16	29	32	4	2,451	3,304	Drilled in 1920. Small shows of gas. Abandoned

ROCKY MOUNTAIN HOUSE SHEET No. 214

(Tps. 33 to 40, Ranges 1 to 14, W. 5th Mer.)

Alberta Assoc. Oilfields	3	3	34	39	10	....	....	Two test holes, 1,000 and 950 feet, drilled in 1915-16. Abandoned

Alberta—Continued

Sullivan Lake Sheet No. 216

(Tps. 33 to 40, Ranges 1 to 14, W. 4th Mer.)

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Rosebud Oil Syndicate	1	5	15	33	2	2,000	200	Drilled in 1926-27 when Ontario Oil Co. took over the well. No results
William Maybin	....	....	19	33	4	....	403	Drilled in 1922. Abandoned
West Regent Oil and Gas Co	....	16	19	34	4	2,200	3,540	Drilled in 1920-23. Small flow of gas. Abandoned
Northwest Oil Exp. Co., "Monitor"	....	11	5	35	4	2,219	600	Drilled in 1920-21. Abandoned
North Western Oil Holdings, Ltd	....	9	1	34	5	....	400	Drilled in 1921. Abandoned
Northwest Co., Ltd., "Tit Hills"	....	10	17	39	7	2,267	3,500	Drilled in 1920-21. Small amount of gas. Abandoned
Town of Castor	....	NE.	26	37	14	2,680	1,455	Gas at 1,430 and 1,455 feet
Hudson's Bay Oil and Gas Co., Ltd., "Paintearth"	....	5	27	39	14	2,400±	3,649	Drilled in 1930-31. Shows of gas and show of oil at 3,394-3,401 feet. Abandoned

Peace Hills Sheet No. 265

(Tps. 41 to 48, Ranges 15 to 28, W. 4th Mer.)

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Camrose	....	....	2	47	20	2,427	1,235	149,200 cub. ft. of gas. Abandoned
Wetaskiwin	1	15	14	46	24	2,482	1,511	Drilled in 1912. Gas amounting to 250,000 cub. ft. For log *See* Geol. Surv., Canada, Mem. 116, p. 73.
Wetaskiwin	2	13	13	46	24	2,486	1,470	Drilled in 1914. Gas flow 70,555 cub. ft. (1919)
Wetaskiwin	3	NE.	14	46	24	2,507	3,185	Drilled in 1914-15. Abandoned
Ponoka Asylum	1	NW.	29	42	25	....	2,500	Drilled in 1916. 100 M cub. ft. of gas. Abandoned
Ponoka Asylum	2	4	32	42	25	....	2,650	Drilled in 1919-20. Deepened in 1925. Some gas
Mutual Oil and Gas Dev. Co. (Globe Drilling Co.)	....	13	14	47	27	....	1,180	Drilled in 1921. Taken over by Globe Drilling Co. in 1924. Some gas. Abandoned

WAINWRIGHT SHEET No. 266

(Tps. 41 to 48, Ranges 1 to 14, W. 4th Mer.)

Algonquin Oil Co., Ltd	1	1	20	45	1	2,051	2,323	Drilled in 1930-31. Abandoned
Algonquin Oil Co., Ltd	2	5	16	45	1	....	2,200	Drilled in 1931. Abandoned
Northwest Co., Ltd., Imperial Ribstone	1	5	5	45	1	1,851	3,489	Drilled in 1926-27. Shows of oil and gas
Northwest Co., Ltd., Imperial Ribstone	2	14	9	45	1	1,796	1,685	Drilled in 1929-30. Produced oil. Abandoned
Meridian Oils, Ltd. (Advance)	1	3	16	45	1	1,938	1,834	Drilled in 1926. (Advance Oil Co.) Drilled in 1929. (Meridian Oil Co.) Produced oil. Abandoned
Meridian Oils, Ltd	2	4	16	45	1	1,912	1,803	Drilled in 1929–30. Produced oil. Abandoned
Meridian Oils, Ltd	3	4	16	45	1	1,994	1,889	Drilled in 1930. Produced oil. Abandoned
Ribstone Oils, Ltd	1	1	1	46	1	1,921	2,050	Drilled in 1926-28. Abandoned
Ribstone Oils, Ltd	2	5	25	46	1	2,087	3,230	Drilled in 1928-29. Obtained calcium chloride water in saturated solution. Abandoned
Rayco Oils, Ltd	1	3	4	47	1	....	2,600	Drilled in 1931. Suspended
Oxville Oil, Gas, and Dev. Co., Ltd	1	14	10	46	2	2,067	2,292	Drilled in 1929-30. Abandoned
London Ribstone Oil Co	1	14	10	43	3	2,080	2,433	Drilled in 1927-28. Suspended
London Ribstone Oil Co	2	5	22	43	3	....	2,122	Drilled in 1929-30. Suspended
British Petroleums, Ltd	1	1	36	45	7	2,187	2,015	Drilled in 1922-23. Shows of oil and gas
British Petroleums, Ltd	2	13	30	45	6	2,251	2,038	Drilled in 1923. Gas and oil obtained
British Petroleums, Ltd	3	4	29	45	6	2,304	2,296	Drilled in 1924. Abandoned
British Petroleums, Ltd	3B	4	29	45	6	2,304	2,259	Drilled in 1925. Produced oil gravity 18·19° Bé.
British Petroleums, Ltd	4	13	30	45	6	2,250	2,036	Drilled in 1924. Some oil
Bethwain Oils, Ltd	1	13	6	45	6	2,247	2,485	Drilled in 1929
Bethwain Oils, Ltd	2	16	4	45	6	2,347	2,305	Drilled in 1929. Some oil
British Wainwright Oil and Dev. Co	1	13	20	45	6	2,296	2,238	Drilled in 1926-27. Some oil
Emerald Oil Co	1	8	30	45	6	2,326	2,425	Drilled in 1926. No production
Edalta Oils, Ltd	1	15	19	45	6	....	2,225	Drilled in 1929. Deepened 1930. No production
Edmonton Wainwright Oils, Ltd	1	4	29	45	6	2,318	2,275	Drilled in 1926. Produced oil
National Exploration Co	1	1	30	45	6	2,317	2,268	Drilled in 1927. A large gas well
Onalta Oils, Ltd	1	8	20	45	6	2,275	2,232	Drilled in 1929-30. Produced oil from 2,227-2,232 feet
Peninsular Petroleums, Ltd	1	16	30	45	6	....	234	Drilled in 1930. Suspended
Sasko-Wainwright Oil and Gas., Ltd	1	1	19	45	6	2,314	2,246	Drilled in 1928. Drilled into production 1929. Oil
Senator Oil and Gas Dev. Co	1	1	23	44	6	2,261	710	Drilled in 1930. Suspended
Anwood Dome (Wainwright Dome)	1	7	31	45	6	2,351	2,308	Drilled in 1926-27. No production
Wainwright Petroleums, Ltd	1	6	30	45	6	2,328	2,252	Drilled in 1929. Some oil
Western Consolidated Oils, Ltd	2	11	30	45	6	2,301	2,233	Drilled in 1926. Abandoned

Alberta—Continued

WAINWRIGHT SHEET No. 266—*Continued*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Admiral Oils, Ltd	1	16	36	44	7	2,226	2,698	Drilled in 1929. No production
Beaumont Oils, Ltd	1	1	10	45	7	2,193	2,182	Drilled in 1929. Some oil
Beaumont Oils, Ltd	2	10	30	45	7	2,206	2,210	Drilled in 1929. Completed in 1932. Some oil
Lloyd Petroleums, Ltd	1	12	6	45	6	....	323	Drilled in 1930. Suspended
Wainwell Oils, Ltd. (Peninsular Petroleums, Ltd.)	1	9	36	44	7	2,219	2,225	Drilled in 1924 (Wainwright Oil Producers Syndicate). Taken over in 1925 by Interior Oil Co. Taken over in 1928 by Wainwell Oil Company who completed well obtaining oil and gas. Taken over by Peninsular Petroleums, Ltd., in 1930
Wainwright Oil Dev. Co., Ltd	1	15	36	44	7	2,211	218	Drilled in 1922. Abandoned
Wainwell Oils, Ltd	2	15	36	44	7	2,194	525	Drilled in 1928. Hole lost
Wainwell Oils, Ltd	2A	15	36	44	7	2,194	2,033	Drilled in 1928-29. A large gas well
Wainwell Oils, Ltd	3	9	36	44	7	2,215	2,072	Drilled in 1928. Oil
Wainwell Oils, Ltd	4	15	36	44	7	2,208	2,052	Drilled in 1929. Oil
Montreal Alberta Oil Co	1	2	15	45	7	....	2,650+	Drilled in 1931. Not completed on January 1, 1932
Northwest Co., Ltd. "Fabyan" (Fabyan Petroleums, Ltd., No. 2)	1	16	18	45	7	2,045	2,730	Drilled in 1921-22. Gas and small amount of oil
Fabyan Petroleums, Ltd	1	8	24	45	8	1,928	2,022	Drilled in 1926. Resumed 1928. Resumed 1930. Some gas
Fabyan Petroleums, Ltd	2	16	18	45	7	....	....	This is Imperial-Fabyan No. 1 well
Fabyan Petroleums, Ltd	3	16	8	45	7	....	....	Not drilled
Fabyan Petroleums, Ltd	4	8	4	45	8	....	1,930	Drilled in 1931
Maple Leaf Oil Co., Ltd	1	1	24	45	8	1,992	1,775	Drilled in 1924. A gas well
Maple Leaf Oil Co., Ltd	2	1	24	45	8	1,937	1,777	Drilled in 1925. Resumed 1929. A gas well
Gratton Oil Co., Ltd	1	SE.	4	45	8	1,938	1,675	Drilled in 1914-15. Log in Geol. Surv., Canada, Mem. 116, p. 59
Viking and Battle Creek Oil Company, "Gratton"	2	1	4	45	8	1,938	1,906	Drilled in 1917-20. Some gas
Northwest Co., Ltd. "Imperial Gratton"	2	2	14	45	8	1,954	2,015	Drilled in 1923. Abandoned
Alberta Pacific Consolidated Oils	....	1	12	45	9	....	65	Drilled in 1917. Abandoned
Irma Oil Dev. Co	1	16	28	45	9	....	55	Drilled in 1923. Abandoned
Irma Oil Dev. Co	2	16	28	45	9	2,252	1,601	Drilled in 1924-26. No results
Duluth Syndicate, MacDonald well	1	3	29	48	10	2,305	2,083	Drilled in 1929. A large gas well
Northwestern Utilties (Harvie)	1	1	17	47	11	....	2,177	Drilled in 1932. 7,600 M cub. ft. of gas

Northwestern Utilities (Kinsella)........	2	4	25	47	11	....	2,184	Drilled in 1932. 18,000 M cub. ft. of gas
Viking Field								
Northwestern Utilities, Ltd.............	1	13	24	48	13	2,285	2,340	Drilled in 1914 (Northern Alberta Nat. Gas. Dev. Co., Ltd.). Taken over by Northwestern Utilities, Ltd., in 1923. Gas at 2,340–2,345 feet with initial open flow of 9,000 M cub. ft.
Northwestern Utilities, Ltd.............	2	5	19	48	12	2,289	2,373	Drilled in 1916 (Northern Alberta Nat. Gas Dev. Co., Ltd.). Taken over by Northwestern Utilities, Ltd., in 1923. Initial open flow 1,750 M cub. ft.
Northwestern Utilities, Ltd.............	3	10	25	48	13	2,290	2,365	Drilled in 1916 (Northern Alberta Nat. Gas Dev. Co., Ltd.). Taken over by Northwestern Utilities, Ltd., in 1923. Initial open flow 5,000 M. cub. ft.
Northwestern Utilities, Ltd.	4	3	30	48	12	2,306	2,343	Drilled in 1916 (Northern Alberta Nat. Gas. Dev. Co., Ltd.). Taken over by Northwestern Utilities, Ltd., in 1923. Initial open flow 2,000 M cub. ft.
Northwestern Utilities, Ltd.............	5	8	36	48	13	2,290	2,230	Drilled in 1916-17. (Northern Alberta Nat. Gas Dev. Co., Ltd.). Taken over by Northwestern Utilities, Ltd., in 1923. Initial gas flow 5,000 M cub. ft.
Northwestern Utilities, Ltd.............	6	5	6	49	12	2,283	2,203	Drilled in 1916-17 (Northern Alberta Nat. Gas Dev. Co., Ltd.). Taken over by Northwestern Utilities, Ltd., in 1923. Initial open flow 8,190 M cub. ft.
Northwestern Utilities, Ltd.............	7	1	6	49	12	2,303	2,215	Drilled in 1919 (Northern Alberta Nat. Gas Dev. Co., Ltd.). Taken over and finished by Northwestern Utilities, Ltd., in 1923. Initial open flow 5,000 M cub. ft.
Northwestern Utilities, Ltd.............	8	2	18	48	12	2,271	2,430	Drilled in 1917 (Northern Alberta Nat. Gas Dev. Co., Ltd.). Taken over b- Northwestern Utilities, Ltd., in 1923. Initial open flow 2,000 M cub. ft.
Northwestern Utilities, Ltd.............	9	8	24	49	13	2,262	2,318	Drilled in 1918 (Northern Alberta Nat. Gas Dev. Co., Ltd.). Taken over by Northwestern Utilities, Ltd., in 1923. Initial open flow 4,500 M cub. ft.
Northwestern Utilities, Ltd.............	10	16	29	48	12	2,316	2,245	Drilled in 1919 (Northern Alberta Nat. Gas Dev. Co., Ltd.). Taken over by Northwestern Utilities, Ltd., in 1923 and completed in 1924. Initial open flow 5,000 M cub. ft.
Northwestern Utilities, Ltd.............	11	16	36	49	12	2,279	2,152	Drilled in 1925. Initial open flow 9,246 M cub. ft.

Alberta—Continued

WAINWRIGHT SHEET No. 266—*Concluded*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Northwestern Utilities, Ltd.	12	9	12	49	13	2,254	2,125	Drilled in 1925. Initial open flow 7,500 M cub. ft.
Northwestern Utilities, Ltd.	13	1	18	49	12	2,239	2,105	Drilled in 1927. Initial open flow 8,115 M cub. ft.
Northwestern Utilities, Ltd.	14	4	4	49	12	2,310	2,198	Drilled in 1927. Initial open flow 5,217 M cub. ft.
Northwestern Utilities, Ltd.	15	16	2	49	13	2,266	2,165	Drilled in 1928. Initial open flow 5,054 M cub. ft.
Northwestern Utilities, Ltd.	16	6	7	49	12	2,256	2,140	Drilled in 1929. Initial open flow 7,760 M cub. ft.
Northwestern Utilities, Ltd.	17	1	31	48	12	2,299	2,215	Drilled in 1929. Initial open flow 4,930 M cub. ft.
Northwestern Utilities, Ltd.	18	8	17	49	12	2,263	2,118	Drilled in 1929. Initial open flow 3,251 M cub. ft.
Northwestern Utilities, Ltd.	19	13	12	49	13	2,255	2,145	Drilled in 1930. Initial open flow 7,000 M cub. ft.
Northwestern Utilities, Ltd.	20	12	18	49	12	2,248	2,110	Drilled in 1930. Initial open flow 7,000 M cub. ft.
Northwestern Utilities, Ltd.	21	13	4	49	12	2,310	2,228	Drilled in 1930. Initial open flow 200 M cub. ft. Abandoned
Northwestern Utilities, Ltd.	22	10	31	48	12	2,283	2,188	Drilled in 1931. Initial open flow 4,200 M cub. ft.
Northwestern Utilities, Ltd.	23	10	31	48	12	2,308	2,215	Drilled in 1931. Initial open flow 3,200 M cub. ft.
Northwestern Utilities, Ltd.	24	10	32	48	12	....	2,145	Drilled in 1932
Hudson Bay Marland Oil Co., Ltd., "Viking"	1	5	8	49	12	2,278	3,040	Drilled in 1928-29. Gas in the "Viking" gas sands. Initial open flow 6,500 M cub. ft. Shows of oil but no commercial production
Hudson's Bay Oil and Gas Co., Ltd., "Viking"	2	8	8	49	12	2,298	2,150	Drilled in 1929. Initial gas flow 7,680 M cub. ft. at 2,140 feet

NOTE. For convenience all wells in the Viking area are grouped, although those in Township 49 are on the Vermilion sheet No. 316.

Brûlé Sheet No. 313 (Tps. 49 to 56, Ranges 15 to 27, W. 5th Mer.)								
Northwest Co., Ltd. (Coalspur)	1	11	3	49	21	....	1,490	Drilled in 1921-23. No oil or gas. Abandoned
Northwest Co., Ltd. (Coalspur)	2	3	3	49	21	3,777	4,305	Drilled in 1924-26. Small amount of gas. Abandoned
St. Ann Sheet No. 314 (Tps. 49 to 56, Ranges 1 to 14, W. 5th Mer.)								
Mrs. C. B. Walker	1	....	36	53	4	....	700	Drilled in 1920. No results. Reported shows of gas and oil
Mrs. C. B. Walker	2	....	36	53	4	....	195	Drilled in 1923. No results. Reported shows of gas and oil
Mrs. C. B. Walker	3	....	36	53	4	....	165	Drilled in 1923. No results. Reported shows of gas and oil
Mrs. C. B. Walker	4	....	36	53	4	....	....	Drilled in 1929. No results. Depth unknown
Mrs. C. B. Walker	5	....	36	53	4	....	....	Drilled in 1929. No results. Depth unknown
Edmonton Sheet No. 315 (Tps. 49 to 56, Ranges 15 to 28, W. 4th Mer.)								
Town of Tofield	1	NW.	36	50	19	....	1,202	Drilled in 1902. Small shows of gas. Abandoned
Town of Tofield	2	SE.	1	51	19	2,295	1,203	Drilled in 1902. Small shows of gas. Abandoned
Fairholm Oil and Gas Co	....	SW.	30	52	23	....	2,065	Drilled in 1913. Small gas flow. Suspended
In Edmonton	....	....	30	52	23	....	940	Abandoned
North West Oil and Gas Co	1	....	....	53	24	....	1,150	South end of 1st Ave., Edmonton. Drilled previous to 1913. Small shows of gas. *See* log Geol. Surv., Canada, Mem. 29E, p. 76
North West Oil and Gas Co	2	....	....	53	24	....	1,800	North side of Jasper Ave. Drilled previous to 1913. Small shows of gas and oil reported. Abandoned
American Canadian Oil Co., "Morinville"	....	SE.	13	56	25	....	3,340	Small shows of gas and oil reported. Abandoned
California Alberta Oil Co., "Egg Lake" or "Morinville"	....	W.½	6	57	25	....	490	Drilled in 1910. Shows of gas and oil. Gas flow 370 M cub. ft. Abandoned. Log in Geol. Surv., Canada, Mem. 29E, p. 85

Alberta—Continued

VERMILION SHEET No. 316

(Tps. 49 to 56, Ranges 1 to 14, W. 4th Mer.)

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Charles W. Hague	....	4	11	51	9	....	300	Drilled in 1921-22. No oil or gas. Abandoned
United Dominion Petroleums, Ltd., J. R. Talpey, Birch Lake well	....	2	14	50	12	2,120	2,411	Drilled in 1921-23. 1,500 M cub. ft. of gas. Oil showings at 2,030 and 2,140 feet. Abandoned
Alberta Pacific Consolidated Oils., Ltd., "Duvernay"	1	5	34	55	12	....	2,417	Drilled in 1920. Gas and oil shows. Abandoned
Frontier Two Hills	1	8	22	54	12	....	....	Drilling 1932. Not completed

VICTORIA SHEET No. 365

(Tps. 57 to 64, Ranges 15 to 27, W. 4th Mer.)

Victoria	....	....	12	58	17	1,850	1,870	Drilled in 1897-9 by Geol. Surv., Canada

TAWATINAW SHEET No. 415

(Tps. 65 to 72, Ranges 14 to 27, W. 4th Mer.)

Athadome	1	9	20	72	24	....	1,900	Drilled in 1932. Abandoned
Athadome	2	3	15	66	23	....	....	Commenced drilling 1932

DUNVEGAN SHEET No. 462

(Tps. 73 to 80, Ranges 1 to 13, W. 6th Mer.)

Pouce-Coupé Oils, Ltd.[1]	....	14	19	79	13	....	1,482	Drilled in 1922. Some gas. Abandoned
Great Slave Oil and Refining Co	....	SW.	19	80	13	....	110	Drilled in 1922. Abandoned
Northwest Co., Ltd. (Pouce-Coupé)	....	7	26	80	13	1,510	3,057	Drilled in 1921-23. 10,627 M cub. ft. of gas at 1,676-1,697 feet. Abandoned

[1]Although this well is within the limits of the Dunvegan sheet it is in British Columbia.

GIROUX SHEET No. 464

(Tps. 73 to 80, Ranges 1 to 13, W. 5th Mer.)

International Oils, Ltd	1	11	14	74	6	1,910	2,845	Drilled in 1926-27. Some gas. Abandoned
International Oils, Ltd	2	....	30	75	6	....	3,105	Drilled in 1928. Show of oil and gas. Abandoned

PELICAN SHEET No. 465

(Tps. 73 to 80, Ranges 14 to 26, W. 4th Mer.)

Pelican Oil and Gas Co. and	....	....	31	78	17	....	....	Five wells drilled, of which three were on the west side of Athabaska River and two on the east side. Large gas flows
Calhoun Oil Co.	....	....	32	77	17	....	....	
Santa Barbara Oils, Ltd	....	6	31	78	17	....	2,120	Drilled in 1912. Abandoned
Geological Survey, Canada	....	....	6	79	17	....	820	Drilled in 1894-6. Heavy flow of natural gas at 820 feet

Note. For complete data and logs of wells in Athabaska area, *See* Ells, S. C.: "Bituminous Sands of Northern Alberta"; Mines Branch, Dept. of Mines, Canada, Pub. 632, pp. 21-29 (1926).

SHAFTESBURY SHEET No. 513

(Tps. 81 to 88, Ranges 14 to 26, W. 5th Mer.)

Peace River Area								
Peace River Oil Co.	1	4	31	85	20	....	1,136	Drilled in 1916-17. Salt and sulphur water at 1,020 feet. Abandoned
Peace River Oil Co.	2	16	24	85	21	....	1,125	Drilled in 1917-18. Heavy, tarry oil at 1,043 feet. Abandoned
Peace River Oil Co.	3	6	4	85	21	....	1,282	Drilled in 1918. Considerable gas at 1,282 feet. Abandoned
Peace River Oil Co.	4	9	24	85	21	1,025	305	Drilled in 1923. Abandoned
Peace River Western Oils Co.	....	3	32	83	21	....	220	Drilled in 1920-21. Abandoned
Victory Oil, Ltd	....	11	31	83	21	1,261	1,557	Drilled in 1918-21. Abandoned. Salt water and gas flowing from casing
North Pacific Oil Co.	....	10	11	85	21	....	850	Drilled in 1918. Abandoned
Tar Island Oil and Gas Co.	1	14	24	85	21	....	1,087	Drilled in 1918. Abandoned. Salt water and gas flowing from casing
Tar Island Oil and Gas Co.	2	....	24	85	21	....	....	Well only spudded in
Community Oil Wells, Ltd	....	1	23	85	21	....	330	Drilled in 1918. Abandoned
Canadian Petroleums, Ltd	1	1	11	85	21	....	1,275	Drilled in 1918. Gas and water at 1,258 feet. Abandoned. Water flowing from casing

Alberta—Continued

Shaftesbury Sheet No. 513—*Concluded*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Canadian Petroleums, Ltd.	2	1	11	85	21	....	3,008	Drilled in 1920-24. Small show of oil at 1,050 feet. Gas and water at 1,135 and 1,400 feet. Abandoned
Peace River Petroleums, Ltd.	1	Lot 9	31	83	21	....	1,162	Drilled in 1918-20. Small amount of oil with gas. Abandoned, water flowing from casing head
Peace River Petroleums, Ltd.	2	9	28	87	20	....	897	Drilled in 1919-20. Show of oil at 897 feet and gas at 851-860 feet. Much water. Abandoned, water flowing from casing
Peace River Petroleums, Ltd.	3	9	28	87	20	....	890	Drilled in 1922. Abandoned. Water flowing from casing. No record
H. L. Williams	....	SE.	23	85	21	....	....	No record
P-M Oil Co.	1	7	36	83	22	1,280	405	Drilled in 1924-5. Abandoned
P-M Oil Co.	2	7	36	83	22	1,285	266	Drilled in 1926-27. Taken over in 1929 by A.B.C. Oil Company
Four X Oils, Ltd.	1	7	36	83	22	....	230	Drilled in 1929. Suspended

Wabiskaw Sheet No. 515

(Tps. 81 to 88, Ranges 14 to 26, W. 4th Mer.)

Northern Production Co. (Edmonton Athabaska Oils, Ltd.)	1	....	30	83	16	....	200	Drilled in 1914. Abandoned
Northern Production Co. (Edmonton Athabaska Oils, Ltd.)	2	....	30	83	16	....	693	Drilled in 1916. Large gas flow at 665 feet. Abandoned

McMurray Sheet No. 516

(Tps. 81 to 88, Ranges 1 to 13, W. 4th Mer.)

Talpey, J. R.	....	SE.	26	83	6	1,650	1,076	Drilled in 1918-19. No oil or gas. Abandoned
Northwest Co., Ltd., McMurray	1	SW.	33	87	7	1,320	504	Drilled in 1917. Abandoned
Northwest Co., Ltd., McMurray	2	SW.	27	85	7	1,550	820	Drilled in 1918. Some gas at 468 feet. Abandoned
Alberta Government	....	5	32	88	8	823	789	Drilled into Precambrian (1922-3)
Alberta Government	....	Lot 8	McMurray		....	790	685	Drilled for salt

See Ells, S. C.: "Bituminous Sands of Northern Alberta"; Mines Branch, Dept. of Mines, Canada, Pub. 632, pp. 21-29.

MacKay Sheet No. 566

(Tps. 89 to 96, Ranges 1 to 13, W. 4th Mer.)

Weymarn	1	....	21	89	3	1,100	495	Drilled in 1928. Small show of oil 337-347 feet
Northern Alberta Exploration Co.	....	6	17	89	9	....	1,475	Several wells drilled 1905-10. Abandoned
Northern Alberta Exploration Co.	....	14	9	89	9	1,041	221	
Athabaska Oil and Asphalt Co.	1	S.½	20	91	9	....	446	Drilled 1908-9. Abandoned 1909
Athabaska Oil and Asphalt Co.	2	S.½	8	90	9	....	740	Drilled 1907-9. Abandoned
Athabaska Oil and Asphalt Co.	3	N.½	4	89	9	....	233	Drilled in 1908. Gas, abandoned
A. Von Hammerstein	....	NW.	24	94	11	....	....	Drilled about 1909. Abandoned
A. Von Hammerstein	....	15	19	92	9	896	950	A little gas and oil, salt water
A. Von Hammerstein	....	....	....	90	9	740	....	Location about ¾ mile north of Poplar Island, east side of river
A. Von Hammerstein	....	....	....	91	9	446	....	Location about ½ mile north of Stony Island, east side of river
A. Von Hammerstein	....	14	8	90	9	812	1,117	Drilled to Precambrian. Small gas and oil shows
A. Von Hammerstein	....	3	6	92	9	790	....	Small gas flow, salt water
A. Von Hammerstein	....	13	7	92	9	822	321	Small water at 325 feet
A. Von Hammerstein	....	6	17	89	9	826	47	Reached top of Palæozoic limestone
A. Von Hammerstein	....	Lot 12 Mackay Settlement	....	95	11	791	615	Small amount of gas
Fort MacKay Oil and Asphalt Co.	1	NW.	18	94	10	....	....	Drilled in 1912-13. Abandoned
Fort MacKay Oil and Asphalt Co.	2	SE.	2	93	10	....	350	Drilled in 1910-11. Abandoned
Fort MacKay Oil and Asphalt Co.	....	10	15	93	10	779	1,080	Small gas flow
Athabaska Oils, Ltd.	....	8	2	96	11	816	1,030	At 765 and 1,000 feet salt water encountered
Athabaska Oils, Ltd.	....	5	1	96	10	878	210	Abandoned, no results

Alberta—Concluded

MacKay Sheet No. 566—*Concluded*

—	Well No.	L.S.	Sec.	Tp.	Range	Elev. Feet	Depth Feet	Remarks
Athabaska Oils, Ltd	....	12	1	96	10	913	175	Abandoned, no results
Athabaska Oils, Ltd	....	14	1	96	10	925	282	Abandoned. Gas reported at 58 feet
Athabaska Oils, Ltd	....	....	1	96	10	....	177	Abandoned, no results
Athabaska Oils, Ltd	....	6	35	95	11	780	123	Abandoned, no results
Alcan Oil Corp	1	13	28	96	10	993	245	Drilled in 1921. Heavy tar
Alcan Oil Corp	2	14	24	96	10	1,037	560	Drilled in 1922. Shows of oil and gas. Abandoned
International Bitumen Co	1	10	32	96	10	975	241	Drilled in 1927. Abandoned
International Bitumen Co	2	1	32	96	10	980	195	Drilled in 1927. Abandoned
International Bitumen Co	3	2	36	96	10	955	352	Drilled in 1928. Suspended
International Bitumen Co	4	16	29	96	10	980	337	Drilled in 1928. Suspended
International Bitumen Co	5	11	6	97	10	947±	305	Drilled in 1929

For complete data on wells in Athabaska area, *See* Ells, S. C.: "Bituminous Sands of Northern Alberta"; Mines Branch, Dept. of Mines, Canada, Pub. 632, pp. 21-29 (1926).

Firebag Sheet No. 616

(Tps. 97 to 104, Ranges 1 to 13, W. 4th Mer.)

Athabaska Spokane Oil Co	....	6	1	97	11	757	105	Drilled only into McMurray formation
Northland Oil Syndicate	....	15	13	97	11	780	96	No results
Northland Oil Syndicate	....	2	24	97	11	858	72	No results
International Bitumen Co	5	11	6	97	10	....	305	*See* Sheet No. 566

Mikkwa Sheet No. 664

(Tps. 105 to 112, Ranges 1 to 12, W. 5th Mer.)

Vermilion Falls	1	....	....	108	6	....	860	Abandoned
Black Rock Petroleums	1	NE.	11	108	8	....	114	Drilled in 1925. Abandoned
Black Rock Petroleums	2	SW.	34	107	8	....	140	Drilled in 1926. Abandoned
Black Rock Petroleums	3	SW.	34	107	8	....	717	Drilled in 1926. No oil or gas. Abandoned

British Columbia

—	L.S.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet	Remarks
Armstrong Oil and Gas Co.		8	35	9	6		475	Drilled in 1924-25. No oil or gas. Suspended
Boundary Bay Oil Co., Ltd.		28	5		W.C.M.		4,117	Drilled about 1923. Some gas between 2,300 and 2,900 feet
British Columbia Oil and Coal Dev. Co., Ltd., No. 1			4	2	5	4,600	700	Drilled in 1914. Abandoned. No results
British Columbia Oil and Coal Dev. Co., Ltd., No. 2			4	2	5		750	Drilled in 1914
British Columbia Oil and Coal Dev. Co., Ltd., No. 3							205	Drilled in 1914 near seepages on Sage Creek. Some gas, oil, and water
British Columbia Oil and Coal Dev. Co., Ltd., No. 4							184	Drilled in 1914 on north bank of Sage Creek. Yields small amount of light oil 48-50° Bé.
British Columbia Oil and Coal Dev. Co., Ltd., No. 5			4	2	5		1,200	Drilled in 1928-30. Gas and oil in shows
British Columbia Oil and Gas Co., "Sage Creek" No. 1	Sage Creek-Flathead Valley							Drilled in 1927-29. Oil reported at 1,000 feet
British Columbia Oil and Gas Co., "Sage Creek" No. 2	Sage Creek-Flathead Valley							Drilled in 1927-28
British Columbia United Oil Co.	SW.	22	16		E.C.M.	300	230	Drilled in 1923. Suspended
Cariboo Oil Co.	Cariboo							Well 180 miles north of Ashcroft in the vicinity of Quesnel. Drilled in 1930-31
Crows Nest Glacier Oil Co., Ltd.								*See* Glacier Oil Co., Ltd.
Empire Oil and Nat. Gas Co. No. 1	8	27	10		E.C.M.		361	Drilled in 1918. Abandoned
Empire Oil and Nat. Gas Co. No. 2	8	27	10		E.C.M.		140	Drilled in 1918. Abandoned
Empire Oil and Nat. Gas Co. No. 3	8	27	10		E.C.M.		5,743	Drilled in 1918-26. Oil and gas showings
Fleming Oil Co., Ltd., No. 1	Lot 2B, Lulu Island						230	Abandoned
Fleming Oil Co., Ltd., No. 2		Lulu Island						Abandoned
Fleming Oil Co., Ltd., No. 3		Lulu Island						Abandoned
Fleming Oil Co., Ltd., No. 4		Lulu Island					170	Abandoned
Glacier Oil Co., Ltd.	Sage Creek						3,260	Taken over by Crows Nest Glacier Oil Co. in 1923 when well was 3,260 feet deep. Some oil and gas. Drilling 1932
Kamloops Nat. Gas, Oil, and Coal Co. No. 1	5	36	19	18	6		662	Drilled in 1920. Abandoned
Kamloops Nat. Gas, Oil, and Coal Co. No. 2	5	36	19	18	6		717	Drilled in 1924. Suspended
Lincoln Oil Co.		32	10		E.C.M.			No information
Monarch Oil and Gas Co.	NE.	29	10		E.C.M.			Shallow depth. Drilled in 1920
Okanagan Coal and Oil Co.	9	8	35	9	6		400?	Drilled near Armstrong, B.C., in 1922-25. No oil or gas (2 wells)

British Columbia—Concluded

—	L.S.	Sec.	Tp.	Range	Mer.	Elev. Feet	Depth Feet	Remarks
Okanagan Oil and Gas Co.	9 miles SE. of Kelowna				......	....	2,265	Drilled in 1930-31. Not completed
Pacific Petrol Products, Ltd.	Sage Creek				......	....	153	Drilled in 1930. No information
Pitt Meadows Oil Co. No. 1	6	18	40	....	E.C.M.	....	1,209	Drilled in 1914. A small showing of oil and nitrogen gas. Abandoned
Pitt Meadows Oil Co. No. 2	....	13	40	....	E.C.M.	....	2,725	Drilled in 1914. A small showing of oil and nitrogen gas at 1,245 feet. Other shows reported
Pouce-Coupé Oils, Ltd.	14	19	79	....	W. of 6	....	1,482	Drilled in 1922. *See* Dunvegan sheet, Alberta
Province Oil and Gas Co., Ltd.	....	30	10	....	E.C.M.	....	....	Drilled in 1920. Suspended
Spartan Oil Co., Ltd., No. 1	Lot 130, Burnaby Lake				....	....	2,000	Gas and oil showings. Suspended
Spartan Oil Co., Ltd., No. 2	Lot 131, Burnaby Lake				....	....	1,800	Drilled about 1922. Oil shows reported. Suspended
Sumas Oil Co., Ltd., No. 1	5	27	19	....	E.C.M.	....	711	Drilled in 1926-29. Show of gas. Abandoned
Sumas Oil Co., Ltd., No. 2	5	27	19	....	E.C.M.	....	770	Drilled in 1929-30. Show of gas. Shut down
Sunshine Oil Co., Ltd.	....	19?	1	....	W.C.M.	....	....	No drilling done
Surrey Oil Co., Ltd.	9	3	7	....	E.C.M.	....	198	Drilled in 1919. Abandoned
Utility Oil and Gas Co., Ltd., No. 1	Lot 16	24	10	....	E.C.M.	....	300	Drilled in 1920-22. No oil or gas. Abandoned
Utility Oil and Gas Co., Ltd., No. 2	16	24	10	....	E.C.M.	....	336	Drilled in 1922-23. Abandoned
Utility Oil and Gas Co., Ltd., No. 3	16	24	10	....	E.C.M.	....	827	Drilled in 1923. Oil shows reported. Abandoned
Vancouver Oil and Nat. Gas Co., Ltd.	....	....	....	....	....	....	....	*See* Pitt Meadow Oil Co.

Northwest Territories

Operator	Location	Depth Feet	Remarks
Fort Norman Oil Co.	Six miles up river from Discovery well. On east bank of Mackenzie River	1,512	Drilling commenced 1921. Between 385 and 500 feet, about 300,000 cub. ft. of gas. No work done on this well after 1921
Northwest Co., Ltd. (Windy Point).	Windy Point, north side of Great Slave Lake	1,806	Drilling commenced 1920. No oil or gas. Well abandoned
Northwest Co., Ltd. (Norman), Discovery well No. 1	Fifty miles below Norman on east bank of Mackenzie River	1,025	Drilling commenced 1920. Oil at 787 and 993 feet. Production probably 60 to 75 bbls. a day
Northwest Co., Ltd., Discovery well No. 2	Close to Discovery No. 1 well	1,602	Oil at 895 feet amounting to 25 bbls. a day, but settled to 2 bbls. a day. Production of well as completed about 110 bbls. a day
Northwest Co., Ltd. (Bluefish location)	Eight miles below Norman on east bank of Mackenzie River	495	Drilling commenced 1921. Abandoned
Northwest Co., Ltd	West bank of Mackenzie River opposite Bear Island	1,704	Drilling commenced 1921. Gas at 145, 300, 385 feet. Small show of oil at 145 feet. Abandoned
Northwest Co., Ltd., "C" location	West bank of Mackenzie River opposite Bear Island	3,057	Drilling commenced 1922. No oil or gas. Abandoned
Northwest Co., Ltd., "D" location.	Bear Island, Mackenzie River	2,304	Drilling commenced 1921. Small show of oil at 1,945 feet. Heavy flow of salt water at 2,060 feet. Abandoned
White Beaver Oil Co.	Hay River, 15 miles south of Great Slave Lake.	712	Drilling commenced 1922. Heavy flow of salt water. Abandoned