

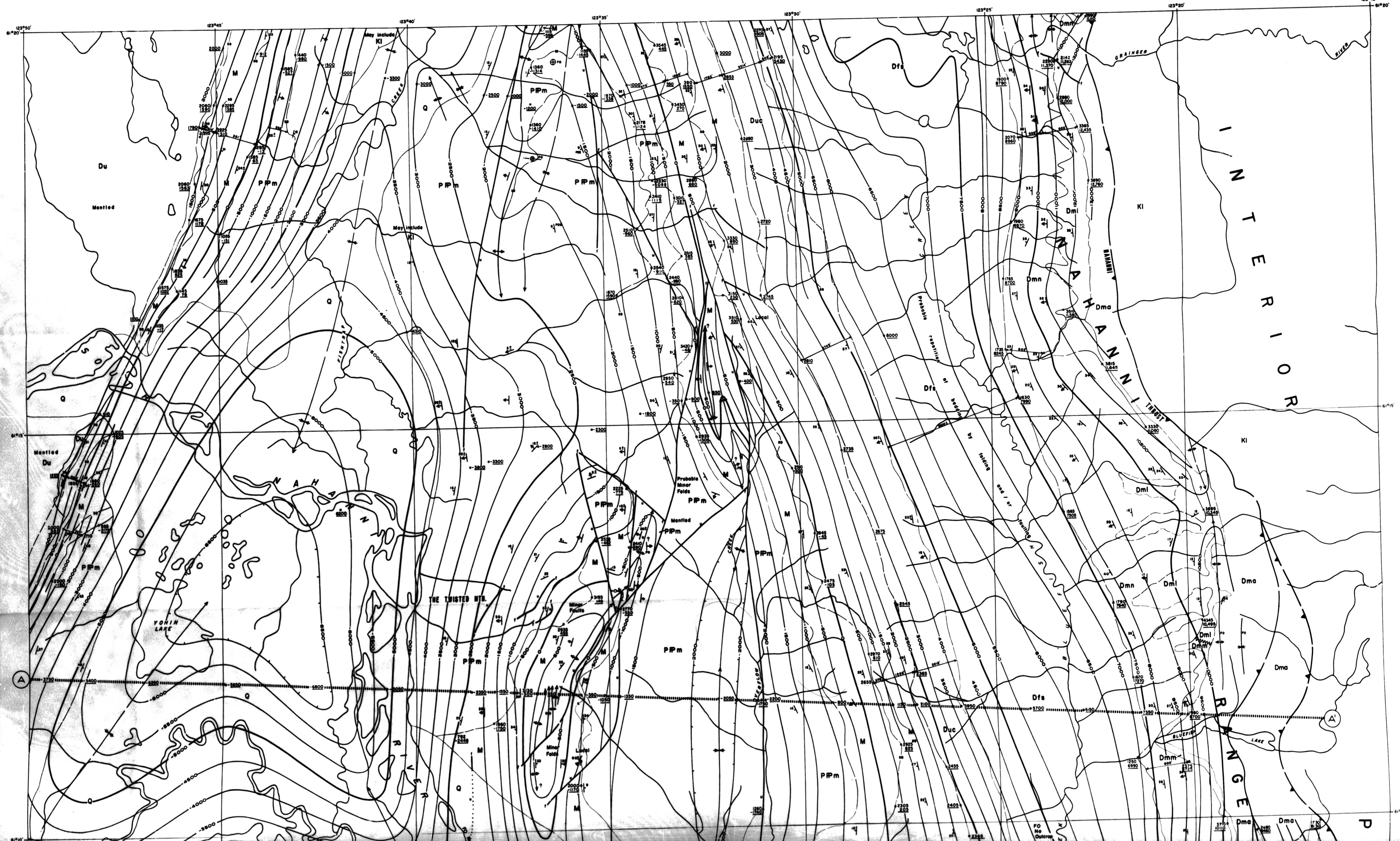
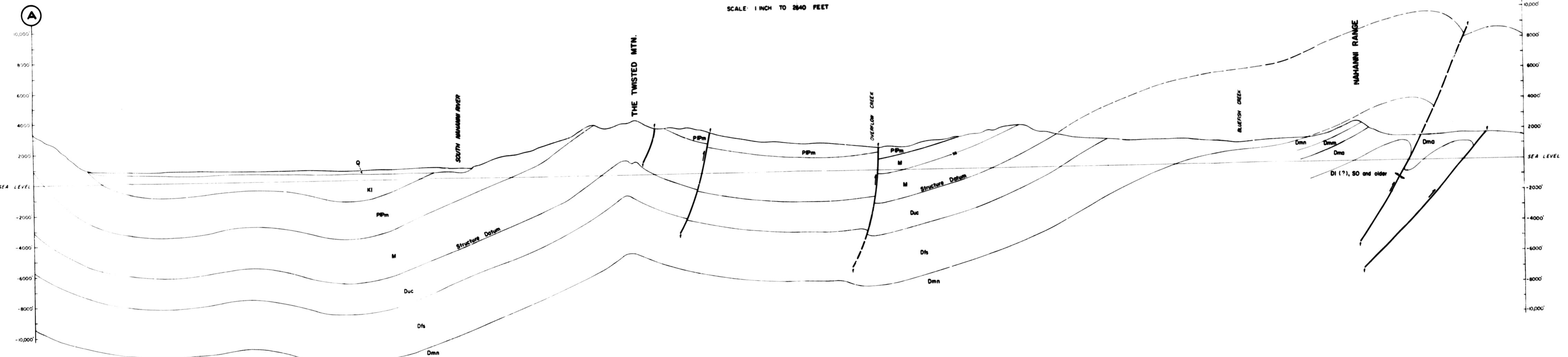
## GEOLOGIC CROSS SECTION A-A'

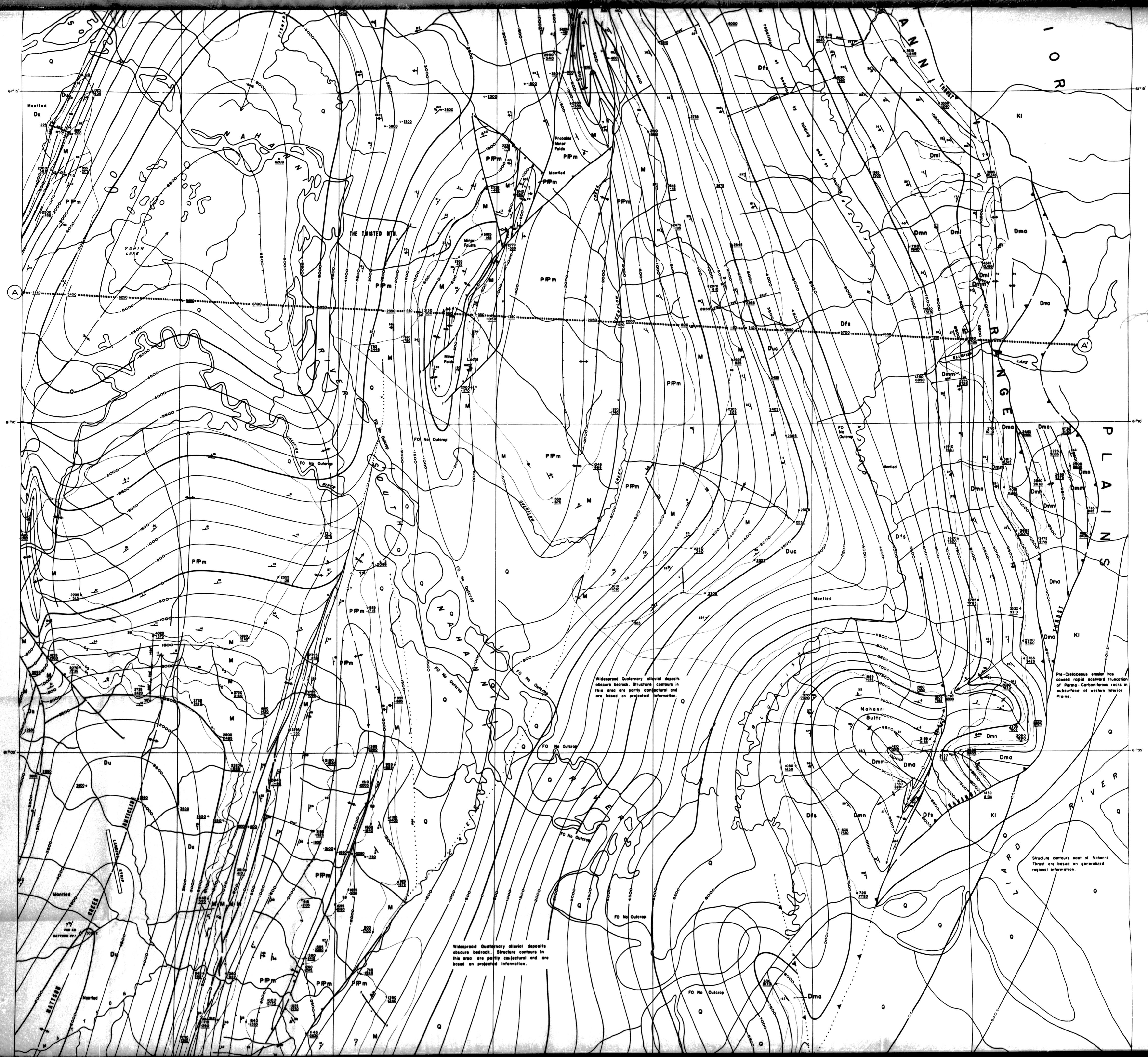
To accompany report on the Twisted Mountain Area  
Constructed with the aid of Multiple Photogrammetric Plotter  
Prepared by V. Ivey Smith Associates Ltd.

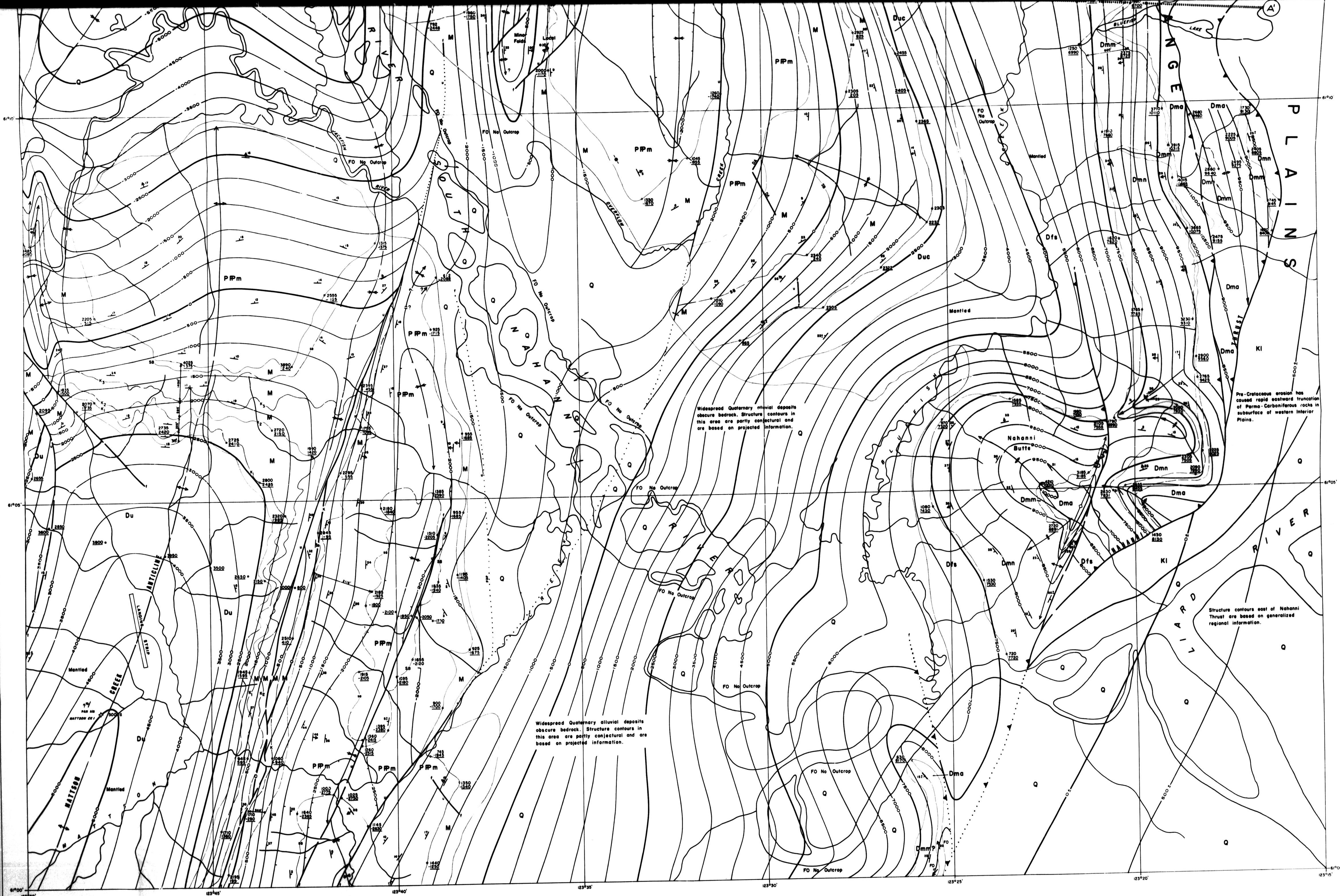
SCALE: 1 INCH TO 2640 FEET

WEST

EAST







AGE	FORMATION	SYMBOL
QUATERNARY		Q
LOWER CRETACEOUS		KI
PERMIAN AND PENNSYLVANIAN		PPm
MISSISSIPPIAN		M
DEVONIAN		Duc
		Dfs
		Dmn
		Dm?
		Dma
		Dm?
		Dm?
SILURIAN AND ORDOVIANIC		DI
		SO

Quantitative information by use of Multiplex photogrammetric plotter.  
Multiplex orientation control from government 1:250,000 scale topographic map series.

#### LEGEND

GEOLOGICAL SYMBOLS	
DA	Distinctive alignment, possible structural significance
U	Fault, dotted where extended through Quaternary deposits, dashed where definite
▲	Thrust fault, triangles on thrust sheet
○	Anticline, arrow denotes plunge, diamond denotes approximate position of apex
—	Syncline, arrow denotes plunge, bars and cross bars denote approximate position of high point
—	Anticline and syncline overturned. Arrows denote direction of dip of limbs and are on side of normal dip
—	Glacial lineation indicating direction of ice movement
—	Contact, dashed where indefinite
—	Key bed
—	Stratigraphic break
—	Indicates correlative beds
—	Facies change
—	Multiplex-measured stratigraphic thickness
—	Line of cross-section

#### AREAL GEOLOGY AND STRUCTURAL CONTOUR MAP OF THE TWISTED MOUNTAIN AREA NORTHWEST TERRITORIES

SCALE: 1 INCH TO 1/2 MILE 1/2 MILES

Structural datum: Base of Mississippian  
Contour intervals: 500 and 1000 Feet

Prepared by —  
V. ZAY SMITH ASSOCIATES LTD.  
— for —

PACIFIC PETROLEUM LTD.  
CALGARY, ALBERTA  
1960

**Areal Geology & Structural  
Interpretation  
of  
The Twisted Mountain Area  
Northwest Territories**

**AREAL GEOLOGY and STRUCTURAL INTERPRETATION**

of

**THE TWISTED MOUNTAIN AREA**

**NORTHWEST TERRITORIES**



**Prepared For**  
**PACIFIC PETROLEUMS LTD.**

by

**V. ZAY SMITH ASSOCIATES LTD.**

**1969**

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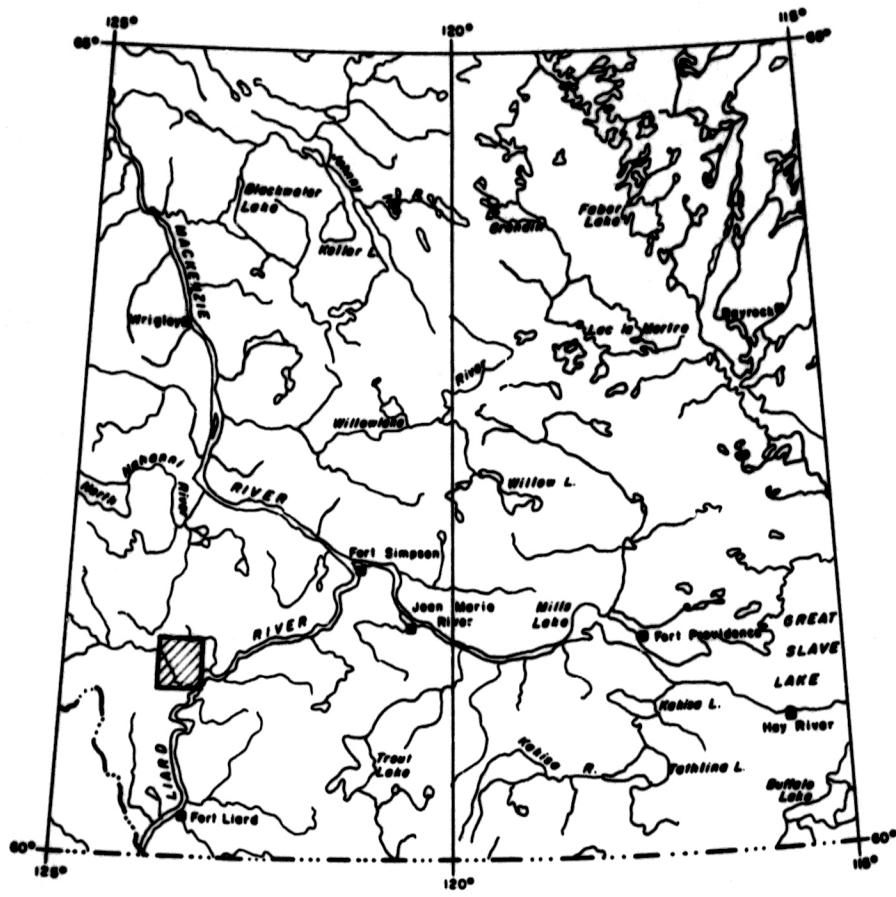
**Figure 1      Regional Location Map (Opposite Page 1)**

**Plates 1 to 6      Color Photographs (Following Page 13)**

**Plate 7      Areal Geology and Structure Contour Map  
of The Twisted Mountain Area ( In Pocket )**

**■Bluefish Lake Stratigraphic Section ( In Pocket )**

FIGURE 1



REGIONAL LOCATION MAP

Project Area

# AREAL GEOLOGY and STRUCTURAL INTERPRETATION

of

## THE TWISTED MOUNTAIN AREA

### NORTHWEST TERRITORIES

#### INTRODUCTION

During the summer and fall of 1969 an areal geologic and structural study of The Twisted Mountain area located in NTS Block 95 G/SW in the Northwest Territories was conducted on behalf of Pacific Petroleum Limited. The purpose of the work was to determine the structural character of The Twisted Mountain anticline and its environs centered about Permit 5520. The work included photogeology, photogrammetry, field work, and incorporation of information from published sources.

Figure 1 is a regional index map showing the location of the project area.

#### METHODS

The initial step in this study included photogeologic mapping of the area by stereoscopic inspection of vertical air photographs obtained from the Dominion government. The airphotos were flown at an approximate scale of 1:60,000 in 1961 and 1963.

The annotated airphotos were subsequently used as a guide for the photogrammetric mapping which was performed with the use of a Multiplex photogrammetric plotter. The Multiplex projects the images provided by air photographs to produce a "model" of the terrain which can be viewed in three dimensions. After the models are adjusted to scale and properly levelled, direct measurement of vertical and horizontal distances can be made. Bedding dips and strikes and elevations of key horizons can be measured, and stratigraphic thicknesses can be calculated. Thus, the quantitative data necessary for the construction of a structure contour map is provided by the Multiplex.

Field work was conducted in late May of 1969 and included a structural check of the photogeologic interpretation and measurement of the Middle Devonian Manetoe Formation and the upper part of the underlying Middle Devonian Arnica Formation. The measured interval was described and sampled by J.C. Scott and S.B. Smith of Pacific Petroleum Limited and Tom Masselink of V. Zay Smith Associates Ltd. The stratigraphic section, measured on the north side of Bluefish Lake, was supplemented by information from Brady (1961), and is portrayed on the lithologic strip log accompanying this report (in pocket).

During the field work a Cessna 185 on floats was used for transporting gas and personnel and for aerial reconnaissance. A Bell Super G-2 helicopter was used for the detailed structural check. Structural observations were plotted on the airphotos and later transferred to the areal geology map.

## PHYSIOGRAPHY

The Twisted Mountain area lies at the eastern edge of the Cordilleran belt and includes a small portion of the western Interior Plains along the eastern edge of the map area.

Elevations range from around 600 feet above sea level in the valley of the South Nahanni and Liard Rivers, to a maximum of around 4,500 feet at the north end of Mattson anticline in the west-central project area, and along the crest of Nahanni Range to the east. Differential erosion of the thrust fault along the east edge of Nahanni Range has produced local topographic relief ranging from 2,000 to 2,500 feet and provides an abrupt topographic boundary between the Cordillera and the Interior Plains to the east.

The area is drained by the South Nahanni River flowing from northwest to southeast to its confluence with the Liard River near Nahanni Butte.

West of the mountain front structure is strongly reflected by topography.

## STRATIGRAPHY

Surface rocks exposed within The Twisted Mountain map area range in age from Middle Devonian through Quaternary. Middle Devonian carbonates are present on the flanks and in the core of the Nahanni Range and to the east lie in fault contact with Lower Cretaceous sandstones and shales of the extreme western Interior Plains. Upper Devonian shales underlie the valley of Bluefish Creek west of Nahanni Range and are exposed in the core of Mattson Creek anticline and also in the extreme northwest map area. Elsewhere, they are overlain by a thick sequence of Permo-Carboniferous limestone, sandstone and shale.

Widespread Quaternary alluvial deposits mask all surface structural detail in the valley of South Nahanni River.

In the subsurface, porous dolomites of the Manetoe and Arnica Formations form the shallowest potential reservoirs.

### MIDDLE DEVONIAN

#### ARNICA FORMATION

The Arnica Formation, consisting mainly of fine-grained, dark grey to black, sometimes porous and vuggy, banded dolomites usually ranges in thickness from around 1,500 to 2,000 feet and grades northeasterly to the brecciated carbonates of the Bear Rock Formation beyond the map area.

The upper 590 feet of the Arnica Formation was measured, sampled, and described during the field investigations.

Pan Am Mattson Creek #1 in the southwestern map area penetrated 1,814 feet of porous Arnica dolomites testing salt water, gas and mud.

## MANETOE FORMATION

Regional relationships indicate that in most of The Twisted Mountain area the Arnica dolomites are overlain by vuggy dolomites of the Manetoe Formation, usually several hundred feet in thickness. Brady reports 510 feet of Manetoe Formation in the vicinity of Bluefish Lake and 560 feet was measured in a similar location during the field work in 1969. The work of Douglas (1960) and Brady indicates the presence of around 400 feet of porous Manetoe dolomites some 7 or 8 miles west of the map area. Approximately 30 miles north and west of The Twisted Mountain, the Manetoe Formation grades laterally to argillaceous limestones of the Funeral Formation.

## LANDRY FORMATION

A short distance north of Bluefish Lake dolomites of the Manetoe Formation give way to dense, cryptocrystalline limestones of the Landry Formation which form an approximate stratigraphic equivalent of the Manetoe. Around 600 feet of Landry Formation were measured photogrammetrically in the Nahanni Range south of Greinger River.

Generally speaking, the porous Manetoe Formation grades westward to argillaceous limestones of the Funeral Formation and eastward to Landry limestone.

However, 112 feet of limestone in the Pan Am Mattson Creek #1 in the southwest project area are questionably identified as Landry Formation.

It is thus apparent that the subsurface distribution of Manetoe-Funeral and Manetoe-Landry facies changes is difficult to predict and with favorable structure, may provide good stratigraphic traps in The Twisted Mountain area.

## NAHANNI FORMATION

The youngest persistent Middle Devonian carbonate sequence is the Nahanni Formation comprised of fine-to medium-grained grey limestones which are massive to thick bedded and

fossiliferous. Thickness of the Nahanni Formation in the region is around 600 to 800 feet including the argillaceous limestones in the lower part of the Nahanni Formation which are often referred to as the Headless Formation.

Although Brady reports approximately 315 feet of Nahanni Formation, Multiplex measurement indicates a thickness of 600 feet (including the Headless Formation).

Because the resistant Nahanni Formation is the stratigraphically highest Middle Devonian carbonate of widespread distribution, it forms the main west-facing dip slopes and provides the backbone of most of the mountain ranges of the eastern Cordillera.

#### UPPER DEVONIAN

#### FORT SIMPSON FORMATION

The Middle Devonian carbonate sequence is overlain by a thick accumulation of shales and occasional sandstones comprising the Fort Simpson Formation of mainly Upper Devonian age. Some shales of the Middle Devonian Horn River and Hare Indian Formations may be present in the lower part of the Fort Simpson Formation of this report. Thickness of the Fort Simpson Formation ranges mainly from 3,000 to 3,500 feet in The Twisted Mountain area.

#### UNNAMED CLASTIC UNIT

The Fort Simpson shales are conformably overlain by an unnamed clastic sequence of Upper Devonian age including shales, thin sandstones, siltstones and mudstone. The section is of variable thickness ranging from around 2,000 feet west of Bluefish Lake to more than 2,800 feet in the north central map area. The beds are poorly resistant in the upper part to moderately resistant in the lower portion.

The unnamed clastic unit and underlying Fort Simpson Formation are mapped as a combined unit designated Du in the central part of Mattson Creek anticline and in the northwestern map area where lack of surface expression precludes their effective separation.

#### PERMO-CARBONIFEROUS

##### MISSISSIPPIAN

The Mississippian sequence of The Twisted Mountain area includes, in ascending order, the Yohin, Clausen, and Flett Formations consisting essentially of sandstone, shale, and limestone respectively. A total thickness of 2,862 feet of Mississippian beds was measured in the north - central map area, 2,394 feet northwest of Yohin Lake, and 2,575 feet at the north end of Mattson Creek anticline. Regional isopachs indicate a probable maximum thickness of around 3,000 feet in the vicinity of The Twisted Mountain.

The base of the Mississippian sequence was selected as a structural datum for the structure contour mapping because it is moderately resistant, well expressed topographically and on air photographs, and is of wide areal distribution.

A short distance west of the map area the Mississippian formations lose their identity and grade into the upper part of the thick shale sequence comprising the Besa River Formation.

##### MATTSON FORMATION

A thick series of sandstones and minor shales including beds ranging in age from Mississippian to Permian comprise the Mattson Formation. It forms resistant dip slopes and good topographic expression on the flanks of Mattson Creek anticline, on the crestal portion of The Twisted Mountain and in the linear northerly trending ridges of the north-central and northwestern map area.

Although a total thickness of Mattson Formation was not measured due to absence of a complete section, over 3,700 feet was measured by Harker (1963) on Yohin Ridge four miles west of the project area.

Variable thicknesses of Mattson Formation have been removed by pre-Cretaceous erosion. In general the formation thins to the north and east.

Regional relationships indicate that the Mattson Formation and underlying Mississippian beds were eroded to a zero edge a short distance east of the map area by this period of pre-Cretaceous erosion.

#### LOWER CRETACEOUS

Lower Cretaceous rocks of The Twisted Mountain area include variable thicknesses of shale and minor sandstone resting unconformably upon the Mattson Formation. Some Lower Cretaceous rocks may be present in the valley west of The Twisted Mountain. The Lower Cretaceous beds are poorly resistant and offer little or no control for structural mapping in the immediate area.

#### QUATERNARY

Variable thicknesses of Quaternary and Recent alluvial deposits, landslide debris etc. occupy the major valleys of the area masking all surface structural detail. This is especially true in the valley of South Nahanni River where a broad, flat-lying expanse of Quaternary alluvium and gravel completely obscures surface outcrop.

## STRUCTURAL GEOLOGY

The accompanying structure contour map (in pocket) portrays the structural geology of The Twisted Mountain area by means of contours. The structure datum portrayed is the base of the Mississippian System. The elevations of key horizons above the structure datum have been adjusted to the anticipated depth or elevation of the underlying basal Mississippian at that point. Key horizons lying stratigraphically below the structure datum have been adjusted to restore the original elevation of the structure datum at that point prior to its removal by erosion. Thus, the final map is contoured to a common structure datum portraying the geologic structure. The thick carbonates of Middle Devonian and older age can be expected to reflect the structural configuration portrayed on the map.

Maximum restored structure datum elevations are encountered along the crest of Nahanni Range where they locally attain a maximum on the order of 13,000 feet above sea level. To the south, elevations of 10,000 to 11,000 feet are typical.

Minimum structure datum elevations based on photogrammetrically constructed geologic cross-sections are encountered in the area northeast of Yohin Lake, where they lie at an anticipated depth of 6,500 feet below sea level.

Local structural relief between the uplifted belt of the Nahanni Range and the adjacent Interior Plains is on the order of 9,000 to 10,00 feet near Nahanni Butte.

The west flank of the Nahanni Range is defined by dips ranging mainly from  $20^{\circ}$  to  $30^{\circ}$ . Dips of lesser magnitude are noted along the crest of the range four miles north of Bluefish Lake where an anticlinal axis occupies the eastern edge of the mountain front. Locally steep and occasionally overturned bedding is noted near the Nahanni thrust and associated faults such as the one bounding the east edge of Nahanni Butte.

Shales of the Fort Simpson Formation in the valley of Bluefish Creek are largely masked by widespread mantled areas and provide little structural data. Probable repetition of bedding along this valley due to the presence of folds and/or faults is

suggested by the northerly trending thrust fault extending into the valley from Nahanni Butte in the south and by the presence of southerly plunging folds located a short distance beyond the northern map boundary. The folds are reflected by the structure contours near the headwaters of Bluefish Creek. Cross-section A-A<sup>1</sup> depicts a structural flattening across the valley of Bluefish Creek.

West of Bluefish Creek resistant Mississippian beds form a bold, west-dipping ridge defined by dips mainly between 20° and 30° locally steepening to around 40°. A northerly trending fault, upthrown to the west, lies roughly coincident with Overflow Creek with a structural displacement of 400 to perhaps 600 feet over most of its length. This fault appears to extend across the valley of South Nahanni River to the lower reaches of Mattson Creek in the southwestern map area where it exhibits similar magnitude of displacement. North of the headwaters of Overflow Creek the west-dipping hogback of Permo-Carboniferous beds is complicated by the presence of longitudinal and transverse faults accompanied by local tight folding.

The axis of a northerly trending synclinal trough, well reflected topographically, lies one to two miles west of Overflow Creek. The lowest structural datum elevation encountered on this synclinal axis is slightly less than 2,050 feet below sea level.

The Twisted Mountain anticline is located between the synclinal axis described above and a deep, apparently local synclinal basin situated between Yohin Lake and South Nahanni River. The anticline is a northerly to northeasterly trending, faulted anticline. It is essentially symmetrical, though local asymmetry is suggested near the faults and tight folds along the east flank. Maximum structure datum elevation encountered is 950 feet above sea level. The crestal area of the anticline exhibits local, minor, northerly to northeasterly plunging, en echelon folding.

Structural relief on the east flank of The Twisted Mountain anticline is on the order of 3,000 feet and on the west flank in excess of 7,500 feet. Structural control in the basinal area west of The Twisted Mountain is largely confined to the outer rim of the basin and the depth portrayed on the map is based on projected information and geologic cross-sections.

The south face of The Twisted Mountain (Plates 5 and 6) forms a bold, cliff-like promontory rising more than 2,500 feet and exposing a cross-sectional view of the anticlinal core. Immediately to the south lies the broad, flat valley of South Nahanni River which conceals all signs of surface bedrock. A thorough check from the air during the field work revealed no outcrops. The northwesterly trending cliff face of The Twisted Mountain is of questionable origin. The presence of a fault in the valley of South Nahanni River could possibly be a factor but no direct structural evidence of this is noted. It is significant that the only faults of large magnitude in the area are longitudinal in orientation and that there is apparently no offset where the north-northeasterly trending hogback of the northwestern map area is cut by the South Nahanni River. It is therefore assumed that surface evidence of the south end of The Twisted Mountain anticline has been removed by the erosive action of South Nahanni River.

As shown on the structure contour map, up to 2,000 feet of structural closure may be present on the basal Mississippian beds of The Twisted Mountain. A few high angle-reverse longitudinal faults associated with minor folds in the crestal area and on the east flank of the anticline appear to be of minor displacement. The area of maximum structural closure is 7-1/2 miles in length and approximately 1-1/2 miles wide. The axis rises in a northerly direction from the vicinity of South Nahanni River at a structure datum elevation of 1,000 feet below sea level to a structural high point of 950 feet above sea level on cross-section A-A'. Exact positioning of a structural apex is precluded by the presence of the minor folds in the crestal area. Faulting locally complicates the northeasterly end of the area of closure. Although surface detail is partly obscured by mantle, northeasterly plunge is apparently present. Minor folding can be expected in the area immediately north of the terminus of the anticlinal axis.

The northern end of the Matson Creek anticline lies within the southwestern map area exhibiting north-northeasterly to northerly plunge over a distance of approximately 12 miles. It is a broad, elongate, faulted anticline with steep outer flanks and a relatively flat crestal area. Dips in Permo-Carboniferous beds on the outer flanks of the feature range mainly from 30° to 45° with locally steeper dips adjacent to zones of longitudinal faulting.

The west flank lies beyond the map area and is defined by dips of similar magnitude.

The lower reaches of Jackfish River at the north end of Mattson Creek anticline form an arcuate pattern, convex to the north, apparently due to structural control imparted by the northerly plunging anticlinal axis.

### CONCLUSIONS

Direct and definitive evidence demonstrating south plunge on The Twisted Mountain anticline in the area between South Nahanni River and The Twisted Mountain is lacking. However, on the basis of structural evidence projected from the flanks of The Twisted Mountain and from the area southwest of the river, up to 2,000 feet of closure on the base of the Mississippian is indicated.

Northerly plunge is moderate to well-defined though complicated locally by minor folding and faulting along the crest and by faulting near the northern end of the area of closure. Although steeply dipping to overturned beds are encountered locally on the east flank, in overall aspect the feature appears essentially symmetrical in the upper part with maximum lateral structural relief on the west flank.

The indicated area of closure has an overall length up to 7-1/2 miles and a width of 1-1/2 miles.

Potential reservoirs in Middle Devonian and older carbonates are present in the area. Furthermore, regional structural and stratigraphic considerations demonstrate that the potential reservoirs are involved in the folding of the surface rocks and may be expected to reflect the visible surface structure on which the structural interpretation is based.

Respectfully submitted,

V. ZAY SMITH ASSOCIATES LTD.

  
George M. Collins, P. Geol.

  
William Brown, Senior Geologist

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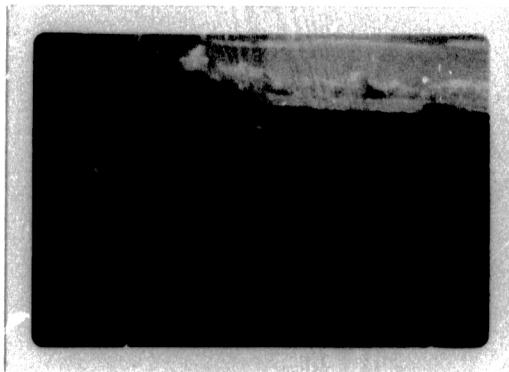


Plate 1

View southwest of westward dipping Middle Devonian carbonates south of Bluefish Lake,

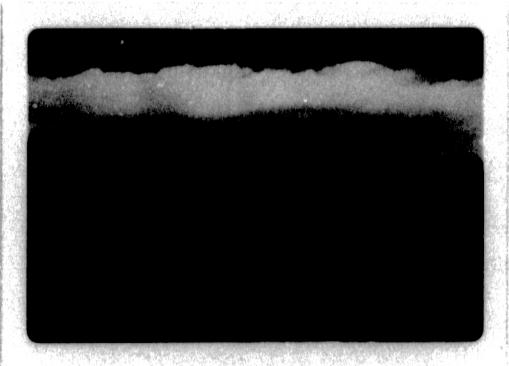


Plate 2

View southeast of westward-facing dip slope of Nahanni Formation along Nahanni Range. Older Devonian carbonates in background.



Plate 1

View southwest of westward dipping Middle Devonian carbonates south of Bluefish Lake.

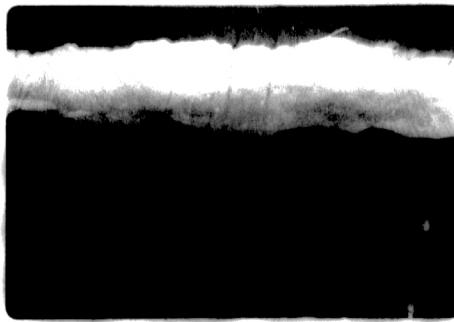


Plate 2

View southeast of westward-facing dip slope of Nahanni Formation along Nahanni Range. Older Devonian carbonates in background.



Plate 3

View north along Bluefish Creek. Nahanni Range at extreme right. Fort Simpson Formation in valley floor and lower part of Upper Devonian clastic unit moderately expressed in right middle-ground. Westward dipping Mississippian rocks form backbone of ridge in center and at left.



Plate 4

View west. West dipping sandstone beds of Mattson Formation form prow underlain by calcareous sandstone and limestone of the Mississippian Flett Formation. Mackenzie Mountains in background.



Plate 3

View north along Bluefish Creek. Nahanni Range at extreme right. Fort Simpson Formation in valley floor and lower part of Upper Devonian clastic unit moderately expressed in right middle-ground. Westward dipping Mississippian rocks form backbone of ridge in center and at left.



Plate 4

View west. West dipping sandstone beds of Maitson Formation form prow underlain by calcareous sandstone and limestone of the Mississippian Flett Formation. Mackenzie Mountains in background.

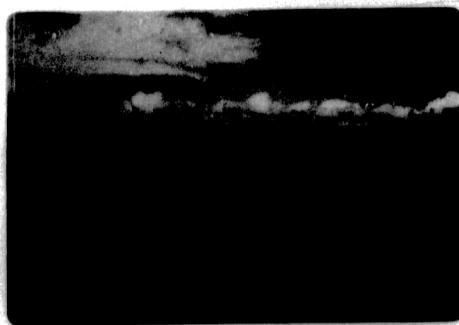


Plate 5

View north showing broad flat valley of South Nahanni River with The Twisted Mountain in the background. Mississippian in core of anticline and Mattson Formation on flanks.

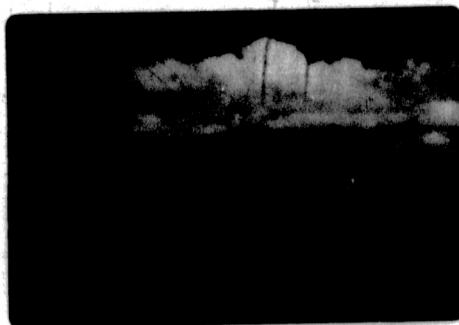


Plate 6

Central part of The Twisted Mountain looking north, tan Mattson Formation sandstones at left, underlain by grey Mississippian carbonates and clastics.



Plate 5

View north showing broad flat valley of South Nahanni River with The Twisted Mountain in the background. Mississippian in core of anticline and Mattson Formation on flanks.



Plate 6

Central part of The Twisted Mountain looking north, tan Mattson Formation sandstones at left, underlain by grey Mississippian carbonates and clastics.

STRATIGRAPHIC SECTION

LOCATION	LATITUDE 61° 11'	OUTCROP SECTION BF BLUEFISH LAKE (NORTH SIDE)
	LONGITUDE 123° 20'	
TOTAL THICKNESS	2355 FEET (Estimated)	
	MAY, 1969	
DESCRIPTION BY T. MASSELINK	Middle Devonian Nahanni, Manetos and Arnica Formations Air Photo: 93A 18041	

REMARKS Thickness and lithologic description of the Nahanni Formation has been adapted from Brady (Field Report 61-1) the Manetos Formation and the upper 577 feet of the Arnica Formation were examined in the field. The thickness of the lower part of the Arnica Formation was estimated. Porosity and permeability properties of the section are based on macroscopic inspection. They should be accurately determined by tests in the laboratory.

● OIL STAINED P PETROLIFEROUS	FOOTAGE	V-Vuggy P-Pinpoint I-Interparticle Excellent Excellent Good Poor Poor	POROSITY TYPE	LITHOLOGY	TEXTURE Medium Coarse Very Coarse F-Fossils	OUTCROP STATION NUMBER	DESCRIPTION	
							Sample #	SCALE: 1 INCH TO 100 FEET
NAHANNI FORMATION	100'						315± of massive bioclastic ls and med grey, cliff-forming ls, med-grey, cryptocrystalline, bioclastic, massive (Brady, 1961). Multiplex measurement indicates 600' Nahanni Fm.	
	200'						The lower 15 feet is recessive and covered, probably consisting of argillaceous limestone. This is overlain by 5 feet med-dk grey fine cryst, thin-bedded argillaceous ls.	
	300'						(AFTER: Brady Field Report 61-1)	
FORMATION	400'			BF 1.	Dol, lt grey med,to coarse, massive bedding, grey weathering quartz veins		Dol, as above, Thick, massive bedding.	
	500'	V		BF 2	Dol, white and grey mottling, massive bedding, grey weathering		BF 3 Dol, as above	
	V			BF 4	Dol, grey, l-med gran, veins of coarse wh.dol, quartz veins massive bedding, laterally changing into ls, med-dk grey, aphanitic, med-thk bedded and vugs more than 1 inch in dia.		BF 5 Dol, med gran grey and coarse gran wh.mottling massive bedding. Quartz in veins and cavities. Vuggy poros-vugs over 1" in dia.	
	V			BF 6	Dol, med gran grey and coarse gran wh.mottling massive bedding. Quartz in veins and cavities. Vuggy poros-vugs over 1" in dia.		BF 7 Dol grey, med-gran with 30% coarse white dol, often as vug lining, poor vugular poros scattered along horizontal bands.	
	600'	V		BF 8	Dol, coarse gran, white and med-gran, grey mottling, massive		BF 9 Dol, coarse gran, white and med-gran, grey mottling, massive	

