PETRO-CANADA

Report on the

GEOPHYSICAL EXPLORATION SURVEY

PROGRAM No. 9229-P28-10E

in

BRACKETT LAKE

NORTHWEST TERRITORIES

Exploration Agreement No. 159

APRIL, 1986

PROJECT ACTION SHEET

RESOURCE EVALUATION BRANCH

PROJECT NUMBER: .... 9229-P28-10E ....

COMPANY: .... PETRO-CANADA ....

REPORT TITLE: GEOPHYSICAL EXPLORATION SURVEY BRACKET LAKE EA.159

The following action has been taken:

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COMMENTS:

Report on the
Geophysical Exploration Survey

PROGRAM NO. 9229-P28-10E

Brackett Lake Survey
Northwest Territories
EXPLORATION AGREEMENT NO. 159

by

Petro-Canada Inc.
April 1986

FIELD WORK PERIOD:	March - April, 1985
LAND USE PERMIT NO.:	N85B293
AREA COORDINATES:	Latitude 65° 05' - 65° 20' Longitude 125° 00' - 125° 45'
DATA ACQUISITION:	Reflection Seismograph (Dynamite) Western Geophysical Company of Canada

Submitted
By

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NWT/Beaufort Region

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1. 1 Mylar Shot Point Map: 96F (South)

2. 7 Seismic Sections: 8511, 8513A, 8513B, 8515, 8517, 8519, 8521

   1 mylar and 2 paper copies of each migrated section (normal and reverse polarities) plus depth migration for all save 8515 and 8517

SECTION ONE

INTRODUCTION

Petro-Canada Inc. conducted a geophysical survey in the Brackett Lake area of the Northern Interior Plains in the Northwest Territories during the 1984-1985 winter season. The lands involved were operated by PCI under Exploration Agreement number 159 referred to as Mackenzie Plains. See Figure 1.1 for the location.

The survey was designed to obtain subsurface information to delineate a feature with hydrocarbon potential. A total of 125 kilometres of seismic data were shot and 131 kilometers of gravity were measured along the seismic lines.

This report, submitted to COGLA as required by the Exploration Agreement, summarizes the procedures of data acquisition, processing, and the results of the interpretation.

The interpretation of this data incorporated Petro-Canada's existing seismic data. Seismic time structure and isochron maps, as well as gravity maps were produced and are enclosed with the report.

Data which has been sent separately from this report includes mylar copies of the seismic base map and seismic sections, and paper copies of seismic sections.

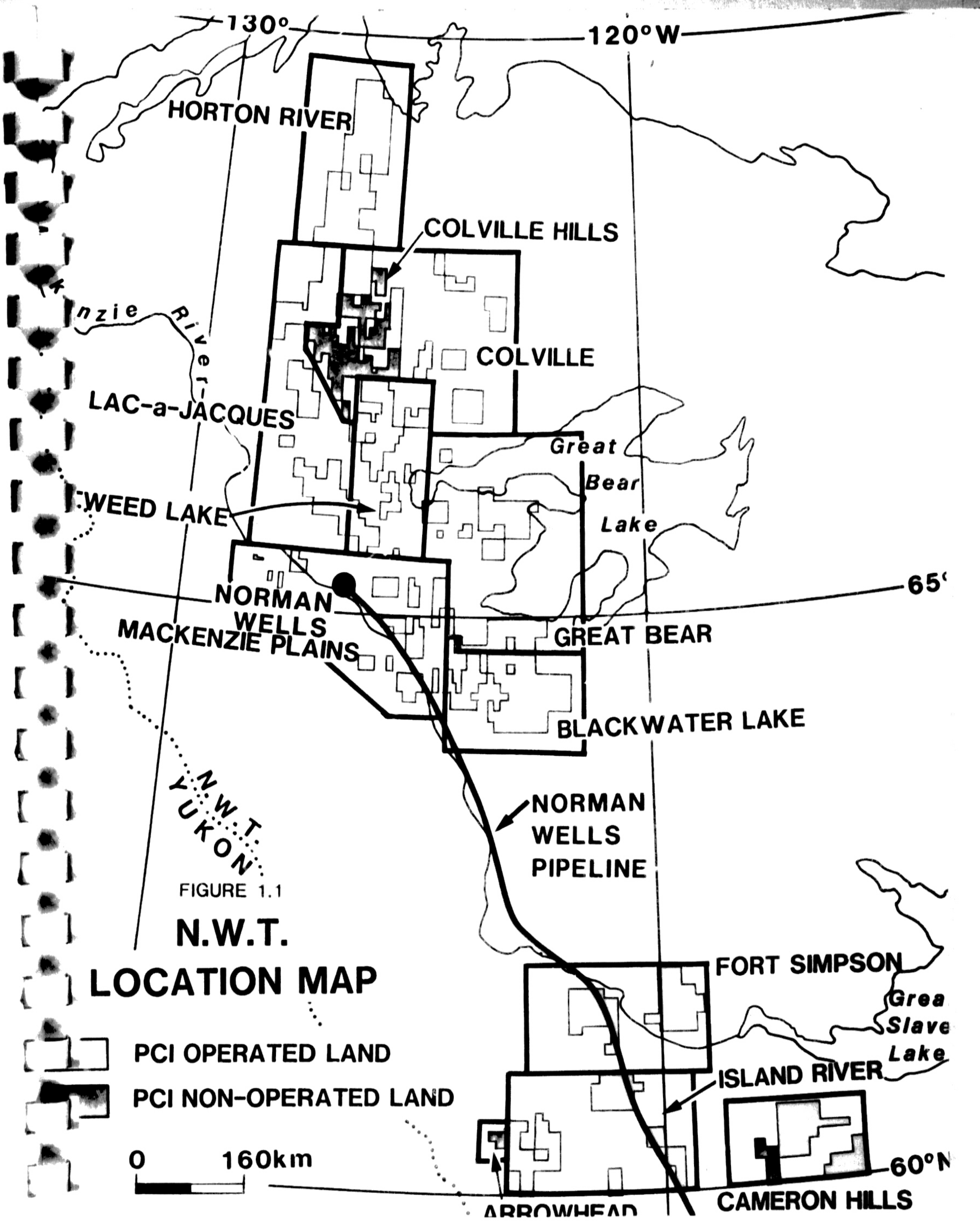


FIGURE 1.1

N.W.T. LOCATION MAP

SECTION TWO

DATA ACQUISITION AND REDUCTION

2.1 Field Operations Summary

2.1.1 Field Conditions

Weather conditions were normal during the course of the program with temperatures in the -40°C to +5°C range in late March. Towards the end of the survey, it became necessary to work a night shift with the recording crew because of the warm daytime conditions.

Drilling formations varied from clay and rock to soft shale and wet sand. The majority of the time, wet clay and rocks were encountered.

Timber growth was often heavy. Elevations varied from 100 to 375 metres above sea level.

2.1.2 Seismic Operations

The survey was conducted by Western Geophysical Company of Canada. Western employed a total of 60 people, of which 50% of the field personnel were native residents. Tables 2.1, 2.2, 2.3, and 2.4 summarize the project chronology, production, drilling, and organization.

Mobilization	March 20, 1985
Start of Drilling	March 20, 1985
Start of Recording	March 21, 1985
Completion of Drilling	April 2, 1985
Completion of Recording	April 4, 1985

Table 2.1 Seismic Project Chronology

Total Recording Days	15
Total Poor Weather Days	Nil
Total Moving Days	Nil
Production Profiles Shot	918
Kilometres Shot	124.56
Average Profiles per Day	61.20
Average Kilometres per Production Day	8.304
Total Days Mobilization/Demobilization	4

Table 2.2 Seismic Production

Total Poor Weather Days	Nil
Total Drilling Days	14
Number of Holes Drilled	950
Average Hole Depth	14.7 metres
Average Holes per Day	67.9
Total Metres Drilled	13,960
Powder Consumed	1,954 kilograms
Average Charge per Hole	2 kilograms

Table 2.3 Seismic Drilling

Misc. Personnel

Party Manager	1
Assistant Party Manager	1
Clerk	1
Mechanic	1
Mechanic's Helper	1
Expediter	1
Expediter's Assistant	1

Recording

Observer	1
Assistant Observer	1
Shooter	1
Shooter's Helper	1
Cable Truck Drivers	3
Recording Helpers	9

Surveying

Surveyor	1
Rodmen	2
Cat Push	1

Native Personnel 49

Drilling

Drillers (includes relief workers)	8
Drill Helpers (includes relief workers)	8
Water Hauler	1
Driller Mechanic	1

Catering

Cooks	2
Assistant Cooks	2
Camp Attendant	1

Line Cutting

Machine Operators	6
Foreman	1
Cook	1
Native Monitor	1

Table 2.4 Project Organization

2.1.3 Gravity Operations

Airborne Geophysical was contracted to undertake the gravity acquisition. Two gravity operators were employed.

Table 2.5 summarizes the project chronology and production.

Project Chronology	
Mobilization Date	March 18-20, 1985
Demobilization Date	April 1, 1985
Production	
Total number of stations	559
Total number of lines	8*
Total distance run	131

Table 2.5 Gravity Project Chronology and Production

* Includes the west end of line 79X which had been shot in 1982.

2.2 Seismic Data Acquisition

2.2.1 Instruments

Table 2.6 summarizes equipment used in drilling, recording, detection, and surveying.

Drilling

8 Drilling Rigs	1 - CF - 110 Mayhew Model 1000 - Air/Water
	6 - CF - 110 Mayhew Model 1000 - Air Drill
	1 - CF - 110 Hillbrand C-1000 Top Drive Air/Water Drill

Recording

Oscillograph	Tektronic	
Amplifiers	Texas Instruments	DFSV
Tape Systems	Texas Instruments	DFSV
Camera	S.I.E.	ERC-10C

Detection

Remote Firing System	Input - Output, Encoder/Decoder
Cables	Mark Products, 660 feet
Geophone Strings	LRS Model 1011 - 14 Hz. 420 Ohm Coil

Surveying

2	Wilde T-16 Theodolite
1	Sokkisha Red II E.D.M.

Table 2.6 Seismic and Survey Instruments

2.2.2 Parameters

The source-detector geometry was a 1551-66-0-66-1551 spread. The interval between geophone groups was 33 metres. The detector array was 9 geophones in line over 66 metres.

Table 2.7 lists the recording parameters used.

Sample Rate	2 milliseconds
Record Length	6 seconds
Recording Filter	Low cut-8 Hz., High cut-128 Hz.
Sub-surface Coverage	1200%
No. of Groups	96
Group Interval	33 metres
Group Array	Inline array over 66 metres
Geophone Group	9
Shot Point Interval	132 metres
Spread Length	1551-66-0-66-1551
Holes per Shot Location	1

Table 2.7 Recording Parameters

2.2.3 **Survey Systems**

New cut lines were surveyed-in using topographic features and sun shots. Station elevations were computed by stadia, and horizontal locations by latitudes and departures. Shot point and station intervals were measured with a chain and rod.

Accuracy of positioning is ± 1 metre in elevation and ± 10 metres in horizontal distance.

2.3 Gravity Data Acquisition

2.3.1 Field Techniques and Measurements

The equipment used was:

2 Lacoste and Romberg G-Meters #387 and #442
(Conversion Constants = 1.07105 and 1.04660)

The observed gravity at Government station #9549.59 (Norman Wells airport terminal) was tied to the field data. The further development of the field base network was accomplished by a "step-by-step" method, where each previously set base was used as the initial base for the next one. The gravity was observed along the seismic lines every 264 metres or every other shot point.

Table 2.8 summarizes the gravity measurements taken.

Gravity station interval	264 metres (every second S.P.)
Number of independent readings at each station	3
Meter setting	On the ground
RMS accuracy of single gravity observation	+/ 0.04 mgal

Table 2.8 Gravity Measurements

2.3.2 Accuracy of Data

Elevation and co-ordinates of each shot point were provided by the seismic reflection survey group.

The absolute accuracy of the Bouguer gravity is affected by the accuracy of the:

Base network	± 0.04 mgal
Observed gravity	± 0.04 mgal
Loop elevation	+/- 0.55m or +/- 0.17 mgal (@ 0.3086 mgal/m)
Positioning	Negligible
Terrain and tidal corrections	± 0.05 mgal

The total absolute accuracy is calculated as the square root of the sum of squares of all the above RMS accuracies.

2.4 Geophysical Data Processing

2.4.1 Seismic

The seismic data recorded were processed at Geophysical Services Incorporated. The following sequence was used:

1. Demultiplex: 2 msec Sample Rate
2. Trace Editing
3. Static Computations - Weathering Statics from First Break Analysis
4. True Amplitude Recovery - 7db/second from 0-3 seconds
5. First Break Noise Suppression
6. Deconvolution - Operator Length: 80 msec
   - Prewhitening: 1%
   - Design Gates: 300-1600 msec near trace; 950-2250 msec far trace
7. Equalization

8. Residual Statics Analysis - Surface Consistent Automatic Statics plus
   Trim Statics

9. Relative Statics and Residual Statics Applications

10. Normal Moveout - Velocity Analysis from Velscans

11. Mean Datum Statics Application - Datum - 150 metres above sea level
    - Replacement Velocity - 3200 metres/sec

12. Stack Mute

13. CDP Stack - 12 fold

14. Migration - Wave Equation Migration
    Kirchoff F/K Domain
    Dip Limited

15. Time Variant Filter - 10/20 - 60/70 Hz.

16. Time Variant Scaling - (10 X 100), 200, 300, 500 msec Gates
    starting at zero

*17. Convert to Depth - Interval Velocities Supplied by PCR (see section
    3.3.3)

18. Display to Film -

    Time Sections Scale a) Horizontal: 24 traces/inch
    Vertical: 7.5 inches/sec - Normal Polarity

    b) Horizontal: 12 traces/inch
    Vertical: 10 inches/sec - Both Polarities

    Depth Sections Scale - Horizontal: 24 traces/inch
    Vertical: Approximately 3 km/sec

* Lines 8511, 8513, 8519 and 8521 were converted to depth. Lines 8515 and 8517 were not.

2.4.2 Gravity

Field processing was done by the contractor and included conversion of meter reading to milligals, plus drift and tidal corrections. The inner zone terrain correction was estimated by the operator in the field. In Calgary, the contractor sorted the field data by lines, rather than by daily loops, and calculated Bouguer gravity using a crustal density of 2.35 grams/cc. The outer zone terrain correction was calculated and, together with the inner zone corrections, were added to the Bouguer gravity. The data were then transcribed onto magnetic tape and delivered to the Gravity and Magnetic Group of Petro-Canada Inc. for final processing as follows:

1) Merging the line oriented data into the Merged Survey File (MSF).

2) Calculation of terrain corrections using a Fast Fourier Transform method.

3) Residual gravity data was created by the upward continuation method. This required the calculation of the field at an elevation of 2 km. above the survey plain minus the observed field. The data was then filtered with a bandpass of .035K sloping to .030K to .30K sloping to .35K where K is the wavenumber.

4) Plotting of the index map, Bouguer gravity and residual gravity maps.

SECTION 3

INTERPRETATION OF RESULTS

3.1 Regional Geology

The Brackett Lake project was centered around Brackett Lake in the Franklin Mountains, 65 km east of Norman Wells in the Northwest Territories, Figure 3.1. Norman Wells is located near the well symbol 36X.

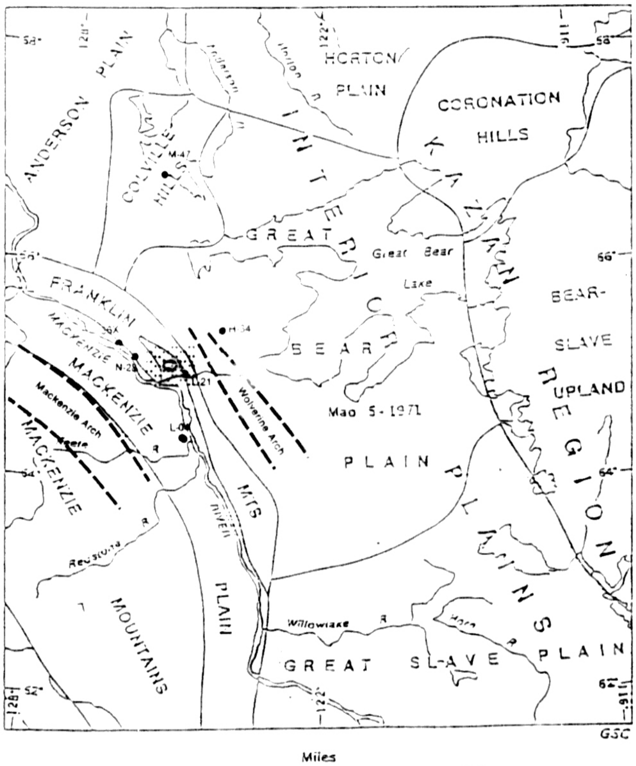
3.1.1 Structural Geology

The survey area is located in an elongate northwesterly trending basin situated between the MacKay Range on the west and the St. Charles Range on the east, Figure 3.2. The valley proper is of low relief with prominent mountains at its boundaries, which appear surficially to be the result of thrust faulting.

During the Proterozoic, a massive sedimentary sequence thickening to the southwest was deposited. These units were uplifted and eroded prior to the deposition of Paleozoic sediments. Various uplifts and movements occurred during Phanerozoic time with major uplift and erosional cycles in post Devonian periods, including the Laramide Orogeny which is primarily responsible for present topography.

3.1.2 Stratigraphy

The stratigraphic succession ranges in age from pre-Cambrian to Recent, Figure 3.3. Paleozoic sediments, based upon the limited well control in the vicinity, are representative of marine deposition. Various erosional cycles have truncated successively older rocks northward, so that Tertiary clastics are at surface in the southern portion of the survey area whereas Siluro - Ordovician carbonates are exposed in the north. Upper Cambrian material is evident in the western mountains.



Miles

0 100 200

0 100 200 300

Kilometres

Divisional boundaries . .

Regional boundary . .

Project Area

Wells •

Figure 3.1 Map of major structural features and geological well control points for the Brackett Lake area (modified from Bostock, 1970).

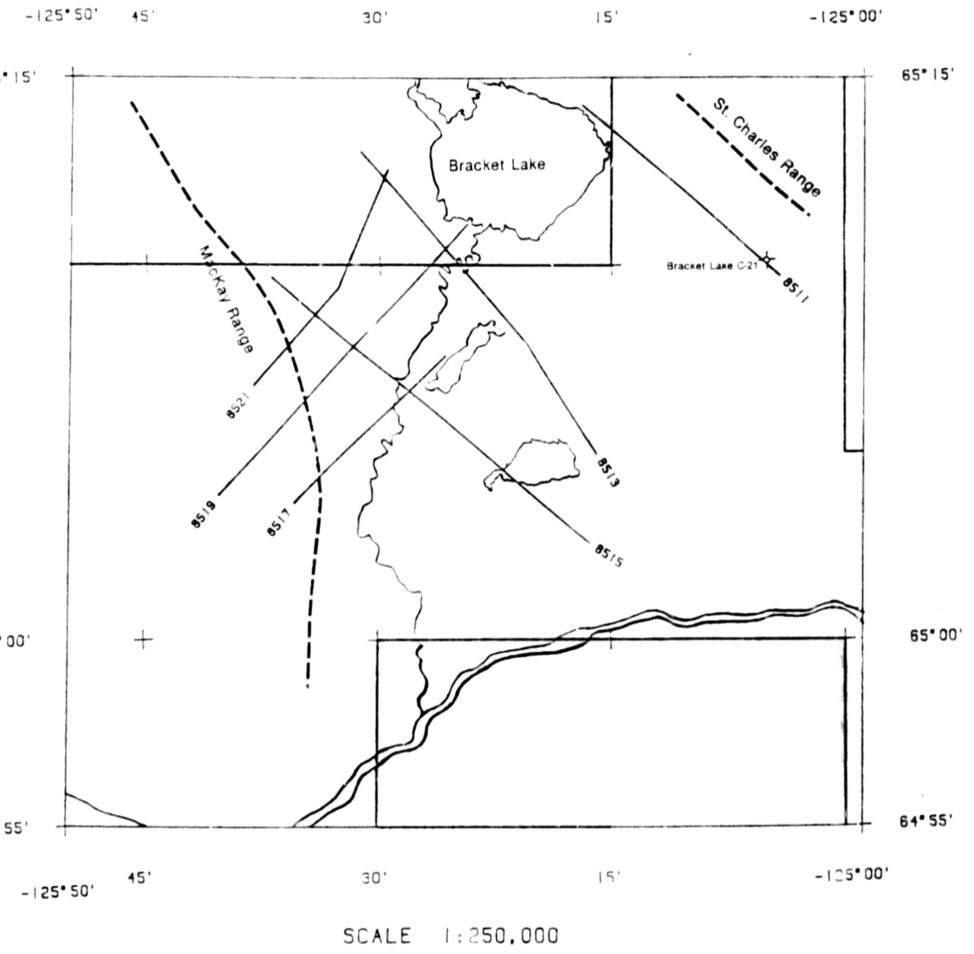


Figure 3.2 Location map of the 1984-85 geophysical program in the Brackett Lake area.

Lying unconformably on the Proterozoic strata is the basal Cambrian Mount Clark sandstone (Old Fort Island) derived primarily from the Canadian Shield, and possibly from the Wolverine Arch to the east, Figure 3.1. The Mount Clark Formation is succeeded conformably by the Mount Cap Formation, a unit expected to consist primarily of marine shales with interbedded sands and dolomite. Above the Mount Cap Formation is the Saline River Formation, which is composed mainly of evaporites (predominantly halite), with an upper shale and dolomite unit.

Siluro - Ordovician carbonates of the Franklin Mountain and Mount Kindle Formations cap the Saline River Formation. In the southeastern portion of the program area, around the Brackett Lake C-21 well, a limited basin of Devonian rocks is present. These rocks include the Bear Rock, Hume, Hare Indian, Kee Scarp (Ramparts) and Imperial Formations.

Unconformably above all units, and successively truncating older strata northward, lie Cretaceous and Tertiary clastics composed of shales and interbedded sands.

3.1.3 **The Prospect**

The primary hydrocarbon reservoir is in the Mount Clark sandstone. The absolute thickness of this unit is unknown; however, over 200 m are present at Cap Mountain below Keele River south of the survey area. The sands in this region are expected to be considerbly less. Traps may be formed by blanket sands draped on structural highs.

Secondary targets in this area include sands within the Mount Cap Formation, porosity traps within the Franklin Mountain below the Cretaceous Unconformity and stratigraphic or structural Cretaceous sand plays.

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UPPER CRETACEOUS	Unnamed: shale	? Disconformity ?
LOWER CRETACEOUS	Unnamed: sandstone	
Regional Unconformity		
UPPER AND MIDDLE DEVONIAN	RAMPARTS FORMATION	
MIDDLE DEVONIAN	HARE INDIAN FORMATION (locally includes Cretaceous shale)	
	HUME FORMATION	
	BEAR ROCK FORMATION	
Regional Unconformity		
SILURIAN UPPER ORDOVICIAN	RONNING GROUP	MOUNT KINDLE FORMATION
		Regional Unconformity
LOWER ORDOVICIAN		Unnamed: dolomite with chert
		Unnamed: dolomite
UPPER CAMBRIAN		Unnamed: dolomite and shale
	SALINE RIVER FORMATION	
MIDDLE CAMBRIAN	MOUNT CAP FORMATION	
	OLD FORT ISLAND FORMATION	
Regional Unconformity		
PROTEROZOIC	DIABASE DYKES	
	COPPERMINE RIVER SERIES	
	Regional Unconformity	
	DIABASE DYKES	
	HORNBY BAY GROUP	Unnamed: stromatolitic dolomite
		Unnamed: sandstone, conglomerate, quartzite

Figure 3.3 Stratigraphic column for the Brackett Lake area.

3.2 Correlation of Geology to Geophysics

Line 8511 crossed the Brackett Lake C-21 well. Figure 3.4 shows the synthetic. All wells evaluated for the geophysical interpretation include:

Keele River L-04	100 kilometres south
Tweed Lake M-47	190 kilometres north
Norman Wells 36X	65 kilometres west
Vermillion Ridge No.1 N-28	40 kilometres west
Whitefish River H-34	35 kilometres northeast
Brackett Lake C-21	On line 8511

The location of these wells in relation to the program area are shown in Figure 3.1.

The Brackett Lake C-21 well penetrated to the Franklin Mountain. This only allowed the identification of the Cretaceous Unconformity, the Kee Scarp and the Hume Formations.

An event believed to be near the top of the Cambrian Salt is indentified by its similarity in appearance to an event in the Tweed Lake M-47 area. The same applies for the events identified as near top of Mount Cap Formation and an intra Mount Cap Formation dolomite unit.

The top of the Proterozoic is identifiable by the truncation of reflected events at the pre-Paleozoic unconformity. This angularity is apparent over most of the region.

3.3 Presentation of Results

3.3.1 Data Quality

Data quality is good to fair over the project area. The 1985 data is superior to the 1982 Petro-Canada data and to the 1972 Aquitaine data purchased by PCR in August 1984. The 1982 data was shot in a more geologically disturbed areas and consequently displays more seismic noise and reflection discontinuity. The 1972 data was shot on a thick Cretaceous section and is prone to multiple reflections.

3.3.2 Seismic Maps

The PCI lines 79X and 71X of the 1982 survey, and the Aquitaine lines 21A, 23 and 25 were incorporated into the mapping. Figure 3.5 shows the seismic base map involved. The earlier data required adjustments to the new due to differences in processing.

The following maps were made at a 1:100,000 scale:

1) Top of Proterozoic Time Structure - Figure 3.6
2) Near Top of Salt Time Structure - Figure 3.7
3) Cretaceous Unconformity Time Structure - Figure 3.8
4) Near Top Mount Cap to Proterozoic Isochron - Figure 3.9
5) Near Top of Salt to Proterozoic Isochron - Figure 3.10
6) "Salt" Isochron - Figure 3.11
7) Cretaceous Unconformity to Near Top Salt Isochron - Figure 3.12
8) Cretaceous Unconformity to Proterozoic Isochron - Figure 3.13
9) Proterozoic Depth Structure - Figure 3.14

3.3.3 Depth Conversion

Because of the presence of rapidly varying topography and formation isopachs, it was felt that producing a Proterozoic depth structure map would provide a clearer and more accurate representation of the subsurface near the zone of interest.

The velocities used in the depth migration seismic sections were:

Cretaceous Interval	2400 m/s
Pre-Cretaceous to Salt Interval	5300 m/s
Salt Interval	4400 m/s
Mount Cap to Proterozoic Interval	4000 m/s

The Cretaceous velocity was calculated from refraction data and sonic logs. The velocity of the pre-Cretaceous to Salt interval was taken from sonic logs and refraction data on the assumption that this zone was primarily carbonaceous as indicated by the nearest wells. The velocity of the salt was obtained from the Tweed Lake M-47 and Norman Wells 36X wells. The only well that would appear to provide a similar section of Mount Cap Formation was the Keele River L-04 well, thus the Mount Cap to Proterozoic velocity was obtained primarily from it. A slightly higher velocity was used than at L-04 on the belief that the Mount Cap in the survey area is less distal and more apt to contain carbonaceous material rather then predominately marine shale.

3.3.4 Gravity Data

The gravity survey index map for the Brackett Lake project is shown in Figure 3.15. The data from this survey was merged with the 1982 data in the vicinity to produce Bouguer and residual gravity maps, Figures 3.16 and 3.17.

3.4 Discussion of Results

3.4.1 Regional Structural Style

The Proterozoic time structure map, Figure 3.6, displays a high at Brackett Lake. Regional dip is to the south. The Top of Salt and Cretaceous time structure maps, Figures 3.7 and 3.8 show similar dip as all Paleozoic strata plunge beneath a thickening Cretaceous and Tertiary wedge. The Cretaceous section rises northward and is erosionally absent north of Brackett Lake.

The seismic data indicates that deformation is complex and that activity occurred frequently in geologic history. Two distinct zones of deformation are evident, the first being characterized by thrust faulting and the second by normal block faulting.

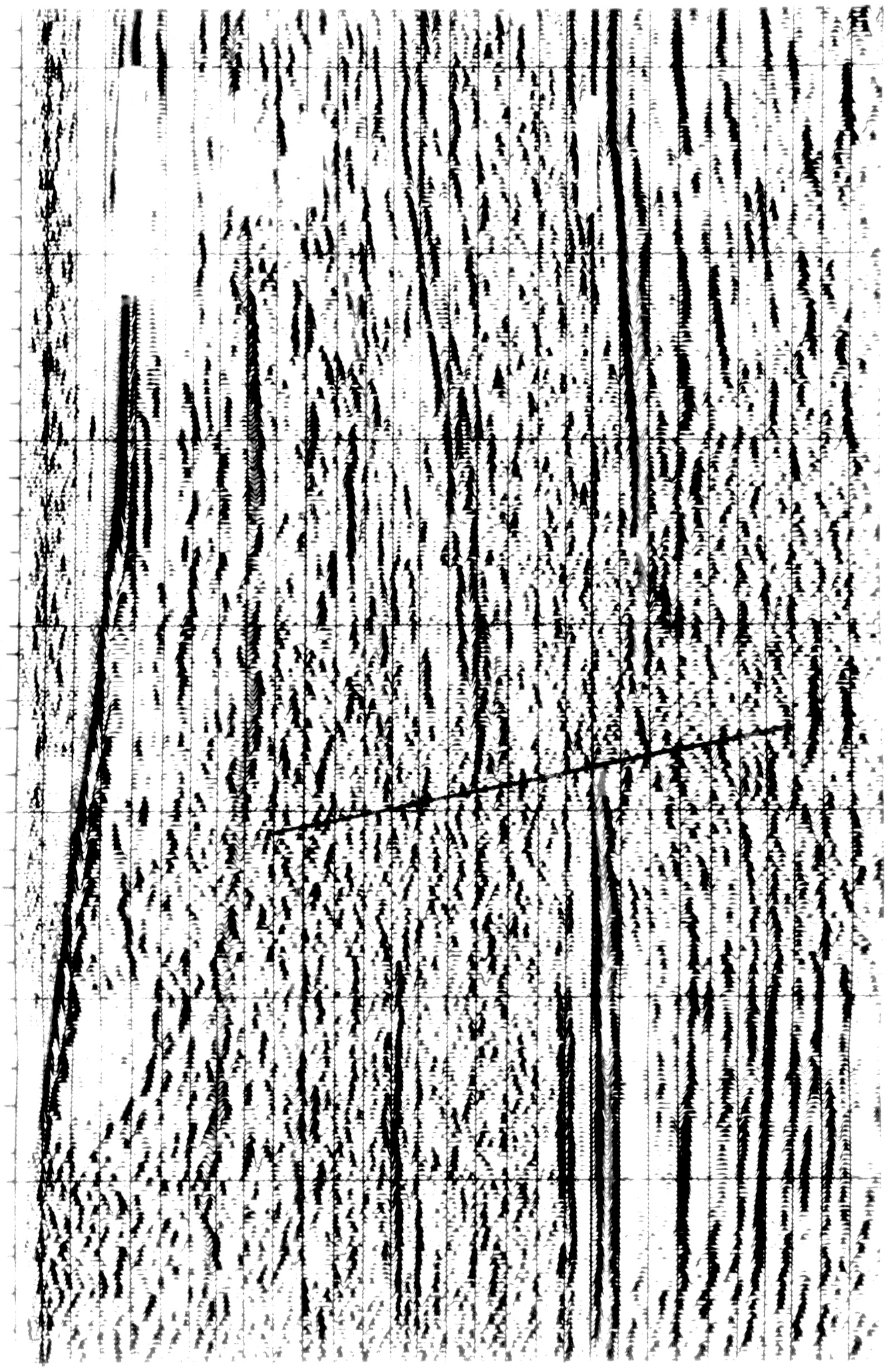
Thrust faults trend northwest-southeast, parallel to the mountains, and are a result of Laramide compression. The thrusting clearly occurs from a decollement in the salt, see Figure 3.18, penetrating through to surface bringing upper Cambrian strata to outcrop.

The normal faults observed are nearly perpendicular to the thrust faults. They appear to involve pre-salt strata only, Figure 3.19, however the ductile nature of salt precludes an absolute age dating. However, these faults clearly predate the Laramide Orogeny as the Cretaceous section is not involved.

3.4.2 Geological History

The Brackett Lake area is interpreted to have been part of a major graben in Early Cambrian time centered between the Mackenzie Arch and the Wolverine Arch, Figure 3.1. A complex series of uplift and erosion then occurred through its history.

The northern extent of this trough is probably near Lac des Bois 160 km northeast. This graben would be an extension of a graben of similar age to the south in the Keele area where wells encountered very thick Cambrian sections.



After the deposition of Middle Cambrian evaporites, the graben ceased subsiding and a normal marine carbonate shelf existed until Devonian time.

The Mount Cap to Proterozoic isochron map, Figure 3.9, indicates southward thickening. A subtle thin nose trends northeast to the southwest over the present day Proterozoic high suggesting the presence of a paleo-ridge.

The Salt to Proterozoic and Salt isochron maps, Figures 3.10 and 3.11, display a similar nose configuration with a dramatic increase in the salt thickness on the flanks by a factor of four.

The Cretaceous Unconformity to Salt isochron, and Cretaceous Unconformity to Proterozoic isochron maps, Figures 3.12 and 3.13, show the presence of a closed thin below Brackett Lake on the ancestral nose. The absence of any Devonian section and much of the Silurian section, makes it difficult to date this uplift absolutely, beyond that it is pre-Cretaceous. Inversion probably began to occur in the Middle Cambrian as evidenced by the block faulting and likely had a major pulse in the pre-Devonian similar to that which occurred in the Keele area.

A final stage of movement occurred during the Cretaceous. At this time, the Proterozoic high appears to have been displaced about two kilometres northward as the region began to uplift in the north and subside again in the south.

3.4.3 Gravity Interpretation

The lack of well control to positively identify the seismic reflectors in the survey area made the use of gravity data particularly important. One objective was to determine the lithology of the section believed to be the salt. The velocity of this interval and consequently the shape of the overall Proterozoic high could be vastly different if it consisted of carbonates as opposed to halite, for example.

The Bouguer gravity map, Figure 3.18, displays a high trend plunging to the southwest, analogous to but more dramatic than the Mount Cap to Proterozoic isochron map. The lows on the flanks correspond closely to the positions of assumed salt thicks and stacking of low density material from thrusting.

The residual gravity map, Figure 3.19, is similar to the Bouguer map but more complicated. The highest gravity values occur in the southwest on the positive trend rather than in the northeast possibly reflecting the presence of an up thrown block of Proterozoic material with a relatively thin overlying Paleozoic section.

3.4.4 The Proterozoic Depth Structure

The Proterozoic time and depth structure maps, Figures 3.6 and 3.14, display a closed Proterozoic high with some fault dependent closure to the northwest. The shape and position of the prospect appear different on the two maps however. The presence of thickening salt on the northwest and southeast flanks, as well as the thick Cretaceous section in the south caused concern that artificial push down could create a time anomaly. Conversion to depth indicates that the closure is indeed valid. The removal of the "push down" effect has resulted in the actual structure being shifted southward, with its major portion being south of Brackett Lake rather than being beneath the lake.

The interval velocities used to convert to depth were varied within the geological ranges expected to examine the effect on the structure.