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MINES AND GEOLOGY BRANCH

BUREAU OF GEOLOGY AND TOPOGRAPHY

GEOLOGICAL SURVEY

PRELIMINARY REPORT

WORLD PETROLEUM SITUATION AND DEVELOPEMENTS IN TURNER VALLEY, ALBERTA

BY

G. S. Hume

Paper 37-6

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WORLD PETROLEUM SITUATION AND DEVELOPMENTS IN TURNER VALLEY, ALBERTA[1]

By G.S. Hume

INTRODUCTION

When the Ontario oil fields were first drilled, in 1861, the demand was for kerosene, or coal oil as it was called. At that time gasoline was a by-product and was wasted. With the development of the internal combustion engine the demand for gasoline became the dominant factor in the oil industry. That now is being seriously challenged by the demand for fuel oil. In the United States, the greatest consumer of oil and oil products in the world, the daily consumption of fuel oil last year was 1,123,000 barrels, only slightly less than the daily gasoline consumption of 1,326,000 barrels. Perhaps the most striking use of fuel oil, other than the development of diesel engines for trucks, has been the extent to which it has been applied to transportation by water. The Normandie, for example, uses oil in her boilers to generate power for four 40,000 horsepower electric motors. When using full power the oil consumed amounts to 60 tons an hour or a ton a minute. A ton is about 7 barrels. It is the same power as would be equivalent to 150 tons of coal an hour which would have to be carried to the stokehold and 10 to 12 tons of ashes and clinkers removed. The use of oil, therefore, has made such boats as the Normandie and Queen Mary possible. It is also interesting to note in this connexion that the Normandie has 80 tons of lubricating oil in the oiling circuit which passes through the whole system once every ten minutes.

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1 An address given to the Ottawa Branch of the Canadian Institute of Mining and Metallurgy, March 1, 1937.

To accompany
Geological Survey Paper 37-6.

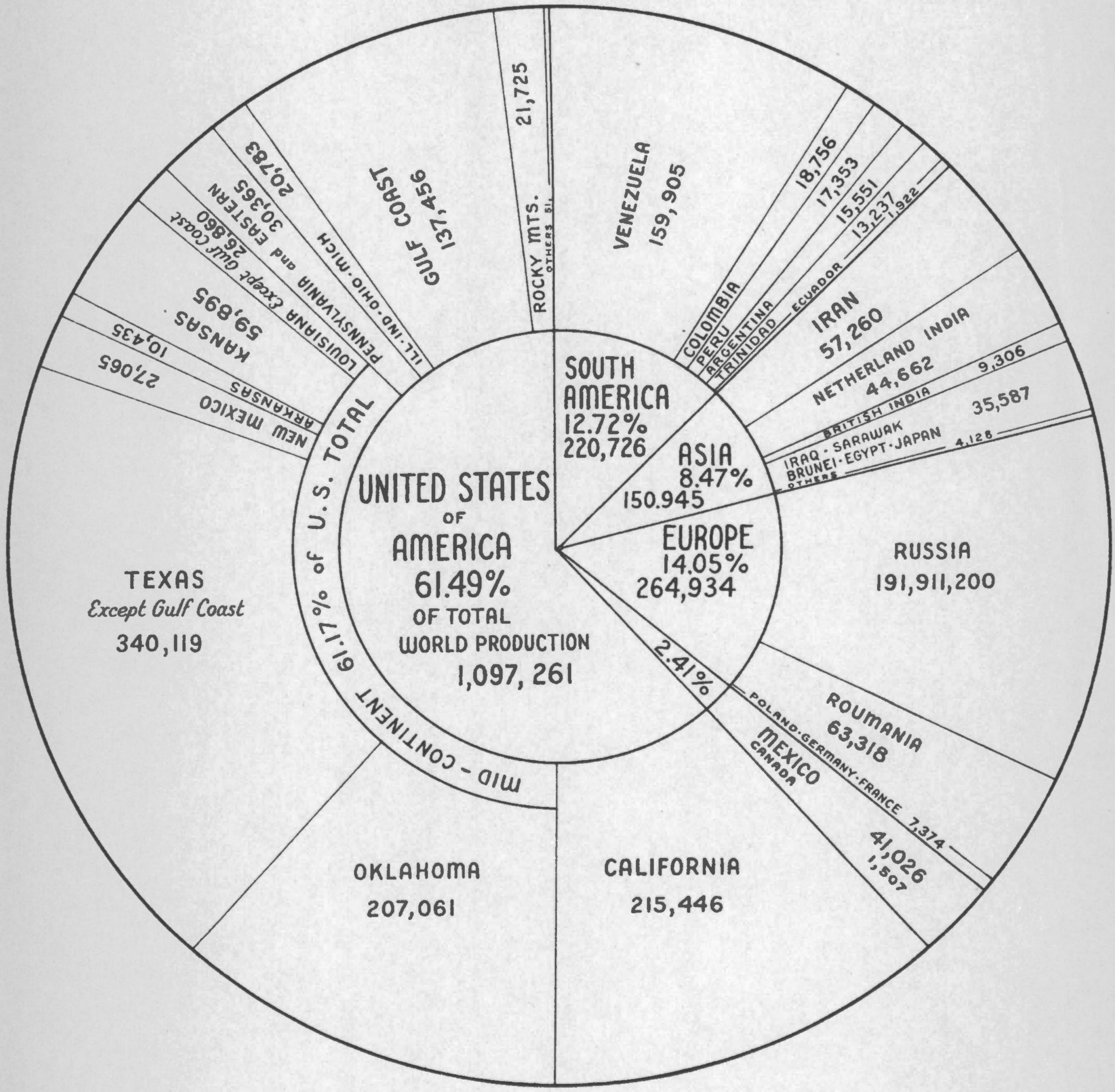

Figure 1. Showing world crude oil production in 1936 in barrels of 42 U.S. gallons, 000 omitted; (from "World Petroleum", February, 1937).

Situation in the United States

The United States has long been the greatest oil producing country of the world, and supplies about 60 per cent of the world's production (Figure 1). The production for 1936 was about 3,000,000 barrels a day, or twice the amount each day that Canada produces in a year, our annual production only amounting to 1,500,000 barrels. There is some fear in United States that this great production cannot be maintained, and although the oil industry is only beginning to catch up on over-production it is well known that oil reserves have been steadily decreasing in spite of very intensive work to discover new supplies. One of the major factors in the oil industry of the United States has been the East Texas field.[1] This field was discovered in September 1930, the discovery well flowing 300 barrels a day. A second well 1 mile west came in with 3,000 barrels a day, a third 10 miles north with 10,000 barrels, and a fourth 25 miles north with 12,000 barrels. This was the start of the development of the greatest field in the world, which when completely developed will have an area of about 218 square miles or 140,000 acres. Ordinarily one well for 10 acres would have proved sufficient for extraction of the oil, but owing to the fact that a thousand operating companies participated in this field there will probably ultimately be 26,000 wells. At the end of 1935, 19,500 wells had been drilled, but the output was very restricted. Before the restrictions became effective, however, the output reached 1,200,000 barrels a day, in May 1933, and at one time the price dropped to 10 cents a barrel. The potential capacity of the field is regarded as 9,380,000,000 barrels--an enormous amount of oil in view of the fact that the

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[1] Zavoico, Basil B.: Geology and Economic Significance of East Texas; World Petroleum, Mar. 1936, pp. 94-136.

total world production up to the end of 1934 was less than 26,000,000,000 barrels. The importance of East Texas is that it still contains between 25 and 30 per cent of the total reserves of the United States. It is estimated that 60 per cent of the oil in the field will be recovered, the high recovery being due to a water drive. Allowing for 20 per cent shrinkage after the oil is taken from the ground, the net estimated recovery will be 4,500,000,000 barrels. Up to the end of 1935, 820,000,000 barrels were produced from this one field. At present the allowable rate of production is 450,000 barrels a day, and at this rate 2,250,000 barrels of oil, the amount that can be obtained from flowing wells, will have been produced by 1944. The remaining 2,250,000,000 barrels will be produced by mechanical means, at an increasingly slower rate as the field is exhausted.

The value of petroleum exported from the United States at present amounts to one-eighth the total value of all exports, and is exceeded only by cotton. Since 1933 the exports of oil have been increasing, but it is becoming apparent that this cannot continue. It is estimated that in 1934 the average cost of producing a barrel of crude oil in the United States was 77.5 cents and the selling price was 98.4 cents.

Situation in Great Britain

Less than 5 per cent of the British imports are of Empire origin.[1] The main sources of Empire petroleum are in Trinidad, Burma, and India. British interests, however, have taken a very active part in developments of petroleum in many parts of the world, but particularly in the Near and Middle East where in the last few years large-scale developments have been undertaken. To ensure a home supply a large plant costing £3,000,000 was opened

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[1] World Petroleum, Dec. 1936, p. 632.

in England in 1935 to make motor fuel by the hydrogenation of coal, the operation of the plant being possible by a protection of 8d a gallon. The plant is capable of a production of 150,000 tons (1,050,000 barrels) a year, equal to about 4 per cent of the British consumption. About 600,000 tons of coal are consumed in making oil, and an additional 750,000 for other purposes, a total consumption of coal of about 4,000 tons a day. The yield of oil obtained is 60 to 70 per cent by weight of the coal, and if creosote is used it amounts to 80 to 90 per cent by weight. The plant employs 2,000 men with an additional 2,000 miners to supply the coal.

Situation in France

France has only one small producing oil field, at Pechelbronn. In 1935 this field gave slightly less than 540,000 barrels, of which about 300,~~000 barrels was produced by drilling~~ and ~~the remainder from shafts~~ and galleries. There is one small field in Algeria, and exploratory work has been going forward in Morocco, but no fields have been found. France has been interested in developments in the Near East, and especially so because of her mandate of Syria. One of the pipe-lines from Kirkuk empties on the Mediterranean at Tripoli in Syria.

Recently with money supplied by the state two plants for the hydrogenation of coal by different processes have been opened up. These plants are capable of producing 10,000 metric tons a year of liquid fuel. Another plant is now under consideration which would provide for the production by synthetic methods of 300,000 tons a year, or about one-tenth of the total present consumption. It has been the experience of every country that the costs under the most favourable conditions thus far developed are at least twice to five times as great as that of refining crude oil.[1]

1 World Petroleum, ~~Dec.~~ 1936, p. 617.

Situation in Germany

Most of the crude oil produced in Germany comes from Hanover, with a production of about 425,000 tons a year. Germany has tried four ways of producing liquid fuels: (1) Coking at high temperatures; (2) Hydrogenation by the Bergius process; (3) Semi-coking at low temperatures; (4) Fischer-Tropsch synthesis of gases. It has been estimated that by hydrogenation Germany would produce 600,000 tons of gasoline in 1936 and from coking 430,000 tons of benzol. The Fischer process uses coke water gas as its basis, and this process has been put into operation on a large scale in the last few years, with the expectation that by the end of 1936 the production from this source will have been brought up to 450,000 metric tons. It was announced by the German Chancellor late in 1936 as the intention of the Government of Germany to render the country completely independent of imported refined oil in three or four years. At present gaoline and gas-oil are the largest import oil items.

Near East Situation

There are three great producing areas in the Near and Middle East (Figure 2). These are Baku on the Caspian sea in Union of Soviet Socialist Republics, Kirkuk east of Tigris river in Iran, and Bahrein, an island in the gulf of Persia. Mosul in Iraq is one of the larger prospective fields, and several smaller producing fields have been to some extent already developed.

Baku comprises about six fields in the Apsheron peninsula, which has an area of only 9 square miles. This field was known to the early Persians by its mud volcanoes, oil and gas seeps, and salt springs. Hand-dug wells were utilized for many centuries, and finally in 1873 drilling began and flowing wells resulted. The oil sands are very incoherent and sometimes a well will produce 25 to 30 per cent of sand with the oil. This has caused considerable difficulty in keeping up production. At the present time the Soviet Government is trying to increase production and bring the Baku fields up to 420,000 barrels a day, which would be slightly more than 150,000,000 barrels a year. In 1935 the production amounted to 136,000,000 barrels, or about 77 per cent of the total oil production of Russia. Two pipelines connect Baku with the Black sea and Russia exports a considerable amount of oil and oil products, but with industrial developments in the country this is decreasing. In 1935 the domestic consumption of oil and oil products increased 15.75 per cent in Russia, and the exports decreased 21.4 per cent. One difficulty is that Baku is rather distant from the greater part of Russia, particularly Asiatic Russia, which eventually will need much larger oil supplies.

Mosul

A concession of 46,000 square miles was originally obtained from the Iraq Government for the development of oil by the British Oil Development Company. This company was purchased by the Mosul Oil Fields, Limited, which in 1935 came under Italian control with a smaller German interest. The rental for the concession has been on an increasing yearly scale, and in 1937 will amount to £200,000. The Italian and German interests apparently found difficulty in meeting these payments and at the same time providing money for development, and in 1936 the Mosul Oil Fields, Limited, was purchased by the Iraq Petroleum Company, which is under British control with French, American, and other smaller interests. It seems certain now that a development program will be put into effect. Certain drilling has been done and a large oil area proved, although it is understood some of the oil at least is high in sulphur and of rather low gravity (20 degrees A.P.I.). A pipe-line from Mosul to Alexandretta on the Mediterranean has been proposed but not yet built. The length will be about 400 miles.

Kirkuk

A concession of 32,000 square miles of territory for oil prospecting was given to the Iraq Petroleum Company in 1925. Between 1927 and 1931 there were thirty wells drilled and a large supply of oil found. A pipe-line opened in 1935 connects the Kirkuk field with two ports on the Mediterranean, one terminal is at Haifa in Palestine under British mandate and the other at Tripoli in Syria under French mandate. The greater part of the pipe-line is 12 inches and it is 1,150 miles long with twelve pumping stations, nine of which are in the desert. Each pumping station has workshops, garages, tank facilities for oil and water, telegraph, telephone, and aerodrome. The pipe-line crosses Tigris, Euphrates, and Jordan rivers and is capable of delivering 4,500,000 tons of oil a year. Its cost was £10,000,000.

Bahrein

Bahrein is an island of 230 square miles in the Persian gulf. A concession was granted to the Standard Oil Company of California and drilling began in 1930. It soon became evident there was a large available production and No. 31 well, which was finished in May 1936, had a flow of 26,880 barrels a day at a depth of 2,273 feet. At the present time production amounts to 3,000,000 tons a year. A refinery is under construction and the field is likely to outrank Kirkuk. The Texas Company which has distributing facilities all over the world, including the Orient, which is an important market for this oil, has now joined with the Standard of California in this enterprise. Another large concession has been granted on the west side of the

Persian gulf, and already one field 40 miles from Bahrein has been discovered. In this new field a well flowing 3,840 barrels a day was brought in last June (1936) of 53° Bé oil at a depth of 2,152 feet.

Thus the Near East fields assume a vast importance because they are strategic in relation to four-fifths of the world's population. From the pipe-line ports of the eastern ~~Mediterranean the distances are no more than~~ half of those from North and South America.

Situation in Japan

Japan consumes about 10,000,000 barrels of oil yearly and less than 2,000,000 barrels of this is produced within the country, the remainder coming mainly from Dutch East Indies and the United States.

Japan has a concession from Russia, renewed in December 1936, for the development of oil in the island of Sakhalin.[1] Originally Sakhalin was Chinese territory but was taken over by Russia in 1850, and after the Russo-Japanese war in 1905 the southern part was ceded to Japan. Japan seized the whole island in 1917. The northern half was returned to Russia in 1925, but in the interval Japan had made an intensive study of the oil resources. In 1925 Russia and Japan entered into an agreement for the development of 14,000 acres of oil territory, divided into 100-acre parcels owned alternately. Japan also pays a royalty on oil produced under terms very advantageous to Russia. Sakhalin's crude production in 1935 amounted to 2,800,000 barrels.

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[1] World Petroleum, Nov. 1936, p. 577

Situation in Canada

The oil fields in the southwestern peninsula of Ontario were among the first developed on the North American continent, and have thus a record of production extending back more than seventy-five years. In the early days in the Oil Springs field in Lambton county a few wells yielded 5,000 barrels a day, and one well is estimated to have produced 7,500 barrels a day. The first developed fields of Oil Springs and Petrolia still are the largest producing fields of Ontario, which now yield about 160,000 barrels a year. The probability of greatly increasing this supply is not good. A small gas and oil field near Moncton, New Brunswick, gives 10,000 to 11,000 barrels a year, but the main objective of this field is the production of natural gas. A third producing area in Canada is that near Fort Norman in the Northwest Territories. No attempts have been made in recent years to extend the known producing area, and at present a yield of 4,000 to 5,000 barrels during the summer months supplies the local requirements. The only other producing fields in Canada are in Alberta where the recent developments have centered around Turner valley. Canada imports more than 30,000,000 barrels of crude oil besides other oil products. The value of imports in 1935 amounted to $44,000,000, whereas the value of imports in 1929 was $76,000,000.

Turner Valley Field

Some drilling was done in Turner valley (Figure 3) in 1913-14, but it was not until the discovery of naphtha in the autumn of 1924 by Royalite No. 4 well that the field entered on its present developments. Royalite No. 4 well during its lifetime produced 911,313 barrels of naphtha, which so far as known has not been exceeded by any other well. Up to June 1, 1936, according to Spratt and Taylor,[1] the field produced 9,473,582 barrels of

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1 Spratt, J.G., and Taylor, V.: Bull. Can. Inst. Min. and Met., Nov. 1936, p. 713

To accompany
Geological Survey Paper 37-6.

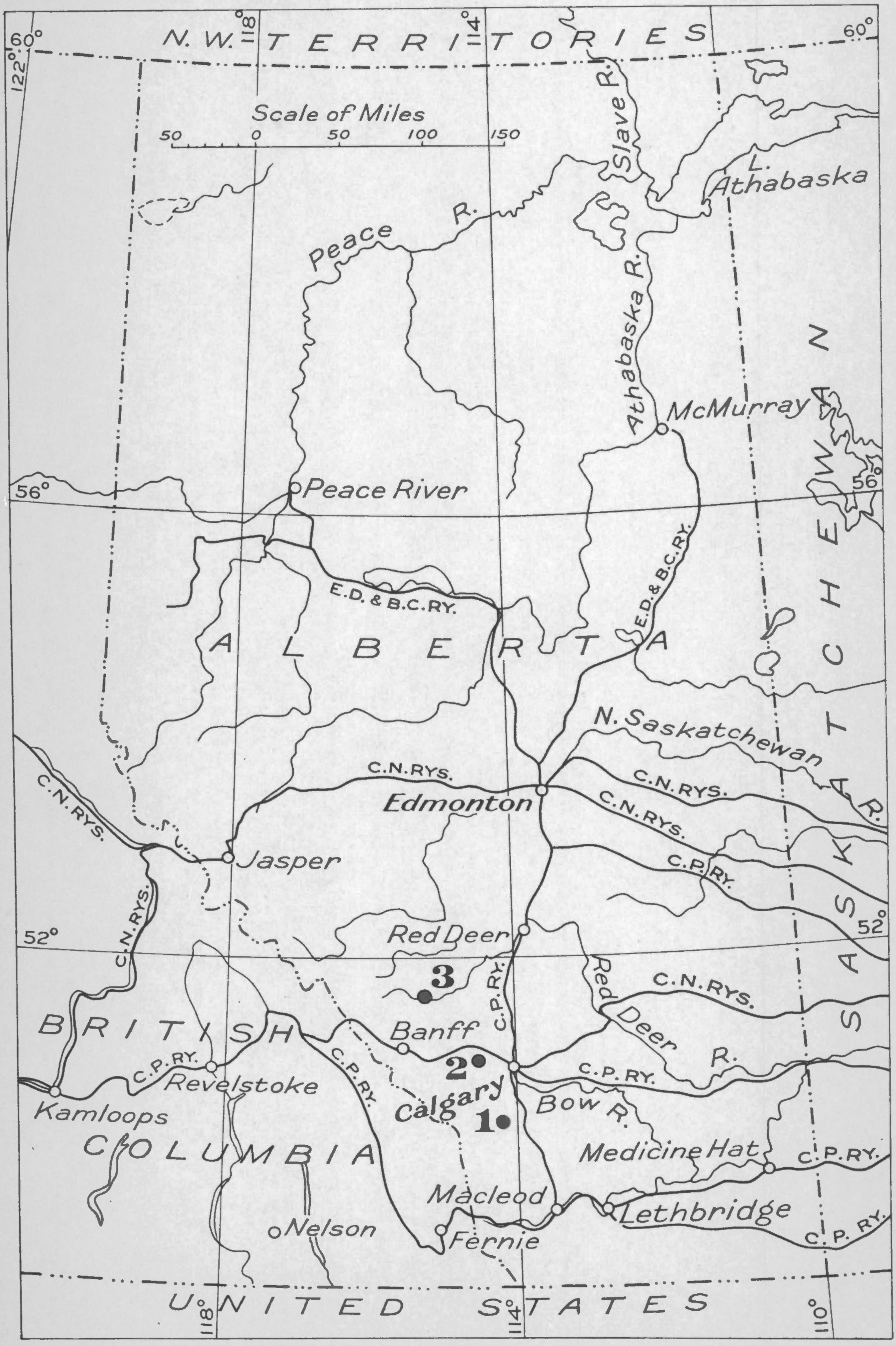

Figure 3. Map showing position of 1, Turner Valley; 2, Jumpingpound; and 3, Red Deer-Foothills areas; Alberta.

naphtha and 829,000,000 M. cubic feet of gas, a large part of which was burnt as waste. In the early days of development the naphtha was recovered by the use of Smith separators, but as the pressures in the field became less several extraction plants were erected. Naphtha-gas wells drilled on the top of the structure usually decline rather rapidly, but the gravity of the oil remains fairly constant in spite of less efficient gas-oil ratio. Wells on the west flank, however, like Model No. 1 (Figure 4) or Advance No. 5A (Figure 5) have shown a change from an original naphtha to a crude oil well. Model No. 1 well, for example, originally produced naphtha with a gravity of 68° A.P.I., whereas it now produces crude oil with a gravity of 46° A.P.I. The rate of oil production in this well has declined only very moderately, and in 1936 was actually increased by tubing methods although the amount of gas produced has fallen from 4,000 M. cubic feet to 500 M. cubic feet and the pressure from 1,900 pounds to 1,025 pounds in June 1936. This well has been in production over six years and up to the end of July 1936 has yielded 322,909 barrels of oil, valued at $916,000. Advance No. 5A well also started off as a naphtha well, but gradually began to produce some crude oil. It was, therefore, evident that crude oil was migrating up the west flank of Turner valley as the gas was drawn off the top. This was the situation so far as concerned crude oil from the Palaeozoic limestone when the Turner Valley Royalties well (Figure 6) was completed in June 1936 with a flow of 850 barrels, which has since been sustained at about 650 to 700 barrels. This well is in the southwest part of Turner valley on the northwest side of Longview hill and is 12 miles from Model No. 1 well, producing crude oil at the north end of the same structure. Turner Valley Royalties well reached the Palaeozoic limestone at a depth of 6,396 feet, and was finished at 6,828 feet. The top of the limestone is 2,155 feet below sea-level in this well. In central Turner Valley

Royalite No. 14 well, the shallowest well in this field to the Palaeozoic limestone reached this horizon at 3,220 feet, or 786 above sea-level. The relief on the top of the Palaeozoic limestone within the productive area of the Turner Valley field is thus 2,941 feet, with the lower limit of the oil zone on the west flank not yet known. Thus there is a mountain of limestone probably more than 3,000 feet high under Turner valley within the producing area of this field. This, of course, makes Turner valley a very exceptional field as it is in other respects, and as already pointed out the western limit of the field has not yet been reached. At this time it is not possible to make any predictions as to how wide the oil zone on the west flank will be. Certain wells in Turner valley give small amounts of water, and as pointed out by Spratt this water is similar in character to water that occurs in a well drilled on the northward extension of the Highwood uplift. This uplift lies west of Turner valley at the C.D. and P. well, in which the limestone was encountered at an elevation of about 460 feet above sea-level, but contained salt water instead of oil or gas. The significance, however, is that this higher uplifted area to the west probably is connected to Turner valley in the Palaeozoic limestone through a syncline separating the two areas, an inference made because of the similarity in character of the salt water in the two areas. This inference is strengthened by the migration of the oil up the west flank as in Advance No. 5A well, because it is presumably moving up under the influence of a water drive from the west owing to the hydrostatic head provided by the Highwood uplift. Thus at some distance down the west flank of Turner valley this water will be encountered and the oil-water boundary will form the west limit of the producing area of Turner valley. In a section drawn westward from Longview C. and E. well through Publix and British Dominion wells it is inferred that in a half mile west of the west boundary of Section 28, on which Turner Valley Royalties well is located, the limestone dips down 1,100 feet provided no faults intervene. There is a possibility of faults, however, overthrusting the limestone and thus bringing it closer to the surface than such a projected dip as known on the west flank would allow. At any rate a width of a quarter of a mile would be very conservative and a width of a half mile may be more probable. Spratt and Taylor assumed a porosity in the oil zone of 10 to 20 per cent and a thickness of 50 to 100 feet, and thus arrived at an average oil content of 100,000 barrels an acre. They allowed a shrinkage of 50 per cent for the loss of gas when the oil is brought to the surface of the ground, and thus arrived at the figure of 50,000 barrels of oil an acre under atmospheric conditions. Assuming that drilling could be extended to the 7,000-foot level of the top of the limestone, they figured there are 5,000 acres of crude oil lands in Turner valley, and thus arrived at a potential capacity of 250,000,000 barrels of oil on the west flank of this oil field. The shrinkage factor of 50 per cent is probably too high except for a limited area close to the gas-oil boundary, but the amount of 250,000,000 barrels is as good an approximation to the probable oil content as can be made at the present time. It is difficult to predict what part of this oil will be recoverable. The pressure in the gas wells at the top of the structure was originally more than 2,000 pounds to the square inch, whereas in June 1936 the maximum was 1,420 pounds and the minimum was 385 pounds a square inch. Gas is the main propulsive force that causes oil to move, and with the decrease of pressure the effect on the oil recovery must necessarily be very marked. To offset this in some degree there is a water drive on the west side of Turner valley. The flow through the pores of the rock must be very slow, and if oil is rapidly extracted the water drive will lag behind in its effect. Undoubtedly, however, a much larger volume of oil will be recovered owing to the water drive than would otherwise have been the case. Spratt and Taylor placed the recovery of oil at 25 per cent, but state this may be conservative. The effect of the propulsive force of gas is apparent in the B. and B. well recently completed, and stated to have an initial flow of about 2,000 barrels of oil a day. This well had a gas flow of about 6,500 M. cubic feet in comparison with 2,000 M. cubic feet from Turner Valley Royalties well. As is evident from the structural contour map (Figure 7) Turner Valley Royalities well reached the top of the limestone at 2,155 feet below sea-level, whereas B. and B. well reached the same horizon at 1,940 feet below sea-level. Both of these are crude oil wells. Century No. 1 well originally produced naphtha, but has now changed into a crude oil well. It reached the top of the Palaeozoic limestone at an elevation of 1,604 feet below sea-level. It is, therefore, apparent that in this area the dividing line between the gas and crude oil must be an approximate level at or just slightly below 1,600 feet below sea-level. Thus, at least a partial explanation of the larger flow of oil in B. and B. well than in Turner Valley Royalities well is owing to its closer proximity to the oil-gas line, with its consequent considerable volume of gas production with the oil. It is not to be assumed that this division between the oil and gas is sharply defined nor will it necessarily be at the same level throughout the whole structure. It would now be expected to be higher up the flank of the structure in those parts like the Home area where the gas pressure is relatively low. This fact again seems to be confirmed by the migration of oil up to Advance No. 5A well, which reached the top of the limestone at an elevation of 1,780 feet below sea-level. Thus, whatever the original character of the oil-gas line on the west flank of the structure it is certain that as a large amount of gas has been removed from the top of the structure, the oil-gas level will vary widely in height along the west edge of the structure.

The geological interpretation of the structure of the Turner Valley field is of great importance in relation to the development of other fields in the foothills. Link and Moore[1] in a paper published in 1934 expressed the belief that the limestone mass under Turner valley was merely a core cut off on the west flank as well as on the east by the low-angle fault underlying this structure (Figure 8). This meant two pulsations of movement, namely, a folding into an anticline then a decapitation of the anticline by a low-angle fault with the limestone torn away entirely on the west side from the parent mass of which it formerly was a part. This idea was in opposition to the belief that the Turner Valley fold is a drag-fold developed on the top of a low-angle thrust fault, and that the faulting is responsible in a large part, if not entirely, for the folding. The correct interpretation was recognized as being of far-reaching economic importance since it is obvious if the limestone is cut off on the western edge, the field must end there. In order to get a picture of the field a model was constructed[2] using small rods for each well and plotting the stratigraphy on them on the scale of 200 feet to 1 inch. The rods were then placed in their proper position in the model with the horizontal scale the same as the vertical. The same stratigraphic horizons were then joined by coloured strings with the result that the model when completed gave a picture in three dimensions. The low-angle fault under the field was traced by means of wires joined to the proper places in each well where the fault had been encountered. From this model it was obvious

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[1] Link, T.A., and Moore, P.D.: Am. Assoc. Pet. Geol., vol.18, No. 11, 1934.

[2] Hume, G.S.: Trans. Roy. Soc., Canada, vol. XXIV, sec. IV, pp. 129-138 (1935).

if the limestone continued down the west flank at the same dip as it had within the limits of the model it would be cut off by the westward projection of the low-angle fault. This was the condition Link and Moore had postulated. However, if the fault should turn down steeply under central Turner valley the limestone might not be cut off on the west flank. The idea[1] that the fault might turn from a relatively low angle to a steep dip at depth was derived from a study, in 1933, of a fault traced for 20 miles in the area of the Hunter Valley well on Red Deer river close to the mountain front. This fault trends northwest and southeast, as do most faults in the foothills. Where it crosses Red Deer river it has a sinuous course owing to it having in places a westward dip of only 8 degrees. Northwestward, however, the fault steepens and cuts straight across the surface regardless of the topography. As erosion is deeper in this north part than at Red Deer river it was deduced that the steep part of the fault was a deeper expression of the same fault that was low-angled where erosion had been less deep. This deduction is of very great economic importance. If the fault which is low-angled where it crosses Red Deer river remained so as far west as the Hunter Valley well it should have been encountered in drilling at a depth of about 5,000 feet. The well has now been drilled to more than 7,000 feet and the fault has not yet been reached, so that the results of drilling confirm the geological deduction in regard to the steepening of the low-angle fault at depth. This same condition apparently occurs also under Turner valley (Figure 9) because it is now obvious that since there is definite proof of migration of oil up the west flank, presumably due to an eastward water drive, the limestone mass cannot be cut off from its roots. In applying

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[1] Hume, G.S.: Discussion of "Structure of Turner Valley Gas and Oil Field, Alberta"; Bull. Am. Assoc. Pet. Geol., vol. 18, No. 11, p. 1447 (1934).

this same steepening of the low-angle faults under other structures it now becomes apparent that areas in the foothills that have been tested by one or two wells and yielded nothing may still have good prospects of oil production. The Jumpingpound anticline is one example. Two deep wells were drilled on this anticline, the first on the east side and the other in the central part. Both wells penetrated the low-angle fault under the structure. In No. 2 Jumpingpound well, drilled in the central part of the structure, the low-angle fault was encountered in the Fernie formation not more than 150 feet stratigraphically above the Palaeozoic limestone. Owing to the belief that has been expressed that the low-angle fault persists as such for some distance westward it was thought no Palaeozoic limestone could be present in this structure. However, as shown in the cross-sections, if the fault turns downward steeply under the central part of the Jumpingpound anticline Palaeozoic limestone must occur on the west flank and the conditions thus are still very favourable for oil and gas production from this horizon.

This conception of the character of these low-angle foothills faults greatly modifies the prevailing ideas in regard to a number of foothills structures, and if Jumpingpound is eventually proved to have Palaeozoic limestone on its western flank, just as Turner valley has been proved to have a limestone mass not cut off on its western edge, confidence will be re-established in drilling a number of other foothills areas where at present drilling has not been attempted or is suspended.

The Plains of Alberta

A comprehensive statement in regard to the prospects for oil on the plains of Alberta cannot be given here. One well, however, needs mention. This is the Arca well being drilled southwest of High river by Imperial Oil Company, the Calgary

Gas Company, and Calgary and Edmonton Corporation. The well location is outside the foothills on a simple fold within the Alberta syncline. The well commenced drilling in Tertiary strata and reached the top of the Palaeozoic limestone at 8,750 feet. The limestone is now being drilled and the results of this well will have a far-reaching effect on further exploration within the Alberta syncline, but will have no bearing on developments within the foothills. In this connexion it should be remembered that many of the great oil fields of the world are on anticlines in basin structures.

The structure of the Arca well was delimited by means of a reflection seismograph. In such geophysical investigations unless the rate of transmission of the vibrations sent out from the explosion point are accurately known the actual depth to the top of the reflecting surface, in this case the top of the Palaeozoic limestone, cannot be precisely caleulated. This is easily understood when it is realized that the depth to the reflecting surface is great and the time of transmission of the vibrations from the explosion point to the reflecting surface and back to the geophones is very small. A small error, therefore, in the rate of transmission of the vibrations may give a considerable error in calculated depth. In this type of work the depths at various shot points are only known relative to one another and the actual depth at any place can only be precisely calculated when the rate of transmission is accurately known. Thus, in seismograph work it is the form of the structure based on relative depths that is obtained. It is known that the Arca well was somewhat deeper to the Palaeozoic limestone than originally anticipated, but this is no condemnation of the method used to determine the structure on top of the limestone. The fact, however, that the anticline on which the well is being drilled is deeper within the Alberta syncline than at first believed may not be as favourable for production as would have been the case were the anticline somewhat higher on the flank of the basin structure. The well will be completed shortly and should it prove productive it is expected that other deep structures within the Alberta syncline will be tested.

Index to Wells in North Part of Turner Valley, as Shown on Figure 4

Township 20, Ranges 2 and 3

	Well	Elev. of Well	Depth to Pal. Ls.	Elev. of Pal. Ls.	Total Depth
1.	Freehold No. 1	3993			4825
2.	Dalfin No. 1	4024			2310
3.	Calmont No. 5	4014			4032
4.	Calmont No. 9	3987			4930
5.	Turner Basin No. 1	4042			5300
6.	Turner Basin No. 2	4041			2970
7.	Turner Basin No. 3	4055			4040
8.	Foothills No. 1	4001	5353	-1352	5915
9.	Foothills No. 4	4023			4559
10.	Model No. 1	4093	5800	-1707	5905
11.	Model No. 2	4083	5524	-1441	6539
12.	Model No. 3	4149	5730	-1581	6234
13.	Royalite No. 26	4076	4893	-817	5083
14.	Royalite No. 27	4135	5185	-1050	5570
15.	Midwest No. 2				3345
16.	Spooner No. 3	4047			3240
17.	Vimy No. 1	4056			3550
18.	Dome No. 1	4044			6005
19.	United No. 4	4043			6360
20.	Richfield No. 2	4034	4728	-694	5070
21.	Spooner No. 1	4060	4690	-630	5260
22.	Spooner No. 2	4023	5080	-1057	5983
23.	Spooner No. 4	4019	5060	-1041	5444
24.	Vulcan No. 1	4012	4862	-850	5030
25.	Vulcan No. 2	4031			4850
26.	Vulcan No. 3	4040			3100
27.	Royalite No. 9	4031	4860	-829	5593

	Well	Elev. of Well	Depth to Pal. Ls.	Elev. of Pal. Ls.	Total Depth
28.	Royalite No. 13	4000	4640	-640	4946
29.	Royalite No. 7	4013	4100	-87	4285
30.	Royalite No. 12	4002	5410	-1385	5638
31.	Dalhousie No. 3	4046			3340
32.	Dalhousie No. 4	4006			3600
33.	Dalhousie No. 6	4056	5023	-967	5595
34.	Royalite No. 21	4002	4308	-306	5034
35.	Dalhousie No. 1	4002	4406	-404	4565
36.	Dalhousie No. 2	4015			3600
37.	Royalite No. 4	3975	3450	+525	3740
38.	Royalite No. 5	3984			3527
39.	Royalite No. 14	4006	3220	+786	3792
40.	Great West No. 1	3903			5400
41.	Cooper Nanton No. 1	3901			4830
42.	Royalite No. 8	4005	3660	+345	3753
43.	Royalite No. 18	3995	3821	+174	3887
44.	Royalite No. 10	4010			2333
45.	Royalite No. 11	4014	3628	+386	4047
46.	Royalite No. 20	4024	4880	-856	5180
47.	Royalite No. 22	4019			2250
48.	Royalite No. 15	4022			3047
49.	Royalite No. 16	4046	4706	-660	5673
50.	Illinois Alberta No. 1	4008	3636?	+372	3831
51.	Illinois Alberta No. 2	4012			3684
52.	New McDougall-Segur No.2	4018	5058	1040	5658
53.	New McDougall-Segur No.3	4028	5415	1387	5834
54.	New McDougall-Segur No.4	4015	4860	-845	5108
55.	Widney	4023	5010	-987	5420
56.	British Dominion No. 2	4046	5064	-1018	5180
57.	McLeod No. 1	4011			3940

	Well	Elev. of Well	Depth to Pal. Ls.	Elev. of Pal. Ls.	Total Depth
58.	McLeod No. 2	4005	3640	+365	4420
59.	McLeod No. 3	4029	4749	-720	4973
60.	McLeod No. 4	4007	3730	+277	7751
61.	McLeod No. 5	4034	4950	-916	5188
62.	Regent No. 1	4001	3734	+267	3908
63.	Regent No. 2	4010			1978
64.	Regent No. 3	3999	3800	+199	
65.	Sioux City No. 1	4019	4385	-366	6194
66.	Canada Southern No. 1	3995			2510
67.	Midfield	3980	3920	+60	4205
68.	Okalta No. 3	3983	4142	-159	4563
69.	Foothills No. 2	3971	4357	-386	4940
70.	Freeman Lundy No. 1	4021	4891	-870	5374
71.	Okalta No. 1	3955	4935	-980	5040
72.	Okalta No. 2	3955	4755	-800	5141
73.	Calmont No. 1	4015	5463	-1448	5877
74.	Royalite No. 1	3931			3924
75.	Royalite No. 2	3964			3175
76.	Royalite No. 3	3916			2830
77.	Royalite No. 17	3993	3463	+530	4034
78.	Royalite No. 19	3951	4463	-512	5020
79.	Highland	3986			3020
80.	Big Chief	3993			4370
81.	British Dominion No. 1	3985			6600

Wells Not in Turner Valley:

82.	Weymarn No. 1	4054			4030
83.	United No. 1	4175			3150
84.	New Valley	3873			
85.	Sentinel	3858			5850

Index to Wells in Middle Part of Turner Valley as Shown on Figures 5 and 7

Township 19, Ranges 2 and 3

	Well	Elev. of Well	Depth to Pal. Ls.	Elev. of Pal. Ls.	Total Depth
1.	Royalite No. 23	4036	4820	-784	5331
2.	Royalite No. 6	4000	4280	-280	4531
3.	Royalite No. 25	4030	4270	-240	4690
4.	Structure No. 1	4044	4733	-689	5212
5.	Midwest No. 1	4029			3740
6.	Mid Royal	4054			2175
7.	Dalhousie No. 5	4035			4900
8.	Dalhousie No. 7	4062	4992	-930	5339
9.	Dalhousie No. 8	4116	6178	-2062	
10.	Royalite No. 24	4043	5255	-1212	5555
11.	Advance No. 5A	4230	6009	-1779	6515
12.	Home No. 1	4199	5110	-911	5280
13.	Home No. 2	4204	5345	-1141	5507
14.	Home No. 3	4206	5032	-826	5139
15.	Home No. 4	4213	5416	-1203	5601
16.	Home No. 5	4228	4480	-252	4898
17.	Baltac	4217	5400	-1183	5874
18.	Calmont No. 2	4200	4773	-573	4927
19.	Calmont No. 4	4209	4824	-615	5084
20.	Calmont No. 7	4200	5017	-817	5414
21.	Alberta Pacific Con. No.1	4245	5463	-1218	5796
22.	Alberta Pacific Con. No.2	4271	5163	-892	5840
23.	Associated No. 1	4224	5170	-946	5410
24.	Associated No. 2	4265	4952	-687	5423
25.	Hargal No. 1	4192	5058	-866	5348
26.	Freehold No. 2	4205	4058	+147	4466
27.	Wellington No. 1	4248	4660	-412	4988
28.	Lowery No. 1	4316	5110	-794	5460

	Well	Elev. of Well	Depth to Pal. Ls.	Elev. of Pal. Ls.	Total Depth
29.	Lowery No. 2	4249	6058	-1809	6584
30.	Mayland No. 1	4216	5451	-1235	6242
31.	Mayland No. 2	4136	4710	-574	5017
32.	Mayland No. 3	4105	5820	-1715	6177
33.	Mayland No. 6	4117	4656	-539	5069
34.	Homestead	4144	4286	-142	4798
35.	East Crest No. 1	4133	4312	-179	4675
36.	East Crest No. 2A	4125	4247	-122	4637
37.	East Crest No. 3	4005	4451	-446	4845
38.	Southwest Pete No. 1	4080	5478	-1398	5493
39.	Southern Lowery No. 1	3985	4540	-555	4850
40.	Southern Lowery No. 2		4350		4740
41.	Southern Lowery No. 3		5147		5622
42.	Commonwealth No. 1	4004	4620	-616	5000
43.	Miracle No. 2	4070	5940	-1870	6710
44.	Spray No. 1	4133			3790
45.	Mercury Royalties				
46.	Mercury No. 1	4009	5270	-1261	5360
47.	Mercury No. 2	4056	5110	-1054	5420
48.	Mercury No. 3	4202	5070	-868	5270
49.	Mercury No. 5	4168			5840
50.	Mercury No. 6				
51.	Mercury No. 7	4146			
52.	Mercury No. 8				
53.	Miracle No. 1	4030	5170	-1140	5395
54.	Miracle No. 3	4039	5490	-1451	6150
55.	Mill City No. 1A	4025	4510	-485	5065
56.	Hylo No. 1	4051	5500	-1449	5665
57.	Kermac No. 1				
58.	Continental No. 1				

Index to Wells in South Part of Turner Valley as shown on Figures 6 and 7

Township 18, Range 2

	Well	Elev. of Well	Depth to Pal. Ls.	Elev. of Pal. Ls.	Total Depth
1.	Sterling Pacific No. 1	4214	5153	-939	6510
2.	Sterling Pacific No. 2	4221	5562	-1341	5720
3.	Sterling Pacific No. 3	4221	6230	-2009	6788
4.	Sterling Pacific No. 4	4228	6709	-2481	
5.	Sterling Pacific No. 5				
6.	Sterling Royalties	4232	4977	-745	5657
7.	Livingstone	4160			3880
8.	Rand				3891
9.	Merland No. 1	4274	4965	-691	5530
10.	Merland No. 2				2690
11.	C. and E. Longview	4452	5592	-1140	6220
12.	Director Royalties	4289	4963	-674	5644
13.	Marjon No. 1	4366	5402	-1036	5854
14.	Marjon No. 2	4324	4930	-606	5870
15.	Publex	4399	4900	-501	5520
16.	Pacalta	4410	5045	-635	5498
17.	Spooner-Anaconda	4503	5510	-1007	6305
18.	Carleton	4600	5460	-860	6110
19.	Renfrew	4581	6010	-1429	6550
20.	British Dominion No. 4	4360	5838	-1478	6217
21.	British Dominion No. 5				
22.	Anaconda No. 2	4251	5080	-829	5548
23.	Century Royalties	4235	5839	-1604	6530
24.	Richland No. 1				
25.	Richland No. 2	4281			
26.	Richland No. 3	4251			
27.	Turner Valley Roy. No. 1	4241	6396	-2155	6828
28.	Turner Valley Roy. No. 2				
29.	Brown and Brown No. 1	4255	6195	-1940	6609
30.	Model Spooner				

	Well	Elev. of Well	Depth to Pal. Ls.	Elev. of Pal. Ls.	Total Depth
31.	Commoil				
32.	Granville				
33.	Share Royalties No. 1				
34.	Davies Peto No. 1				
35.	Sunburst No. 1				
36.	Sovereign Royalties	4340	5792	-1452	6234
37.	Highwood Sarcee No. 1	4497	5348	-851	5755
38.	Highwood Sarcee No. 2	4101	5699	-1598	6560
39.	Union Freehold	4226	5595	-1369	6462
40.	Hoffar Lundy	4244			4300
41.	Newfold	4171	5810	-1639	6254
42.	Foundation Roy.	4096	6020	-1924	6474
43.	Westside Roy.	4073	5938	-1865	6378
44.	Monarch Roy.				
45.	Brown No. 1				
46.	Brown No. 2				
47.	Firestone				
48.	Prairie				
49.	National No. 2				