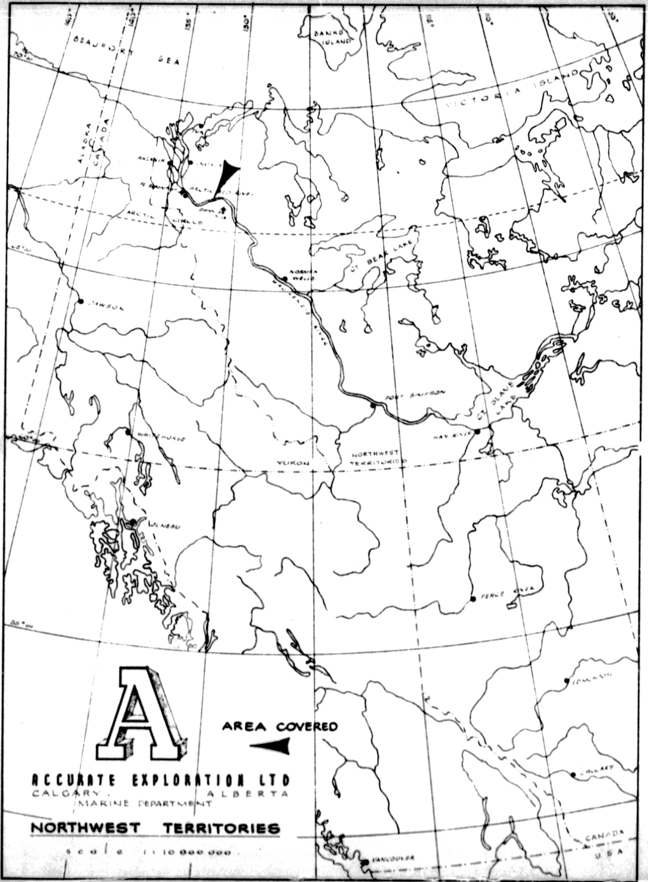
# MARINE SEISMIC SURVEY
# IN THE
# MACKENZIE RIVER AREA
# OF THE
# NORTHWEST TERRITORIES

FOR

RICHFIELD OIL CORPORATION

ACCURATE EXPLORATION LTD.
April, 1961


BEAUFORT SEA
BANKS ISLAND
VICTORIA ISLAND
ALASKA
CANADA
AKLAVIK
ARCTIC RED RIVER
ARCTIC CIRCLE
NORMAN WELLS
GT BEAR LAKE
DAWSON
FORT SIMPSON
GT SLAVE LAKE
HAY RIVER
WHITEHORSE
YUKON
NORTHWEST TERRITORIES
JUNEAU
PEACE RIVER
CALGARY
VANCOUVER
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AREA COVERED
ACCURATE EXPLORATION LTD
CALGARY, ALBERTA
MARINE DEPARTMENT
NORTHWEST TERRITORIES
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# INDEX

## INTRODUCTION

A marine seismograph survey was carried out in the Mackenzie River in the Northwest Territories of Canada during the summer of 1961. This report includes an interpretation of 20 miles of seismic data recorded between Longitude 132° 00' W and 131° 15' W and between Latitude 66° 20' N and 67° 30' N.

A total of 179 locations were shot in this area.

The field work was carried out between July 12 and July 15, 1960 by Accurate Exploration Ltd., Party 206.

The crew operated under Northwest and Yukon Territories Oil and Gas Exploratory License No. 499. Permission to do the required work was obtained from the Federal Government.

OBJECT

The object of the survey was to obtain general subsurface reconnaissance data and to locate structures, reefs, faulting, and stratigraphic features which may be present in the area. The survey was carried out across an area for which only scanty subsurface data exists.

## CONCLUSIONS AND RECOMMENDATIONS

A number of minor structural folds were found superimposed on moderately northwest dipping beds. Frequent indications of faulting were found, which, in a number of cases, are confirmed by surface mapping.

A rather abrupt divergence westward of the reflecting horizons west of Shot Point 1244 is postulated as being possibly indicative of reef development within shales of the Upper Devonian Fort Creek formation. The top of this anomaly appears to lie approximately 1650 feet below the surface near Shot Point 1242, which appears to be the most favourable location.

Control defining the feature is limited, and a seismic refraction line, either land or marine, is suggested as a method to obtain better control.

Respectfully submitted,
ACCURATE EXPLORATION LTD.

R. G. Lindseth,
Seismologist.

A. E. Pallister, P.Geoph.

## GEOLOGICAL CONSIDERATIONS

Eroded beds of Upper Devonian age outcrop along the river over the length of this survey. Approximately 60 miles northwest, at the entry into the Mackenzie Delta, the Upper Devonian consists of 2,700 feet of shales of the Fort Creek formation, overlain by roughly 2,500 feet of sands and shales of the Imperial formation. These beds rise rapidly southeastward, and thin considerably due to erosion. In the Grandview Hills No. 1 Well, located south of this survey (see Index Map), the entire Imperial formation is missing and only 1,550 feet of the Fort Creek remain.

Well log correlation between the Grandview Hills and the Point Separation Wells indicates a drop of the Ramparts and older beds from Grandview Hills towards Point Separation of roughly 3,600 feet, or 0.420 seconds in reflection time, which, when corrected for elevation difference between these wells, represents an absolute drop of some 4800 feet, or 0.635 seconds in return travel time. Southeastward 120 miles, in the Norman Wells Area, over 1,600 feet of Fort Creek has been found to underlie the Imperial. The Fort Creek formation assumes considerable economic importance in the Norman Wells Area, as the production obtained there is from a reef built on a limestone bed occurring within the Lower Fort Creek shales.

Slightly east of Longitude 131° W, the Mackenzie River courses in a more northerly direction. Upstream from this bend, the Ramparts formation of Middle Devonian age is reported to outcrop and is found along the river south to a point beyond Fort Good Hope. The exposed formation at the outcrop is reported as Middle Ramparts shale, with the Upper Ramparts limestone member occurring farther south.

Beneath the Ramparts is slightly less than 1,000 feet of the Lone Mountain (Bear Rock) formation of Lower Devonian or Silurian age. The formation consists of highly porous brecciated dolomites and limestones. The Lone Mountain, in turn, is underlain by a substantial thickness (likely several thousand feet) of older beds.

A number of major faults form a quadrangular grid over the area, and these and numerous smaller faults may be mapped by surface work. It appears that the Mackenzie River may often follow a fault trace, or is at least influenced in its course by faulting. The river flows along the foot of the Mackenzie Mountains over much of its course, and hence seismic studies of the subsurface may be expected to find the effects of the considerable tectonic activity associated with the Mackenzie orogeny.

Good production of petroleum has been found in the Upper Devonian reef at Norman Wells, but results to date in other wells drilled into reefs and anticlinal structures in the area surrounding the field have not obtained production. Reef limestones of the same age as the Norman Wells reef were found in wells at Seepage Lake, Mac No. 1, Bay No. 1, Raider Island, Judile, Morrow Creek and Hoosier Ridge. All of these tests were drilled within a radius of 50 miles of Norman Wells. Although some shows were found, lack of porosity precluded production in some cases, while water was found in other tests. The two wells at Grandview Hills and Point Separation encountered no reef.

## DISCUSSION OF DATA

### SEISMIC DATA

The seismic data obtained from the survey are rather sparse often and intermittent. Where information was obtained, it was often of fair to good quality but the data came chiefly from the relatively shallow part of the section above 3,000 foot depth. Considerable experimentation with charge size, cable depth and noise elimination was tried in an effort to improve quality, without substantial improvement. The same instruments and shooting procedure, operating in the Norman Wells area before and after this survey, obtained excellent reflections, including an excellent exposition of productive reef of the Norman Wells field.

The section at Norman Wells consists of largely the same or equivalent horizons as expected over the length of this survey. Hence, it would appear that the difference in results is due to some basic difference within the section, perhaps a lateral lithologic change, or to structural disturbances.

A surface fault map, provided by Richfield Oil Corporation, indicates a number of locations along the river where surface faulting may be correlated to the breaks in seismic data. No certain seismic correlations across faults have been made. The hade of the faulting appearing on the seismic sections would indicate reversed faulting. In some instances it appears that normal faulting may occur, with displacement thrown down to the northwest.

# MAP DISCUSSION AND INTERPRETATION

## INTRODUCTION

In making the interpretation, records were inspected and any apparently legitimate reflections picked. A shallow group of reflectors was found to appear intermittently, and, occasionally, deeper horizons were found roughly 0.200 seconds and 0.500 seconds after the upper reflections. Seismic sections in variable density presentation were made for the entire survey and "wiggly trace" presentation for many of the lines.

Where reflecting horizons exist, mapping has been based on a continuous horizon within the upper group of reflectors, and values for the mapping horizon have been placed on the maps. The horizon was carried within the upper group of reflectors, rather than on top, as the top two reflectors were found to be quite variable in quality and were often lost in the seismic noise immediately following the first breaks. It is quite possible that the correlations of the mapping horizon may not always represent the same reflector within the group. The group of reflectors is thought to represent a series of horizons extending from the Lower Fort Creek to the Lone Mountain. The reflector used for mapping may correspond to a Lower Fort Creek horizon or perhaps to the top of the Ramparts formation.

After mapping the more prominent reflectors, the variable density sections were examined for indications of other possible continuous events. Where a reasonable segment of dip appeared, it was used to obtain the rate of dip, and from this, form lines were drawn on the maps to aid in visualization of structure. Where form lines alone appear, without values, they are based on dips taken from apparent dip segments found on the variable density sections near the estimated depth of horizon. The form lines represent the same relative rates of dip as do the contour lines for the horizons, but of course provide no absolute depth measurements and are often broken by broad gaps of no data. For ease of illustration, contours and form lines considered to be of equal value were joined. The group of reflectors drops steadily in the section westward, although strong dip is not indicated. Hence, a fair amount of downstream dip may exist in the areas of no data, or faulting may play a part in the lowering of the section. The seismic events usually terminate rather abruptly, as though faulted, and the intervening portions of line often contain indications of erratic dips, diffracted and refracted events which all may be indicative of faulting.

The map is based on fairly reliable information separated by breaks of poor data. Reflections recorded were generally of fair quality and occasionally reached a depth of 0.8 seconds reflection time. No certain identification has been made of the deepest horizon, but it may be expected to lie near the Cambrian or Pre-Cambrian.

The numerous breaks in continuity of data may be due to faulting. In some cases, indications of faulting are substantiated by a fault located on surface geology, which, if projected, hits the seismic line at the point of cessation of reflections.

The eastern half of Line 28 is devoid of reflections, which may be attributed to the influence of a mapped surface fault. Fair reflections are recorded from the shallow horizons over the western half of the line, indicating slightly undulating beds with net east dip of approximately 0.030 seconds, or 150 feet.

Line 27 recorded no reflections, although the downstream end of the variable density section appears to have some evidence of weak continuity with flat dip.

Perhaps the best line of profile, and certainly the most interesting feature of the entire survey, was recorded on Line 26. Fairly good reflections from the shallow group were recorded over the length of the line, and a few deeper reflections were obtained.

Contouring of the horizon used for mapping outlines a broad overturn of little vertical relief. Inspection of the reflecting group reveals a lensing effect over the central part of the line, in which the reflecting group appears to thicken suddenly westward. This may be indicative of a reef and should by all means be verified by additional work. The relatively thin cover and convenient location along the river shore make the economic considerations particularly attractive for a drilling test.

The abrupt termination of the horizon at both ends of the line has again been assumed to signify the presence of faulting.

The reflection data on Line 25 have passed the peak in quality reached farther upstream. The reflected events recorded downstream of Line 26 are of inferior quality and occur much less frequently.

Fairly definite west dip component is recorded on Line 25 east of Longitude 131° 45', but west of this point a small number of relatively fair reflections indicate dip reversal, so that a well-defined trough is suggested between the two fairly well delineated slopes. Continuing westward is a long stretch of rather unreliable information, which if anything, appears to be flat. A few rather weak reflectors at Shot Points 1149 to 1150 serve to help locate the horizon in the section at this point and indicate slight east dip.

A fault situation, similar to that mentioned previously, exists here, where a fault on the surface may be projected into a zone of no energy return on the records.

Most of Line 24 is of such poor quality that, if faulting controls reflection quality, the line may be suspect of a fault running the length of its eastern portion. A few suggested continuities on the variable density section indicate very gentle downstream dip over most of the line.

## REEF STUDIES

The presence of a reef body within the Fort Creek shales is postulated on Line 26. The reef edge appears to lie under Shot Point 1245, with the body of the reef lying west of this point.

Evidence for the postulated possible reef is based entirely on this line. Primary evidence is found at Shot Point 1244, where the reflection group abruptly diverges to admit an additional reflecting horizon. Supporting evidence is supplied by the continued divergence of the reflectors westward. A total of approximately .025 seconds of divergence is obtained, equal to approximately 150 feet of drape or increased thickness of the section. The greater portion of this amount, roughly 120 feet, occurs near the postulated reef edge at Shot Point 1245.

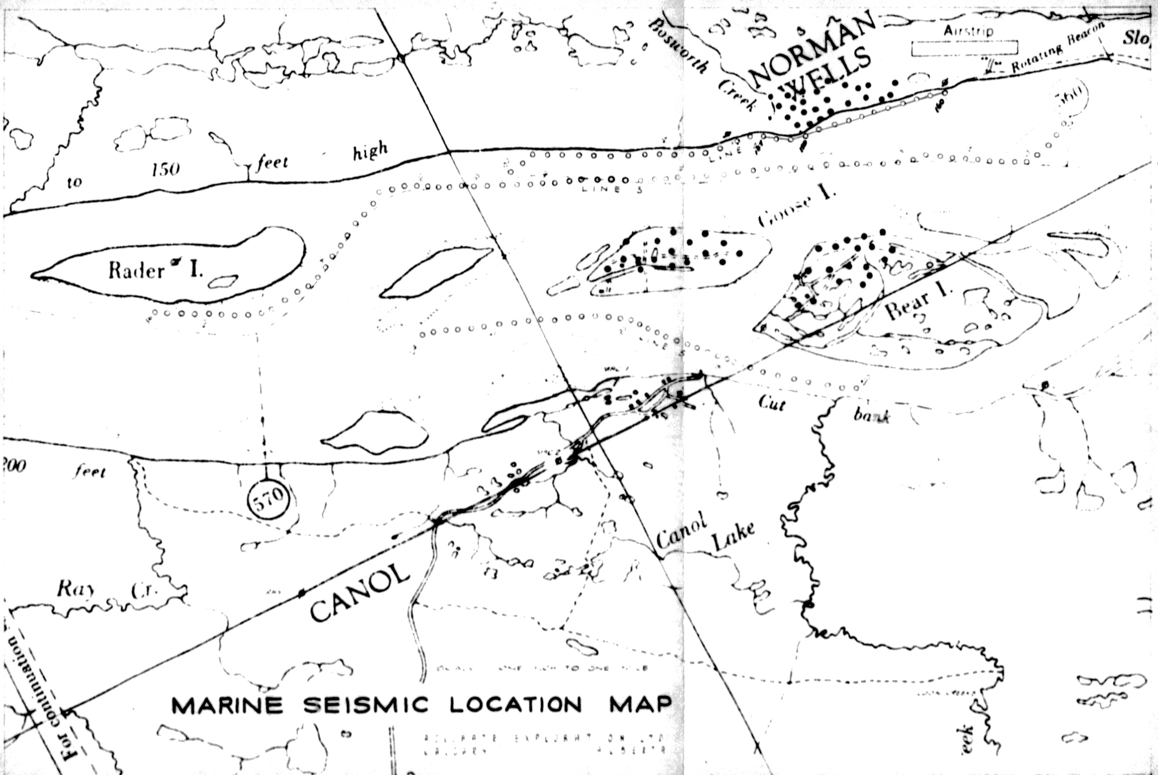
Evidence for this reef is meagre. In the absence of a number of continuous reflectors, the "standard" reef detection methods of isochron thinning and mapping of drape of the overlying beds can not be used. The only indication found here is the direct evidence of abrupt thickening of the group of reflectors associated with the mapping horizon.

At Norman Wells, no other evidence than direct reflection mapping is needed to elegantly define the reef. (See following insert).

To obtain optimum benefit of the present data, seismic playback work, in addition to the seismic playback sections supplied as part of this survey, has been done on a new recently obtained MagneTrace playback machine of the latest model. A high action normal move-out cam has been used, together with effective instrument control over the very early part of the record. The effect of this has been to practically eliminate the first arrival pattern and improve shallow reflection data.

No corrections have been applied except the normal move-out dynamic correction and the shot point datum static correction.

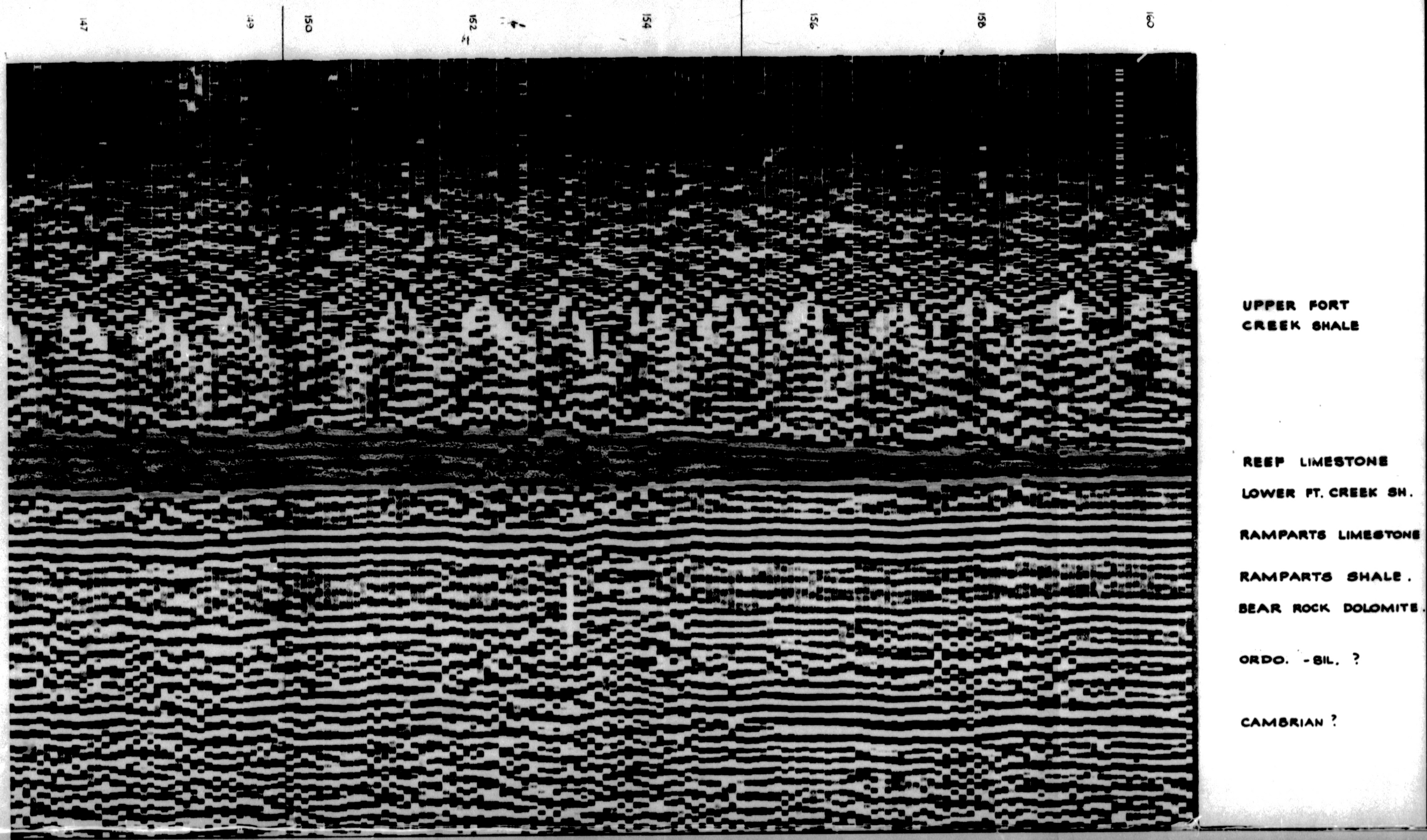
Results of this work may be seen on the enclosed Magnesection of Line 26.




MARINE SEISMIC LOCATION MAP

DRAWING NO. 163 - 12

NORMAN WELLS FIELD LINE 4.



The reef at Norman Wells is built upon a limestone member occurring within the lower Fort Creek shales. It appears that this limestone base is relatively local in nature[1] rather than the type of broad platform found in the Alberta plains, and may vary in thickness from 0 to 160 feet. In searching for reef developments similar to Norman Wells, it may be a prerequisite to locate the limestone base member first. This in turn may be related to the quality of reflection data, as the limestone member should provide a good reflecting horizon.

It is suggested that an excellent aid in the search for limestone beds and reef bodies in the Grandview Hills area would be refraction profiling. The relatively shallow depths, the favourable stratigraphic and velocity sequence and the relatively simple logistical requirements, favour successful use of this method.

Reflection shooting obtains reef indications by measuring the effects of the relatively high velocity contrast between the vertical section of the reef and the surrounding shales. The refraction method would measure, in some cases, the effects longitudinally across the reef, providing a much greater comparative section.

Synthesis of the refraction time travel paths indicates relatively short profiles would be required. These would be on the order of one to five miles in length in the Grandview Hills area, depending on depth of the mapping horizon. The spreads could be laid out in any convenient location, need not be continuous, and could cover considerable area with minimum cost.

As an added dividend, the shooting could be arranged to provide reliable determination of the amount of displacement of faulting crossed.

Suggested procedure for reconnaissance is as follows: an initial reversed refraction profile would be shot to determine accurately the existing velocity contrasts and the length of profile required. This should be done in an uncomplicated portion of the area, preferably where the limestone member of the Fort Creek formation is absent. A travel-time/distance relation would be established to permit refracted energy to be obtained from the Ramparts Limestone. Fan or line profiles could then be laid out at distances within the established range.

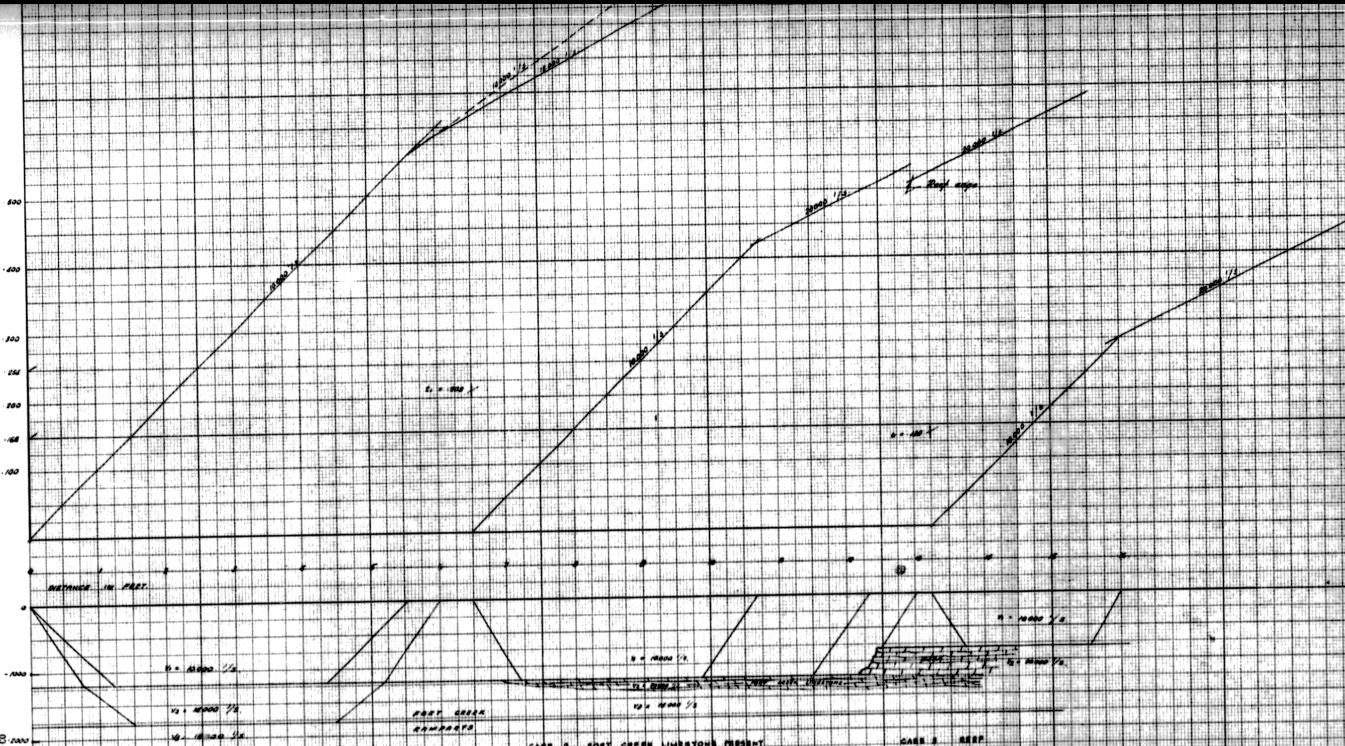
The presence of a limestone member above the Ramparts would cause an abrupt decrease in the travel time.

Where the limestone member is present it would be mapped by shooting continuous uni-directional refraction profile, with occasional reversed shots to control regional velocity variations. The presence of bioherms would appear as an abrupt drop of the time travel curve, in much the same manner as a fault, with displacement equal to the thickness of the reef. True faulting could be distinguished by its effects on another horizon.

A further advantage with the refraction method would be a fairly positive location of the reef edge.

This method is suggested as verification of the postulated reef on Line 26. One short line shot across the apparent reef edge should supply a reliable solution. Hypothetical refraction curves are shown in Fig. 2.

(1) "The Lower Mackenzie River Area, Northwest Territories and Yukon", by G. S. Hume - GEOLOGICAL SURVEY OF CANADA, p. 93.




PROJECT No. 206-518 APRIL 1961

HYPOTHETICAL TIME-DISTANCE CURVES.
REFRACTION SHOOTING FOR REEFS.
GRANDVIEW HILLS

**MACKENZIE RIVER AREA.**

Interpretation by R. O. Lindsay
Richfield Exploration Ltd. Calgary

FIG. 2.

VELOCITY DATA

Continuous velocity logs in both the Point Separation and the Grandview Hills Wells provided excellent data of considerable value in the interpretation.

Good correlations of log character and velocities exist between the two wells in the Ramparts and deeper section. The shallower section differs somewhat, and the points of difference provide the basis for some speculation on the reasons for the variation.

Both wells indicate, velocity-wise, a very laminate section in beds of the Upper Devonian, containing very thin lenticular beds, having extreme variations in velocity. In both surveys the integration curve of the velocity log tended to deviate somewhat from the check shots while logging this section, probably due to the erratic changes in velocity. The condition was somewhat accentuated in the Point Separation Well.

Seismic velocities in the Ramparts and deeper sections may be correlated closely between the two wells. Shallower beds may not be correlated so well. A very weak correlation of the velocity logs suggests the section from 1960 feet to 2490 feet (Imperial and Upper Fort Creek) in the Point Separation Well may be similar to the section from 1340 feet to 1567 feet (Lower Fort Creek) in the Grandview Hills Well.

The inconsistencies of the velocity log correlations suggest some difference may exist in the nature of the Fort Creek section between Point Separation and Grandview Hills.

# APPENDIX "A"

## COMPUTING

Records were computed using a datum velocity of 9,000 feet per second and a datum of sea level. The depth of water was corrected at 5,000 feet per second and the remainder of the computation was made using the standard correction to datum.

| | | | | |
|---|---|---|---|---|
| Em | = | elevation of water | | |
| Ds | = | depth of shot | | |
| Es | = | elevation of shot | | |
| Dw | = | depth of water | | |
| Vd | = | velocity to datum | = | 9,000'/" |
| Vw | = | velocity of water | = | 5,000'/" |
| Dd | = | distance to datum | | |
| Ed | = | elevation of datum | | |
| $EV_2$ | = | elevation of river bed | | |
| td | = | correction to datum | | |

eg.

$$Em - Ds = Es$$

$$Em - Dw = EV_2$$

$$EV_2 - Ed = Dd$$

$$td = \frac{EV_2 - Ed}{Vd} + \frac{Es - EV_2}{Vw}$$

# APPENDIX "B"

## AREA

The project area was located between Longitudes 131° 15' W and 132° W and Latitudes 67° 20' N and 67° 30' N. All the work was done on the surface of the Mackenzie River.

The operational headquarters for the operation was located on the housing boat which followed the recording and shooting boats during the survey. Inuvik was used as a basing port for supplies and repairs.

# APPENDIX "C"

## SURVEYING

The course of the boat and shot locations were plotted by the surveyor on hydrographic charts by the use of a sextant. Vertical control was obtained from bench marks established along the Mackenzie River.

In addition to the above, a short range radar set with a special polaroid camera attachment was used. At each shot location and at the time the shot was fired, a picture was taken of the radar screen. By use of a slide projector, these pictures were superimposed on a base map to obtain the exact location of each shot point and to obtain a check of the locations as plotted by the surveyor on the hydrographic charts.

## APPENDIX "D"

**RECORDING**

Recording instruments used were a set of Carter type FR1 with a magnetic tape system. A line filter and preamplifier were used between the geophone cable and the instruments.

The cable used was a 12-trace Vector oil-filled Bay cable and was floated near the surface. The total length of the cable was 1442 feet, with a gap of 131 feet across the center and six geophone stations at intervals of 100 feet on each side of the center. Geophones used were Electro-Tech EVP-1 pressure geophones of 4 dual phones per trace, distrib-uted uniformly over a surface coverage of 100 feet.

Explosives used were Nitrone 5-1 packed in 1-pound cans, Nitrone 5-M packed in 16 2/3-pound cans and Nitrone primer packed in 1-pound cans. The charges were fired with the aid of boosters and seismic caps. The optimum charge used in most cases was 16 2/3 pounds at a depth of about 5 feet.

Depth of water varied, with the average depth being about 35 feet. River current over most of the area was from 3 to 4 miles per hour.

# APPENDIX "E"

## RECORD DISCUSSION

Record quality over most of the area was poor. Due to the poor quality of the records, it was not possible to record correlative events from the sub-surface formations from the monitored records. To identify dips and possible faul's, it was necessary to obtain variable density play-back sections.

# APPENDIX "F"

## RECORD CROSS SECTIONS

Corrected record cross sections were obtained by re-playing the magnetic tapes on a MagneTrace Model 602 playback machine. The normal move-out was removed from the individual traces by applying normal moveout corrections which were determined for the area. Individual trace corrections to remove surface velocity effects were determined when possible from a reliable reflection. An overall correction was applied to obtain a raw time for the reflections on the record equal to the computed values.

Oscillographic playback sections were not obtained for all the records, as they appeared to be of very limited values for interpretation. Only variable density sections were obtained for all the records and these were used in interpreting the recorded data.

## APPENDIX "C"

### STATISTICS

| | |
|---|---|
| Seismograph Survey Started - | July 12, 1960 |
| Seismograph Survey Completed - | July 15, 1960 |
| Number of Days Worked - | 3 |
| Total Number of Locations Shot - | 179 |
| Number of Miles Shot - | 22½ |
| Total Amount of Explosives Used - | 2874 lbs. |
| Total Number of Boosters, Caps and Primers Used - | 361 |
| Explosive Used per Shot - | 16.1 lbs. |
| Average Number of Locations Shot - per Working Day | 60 |
| Average Number of Miles Shot - | 7 |

# STATISTICAL REPORT

# OF A

# MARINE SEISMIC SURVEY

# IN THE

# MACKENZIE AND ARCTIC RED RIVERS AREAS

# OF THE

# NORTHWEST TERRITORIES

for

RICHFIELD OIL CORPORATION

ACCURATE EXPLORATION LTD.

May, 1961.

# I N D E X

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INTRODUCTION

A marine seismograph survey was carried out in the Mackenzie and Arctic Red Rivers in the Northwest Territories of Canada during the months of June and July, 1960.

This Statistical Report covers approximately 20 miles of work shot for the Richfield Oil Corporation of Canada, between Longitude 134° 10' W and 133° 50' W and between Latitude 67° 20' N and 67° 40' N.

A total of 199 locations were shot in this area.

The field work was carried out in the period between June 27, 1960 and July 2, 1960, by Accurate Exploration Ltd., Party 206.

The crew operated under Northwest and Yukon Territories Oil and Gas Exploration License No. 499. Permission to do the required work was obtained from the Federal Government.

**AREA**

The project area was located between Longitudes 134° 10' W and 133° 50' W and Latitudes 67° 20' N and 67° 40' N. All the work was done on the surface of the Mackenzie and Arctic Red Rivers.

The operational headquarters for the operation was located on the housing boat which followed the recording and shooting boats during the survey. Inuvik was used as a basing port for supplies and repairs.

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Em = elevation of water
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Es = elevation of shot
Dw = depth of water
Vd = velocity to datum = 9000'/"
Vw = velocity of water = 5000'/"
Dd = distance to datum
Ed = elevation of datum
$EV_2$ = elevation of river bed
td = correction to datum

eg.

$$Em - Ds = Es$$

$$Em - Dw = EV_2$$

$$EV_2 - Ed = Dd$$

$$td = \frac{EV_2 - Ed}{Vd} + \frac{Es - EV_2}{Vw}$$

## RECORD DISCUSSION

Record quality over most of the area was poor. Due to the poor quality of the records, it was not possible to record correlative events from the sub-surface formations from the monitored records. To identify dips and possible faults, it was necessary to obtain variable density play-back sections.

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Oscillographic play back sections were not obtained for the records, as they appeared to be of very limited values for interpretation. Only variable density sections were obtained for all the records.

- 8 -

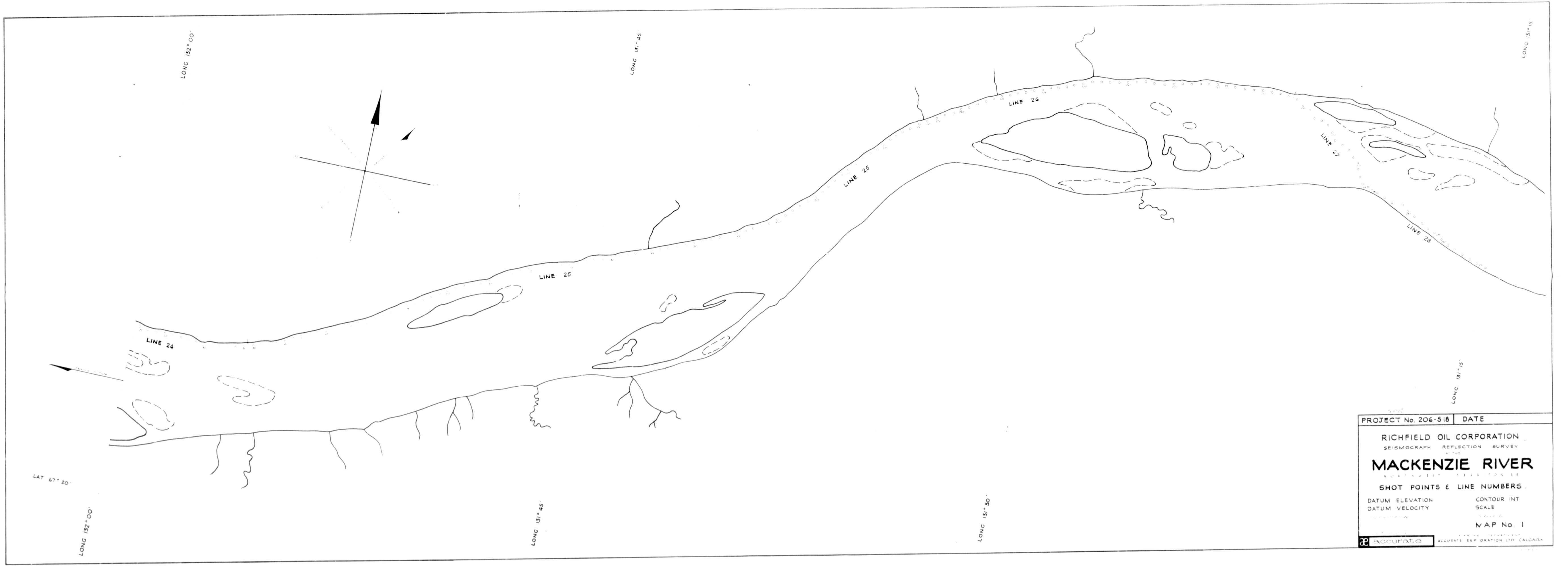
## OPERATING STATISTICS

| | |
|---|---|
| Seismograph Survey Started | - June 27/60 |
| Seismograph Survey Completed | - July 2/60 |
| No. of Days Worked | - 5 |
| Total No. of Locations Shot | - 199 |
| No. of Miles Shot | - 24 |
| Total Amount of Explosives Used | - 2679 lbs. |
| Total No. of Booster Caps & Primers Used | - 450 |
| Average Explosives Used per Shot | - 13.5 lbs. |
| Average No. of Locations Shot per Working Day | - 40 |
| Average No. of Miles Shot per Working Day | - 5 |

Respectfully submitted,
ACCURATE EXPLORATION LTD.

R. O. Lindseth,
Seismologist.

A. E. Pallister, P.Geoph.


LONG 132° 00'
LONG 131° 45
LONG 131° 15
LINE 24
LINE 25
LINE 25
LINE 26
LINE 27
LINE 28
LAT 67° 20'
LONG 132° 00'
LONG 131° 45
LONG 131° 30'
LONG 131° 15
PROJECT No. 206-518
DATE
RICHFIELD OIL CORPORATION
SEISMOGRAPH REFLECTION SURVEY
IN THE
MACKENZIE RIVER
NORTHWEST TERRITORIES
SHOT POINTS & LINE NUMBERS.
DATUM ELEVATION
DATUM VELOCITY
CONTOUR INT
SCALE
MAP No. 1
accurate
ACCURATE EXPLORATION LTD CALGARY