PRELIMINARY EVALUATION OF OIL POTENTIAL

IN THE GREAT SLAVE LAKE AREA OF THE

NORTH WEST TERRITORIES, CANADA

January 12, 1959

By: B.Sc. P. Eng.

Signed: W Lindo.

CONFIDENTIAL

C O N T E N T S

SUMMARY

Oil seepages were investigated in the area of Sulphur Bay which lies on the west side of Great Slave Lake in the North West Territories.

To the West, at a distance of from five to ten miles inland, the Presquile Dolomite forms an oil bearing reservoir at shallow depths. It is overlain by a cap of up to fifty feet of hard, dark grey bituminous shale (Spence River Shale) covered by a thin layer of alluvial gravel and overburden.

The section has been extensively drilled and cored and oil impregnated sections of over 160 feet have been recovered. Cored sections from one hundred and sixteen (116) stratigraphic test holes have been examined and described in detail.

This dolomitic reef has been delineated and covers a proven area of over fifty six square miles, with a net pay section averaging some 55 feet in thickness.

The reef structure was drilled and cored during 1956, over the area in a program designed only to evaluate the lead and zinc mineralization associated with the vuggy dolomitic reef, and the oil content and the excellent porosity/permeability characteristics were ignored at that time. However, oil and gas shows were obtained during the coring process and a badly weathered sample of the oil has been analyzed. The gravity was 18° API but estimates by the laboratory of oil bled from the

interior of a broken core sample (which had been weathered for some months) would indicate that the actual reservoir fluid will have a gravity of 27° API or higher. A small flow of oil was obtained from a well drilled some miles to the west, but producing from the same formation. The Division of Fuels, Ottawa ran an analysis on a sample and this gave a gravity of 32.8° API.

Bituminous infilling in the cores is only sporadic and average permeability of the core is excellent. Five samples analyzed averaged porosity of 15% and permeabilities greater than 700 millidarcies.

A conservative evaluation of the reservoir capacity, assuming an average porosity of 7% and a water saturation which is no doubt excessive (40%), indicates an oil in place in excess of 620 million barrels.

The reservoir fluid will be almost completely undersaturated due to its proximity to the outcrop and shallow depth. Solution gas-oil ratios will probably be less than 20 cubic feet per barrel. Low recoveries from solution gas drive must be expected, but the fact that a large volume of continuous, oil bearing reef structure is encountered close to the surface would make the prospects of a close spaced drilling pattern, and the inception of a pressure maintenance/water flood project, highly economical. Miscible slug followed by water injection or alternatively in situ combustion, are clearly indicated, with a corresponding greatly

improved recovery factor. Results from the South Belridge test pattern, which has been operated in California on an experimental basis for the last four years, show a recovery by in situ combustion in excess of 72%.

Consideration of regional economics serves to emphasize the following points:

1) The area is situated directly on the shore of Great Slave Lake which forms part of the MacKenzie river system, the main traffic artery through the Territories. The highway constructed from Edmonton to Hay River which has now been extended to Fort Providence, Fort Rae and then to Yellowknife, passes through the area. Completion of the last leg of the rail connection from the shores of Great Slave Lake to Edmonton is now in the final stages preparatory to construction. A winter tractor road traverses the property. The location is thus highly accessible.

2) Demands for high octane fuel in the immediate area and also for air traffic supplying the "DEW" Line are increasing rapidly. Mining operations at Coppermine and Port Radium and the present rapidly expanding activity throughout the Territories will serve to accentuate the demand. The present gasoline supplies are brought in by long freight hauls either from the small refinery at Norman Wells or by rail and boat from Edmonton.

3) A small capacity refinery using the "coking" process could be designed locally to accommodate this crude and the resulting

supply of asphalt would find a ready market for the all-weather highway system which is now in process of construction across the entire Yukon and the Territories.

4) Political necessity in the last 12 months has created a tremendous amount of land activity* from the Alberta border north throughout the Territories as far as the MacKenzie Delta and the Arctic. Accelerated development of this entire area, which is recognized as having an almost unlimited oil and gas potential, together with the vigorous activity in Alaska, will call for rapid development of pipeline outlets coupled with tanker transportation, to make the entire Alaskan and North Canadian area a source of supply alternate to Middle East and Venezuelan crude. Development of the Athabaska tar sands in the very near future will probably serve to complement the Territorial oil production. Pipeline outlets to the Pacific, at Skeena River or at Juneau, or to Churchill on the Hudson's Bay, are already being investigated.

* NOTE: 38.3 million acres were taken out under permit in August 1958 and a further 3.1 million acres in November.

A total of 1438 permits covering 70.7 million acres were under active permit at the end of November 1958.

A temporary 4-inch line was laid along the Canol Road, from Norman Wells to Whitehorse, as an emergency war time measure and carried crude for refining at a point which is only fifty miles from the Pacific coast. Reconstruction of a line over this same route is now being considered.

A relatively small outlay in capital and equipment on the permits will provide for the carrying out of a further slim-hole coring and testing program which would serve to completely delineate the reservoir and also to indicate the most favourable process for production and development.

A map and notes on a 61,272 acre permit surrounding Fort Providence have also been included. This acreage contains one well which was drilled on this permit 1½ miles south east of Fort Providence in July 1951. A small sweet gas flow, estimated at 40 ! cf per day, was tested and the well was capped as a potential gas well. This well will revert to the present permit holders when a lease is taken out.

PROJECT Y(1)

Reserve Evaluation:

Productive Area

(6 miles x 6 miles = 36 square miles averaging 70 feet net pay.
(
(10 miles x 2 miles = 20 square miles averaging 30 feet net pay.

Volume: 36 x 640 x 70 = 1,612,800 Acre-feet

20 x 640 x 30 = 384,000 Acre-feet

1,996,800 Acre-feet

(Use 2 million)

Factors Used:

Average Porosity	7%
Connate Water	40%
Shrinkage	0.95

Oil in Place

0.07 x 0.60 x 0.95 x 7758 = 310 bbl. per Acre-foot

$310 \times 2 \times 10^6$ = 620 million barrels

Recoverable Oil

(a)	5% Recovery Factor	31 million barrels
(b)	10% Recovery Factor	62 million barrels

DISCUSSION

DISCUSSION

Permits

Three exploration permits were purchased directly that they became available, from the Dominion Government in December 1958, in the Great Slave Lake area, North West Territories, Canada. They are located between Latitudes 61° 10' N and 61° 30' N and Longitudes 115° 45' W and 116° 20' W and cover a total area of 184,464 acres.

A fourth permit of 61,272 acres was also purchased in the Fort Providence area, some fifty miles to the west. It is located between Latitudes 61° 20' N and 61° 30' N and Longitudes 117° 30' W and 117° 45' W.

These permits may be converted to leases at any time. A maximum block of 4 x 4 "Sections" (approximately sixteen square miles) may be taken and the remainder divided up in checker-board pattern until fifty percent of the acreage is under lease. The remaining half reverts to the Crown. Careful selection of lease blocks, under this very advantageous system, enables the operator to select more than 75% of the recoverable reserves in the field.

Rentals

In addition to the bonus, a rental of five cents per acre has been paid which holds the area in good standing for 18 months (to June 1960).

All of the rental cost is recoverable when balanced against the expenditure made on the property. A "deep test" on the permit area is given credit for twice its actual cost. Permits can be renewed for a further period of eighteen months and then yearly for a total of nine years.

Permits may be "grouped" for the purpose of expenditures. Work being done on one area can then be applied to rentals on the whole property. (NOTE: There is no other area in the world where exploration regulations and conditions are so favourable.)

Lithology

The Fort Creek formation of the Upper Devonian outcrops along the western shore line of Great Slave Lake. On the eastern shore the Canadian Shield (Precambrian) is at the surface.

From five to ten miles to the west in the area under discussion the sequence is as follows:

Surficial deposits: Alluvial Gravel and Boulder Clay.

Hay River-Simpson: Shale group.

Spence River: Shale.

Slave Point: Appears to be an off-reef facies of the Presqu'ile. A tight grey limestone with some local lenses of bituminous shale and sandstone.

Breccia-green shale: Dolomite and/or anhydrite breccia with one or more thin beds of green, waxy shale, occasionally pyoritic. Possibly correlates with the bituminous shales of the Fort Creek formation which is part of the producing zone at Norman Wells.

Presqu'ile: Middle Devonian: is a reef dolomite, fine grained to coarsely recrystallized, white to brown, vuggy with calcite crystals in the vugs, brecciated and often

fossiliferous throughout.

Pine Point: Formation of dense grey limestone and shale underlying the Presqu'ile.

Evaporite: Includes anhydrite with some interbedded dolimite and shale.

Red Beds: Variable from red dolomite shale to red shaley dolomite, red anhydrite and silty shale.

Development to Date

Imperial Oil drilled Imperial N.W.T. Windy Point # 1 on the west shore of the lake in 1920, suspended it, and the next year deepened the well to the Precambrian. The well was not adequately tested and was abandoned in 1921. The Presqu'ile appears as a contact just below the surface but the section was tight.

A mining company drilled and cored, and outlined in some detail the Presqu'ile Dolomite reef in an extensive development program during the Spring and Summer of 1956.

Cores and core descriptions of the sections recovered in one hundred and sixteen (116) holes, ranging in depth from 50 feet to 705 feet, have been examined and described in detail. (The core was examined on the lease where it has been abandoned.) Recovery by diamond coring was excellent - usually 100%. One typical core description is enclosed. Sporadic showings of lead and zinc (galena blobs) were observed but in the absence of commercial mineralization the project was abandoned. (Note: This reef lies on regional strike with the Pine Point lead deposit, some forty miles to the south and east, which

is considered to be the largest lead/zinc reserve in the world.)

Oil stained dolomitic reef sections in excess of 160 feet were recovered.

Reserves

An isopach using very conservative values of Net Pay was constructed. The oil in place was calculated on the basis of the coring, which covered a complete north-south cross section and seven east-west sections. Holes were usually 1000 feet apart with some local 100 ft. step-outs.

A value of 40% was used for connate water but a value ranging from 10% to 15% is more probable for this vuggy section.

A proven area of some 56 square miles averaging 55 feet in net thickness has been established giving an oil in place of 620 million barrels.

Absence of any significant pressure has not been established but only assumed in view of the shallow nature of the reef and the close proximity to the outcrop.

A minimum recovery factor of 5% would indicate a recoverable reserve of 31 million barrels. However, localized water injection and close spacing re-pressurization could raise this figure into the 40% to 50% range.

The section has never been acidized. The holes were drilled with native, high water-loss muds which would tend to block the effective

permeability, but both oil and gas flows were reported as delaying the development on numerous occasions.

Initial Program

A tentative, preliminary coring program has been suggested in order to establish the following:

1) Obtain a maximum reef section of fresh core for full core analysis, oil and water saturations, and possibly Kg/Ko and Kw/Ko determinations. Coring of some of the section with oil based mud in an effort to establish residual water saturation should be attempted. Treatment with retarded acid may show that considerable residual reservoir pressure still remains at some distance away from the bore hole, and primary recovery on pump is worth while.

2) A close pattern (5-acre) five-spot pilot water flood could be carried out with a minimum of expenditure. A surface line from a local slough or from one of the many small lakes would suffice for the initial water supply.

3) "In situ" Combustion should be considered, particularly if the residual water content is high i.e. in the 30% to 40% range. This may be possible, due to some invasion in local areas by surface waters.

4) A reduced scale pilot water flood employing, on an experimental basis, a small quantity of liquid with favourable viscosity (e.g. a slug of diesel oil) should be tested. If the residual oil has an unfavourable viscosity ratio as compared with cold water (due to low formation temperature and low solution gas) bottom hole heaters may be required in order to achieve maximum recovery. Gas is available in the area and a hot water flood may prove more efficient. Injection of a "miscible slug" would be very advantageous in improving the fractional flow characteristics of the reservoir.

Any or all of the above preliminary production tests can be carried out at the minimum of cost due to the shallow depth of the producing horizon.

Note on the Western Permit in the Fort Providence Area

An outline on the drilling history of the capped gas well, North West Territories # 1, is enclosed. This well was taken down to a total depth of 1678 feet in July 1951 and found the Slave Point at 1315 feet. No reef was identified apparently. The gas flow originated in the Spence River and/or Slave Point but the reported contacts may be open to question as little drilling has been done in the area and correct identification of these formations is difficult. Some authorities consider this to be the productive section at Norman Wells. This permit lies on strike with

the Norman Wells* Reservoir.

A wildcat program in this area, which again is easily accessible, is definitely indicated. The so-called Upper Devonian should be cored and tested - preferably acidized, and coring of the Middle Devonian section, to be found from about 1500 to 1600 feet from the surface, should be carried out.

* NOTE:

Norman Wells: Proved Recoverable Reserve of 63 million barrels based on 25% Recovery Factor. The factor used is conservative for this type of reservoir due to the fact that two thirds of the productive area lies beneath the MacKenzie River and will not be drilled. (ref. Imperial Oil.)

ENGINEERING EXPERIMENT STATION

UNIVERSITY OF UTAH

18 December 1956

Results of Tests on Great Slave Lake Crude: Weathered Sample

1. Atmospheric Distrillation (packed column) Pressure: 645 mm Hg

Percentage distilled	Temperature (deg. Centigrade)	
0	91)	(Initial boiling point)
10	246)	Natural gasoline - almost
20	277)	good enough to use straight
30	300)	
40	318)	Kerosene
45	326)	

Above 326 degrees Centigrade (temperature of top of column) cracking reactions occured and from 45 to 80 percent fraction of the crude was readily obtained as cracked products with a boiling range of 275 to 325 degrees centigrade. By separating these fractions additional gasoline can be produced. About 20% is residual and sets up like road tar.

11. Percentage Sulfur

Fraction tested: 10 - 20% (boiling range, 246 - 277° C.)

Sulfur, percent: 0.4 (Most of sulfur probably remains in residue)

111. Gravity of Crude

Degrees API, 18 Specific Gravity 0.94

IV. Sulfuric Acid Extraction

Fraction	Percentage removed by acid	
10-20%	6.4	Nitrogenous and sulphurous compounds
40-50%	22	which must be removed
5-10%	3.5	

Operator, Donald D. Woolley.

REPORT OF OIL RECOVERY IN GREAT SLAVE LAKE AREA

Reference: Department of Northern Affairs and Natural Resources:
Schedule of Wells, June 1955.

Well: Punch Deep Bay Test #3.

Location: Lat. 61° 22' 30" N.
Long. 116° 52' W.

Drilled: May 16, 1952 to June 9, 1952.

Test: (1082' - 1083') Small flow of oil.

Oil Analysis. Division of Fuels, Ottawa.

Colour: Blackish Brown

Gravity: 32.8° API

Pour Point: 50°F

Viscosity: 93 secs at 70° F (= 18 centipoise)
57 secs at 100°F (= 9 centipoise)

Contacts: Spirit River: 780 feet
Slave Point: 830 feet
Presqu'ile Dolomite: not identified
Total Depth: 1327 feet

CORE ANALYSIS

PRESQU'ILE DOLOMITE: GREAT SLAVE LAKE AREA

COPY Chemical & Geological Laboratories Ltd., Edmonton Oct. 26, 1957

Lab. No.: E10684

Sample Number	Midpoint of Sample in feet	Permeability md. Vertical	Permeability md. Radial	Porosity Percent	Description
D_2	100	1344	1000+	18.6	CVIS
E_{23}	46	(a)	290	15.8	CVIS
F_4	138	1321	1000+	24.9	CVIS
F_1	50	2.6	146	11.1	CSVIS
W_{19}	163	131	1000+	6.3	CSVIS

Core Description Symbols:

C:	Cracks
V:	Vuggy
I:	Intergranular
S:	Stained
SV:	Slightly vuggy
(a):	Unsuitable for test

DESCRIPTION: TYPICAL CORED SECTION

DIAMOND DRILL RECORD

PROPERTY:

HOLE NO.: W-9

DIP: -90°

SHEET NO.: 1

LOCATION: 1000' West W-3

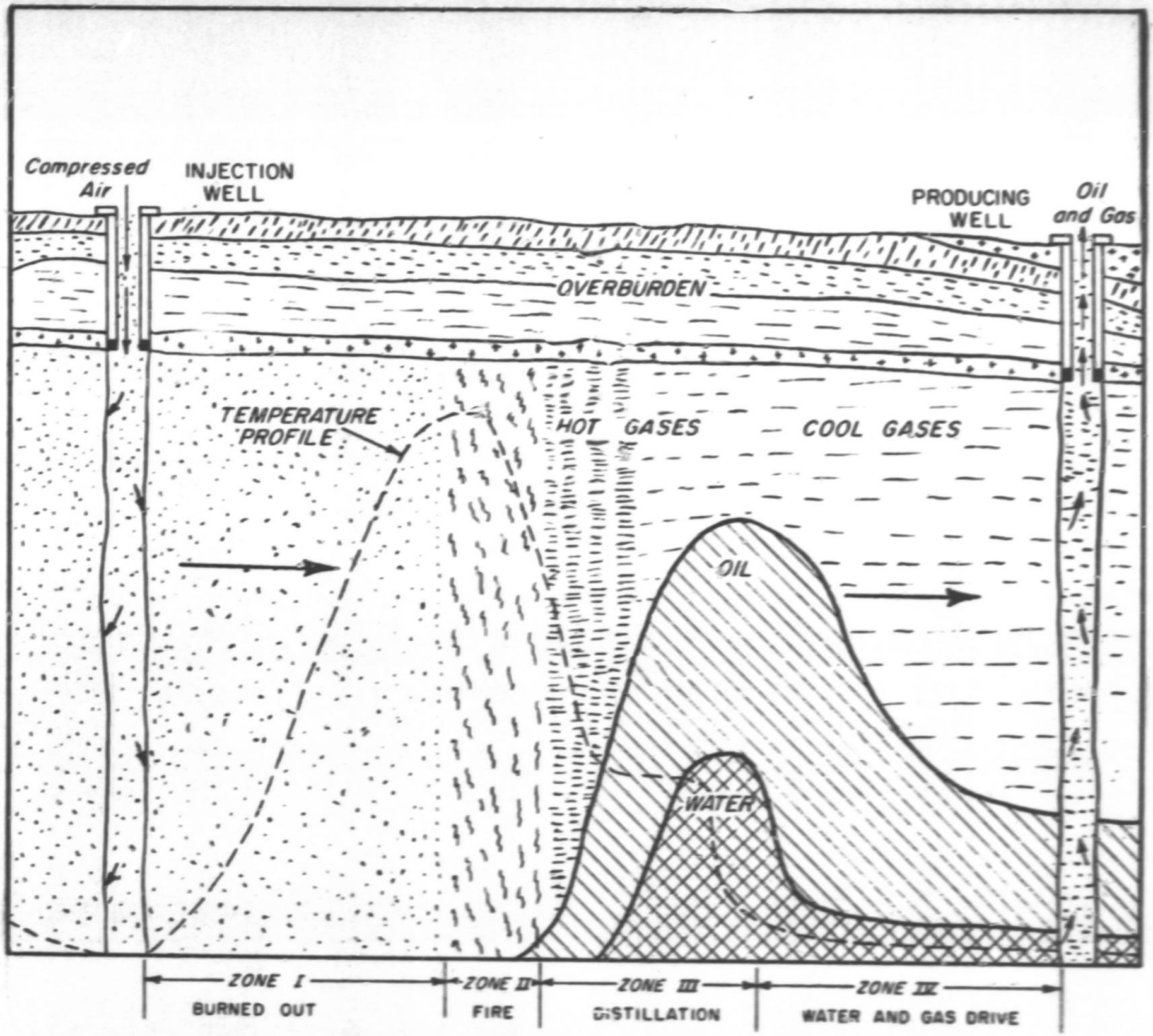
STARTED: July 24, 1956

COMPLETED: July 26, 1956

DEPTH OF HOLE: 204'

Interval	Contact	Core Description
0 - 7'		Bedrock 4, Casing 7
8 - 28'	Slave Point	Limestone, greyish, slightly fossiliferous
28 - 72'	Presqu'ile	Dolomite, alternating, white coarsely recrystallized and brown fine grained, vuggy throughout, slightly oil stained and containing curved crystals of dolomite in vugs.
73 - 112'		Dolomite, white coarsely recrystallized, heavily stained with oil, bleeding in places, vuggy and containing curved crystals of dolomite in vugs.
112 - 149'		Dolomite, brown, fine grained, heavily oil stained at beginning of section, vuggy and containing crystals of calcite in vugs, some pyrobitumene observed
149 - 155'		Dolomite, white, coarsely recrystallized, heavily oil stained.
155 - 160'		Dolomite, brown fine grained, vuggy, slightly oil stained.
160 - 164'		Dolomite, brown, fine grained, slightly vuggy.
164 - 169'	Pine Point	Limestone, light brown, heavily fossiliferous and containing rounded to oblong fossils throughout.
169 - 182'		Limestone, alternating banks of fine grained brown dolomite and light brown limestone (heavily fossiliferous).
182 - 204'		Limestone, alternating light brown to dense black, fine grained, slightly fossiliferous.

END OF HOLE W-9 at 204'. Recovery: 97.7%



RECOVERY OF OIL BY HEAT FROM IN SITU COMBUSTION

1. Burned Out Zone - Incoming air is preheated by hot rock left by the combustion front which has just passed. There is no oil left, not even carbon.

2. Burning Zone - Area of actual burning may only be a few inches thick (600 to 1,200° F) never reaching the fusion temperature of the rock. Fuel is coke or carbon remaining from cracking and distillation of oil in zone just ahead. More fuel may be added by injecting gas. In a well-saturated reservoir as little as 10 per cent of the reservoir crude would be consumed as fuel.

3. Distillation Zone - Action of hot gases from Zone 2 induces cracking, distillation and condensation. Oil and water are moving partly by distillation and partly by flow. Both are driven by non-condensable gases such as N_2, CO_2, CO, and O_2. It is believed by some that the hot water bank (hot water flood) is a very important factor in the recovery mechanism.

4. Water and Gas-Drive Zone - Near original reservoir temperature where non-condensable gases push fluids ahead by gas drive.

PROJECT # T (1)

Operation	Time	Estimated Cost

Stage I Stratigraphic Test

1. Move in Core Hole Rig on Location.

2. Drill 5" hole to feet using Native mud.

3. Cement 4" Surface Casing.

4. Core to feet with native mud and aquagel.

5. Circulate out mud and displace with diesel fuel.

6. Cut 10 foot core with oil.

7. Displace oil with mud.

8. Core to feet.

9. Lay out full cored section and photograph. Log core by description.

10. Omit 10 foot oil base core. Pack this section in polyethylene bags, as pulled, and ship to Laboratory for water saturation analysis.

11. Box core in 3 foot boxes and label carefully.

12. Select samples at 5 foot intervals for analysis to give an average sampling of the entire section. Wrap these samples in individual polyethylene bags, label carefully and ship to Chemical and Geological Laboratories, Edmonton, for analysis.

13. Displace mud in hole with water.

14. Acidize with 500 gallons of inhibited, retarded, Hydrochloric Acid.

	Time	Estimated Cost
15. Flow back to pit to clean up.		
16. Produce into tank for guaging production rate. Check gravity and water cut. Can three - 1 gallon samples and ship to Chemical and Geological Laboratories, Edmonton, for analysis.		

Stage II Pilot Water Flood - Five Acres

1. Move rig to pattern locations.

2. Drill "five-spot" water injection pattern plus one internal control well. (five holes)

3. Inject water in "five-spot" pattern. Check pressures, production and "cuts" to evaluate pilot pattern.

4. Modify pattern by using a *miscible slug followed by water.

Note *If suitable propane/butane mixture is not available at economic rates a slug of light oil e.g. deisel oil should be employed.

Stage III Improved Recovery Techniques

(a) Bottom Hole Heater.

(b) In Situ Combustion.

Study of both of the above techniques should be carried out. Basic data should be forwarded to a qualified commercial laboratory for evaluation but a practical field pilot test could be originated at reasonable cost in view of the shallow nature of the producing horizon.

NOTES ON OUTLINE OF POSSIBLE EXPANSION AND DEVELOPMENT

Phase I — Dec 19/58 - Dec 19/59 (12 months)

a. Preliminary Evaluation with Primary Recovery techniques.

b. Pilot Waterflood.

c. Further exploratory Drilling and Farmouts.

Phase II — Dec 19/59 - May 19/60 (6 months)

a. Consideration of Land Values. Leasing?

b. Farmout of Interest for development.

c. Consideration of Alternate Recovery Methods.

Phase III — May 19/60 - May 19/61 (12 months)

a. Go to Lease.

b. Go to full scale production.

c. Acquire further land spread.

d. Set up exploration program on west block.

e. Consider expanded outlets - pipeline - river barge and tanker outlet - possible overseas markets: Japan? Europe?

f. Local refining prospects. "Dew Line" requirements.

The above outline is highly tentative. The vigorous exploration activity and development that is now going on would suggest that the whole timetable will be accelerated. Two Shell rigs are operating in the Rabbit Lake Area, (35 miles South) where proven gas reserves have already been established.

NOTES ON COMPLETION OF NORTH WEST TERRITORIES # 1

REFERENCE: Department of Northern Affairs and Natural Resources.

Schedule of Wells. June 1955

WELL: North West Territories # 1

LOCATION: Latitude 61° 20' 40" N
Longitude 117° 37' W
1½ miles S. E. of Fort Providence

ELEVATION: 492 feet

DRILLED: July 7, 1951

SUSPENDED: July 30, 1951 at 1678 feet

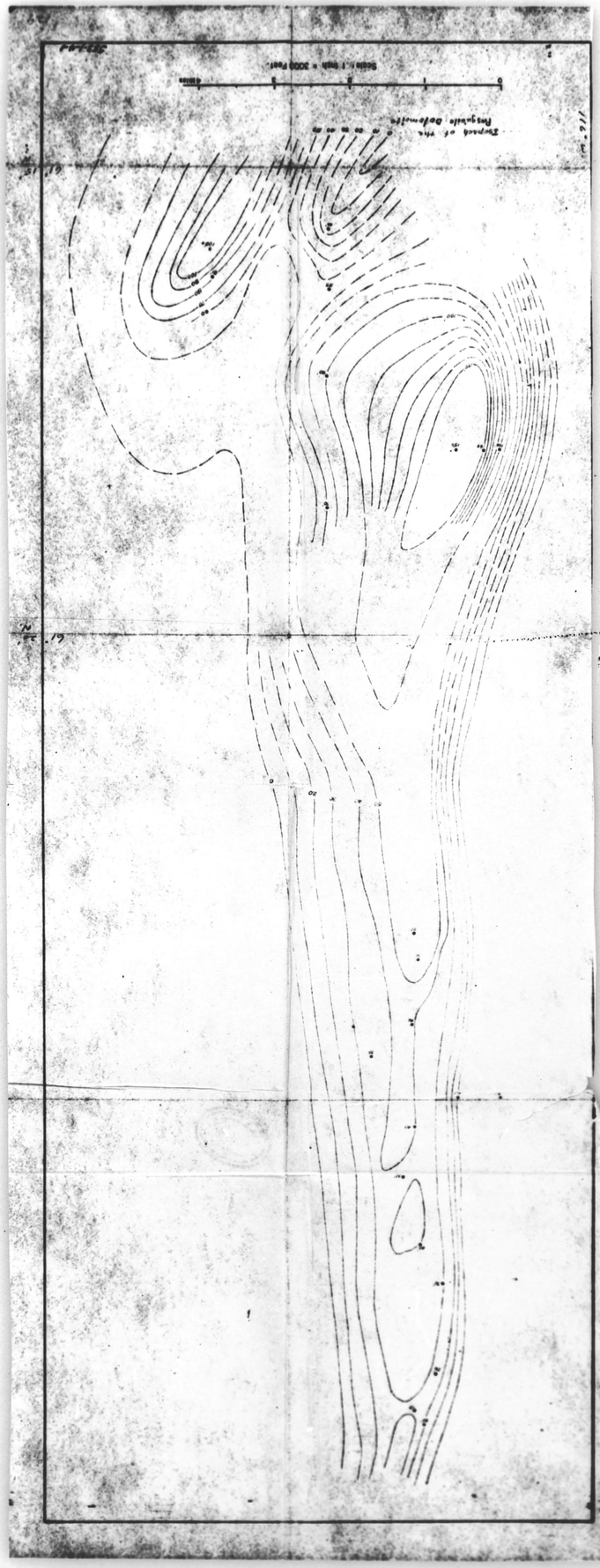
CASING: 7" at 307 feet. Cemented with 125 sacks.

TEST: (1068-1597') 450' of water cut gassy mud, sweet gas flow estimated at 40 Mcf per day

STATUS: Left capped as a potential gas well

Contacts

Hay River - Simpson	175'
Spence River	1180'
Slave Point	1315'
Breccia - green shale	1555'
Presqu'ile	Not identified
Red Beds	1640'
Total Depth	1678'


Scale: 1 inch = 3000 Feet.
Equivalent Deformation