NOTE: 693-15-5-1

REPORT SUBMITTED SEPTEMBER 10, 1969

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Abstracted for
Geo-Science Data Index

Date _____

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Geo-Science Data Index

Date _____

EVALUATION

FROM GEOPHYSICAL AND GEOLOGICAL DATA

OF THE

REDSTONE PROJECT

NORTHWEST TERRITORIES, CANADA

FOR

OIL & GAS OPERATIONS UNIT
Oil and Mineral Division
NOV 12 1969
OTTAWA, CANADA
Dept. of Indian Affairs & Northern Development

OPERATION GEOQUEST

Abstracted for
Geo-Science Data Index

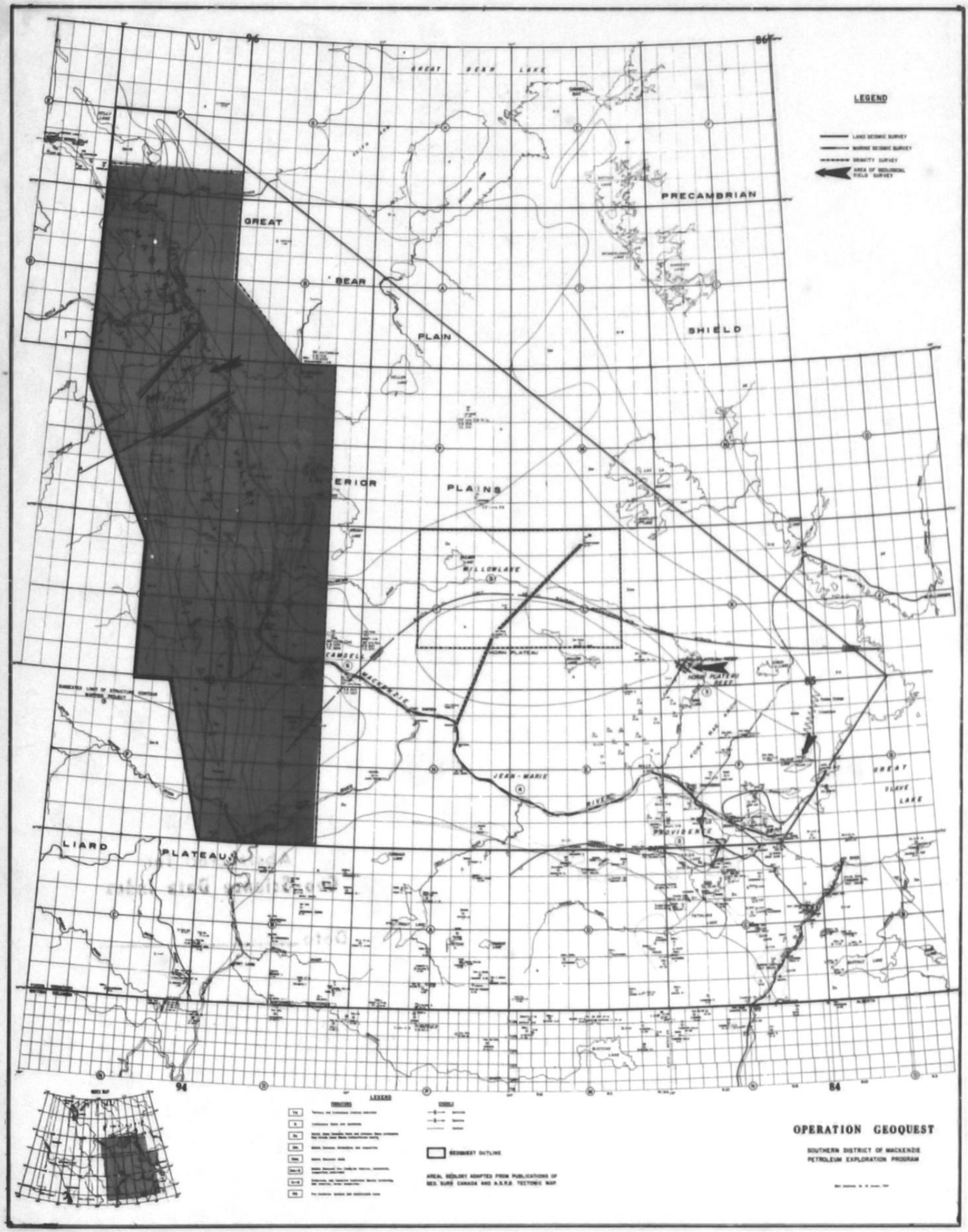
By

Date_____

PALLISTER and ASSOCIATES

V. Ray Smith ASSOCIATES LTD.

July, 1969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OPERATION GEOQUEST CONCEPT

Operation Geoquest - an Operation of the Kenting group of companies and V. Zay Smith Associates Ltd. - is a combined geological/geophysical exploration program designed for the purpose of solving some of the basic geological and geophysical problems in the Northwest Territories of Canada.

Six areas of geologic significance including reefs, carbonate fronts, salt basins, Foothills structure and geasynclinal hinge line, were selected for study.

The Director of Resource and Economic Development Group, Department of Indian Affairs and Northern Development, Ottawa, has approved in principle that expenditures incurred in Operation Geoquest may be allocated to permits or group of permits in the Yukon and Northwest Territories. Application of these expenditures will be honoured up to the total cost of the entire survey.

An extended release date of these data has also been granted by the Department.

The following is a report of the work conducted in the Redstone Project within the Operation Geoquest area.

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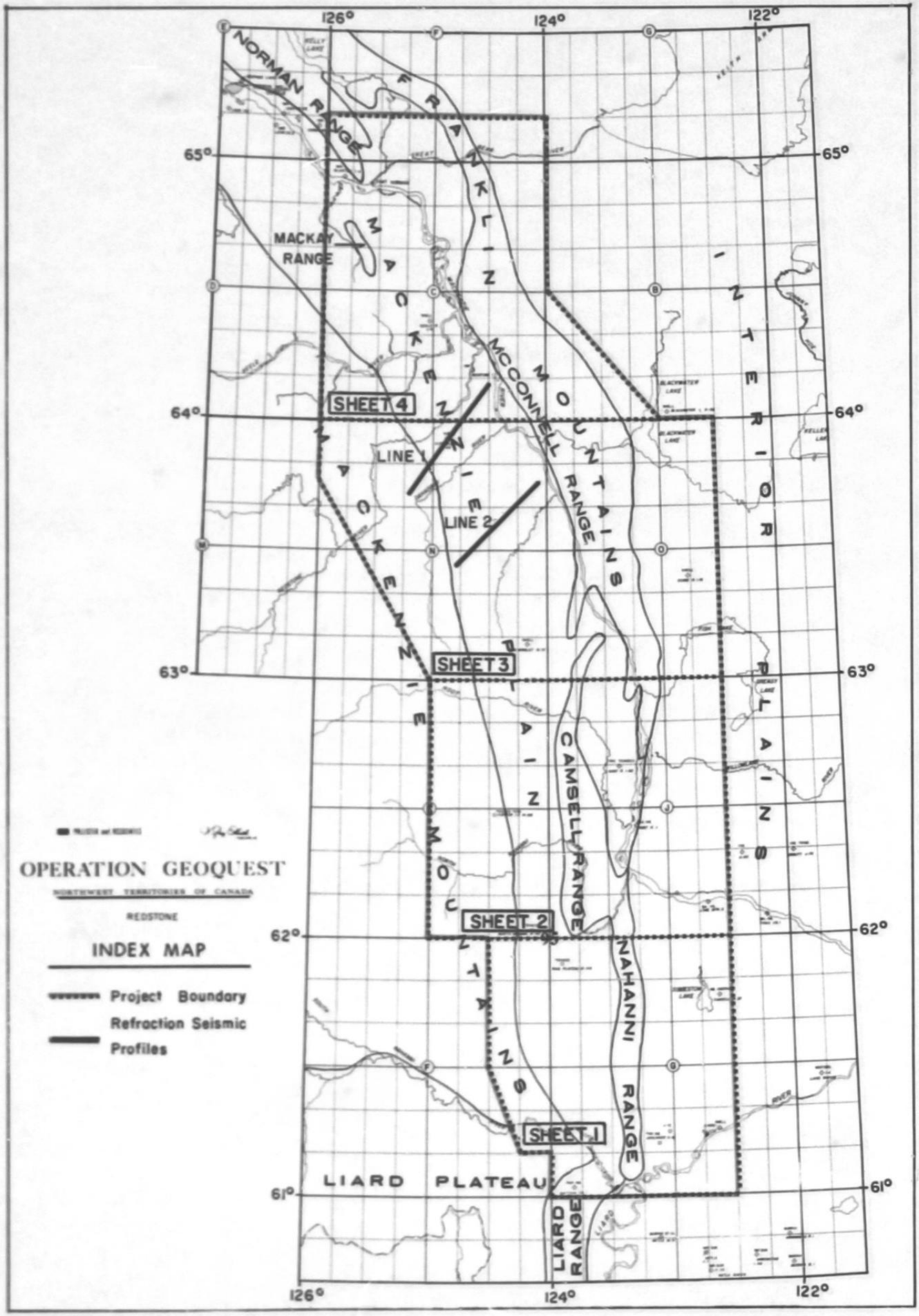
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ABSTRACT

The Redstone Project is located in the southwestern part of the Northwest Territories encompassing the area of the Mackenzie and Franklin Mountains and the western portion of the Interior Plains.

The Project consisted of constructing contour maps on the top of the Middle Devonian Nahanni (Hume) Formation over an area of approximately 23,000 square miles. These maps were constructed by use of well data, photogeologic and photogrammetric mapping, field observations and data from the seismic refraction and gravity profiles.

Results of the combined survey describe the stratigraphic section ranging in age from the Precambrian to Tertiary overlain by varying amounts of Recent alluvial deposits. The maps also display the trend, size and shape of various structural features.

The use of seismic refraction and gravity was found to be an effective aid to photogeologic mapping in an area of complex folding and faulting in areas where Recent alluvial deposits mask structural trends.

PART I

REGIONAL GEOLOGIC SETTING

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PART I

REGIONAL GEOLOGIC SETTING

PHYSIOGRAPHY

Operation Geoquest covers parts of two major physiographic divisions: the Interior Plains and the Cordilleran Belt. The Mackenzie River is the main drainage. It originates in Great Slave Lake and flows west-northwesterly across the Interior Plains entering the Cordilleran Belt near Camsell Bend; from there it flows north-northwesterly through the Mackenzie Valley.

INTERIOR PLAINS

The Interior Plains form a vast area of low topographic relief lying between the Precambrian Shield on the east and the Cordilleran Belt on the west. The land surface is gently undulating at most places.

The Interior Plains are about 300 miles wide in the south in the vicinity of Great Slave Lake, narrowing to the north to a width of approximately 175 miles near Great Bear Lake. The land is poorly drained; for the most part, lakes and ponds are numerous. Interior Plains elevations within the Operation Geoquest area range from a low of 250 feet in the vicinity of Great Bear River to as much as 2,500 feet in the Horn Plateau that surmounts the plain. At most places, however, the land stands at elevations ranging from about 500 feet to 1,500 feet.

The Interior Plains are underlain by flat-lying to gently dipping strata comprised of carbonates, clastics and evaporites of Paleozoic and Mesozoic age. Bedrock is mantled by a variable thickness of glacial drift. Thus, outcrops are relatively sparse over most of the area. Some exposures exist along streams which have cut through the glacial cover; others are present in the rims of plateaus. Numerous significant exposures are located in the eastern part of the Interior Plains near the Precambrian Shield. Some gentle cuestas dipping gently to the southwest are present, providing an opportunity to study at the surface early Paleozoic rocks which are buried in the basin down-dip to the southwest.

Several scattered plateaus rise abruptly several hundred feet to nearly 2,000 feet above the general level of the Interior Plains. These include the Horn Plateau located northwest of Great Slave Lake, and the Ebbutt and Martin Hills located in the western part of the Interior Plains in front of the Cordillera. These broad features represent erosional remnants of flat-lying to gently dipping Cretaceous beds.

Evidence of continental glaciation is widespread in the Interior Plains. The Operation Geoquest area has been subjected to several periods of glaciation during the Pleistocene Epoch. A variety of glacial deposits is present. Drumlins indicate that the ice tended to move westerly and northwesterly from the Great Slave Lake area across the Interior Plains during the latest glacial advance. The plateaus that surmount the plains tended to deflect the ice around them. The continental ice sheets appear to have coalesced with the piedmont glaciers along the Cordilleran Belt. As deglaciation proceeded, vast proglacial lakes formed in the Interior Plains. These lakes were the ancestral Great Slave and Great Bear Lakes which formed part of a vast series of glacial lakes extending from the Great Lakes area of the United States and eastern Canada to Great Bear Lake.

At one time, Great Slave Lake stood about 500 feet higher than its present level. It surrounded the Horn Plateau and may have stretched 350 miles to the west to the vicinity of the Cordilleran Belt.

In summary, the landscape of the Interior Plains consists of a varied plains and low-lying plateau region that had reached the late mature stage in the erosional cycle before being subjected to multiple continental glaciation during the Pleistocene Epoch. Much of the area has been reverted to the initial stage in the erosional cycle and is being subjected to light to moderate erosion.

CORDILLERAN BELT

The Cordilleran Belt lies west of the Interior Plains and covers parts of three physiographic subdivisions: the Mackenzie Mountains, the Franklin Mountains and the Mackenzie Valley. The Operation Geoquest area includes rugged, moderately complex mountains and a broad intermontane valley. The Mackenzie River flows through the valley lying between Mackenzie Mountains on the west and the Franklin Mountains on the east.

The Mackenzie Mountains form an important subdivision of the Cordilleran Belt. They extend from the southern part of the Operation Geoquest area near South Nahanni River, northwesterly to the western project boundary at Keele River. Sediments of mainly Paleozoic age are well exposed throughout much of the length of the Mackenzie Mountains. Summit elevations are in the order of 4,500 to 5,000 feet, and local topographic relief of about 3,000 feet is present. The topography consists of a series of north-northwesterly trending ridges and valleys produced by differential erosion under the influence of structural control.

The Franklin Mountains form the leading edge of the Cordilleran Belt. They extend from Nahanni Butte, at the southern project boundary, northerly and northwesterly to the northern part of the Operation Geoquest area, a distance of 325 miles. The Franklin Mountains rise abruptly above the Interior Plains and are made up of a series of distinct, linear ranges which are named, from south to north, the Nahanni, Camsell, McConnell and Norman Ranges. Summit elevations range from about 4,500 to 5,000 feet. As much as 3,000 feet of topographic relief are present.

Outcrops of Paleozoic strata are common throughout the length of the mountains where the configuration of topography strongly reflects rock structure and lithology. In some areas, the ranges have been overridden by glaciers.

The Mackenzie Valley is an area of relatively low to moderate topographic relief lying between the Franklin and Mackenzie Mountains. It trends north-northwesterly parallel to the geologic grain of the region. It is an elongate intermontane structural basin varying in width from 30 to 50 miles, and is nearly 300 miles long within the Operation Geoquest area. Although the general level of the valley stands at about 500 to 1,500 feet, elevations as low as 200 feet occur along the Mackenzie River and as high as 3,000 feet exist in some places.

Bedrock is comprised of comparatively soft clastics of Upper Devonian, Cretaceous and Tertiary age. Some resistant Paleozoic beds are exposed along structural uplifts such as in the Mackay Range in the north. Outcrops are common in such areas.

In the southern two-thirds of the Mackenzie Valley, the topography reflects variations in structure and lithology of bedrock. Exposures are relatively widespread. To the north, however, bedrock appears to change character and is partly concealed beneath deposits of glacial drift. In some of these areas outcrops are relatively scarce except where tributaries of the Mackenzie River have incised beneath the glacial drift.

In summary, the Cordilleran Belt consists of a moderately complex mountain region that had attained the late youthful to early mature stage in the erosional cycle before undergoing multiple Pleistocene glaciation. It is being very vigorously eroded by streams at present.

STRATIGRAPHY

In the following paragraphs, concepts dealing with the regional stratigraphic development in the Operation Geoquest area are reviewed and discussed. Details of the stratigraphy have been reported in the literature by geologists who have studied the area in past years. Thus, one may refer to pertinent publications listed in the Selected Bibliography in order to review details. The age, correlation and lithology of the various stratigraphic units are shown in the accompanying stratigraphic correlation chart. More detailed discussions of the local stratigraphy of the Redstone Project will be included under Part IV of this report.

Sediments of Proterozoic, Paleozoic, Mesozoic and Cenozoic age are present within that part of the Mackenzie Basin covered by Operation Geoquest. The Paleozoic assemblage is comprised of Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian and Permian carbonates, clastics and evaporites. The Mesozoic sequence is made up of Cretaceous sandstone and shale. Tertiary clastics, Quaternary alluvium and glacial drift make up the Cenozoic section. Although many periods of the geologic column are represented, important gaps exist in the geologic record. Recurring cycles of subsidence, deposition, uplift and erosion have taken place.

Sediments were deposited in two main depositional environments which have tended to persist since the beginning of the Paleozoic Era. The Cordilleran geosyncline lay to the west along the present day location of the Cordilleran Belt. Relatively stable shelf conditions were present in the Interior Plains. During the Paleozoic Era, carbonates, clastics and evaporites were deposited in dominantly marine environments. Marine shale and sandstone

accumulated during the Mesozoic Era and were derived from uplifts in the geosyncline to the west and partly from the Precambrian Shield to the east.

A thick sedimentary sequence accumulated in the miogeosynclinal belt, and the total sedimentary section probably exceeds 20,000 feet in thickness. In contrast, the sedimentary sequence is comparatively thin over the stable shelf where the present stratigraphic section ranges from a thin edge to about 5,000 feet in thickness.

Paleozoic sedimentation in the Operation Geoquest area probably began in the Cordilleran Belt as the miogeosyncline was subsiding. Marine waters gradually encroached on the stable shelf, advancing toward the Precambrian Shield where well-sorted coarse clastics were deposited under shallow-water marine conditions.

Subsidence continued very slowly in the Interior Plains. Interbedded carbonates, clastics and evaporites were laid down in a marine, shallow-water restricted environment. Extensive tidal flats probably were present and different parts of the area were probably emergent at various times. In the miogeosynclinal belt to the west, thicker deposits of carbonates, clastics and evaporites accumulated.

During Upper Ordovician and Silurian time, well-aerated marine waters were present and thick deposits of carbonates were laid down. Marine organic life was widespread and reefs grew in places. Although this depositional environment persisted into Lower Devonian time in the Cordilleran geosyncline, the stable shelf was emergent and subjected to widespread erosion. This period of uplift and erosion probably coincided with the Caledonian epeirogeny.

In the Interior Plains of the Operation Geoquest area, the stratigraphic succession was truncated progressively from west to east toward the Precambrian Shield. Erosion was most conspicuous in the southern part of the Operation Geoquest area where strata of Cambrian, Ordovician and Silurian age are interpreted to have been removed over a broad area. Their southern limit is bounded by a line drawn from the north arm of Great Slave Lake west-northwesterly along the north edge of the Horn Plateau and southwesterly towards Nahanni Butte. Broad differential uplifts occurred in the Cordilleran Belt as indicated by thinning in various places such as in the Redstone Arch and the Fort Norman area.

Renewed subsidence during Middle Devonian time effected further sedimentation. At first, three different sedimentary environments originated. A shallow evaporitic basin was present over the stable shelf lying east in the Interior Plains. The present location of the Franklin Mountains and Mackenzie Valley cover a transitional zone between the evaporite basin to the east and an area of carbonate deposition to the west. It appears that some areas in the transition zone were emergent at times resulting in the development of karst topography. Continued subsidence permitted the advance of warm, well-aerated marine waters and deposition was dominated by carbonates. Environments were satisfactory in places for the prolific growth of marine life and reef development.

Coinciding with this period of carbonate deposition, or shortly thereafter, very fine clastics and, in a few places, evaporites were deposited. During Upper Devonian time, a change in the depositional pattern occurred whereby clastic deposition dominated over carbonate sedimentation.

To the west, in the rapidly subsiding geosyncline, a thick sequence of fine clastics accumulated during Upper Devonian time and was probably derived from uplifts within the geosyncline to the west and from the Precambrian Shield to the east. Subsidence and deposition probably persisted in the Mississippian, Pennsylvanian and Permian Periods over most of the Operation Geoquest area. However, much of the stratigraphic record of these three systems has been removed during a widespread period of uplift and erosion that probably occurred in accompaniment with late Paleozoic crustal movements. Nevertheless, stratigraphic evidence present in the southern part of the Cordilleran Belt included by Operation Geoquest and in areas to the south indicates that clastics, both fine and coarse, argillaceous carbonates and carbonates were deposited in a pattern reflecting the shelf-miogeosyncline environments that had persisted throughout the Paleozoic Era.

The stratigraphic record of Mesozoic sedimentation in the Operation Geoquest area is restricted to the Cretaceous Period. During Cretaceous time, marine seas invaded the area. Subsidence continued and resulted in the accumulation of dominantly marine shale and sandstone which were derived from uplifts within the Cordilleran Belt to the west and from an eastern source, the Precambrian Shield. Sedimentation in the Cordilleran Belt may have resulted in the accumulation of approximately 10,000 feet or more of Cretaceous rocks, whereas deposits were thinner over the Interior Plains - in the order of 2,000 to 3,000 feet.

The Cretaceous Period culminated in the Laramide orogeny. Deformation, uplift and erosion were widespread. During and after the orogeny, thick deposits of nonmarine coarse to fine clastics were deposited in local basins during the Tertiary Period. It is also conceivable that Tertiary deposition under continental conditions was widespread in the Operation Geoquest area, the stratigraphic record having been removed by subsequent erosion. Thereupon, the area was subjected to multiple continental glaciation during the Pleistocene Epoch. Following deglaciation, erosion was renewed and continues today.

STRUCTURE

Operation Geoquest covers parts of two main structural provinces which correspond closely to the physiographic divisions. They are the Interior Plains and the Cordilleran Belt. The Operation Geoquest area has been subjected to several periods of orogenic and epeirogenic deformation since the Precambrian.

Important structural movements occurred in the Paleozoic Era during late Silurian and/or Lower Devonian time (Caledonian epeirogeny). Other structural movements took place during early Upper Devonian time and presumably during late Paleozic time. Laramide orogenesis, the most important Mesozoic deformation, originated late in the Cretaceous and continued during early Tertiary time.

A variety of structural features occur in the Operation Geoquest area. Orogenic folds and faults characterize the Cordilleran Belt; less intense tectonic structures are present in the Interior Plains. Compaction folds and solution collapse structures are also anticipated. Some likelihood exists that salt flowage and tectonic accumulation associated with deformation may have occurred in the Cordilleran Belt.

Structures caused by igneous activity are not known within the Operation Geoquest area but should not be overlooked because they are known elsewhere in the Mackenzie Basin. However, their effects are very local. Of lesser importance are structures that could have been caused by the dislocation of surface bedrock during glaciation and isostatic rebound following deglaciation.

INTERIOR PLAINS

The Interior Plains structural province forms a vast area of gentle to moderate structural intensity lying between the Precambrian Shield on the east and the Cordilleran Belt to the west. The area was relatively stable during the Paleozoic and Mesozoic Eras. Near the eastern part of the Interior Plains, in the vicinity of the Precambrian Shield, Paleozoic strata dip very gently to the west and southwest toward the Cordilleran Belt at rates ranging from 15 to 20 feet per mile. The rate of dip gradually increases into the basin, but rarely exceeds 250 feet per mile.

The Paleozoic sequence is unconformably overlain by Cretaceous strata that are preserved as erosional remnants over broad areas. Cretaceous beds appear to be flat-lying to gently dipping. Some gentle folds and flexures are present in the Interior Plains in addition to other major structural elements. These include the Tathlina and Fort Rae Arches, an unnamed uplift west of Fort Simpson, and the northerly trending structural hinge line present in the western part of the Interior Plains.

The Tathlina Arch is a major structural feature in the Interior Plains southwest of Great Slave Lake. Only the north flank of it is covered by Operation Geoquest. This broad positive feature originated early in the Paleozoic Era and remained positive at least into Middle Devonian time. Some parts of the uplift probably were controlled by basement faults. The Fort Rae Arch may represent a subsidiary part of the Tathlina Arch. Stratigraphic evidence for the arch occurs along the edge of the Interior Plains, east of the Operation Geoquest area, where Paleozoic strata thin over the arch in the vicinity of Fort Rae, suggesting it to be a broad gentle positive feature.

In the western part of the Interior Plains in front of the Cordillera, a northerly trending zone of relatively steeper dip is present. It separates the Interior Plains from the Cordilleran Belt. This structural hinge line trends northerly along longitude 123°W. Some local structural elements are developed along it; one of them is an unnamed uplift which is interpreted to be present west of Fort Simpson in the area lying within the drainage loop, convex to the east, formed by the lower reaches of the Liard River and part of the Mackenzie River. This positive element was uplifted and truncated during post-Mississippian, pre-Cretaceous time and was further elevated during the Laramide orogeny.

CORDILLERAN BELT

The Cordilleran Belt is located in the western part of the Operation Geoquest area where moderate to very intense deformation prevailed during the Laramide orogeny. Although parts of the area had been subjected to pre-Laramide crustal movements, most of the

deformation was accomplished during the Laramide disturbance. Numerous folds and faults are present, and they range from simple to complex and moderate to intense. Regional structural trend is north-northwesterly although considerable local variation exists.

Operation Geoquest covers parts of three structural subprovinces: the Mackenzie and Franklin Mountains and the intervening Mackenzie Valley.

The Franklin Mountains form the eastern leading edge of the Cordilleran Belt and are characterized by moderate folds and faults developed mainly in strata of Cambrian through Middle Devonian age. A major northerly to northwesterly trending thrust fault marks the eastern boundary of the Franklin Mountains at many places. It gives a sense of motion towards the Interior Plains.

Only a small part, the eastern front, of the Mackenzie Mountains is included in the project. Structural trend is to the north-northwest. Structures consist of a series of moderately to intensely deformed folds and faults.

The Mackenzie Valley forms a narrow, elongate structural basin lying between the Franklin Mountains on the east and the Mackenzie Mountains on the west. This north-northwesterly trending synclinorium is characterized by gently to moderately and locally intensely folded and faulted structures parallel to the structures in the Mackenzie and Franklin Mountains. Folds at the surface are defined mainly in rocks of Upper Devonian and younger age. Thus, Middle Devonian and older strata, which contain promising reservoirs, are buried in the subsurface.

PART II

SEISMIC EXPLORATION

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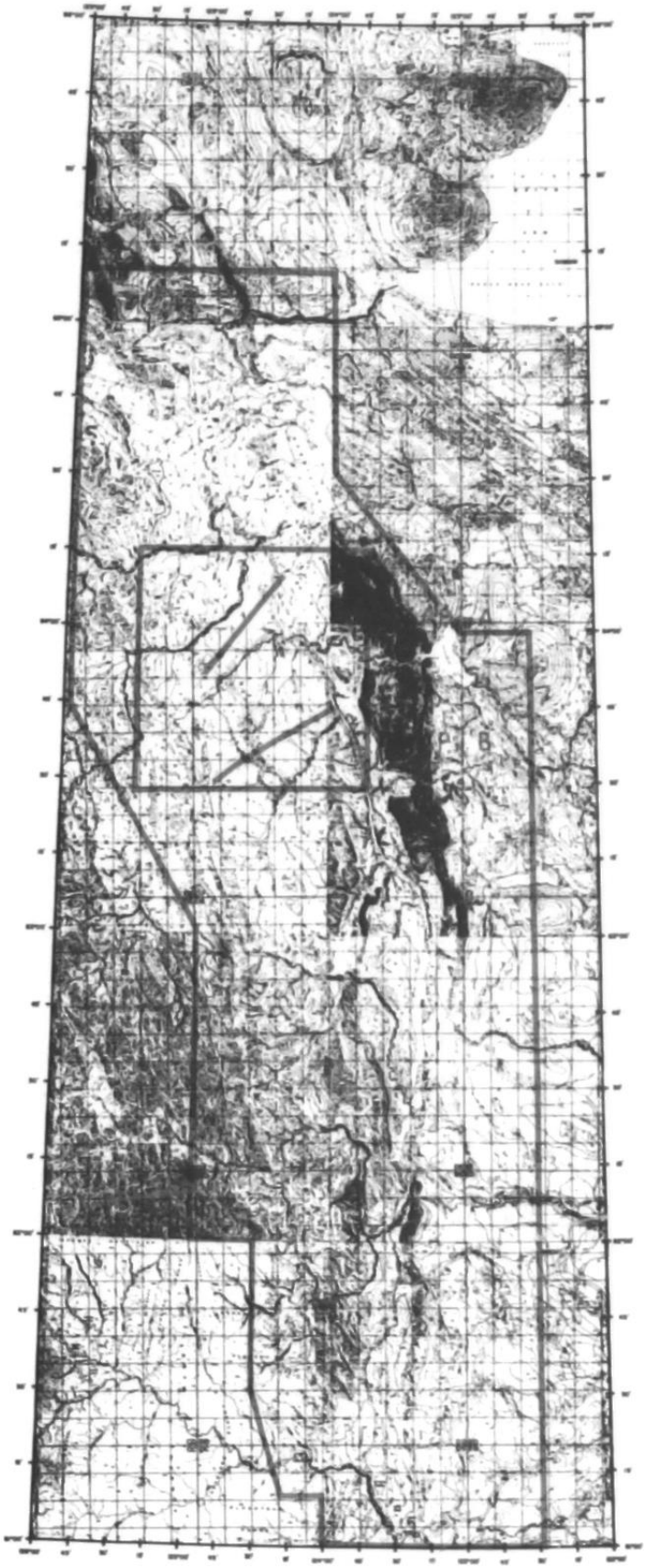


PROJECT SEVEN

REDSTONE

PART II

SEISMIC EXPLORATION

EXPLORATION PROGRAM

This report presents the interpretive results and field techique summary of the Redstone Project of Operation Geoquest.

The survey consisted of two lines, each approximately 35 miles of continuous in-line refraction profiling, augmented by several broadside profiles recorded at selected spreads on the in-line cable layout.

The field operations commenced in late July, 1968, and were completed in late August, 1968.

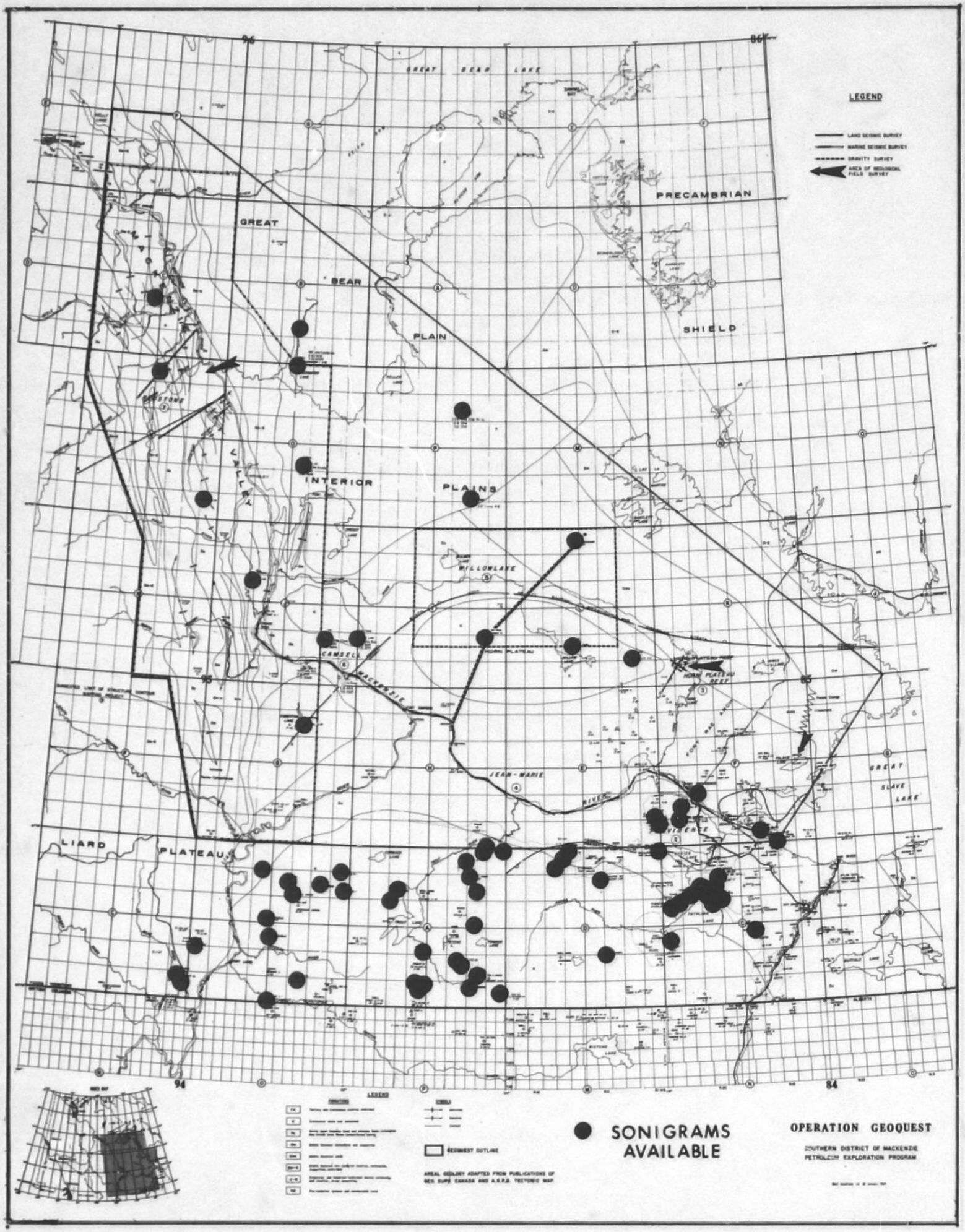
The field work was performed by Petroleum Geophysics Division, Kenting Exploration Services Limited, while field supervision and interpretation was handled by Canwest Geophysical Limited.

Major geographic features in the vicinity of the geophysical program include the Mackenzie River on the east, the Redstone River on the north, the Johnson River on the south and the Mackenzie Mountains on the west.

Surface topography varies from low lying muskeg-covered plains on the east to foothills and mountainous terrain on the west.

The objective of the survey was to map the Middle Devonian carbonate section by the refraction method to gain more knowledge of its structural attitude in the area.

The quality of the in-line data from Line 1 was generally good. The only exceptions were caused by surface conditions, usually muskeg, as at shotpoint 123. The quality of the data on Line 2 was also generally good. The continuity of these lines had to be broken between shotpoints 299 and 309 because of muskeg which could not be negotiated to lay cable. The broadside shots into Line 1 yielded fair data and those shot into Line 2 were good.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DISCUSSION OF RESULTS

The main feature of both Lines 1 and 2 is the syncline located near the middle of both lines with the section above the Middle Devonian carbonate marker horizon thinning toward the northeast and southwest ends of the lines and the Middle Devonian carbonate section rising in these directions. Line 1 is controlled by the Shell Cloverleaf I-46 well at about shotpoint 277.

As indicated by the table in Appendix VI under "Procedures", the velocities on the Sonigram taken at the well agree quite well with the velocities indicated on the refraction profile. Also the depth computed for the high-velocity refracting surface at shotpoint 277 agrees quite well with the major velocity break on the Sonigram, identified as the Hume limestone. A velocity break in the refraction profile from approximately 10,500 feet per second to 14,000 feet per second was interpreted to correlate with top of the Upper Devonian Imperial Formation as based on the operator's picks. A depth calculated from the survey for this break disagreed with the depth logged on the Sonigram. However, the intercept time used in the calculation was rather questionable and an increase of about 0.010 to 0.015 second in this time would give a close tie.

This same velocity break is seen on all parts of Line 1, but at shotpoint 343 it is shallow and less distinct. No measure of the depth could be made at this point. Elsewhere, sediments overlying the Imperial appear to range in thickness from about 500 feet at the southwest end of the line to a maximum of about 4,500 feet near shotpoint 255 and about 2,000 feet northeast of shotpoint 189. The depth of the Imperial Formation could be questioned since no reverse time checks were recorded on this marker. Control on the Middle Devonian carbonate marker was more reliable, as reverse coverage was obtained on it over most of the line.

The limitations of accuracy of the shape and depth of the two profiles are governed by three or four main factors. Estimates of the depth of the various refracting levels are controlled by the amount of reverse shooting detail obtained for each refractor.

Faulting, and dips approaching the critical angle of refraction, both affect the accuracy of the measurements. More detailed shooting would be required to improve the results. The considerable depths involved made it difficult to stay "on the marker" with the offsets used. This is true of Line 2 in particular, and the depth of the marker beneath this line is probably deeper than shown. On Line 1 it is felt that the depth of the marker at its deepest point is more nearly as shown.

CONCLUSIONS

It was concluded that the objective of the survey was satisfied within the limits of the data acquired. The Middle Devonian carbonate section was mapped continuously on most of Line 1 and on enough of Line 2 to indicate its structural attitude satisfactorily. It was shown to assume a synclinal attitude to the east of the Dahadinni Range. The Dahadinni Range plunges to the north in the vicinity of the southwest end of Line 1. This end of the line shows that the shape of the range persists under Line 1 at a depth of approximately 1,500 to 2,000 feet below the surface and is probably faulted. The formation dips in an easterly direction to reach a depth of approximately 6,000 feet subsea under Line 1 and to a depth probably exceeding 6,500 feet subsea below Line 2 before rising again to a depth approximately 1,500 to 2,000 feet subsea below each line.

By: H. E. Bowman,
Interpretations Manager.

CANWEST GEOPHYSICAL LIMITED

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GRAVITY EXPLORATION

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PART III

GRAVITY EXPLORATION

INTRODUCTION

Gravity survey data was used to assess structure of Middle Devonian carbonates in an area bounded by the Keele and Johnson Rivers in the Northwest Territories. The survey consisted of two lines 37.5 and 32.5 miles long with stations at intervals of 600 feet. Seismic refraction lines were followed in a southwest direction beginning at the Mackenzie River. On the basis of a calculated 0.4 gm/cm^3 density contrast between carbonates and overlying shales, interpretation of the Bouguer gravity profiles suggests that the shale/carbonate interface has been deformed by major thrust and normal faulting in addition to folding. Vertical displacement at these faults is in the order of 3,000 feet.

Although the lines are 25 miles apart, a good deal of structural similarity is common to the two lines. The results of an interpretation of the gravity data show good correspondence to the refraction seismic survey interpretation. The gravity method, however, appears to have provided increased resolution of faulting. Application of gravity surveying in this area is strongly recommended because of the strong gravitational response of elevation of the Middle Devonian shale/carbonate interface.

RESIDUAL ANOMALY

REGIONAL ANOMALY

REGIONAL ANOMALY

RESIDUAL ANOMALY

Calculated residual anomaly

SOUTHWEST

NORTHEAST

TOPOGRAPHY

SHELL CLOVERLEAF I-H6

TOPOGRAPHY

SHALE
CARBONATES

GRAVITY INTERPRETATION

REFRACTION PROFILE

SHALE
CARBONATES

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OPERATION GEOQUEST

NORTHWEST TERRITORIES OF CANADA

REDSTONE
INTERPRETATION

ONE THOUSAND METER
UNIVERSAL TRANSVERSE MERCATOR GRID

LINE 1

(S) 1 ..... Gravity meter base station

(S) 2 ..... Gravity meter station

CONCLUSIONS

From well logging it has been shown that the Middle Devonian shale/carbonate contact is also a major density interface. The density contrast at this interface is 0.4 gm/cm^3. On the basis of this information, the analysis of the gravity data indicates that a considerable amount of structural deformation of Middle Devonian strata has occurred. This deformation appears to involve thrust faulting, folding and normal faulting, particularly within the central part of the profiles 1 and 2.

Thrust faulting appears to have caused elevation of the shale/carbonate interface from a depth of about 5,000 feet below sea level to about 500 feet above sea level. Interpreted normal faults are associated with vertical throws in the order of 2,000 to 2,500 feet. Normal faulting is most evident in the northeastern parts of the two gravity lines.

A good deal of structural similarity is evidenced in the two gravity lines which are 25 miles apart. The gravity method, however, appears to have provided structural detail, particularly faults, that were not evident on the seismic refraction profiles.

With additional information, such as that provided by well logging, it may be possible to down or up grade gravity features that take on lesser or greater significance than was first apparent to the interpreter.

By: A. Spector, Ph.D., P. Eng.,
Senior Geophysicist.

HUNTEC DIVISION, Toronto

SOUTHWEST

REGIONAL ANOMALY

TOPOGRAPHY

RESIDUAL ANOMALY

SHALE
CARBONATES

NORTHEAST

REGIONAL ANOMALY

RESIDUAL ANOMALY

Calculated residual anomaly

TOPOGRAPHY

MACKENZIE RIVER

REFRACTION PROFILE

GRAVITY INTERPRETATION

SHALE
CARBONATES

ELEVATION - FEET

REGIONAL ANOMALY - MILLIGALS

RESIDUAL ANOMALY - MILLIGALS

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OPERATION GEOQUEST

NORTHWEST TERRITORIES OF CANADA

REDSTONE

INTERPRETATION

ONE THOUSAND METER
UNIVERSAL TRANSVERSE MERCATOR GRID

LINE 2

1010 ..... Gravity meter base station

Z10 ..... Gravity meter station

Surveyed & Interpreted by:
HUNTEC LIMITED, Toronto, Canada - January, 1968
Job No. PW68/05

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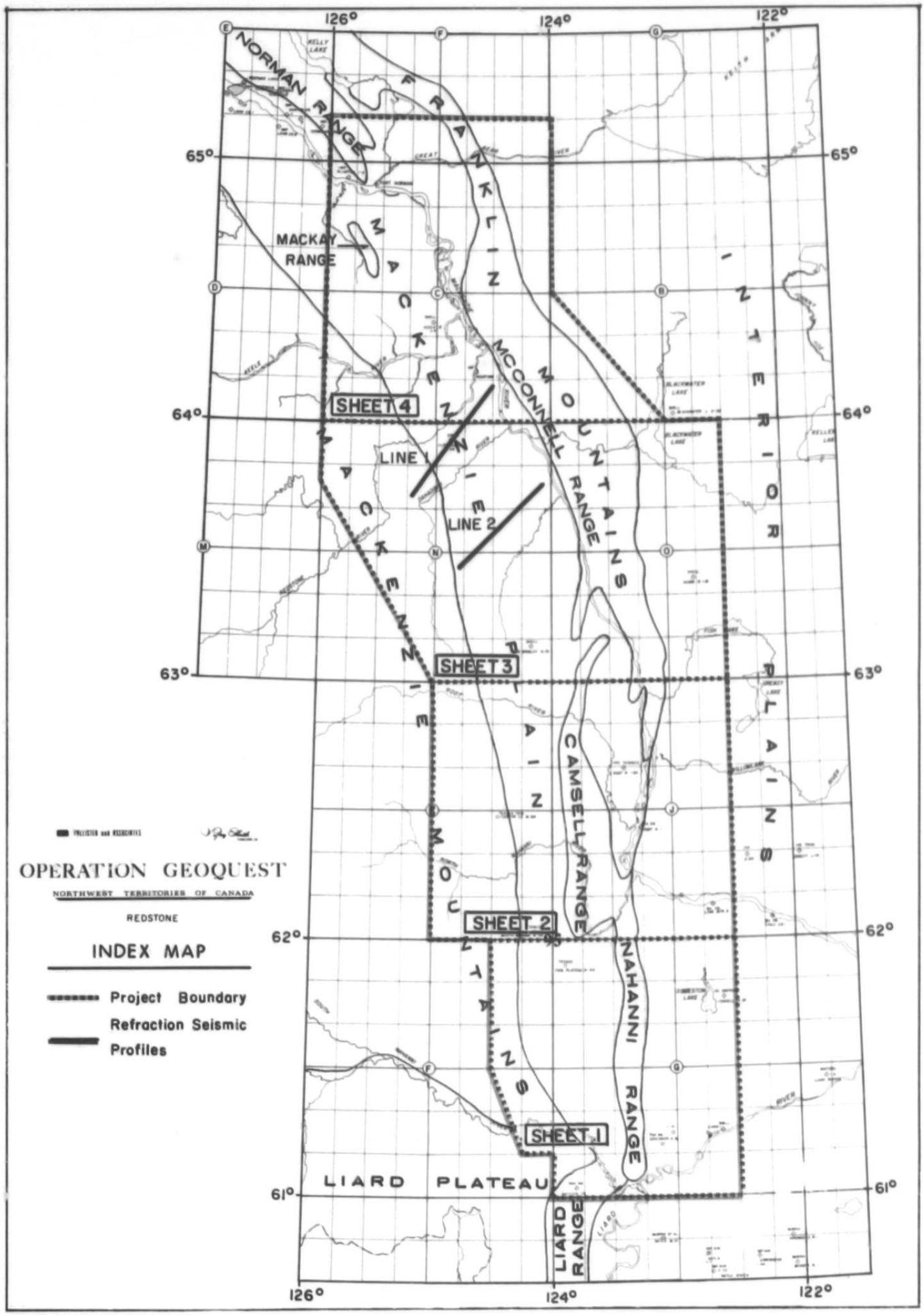
126°
124°
122°
65°
64°
63°
62°
61°
NORMAN RANGE
FRANKLIN MOUNTAINS
MACKAY RANGE
MACKENZIE MOUNTAINS
MACKENZIE
McCONNELL RANGE
INTERIOR PLAINS
SHEET 4
SHEET 3
SHEET 2
SHEET 1
LINE 1
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CAMSELL RANGE
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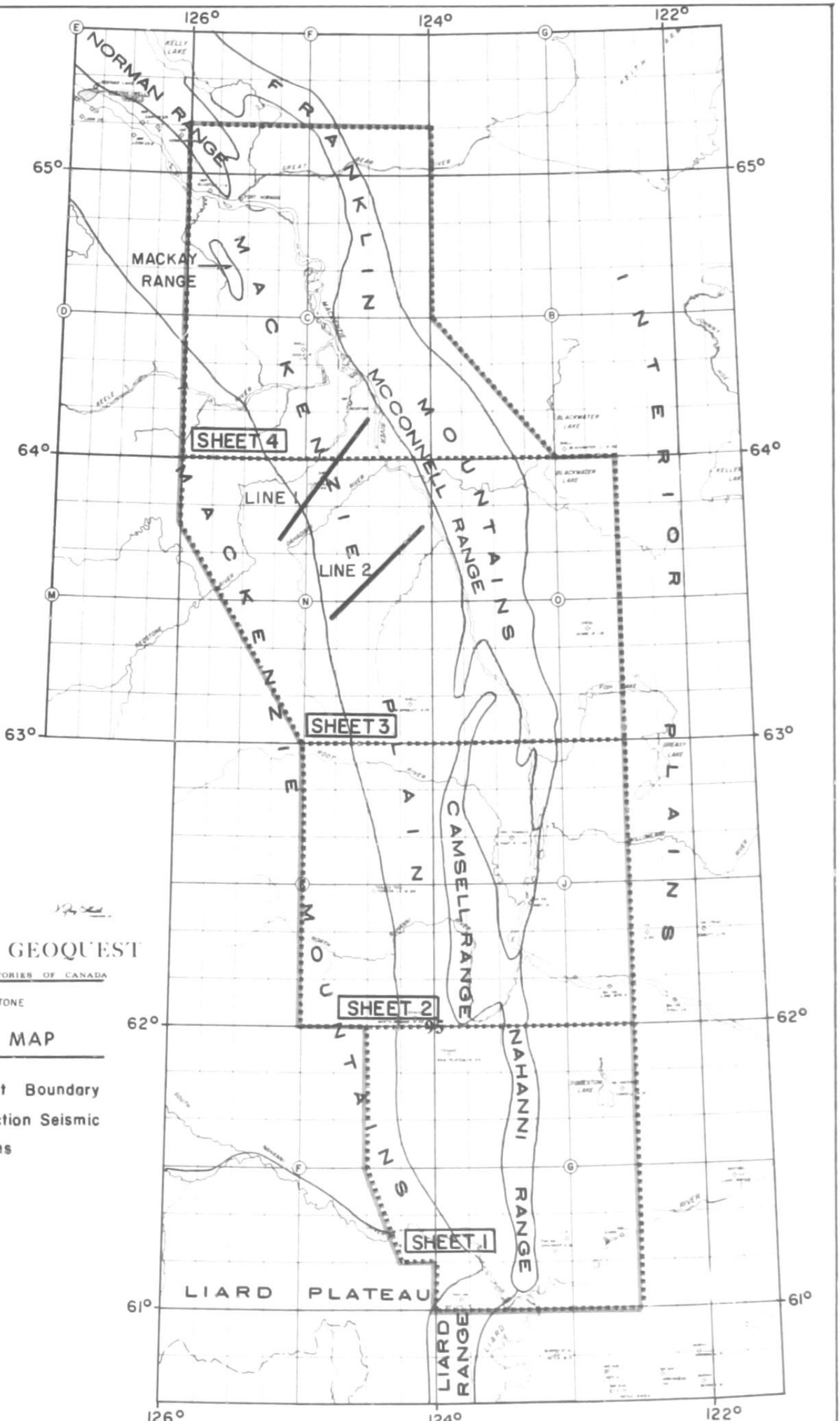

PRINCIPAL AND ASSOCIATES

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NORTHWEST TERRITORIES OF CANADA

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PART IV

GEOLOGIC EXPLORATION

INTRODUCTION

The aim of this program is to construct a set of structure contour maps of the top of the Middle Devonian Nahanni (Hume) Formation covering the area shown on the opposite page. Quantitative data necessary for the compilation of the maps were derived through the use of a multiplex photogrammetric plotter and the incorporation of refraction seismic profiles in the Mackenzie Plain. The latter are oriented approximately normal to structural fabric in an area of poor surface bedrock expression, thus providing valuable quantitative information in a part of the area which is otherwise poorly adaptable to photogrammetric mapping.

The program, referred to as the Redstone Project of Operation Geoquest, encompasses an area of 23,000 square miles in the southwestern part of the Northwest Territories. Three primary physiographic subdivisions, the Mackenzie and Franklin Mountains and the intervening Mackenzie Plain, are included. Portions of the western Interior Plains lie within the eastern map area.

The Redstone Project demonstrates the effectiveness of combining geophysical and geological techniques in structural mapping programs. The mapping incorporates surface and subsurface data from a variety of sources to provide an integrated quantitative structural interpretation. Well data, photogeologic and photogrammetric mapping, field observations, data from two refraction seismic and gravity profiles, and information from various published and open file sources, are included.

The evaluation maps portray areal geology and show geologic structure by means of contours drawn on the top of the Middle Devonian Nahanni (Hume) Formation. They depict the location, trend, size and shape of the various geologic features. The magnitude of closures and the degree of throw on faults are shown, as well as the axial surface traces of anticlines and synclines, location of faults, dips and formational boundaries, and other pertinent geologic detail.

Structure datum elevations of control points are derived from the use of a multiplex plotter, refraction seismic profiles, and published well top elevations.

The top of the Nahanni Formation of Middle Devonian age was selected as the datum horizon because it is a persistent unit present over most of the area. It is well expressed in surface exposures and most accurately reflects the structure of the Middle Devonian and older carbonates which provide the prime potential reservoirs in the area. Also important is the suitability of the Nahanni Formation as a marker horizon for geophysical studies.

METHODS

The program began with a photogeologic study of the area using vertical airphotos obtained from the Dominion government. Photo coverage in NTS blocks 95F, G, J, K, and N, were flown during the period 1961 to 1964 at a scale of approximately 1 inch to 1 mile. The photographs were taken with a six inch focal length camera along east-west flight lines. The remainder of the area is covered with north-south photography at a scale of approximately 1 inch to 3,000 feet taken during the period 1949 to 1952, also with a six inch focal length lens.

Photogeologic mapping provided the areal geology and pinpointed problem areas for field checking. During the photogeologic interpretation phase, a series of key flights of airphotos were selected for quantitative multiplex mapping. These were chosen so as to provide the maximum amount of information and included 1/3 to 1/2 of the total coverage within any given area of good surface outcrop expression.

During the period August 9 - 17, 1968, a structural field check was conducted by V. Zay Smith Associates Ltd. to confirm the photogeologic structural interpretation, to clarify structural relationships in problem areas, and to provide supplementary dip information in areas lacking good surface expression. Useful information was obtained during this phase of the program especially along stream channels where bedding is exposed by erosion but often is not visible on air photographs.

The structural check consisted of a low-level reconnaissance study using a fixed-wing aircraft and by detailed work using a helicopter.

During the field work a series of colored photographs were taken in the area, some of which are shown on Plates 1 thru 9 at the end of this section.

After incorporation of the field work data, the multiplex plotter was used to map the geology of the key strips selected earlier. The multiplex is a photogrammetric plotter that projects the images of air photographs so the terrain can be viewed in three dimensions. These "models" are set up in the plotter to a selected scale allowing measurement of horizontal and vertical distances and elevations. The use of such quantitative information permits the calculation of stratigraphic thicknesses and elevations of key horizons.

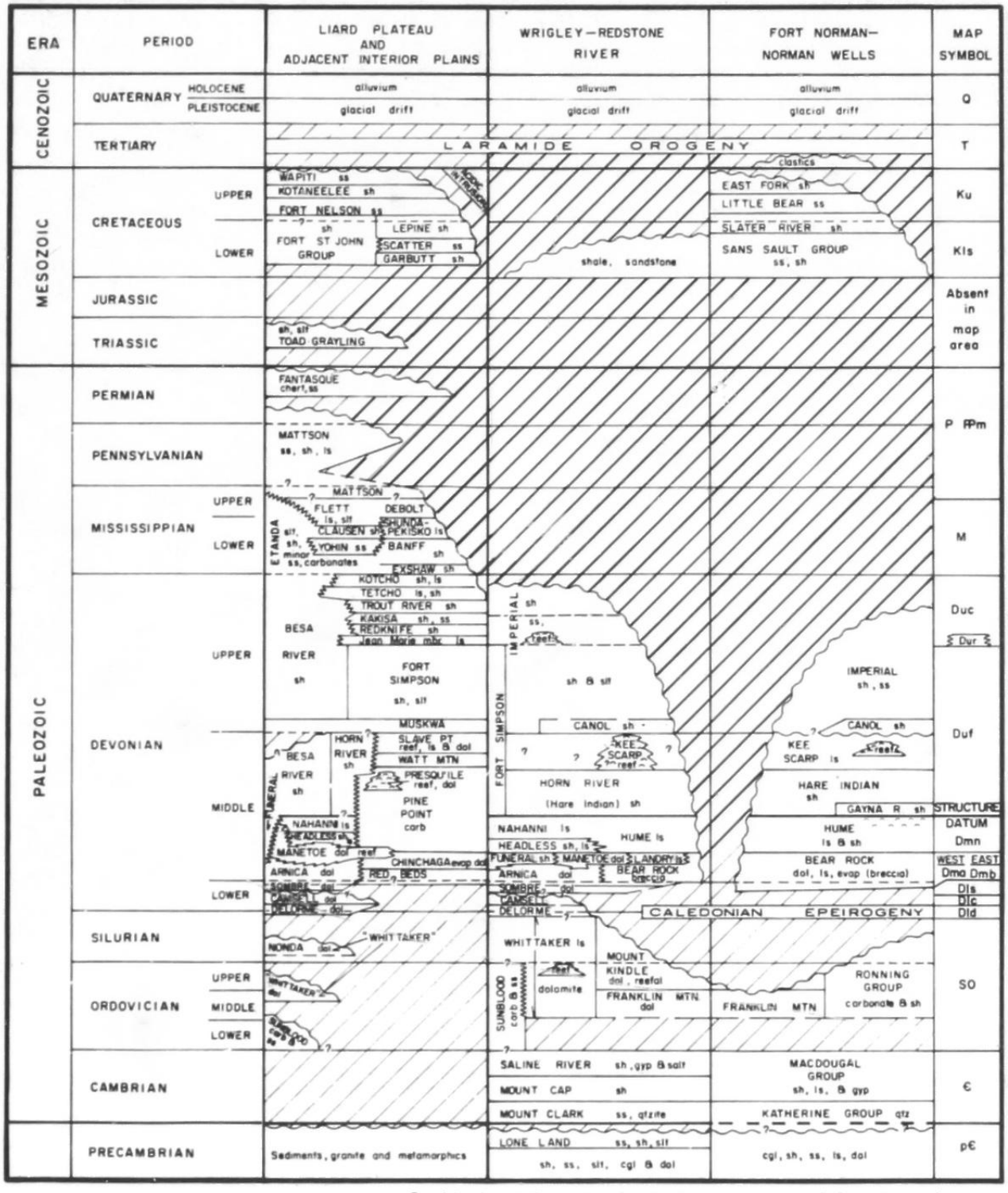
Supplementary elevations were derived from topographic maps obtained from the Dominion government.

In some cases it was necessary to construct isopach maps using formational thicknesses derived from photogrammetric measurements, well information and published field-measured thickness. The isopach maps were used to "reduce" ground elevations of key horizons to a common datum (top of Nahanni or Hume Formation). In a similar fashion, isopach values were used to restore the structure datum in areas where it has been removed by Tertiary and Quaternary erosion.

Multiplex work sheets were reduced photographically to a scale of 1 inch to 2 miles and incorporated into the photogeologic map. After conversion of control points to corresponding structure datum elevations, the values were contoured using intervals of 500 feet, 1,000 feet or 5,000 feet depending on the complexity of structure and steepness of dip.

Four map sheets cover the entire area and are numbered from south to north. Each sheet is accompanied by a geologic cross section reflecting the quantitative data acquired during the mapping to provide a more graphic picture of the geologic structure. The cross sections are shown at a horizontal and vertical scale of 1 inch to 2 miles. They were constructed from geologic topographic profiles compiled with the multiplex plotter.

In the Mackenzie Plain some control points were obtained directly from seismic profiles. These provided valuable control for contouring in the northern part of Sheet 3 and the southern part of Sheet 4 where poor surface expression of bedrock prevents effective use of photogrammetric mapping techniques. Details of the geophysical work are discussed in the Part II, Seismic Exploration section of this report.



STRATIGRAPHIC CORRELATION CHART

STRATIGRAPHY

The stratigraphic section includes formations ranging in age from Precambrian to Tertiary with variable amounts of unconsolidated glacial and alluvial deposits of Quaternary and Recent age. Rocks from all periods are represented in the stratigraphic column with the exception of Triassic and Jurassic sediments which are absent due to non-deposition or erosion. The Paleozoic sequence is comprised mainly of marine carbonates and clastics with some evaporites. Cretaceous rocks, the only representatives of the Mesozoic Era, are marine and non-marine shales, siltstones and sandstones. Quaternary alluvial deposits, glacial drift and Tertiary clastics make up the Cenozoic section.

Inspection of the Stratigraphic Correlation Chart (opposite page) reveals the effect of various periods of uplift and erosion on the overall distribution of sediments in the region. A miogeosynclinal depositional environment was fairly persistent in the Cordilleran region until the onset of the Laramide orogeny. Prior to that, periods of emergence and erosion were relatively minor.

The eastern edge of the project area includes part of the Interior Plains, a vast region of stable shelf depositional character throughout most of Paleozoic and Mesozoic time.

PRECAMBRIAN

Exposures of Precambrian rocks are known only in two locations within the project. In the vicinity of Cap Mountain on Sheet 3, sandstone, conglomerate and mudstone of the Lone Land Formation of Proterozoic age are underlain by older unnamed clastic units including mainly reddish brown and green shale, siltstone and sandstone. More than 5,000 feet of Precambrian rocks are exposed.

A small exposure of Precambrian strata is also mapped in the eastern Franklin Mountains on Sheet 4.

CAMBRIAN

In the Franklin Mountains Cambrian rocks crop out in the vicinity of Cap Mountain, Blackwater Lake, and Mount Clark. Smaller exposures are present near the north end of McConnell Range and near Bear Rock in the southern Norman Range.

In the McConnel Range, Douglas and Norris (1963), measured 450 feet of fine-grained sandstone of the Mount Clark Formation resting unconformably on the Precambrian Lone Land Formation.

The overlying Mount Cap Formation consists of around 200 feet of green and red shales and sandstones. Youngest of the Cambrian rocks are the red and green shales of the Saline River Formation which locally contains gypsum and salt. Thick sequences of inter-bedded salt and varicolored shales encountered in Shell Keele River L-4 on the lower Keele River and in Imperial Vermillion Ridge No. 1, approximately 20 miles northwest of Fort Norman (beyond the project boundary) are thought to be Saline River Formation or its equivalent and to indicate the presence of a Cambrian evaporitic basin.

SILURIAN AND ORDOVICIAN

The presence of a persistent depositional environment existing in Silurian and Ordovician times produced a thick, monotonous succession of dolomites with some limestone and occasional clastics.

In the western project area the Silurian-Ordovician sequence includes, in ascending order, the Sunblood, Whittaker, and lower Delorme Formations. The Sunblood is comprised of up to 5,500 feet of limestone and sandy dolomite with occasional sandstones. Weathering typically imparts an orange to reddish color to the Sunblood Formation. The basal Sunblood contact with the underlying Cambrian clastics may be unconformable.

The Silurian-Ordovician sequence is generally referred to as the Franklin Mountains and overlying Mount Kindle Formations in the northern and eastern project area.

The Whittaker Formation, consisting of dark grey limestones and dolomites and calcareous shales, conformably overlies the Sunblood Formation and attains thicknesses of 3,000 to 4,000 feet in the western map area. The lower part of the Whittaker Formation is mainly a massive carbonate unit and the upper portion consists of more recessive shaly limestones and siltstones. Whittaker dolomites are often fossiliferous and in places have been described as reefoid. Good porosity has been reported in a number of locations.

In the Cordilleran region, the Delorme Formation may straddle the Silurian-Devonian boundary. The Delorme Formation includes mainly thin bedded carbonates and shales conformably resting upon the Whittaker Formation. Fossil evidence indicates a probable Upper Silurian age for the lower part of the Delorme but does not allow exact placement of the Devonian-Silurian boundary. On the Delorme Range in the Mackenzie Mountains, the Delorme Formation attains a thickness of 650 feet.

In the Franklin Mountains the Silurian-Ordovician carbonate sequence is referred to as the Franklin Mountain Formation in the lower part, which consists of grey, fine-grained, occasionally silty dolomite and some limestone. Massive grey dolomites of the Mount Kindle Formation conformably overlie the Franklin Mountain Formation. The Mount Kindle - Franklin Mountain contact is gradational and poorly expressed. Porous zones are reported in surface exposures and in well samples in the region. Reefal developments also occur within the Mount Kindle.

LOWER DEVONIAN

As mentioned earlier, fossil evidence indicates a Silurian age for at least the lower part of the Delorme Formation while Devonian fauna are reported a few hundred feet above the base of the formation. The Delorme has been bevelled in an easterly direction by a pre-Middle Devonian erosional interval, probably connected with the Caledonian epeirogeny. In the southwestern project area, the Delorme Formation is overlain by the Camsell and Sombre Formations forming a thick monotonous succession of dolomites. The Arnica Formation is also composed of fine grained dolomites, resting with apparent conformity on the Sombre Formation and is probably of Lower Devonian age in the lower part. The Lower Devonian sequence attains maximum thicknesses on the order of 6,000 feet in the western project area.

The Camsell and Delorme Formations are bevelled in an easterly and northeasterly direction in the subsurface and are absent in the Franklin Mountains to the east where the Bear Rock Formation rests on Silurian-Ordovician carbonates.

MIDDLE DEVONIAN

The Arnica Formation, usually 1,000 to 2,000 feet thick in the southwestern project area, consists of fine grained, dark grey to black, banded dolomites which grade northeasterly to brecciated carbonates of the Bear Rock Formation.

The laterally equivalent Funeral and Manetoe Formations rest on the Arnica dolomites in the southwestern map area and are approximately equivalent to the Landry limestone and upper Bear Rock Formation to the northeast. The Funeral consists of argillaceous limestones, commonly in excess of 1,000 feet in thickness. Dolomites of the Manetoe Formation are notably vuggy, usually several hundred feet thick, and appear quite favorable as a reservoir rock. The northeasterly equivalent of the Manetoe Formation is the crypto to medium-grained limestone referred to as the Landry Formation.

In the northeastern project area the Bear Rock Formation rests unconformably on carbonates of Silurian and Ordovician age and is conformably overlain by the Hume Formation. Maximum thicknesses of Bear Rock Formation are in the order of 1,000 to 2,000 feet comprised mainly of brecciated dolomites with some limestone and evaporites.

The youngest persistent Middle Devonian carbonate sequence in the region is the Nahanni Formation, usually referred to in the northern project area as the Hume Formation. The Nahanni or Hume Formation is comprised of fine to medium-grained grey limestones, massive and thick bedded and fossiliferous. In much of the southwestern map area the lower part of the Hume Formation contains argillaceous limestones and shales usually less than 200 feet thick known as the Headless Formation.

The Hume Formation is characterized by a very fossiliferous upper unit which is locally reefal, a shaly more recessive unit in the middle part and a lower limestone containing abundant brachiopod fauna.

A short distance southwest of the map area, the Nahanni Formation undergoes a southwestward facies change to shales and is included in the lower part of the Besa River Formation.

The Nahanni Formation provides an easily identifiable and well expressed marker unit within the project area thus providing an excellent structure datum. Shales of the Middle Devonian Horn River Formation overlie the Hume Formation over most of the region, attaining a maximum thickness of 725 feet near Redstone River in the western part of Sheet 3. In most places it is 200 to 300 feet thick. In the Fort Norman region, shales equivalent to the Horn River are referred to as the Hare Indian Formation. The Hare Indian Formation is overlain by the Kee Scarp Formation, a reefal carbonate which forms the reservoir rock at the Norman Wells oilfield approximately 40 miles northwest of Fort Norman.

UPPER DEVONIAN

The Horn River and Hare Indian shales, where present, are mapped with the Fort Simpson Formation, a widespread, thick sequence of shales and siltstones ranging in thickness most commonly from 2,000 to 3,000 feet. In the southern part of Sheet 1 the Fort Simpson is usually inseparable on air photographs from Middle Devonian Horn River and Besa River shales and attains a thickness in excess of 4,500 feet.

The Fort Simpson shales are conformably overlain by a thick poorly expressed to moderately well expressed, unnamed sequence of sandstones and shales. In or near the base of these clastics, reefal limestone units of Upper Devonian age are often encountered in the Mackenzie Plain. This reefal unit is designated 'Dur' on the maps and is encountered between Root and Mackenzie Rivers on Sheet 2 on the flanks of the Root River anticline. Occurrences are also noted on the west flank of the Camsell Range along Carlson Creek and on the Root River where they clearly define a northwesterly plunging anticlinal nose. A short distance to the north on Sheet 3 they also crop out on the flanks of Wrigley and West Wrigley anticlines.

Thickness measurements made with the multiplex and those obtained from published and open file sources reveal a westward thinning in the Fort Simpson Formation from 3,000 feet or more in the vicinity of Nahanni, Camsell and Dahadinni Ranges on Sheets 1, 2 and 3 respectively, to less than 2,000 feet in some parts of the western project area. Since the nature of the relationship between the Fort Simpson Formation and the overlying unnamed clastic units is poorly understood, the cause of the westward thinning cannot be definitely determined. It appears likely that the thinning is depositional in nature in view of the fact that erosional intervals at the end of Fort Simpson time are unknown in the region.

In the vicinity of Sheets 3 and 4, Upper Devonian beds were truncated by a period of uplift and erosion prior to Cretaceous and Tertiary deposition. Lack of knowledge concerning the shape of the unconformable surface poses a problem for structural mapping in the northern Mackenzie Plain in places where the basal Cretaceous contact offers the only available surface control. For this reason, the seismic profiles in that area were of particular value for contouring control.

Seismic and surface geologic information suggested the presence of a greater thickness of Upper Devonian sediments than indicated by released formational tops in Shell Cloverleaf I-46. Since all released tops of the contacts are inferred, a detailed lithologic log was made by inspection of samples stored in Calgary. Microfossil evidence indicates the contact could be present anywhere below 930 feet in the hole because this is the first occurrence of Ceramid, a small Cretaceous pelecypod. Since a pick cannot be made on the basis of lithology, the contact for the purpose of structure contouring was placed at that depth giving a total thickness of 4,590 feet of Devonian beds as opposed to 3,025 feet based on operator's tops.

The Cretaceous - Upper Devonian contact referred to in the discussion of seismic and gravity work coincides with the operator's pick which is coincident with a velocity and density interface. The interface may, however, be within the Upper Devonian section.

On Sheet 4, truncation during the pre-Cretaceous erosional interval has apparently been quite severe as indicated by the Keele River L-4 dry hole in which Cretaceous beds rest directly on the Saline River Formation of Cambrian age.

Thirty-five miles to the north near Police Island on the Mackenzie River, Tertiary beds were observed resting on the Middle Devonian Bear Rock Formation indicating the absence of the Hume Formation in that area also. Unconformable relationships have also been noted in the Redstone River area near latitude 64°N. (Douglas and Norris, 1963). According to Douglas and Norris, shales which they believe to be of Cretaceous age are resting on the Fort Simpson Formation while 15 miles to the southwest the Fort Simpson Formation is overlain by around 5,000 feet of Upper Devonian clastics.

The above evidence strongly suggests the existence of a structural trend, oriented approximately to the north extending from the vicinity of the Redstone River across the lower reaches of Keele River to Police Island on the Mackenzie River and beyond. Uplift along this structural trend, sometime between late Upper Devonian and the beginning of Cretaceous time, resulted in moderate to severe bevelling of Upper Devonian and older rocks.

At present, the areal extent of this structural trend and the severity of stratigraphic truncation is largely unknown. An appropriate symbol has been used on Sheet 4 to suggest the probable maximum extent of the post-Devonian, pre-Cretaceous deformation. The Hume Formation may be locally absent due to such uplift and erosion. Because of the possible absence of the structure datum in the area, and due to lack of control, structure contours are not shown on the portion of the map so affected. Instead, structural form lines are used to show the configuration of the Tertiary surface rocks in that part of the area.

MISSISSIPPIAN

Mississippian rocks are mainly confined to the Yohin syncline on Sheet 1 and a small occurrence on the northerly extension of Yohin syncline on Sheet 2.

The Mississippian sequence includes, in ascending order, the Yohin Formation, consisting mainly of sandstone; the Clausen Formation, a shale unit; and the Flett Formation containing mainly limestone. Maximum thickness of the three units within the project area is in the order of 2,600 feet. The moderately to strongly resistent nature of the Mississippian beds provides good structural control along the flanks of the Yohin syncline.

Immediately southwest of the project area the Yohin, Clausen and Flett Formations grade laterally to the shales of the Upper Bear River Formation.

PERMIAN AND PENNSYLVANIAN

The age of the Mattson Formation has been the subject of considerable speculation because definitive fossil evidence is lacking. It has been generally accepted that the Mattson includes beds of Mississippian, Pennsylvanian and Permian age as shown on the accompanying stratigraphic correlation chart, although such dating was quite speculative. Recent work by Bamber et al (1968) suggests the Mattson Formation to be primarily of

Mississippian age and to contain few if any, Pennsylvanian beds. He equates the Permian Kindle Formation of northeastern British Columbia with the upper part of the Mattson Formation in the Liard Plateau region. Within the map area, upper Mattson beds occur only in the extreme southwest corner of Sheet 1.

As in the case of Mississippian beds, the Mattson Formation is restricted to the southern project area where it provides good local structural control due to its moderately to strongly resistant character. Over 3,000 feet of Mattson has been measured on Yohin Ridge consisting mainly of fine-grained, light grey sandstone weathering yellowish brown in the lower part, fine and medium-grained light brown sandstones weathering tan to brown in the central part, and interbedded calcareous sandstones and fossiliferous limestones in the upper part.

A short distance south of the map area, the Fantasque Formation consisting of bedded chert and sandstone up to a few hundred feet thick, rests unconformably on the Mattson and is believed to be Permian in age. The Fantasque Formation has probably been entirely removed by pre-Cretaceous erosion in the project area. If present, it would be restricted to the southern part of Sheet 1 and included with the Mattson Formation on the map.

CRETACEOUS

Prior to the onset of Cretaceous deposition a widespread erosional interval stripped away any Triassic and Jurassic units which may have been present within the Redstone Project.

Within the map area both Upper and Lower Cretaceous beds are present. In the south, the Fort St. John Group consisting of poorly resistant shales, siltstones and sandstones, blankets much of the Interior Plains east of the Franklin Mountains. Because of the generally poor surface expression and the more gently folded character of Interior Plains structure, contacts are generalized and control points are sparse.

The extent of Upper Cretaceous beds is unknown but they have been described on Great Bear River near the eastern edge of the project and a short distance west and southwest of Fort Norman where they include shales and sandstones of the Lower Cretaceous Sans Sault Group and Slater River Formation and Upper Cretaceous beds including the upper portion of the Slater River Formation, sandstones of the Little Bear Formation and overlying shales of the East Fork Formation.

In the northern Mackenzie Plain and in the Interior Plains north of latitude 64°N., Cretaceous beds are mapped as a combined unit designated by the letter K.

TERTIARY

Tertiary sediments in the Fort Norman region attain a thickness on the order of 5,000 feet at the south end of MacKay Range. Included are sandstones, gravels, mudstones, siltstones and shales often with coal and lignite seams.

Numerous well preserved fossil leaves indicate an Eocene age for these deposits which resulted from clastic shedding in adjacent areas of Laramide uplift.

QUATERNARY

Quaternary deposits within the map area are generally thin and mainly confined to alluvial deposits in the valleys of the major drainages and glacial drift which is widespread in the Interior Plains and in the northern part of Sheet 4.

STRUCTURAL GEOLOGY

INTRODUCTION

The Redstone Project encompasses parts of three structural provinces which are coincident with the physiographic provinces described earlier. These include part of the Mackenzie Mountains in the west, the Mackenzie Plain in the central portion of the map area, bounded on the east by the Franklin Mountains including, from south to north, the Nahanni, Camsell, McConnell and Norman Ranges. Low-lying terrain along the eastern edge of the project area is part of the Interior Plains.

Structural deformation within the various provinces varies from mild to intense and is usually a product of the Laramide orogeny. In most places deformation appears to affect the entire stratigraphic section with the exception of the Quaternary deposits. In view of the time of such folding it has been demonstrated that geologic structure visible at the surface accurately reflects that which is present in the subsurface. Confirmation of this is seen in numerous places where surface folds can be traced from areas of early Paleozoic rocks through progressively younger strata into Cretaceous and Tertiary terranes. In such instances, rocks of all ages are equally affected.

Such evidence demonstrates the validity of predicting geologic structure in older strata of the subsurface on the basis of structures visible in younger rocks at the surface. Structural mapping can be done most effectively by the use of photogrammetric plotting instruments which allow direct measurement of elevations and stratigraphic thicknesses within the projected airphoto image as described in the section entitled "Methods".

The Redstone Project area as a whole lends itself quite well to such an approach although in some areas mapping is hampered by the lack of topographic expression and areas mantled by a veneer of glacial drift or alluvium as in the western Interior Plains. Difficulty is also encountered where non-resistant lithologies form surface bedrock over unusually large areas resulting in lack of morphologic surface expression.

The areal geologic interpretation shown on the accompanying maps depicts surface geology based on photogeologic features visible at the surface and do not in every case coincide with the configuration of the structure contours drawn on the underlying datum horizon. Surface traces of faults are shown, and these are considered to offset structure datum contours except where surface offset appears negligible. Many of the faults appear to be vertical or nearly vertical and are so depicted on the maps. For the purpose of contouring, thrust faults known to have moderately low angles in some places, are depicted as vertical to avoid unnecessary complexity of presentation.

The following discussion deals with the more significant aspects of the geologic structure in the various geologic provinces.

INTERIOR PLAINS

The character of geologic structure in the Interior Plains is largely responsible for the general lack of surface control since broad gentle folds of the type normally encountered there seldom form strongly expressed outcrop. A widespread veneer of glacial drift also tends to mask surface features in the Interior Plains.

Though control is sparse in most parts of the Interior Plains, certain broad features can be mapped on the basis of widespread relationships of formational contacts, elevations and released well top data. The broad gentle folds mapped in the eastern project area represent the transitional phase of structural activity between the strongly folded and faulted Cordilleran Region to the west and the relatively stable eastern Interior Plains.

A very broad structurally high area of regional magnitude is depicted on the eastern portion of Sheet 1, where regional westerly dip as little as 50 feet per mile defines the west flank of the Liard - Sibbeston uplift. The eastern part of the feature lies beyond the project boundary.

Farther north, in the area east of Camsell Bend and along Willowlake River, north-northeasterly folds are probably present in the subsurface and may be expected to range from gentle to moderate in intensity as suggested by the Willowlake anticline located eight miles east of the McConnell Range. Inspection of this feature suggests that faulting along the east flank is somewhat less important than folding in the area. From a maximum restored structure datum elevation on the order of 2,600 feet above sea level the axis plunges southerly to around 1,000 feet below sea level in the vicinity of Willowlake River where moderately steep opposing dips were observed in Devonian shales during the field check. Continuation of southerly plunge beyond this point can be expected in the subsurface. The fault, upthrown to the west, which borders the Willowlake structure on the east flank appears to involve relatively moderate displacement. The northern end of the trend displays several minor en echelon anticlines exhibiting an overall northerly plunge. Anticlinal trends similar to the Willowlake fold can be expected beneath Upper Devonian and Cretaceous cover in other parts of the extreme western Interior Plains. Contorted folding in Upper Devonian shales along the Willowlake River near the eastern edge of the map area was reported by Williams (1922).

Field observations show continuous easterly to southeasterly regional dip at the rate of 3° to 6° along Great Bear River east of Mount St. Charles.

FRANKLIN MOUNTAINS

The Franklin Mountains form a narrow, elongate, arcuate chain of mountain ranges extending southeasterly from the Norman Range to include the McConnell Range, Camsell Range and Nahanni Range which has its southern terminus at Nahanni Butte at the southern edge of the project area. The Franklin Mountains form the eastern limit of the Cordilleran belt and vary in width from approximately two to four miles in the Nahanni and Camsell Ranges to more than 20 miles in the central McConnell Range near latitude 62°N. The Franklins are moderately to strongly uplifted and in most cases are bounded on the east flank by a thrust fault upthrown to the west. South of Ochre River at latitude $63^{\circ}30'$N. the mountain trend separates in a vaguely en echelon fashion with the Camsell Range on the west and the southern end of the McConnell Range 20 miles farther east.

The southern terminus of the McConnell Range is located near the mouth of the Willowlake River.

Vertical displacement on thrust faults is commonly on the order of 8,000 to 10,000 feet and in some cases greater than 10,000 feet as in the vicinity of Cap Mountain where basal Cambrian beds attain an elevation of over 4,000 feet above sea level, resulting in a restored structure datum elevation well in excess of 10,000 feet. Beneath the Cambrian rocks is a broad exposure of more steeply dipping Precambrian beds. The divergence in dip between the two units suggests the presence of a strong angular unconformity. The only other exposure of Precambrian rocks noted in the project area also occurs in the McConnell Range just north of the Saline River. The exposure is much smaller than that in the Cap Mountain area.

The only major exposures of Cambrian rocks are also confined to the McConnell Range along with widespread exposures of Silurian-Ordovician and Devonian carbonates. Though the presence of such widespread exposures of older rocks suggests more intense tectonic activity and greater uplift than in the mountains to the west, inspection of the structural interpretation maps reveals that the magnitude of uplift in the western map area is greater in a number of places but because of a vastly greater thickness of the stratigraphic section, Cambrian and Precambrian rocks have not been exposed by subsequent erosion.

The Nahanni, Camsell and southern McConnell Ranges are characterized throughout most of their length by moderately to steeply westward dipping Middle Devonian carbonates whose resistent character provides well expressed dip slopes and strong topographic contrast with the recessive Middle and Upper Devonian shales to the west. The persistent west-facing slope is defined mainly by dips ranging from 20° to 40°. In many parts of the range westerly dip of this magnitude exists across the entire width of the mountain ridge while in other places drag folding along the leading edge of the overthrust sheet has produced anticlinal noses and a few relatively minor doubly plunging anticlines.

Transverse faults are present though usually of minor displacement with throws of less than a few hundred feet. A few accessory longitudinal faults can be seen west of the main thrust but are of local extent. Along the lower reaches of the South Nahanni River near Lone Mountain faulting has interrupted the regional structural fabric separating the northern Nahanni Range from the southern end of the Camsell Range. The exact character of the faulting is somewhat obscure due to widespread alluvial deposits. The Camsell thrust appears to swing abruptly parallel to the river valley and die out along the front of the Nahanni Range. The Nahanni thrust disappears immediately north of Lone Mountain and probably continues in the subsurface perhaps to merge with the subsurface extension of the McConnell Range structural trend.

As mentioned earlier, the Franklin Mountains become more complex north of the Lone Mountain area with the Camsell and McConnell Ranges separated by an intermontane basin more than 50 miles long and over 20 miles wide. Surface bedrock in the basin is the Upper Devonian Fort Simpson Formation and the overlying Upper Devonian clastic unit. The Upper Devonian reefal limestone overlies the Fort Simpson Formation in the central part of the Root River anticline where it locally provides good structural control. The Root River closure was tested by French Petroleum Tenneco Root River I-60 which bottomed in Precambrian at a depth of 8,571 feet. The hole tested salt water in the Manetoe and Bear Rock Formations.

Sixteen miles to the south, B.A.-H.B. Root River No. 1 was drilled on the east bank of the Mackenzie River but failed to reach the Middle Devonian carbonates.

The oval shaped anticline tested by Root River I-60 has an independent closure of around 500 feet and displays a maximum structure datum elevation of slightly less than 1,000 feet. The south end of the anticline is complicated by a transverse fault uplifted on the east. Northerly plunge on this segment of the axis is mapped but the existance of south plunge lacks good definition. From a structural saddle five miles north of Root River I-60, the axis rises to the north for a distance of five miles where it is intersected by a northeasterly trending fault upthrown on the northwest side. In the vicinity of the axis, throw on this fault may be on the order of 400 feet.

Northerly plunge may be present for a distance of two miles on the north side of the fault, though strong evidence is lacking. At this point the axis appears to be offset one mile to the northeast and then rises to an inferred apex 11 miles to the northwest.

From the inferred apex, northerly plunge has been observed in the field for a distance of approximately seven miles. Closure on this feature may be on the order of 500 feet.

The Root River anticlinal trend is separated from the McConnell Range by a synclinal trough with minimum structural datum elevations of below -4,000 feet. In the vicinity of Old Fort Island on the Mackenzie River, a branching segment of the McConnell Range swings southwestward from the main trend and disappears beneath the Upper Devonian shales at Old Fort Island. The ridge is bounded on the southeast by a thrust, upthrown to the northwest which may interrupt the synclinal trend in the subsurface.

North of latitude 63°N. the Franklin Mountains become more complex. West of Blackwater Lake they attain a width of 20 to 25 miles and faulting assumes greater importance. A medium to high angle thrust fault, upthrown to the west borders the mountains on the east. A number of longitudinal faults showing similar displacement are seen paralleling the main thrust several miles to the west. Numerous relatively minor transverse faults, varying in their direction of throw, can also be seen. The main thrust is parallelled in several places south of Blackwater Lake by moderately to steeply east dipping carbonates of the Middle Devonian Nahanni and Bear Rock Formations suggesting more minor displacement along the main thrust than encountered farther south.

Steeply west-dipping beds of the Nahanni Formation define the west flank of the McConnell Range where they are uplifted in a topogruphic ridge one to three miles in width bordered on the east by a longitudinal fault of moderate to strong displacement. This fault may represent an extension of the fault bordering the east flank of the Camsell Range and in the Mount Gaudet area near Wrigley.

The central part of the McConnell Range forms a moderately uplifted, broad upland with large mesa-like hills capped by Nahanni carbonates. Farther north, in the region around Saline River and Little Smith Creek, broad mantled areas are present and surface detail is obscured. North of Little Smith Creek, Bear Rock and Silurian-Ordovician beds are moderately well exposed and broken by a network of normal faults. In the Mount St. Charles area and south of Great Bear River, the McConnell Range once again becomes quite narrow. The segment south of the river is approximately 17 miles long and is bounded on the west by a fault upthrown to the east which places Silurian-Ordovician and Cambrian beds in contact with Tertiary deposits to the west. The east flank is defined by steeply to vertically dipping beds of the Nahanni Formation referred to as Hume Formation in this area. The fault relationship is unique compared to those observed in other parts of the range. Immediately north of the Great Bear River

up-to-the-west faulting along the east edge of the mountains is once again present. Transverse faulting in the vicinity of the river apparently separates the two segments.

The only other portion of the Franklin Mountains within the project area is the southern end of the Norman Range which terminates at Mackenzie River three miles west of Fort Norman. This portion of the range is also bordered on the east by a west dipping thrust fault which exposes Cambrian beds in the east face of the ridge. West-dipping Middle Devonian and Silurian-Ordovician carbonates are moderately to poorly expressed and show an overall regional dip ranging mainly from 4° to 15°. A few dips along the west edge of the Hume exposures range from 20 to 25°.

The Hume Formation is inferred to be absent in the area east of the Norman Range as indicated on the map. As discussed earlier the limits of this sub-Cretaceous erosional edge of the Hume Formation is highly speculative and based on sparse, widely spaced control points. It should be pointed out that the presence of Tertiary beds in contact with Silurian-Ordovician rocks between Brackett River and the Norman Range to the west is largely an inferred relationship because surficial deposits in the mantled areas adjacent to the flanks of the Silurian-Ordovician exposures may mask rocks other than Tertiary in age. The Tertiary age assignment is based on the known presence of numerous Tertiary occurrences a short distance to the southeast.

Eleven miles south of the southern end of Norman Range, the MacKay Range, 15 miles long and one to one and one-half miles wide, forms an isolated strongly uplifted mountainous ridge bounded on the east by a west-dipping thrust. The MacKay Range appears to be related to an extension of the Norman Range but is oriented in an en echelon fashion relative to the southern end of the Norman Range. Cretaceous rocks lie in contact with the Hume Formation on the west flank of the range while on the east flank Upper Devonian beds are encountered adjacent to the main fault, where they are unconformably overlain by Tertiary sediments.

MACKENZIE MOUNTAINS

The eastern portion of the Mackenzie Mountains lies within the western map area and is separated from the Franklin Mountains to the east by the intervening Mackenzie Plain. The eastern limit of the Mackenzie Mountains is somewhat arbitrary in places but is here considered to include the narrow satellite ranges lying some 10 to 20 miles east of the main body of mountains and known as the Iverson and Dahadinni Ranges. The intermontane structural basin separating the two mountainous areas is over 100 miles in length and is characterized by moderate to intense folding and occasional transverse faults most commonly displaying an offset of a few hundred feet.

Anticlinal features of interest in the basin include an oval shaped, doubly plunging anticline west of the Redstone River near latitude 63°40'N which displays independent surface closure on the order of 2,000 feet over an area 8 to 10 miles in length and two miles in width. The oldest rocks exposed in the core are those of the Middle Devonian Funeral Formation which are included with the 'Dma' map unit on the structural interpretation maps. Immediately adjacent to this closure on the opposite side of the Redstone River is a faulted, doubly plunging anticline showing an indeterminate amount of potential fault closure perhaps on the order of a few hundred feet. Four miles northeast of Redstone River in the same area another anticline is defined by moderately resistant beds in the lower part of the 'Duc' map unit ranging mainly from 6° to 10° on the northeast flank and bordered by a longitudinal fault upthrown to the southwest.

The southwest flank of the anticline is steeper especially on the outer edge of the southwest flank. Closure on this feature is questionable but may be present near the north end. The southeast end of the axis is a continuation of an anticlinal trend which emanates in a northwesterly direction from the Dahadinni Range.

Other anticlines in the basinal area are either of minor size or fail to show definite closure.

The Iverson Range forms an uplifted ridge up to six or eight miles wide and over 60 miles long. It is bounded on the east flank by a thrust fault, which is upthrown from the west showing displacement ranging up to a maximum of around 8,000 feet a few miles north of English Chief River.

In the vicinity of North Nahanni River on Sheet 2, the southern end of the Iverson Range appears to merge gradually with the Whittaker and Delorme Ranges to the west. Its northern terminus lies adjacent to the upper reaches of Dahadinni River just north of latitude 63°N. where it plunges beneath Upper Devonian sediments. The northern end of the range lies a few miles west of the southern end of the Dahadinni Range, forming an en echelon relationship.

The west flank of the Iverson Range is defined by westerly dipping beds of the Nahanni Formation with dips most frequently on the order of 25°. Folding is the dominant tectonic mechanism although some relatively minor faults are mapped west of the main thrust fault. A number of short anticlinal and synclinal folds are seen, and the oldest rocks exposed along the range are those of the Sombre Formation of Middle and Lower Devonian age. Maximum restored structure datum elevations encountered along the crest of the uplift are slightly in excess of 7,000 feet above sea level.

The Dahadinni Range can be traced for a distance of slightly less than 70 miles from latitude 63°N. at the southern boundary of Sheet 3 to the vicinity of Redstone River near the north edge of the sheet. It too is bounded over most of its length on the east side by a thrust upthrown from the west. The southern part of the range, however, appears to have a normal but steeply dipping contact between the Nahanni Formation and the overlying For Simpson Formation. The main thrust, which gives a sense of motion to the east, is accompanied in this area by occasional easterly dipping thrusts of minor magnitude.

Bifurcations of the main trend jut out to the north-northwest in two places suggestive of the relationship noted between the northern end of the Iverson Range and the southern end of the Dahadinni Range. The northernmost of these bifurcations forms a structural closure which has been breached by the Dahadinni River exposing the Middle Devonian Bear Rock Formation in the core. Northwesterly plunge is well expressed and southeasterly plunge is somewhat weaker providing an area of approximately 500 feet of closure one mile in width and six miles long. The feature is strongly asymmetric to the northeast with dips on the steeper side in excess of 65° and dips ranging from 10 to 18° on the southwest flank.

The southern end of the Dahadinni Range is terminated by the disappearance with southerly plunge of the Nahanni Formation beneath the Upper Devonian Fort Simpson. At the north end a series of short northerly plunging anticlinal noses bounded on the east by the Dahadinni thrust fault gradually disappear beneath the younger shale units in the vicinity of the Redstone River. A northwesterly trending transverse normal fault, upthrown on the southwest, emerges from the Dahadinni thrust 15 miles south of the Redstone River. Displacement along

this fault reaches a maximum of perhaps 1,000 feet between the Redstone River and the north end of the Dahadinni Range. Strata of the Lower Devonian Camsell Formation, the oldest rocks exposed in the Dahadinni Range, crop out in the valley of Dahadinni River on the south face of Mount Haywood. Maximum offset noted between the Upper Devonian clastic units on the east and the overthrust Middle Devonian carbonates on the west is 3,000 to 4,000 feet in the central and northern part of the range. The maximum restored structure datum elevation in excess of 7,000 feet occurs near the southern end of the range.

Structural patterns in the Mackenzie Mountains of the extreme western project area are more diverse in character than the structural relationships observed in the thrust-faulted mountains to the east. For the most part, the east flank of this portion of the Mackenzie Mountains is unfaulted, though in places it is defined by very steeply eastward dipping beds. In the southern map area the mountains merge with and include the Nahanni Plateau, a broad regional uplift locally associated with faulting. A northerly to north-northwesterly trending structural fabric is typical of the somewhat random structural patterns noted in this part of the Mackenzie Mountains. Numerous moderately to tightly folded anticlines and synclines are mapped exposing Lower Devonian and Silurian-Ordovician rocks in many places. Both east dipping and west dipping reverse faults are mapped; few are of the regional magnitude seen in the the Franklin Mountains. In the western part of the Sheet 2 map area a considerable amount of normal faulting is evident, especially in the vicinity of North Nahanni River.

The maximum restored structure datum elevations encountered in the project area occur on the crest of the Whittaker anticline in the west central part of Sheet 2 where they exceed 25,000 feet above sea level. Overall structural relief between there and the deeper portions of the southern end of the Mackenzie plain is greater than 30,000 feet. The Whittaker anticline is a broad, northwesterly trending, doubly plunging anticline over 15 miles long and 5 miles wide. Faulting is minor or absent and the oldest rocks exposed in the core are Silurian-Ordovician carbonates.

The southern end of the Nahanni Plateau in the southwestern part of Sheet 1 forms a broad dome which is northerly trending and slightly sinuous, rising to a structural high at Lafferty Creek. Within the map area however, closure on the west flank is weak or lacking but may be present beyond the sheet boundary. Arnica dolomites form widespread exposures in the central part of the feature which is over 30 miles long and 15 miles wide. A few minor normal faults are present on the north end and on the east flank of the dome. Remnants of the Nahanni Formation cap the higher hills in the central part of the uplift and the maximum structure datum elevation is slightly less than 6,000 feet above sea level.

Several smaller anticlinal features are mapped on the southwest corner of Sheet 4 two of which show modest closure and have Bear Rock exposures in their cores. Two southeasterly plunging anticlinal noses are present at the western sheet boundary, but show no closure within the map area.

MACKENZIE PLAIN

The Mackenzie Plain extends from the South Nahanni River northward to beyond the project boundary, a distance of 280 miles within the project area. It is a broad, intermontane basin separating the Mackenzie Mountains on the west from the Franklin Mountains to the east. On the accompanying maps it attains its maximum overall width of around 50 miles in the area north of Keele River on Sheet 4. In the Johnson River area it is approximately 30 miles wide and from there tapers southward to a point near Twisted Mountain on the South Nahanni River.

The maximum structure datum elevations mapped in the Mackenzie Plain are located on the crest of the Ram Plateau in the west-central part of Map Sheet 1. The high point in this region is around 4,800 feet. The lowest datum elevation encountered is located between Johnson and Dahadinni Rivers near seismic line No. 2 where a maximum depth is indicated by seismic data. A similar depth may be attained in the northwesterly trending synclinal basin 10 miles southwest of the MacKay Range. Though older rocks in this area are masked by a cover of Tertiary sediments, moderately steep dips in Paleozoic and Cretaceous rocks to the southwest and northeast suggest that similar depths may be reached in the deepest part of the syncline.

Rocks of Upper Devonian age including the shales of the Fort Simpson Formation and the overlying unnamed Upper Devonian clastic sequence containing occasional limestones, form bedrock over the greater part of the Mackenzie Plain. In the region adjacent to the lower reaches of the Dahadinni River and to the north Cretaceous and Tertiary rocks cover the bevelled Upper Devonian and older beds.

Folding in the region is typically of mild to moderate intensity. Faults are mainly minor and normal in attitude with the exception of a high angle reverse fault upthrown to the west which borders the southern part of Ram anticline. Maximum displacement on the order of 5,000 feet may be present locally on this fault.

The overall structural grain is mainly northerly to northwesterly. A number of interesting and potentially significant features were mapped. The following discussion deals with the more significant aspects of the features in approximate geographic order from south to north.

The southernmost area of interest in the Mackenzie Plain is the Twisted Mountain anticline near South Nahanni River on Map Sheet 1. Northerly to northeasterly plunge is well defined in the surface rocks while southerly plunge is based on a few widespread isolated dips. The South Nahanni River forms a broad flood plain south of Twisted Mountain obscuring definitive surface evidence in the area. Faulting is present and has been observed in the field southwest of the river. On the structural interpretation map it is shown connecting with minor faulting on the east flank of the anticline. In any case, closure is probably present though southerly plunge may be considerably less than northerly plunge. A minimum closure of around 500 feet over a length of 5 miles and a width one and one-half miles may be expected. The maximum structure datum elevation indicated is slightly above -5,000 feet.

The Ram Plateau, mentioned earlier, is a broad uplift located some 25 miles northwest of Twisted Mountain. Minor normal faults occur on the north, east and southeast flanks and locally on the crest of the anticline. Surface closure of nearly 2,000 feet is mapped over an area 18 miles long and 8 miles wide. Maximum throw on the faults on the northern and southeastern flanks is around 400 feet. Maximum structure datum elevation on the crest of the anticline is 4,815 feet, and the oldest rocks exposed at the surface are those of the Middle Devonian Funeral Formation which is included in the 'Dma' map unit.

One of the more persistent geological features in the Mackenzie Plain is the Yohin syncline which extends from the southern map area along the eastern edge of the Mackenzie Plain to the central reaches of Carlson Creek on the west side of Camsell Range. The overall length is more than 100 miles and maximum width around 14 miles. Northwest of Twisted Mountain a maximum structural depression of below -12,000 feet is indicated. The syncline terminates abruptly a short distance south of Yohin Lake but rises in a northerly direction to approximately -3,000 feet west of Cli Lake where it again assumes northerly plunge descending to an elevation of below -4,000 feet west of Camsell Bend. From this area it again rises gently to the north and terminates adjacent to the northern end of Ram anticline where it merges with a longitudinal fault in the valley of Carlson Creek.

On the eastern edge of Nahanni Plateau, 10 miles south of North Nahanni River, lies a north-northwesterly trending doubly plunging anticline, 12 miles in length which may be considered to lie on the extreme western edge of the Mackenzie Plain. This anticline shows a closure of up to 1,500 feet over a length of seven miles and a width of one and one-half miles. The oldest rock exposed in the core of the feature is the Middle Devonian Funeral Formation.

Fifteen miles to the northeast adjacent to the North Nahanni River where it emerges from the Mackenzie Mountains and swings abruptly northward, an arcuate, closed anticline shows about 1,300 feet of closure over a width of three miles and a length of about seven miles. Middle Devonian Arnica beds are mapped in the central core of the anticline. The axis swings abruptly from a northerly trend to a northwesterly orientation in the vicinity of the apex. The northeast flank is interrupted slightly by a minor normal fault about two miles long which roughly parallels the main axis. The anticline, referred to by the Geological Survey of Canada as the English Chief anticline, lies at the edge of an uplifted area which extends westerly and northwesterly from the southern part of the Ram anticline 14 miles to the east. The closure described above lies at the south end of the English Chief anticline whose overall length is approximately 45 miles. A small area of modest closure occurs three miles north of English Chief River, and a broader area of minor closure may be present a short distance north of Iverson Lake. Texaco Teck Iverson Lake M-69 dry hole which tested the outer part of the east flank of this structure is located one and one-half miles northeast of Iverson Lake. At this writing, details have not been released.

The Ram anticline extends for a distance of 45 miles in a northerly direction from near latitude 62°N. to a point approximately three miles south of English Chief River. In the area south of North Nahanni River, the east flank of Ram anticline is bordered by a high angle reverse fault upthrown to the west. The fault is accompanied by steep easterly dips in the Nahanni Formation ranging up to 80° which lend a strong eastward asymmetry to the anticline. The dips defining the west flank range mainly from 2° to 6°. The east flank is broken by two normal faults trending northerly to northeasterly showing a maximum displacement of perhaps 800 feet. Overall closure on the anticline is around 900 feet, and the area of closure is approximately 3 1/2 miles wide and 12 miles long. Beyond the north Nahanni River the Ram

anticline loses its sharply asymmetric character and north of Carlson Lake displays a second area of closure. Approximately 500 feet of closure is mapped over an area three miles wide and six to eight miles in length. Poor surface detail around Carlson Lake mask the extent of southerly plunge. The axis plunges north-northwesterly from the apex to about three miles south of English Chief River and the Root River.

Surface rocks are comprised mainly at the Upper Devonian clastic unit which is very gently folded into a series of northerly trending anticlinal and synclinal folds. The deepest strucutre datum elevations mapped in the central part of the basin lie below -5,000 feet. Two depressions of this magnitude are present. The northernmost depression is cut along the southwest side by an inferred fault upthrown to the west which displays a maximum displacement on the order of 2,500 feet near Root River. The fault is based on structure contour relationships in the area, photographic evidence and a steep field observed dip on the north side of Root River which tends to confirm the existence of structural complexity in an area of otherwise extremely gentle folds. Axes on the north and south ends of the basinal area plunge toward the central area of maximum depression.

A northwesterly plunging anticlinal nose extends northwestward from the west flank of Camsell Range at Root River for a distance of 15 miles. The southern end of this fold is locally well defined by the presence of resistant Upper Devonian reefal units in the lower part of the unnamed clastic sequence. A small area of closure may exist in the vicinity of the river but cannot be mapped due to the presence of widespread Quaternary deposits.

The southern terminus of the West Wrigley anticline lies en echelon to the northwest end of the anticlinal nose described above. It is offset approximately two miles at that point and is traced north-northwestward for a distance of approximately 28 miles. A broad, oval shaped, faulted area of closure is present near the southern end. A longitudinal, normal fault around 3/4 mile west of the main axis is upthrown about 600 feet on the west side. A northeasterly trending normal fault cuts the main axis at a point 1 1/4 miles north of Shell West Wrigley G-70. Overall closure on this anticline is approximately 1,400 feet. The area of closure is 7 miles wide and approximately 10 miles long. Highest structure datum elevations are encountered on the uplifed western portion of the feature.

Shell West Wrigley G-70 tested the eastern part of the closure encountering the structure datum at an elevation of -1,088 feet. The hole was drilled to a total depth of 12,250 feet, bottomed in Silurian-Ordovician beds and was reported dry and abandoned.

The Wrigley anticline, located 10 miles east of the West Wrigley anticline, can be traced north and northwest for a distance of approximately 46 miles. In gross aspect it is similar in configuration to the West Wrigley anticline with an area of closure near the southern end of the axis and supplementary folding on the southeast flank. Structural control of fair quality indicates the presence of closure on the order of 1,000 feet over an area 22 miles long and 8 miles wide. En echelon folding produces a bifurcation of the axis on the southeastern flank of the feature. The closure is oval in shape, and appears to be uncomplicated by faulting. The flanks are marked by fairly well defined dips ranging mainly from 5° to 12° on the west flank and 15° to 20° on the east flank.

The Crescent Ridge anticline is defined by opposing dips of 15° to 20° in the valley of the Dahadinni River. The axis is mapped for a length of 15 miles and is based in part on poorly expressed surface information. No surface evidence is seen for south plunge on either the Cloverleaf trend or the Crescent Ridge anticline. As pointed out earlier, the overall effect

of the sub-Cretaceous unconformity on the thickness of the underlying Upper Devonian section is speculative. However, on the basis of the best available information, a local line of structural culmination appears to trend northeasterly in the vicinity of the basal Cretaceous contact south of Dahadinni River, separating the Crescent Ridge and Cloverleaf trends from the basinal area to the south.

A small oval shaped closure is suggested east of Mackenzie River in the vicinity of Little Smith Creek. This feature is based on poor dip control and is very interpretive in nature.

From the Dahadinni River area northward, structure contouring becomes increasingly interpretive in view of the presence of Cretaceous and Tertiary sediments which may or may not accurately reflect the structure of the underlying Hume Formation, as indicated by relationships at the Shell Keele River L-4 well.

A structural closure is indicated in the vicinity of Imperial Oil Redstone No. 1 on the lower Redstone River but is based on northwestward plunge mapped in Cretaceous and Tertiary formations to the northwest.

As discussed earlier, post-Devonian, pre-Cretaceous deformation and local removal of the Middle Devonian Hume Formation is inferred in the north central portion of Map Sheet 4. For this reason structure contours are not shown in the area so affected since quantitative evaluation would be partly hypothetical in view of the tectonic history involved. Instead, structural "form lines" depicting the general configuration of surface rocks without quantitative evaluation are shown.

CONCLUSIONS

The four map sheets accompanying this report were compiled mainly through the use of photogrammetric mapping techniques capable of providing quantitative information (i.e. elevations, stratigraphic thicknesses, etc.) in order to portray not only areal distribution of stratigraphic units, the location of faults, anticlinal and synclinal axes and other structural features, but also to show the amount of structural relief and areal extent of such structures.

The incorporation of seismic and gravity information along two profiles in the central Mackenzie Plain provided valuable control in an area of poor surface expression.

The Cordilleran Belt within the project area lends itself well to such mapping techniques. Similar results may be expected through the use of such methods over the entire eastern Cordilleran Belt and adjacent Interior Plains.

By: G. M. Collins, P. Geol.,
Manager.

W. Brown,
Senior Geologist.

V. ZAY SMITH ASSOCIATES LTD.

Plate 1

The Twisted Mountain as seen from the vicinity of South Nahanni River. Mississippian carbonates in anticlinal core, Permo-Carboniferous sandstone of the Mattson Formation on outer flanks.

Plate 2

West dipping Middle Devonian Nahanni Formation on the west flank of Nahanni Range: View north.

Plate 3

View northwest showing Middle Devonian carbonates exposed on east side of Camsell Range.

Feb 20, 69

TABLE 1: PRINCIPAL FACTS

OPERATION GEOQUEST

PROJECT 7: REDSTONE

LINE A

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
101	430.9	174.41	168.19	155.00	+10.70
102	438.5	173.96	168.52	155.09	+10.74
103	439.7	173.89	168.65	155.19	+10.74
104	446.3	173.41	168.70	155.09	+10.54
105	454.1	172.56	168.85	154.94	+10.34
106	490.5	170.11	169.92	154.90	+10.20
107	540.0	166.97	171.53	154.99	+10.19
108	579.2	164.49	172.82	155.08	+10.18
109	620.4	161.81	174.08	155.08	+10.08
110	642.9	160.32	174.79	155.10	+10.00
111	656.6	159.64	175.48	155.37	+10.17
112	670.1	158.99	176.18	155.66	+10.36
113	661.5	159.79	176.26	156.00	+10.60
114	631.2	161.82	175.53	156.20	+10.70
115	622.9	162.13	175.15	156.07	+10.47
116	621.7	162.09	175.08	156.05	+10.35
117	617.7	162.56	175.25	156.33	+10.53
118	614.8	162.89	175.40	156.57	+10.67
119	613.9	163.03	175.53	156.73	+10.78
120	616.5	162.63	175.46	156.59	+10.59
121	616.1	162.21	175.09	156.22	+10.07
122	611.6	162.90	175.45	156.72	+10.47
123	611.1	162.42	174.99	156.28	+ 9.98
125	612.8	161.99	174.92	156.16	+ 9.66
126	617.0	161.67	175.09	156.19	+ 9.59
127	614.7	161.48	174.77	155.95	+ 9.25
128	616.0	161.40	174.90	156.04	+ 9.24
129	623.9	161.01	175.26	156.18	+ 9.28
130	622.8	161.06	175.38	156.31	+ 9.31
131	623.6	160.99	175.47	156.38	+ 9.28
132	624.5	160.73	175.39	156.26	+ 9.06
133	626.5	160.65	175.40	156.28	+ 8.98
134	626.9	160.27	175.33	156.13	+ 8.73
135	633.5	159.76	175.54	156.14	+ 8.64
136	639.3	159.22	175.63	156.06	+ 8.51
137	639.3	158.93	175.44	155.86	+ 8.26
138	641.7	158.63	175.44	155.79	+ 8.09

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
139	643.5	158.38	175.45	155.74	+7.89
140	648.4	157.81	175.42	155.56	+7.61
141	652.0	157.32	175.43	155.44	+7.39
142	652.2	157.08	175.22	155.24	+7.18
143	655.4	156.69	175.21	155.14	+6.94
144	656.9	156.63	175.38	155.26	+6.96
145	657.6	156.15	175.05	154.91	+6.81
146	661.7	155.40	174.85	154.58	+6.08
147	672.4	154.78	175.29	154.70	+6.10
148	680.5	154.15	175.52	154.68	+5.98
149	694.5	153.07	175.84	154.57	+5.77
150	749.1	149.26	177.25	154.31	+5.46
151	789.0	146.65	178.47	154.31	+5.31
152	767.1	147.91	177.76	154.27	+5.22
153	780.6	148.83	177.82	154.24	+5.09
154	743.8	149.14	176.95	154.18	+4.93
155	734.7	149.54	176.61	154.11	+4.76
156	731.0	149.62	176.43	154.05	+4.65
157	732.9	149.34	176.43	153.99	+4.49
158	738.3	148.78	176.48	153.87	+4.10
159	743.7	148.26	176.55	153.78	+4.08
160	749.4	147.82	176.73	153.70	+3.98
161	754.8	147.40	176.99	153.87	+3.97
162	759.1	147.14	177.14	153.89	+3.89
163	765.7	146.58	177.29	153.84	+3.74
164	774.1	145.94	177.53	153.83	+3.63
165	782.3	145.32	177.70	153.82	+3.52
166	790.1	144.39	178.04	153.73	+3.33
167	807.8	143.52	178.52	153.79	+3.29
168	829.5	142.11	179.26	153.86	+3.26
169	853.9	140.28	179.83	153.68	+2.98
170	876.0	138.75	180.47	153.64	+2.84
171	876.0	138.65	180.45	153.63	+2.73
172	872.1	138.85	180.38	153.67	+2.67
173	879.9	138.09	180.44	153.49	+2.44
174	883.3	137.80	180.55	153.50	+2.30
175	889.9	137.20	180.67	153.42	+2.12
176	904.2	136.06	180.97	153.28	+1.80
177	897.2	136.49	180.83	153.35	+1.90
178	896.1	136.52	180.84	153.40	+1.90
179	905.3	135.86	181.14	153.41	+1.81
180	909.7	135.45	181.22	153.37	+1.67
181	896.3	136.24	180.85	153.40	+1.60
182	910.5	135.10	181.21	153.33	+1.43
183	935.2	133.45	181.89	153.25	+1.25
184	961.4	131.45	182.45	153.01	+ .91
185	974.1	130.92	182.80	152.97	+ .77

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
186	946.9	132.20	182.02	153.02	+ .72
187	936.8	132.77	181.73	153.04	+ .64
188	939.9	132.43	181.76	152.98	+ .48
189	942.5	132.19	181.85	152.99	+ .49
190	946.3	131.84	181.94	152.96	+ .46
191	951.1	131.38	182.02	152.89	+ .39
192	937.9	132.04	181.51	152.79	+ .29
193	923.3	132.86	181.04	152.77	+ .27
194	901.7	134.13	180.37	152.75	+ .25
195	884.5	135.10	179.80	152.71	+ .21
196	857.9	136.66	178.96	152.69	+ .19
197	843.5	137.41	178.43	152.60	+ .10
198	838.6	137.70	178.34	152.66	+ .16
199	837.0	137.69	178.27	152.63	+ .13
200	836.6	137.39	178.01	152.39	- .11
201	837.9	137.21	178.03	152.37	- .13
202	835.5	137.39	178.08	152.49	- .01
203	833.2	137.56	178.12	152.61	+ .11
204	834.3	137.39	178.13	152.58	+ .08
205	836.5	137.15	178.16	152.55	+ .05
206	836.7	136.93	178.05	152.43	- .07
207	836.1	136.84	177.99	152.39	- .11
208	839.0	136.52	178.03	152.33	- .17
209	842.4	136.20	178.11	152.31	- .19
210	844.8	135.87	178.10	152.23	- .17
211	846.9	135.53	178.06	152.12	- .18
212	853.2	134.89	178.11	151.98	- .42
213	855.3	134.65	178.15	151.96	- .34
214	858.9	134.22	178.14	151.84	- .36
215	863.8	133.68	178.17	151.71	- .44
216	855.3	133.80	177.58	151.39	- .61
217	848.9	133.98	177..6	151.26	- .74
218	847.9	133.76	177.03	151.06	- .79
219	846.0	133.52	176.72	150.81	- .99
220	856.1	132.54	176.80	150.58	-1.12
221	864.5	131.61	176.74	150.27	-1.33
222	873.5	130.71	176.78	150.13	-1.37
223	887.2	129.43	176.89	149.82	-1.63
224	910.7	127.51	177.27	149.48	-1.98
225	941.1	125.29	178.02	149.40	-1.90
226	967.7	123.10	178.40	149.07	-2.13
227	981.2	121.72	178.39	148.74	-2.36
228	1019.8	118.76	179.15	148.32	-1.68
229	1067.3	115.16	180.10	147.82	-3.08
230	1133.0	110.31	181.54	147.24	-3.56
231	1191.1	105.83	182.61	146.54	-4.16
232	1216.6	103.70	182.98	146.02	-4.58

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
233	1311.4	96.99	185.27	145.31	-5.24
234	1386.3	91.59	187.00	144.65	-5.85
235	1393.3	90.95	187.11	144.54	-5.86
236	1408.5	89.49	187.16	144.13	-6.17
237	1487.7	83.87	189.07	143.72	-6.48
238	1451.2	86.18	188.05	143.71	-6.39
239	1513.7	81.80	189.64	143.38	-6.62
240	1518.7	81.21	189.61	143.20	-6.70
241	1545.7	79.21	190.24	142.90	-6.90
242	1572.0	77.16	190.75	142.60	-7.00
243	1591.9	75.52	191.06	142.31	-7.14
244	1539.5	79.08	189.78	142.64	-6.71
245	1538.5	79.07	189.76	142.64	-6.56
246	1552.2	78.13	190.19	142.65	-6.35
247	1571.1	76.72	190.65	142.53	-6.27
248	1575.5	76.30	190.72	142.47	-6.23
249	1575.0	76.26	190.74	142.50	-6.00
250	1597.4	74.65	191.32	142.40	-5.90
251	1603.4	74.20	191.51	142.41	-5.79
253	1605.6	73.79	191.47	142.40	-5.43
254	1643.9	71.14	192.50	142.36	-5.24
255	1679.1	68.55	193.33	142.21	-5.29
256	1669.3	69.17	193.12	142.29	-5.01
257	1676.1	68.61	193.27	142.24	-4.96
258	1606.5	73.39	191.58	142.69	-4.31
259	1519.1	79.36	189.40	143.18	-3.67
260	1445.7	83.94	187.17	143.20	-3.60
261	1407.8	86.35	186.09	143.18	-3.37
262	1377.4	88.34	185.31	143.23	-3.17
263	1354.8	89.99	184.91	143.42	-2.78
264	1341.8	90.88	184.65	143.56	-2.54
265	1339.7	90.92	184.57	143.55	-2.25
266	1342.7	90.72	184.74	143.62	-1.98
267	1360.5	89.43	185.21	143.54	-1.96
268	1384.8	87.77	185.91	143.50	-1.80
269	1413.1	85.85	186.72	143.44	-1.66
270	1457.7	82.78	187.93	143.29	-1.81
271	1467.4	82.02	188.16	143.22	-1.78
272	1450.3	83.06	187.67	143.26	-1.54
273	1457.8	82.30	187.70	143.06	-1.64
274	1455.3	82.32	187.56	142.99	-1.51
275	1460.9	81.63	187.47	142.93	-1.42
276	1443.6	82.65	186.96	143.15	-1.05
277	1442.5	82.34	186.61	142.83	-1.17
278	1422.2	83.28	185.75	142.70	-1.20
279	1337.9	88.33	182.94	142.67	-1.13
280	1262.5	92.78	180.39	142.53	-1.20
281	1176.9	97.71	177.36	142.21	-1.29

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
282	1125.7	100.53	175.44	141.97	-1.43
283	1079.9	102.69	173.38	141.21	-1.99
284	1042.2	106.77	174.02	142.81	-2.81
285	1143.2	98.12	174.96	140.55	-2.45
286	1288.4	88.79	179.37	140.41	-2.39
287	1422.9	80.01	183.32	140.15	-2.55
288	1502.7	74.72	185.62	139.91	-2.59
289	1505.8	74.30	185.59	139.57	-2.83
290	1517.8	73.25	185.75	139.37	-2.93
291	1536.9	71.63	186.01	138.94	-3.26
292	1554.1	70.25	186.33	138.74	-3.26
293	1576.4	68.65	186.93	138.65	-3.15
294	1607.1	66.56	187.82	138.60	-3.10
295	1625.9	65.03	188.14	138.35	-3.25
296	1674.5	61.54	189.31	138.03	-3.37
297	1695.5	60.12	189.95	138.02	-3.28
298	1675.1	61.30	189.29	137.99	-3.21
299	1670.3	61.35	188.97	137.82	-3.18
300	1688.1	60.12	189.50	137.81	-3.09
301	1702.6	58.94	189.78	137.64	-3.16
302	1718.7	57.89	190.33	137.70	-3.00
303	1711.9	58.36	190.25	137.82	-2.78
304	1726.0	57.25	190.55	137.80	-2.60
305	1686.7	59.83	189.54	137.99	-2.31
306	1662.2	61.40	188.89	138.09	-2.06
307	1615.4	64.29	187.46	137.99	-2.01
308	1550.0	68.25	185.36	137.89	-2.01
309	1573.0	66.91	186.27	138.10	-1.65
310	1603.5	64.51	186.82	137.71	-1.89
311	1605.2	64.15	186.70	137.55	-1.85
312	1589.7	65.50	186.68	138.00	-1.35
313	1543.2	68.59	185.48	138.32	- .88
314	1541.3	68.75	185.55	138.44	- .61
315	1615.1	64.24	188.07	138.71	- .19
316	1680.6	60.23	190.31	138.84	+ .04
317	1743.4	56.22	192.29	138.90	+ .30
318	1788.5	53.75	194.15	139.37	+ .87
319	1821.9	51.87	195.51	139.72	+1.32
320	1834.7	51.53	196.46	140.27	+1.97
321	1858.9	50.57	197.86	140.93	+2.83
322	1912.4	47.72	200.14	141.57	+3.57
323	1924.6	47.38	201.04	142.10	+4.30
324	1950.1	46.06	202.20	142.48	+4.78
325	1937.1	47.53	202.54	143.21	+5.61
326	1940.3	47.64	203.03	143.71	+6.31
327	1937.4	48.14	203.34	144.11	+6.81
328	1945.6	47.59	203.65	144.07	+6.97

Line A (Contd) 6

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
329	2020.1	42.78	205.95	144.09	+ 7.09
330	2011.4	43.77	206.22	144.62	+ 7.72
331	2026.2	42.90	206.82	144.77	+ 7.97
332	1977.1	46.18	205.57	145.02	+ 8.42
333	1922.0	49.68	203.97	145.11	+ 8.61
334	1893.1	51.74	203.41	145.43	+ 9.08
335	1923.8	50.17	204.81	145.90	+ 9.70
336	1920.3	50.45	204.84	146.14	+10.04
337	1922.4	50.81	205.49	146.71	+10.71
338	1899.4	52.79	205.39	147.33	+11.53
339	1953.6	49.53	207.31	147.59	+11.89
340	2035.3	44.28	209.85	147.62	+12.07
341	2118.0	38.79	212.22	147.46	+12.06
342	2131.2	38.02	212.79	147.53	+12.23
343	2089.7	40.76	211.71	147.72	+12.52
344	2104.0	39.69	212.07	147.64	+12.64
345	2093.2	40.23	211.68	147.58	+12.78
346	2063.9	42.05	210.83	147.62	+12.87
347	2056.1	42.33	210.46	147.49	+12.89
348	2110.9	38.73	212.11	147.47	+13.07
349	2128.2	37.45	212.54	147.36	+13.01
350	2125.9	37.51	212.46	147.36	+13.16
351	2123.7	37.43	212.27	147.23	+13.23
352	2129.7	36.89	212.38	147.16	+13.26
353	2130.2	36.72	212.33	147.09	+13.29
354	2155.6	34.84	212.92	146.91	+13.31
355	2159.0	34.60	213.02	146.91	+13.41
356	2175.8	33.40	213.47	146.84	+13.54
357	2145.0	35.12	212.45	146.76	+13.56
358	2149.8	34.67	212.54	146.71	+13.61
359	2153.1	34.10	212.37	146.44	+13.44
360	2154.0	33.61	212.05	146.09	+13.29
361	2135.3	34.15	210.94	145.55	+12.85
362	2105.1	35.51	209.54	145.07	+12.57
363	2075.8	37.00	208.36	144.79	+12.39
364	1998.6	41.74	205.91	144.71	+12.41
365	2000.0	41.45	205.84	144.59	+12.49
366	1970.1	43.11	204.77	144.44	+12.44
367	1983.6	42.22	205.25	144.50	+12.60
368	1990.5	41.76	205.52	144.56	+12.76
369	1973.3	42.80	205.03	144.60	+12.90
370	2029.9	38.68	206.34	144.18	+12.68
371	2050.1	36.84	206.60	143.92	+12.62
372	2020.2	38.38	205.31	143.54	+12.34
373	2007.6	45.21	201.64	143.22	+12.12
374	1851.1	48.56	199.77	143.08	+12.18
375	1833.5	49.34	198.99	142.84	+12.04

Line A (Contd) 7

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
376	1822.2	49.90	198.57	142.76	+12.06
377	1817.7	50.13	198.46	142.79	+12.29
378	1818.9	50.09	198.62	142.91	+12.51
379	1826.3	49.64	198.95	143.02	+12.62
380	1841.4	48.85	199.67	143.28	+13.28
381	1866.1	47.37	200.62	143.47	+13.57
382	1902.7	44.91	201.69	143.42	+13.72
383	1883.1	46.05	201.07	143.40	+13.80
384	1835.4	49.05	199.66	143.46	+14.01
385	1812.5	50.20	198.74	143.24	+13.94
386	1804.6	51.05	198.93	143.67	+14.52
387	1808.3	50.87	199.21	143.83	+14.83
388	1819.5	50.29	199.78	144.06	+15.21
389	1823.2	50.04	199.97	144.14	+15.44
390	1830.9	49.53	200.27	144.20	+15.70
391	1852.4	48.21	201.06	144.33	+15.93
392	1880.5	46.50	202.07	144.48	+16.28
393	1902.7	44.50	202.26	144.00	+15.90
394	1930.4	41.59	202.06	142.94	+15.04
395	1920.5	41.64	201.26	142.45	+14.65
396	1890.8	43.40	200.32	142.42	+14.79
397	1868.8	44.70	199.64	142.41	+14.91
398	1852.4	45.54	199.02	142.29	+14.99
399	1830.6	46.50	198.01	141.95	+14.75
400	1826.3	46.58	197.78	141.86	+14.96
401	1819.3	46.82	197.45	141.74	+14.64
402	1816.6	47.07	197.53	141.90	+15.10
403	1813.4	47.50	197.75	142.22	+15.62
404	1814.0	47.57	197.98	142.43	+16.03
405	1846.4	45.46	199.00	142.46	+16.16
406	1897.0	41.99	200.37	142.28	+16.18
407	1922.6	40.15	201.03	142.25	+16.30
408	1921.2	39.82	200.67	142.04	+16.24
409	1897.5	40.82	199.53	141.62	+16.02
410	1799.9	46.38	196.01	140.99	+15.49
411	1652.2	54.30	190.14	139.64	+14.24
412	1591.6	57.16	187.38	138.74	+13.54
413	1533.0	60.73	185.52	138.68	+13.63
414	1615.1	55.79	188.41	139.05	+14.15
415	1654.6	53.99	190.42	139.85	+15.15
416	1695.5	52.66	193.03	141.21	+16.61
417	1739.8	46.84	197.12	142.10	+17.60
418	1858.6	43.52	199.43	142.51	+18.21
419	1876.9	42.33	200.04	142.67	+18.52
420	1922.5	39.89	201.98	143.20	+19.20
421	1865.7	43.41	200.24	143.20	+19.30

Line A (Contd) 8

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
422	1939.9	38.46	202.35	142.94	+19.24
423	1871.8	42.56	200.13	142.81	+19.21
424	1832.5	44.65	198.62	142.60	+19.20
425	1834.9	44.35	198.64	142.54	+19.29
426	1865.5	43.01	200.26	143.23	+20.13
427	1969.3	36.62	203.72	143.51	+20.51
428	2047.5	31.96	206.52	144.03	+21.23
429	2127.6	26.98	209.17	144.11	+21.41
430	2287.4	16.95	214.25	144.20	+21.60
431	2345.1	13.24	216.06	144.24	+21.67

TABLE 2: PRINCIPAL FACTS

OPERATION GEOQUEST

PROJECT 7: REDSTONE

LINE B

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
101	428.3	149.83	172.48	159.47	10.87
102	530.9	143.50	175.88	159.72	11.09
103	609.6	138.71	178.55	159.98	11.32
104	657.7	135.64	180.06	160.02	11.32
105	674.2	134.78	180.83	160.28	11.56
106	688.6	134.00	181.47	160.49	11.75
107	705.2	133.11	182.20	160.71	11.95
108	732.3	131.56	183.26	160.93	12.13
109	760.5	129.90	184.32	161.13	12.30
110	789.0	128.11	185.27	161.21	12.35
111	833.7	125.33	186.76	161.33	12.43
112	904.1	121.01	189.13	161.54	12.56
113	1033.5	112.89	193.25	161.70	12.76
114	1080.9	109.95	194.84	161.84	12.80
115	1027.7	113.50	193.46	162.08	13.08
116	1037.2	112.70	193.62	161.96	12.93
117	1042.3	112.36	193.82	162.00	12.94
118	1058.6	111.08	194.14	161.82	12.73
119	1093.4	108.83	195.23	161.85	12.73
120	1163.5	104.39	197.44	161.91	12.77
121	1147.3	105.31	196.91	161.88	12.72
122	1141.6	105.59	196.72	161.86	12.67
123	1177.2	103.28	197.82	161.86	12.62
124	1220.3	100.56	199.21	161.94	12.67
125	1278.9	96.75	200.95	161.89	12.59
126	1331.2	93.20	202.39	161.72	12.36
127	1374.6	90.72	204.06	162.06	12.67
128	1424.1	87.42	205.47	161.96	12.54
129	1478.4	83.99	207.21	162.04	12.58
130	1493.0	83.05	207.71	162.09	12.60
131	1475.9	83.94	207.06	161.96	12.45
132	1406.8	88.15	204.84	161.86	12.33
133	1343.1	92.10	202.86	161.82	12.28
134	1291.0	95.19	201.11	161.67	12.10
135	1255.7	97.10	199.74	161.38	11.79

Line B (Contd) 2.

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
136	1224.4	98.92	198.68	161.28	11.67
137	1214.5	99.72	198.61	161.52	11.89
138	1237.0	98.05	199.31	161.53	11.88
139	1283.4	95.35	200.84	161.64	11.97
140	1321.2	92.82	201.93	161.57	11.88
141	1264.7	96.23	200.09	161.46	11.75
142	1240.9	97.38	199.08	161.27	11.53
143	1226.3	97.83	198.23	160.87	11.11
144	1174.8	100.89	196.48	160.71	10.94
145	1073.6	106.72	192.76	160.19	10.41
146	1127.6	103.07	194.36	160.03	10.23
147	1222.1	97.45	197.70	160.48	10.67
148	1267.4	94.53	199.09	160.47	10.65
149	1334.9	90.16	201.13	160.48	10.61
150	1391.2	86.43	202.76	160.36	10.51
151	1441.0	83.24	204.31	160.38	10.52
152	1462.2	81.82	204.98	160.37	10.50
153	1485.4	80.39	205.76	160.47	10.59
154	1510.8	78.84	206.77	160.70	10.71
155	1537.8	77.39	207.82	160.93	10.91
156	1565.5	75.59	208.70	160.95	10.97
157	1604.4	73.28	210.11	161.18	11.12
158	1604.7	73.49	210.02	161.48	11.38
159	1594.7	74.26	210.03	161.66	11.51
160	1581.1	75.05	209.86	161.64	11.44
161	1556.8	76.46	209.05	161.57	11.31
162	1518.5	78.84	207.89	161.59	11.28
163	1506.1	79.18	207.13	161.20	10.83
164	1441.0	83.38	205.27	161.34	10.88
165	1428.1	84.00	204.73	161.20	10.66
166	1393.8	86.02	203.59	161.11	10.52
167	1428.8	83.86	204.79	161.24	10.61
168	1454.5	82.24	205.65	161.31	10.65
169	1452.4	82.04	205.32	161.04	10.34
170	1507.2	78.19	206.69	160.73	9.93
171	1553.8	74.79	207.17	160.34	9.44
172	1602.6	71.57	209.19	160.39	9.29
173	1656.2	68.06	210.76	160.24	9.07
174	1702.4	65.20	212.31	160.38	9.13
175	1739.7	62.70	213.38	160.30	8.94
176	1787.7	59.72	214.98	160.43	8.95
177	1847.0	56.09	216.99	160.62	9.16
178	1840.5	57.01	217.36	161.19	9.49
179	1820.7	58.45	217.01	161.45	9.65
180	1788.0	60.40	215.94	161.38	9.48

TABLE 2: PRINCIPAL FACTS

OPERATION GEOQUEST

PROJECT 7: REDSTONE

LINE B

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
101	428.3	149.83	172.48	159.47	10.87
102	530.9	143.50	175.88	159.72	11.09
103	609.6	138.71	178.55	159.98	11.32
104	657.7	135.64	180.06	160.02	11.32
105	674.2	134.78	180.83	160.28	11.56
106	688.6	134.00	181.47	160.49	11.75
107	705.2	133.11	182.20	160.71	11.95
108	732.3	131.56	183.26	160.93	12.13
109	760.5	129.90	184.32	161.13	12.30
110	789.0	128.11	185.27	161.21	12.35
111	833.7	125.33	186.76	161.33	12.43
112	904.1	121.01	189.13	161.54	12.56
113	1033.5	112.89	193.25	161.70	12.76
114	1080.9	109.95	194.84	161.84	12.88
115	1027.7	113.50	193.46	162.08	13.08
116	1037.2	112.70	193.62	161.96	12.93
117	1042.3	112.36	193.82	162.00	12.94
118	1058.6	111.08	194.14	161.82	12.73
119	1093.4	108.83	195.23	161.85	12.73
120	1163.5	104.39	197.44	161.91	12.77
121	1147.3	105.31	196.91	161.88	12.72
122	1141.6	105.59	196.72	161.86	12.67
123	1177.2	103.28	197.82	161.86	12.62
124	1220.3	100.56	199.21	161.94	12.67
125	1278.9	96.75	200.95	161.89	12.59
126	1331.2	93.20	202.39	161.72	12.36
127	1374.6	90.72	204.06	162.06	12.67
128	1424.1	87.42	205.47	161.96	12.54
129	1478.4	83.99	207.21	162.04	12.58
130	1493.0	83.05	207.71	162.09	12.60
131	1475.9	83.94	207.06	161.96	12.45
132	1406.8	88.15	204.84	161.86	12.33
133	1343.1	92.10	202.86	161.83	12.28
134	1291.0	95.19	201.11	161.67	12.10
135	1255.7	97.10	199.74	161.38	11.79

STN	ELEVATION	OBS. GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
136	1224.4	98.92	198.68	161.28	11.67
137	1214.5	99.72	198.61	161.52	11.89
138	1237.0	98.25	199.31	161.53	11.88
139	1283.4	95.35	200.84	161.64	11.97
140	1321,2	92.82	201.93	161.57	11.88
141	1264.7	96.23	200.09	161.46	11.75
142	1240.9	97.38	199.08	161.27	11.53
143	1226.3	97.83	198.23	160.87	11.11
144	1174.8	100.89	196.48	160.71	10.94
145	1073.6	106.72	192.87	160.19	10.41
146	1127.6	103.07	194.36	160.03	10.23
147	1222.1	97.45	197.70	160.48	10.67
148	1267.4	94.53	199.09	160.47	10.65
149	1334.9	90.16	201.13	160.45	10.61
150	1391.2	86.43	202.76	160.36	10.51
151	1441.0	83.24	204.31	160.38	10.52
152	1462.2	81.82	204.95	160.37	10.50
153	1485.4	80.39	205.76	160.47	10.59
154	1510.8	78.94	206.77	160.70	10.71
155	1537.8	77.39	207.82	160.93	10.91
156	1565.5	75.59	208.70	160.95	10.97
157	1604.4	73.28	210.11	161.18	11.12
158	1604.7	73.49	210.42	161.48	11.38
159	1594.7	74.26	210.29	161.66	11.51
160	1581.1	75.05	209.86	161.64	11.44
161	1556.8	76.46	209.05	161.57	11.31
162	1518.5	78.84	207.89	161.59	11.28
163	1506.1	79.18	207.13	161.20	10.83
164	1441.0	83.38	205.27	161.34	10.88
165	1428.1	84.00	204.73	161.20	10.66
166	1393.8	86.02	203.59	161.11	10.52
167	1428.8	83.86	204.79	161.24	10.61
168	1454.5	82.24	205.65	161.31	10.65
169	1452.4	82.04	205.32	161.04	10.34
170	1507.2	78.19	206.69	160.73	9.93
171	1553.8	74.79	207.73	160.34	9.44
172	1602.6	71.57	209.17	160.29	9.29
173	1656.2	68.06	210.76	160.24	9.07
174	1702.4	65.20	212.31	160.38	9.13
175	1739.7	62.70	213.38	160.30	8.94
176	1787.7	59.72	214.98	160.43	8.95
177	1847.0	56.09	216.99	160.62	9.16
178	1840.5	57.01	217.36	161.19	9.49
179	1820.7	58.45	217.01	161.45	9.65
180	1788.0	60.40	215.94	161.38	9.48

STN	ELEVATION	OBS.GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	ANOMALY
181	1761.5	61.90	215.01	161.26	9.26
182	1758.7	62.20	215.11	161.45	9.30
183	1789.3	60.39	216.23	161.64	9.39
184	1788.6	60.39	216.23	161.56	9.18
185	1742.9	63.13	214.74	161.47	9.02
186	1725.9	63.92	213.99	161.24	8.56
187	1707.9	64.98	213.42	161.22	8.52
188	1703.6	64.75	212.85	160.78	7.98
189	1700.4	64.66	212.53	160.56	7.61
190	1698.0	64.86	212.55	160.65	7.53
191	1672.6	66.31	211.66	160.54	7.27
192	1645.6	67.60	210.48	160.18	6.83
193	1615.7	69.18	209.29	159.91	5.96
194	1573.5	71.51	207.70	159.61	6.49
195	1533.0	73.82	206.26	159.41	5.63
196	1500.0	75.52	204.92	159.08	5.08
197	1478.5	76.57	203.99	158.81	4.71
198	1453.8	77.98	203.13	158.71	4.71
199	1433.0	79.00	202.24	158.46	4.24
200	1418.7	79.39	201.35	158.00	3.60
201	1400.9	80.09	200.42	157.62	3.13
202	1385.1	80.86	199.75	157.33	2.75
203	1363.9	81.87	198.83	157.06	2.39
204	1356.8	82.43	198.77	157.22	2.45
205	1376.0	81.51	199.71	157.57	2.71
206	1377.5	81.43	199.83	157.65	2.71
207	1383.8	81.30	200.35	157.97	2.93
208	1385.1	81.32	200.55	158.13	2.99
209	1383.5	81.07	200.21	157.84	2.61
210	1393.7	80.57	200.71	158.03	2.71
211	1391.2	80.37	200.32	157.72	2.31
212	1384.0	80.80	200.13	157.75	2.24
213	1376.3	80.63	199.30	157.15	1.55
214	1379.3	80.64	199.65	157.41	1.72
215	1382.8	80.23	199.63	157.28	1.50
216	1381.5	80.40	199.71	157.41	1.53
217	1392.1	79.75	200.12	157.49	1.52
218	1384.1	80.28	199.94	157.55	1.49
219	1383.7	80.25	199.92	157.55	1.40
220	1391.5	79.43	199.90	157.29	1.04
221	1398.1	78.67	199.82	157.00	.70
222	1405.6	78.02	199.92	156.88	.53
223	1408.9	78.07	200.33	157.19	.79
224	1412.7	77.96	200.63	157.37	.93
225	1418.2	77.58	200.82	157.39	.90
226	1423.0	77.03	200.78	157.20	.66
227	1428.6	76.47	200.80	157.05	.46
228	1433.2	75.91	200.73	156.84	.21
229	1435.9	75.88	201.01	157.03	.35

STN	ELEVATION	OBS.GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
230	1439.4	75.73	201.24	157.16	.43
231	1450.7	75.37	201.99	157.57	.79
232	1484.7	73.10	202.97	157.50	.68
233	1516.3	70.81	203.71	157.28	.41
234	1541.7	68.96	204.32	157.10	.18
235	1553.6	68.14	204.67	157.10	.13
236	1575.5	66.72	205.37	157.12	.11
237	1586.8	65.74	205.50	156.91	-.15
238	1588.1	65.23	205.18	156.54	-.57
239	1593.4	65.12	205.60	156.81	-.35
240	1602.7	64.28	205.70	156.72	-.48
241	1616.8	63.16	205.95	156.54	-.61
242	1615.4	62.82	205.53	156.16	-.94
243	1617.8	62.41	205.40	155.96	-1.09
244	1719.6	62.02	214.65	155.70	-1.30
245	1607.7	62.43	204.58	155.45	-1.50
246	1581.7	63.73	203.49	155.15	-1.75
247	1551.9	65.42	202.43	155.01	-1.84
248	1515.7	67.50	201.15	154.83	-1.97
249	1483.1	69.21	199.84	154.52	-2.23
250	1455.1	70.55	198.60	154.14	-2.56
251	1421.6	72.28	197.24	153.81	-2.84
252	1394.2	73.55	195.99	153.39	-3.21
253	1361.4	75.32	194.73	153.13	-3.42
254	1336.2	76.58	193.67	152.85	-3.65
255	1313.4	77.48	192.47	152.35	-4.10
256	1292.3	78.51	191.57	152.10	-4.30
257	1272.8	79.21	190.49	151.51	-4.84
258	1258.7	79.70	189.71	151.16	-5.14
259	1242.2	80.50	189.02	150.97	-5.28
260	1222.0	81.37	188.04	150.62	-5.58
261	1201.6	82.32	187.13	150.33	-5.75
262	1186.5	82.84	186.28	149.94	-6.03
263	1168.3	83.24	185.02	149.24	-6.62
264	1159.4	83.66	184.65	149.14	-6.61
265	1152.5	83.78	184.18	148.88	-6.76
266	1140.7	84.21	183.55	148.61	-6.92
267	1130.4	84.47	182.89	148.27	-7.15
268	1126.1	84.45	182.52	148.03	-7.28
269	1123.3	84.54	182.40	148.00	-7.20
270	1121.3	84.46	182.18	147.84	-7.16
271	1107.6	85.18	181.66	147.74	-7.12
272	1101.2	85.37	181.30	147.58	-7.15
273	1091.6	85.65	180.72	147.29	-7.31
274	1086.7	85.69	180.36	147.08	-7.38
275	1084.8	85.61	180.15	146.93	-7.40
276	1080.1	85.88	180.03	146.96	-7.24
277	1084.5	85.47	180.09	146.88	-7.18
278	1096.5	84.52	180.31	146.73	-7.20
279	1094.5	84.74	180.36	146.86	-6.94

STN	ELEVATION	OBS.GRAVITY	FREE AIR GRAVITY	BOUGUER GRAVITY	RESIDUAL ANOMALY
280	1077.5	85.67	179.76	146.76	-6.90
281	1086.4	85.29	180.27	147.00	-6.53
282	1091.4	84.80	180.29	146.86	-6.54
283	1088.0	85.18	180.39	147.07	-6.19
284	1090.2	85.13	180.59	147.20	-5.93
285	1089.2	85.34	180.75	147.39	-5.61
286	1094.6	84.95	180.91	147.39	-5.47
287	1109.2	84.04	181.43	147.46	-5.27
288	1113.1	83.85	181.66	147.57	-5.03
289	1110.2	84.30	181.89	147.89	-4.57
290	1119.0	83.68	182.15	147.88	-4.45
291	1130.2	83.25	182.83	148.22	-3.98
292	1136.7	83.14	183.39	148.58	-3.48
293	1137.4	83.25	183.61	148.78	-3.15
294	1130.9	83.34	183.15	148.52	-3.28
295	1122.7	83.60	182.68	148.30	-3.36
296	1107.7	84.46	182.19	148.26	-3.27
297	1091.2	85.22	181.44	148.03	-3.37
298	1087.0	85.43	181.31	148.02	-3.24
299	1089.4	84.98	181.14	148.78	-3.35
300	1092 7	84.48	181.01	147.54	-3.48
301	1087.8	85.15	181.27	147.96	-2.88
302	1087.7	84.83	180.99	147.68	-3.00
305	1096.5	83.90	181.05	147.47	-3.05
306	1097.6	83.83	181.14	147.53	-2.82
307	1099.5	83.85	181.40	147.73	-2.46
308	1101.0	83.99	181.73	148.01	-2.02
309	1105.8	83.40	181.64	147.77	-2.10
310	1093.2	84.15	181.25	147.78	-1.93
311	1094.9	84.39	181.71	148.18	-1.36
312	1095.5	84.26	181.70	148.15	-1.23
313	1100.2	83.84	181.78	148.08	-1.14
314	1115.8	82.81	182.27	148.10	- .96
315	1139.6	81.44	183.19	148.29	- .61
316	1164.6	79.84	183.99	148.32	- .63
317	1192.2	78.24	185.04	148.53	- .34
318	1227.8	76.35	186.55	148.95	+ .20
319	1252.6	74.92	187.51	149.15	.55
320	1274.4	73.25	187.95	148.93	.55
321	1290.9	72.36	188.67	149.14	.89
322	1300.1	71.42	188.64	148.83	.66
323	1316.1	70.27	189.05	148.75	.75
324	1333.8	69.17	189.67	148.82	1.01
325	1347.3	68.35	190.17	148.91	1.06
326	1360.6	67.27	190.40	148.73	1.01
327	1372.1	65.79	190.05	148.85	1.27
328	1388.0	65.70	191.51	149.00	1.66
329	1406.1	64.54	192.10	149.04	1.99
330	1422.2	62.14	192.27	148.72	1.52
331	1432.1	62.45	192.56	148.70	1.75
332	1454.1	61.42	193.65	149.12	2.33

Plate 1

The Twisted Mountain as seen from the vicinity of South Nahanni River. Mississippian carbonates in anticlinal core, Permo-Carboniferous sandstone of the Mattson Formation on outer flanks.

Plate 2

West dipping Middle Devonian Nahanni Formation on the west flank of Nahanni Range: View north.

Plate 3

View northwest showing Middle Devonian carbonates exposed on east side of Camsell Range.

Plate 4

Prominent exposure of Upper Devonian clastic unit underlain by Upper Devonian Fort Simpson Formation on Ram anticline. View is north from south shore of Carlson Lake.

Plate 5

Middle Devonian Nahanni and Bear Rock Formations on the west flank of Mount Gaudet northwest of Wrigley.

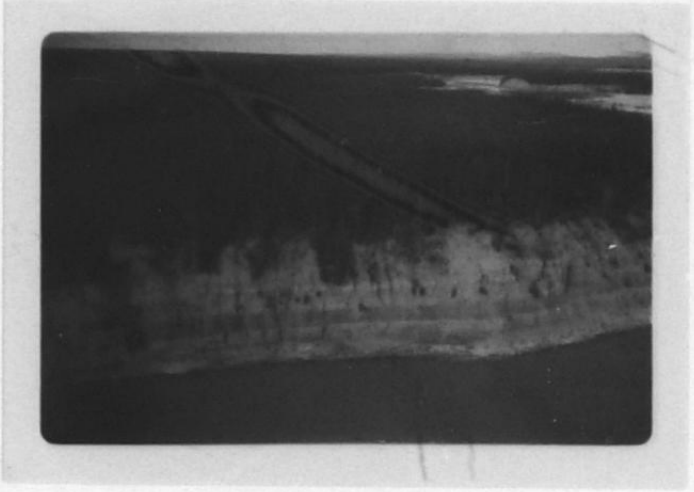


Plate 6

Cretaceous shales in banks of Redstone River near latitude 64°N.

Plate 7

Tertiary clastics near southeast end of MacKay Range. View north.

Plate 8

Middle Devonian Hume Formation at north end of MacKay Range.

Plate 9

Bioherms in upper part of Hume Formation west of Mount St. Charles.

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PART V

SUMMARY OF CONCLUSIONS

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PART V

SUMMARY OF CONCLUSIONS

The Redstone Project of Operation Geoquest demonstrates the effectiveness of combined geophysical and geological techniques in quantitative structural geologic mapping programs. Although standard photogrammetric mapping procedures are effective over most of the area, other parts are mantled and lack good surface expression necessary for such mapping. Information obtained from geophysical work in such areas is extremely valuable in providing the necessary control for structure contouring.

Northwest of Dahadinni River seismic Line 1 shows the lowest structure datum elevation to be -6,000 feet at a point about 3 3/4 miles northeast of Shell Cloverleaf I-46. It also reveals a structural high coincident with the well location showing lateral structural relief of more than 700 feet. This anticlinal fold is visible at the surface only in the form of a short inferred axis based on poorly expressed surface information.

The Cloverleaf axis is mapped as a northwesterly plunging anticlinal nose. Northwest of the lower reaches of Johnson River a series of northwesterly trending anticlinal and synclinal folds are mapped on the basis of poorly expressed surface information and confirmed by data from seismic Line 2. Opposing plunge may be present on the anticlinal folds but lack of data prevents confirmation.

In the central part of seismic Line 2, structure datum elevations as deep as -6,000 feet are indicated. Seven miles southwest of the main synclinal axis, the west flank of the structural depression flattens to form a structural terrace two miles or more wide. Farther southwest, the structure datum rises steadily to the edge of the mountain front.

The synclinal basin mapped west of the West Wrigley anticline is based on photogeologic mapping.

The gravity interpretation suggests the presence of a number of faults, some of considerable magnitude. The locations of such possible faults are indicated by an appropriate symbol on the accompanying maps although the structure contouring utilizes datum elevations obtained from the seismic profiles. Faults cannot be mapped in the heavily mantled parts of the Mackenzie Plain but regional tectonics suggest that longitudinal faults may be present.

Respectfully submitted,

C. I. Klipfel, B. S., P. Geoph.,
Manager, Evaluation Department.

PALLISTER and ASSOCIATES

G. M. Collins, P. Geol.,
Manager.

V. ZAY SMITH ASSOCIATES LTD.

PART VI

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PART VI

APPENDIX

SEISMIC FIELD PARAMETERS

RECORDING

Amplifiers	-	Geospace 111B 24 channel
Tape Transport	-	Geospace AM-200
Geophones	-	Natural frequency: 7.5 c.p.s.
	-	4 per trace
	-	Interval between geophones: 15 feet
Instrument Setting	-	(standard) Monitor Playback
Filters	-	Low cut: Refraction out out
	-	High cut: 1-60 1-60
AGC	-	Attack: normal
	-	Release: normal
Final Gain	-	85 - 100%
Suppression:	-	(Initial) Minimum
Spread Arrangement	-	Total length 13,800'
	-	Two group overlap between adjacent spreads
	-	Coverage: 100%
	-	Shotpoint Spacing: 13,200'
	-	Single holes
	-	Group Spacing: 600'
	-	Geophones: 4 per trace buried in a nest 15' by 15'

SURVEYING

- Seismometer stations and shotpoints chained at intervals of 600 and 13,200' respectively.
- Horizontal Control: Wild Theodolite
- Vertical Control: Wild Theodolite

DRILLING

	Type	No. Used
Drills Used:	Mayhew 200 model Helidrills	2
Hole Depth:	80 - 100 feet	
Charge Size:	50 to 500 pounds - average, 300 pounds	

LINE CUTTING

All line cutting was done by hand axe and power saw. Usually two crews of about five to eight men per crew were utilized with one cutting narrow walkable seismic lines while the other was clearing and constructing heliparts at shotpoint locations, recorder locations (spread midpoint) and line crew drop points (quarter spread locations).

TRANSPORTATION

All material, supplies and personnel were transported to and from the line by Bell 204 or 206 model helicopters. The larger helicopter (204) was used to move helidrills between locations, assist in spread layout and pickup. The small was best utilized for scouting, shooting, layout and pickup when travel distances were excessive for the 204.

FIELD RECORDING AND SHOOTING TECHNIQUES

Both lines were shot utilizing a full cable layout of 24 traces over 13,800 feet. Two-group overlaps were used to maintain continuity between adjacent spreads. Shots were recorded from shotpoints sufficiently offset to record the marker over the length of the spread (usually two or three times shotpoint interval from near detector) and in addition other shots were placed at cable end locations and other intermediate offset distances to record the full refraction spectrum to the marker. For a more complete study of the shots fired refer to time-distance, delay time and depth section.

INTERPRETATION PROCEDURES

Raw refraction times were picked and plotted in the field as the first step in the interpretation and to control the offset distances required to follow the primary marker. Velocities recognized on this plot were the basis for preliminary computations for datum corrections, delay time calculations, and mid-point depth estimates.

Datum corrections were made to correct each refraction to a horizontal velocity reference surface established at sea level using a correctional velocity of 8,000 feet per second along the angular entrance and emergent path. No effort was made to correct for weathering variations at this stage.

Corrected refraction times were plotted versus distance from shot, to form time-distance curves of all events noted. The slopes of the various segments were registered and averages were determined from reversed profiles to estimate the true refracting velocity. Delay times were then computed by removing the theoretical horizontal time at the appropriate marker velocity between shot and detector from corrected refraction times to leave a residual entrance and emergent delay time. The delay times were first plotted in their respective surface positions, then related between adjacent spreads to form a continuous relative delay time curve. At this stage two curves in surface position extending over the line were compared to identify the residual effects of surface conditions (weathering and elevation). Manageable computing irregularities were removed to smooth the curves.

The corrected delay times were checked for reciprocity and the reverse time law and then substituted into multi-layer midpoint formulae to determine the depths and thicknesses of refractors noted. Velocity functions were computed and the migration distance from emergent point to surface detector calculated.

Using the migration distances gained from the preceding, the two relative delay time curves were shifted to place the delay times in their true subsurface emergent position. Note that migration is a function of depth and velocity is variable; migration distance variations between adjacent midpoint computations were treated linearly and prorated over the intervening distance.

The two migrated relative continuous delay time curves were averaged when appropriate to form a single average migrated continuous delay time or relative time-depth curve. In this process up-dip components measured from up-dip shot hole environments were preferred to the opposite because of the geometry of the paths; this is particularly evident in steep dip zones.

The midpoint depth estimates were placed on the depth profile and the relative depth curves from delay times were superimposed to measure coherence. Differences observed were identified as ambiguities and attempts were made to reconcile by a system of second approximation. Most were resolved but one major area was not. (Line 2).

In the preceding, steps were taken to check the accuracy of the initial estimate of the true horizontal velocity. The reversed delay time curves in subsurface position offer a simple check on the original velocity assumption since the two curves when correctly migrated should show similar dip attitudes and be parallel; if not, then the horizontal velocity used in their calculation was wrong and the measure of divergence between the curves is a measure of the error.

This formula was used:

$$\frac{1}{V_{true}} = \frac{1}{V_h} + \frac{dt}{dx}$$

Where: Vtrue is the true horizontal refracting velocity.

Vh is the horizontal velocity assumed.

dt is the difference in time between one migrated curve and the averaged curve over dx the distance such time difference was measured.

The identifications of the various refracting events were based on the survey in the Shell Cloverleaf well which occupies a position about the midpoint of Line 1. The accuracy of the computations can be checked by comparison of refraction to well data.

On Line 1, four velocities were recorded which corresponded quite well to those indicated on a sonic log of the Shell Cloverleaf I-46 well located near shotpoint 277. Refer to the table below:

SHELL CLOVERLEAF I-46	REFRACTION DATA	
FORMATION	VELOCITY	VELOCITY
Drift (?)	Not recorded	8,000'/s
Cretaceous	10,080'/s	10,300 - 12,000'/s
Upper Devonian	13,050'/s	13,000 - 14,000'/s
Middle Devonian Carbonates	18,750'/s	19,000 - 21,000'/s

Since refraction velocities normally register slightly higher than the true velocity, the agreement here is quite good. One Line 2 the 10,500 foot per second Cretaceous layer may be evident on the northeast end of the line but is very thin or non-existent on most of the line.

A number of record sections were constructed to facilitate the study of secondary events recorded. Further, cable end shots were corrected for elevation and normal moveout and played in reflection filter settings to determine reflection content of the recordings. Usually, reflection data is poor, however, strong events are recorded to a time of 2 seconds at shotpoint 299; the events are correlative with breaks shown on the synthetic seismogram in the Cloverleaf well location.

GRAVITY FIELD PARAMETERS AND INTERPRETATION PROCEDURES

GENERAL

Between August 13 and August 23, 1968, a gravity meter survey was carried out by Huntec Division, Kenting Exploration Services Limited for Operation Geoquest along two seismic refraction lines between the Keele and Johnson River, west of the Mackenzie River in the Northwest Territories, latitude 62°45'N, longitude 124°30'W. The two lines, called Line 1 and Line 2, are 37.5 and 32.5 miles long and trend in a southwesterly direction. The Shell Cloverleaf I-46 well is located at gravity station 277 of Line 1. Altogether 330 gravity meter stations, at intervals of 600 feet, were established along Line 1 and 297 stations along Line 2.

The survey crew consisted of a geophysicist and operator and was based at the seismic base camp, two miles north of the Dahadinni River on the west bank of the Mackenzie River. A Bell G-2 helicopter was used in establishing gravity control at base stations in the survey.

The principal objective of the gravity survey was to assess structure of the Middle Devonian carbonate formations in this area.

Location of Gravity Stations

The location maps (Figures 1A and 1B) show the positions of the gravity meter stations. The scale of these maps is 1:50,000.

Line 1 stations are numbered consecutively from 101 to 431, and Line 2 from 101 to 397. Stations 101 on both lines are approximately 2,200 feet from the shore of the Mackenzie River. The Shell Cloverleaf I-46 well is located adjacent to station 277 on Line 1. It is seen in Figures 1A and 1B that Line 1 is a relatively straight line; Line 2 involves a series of line segments which have different azimuths.

SPECIFICATIONS

Horizontal Control

The gravity meter stations are located at intervals of 600 feet. The horizontal positions of the stations were previously determined in surveys by Pallister and Associates for locating seismic shotpoints. The accuracy of chaining was assumed to be 1:3,000.

Vertical Control

The elevations of the gravity meter stations, to the nearest 0.1 foot, were supplied by Pallister and Associates.

Gravity Survey

Instrument

World-Wide gravity meter was used in the survey. The scale constant was 0.09106 mgal/scale division.

Gravity Meter Base Stations

Base stations were established at intervals of approximately 10,000 feet along each line, see Figures 1A and 1B. These stations were established using the conventional method of base looping. A maximum misclosure of 0.01 mgal. was tolerated in the base station loops; in the event of a larger misclosure, a loop was rejected and repeated.

Gravity Meter Detail Stations

The observed gravity at each detail station was determined in a gravity loop which begins and terminates at a base station within two hours. When the drift in a loop exceeded 0.1 mgal. per hour, the loop was rejected and repeated.

Dominion Observatory Network Tie

The gravity survey was tied to the Dominion Observatory gravity station 9091/67 which is located at Wrigley Airport, Northwest Territories (63°12' N, 123°25'W). The observed gravity at this station is 982100.71 mgal. A gravity datum of 982000.00 mgal. was set in the reduction in order to facilitate easier handling of the data, e.g., the observed gravity of Wrigley becomes 100.71 mgal.

DATA REDUCTION

Field Calculations

Preliminary data reduction was done in the field. Observed gravity in units of milligals was computed at the end of each day's surveying. This served as a check for excessive instrument drift and gravity meter misreadings. The observed gravity calculation involves correction for the following effects:

(a) time dependence of the gravity field, i.e., a difference in instrument height of one foot produces a gravity anomaly of about 0.06 mgals.

(b) time dependence of the gravity field, i.e., the gravity readings drift with time at an observed rate of about 0.05 mgals/hour. This is due to variation in instrument temperature, earth tides and instrument mechanical creep.

Field calculation also involved adjusting the data to the Wrigley observed gravity datum.

Computer Data Reduction

Operations in Toronto involved reducing the observed gravity to Bouguer gravity values. The elevation, observed gravity and latitude of each station were recorded on punch cards. The following corrections were made to the observed gravity data using the Univac 1108 computer:

(a) Latitude Correction: $+1.307 \sin 2\phi$ mgals/mile in a north-south direction, where ϕ is the mid-latitude of the survey area, $62^{\circ}45'$ N.

(b) Free Air Correction: +0.09406 mgals/foot of elevation above sea level.

(c) Bouguer Correction: $-0.01276\ D_B$ mgals/foot above sea level, where D_B is the Bouguer density (see below).

(d) Terrain Correction: (see below).

Bouguer Density Determination

The Bouguer density, D_B, is the mean density of material between survey stations and the elevation datum, sea level. Without intensive drill-hole density logging and drill core density determinations, probably the most objective method of estimating D_B is to analyze the set of gravity data.

The approach consists of determining a linear relationship between free air gravity $\Delta_g FA$ (observed gravity after latitude and free air corrections) and elevation:

$$g_o = C_1 + C_2 e$$

where e = elevation in feet

$$C_2 = 0.01276\, D_B$$

This relationship was determined using the method of least sum of squares, finding the best values of C_1 and C_2:

$$\sum_{i=1}^{k} [\Delta g_{FA} - g_o]^2 = \text{minimum}$$

where k is the number of gravity stations along a given line. The result of applying the least squares technique was:

$$D_B = 2.40 \text{ gm/cm}^3$$

The figure for D_B is low in terms of the observed densities of shales and carbonates, i.e., 2.4 to 2.7 gm/cm^3. This indicates that near-surface rocks in the area have a relatively lower density. This may be due to the fact that Quaternary drift covers much of the area.

The data was then processed to calculate Bouguer gravity.

Terrain Correction

Topographical features at the western ends of the survey lines made it necessary to correct the gravity for terrain effects. This area is in the foothills of the Mackenzie Mountains. A measure of topographical relief can be seen in the elevation differences between successive gravity stations, e.g., 150 feet in a distance of 600 feet.

The gravitational effects of terrain were estimated using the station elevations for topographic control. A computer program facilitated computation of terrain effects. The technique assumes that the topography is two-dimensional in shape and that material below ground level has a uniform density, 2.4 gm/cm^3. Less than 10% of the stations required terrain correction greater than 0.5 milligals.

Presentation of Survey Data

Bouguer gravity values are plotted on the location maps (Figures 1A and 1B). Table I includes the elevation, observed gravity, free air gravity, Bouguer gravity and residual gravity data for the survey stations. The gravity values are in units of milligals.

Bouguer Gravity Profiles

The Bouguer gravity profiles are both characterized by a step-like anomaly whose amplitude is about 10 milligals (Line 2: stations 230 - 280, Line 1: stations 200 - 300). Additional "step-like" features are found particularly along the southwest half of Line 2 but these have much smaller amplitude. A most conspicuous gravity high is present in the middle of Line 1 and the amplitude of this feature is approximately 10 milligals. It is possible that this feature is absent in Line 2 because of this line's shorter length in the southwest direction.

INTERPRETATION

Distribution of Density with Depth

In the Shell Cloverleaf I-46 well, a sonic log was measured. From this log, compressional wave velocities for particular geological formations were calculated (CDP Computer Data Processors Ltd, 1967). An estimate of bulk density can be determined from compressional wave velocity, using an empirical relationship based on laboratory measurement of 300 samples of marine sedimentary rock (Nafe and Drake, 1961). The estimates of average bulk density are as follows:

1.	Cretaceous sandstone:	2.3 gm/cm^3
2.	Imperial Formation sandstone, shale:	2.4 gm/cm^3
3.	Canol Formation shale:	2.3 gm/cm^3
4.	Hare Formation shale:	2.3 gm/cm^3
5.	Hume Formation limestone:	2.7 gm/cm^3
6.	Bear Rock Formation dolomite:	2.7 gm/cm^3

It is apparent that a major density interface exists near the contact between Middle Devonian shales and the underlying Middle Devonian and older carbonates - 0.4 gm/cm^3. This interface coincides with the top of the Hume Formation. At the Shell Cloverleaf I-46 well, the density interface is at a depth of 5,517 feet below K.B. (-4,062 feet).

A secondary density contrast is seen at the contact between Cretaceous rocks and the underlying Upper Devonian rocks. The density change is in the order of 0.1 to 0.2 gm/cm^3.

In addition to the gravitational effects due to structure involving the shale/carbonate interface, substantial contributions to the gravity data may be due to the following effects:

(a) variations in the thickness of the Cambrian/Proterozoic sequence. It is assumed that this variation is gradual across the length of the survey lines and that the gravity effect is incorporated in the regional anomaly;

(b) isostatic effect of the Mackenzie mountains. Areas in vicinity of major mountain ranges are associated with relatively large negative gravity anomalies (see Garland, 1965). These anomalies are related to deep crustal structure. It is assumed that the isostatic effect of the Mackenzie Mountains is incorporated in the regional anomaly;

(c) variations in thickness and density of Cretaceous and younger sediments. Short wavelength anomalies which are conspicuous in the Bouguer gravity profiles are near-surface effects probably due to variations in thickness of Pleistocene cover. Analysis of the Bouguer gravity profiles will deal only with the broader features in the data in terms of relating these to structure of the shale/carbonate interface at depth.

(d) presence of evaporite piercement features or similar features associated with salt tectonics.

Regional Anomaly

The regional anomaly is a component of the gravity data which is due to the following features:

(a) variations in density at great depth, e.g., in the Archaean basement

(b) isostatic effect of the Mackenzie Mountains, a negative gradient in the direction of the Mackenzie Mountains

(c) variations in thickness of the Cambrian/Proterozoic succession

The method of estimating the regional anomaly is described schematically in Figure 4.

The method consists of using the refraction depth profiles as control to estimate the component of the Bouguer gravity data that is not associated with elevation of the shale/carbonate interface. The upper surface of the carbonate section is identified by the compressional wave velocity, 22,000 feet/sec. The shale formations have a velocity of 14,000 feet/sec. The difference in wave velocities corresponds well to a density contrast of about 0.4 gm/cm^3.

The refraction depth profile was examined for locations where the shale/carbonate interface was relatively flat. At these locations the elevation of the interface relative to a datum of -4,000 feet was noted. The elevation difference, E, was converted to a gravity effect using the infinite slab approximation.

$$g = 0.01278\ D.E. \quad \text{milligals}$$

where D = shale/carbonate density contrast = 0.4 gm/cm^3

E = elevation difference in feet

This gravity effect was then subtracted from the Bouguer gravity profile. The difference was defined as the regional anomaly. Approximately six points on each profile were determined in this way. A smooth curve was then fitted to these points.

The estimated regional anomalies for Lines 1 and 2 are shown in
The regional anomalies are surprisingly similar; a maximum 10 to 15 miles southwest of the northeastern ends of the lines. The amplitude of this maximum is in the order of 10 milligals. The negative gradient in both profiles in the southwestern direction can easily be explained by the isostatic effect of the Mackenzie Mountains. The maximum could be due in part to the gravity effect of a decrease in thickness of the low density Proterozoic sequence of sediments.

The establishment of a "gravity datum", i.e., the regional anomaly makes it now possible to consider the gravity data in terms of structure of the shale/carbonate interface.

Geological Interpretation

The interpretation was carried out in two steps. First, the gravity profiles were inspected for significant, resolvable anomalies. These selected anomalies were analyzed using simple models, with particular emphasis on depth determinations and estimates of thickness. Second, a continuous geological section was constructed which produced the best fit to the residual Bouguer gravity profile. The results from the first phase of the interpretation were intended as guidelines to the synthesis of the continuous geological sections.

Analysis of Selected Anomalies

Bouguer gravity profiles 1 and 2 are characterized by a number of step-like gravity anomalies which involve large gravity gradients. It was tentatively assumed that these gravity features were caused by vertical faulting at depth which causes displacement of the shale/carbonate interface. Using the faulted slab formulas developed by Bancroft (1961) it is possible to estimate the depth and throw (see Figure 5) associates with each interpreted fault.

The results of this analysis are shown on Table II.

In the Shell Cloverleaf I-46 well, the shale/carbonate interface is at a depth of 5,517 feet below K.B. The well is located in a broad minimum of profile 1. The shale/carbonate interface depth is thus considered to be "deep".

The depth, 2,200 feet from Line 1 (210 - 250) is therefore unexpectedly shallow. The estimate is related to the magnitude of the gradient of the anomaly. An increase in observed gradient could be due to the superposition of other effects, e.g., a change in thickness of the shallow, low density Cretaceous and Pleistocene sediments. This area is covered by drift and a variation in thickness associated with faulting is a likely possibility.

The second analyzed Line 1 (300 - 360) yields a depth of 4,730 feet which is comparable to the shale/carbonate interface depth at the Cloverleaf well.

Near the southwestern end of Line 1, between stations 410 and 418, a pronounced gravity minimum was observed. The anomaly amplitude is -38 milligals. The sharp gradient along the flanks of the anomaly indicate that the anomaly is due to effects close to ground level. Because the anomaly is observed in a topographic low, it is suggested that the anomaly could be caused by a locally thick sequence of low density Pleistocene alluvial sediments.

Results of analysis of "fault-like" gravity anomalies in profile 2 are included in Table II. Anomalies 2 (180 - 200) and 2 (230 - 270) yield depth estimates of 3,700 and 4,500 feet, respectively. These are reasonable depths to the shale/carbonate interface. The shallow depth at 2 (270 - 300) could be considered in the same way as anomaly 1 (210 - 250).

Profile 2, as well as profile 1, is characterized by numerous short wavelength anomalies; 1,200 to 1,800 feet wide which have amplitudes usually less than 0.5 milligal. These anomalies are located in areas along the line that are drift covered. They are probably due to variations in thickness and density of the surficial deposits.

TABLE II

ANALYSIS OF SELECTED ANOMALIES USING FAULTED SLAB APPROXIMATION

Line	Location (s.p. interval)	Amplitude (milligals)	Gradient (milligals/mile)	Throw (feet)	Depth (feet)	Downside
1	210 - 250	7.2	4.3	1400	2200	SW
1	300 - 360	17.0	4.6	3300	4730	NE
2	180 - 200	10.0	3.7	2000	3700	SW
2	230 - 270	8.0	2.6	1600	4500	SW
2	270 - 300	4.3	2.5	830	2500	NE

Interpreted Sections

The residual Bouguer gravity profiles were used to construct interpreted geological sections. The interpretation is based on the assumption that the gravity data are wholly related to variations in elevation of the Middle Devonian shale/carbonate interface. The short wavelength gravity effects of the low density Cretaceous and Pleistocene sediments were disregarded.

The method of constructing a geological section whose gravity effect approximates an observed gravity profile was developed by Spector (1963). The basic model used in the analysis is the faulted slab, shown in Figure 6a. The parameters that are necessary to define the gravity effect of this model are as follows:

S - the horizontal distance of the leading edge of he slab from a reference point on the gravity profile

h - the depth to the upper surface of the slab

t - the slab's thickness

A - the angle between the slab's leading edge and the horizontal

- the slab's density contrast

The gravity effect of the slab is a complex mathematical expression (see Spector, 1963). However, in terms of the above parameters, the expression can be written in the following schematic way:

$$g(x) = F(x, s, h, t, A)$$

In Figure 6b we see how a buried hill can be considered as the difference between the gravity effects of two slabs, one having the leading edge CD:

$$g(x) = F(x, s, h, t, A) - F(x, s_2, h, t, A_2)$$

In this way, the gravity effect at any point along a profile involving a proposed geological section can be quickly determined using a distribution of slab models. After one or two iterative steps, a theoretical geological section can be constructed which produces a computed gravity profile approximating the observed effect to within the desired degree of fit. The "goodness of fit" between computed and observed gravity values was taken to be 0.50 mgal.

The interpreted geological sections are shown in Figure 7A and 7B. Relief on the shale/carbonate interface is interpreted on the basis of a best fit to the residual gravity data. The seismic refraction depth profiles are also shown on the profiles for purposes of comparison. Structural information derived from available geological mapping is included for the purpose of projecting structure to depth.

It is noted that the general form of the section interpreted from the gravity data is very similar to the seismic profile. However, a considerable amount of additional structural detail on the shale/carbonate interface has been resolved from the gravity data.

At the northeastern end of Line 1 the interface has the appearance of a homocline. In the interval between shotpoints 101 to 120, the interface is approximately flat; between 120 and 155 the dip is 4° and between 155 and 190 it is 3°. Further southwest it is relatively flat with the exception of a fold structure between 195 and 215. The amplitude of this fold is 200 feet.

At shotpoint 230 a vertical fault is interpreted with a throw of 2,500 feet. An anticlinal feature is penetrated by the Cloverleaf well. The anticline is flanked on the southwest by another fault. The throw of this "normal" fault is about 1,200 feet.

A major thrust fault is interpreted in the vicinity of shotpoints 322 to 327. The dip of the fault plane, 60°, was assumed from geological mapping. The interpreted vertical throw of this fault is over 2,500 feet.

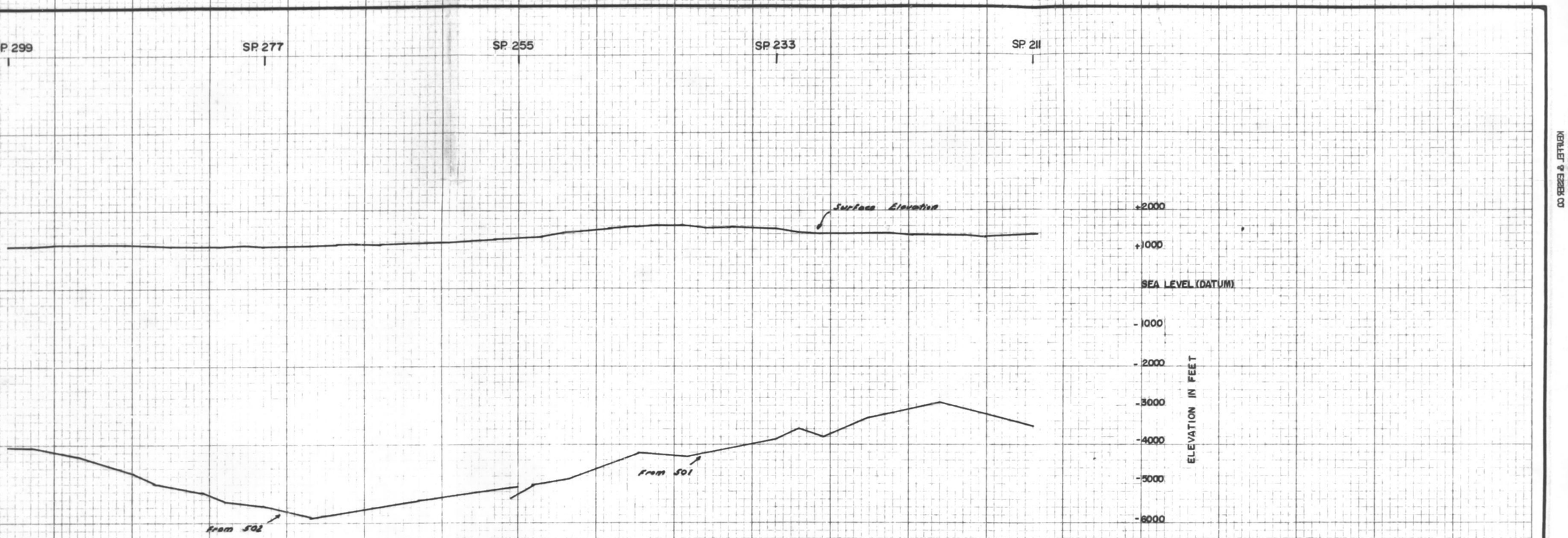
Southwest of the thrust fault the shale/carbonate interface is quite sinusoidal particularly between shotpoints 380 to 431. The folds correlate quite well with folding observed in surface mapping. A graben feature was considered to explain the large negative gravity anomaly between 410 and 420. The fit is very poor and therefore indicates that this anomaly, to a large extent, is due to near-surface effects, a thick accumulation of low density Pleistocene, e.g., along an erosion feature.

The interpreted section for Line 2 is very similar to that for Line 1. The graben-like features in the central part of the section are similar to the down-faulted features presented in Line 1. The northeastern part of Line 2 includes a series of normal faults. The gravity lows that are associated with these interpreted features appear to coincide with topographic lows. An alternate interpretation for the gravity lows would be thick accumulations of low density Pleistocene sediments which have filled eroded valleys in the Devonian bedrock.

A normal fault is interpreted in the neighbourhood of shotpoint 195. The throw of this fault is 1,800 feet.

The shale/carbonate interface immediately to the southwest, dips 2° southwest. At shotpoint 250 it is cut by another fault with a 2,000-foot throw. Normal faults at 280 and 310 flank graben-like features.

The southwestern end of Line 2 has the appearance of homocline. The interface dips at 5° between shotpoints 330 to 360, it is flat between 360 and 375 and dips at 8° between 388 and 375.



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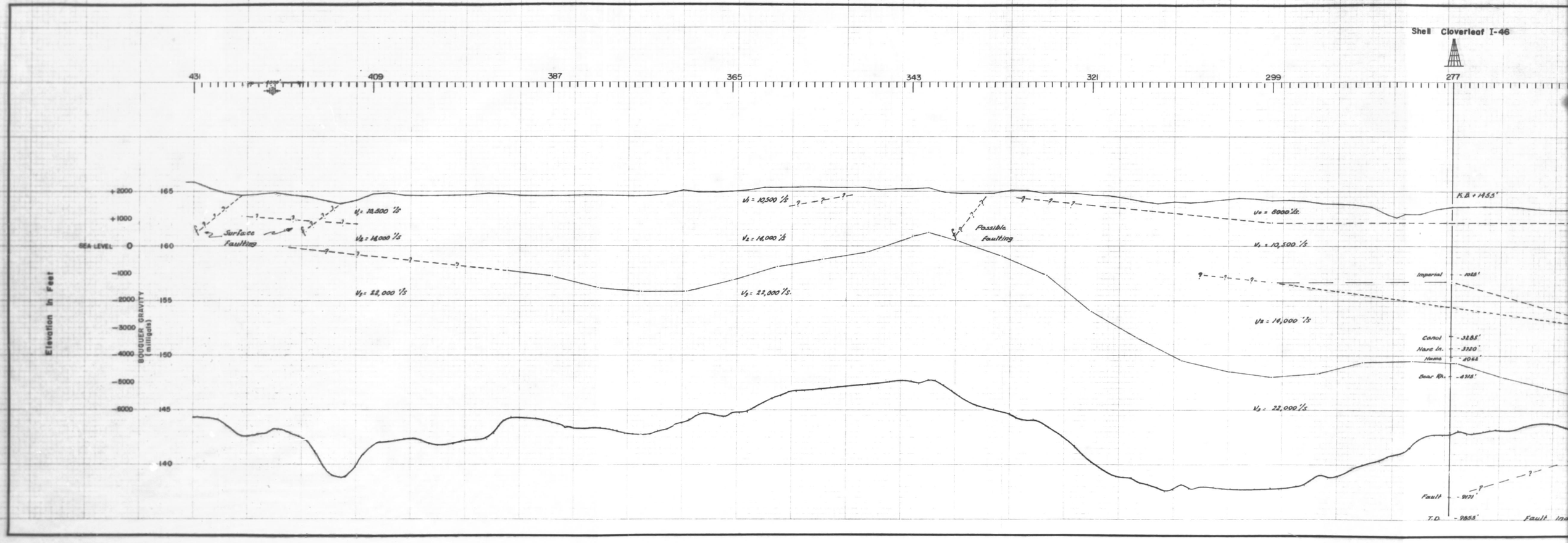
BROADSIDE REFRACTION PROFILE
LINE 2

OPERATION GEOQUEST
N.W.T.
PROJECT 7
REDSTONE

INTERPRETATION BY:
INTERPRETER: D.G. MOULD
DATUM: SEA LEVEL

CANWEST GEOPHYSICAL LTD.
SUPERVISOR: H.E. BOWMAN


Shell Cloverleaf I-46
431
409
387
365
343
321
299
277
+2000
+1000
SEA LEVEL 0
-1000
-2000
-3000
-4000
-5000
-6000
Elevation in Feet
165
160
155
150
145
140
BOUGUER GRAVITY (milligals)
V1 = 10,500 '/s
V2 = 14,000 '/s
V3 = 22,000 '/s
Surface Faulting
Possible faulting
V4 = 8000 '/s
K.B. + 14.5'
Imperial - 1088'
Canal - 3285'
Hare Ln. - 3320'
Hemo - 4044'
Bear Rh. - 4318'
Fault - 9171'
T.D. - 9853'
Fault Inf

overleaf I-46

North approximately 41° East

277 255 233 211 189 167 145 123 101

K.B. +453'

SURFACE ELEVATION

REFRACTION HORIZON

V_1 = 8000 '/s

V_2 = 10,500 '/s

REFRACTION HORIZON

-1015'

-3285'

-3320'

-4062'

-4315'

BOUGUER GRAVITY

V_3 = 14,000 '/s

NAHANNI (HUME) REFRACTION HORIZON

V_4 = 22,000 '/s

Questionable continuity between S.P. 255 & 233

-9171'

-9855'

Fault indicated on sonic at about -9171 Ft.

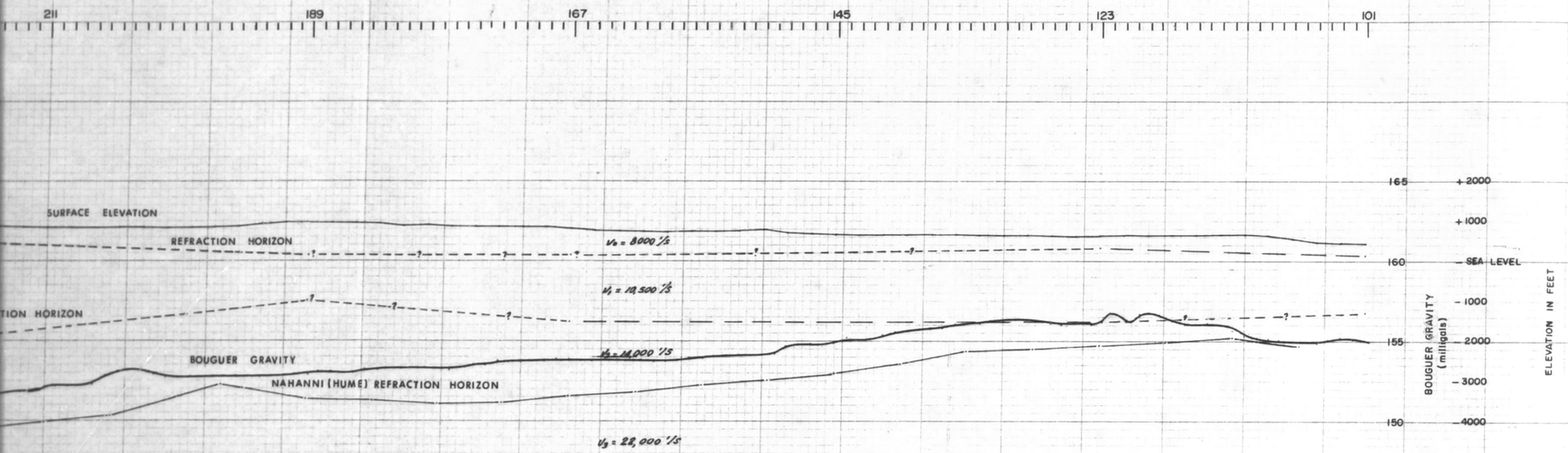
BOUGUER GRAVITY (milligals)

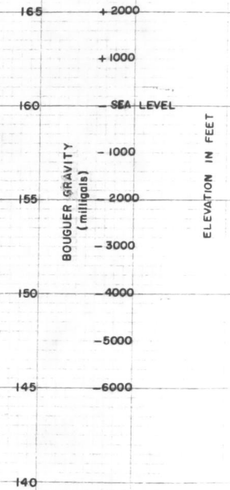
165 160 155 150 145 140

+2000 +1000 SEA LEVEL -1000 -2000 -3000 -4000 -5000 -6000

ELEVATION IN FEET

North approximately 41° East





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REFRACTION DEPTH PROFILE
LINE I

OPERATION GEOQUEST

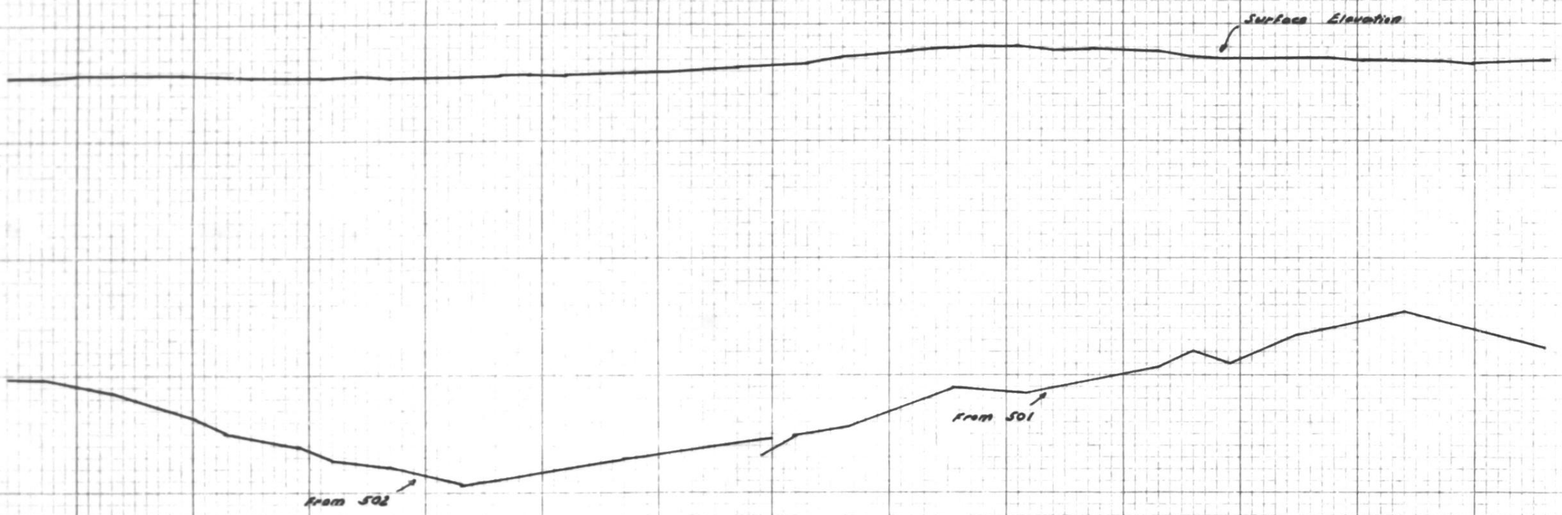
N.W.T.
PROJECT 7
REDSTONE

INTERPRETATION BY: CANWEST GEOPHYSICAL LTD.

INTERPRETER: D.G. MOULD SUPERVISOR: H.E. BOWMAN

DATUM : SEA LEVEL

SP 299 | SP 277 | SP 255 | SP 233 | SP 211



+2000
+1000
SEA LEVEL (DATUM)
-1000
-2000
-3000
-4000
-5000
-6000
ELEVATION IN FEET

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BROADSIDE REFRACTION PROFILE
LINE 2

OPERATION GEOQUEST
N.W.T.
PROJECT 7
REDSTONE

INTERPRETATION BY:
INTERPRETER, D.G.MOULD
DATUM: SEA LEVEL

CANWEST GEOPHYSICAL LTD.
SUPERVISOR, H.E. BOWMAN

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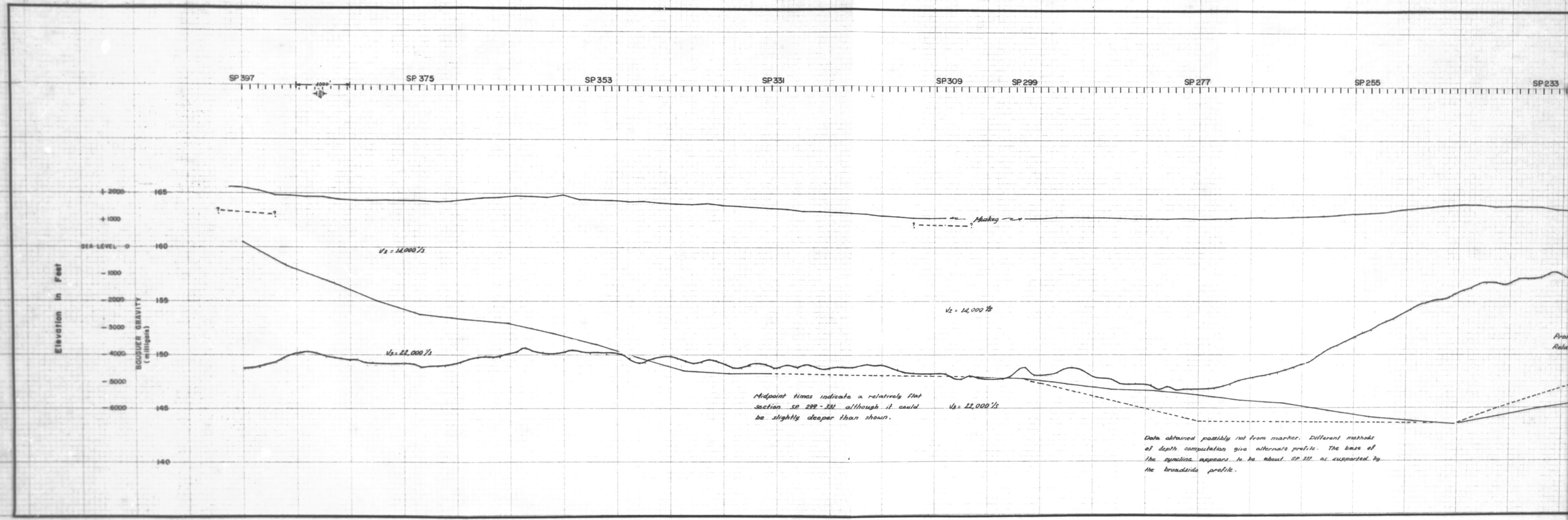
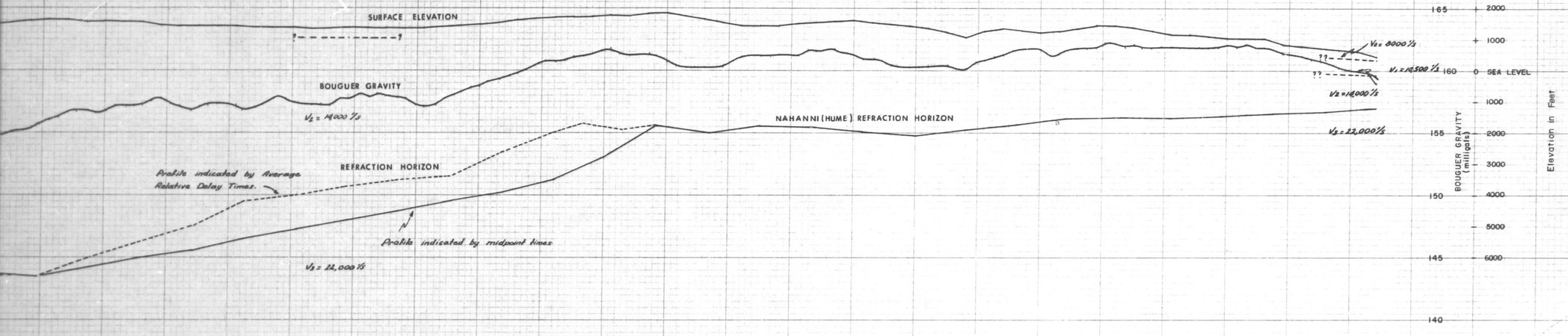
NEW YORK


SP 397
SP 375
SP 353
SP 331
SP 309
SP 299
SP 277
SP 255
SP 233
4000'
+2000
+1000
SEA LEVEL 0
-1000
-2000
-3000
-4000
-5000
-6000
Elevation in Feet
165
160
155
150
145
140
BOUGUER GRAVITY (milligals)
Marker
V2 = 14,000 f/s
V2 = 22,000 f/s
V2 = 14,000 f/s
V2 = 22,000 f/s
Midpoint times indicate a relatively flat section SP 299 - 331 although it could be slightly deeper than shown.
Data obtained possibly not from marker. Different methods of depth computation give alternate profile. The base of the syncline appears to be about SP 277 as supported by the broadside profile.

North approximately 46° 30' East

SP233 SP211 SP189 SP167 SP145 SP123 SP101



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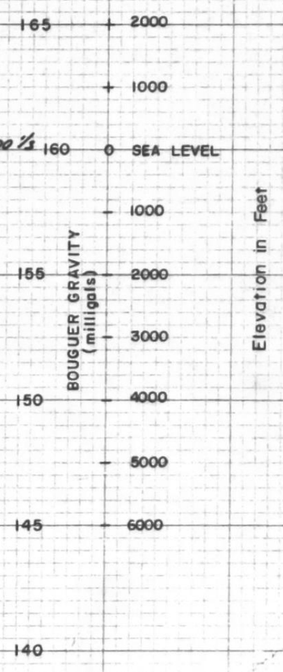
REFRACTION DEPTH PROFILE
LINE 2

OPERATION GEOQUES
N.W.T.
PROJECT 7
REDSTONE

INTERPRETATION BY: CANWEST GEOPHY
INTERPRETER: D.G. MOULD SUPERVISOR:
DATUM: SEA LEVEL

North approximately 46° 30' East

SP 145 SP 123 SP 101



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REFRACTION DEPTH PROFILE
LINE 2

OPERATION GEOQUEST

N.W.T.

PROJECT 7

REDSTONE

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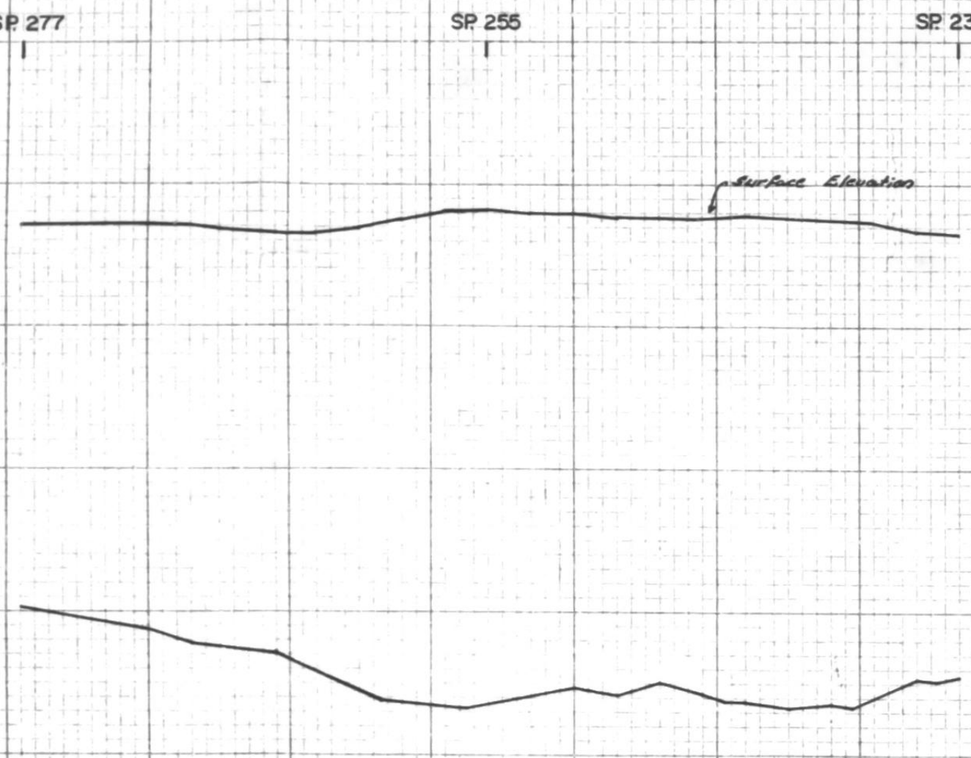
INTERPRETER: D.G. MOULD SUPERVISOR: H.E. BOWMAN

DATUM: SEA LEVEL



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BROADSIDE REFRACTION PROFILE
LINE 1

OPERATION GEOQUEST

N.W.T.

PROJECT 7
REDSTONE

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INTERPRETER: D. G. MOULD SUPERVISOR: H.E. BOWMAN.

DATUM: SEA LEVEL

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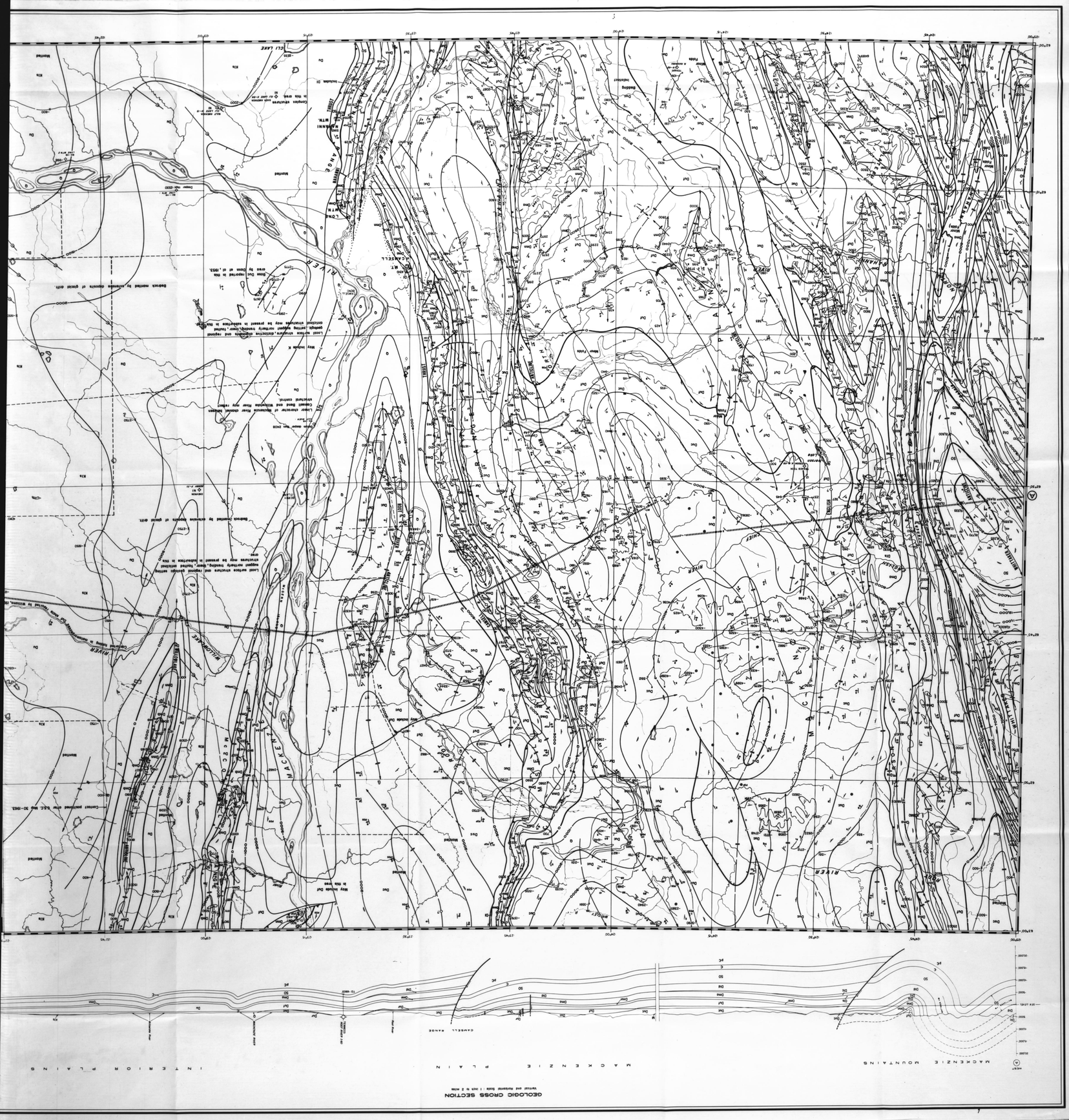
105 M.M.

11x

November 1973



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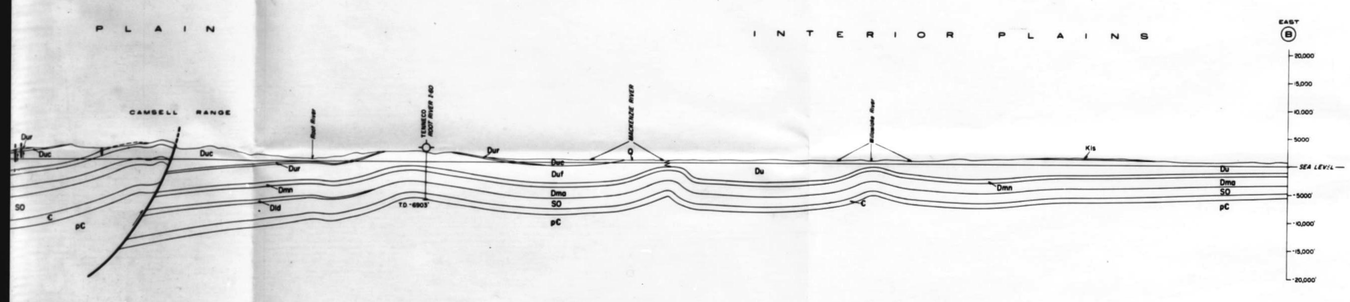
105 M.M.

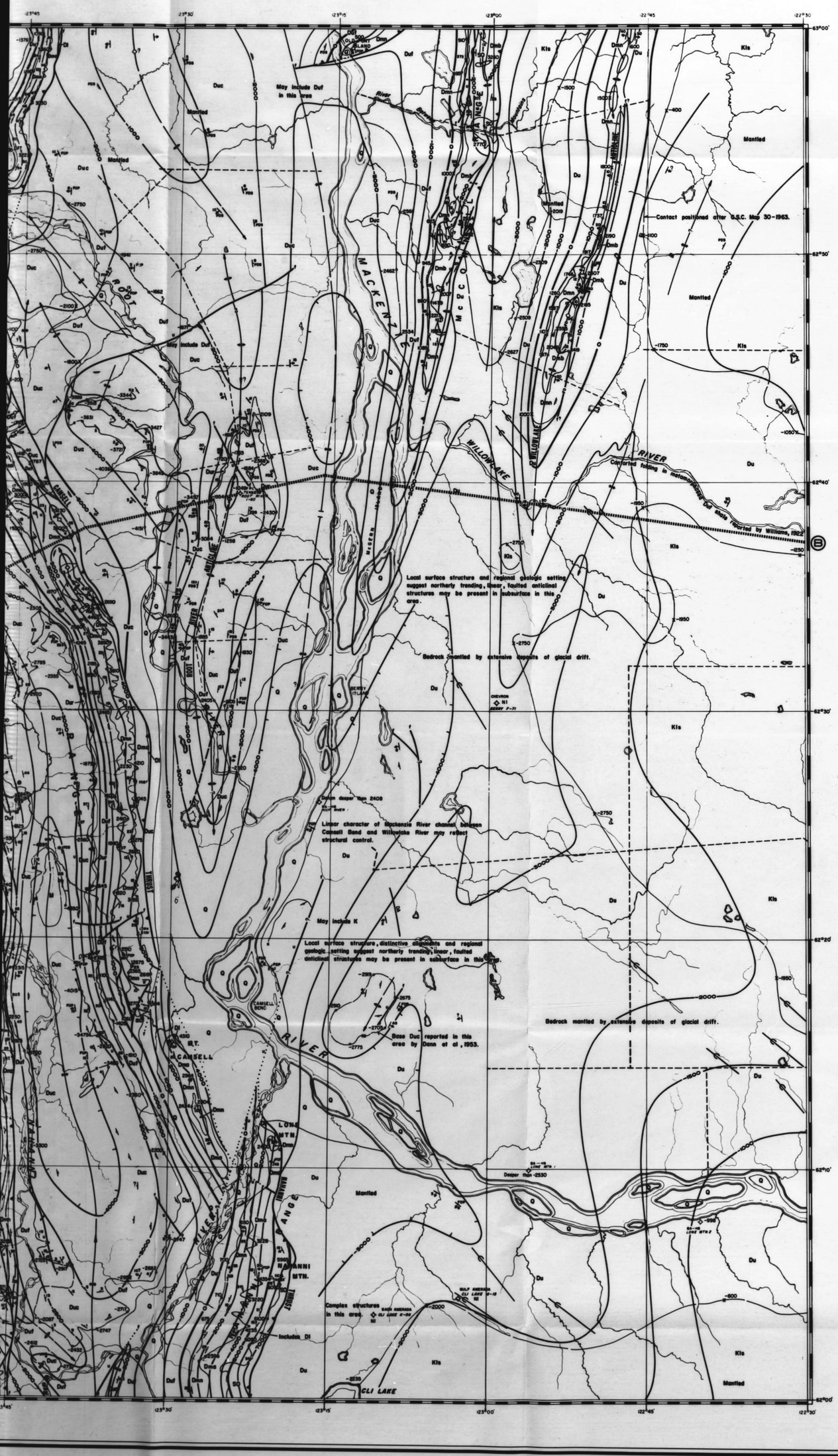
11x

November 1973

LOGIC CROSS SECTION

and Horizontal Scale : 1 inch to 2 miles





LEGEND

FORMATION OR GROUP AND SUMMARY LITHOLOGY

AGE	SYMBOL		
QUATERNARY	Q	Recent alluvium, terrace deposits, landslide debris and glacial drift undivided.	
TERTIARY	T	Undivided. Gravel, sandstone, siltstone, mudstone; some coal and lignite.	
UPPER CRETACEOUS	Ku	East Fork. Shale. Little Bear. Sandstone.	K
LOWER CRETACEOUS	Kls	Fort St. John Group. Shale, siltstone, sandstone. Southern map area. Slater River. Shale Sans Sault. Sandstone, shale. Northern map area.	K
PERMIAN AND PENNSYLVANIAN	PPm	Fantasque. Sandstone, chert. Mattson. Sandstone. May include beds of Mississippian age.	
MISSISSIPPIAN	M	Flett. Limestone. Clausen. Shale. Yohin. Sandstone.	
UPPER DEVONIAN	Duc	Unnamed clastic sequence. Sandstone, shale.	Du
	Dur	Unnamed reef limestones. Lies in lower part, or at base of Duc.	Du
	Duf	Ft. Simpson. Shale. Includes Middle Devonian Horn River Formation.	
MIDDLE DEVONIAN	Dmn	Nahanni (Hume). Limestone. Headless. Argillaceous limestone.	Dml
	Dma	Arnica. Limestone. Grades northeastward to Bear Rock. In upper part also includes the laterally equivalent: Landry. Limestone. Base mapped locally as ——L——. Funeral. Argillaceous limestone. Base mapped locally as ——F——. Manetoe. Porous dolomite. Base mapped locally as ——M——.	Dml
	Dmb	Bear Rock. Dolomite and limestone; brecciated. Grades southwestward to Arnica. In upper part includes Landry, Funeral, and Manetoe where present	Dml
LOWER DEVONIAN	Dls	Sombre. Dolomite.	Dl
	Dlc	Camsell. Dolomite, limestone; brecciated. Base mapped locally as ——C——	Dl
	Dld	Delorme. Dolomite.	Dl
SILURIAN AND ORDOVICIAN	SO	Whittaker and Sunblood. Limestone, reefal dolomite, sandstone; southwestern project area. Base of Whittaker mapped locally as ——W——. Mt. Kindle and Franklin Mountain. Reefal dolomite, dolomite. Northeastern project area.	
CAMBRIAN	C	Saline River. Shale, gypsum. Mt. Cap. Shale, siltstone, dolomite, limestone. Mt. Clark. Sandstone, quartzite.	Mackenzie Group. Katherine Group.
PRECAMBRIAN	pC	Lone Land in upper part. Sandstone, shale, siltstone, conglomerate, mudstone. Lower part; unnamed shale, siltstone, sandstone, dolomite.	

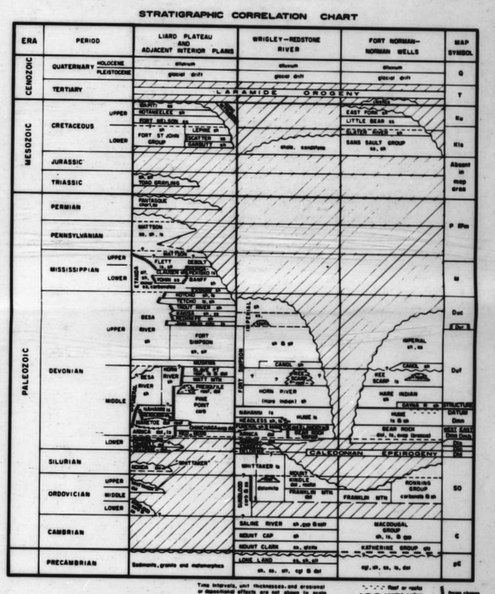
GEOLOGICAL SYMBOLS

- Trace of bedding in stream cut appears horizontal. May represent flat-lying beds or strike.
- Bedding appears horizontal on photographs
- Recognizable dip 1° or less
- Dip group 1, 1° to 3°
- Dip group 2, 3° to 10°
- Dip group 3, 10° to 25°
- Dip group 4, 25° to 45°
- Dip group 5, 45° to nearly vertical
- Bedding appears vertical on photographs
- Overturned bedding
- General dip of beds having subordinate folds
- Dip and strike. Amount of dip cannot be estimated on photographs

Photo estimated

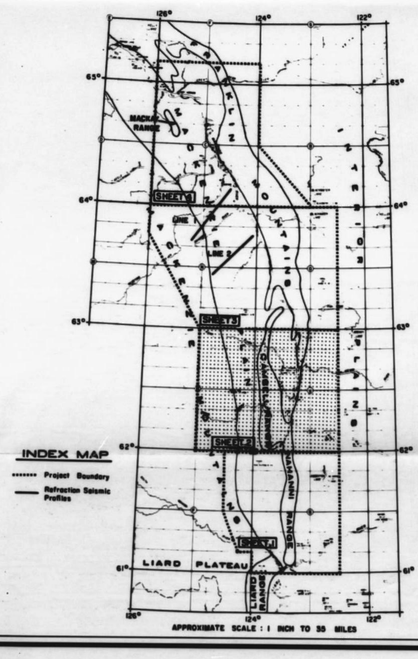
- Dip component
- Field measured dip, V. Zay Smith Assoc. Ltd., 1968.
- Field observed published dip or component
- Dip measured photogrammetrically
- Refraction seismic profile and shot point location number. Structure datum elevation in feet.
- Structure datum elevation in feet. Measured with Multiplex photogrammetric plotter. Control points on strata lying above or below datum are projected to datum using quantitative information derived photogrammetrically. Structure datum restored where removed by erosion.
- Structure datum elevation derived from topographic map control.
- Structure contours on top of Middle Devonian carbonate (Hume or Nahanni Formation)
- Field observed
- Field observed published information
- Strike line of prominent ridge or bedding. Direction of dip cannot be determined on photographs.
- Fracture or joint
- Distinctive alignment, possible structural significance
- Fault; dotted where extended through Quaternary deposits.
- Thrust fault. Triangles on thrust sheet. Structure contours depict faults as vertical.
- Anticline, arrow denotes plunge, diamond denotes approximate position of apex.
- Syncline, arrow denotes plunge, brush and cross bars denote approximate position of high point.
- Structural terrace
- Monocline
- Glacial lineation indicating direction of ice movement
- Prominent scarp or steep slope
- Apparent unconformable contact
- Contact, dashed where indefinite
- Contact, inferred
- Key bed; subtended letter or number indicates local correlation.
- Stratigraphic break; subtended letter or number indicates local correlation.
- Indicates correlative beds or formations
- Facies and/or nomenclature change
- Outcrop area
- Cross section
- Location of possible fault as suggested by gravity interpretation.

STRATIGRAPHIC CORRELATION CHART



WELL SYMBOLS

- Well location or drilling well
- Dry and abandoned test
- Oil well
- Capped oil well
- Gas well
- Capped gas well
- Oil and gas well
- Capped oil and gas well
- Nb Information available



PALLISTER and ASSOCIATES — V. Zay Smith Associates Ltd.

OPERATION GEOQUEST

NORTHWEST TERRITORIES OF CANADA

REDSTONE PROJECT

AREAL GEOLOGY
AND
STRUCTURE CONTOUR MAP

STRUCTURE DATUM: TOP OF MIDDLE DEVONIAN CARBONATE (HUME–NAHANNI FORMATIONS)

STRUCTURE CONTOUR INTERVAL: 500 AND 1000 FEET

SCALE : 1:126,720

(1 INCH TO 2 MILES)

Areal geology compiled by:

1. Photogeologic mapping and field studies conducted by V. Zay Smith Associates Ltd. during 1968 and 1969.
2. Incorporation of published and open file information.

Quantitative structural data derived from:

1. Refraction seismic survey in Mackenzie Plain conducted during summer 1968 by Huntec Limited, Petroleum Geophysics Division.
2. Field observations by V. Zay Smith Associates Ltd. during summer 1968.
3. Elevations, stratigraphic thicknesses and structural attitudes measured with a Multiplex photogrammetric plotter.
4. Supplementary elevations computed from Department of Mines and Technical Surveys topographic maps.
5. Published and open file information.

SHEET 2

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MICROMAT 11x November 1973
105 M.M.

OPERATION GEOQUEST

NORTHWEST TERRITORIES OF CANADA

REDSTONE
MAP A

SCALE 1:50,000

UNIVERSAL TRANSVERSE MERCATOR GRID

KEELE RIVER

REDSTONE RIVER

DAHADINNI RIVER

MACKENZIE

INDEX MAP

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QUEST

CANADA

PRELIMINARY AND ASSOCIATES

Location Map

SEISMIC SHOT POINTS and GRAVITY STATIONS

CONTOUR INTERVAL

DATUM ELEVATION

DATUM/GEOCITY FT. /SC.

Interpretation By:

MAP A
MAP NO. 1

LEGEND

TOPOGRAPHY TAKEN FROM
N.T.S. MAPS
ISSUED BY THE DEPARTMENT OF
PUBLIC WORKS OF CANADA
REVISED TO 1961 AND CHANNEL
AND MARKERS TO SEPT. 1961

GRID - U.T.M. GRID CO-ORDINATES
IN FEET.

MACKENZIE RIVER

BLACKWATER RIVER

MILE 430

MILE 420

MILE 410

7,090,000 m N

1,350,000 FT N

1,355,000 FT N

1,360,000 FT N

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105 M.M.
November 1973
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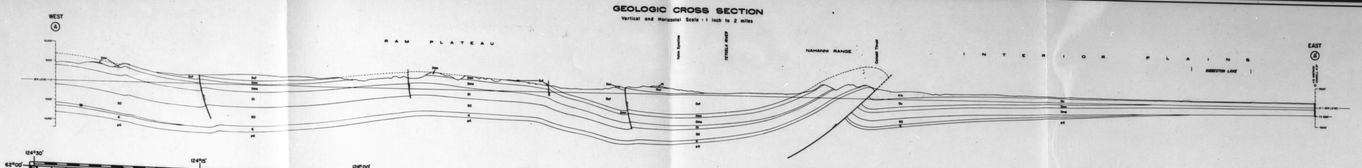
GEOLOGIC CROSS SECTION

Vertical and Horizontal Scale - 1 inch to 2 miles



LEGEND

FORMATION OR GROUP AND PREDOMINANT LITHOLOGY

AGE	SYMBOL		
QUATERNARY	Q	Recent alluvium, terrace deposits; landslide debris and glacial drift undivided.	
TERTIARY	T	Undivided. Gravel, sandstone, siltstone, mudstone; some coal and lignite.	
UPPER CRETACEOUS	Ku	East Fork. Shale.	K
LOWER CRETACEOUS	Kls	Little Bear. Sandstone.	
		Fort St. John Group. Shale, siltstone, sandstone. Southern map area. Slater River. Shale. Sans Sault. Sandstone, shale. Northern map area.	
PERMIAN AND PENNSYLVANIAN	PIPn	Fantasque. Sandstone, chert. Mattson. Sandstone. May include beds of Mississippian age.	
MISSISSIPPIAN	M	Flett. Limestone. Closson. Shale. Yahtin. Sandstone.	
UPPER DEVONIAN	Duc	Unnamed clastic sequence. Sandstone, shale.	Du
	Dur	Unnamed reef limestones. Lies in lower part, or at base of Duc.	
	Dus	Ft. Simpson. Shale. Includes Middle Devonian Hare River Formation.	
MIDDLE DEVONIAN	Dnm	Nahanni (Hume). Limestone. Headless - Argillaceous limestone.	Dnd
	Dna	Arnica. Limestone. Grades northeastward to Bear Rock. In upper part does include its laterally equivalent Landry. Limestone. Fossil locality as Funeral. Argillaceous limestone. Base mapped locally as Meander. Pelvas Dolomite. Base mapped locally as	
	Dnb	Bear Rock. Dolomite and limestone; brecciated. Grades southeastward to Arnica. In upper part includes Landry, Funeral, and Meander where present	
LOWER DEVONIAN	Dls	Sombre. Dolomite.	Dl
	Dlc	Camsell. Dolomite, limestone; brecciated. Base mapped locally as	
	Dld	Delorme. Dolomite.	
SILURIAN AND ORDOVICIAN	SO	Whittaker and Sunkhead. Limestone, reefal dolomite; sandstone, southeastern project area. Base of Whittaker mapped locally as Mt. Kindle and Franklin Mountain. Reefal dolomite, dolomite. Northeastern project area.	
CAMBRIAN	∈	Saline River. Shale, gypsum.	Mackenzie Group.
		Mt. Clark. Sandstone, quartzite.	Katherine Group.
PRECAMBRIAN	pЄ	Lowland in upper part. Sandstone, shale, siltstone, conglomerate, mudstone. Lower part; unnamed shale, siltstone, sandstone, dolomite.	

GEOLOGICAL SYMBOLS

- Trace of bedding in stream cut appears horizontal. May represent flat-lying beds or strike.
- Bedding appears horizontal on photographs
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- Dip group 2, 5° to 15°
- Dip group 3, 15° to 25°
- Dip group 4, 25° to 45°
- Dip group 5, 45° to nearly vertical
- Bedding appears vertical on photographs
- Overturned bedding
- General dip of beds having subordinate folds
- Dip and strike, amount of dip cannot be estimated on photographs
- Dip component
- Field measured dip, V.Zay Smith Assoc. Ltd., 1968
- Field observed published dip or component
- Dip measured photogrammetrically
- Refraction seismic shotpoint and shot point location number. Structure datum elevation in feet.
- Structure datum elevation in feet. Measured with altimeter, photogrammetric, or plotter. Control points on strata lying above or below datum are projected to datum using quantitative information derived photogrammetrically. Structure datum restored where removed by erosion.
- Structure datum elevation derived from topographic map control.
- Structure contours on top of Middle Devonian carbonate (Hume or Nahanni Formation)
- Field observed
- Field observed published information
- Strike line of prominent ridge or bedding. Direction of dip cannot be determined on photographs
- Fracture or joint
- Distinctive alignment, possible structural significance
- Fault, dotted where extended through Quaternary deposits
- Thrust fault, triangles on thrust sheet. Structure contours depict folds on thrust.
- Anticline, arrow denotes plunge, diamond denotes approximate position of apex.
- Syncline, arrow denotes plunge, break and cross bars denote approximate positions of high point.
- Structural terrace
- Monocline
- Glacial lineation indicating direction of ice movement
- Prominent escarp or steep slope
- Apparent unconformable contact
- Contact, dashed where indefinite
- Contact, inferred
- Key bed, subtended letter or number indicates local correlation.
- Stratigraphic break, subtended letter or number indicates local correlation.
- Indicates correlative beds or formations
- Facies and/or nomenclature change
- Outcrop area
- Cross section
- Location of possible fault as suggested by gravity interpretation.

STRATIGRAPHIC CORRELATION CHART

ERA	PERIOD	LARD PLATEAU MACKENZIE MTS.-NAHANNI RANGE PLAINS	WRIGLEY-REDSTONE RIVER	FORT NORMAN-NORMAN WELLS	MAP SYMBOL
CENOZOIC	QUATERNARY				Q
	TERTIARY				T
MESOZOIC	CRETACEOUS				Ku, Kls
	JURASSIC				Absent or not shown
	TRIASSIC				
PALEOZOIC	PERMIAN				P-Pn
	PENNSYLVANIAN				
	MISSISSIPPIAN				M
	DEVONIAN				Duc, Dus, Dur, Dnm, Dna, Dnb, Dls, Dlc, Dld
	SILURIAN				SO
	ORDOVICIAN				
	CAMBRIAN				∈
PRECAMBRIAN		Sediments, grains and metamorphics			pЄ

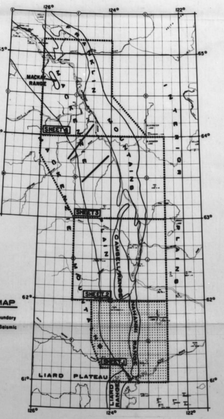
Time intervals, unit thicknesses and stratigraphical relations are not shown to scale.

WELL SYMBOLS

- Well location or drilling well
- Dry and abandoned test
- Oil well
- Capped oil well
- Gas well
- Capped gas well
- Oil and gas well
- Capped oil and gas well
- Well information as of November 15, 1968
- NI No information

INDEX MAP

- Project Boundary
- Refraction Seismic Profiles



PRELISTER and ASSOCIATES

OPERATION GEOQUEST

NORTHWEST TERRITORIES OF CANADA

REDSTONE PROJECT

AREAL GEOLOGY
AND
STRUCTURE CONTOUR MAP

STRUCTURE DATUM: TOP OF MIDDLE DEVONIAN CARBONATE (HUME-NAHANNI FORMATIONS)

STRUCTURE CONTOUR INTERVAL: 500 AND 1000 FEET

SCALE : 1:126,720

(1 INCH TO 2 MILES)

Areal geology compiled by:
1. Photogeologic mapping and field studies conducted by V.Zay Smith Associates Ltd. during 1968.
2. Incorporation of published and open file information.

Quantitative structural data derived from:
1. Refraction seismic survey in Mackenzie Plain conducted during summer 1968 by Hunter Limited, Petroleum Geophysics Division.
2. Field observations by V.Zay Smith Associates Ltd. during summer 1968.
3. Elevations, stratigraphic thicknesses and structural attitudes measured with a Multiplex photogrammetric plotter.
4. Supplementary elevations computed from Department of Mines and Technical Surveys topographic maps.
5. Published and open file information.

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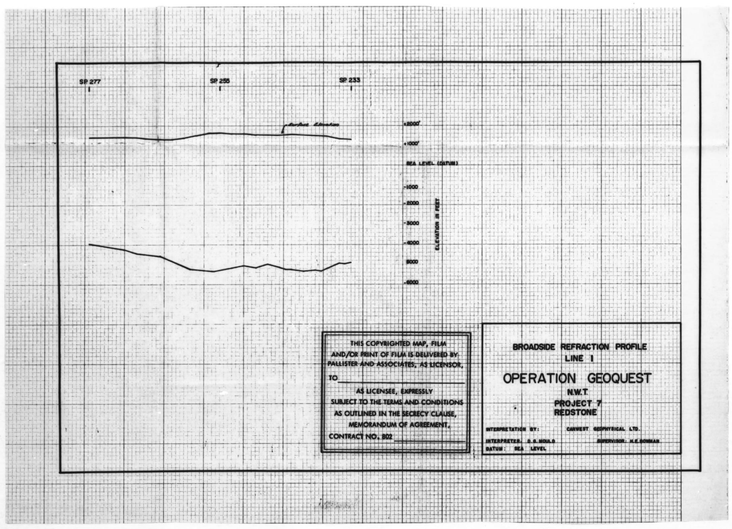

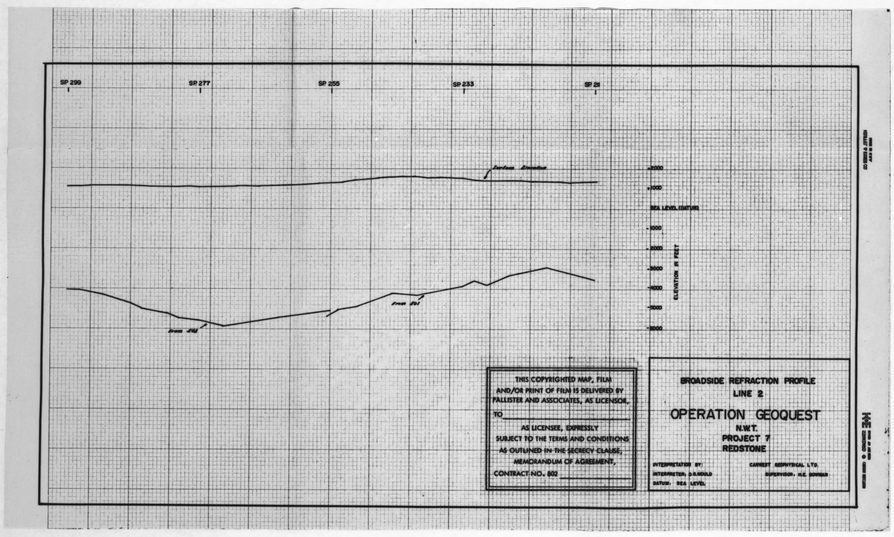

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SURFACE ELEVATION PROFILE

RELATIVE DELAY TIMES (SURFACE POSITION)

ONE WAY DATA ONLY

SUBSURFACE POSITION

RELATIVE DELAY TIME

ELEVATION IN FEET

SURFACE POSITION

DEPTH PROFILE OF REFLECTION IN FEET

SCALE CHANGE

$V_{RMS} = 8000$ ft/s

$V_A = \frac{8400 + 11400 + 10400}{3} = 10000$ ft/s

$V_I = \frac{12400 + 6200 + 13600}{3} = 10733$ ft/s

331 353 375 397

+4000 +3500 +3000 +2500 +2000 +1500 +1000 +500 0 +500 +1000 +1500 +2000 +2500 +3000 +3500 +4000 +4500 +5000 +5500 +6000 +100 0 -100 -200 -300 -400 -500 -600 -700 -800 -900 -1000

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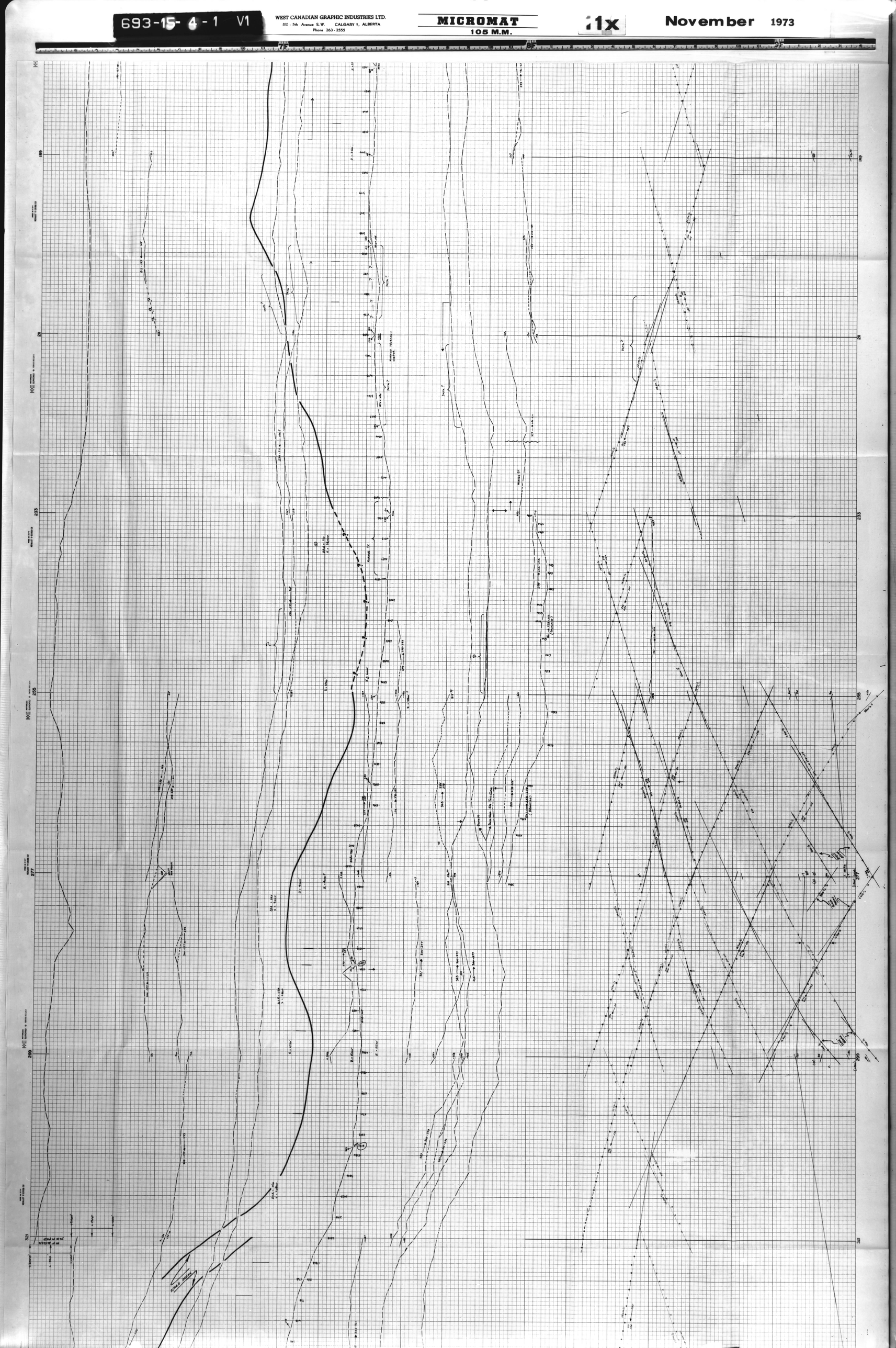

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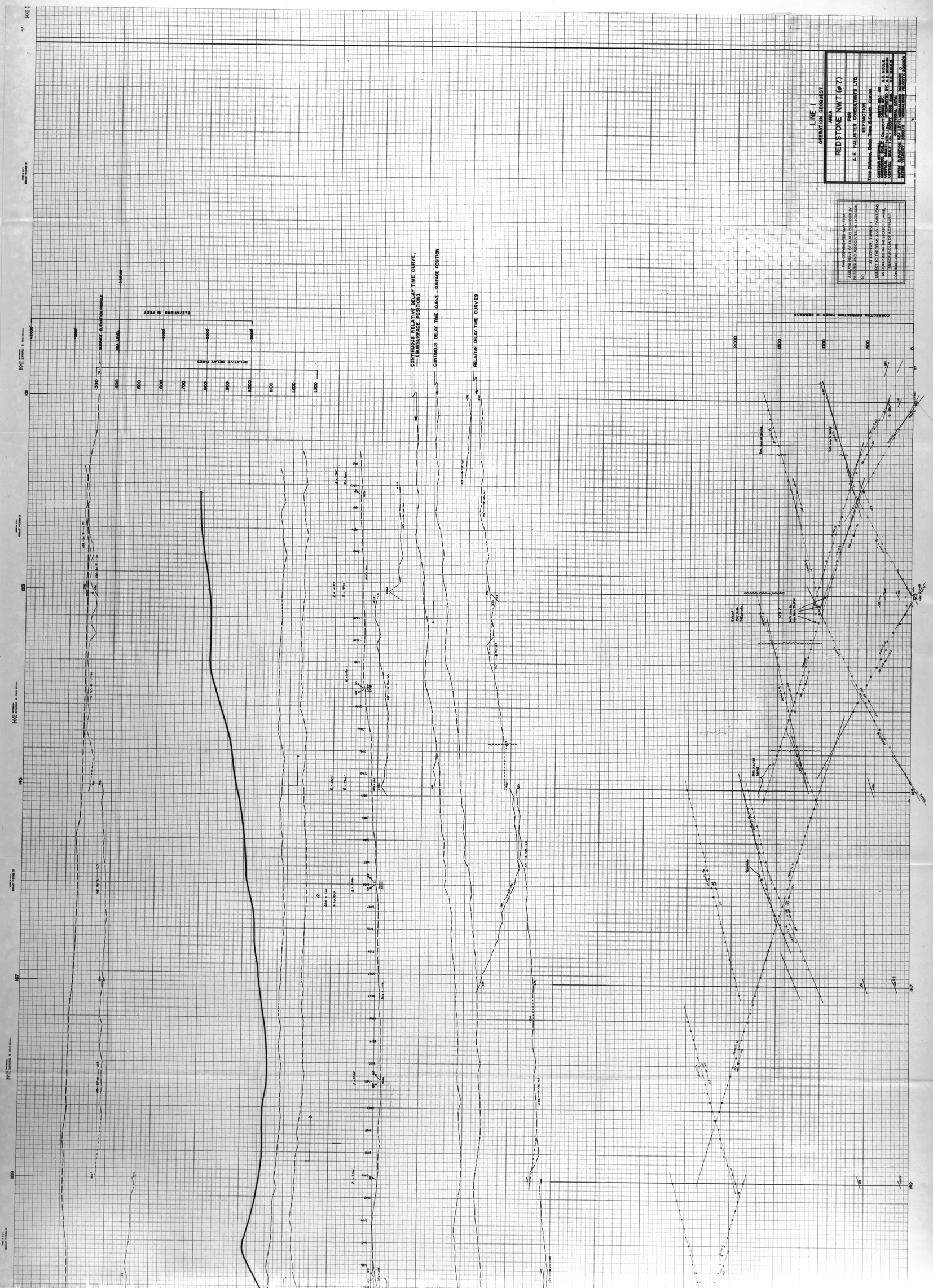

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LINE 2

OPERATION: GEOQUEST

AREA

REDSTONE NWT (67)

FOR

A.E. PALLISTER CONSULTANTS LTD.

REFRACTION

Time Depth - Delay Time & Depth Curves

CONTOUR INTERVAL: 20
PARTY NO.:
HORIZONTAL SCALE: 1cm = 100Ft/500ft BY: D.G. MOLAD
VERTICAL SCALE: 1cm = 11sec INTERPRETED BY: A.E. BOWMAN
VERTICAL SCALE: 1cm = 100Ft. FINAL MAP BY: D.G. MOLAD

CORRECTIONAL DATUM
DATUM ELEVATION Geo (Low) NORMAL(2700 VELOCITY: 8000'/S) WEATHER: C
DATUM VELOCITY 8000'/S NORMAL(2700 VELOCITY 8000'/S

Earthstation Identification
Vse = 8000 ft/s
V0 = 10600 ft/s
V1 = 18500 ft/s
V2 = 21000 ft/s

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TO
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SUBJECT TO THE TERMS AND CONDITIONS
AS OUTLINED IN THE AGENCY-USAGE
MEMORANDUM OF AGREEMENT
CONTRACT NO.: 403

DISTANCE IN METRES

DELAY TIME IN SECONDS

ELEVATION IN FEET

SCALE CHANGE

AVERAGE RELATIVE DELAY TIME CURVE

CONTINUOUS RELATIVE DELAY TIME CURVE - SUBSURFACE POSITION

CONTINUOUS RELATIVE DELAY TIME CURVE - SURFACE POSITION

DELAY TIME CURVES

final corrected datum (dd and refract. comp.)/file

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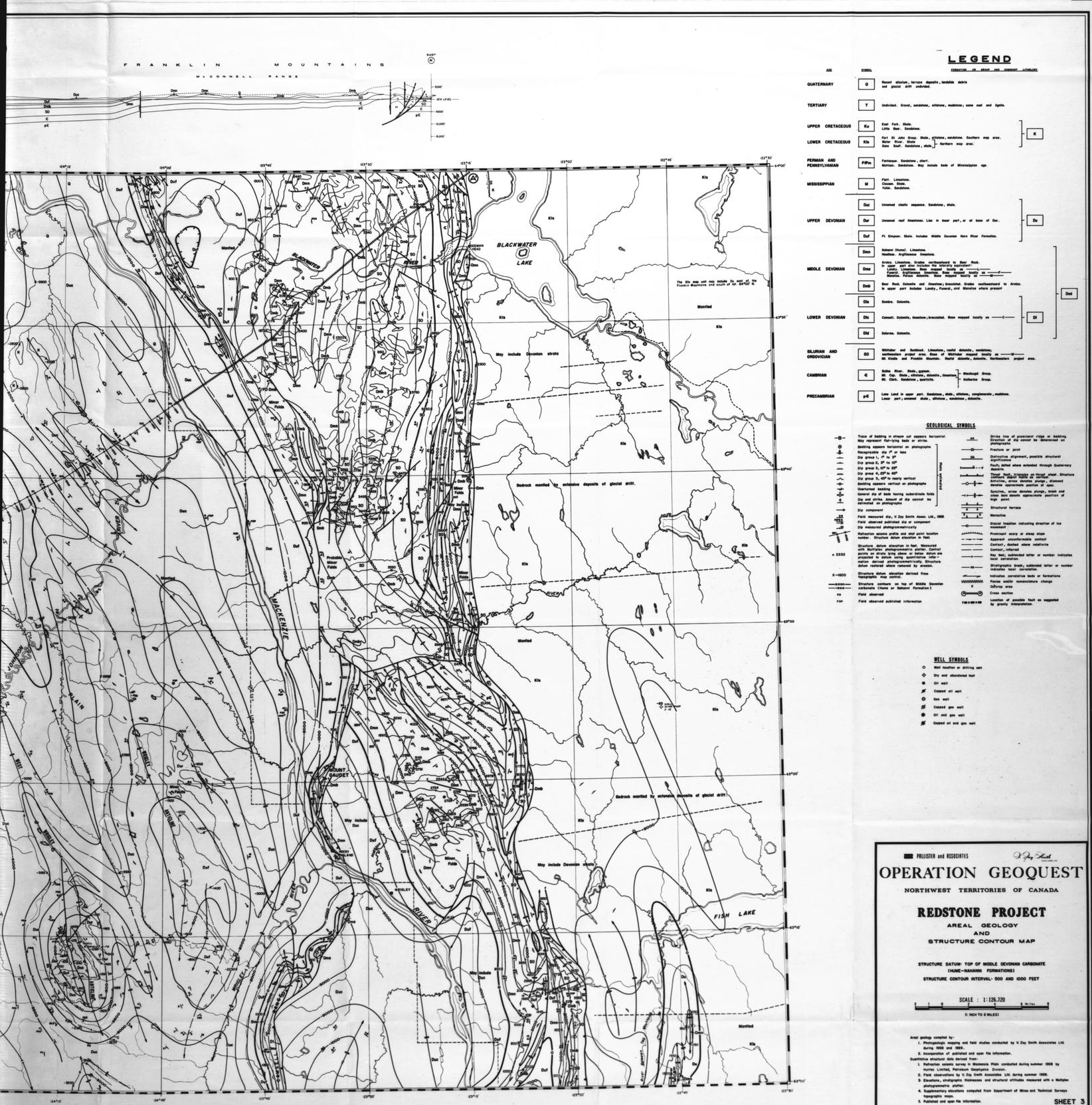

LEGEND

AGE	SYMBOL	FORMATION OR GROUP AND DOMINANT LITHOLOGY	
QUATERNARY	Q	Recent alluvium, terrace deposits, landslide debris and glacial drift undivided.	
TERTIARY	T	Undivided. Gravel, sandstone, siltstone, mudstone; some coal and lignite.	
UPPER CRETACEOUS	Ku	East Fork Shale. Little Bear Sandstone.	K
LOWER CRETACEOUS	Klk	Fort St. John Group. Shale, siltstone, sandstone. Southern map area. Slater River Shale. Slate Shale Sandstone, shale. Northern map area.	
PERMIAN AND PENNSYLVANIAN	PIPe	Fantasque - Sandstone, chert. Mattson - Sandstone. May include beds of Mississippian age.	
MISSISSIPPIAN	M	Flett - Limestone. Canyon - Shale. Yahk - Sandstone.	
UPPER DEVONIAN	Dsc	Unnamed clastic sequence. Sandstone, shale.	Du
	Dur	Unnamed reef limestone. Lies in lower part, or at base of Dsc.	
	Dsf	Ft. Simpson - Shale. Includes Middle Devonian Horn River Formation.	
MIDDLE DEVONIAN	Dne	Nahanni (Nahc) - Limestone. Headless - Argillaceous limestone.	Dsd
	Dnb	Arnica - Limestone. Grades northeastward to Bear Rock. Upper part also includes the Watrous, Dumbbell, Landry, Limestone. Base mapped locally as ——— Funeral - Shale, limestone. Base mapped locally as ——— Simpson - Shale, limestone. Base mapped locally as ———	
	Dnb	Bear Rock - Dolomite and limestone; brecciated. Grades southeastward to Arnica. In upper part includes Landry, Funeral, and Manetoe where present	
LOWER DEVONIAN	Dis	Sombre - Dolomite.	Dl
	Dic	Camsell - Dolomite, limestone; brecciated. Base mapped locally as ———	
	Did	Delorme - Dolomite.	
SILURIAN AND ORDOVICIAN	SO	Whittaker and Sunblood - Limestone, reefal dolomite, sandstone, southwestern project area. Base of Whittaker mapped locally as ——— Mt. Kindle and Franklin Mountain - Reefal dolomite, dolomite. Northeastern project area.	
CAMBRIAN	C	Saline River - Shale, gypsum. Mt. Cap - Shale, siltstone, dolomite, limestone. Mt. Clark - Sandstone, quartzite.	Mackenzie Group. Katherine Group.
PRECAMBRIAN	pE	Lone Land in upper part - Sandstone, shale, siltstone, conglomerate, mudstone. Lower part; unnamed shale, siltstone, sandstone, dolomite.	

GEOLOGICAL SYMBOLS

Trace of bedding in stream cut appears horizontal.
May represent flat-lying beds or strike.
Bedding appears horizontal on photographs.
Recognizable dip 1° or less
Dip group 1, 1° to 5°
Dip group 2, 5° to 15°
Dip group 3, 15° to 30°
Dip group 4, 30° to 45°
Dip group 5, 45° to nearly vertical
Bedding appears vertical on photographs
Overturned bedding
General dip of beds having subordinate folds
Dip and strike, Amount of dip cannot be estimated on photographs
Dip component
Field measured dip, V. Ray Smith Assoc. Ltd., 1965
Field observed published dip or component
Dip measured photogrammetrically
Refraction seismic profile and shot point location number. Structure datum elevation in feet.
Structure datum elevation in feet. Measured with Multiplex photogrammetric plotter. Control points on strata lying above or below datum are projected to datum using approximate interformation derived photogrammetrically. Structure datum restored where removed by erosion.
Structure datum elevation derived from topographic map control.
Structure contours on top of Middle Devonian carbonate (Hume or Nahanni Formation)
Field observed
Field observed published information

Strike line of prominent ridge or bedding. Direction of dip cannot be determined on photographs
Fracture or joint
Dominantly alignment, possible structural control indicated
Fault, dashed where extended through Quaternary deposits
Thrust fault, triangles on thrust sheet. Structure contours depict thrusts as vertical.
Anticline, arrow denotes plunge, diamond denotes approximate position of apex.
Syncline, arrow denotes plunge, knob and tail denotes basin, denote approximate position of axial point
Structural terrace
Monocline
Glacial lineation indicating direction of ice movement
Prominent scarp or steep slope
Apparent unconformable contact
Contact, dashed where indefinite
Contact, inferred
Key bed, subtended letter or number indicates local correlation.
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Indicates corrective beds or formations
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Outcrop area
Cross section
Location of possible fault as suggested by gravity interpretation.

WELL SYMBOLS

Well location or drilling well
Dry and abandoned well
Oil well
Capped oil well
Gas well
Capped gas well
Oil and gas well
Capped oil and gas well

PELLISTER and ASSOCIATES — V. Ray Smith Associates Ltd.

OPERATION GEOQUEST

NORTHWEST TERRITORIES OF CANADA

REDSTONE PROJECT

AREAL GEOLOGY AND STRUCTURE CONTOUR MAP

STRUCTURE DATUM: TOP OF MIDDLE DEVONIAN CARBONATE (HUME-NAHANNI FORMATIONS)

STRUCTURE CONTOUR INTERVAL: 500 AND 1000 FEET

SCALE : 1:126,720

0 INCH TO 2 MILES

Areal geology compiled by:
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Quantitative structural data derived from:
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3. Elevations, stratigraphic thicknesses and structural attitudes measured with a Multiplex photogrammetric plotter.
4. Supplementary elevations computed from Department of Mines and Technical Surveys topographic maps.
5. Published and open file information.

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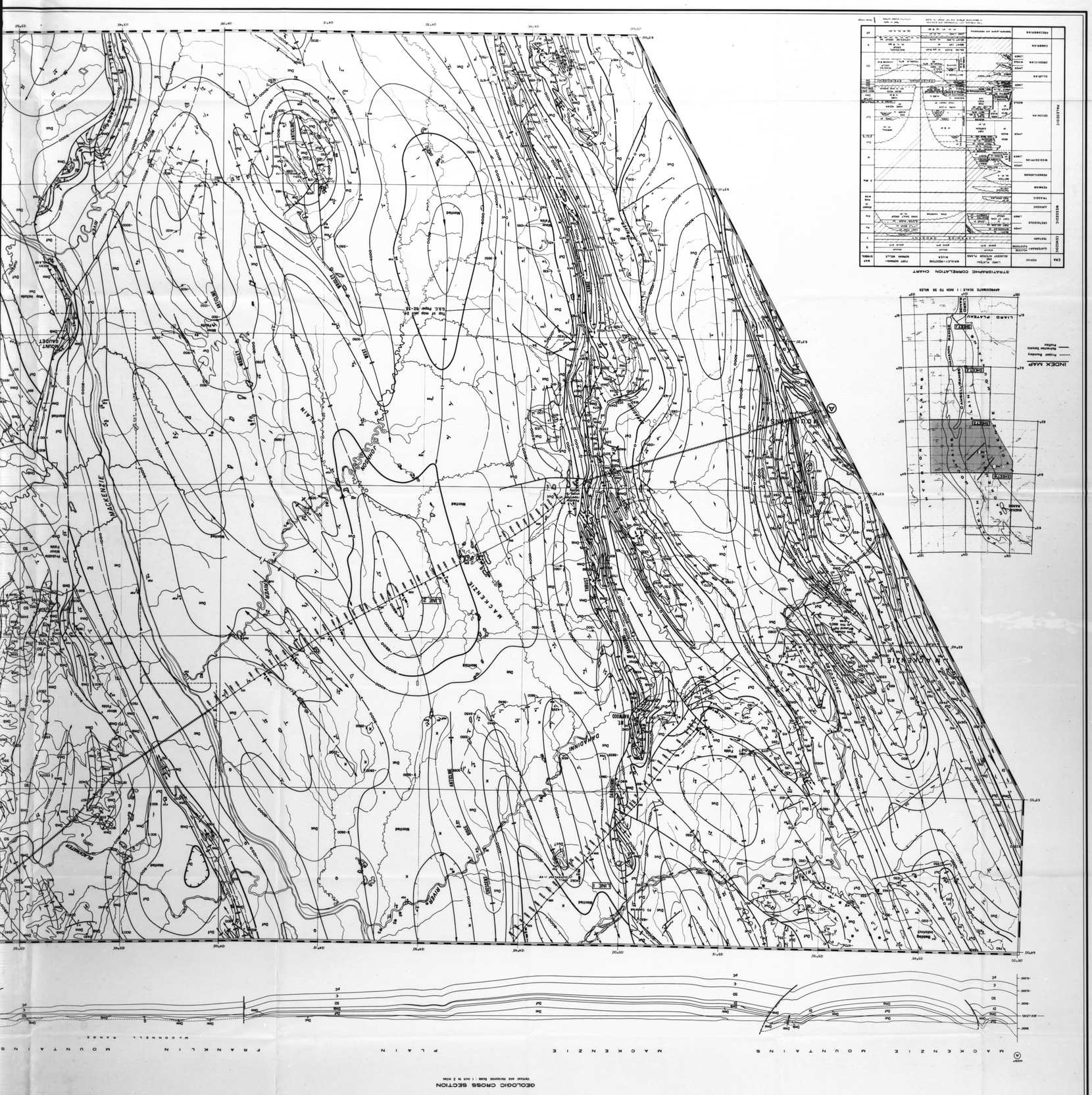

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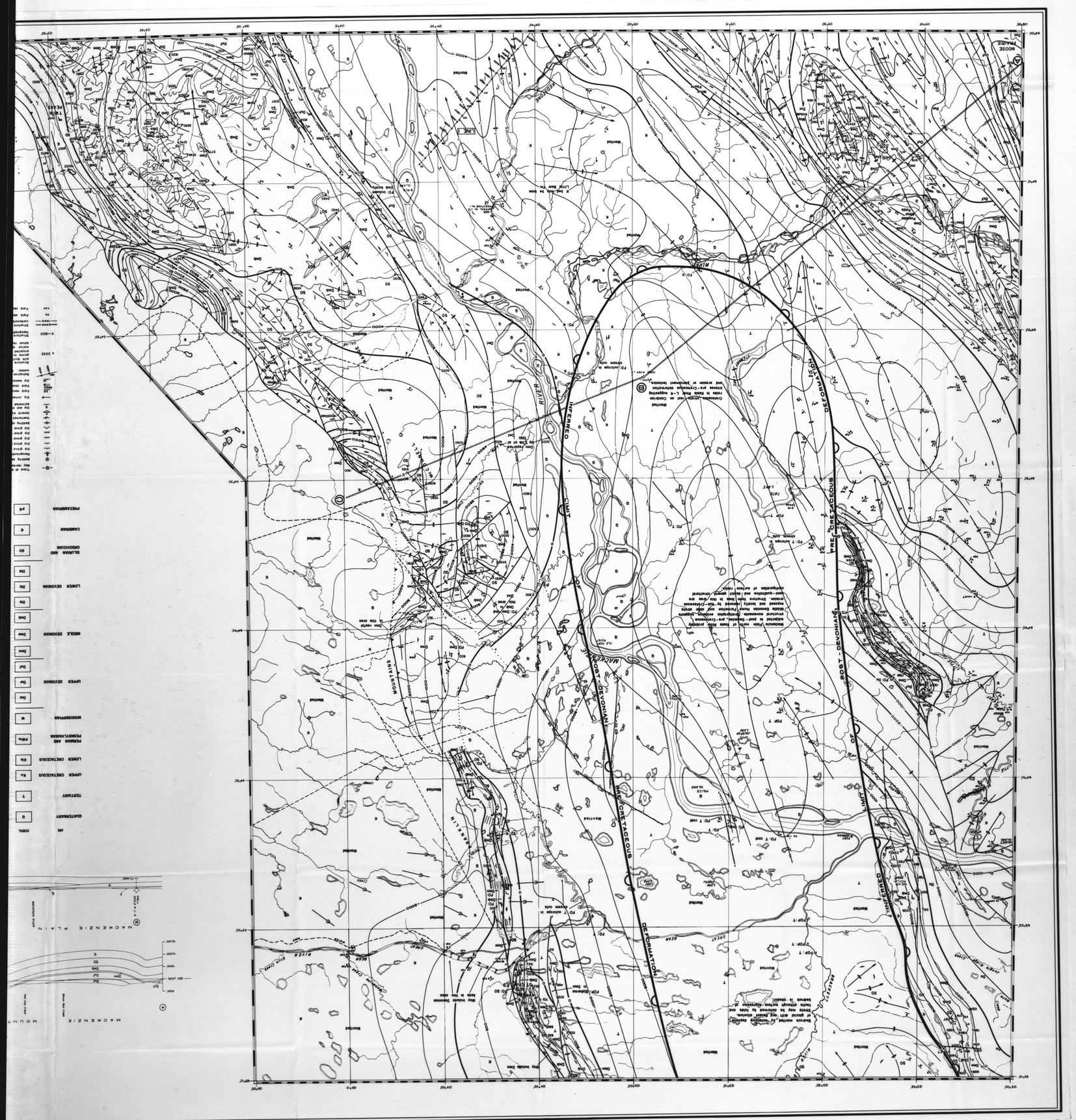

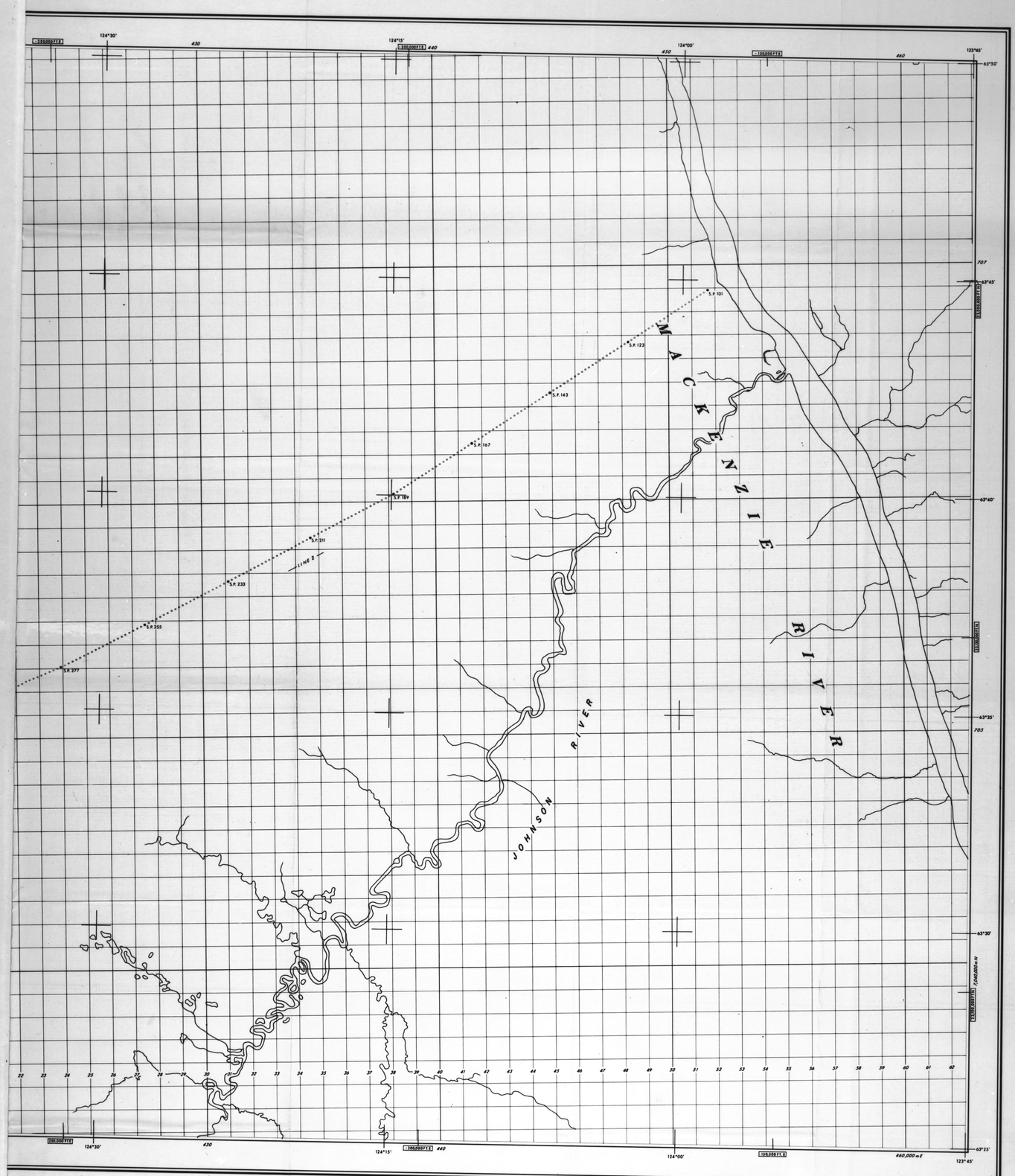

PRELISTER and ASSOCIATES

Location Map
SEISMIC SHOT POINTS and GRAVITY STATIONS

CONTOUR INTERVAL

DATUM ELEVATION

DATUM VELOCITY FT./SEC.

Interpretation By:

MAP B
MAP NO. 1

LEGEND

TOPOGRAPHY TAKEN FROM N. T. S. MAPS

ISLAND NAMES TAKEN FROM PUBLIC WORKS OF CANADA PUBLICATION SHOWING CHANNEL AND MARKERS TO SEPT. 1967.

(7330) = C.U.T.M. GRID CO-ORDINATES IN FEET.

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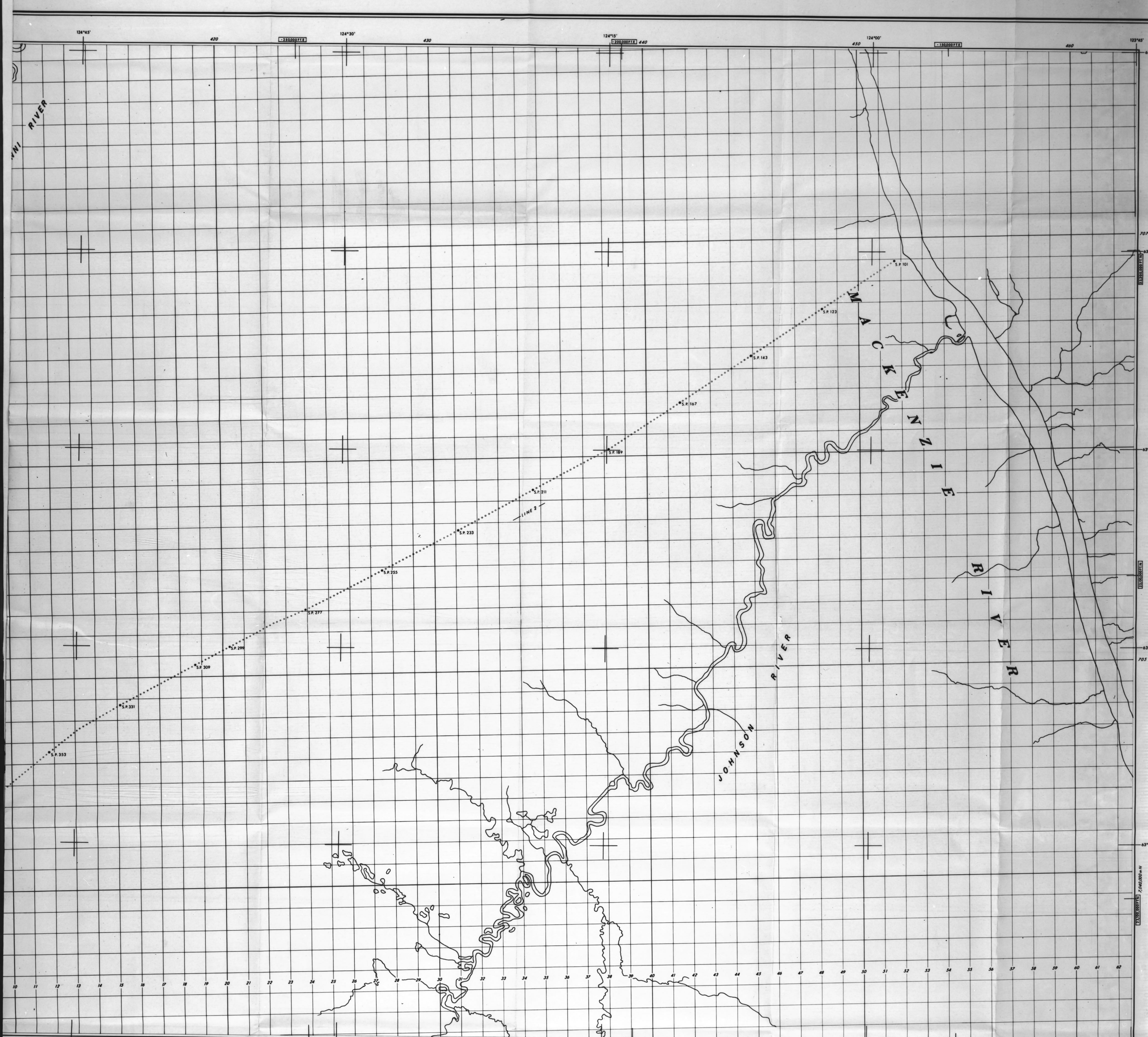

MAPS COMPILED BY:
JACK HILL, A.L.S., D.L.S.
MAPS DRAWN BY:
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OPERATION GEOQUEST

NORTHWEST TERRITORIES OF CANADA

REDSTONE
MAP B

SCALE 1:50,000

ONE THOUSAND METER
UNIVERSAL TRANSVERSE MERCATOR GRID

PELLISTER and ASSOCIATES

Location Map
SEISMIC SHOT POINTS and GRAVITY STATIONS

CONTOUR INTERVAL

DATUM ELEVATION | DATUM VELOCITY FT./SEC.

Interpretation By:

MAP B
MAP NO. 1

LEGEND

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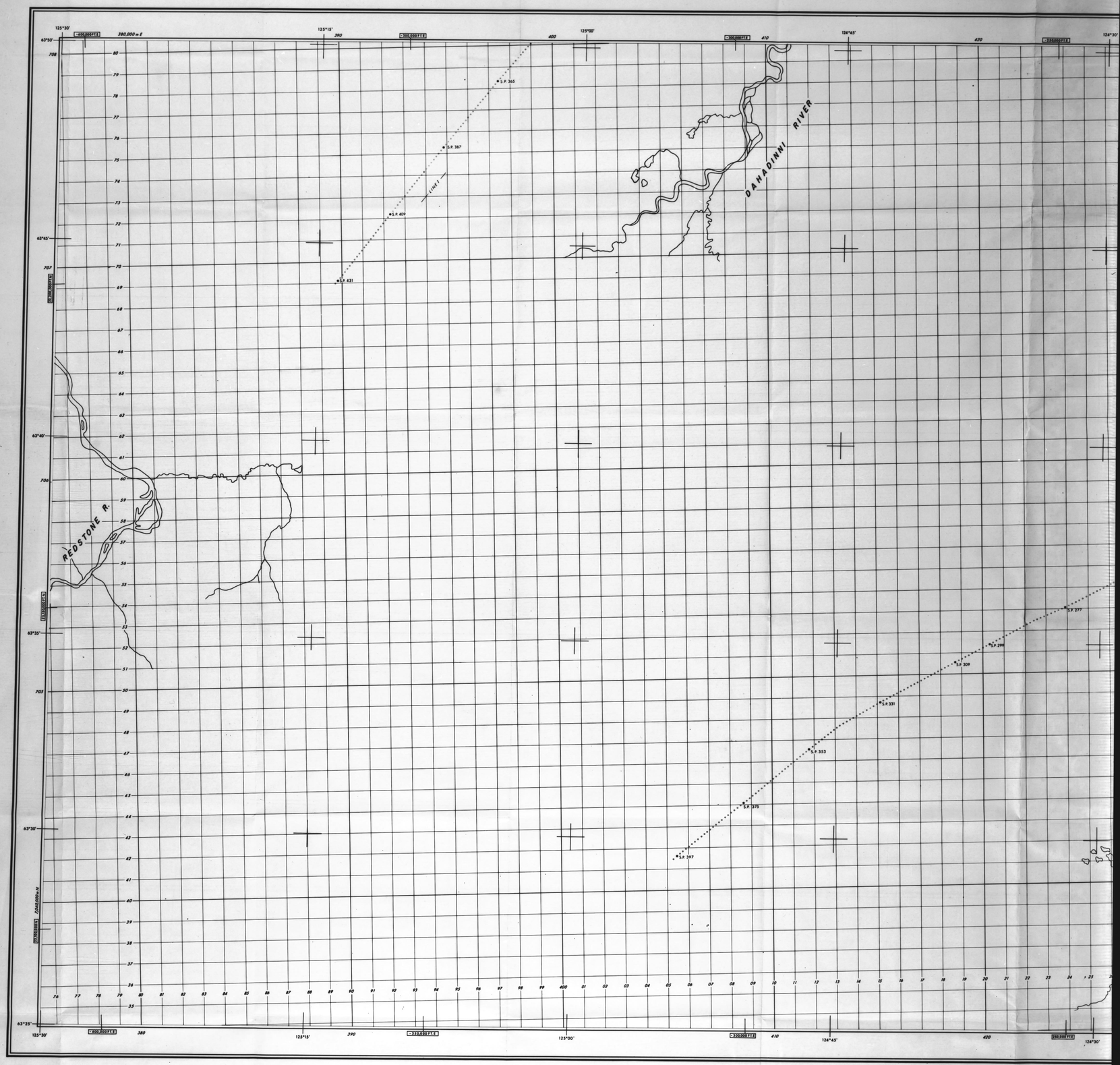

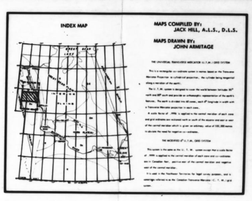

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REDSTONE
MAP B

SCALE 1:50,000

ONE THOUSAND METER
UNIVERSAL TRANSVERSE MERCATOR GRID

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