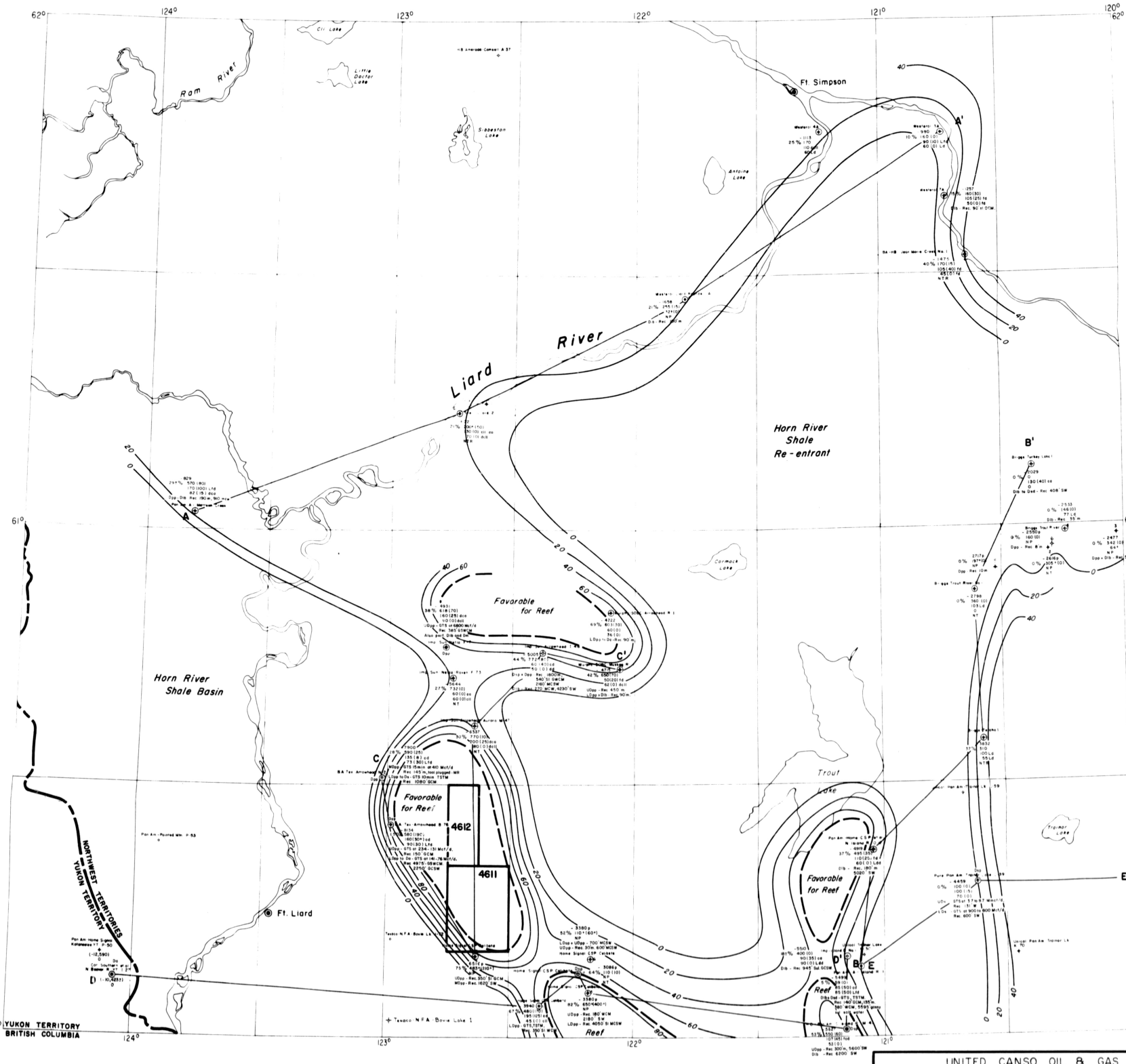

FORMATION SYMBOLS

Dsp	Slave Point	
Dpp	Pine Point (Nahanni)	
	UDpp - Upper	Ds-Sulfur Point
	MDpp - Middle	
	LDpp - Lower	
Dlb	Lonely Bay	
Dhs	Headless	
Ded	Middle Devonian Sandstone	
Dc	Chinchaga	
Dma	Manetoe	
Ds	Arnica	

**GROSS LITHOLOGY SYMBOLS*

ca	Calcarenite
cli	Calcilutite
dca	Dolomite Calcarenite
dcli	Dolomitic Calcilutite
dd	Dense Dolomite
fd	Finely Crystalline Dolomite
cd	Coarsely Crystalline Dolomite
Ldd	Limy Dense Dolomite
Lfd	Limy Finely Crystalline Dolomite
Lcd	Limy Coarsly Cr-stalline Dolomite

Dsp — Producing or major show horizon

-3086 p — Untagged Well; Projected Datum to top of Lonely Bay

110 * — Penetrated Thickness of Pine Point or Nahanni Formations

N P — Not Penetrated or Partially Penetrated

Percentage of reef and/or reef flank sediments in Pine Point + Lonely Bay stratigraphic interval.

-2800 — Logged Well; Datum on top of Lonely Bay

60% 560(380) — Thickness of Pine Point (Approx Porosity Feet)

160(80)cd — Thickness of Lonely Bay (Approx Porosity Feet) Gross Lithology*

90(20)Ltd — Thickness of Headless (Approx Porosity Feet) Gross Lithology*

(10,590') — Approx Top of Lonely Bay in Basinward Horn River Shale Facies

N.P. Not Penetrated
N.T. No Tests
N.T.R. No Tests Reported

C' Cross Section Line

Approximate outline of dolomitized Pine Point Reef or areas favorable for Reef.

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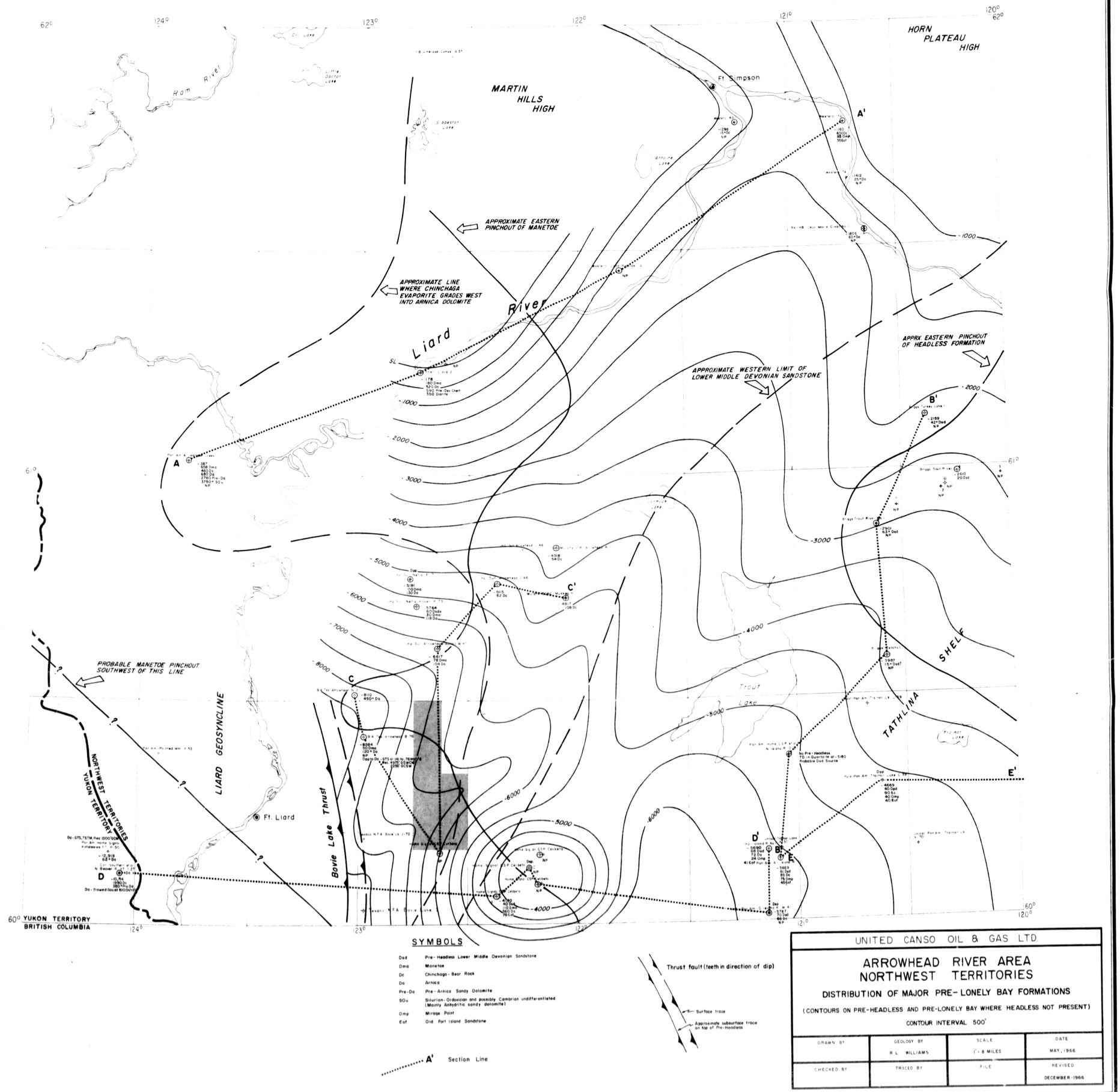
ARROWHEAD RIVER AREA NORTHWEST TERRITORIES

PERCENTAGE CONTOURS SHOWING RATIO OF REEF AND/OR REEF FLANK ROCKS CONTAINED IN COMBINED PINE POINT AND LONELY BAY FORMATIONS

CONTOUR INTERVAL = 20%

DRAWN BY	GEOLOGY BY	SCALE	DATE
	R.L. WILLIAMS	1" = 8 MILES	MAY, 1966
CHECKED BY	TRACED BY	FILE	REVISED

PLATE No. 7



SYMBOLS

Dsd	Pre-Headless Lower Middle Devonian Sandstone
Dma	Manetoe
Dc	Chinchaga - Bear Rock
Da	Arnica
Pre-Da	Pre-Arnica Sandy Dolomite
SOu	Silurian-Ordovician and possibly Cambrian undifferentiated (Mainly Anhydritic sandy dolomite)
Omp	Mirage Point
Eof	Old Fort Island Sandstone

Thrust fault (teeth in direction of dip)

Surface trace

Approximate subsurface trace on top of Pre-Headless

A' Section Line

UNITED CANSO OIL & GAS LTD.

ARROWHEAD RIVER AREA NORTHWEST TERRITORIES

DISTRIBUTION OF MAJOR PRE-LONELY BAY FORMATIONS

(CONTOURS ON PRE-HEADLESS AND PRE-LONELY BAY WHERE HEADLESS NOT PRESENT)

CONTOUR INTERVAL 500'

DRAWN BY	GEOLOGY BY	SCALE	DATE
	R. L. WILLIAMS	1" = 8 MILES	MAY, 1966
CHECKED BY	TRACED BY	FILE	REVISED
			DECEMBER-1966

362-1-4-2

GEOLOGY AND PETROLEUM POSSIBILITIES OF THE ARROWHEAD RIVER AREA NORTHWEST TERRITORIES

R.L.Williams

May 6, 1966


GEOLOGICAL & EVALUATION
Resource Management Division
JUN 6 1967
OTTAWA, CANADA
Dept. of Indian Affairs & Northern Development

G E O L O G Y

A N D

P E T R O L E U M P O S S I B I L I T I E S

O F T H E

A R R O W H E A D R I V E R A R E A

N O R T H W E S T T E R R I T O R I E S

R.L. Williams
United Canso Oil & Gas Ltd.
Calgary, Alberta.

May 6, 1966

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GEOLOGY AND PETROLEUM POSSIBILITIES OF THE ARROWHEAD RIVER AREA, NORTHWEST TERRITORIES

GENERAL STATEMENT

On January 27, 1966, Freeport, General Crude, Gridoil and United Canso jointly purchased Permits 4611 and 4612 containing a total of 95,140 acres located in the Arrowhead River area, District of Mackenzie, Northwest Territories, approximately 95 miles north of Fort Nelson, British Columbia (Figure 1). Principal way of access for field operations is a winter road which enters the Arrowhead River area from Fort Nelson.

The two permits are located along a trend considered favorable for hydrocarbon accumulations in the lower Upper Devonian Slave Point and Middle Devonian Pine Point formations. Secondary objectives are the Upper Devonian Jean Marie member of the Redknife formation and the lower Middle (?) Devonian Manetoe formation. All four objectives can be tested by an 8,000- to 9,500-foot Manetoe well. The deeper depth would be necessary if the Arrowhead River structural configuration fails to conform to the interpretation shown on accompanying Plates 3, 5 and 8. Evidence supporting existence of a structural nose within the area covered by the subject permits is discussed on page 6 of this report. Traps in the major objectives are anticipated to be stratigraphic and it is not imperative to these plays that a structural high exist although the additional depth would appreciably increase drilling costs.

The four plays are illustrated on the enclosed maps which cover an area of 20,000 square miles. Approximately 45,000 feet of samples and cores from 30 wells were examined during the preparation of this report. Details of each play are given in the section dealing with stratigraphy.

The objective in the Slave Point is a dolomitized platform-edge reef similar to the gas producing reefs at South Island River, and at Petitot, Kotcho Lake and Evie Lake fields in northeastern British Columbia. Approximately 250 feet of Slave Point reef could be present within the prospect.

The Pine Point play also has as its objective a dolomitized reef. Up to 900 feet of reef is anticipated in the area covered by the permits. Pine Point reef-flank beds produce

gas at Netla 20 miles north of the joint interest acreage.

The Jean Marie and Manetoe plays are ranked as secondary because they are not as well controlled as the Slave Point and Pine Point plays. At Celibeta and north of Arrowhead River approximately 230 feet of reefoid limestone occurs at the top of the Jean Marie. The reefs are best developed over structural highs. The reef trend may continue beneath the permits if existing structure compares favorably to that shown on the accompanying maps. The Jean Marie is a promising, but as yet unproductive, reservoir objective.

Since a number of wells in the Celibeta area did not penetrate below the upper Pine Point the Manetoe play is more poorly controlled than the above mentioned three plays. Existing control suggests the coarsely crystalline porous dolomite of the Manetoe pinches out due to erosional truncation along the south edge of the permits. Up to 100 feet of Manetoe could be preserved along an erosional stratigraphic trap. Although the Manetoe is to date non-productive of hydrocarbons it has all the prerequisites of a prolific producer.

The two well locations shown on the accompanying maps are Pan American Pointed Mountain P-53 and Texaco-NFA Bovie Lake J-72. At last report the Pan American wildcat was at a depth of 4,200 feet. Texaco has suspended operations at Bovie Lake J-72 until next winter.

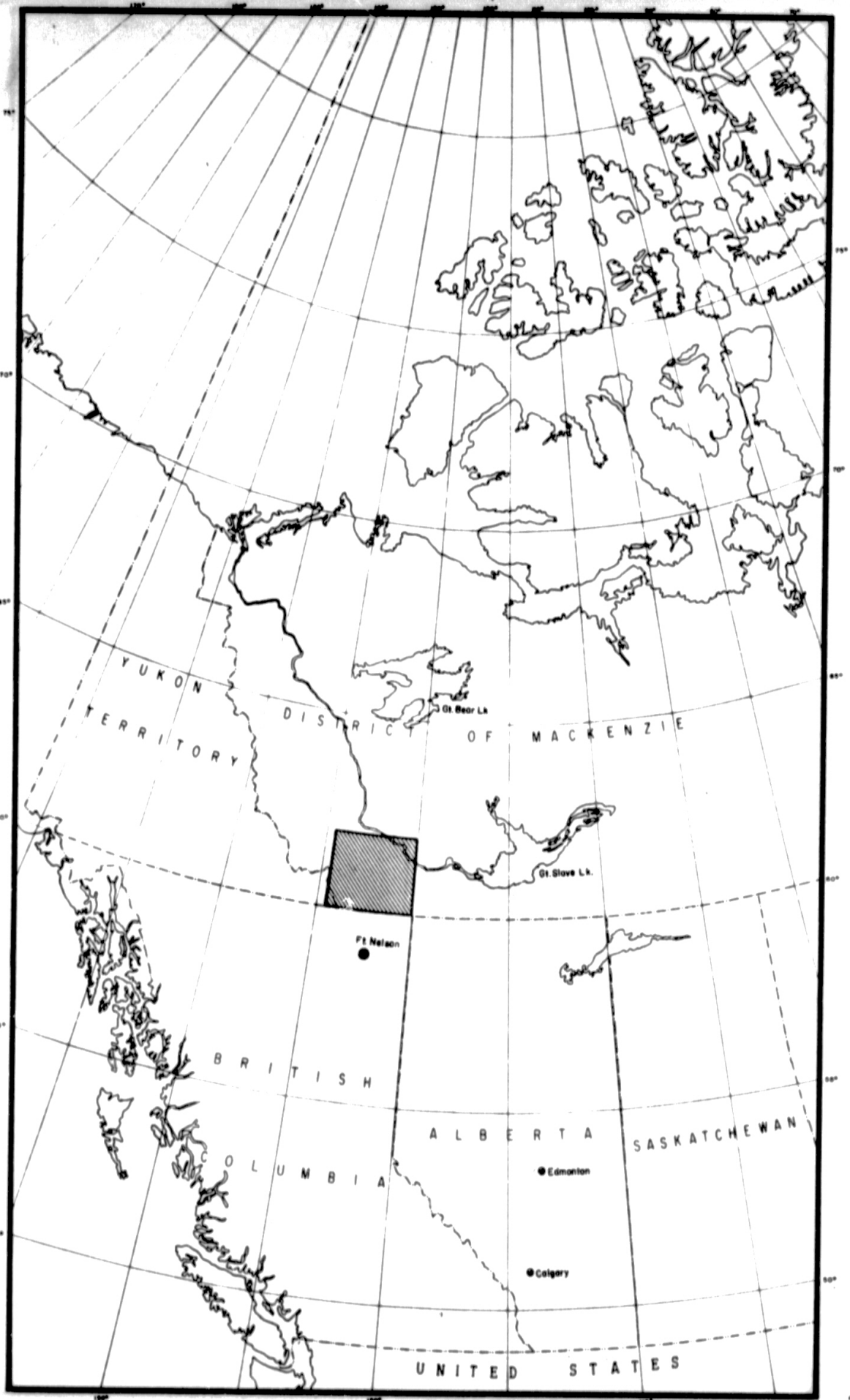

FIGURE 1 - INDEX MAP SHOWING LOCATION OF ARROWHEAD RIVER AREA

PHYSIOGRAPHY AND ACCESSIBILITY

The eastern two-thirds of the map area lies within the Interior Plains. The plains are low-lying and covered by muskeg with occasional small lakes situated between low rolling hills. Exposures of bedrock are reportedly very rare except along Liard River and its tributaries. Principal surface rocks are sandstone and shale of the Cretaceous Fort Nelson formation and Fort St. John Group. Shales of the Upper Devonian Fort Simpson formation are poorly exposed along the broad flood plains near Fort Simpson. Flat upland areas west and northeast of Fort Simpson rise about 1,500 feet above the general level of the plains and are known as Martin Hills and Horn Plateau, respectively. Both uplands are capped by resistant sandstone of the Fort Nelson formation. About 45 miles south of Fort Simpson a prominent east-west trending escarpment attains an elevation of 1,250 feet. The escarpment is capped by the Fort St. John Group which unconformably overlies Upper Devonian limestone and shale.

The western third of the map area lies within the Liard Plateau of the southern Mackenzie Mountains. The highest peaks rise about 5,000 feet above the general elevation of the Interior Plains. Although Liard Plateau is heavily wooded, bedrock exposures are good along escarpments and major drainage systems.

The Arrowhead River permits are located 120 miles southwest of Fort Simpson, Northwest Territories. Fort Simpson is serviced by commercial aircraft. The Liard River is navigable by specially constructed river boats between Fort Simpson and Fort Nelson, British Columbia. The settlement of Fort Liard is located 25 miles west of the permits. It includes a school, mission, churches, Hudson's Bay store and Royal Canadian Mounted Police post. Drilling equipment is moved into the Arrowhead River area from Fort Nelson after freeze-up.

STRUCTURE

The portion of the Interior Plains covered by the enclosed maps contains three distinct structural elements (see Plate 8). Martin Hills and Horn Plateau are positive basement features and the Middle Devonian Chinchaga formation rests directly upon metasediments and associated quartz diorite, diorite and granite intrusives. The Devonian rocks dip south and southwest off of Martin Hills and Horn Plateau toward the Arrowhead River area. Regional dip is interrupted by a series of sharp southwest-plunging folds. These folds appear to be subordinate irregularities along a broad basement arch extending from the Celibeta and Arrowhead River areas east to the edge of the map area. This positive area is probably the western expression of the Tathlina high which centers about 80 miles southwest of Great Slave Lake. Basement rocks along the arch consist of quartzite, argillite, chert and quartz diorite and granite intrusives. They are covered by a normal thickness of Headless and younger rocks and a thin veneer of pre-Headless sediments. Locally along the crests of the subordinate southwest-plunging folds basement rocks immediately underlie the Headless formation and served as the source for lower Middle Devonian sandstones which along with thin sections of the Chinchaga, Mirage Point and Old Fort Island formations fill the intervening lows. The marked increase in thickness of pre-Headless rocks west of the Celibeta and Arrowhead River areas marks the boundary between the Tathlina shelf and Liard geosyncline. These two structural features existed throughout most of pre-Headless time.

The westerly dipping Bovie Lake thrust occurs at the edge of the Tathlina shelf west of the Arrowhead River permits. South of Texaco-N.F.A. Bovie Lake J-72 approximately 160 feet of gently west-dipping Mississippian limestone and shale outcrop in the hanging-wall of the fault. The foot-wall rocks are not exposed (Plate 2). Here the throw of the fault exceeds 1,500 feet according to Douglas and Norris (1959). Three miles southwest of British American-Texaco Arrowhead B-76 Cretaceous sandstones of the Fort St. John Group are folded into a north-plunging anticline broken along the west flank by the Bovie Lake thrust. Throw on the fault is here estimated by Douglas and Norris (1959) to be of the order of 500 feet.

The structure contours drawn on the Devonian of Plates 3, 5 and 8 are based solely upon subsurface control as there appears to be no direct relation between the gentle folds in the surficial Cretaceous rocks and the sharp folds in the unconformably underlying pre-Cretaceous rocks. However, the

poorly exposed Cretaceous Fort St. John shales, reported by Douglas and Norris (1959) to be folded into a slightly north-plunging syncline along Petitot River between the Celibeta Mississippian outcrop and Bovie Lake thrust (Plate 2), could be a Cretaceous expression of the sharp syncline shown on the Devonian maps between the Celibeta and Arrowhead River folds.

The Celibeta anticline is well defined and contains a small closure at Home-Signal-CSP Celibeta #2 which causes a gas trap in the Upper Devonian Slave Point formation.

The Arrowhead River anticline is not as well controlled as Celibeta. The structure is drawn beneath Permits 4611 and 4612 by extending the nose suggested by northern control. Surrounding control wells suggest thinning of the normal Fort Simpson shale interval toward the anticipated trend of the anticline. Stratigraphic convergence is noted in the Fort Simpson across Celibeta anticline (cross-section D-D'). Probable existence of a structural high beneath the permits is further supported by its apparent influence upon thickness and distribution of pre-Headless rocks, particularly Manetoe erosional truncation along the anticipated northwest flank and across the probable southwest plunge, the facies change from Arnica dolomite to Chinchaga evaporitic dolomite along the suggested crest of the fold, and the absence of pre-Chinchaga rocks along the controlled northern axis of the fold.

The western third of the mapped area lies within the Liard Plateau physiographic subdivision which coincides with the pre-Headless Liard geosyncline. The area is sharply folded and thrust faulted along a north-south alignment. The structure of Liard Plateau is quite complex as demonstrated by Plate 2.

STRATIGRAPHY

Cretaceous

The Upper Cretaceous of the Arrowhead River area is composed of three major units. They are, in descending order, the Wapiti, Kotaneelee and Fort Nelson formations (Stott, 1960). Erosional remnants of the non-marine Wapiti occur along Petitot River and Liard synclines and consist of less than 50 feet of medium-grained sandstone, occasional conglomerate and lenticular seams of low-grade coal. The conformably underlying Kotaneelee consists of between 500 and 1,000 feet of interbedded mudstone, shale, siltstone and fine-grained sandstone of mainly marine origin. The Fort Nelson formation underlies the Kotaneelee along Petitot River and Liard synclines. The formation also crops out intermittently along other structures in the Liard Plateau. Within the Interior Plains the formation forms the cap rock of Martin Hills and Horn Plateau and is poorly exposed along a broad northwest trending belt southwest of Trout Lake. Best exposures occur where Petitot River transects Liard and Petitot River synclines. Here the formation consists of 450 to 500 feet of cross-bedded massive coarse-grained sandstone, conglomerate and shale. Abundant coal and carbonaceous material suggest a partial non-marine origin for the formation.

The Lower Cretaceous Fort St. John Group crops out along the major synclines within the Liard Plateau. It is also the surficial bedrock of most of the Interior Plains included in the map area except where it is covered by erosional remnants of the Fort Nelson formation or where it has been eroded to expose the unconformably underlying Upper Devonian rocks. It consists of 3,800 to 4,900 feet of micaceous gypsiferous locally bentonitic shale, siltstone and glauconitic fine-grained sandstone.

Permo-Pennsylvanian

The Mattson formation crops out within the Liard Plateau and is reported by Douglas and Norris (1960) to consist of between 3,100 and 3,700 feet of interbedded fossiliferous limestone, sandy dolomite, calcareous medium- to coarse-grained sandstone and carbonaceous shale of mainly marine origin. The Mattson unconformably underlies Cretaceous strata and pinches out rapidly eastward due to erosion, or non-deposition, before reaching the Interior Plains.

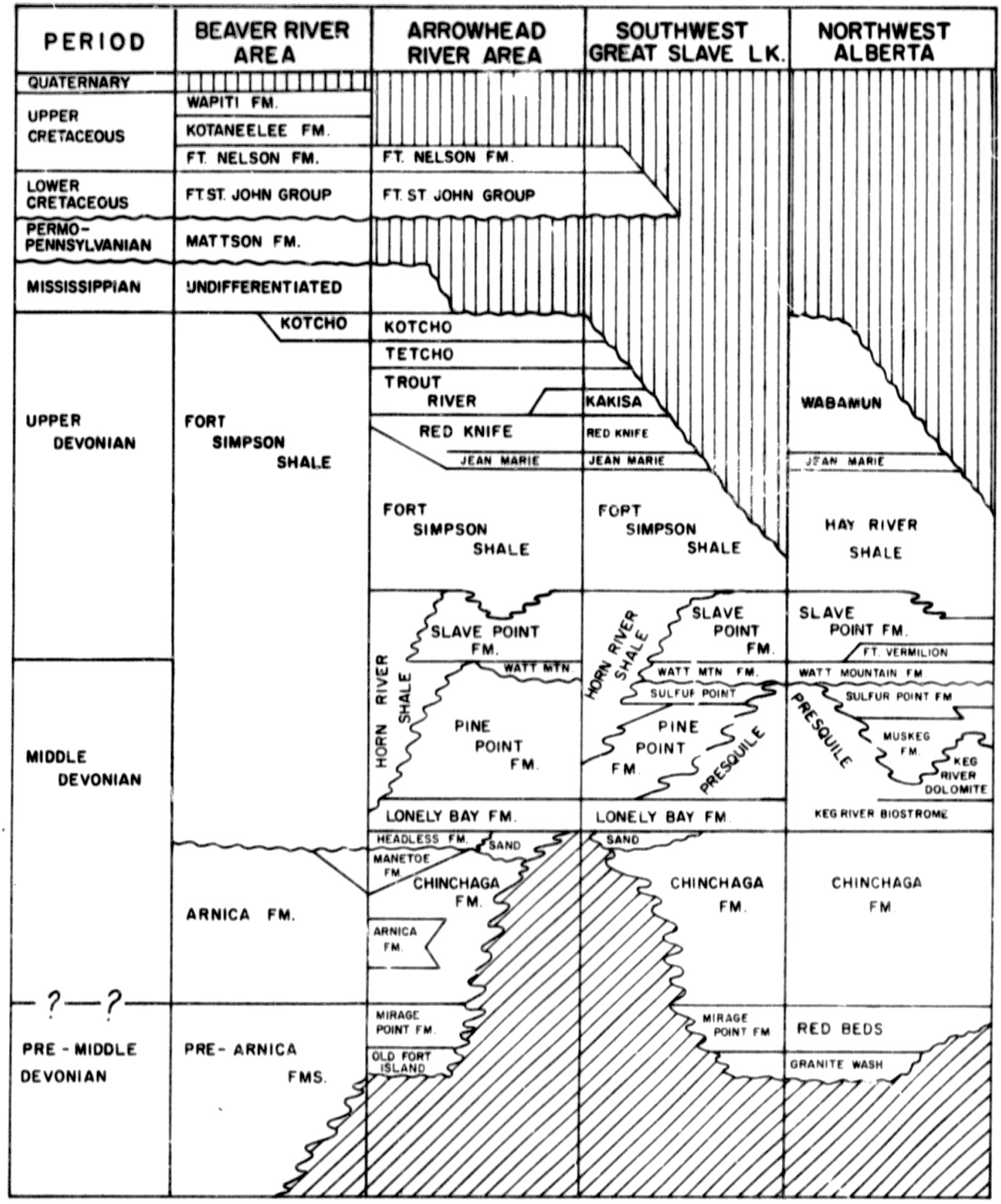

FIGURE 2 — GENERALIZED COMPARISON OF ARROWHEAD RIVER STRATIGRAPHIC SECTION TO ADJACENT AREAS

Mississippian

An undifferentiated sequence of marine Mississippian rocks is well exposed in the Liard Plateau and thins rapidly east and northeast, due to progressive pre-Cretaceous erosional truncation. The zero edge is located a few miles east of the Celibeta area. Approximately 2,400 feet of interbedded dark micaceous shale, siltstone, argillaceous sandstone and shaly limestone has been provisionally included within the Mississippian at British American-Texaco Arrowhead N-2. The yellowish-grey crinoidal limestones exposed along Petitot River at the crest of Celibeta anticline have been included in the Mississippian by Douglas (1959).

Upper Devonian

The Upper Devonian conformably underlies undifferentiated Mississippian rocks in the southwestern third of the map area. East and north of Celibeta the Mississippian has been removed by erosion and the Upper Devonian is unconformably overlain by Cretaceous rocks. Pre-Cretaceous erosion has removed the entire Upper Devonian section at Shell Liard #2 on the south edge of the Martin Hills high. East from Celibeta the top of the Upper Devonian is relatively unaffected by erosion within the limits of the present map area.

The youngest Upper Devonian rocks consist of alternating limestone and shale units having a combined thickness varying between 1,150 and 1,700 feet. They have been subdivided in descending order into the Kotcho, Tetcho, Trout River, Kakisa and Redknife formations. This group is equivalent to the Wabamun formation of north-central Alberta.

The type section of the Kotcho formation is the interval 3,473 feet to 4,165 feet in Imperial Island River No. 1. It consists mainly of light grey calcareous to non-calcareous shale with occasional thin beds of argillaceous limestone.

The Tetcho is identified in Imperial Island River No. 1 between 4,165 and 4,415 feet. It consists of buff to cream, sparse calcarenite with shale partings. It becomes increasingly silty toward the base and to the west.

Crickmay (1957) defined the Trout River formation from the type section along Trout River as 174 feet of silty limestone and calcareous sandstone. Belyea and McLaren (1962) restricted the type section to the upper 130 feet of sandy limestone and calcareous sandstone and placed the lower 44 feet

of Crickmay's Trout River in the underlying Kakisa formation. Both the Trout River and Kakisa become increasingly shaly westward from the Great Slave Lake type areas. They cannot be reliably differentiated in the subsurface within the present map area and are carried as separate units only on cross-section $B-B^1$. At Briggs Turkey Lake No. 1 the interval 160 to 310 feet is included in the Trout River. Here the formation consists mainly of grey calcareous, very argillaceous, siltstone and occasional thin beds of oolitic limestone. The Kakisa is represented in this well by the interval 310 to 490 feet and consists of 70 feet of buff sparse calcarenite which grades downward into grey siltstone and shale.

The Redknife formation is subdivided within the map area into two members. The uppermost member consists of 250 to 340 feet of greenish-grey shale and calcareous siltstone. The lower Jean Marie member consists of 25 to 65 feet of buff to light grey argillaceous calcisiltite and sparse calcarenite which is a good electric-log marker that can be carried in the subsurface from the Celibeta-Arrowhead River area far into north-central Alberta. West of Celibeta and Arrowhead River the basal Jean Marie marker pinches out into shales of the upper Redknife member and the underlying Fort Simpson. As demonstrated by Plate 3 the basal Jean Marie marker locally serves as a platform for reef growth into the base of the upper Redknife member. These reefs are developed at Trout River, Celibeta and Arrowhead River. They are also exposed along Root River anticline and Yohin syncline 120 miles north-northwest of Arrowhead River. They appear to be directly related to Middle Devonian structural highs. Maximum known reefoid development occurs at Home-CSP Celibeta No. 2 on the crest of Celibeta anticline (see cross-section $D-D^1$). Here the Jean Marie member is 295 feet. The upper 230 feet is porous slightly dolomitic reefoid limestone. The extreme basal portion of the reef was tested and yielded 300 feet of slightly gas-cut mud and 100 feet of mud-cut salt water. The Jean Marie reefs are a promising reservoir objective throughout this portion of the Interior Plains.

The middle unit of the Upper Devonian in theArrowhead River area is the Fort Simpson shale. It ranges in thickness from 1,072 to 2,190 feet. Most of the thickening is at the expense of the underlying Slave Point formation and carbonates of the Middle Devonian which grade into shale north and west of the Arrowhead River area. However, some anomalously thin sections are due to stratigraphic convergence of the Fort Simpson across structural highs such as occur at Celibeta (cross-section $D-D^1$). Locally the base of the Slave Point becomes very bituminous and pyritic. Some geologists have attempted to apply

formation status to this phase and call it Spence River shale. It is a facies directly related to the shale-out of the underlying Slave Point and is not designated as a separate formation in this report.

The lowermost Upper Devonian rocks within the Arrowhead River area comprise the Slave Point formation. It is composed of a complex of shelf fragmental limestones, shelf-edge calcilutites, reef-flank coarse fragmental and brecciated limestones, very organic reef limestones and coarse reefoid dolomites. The thickness of the Slave Point is quite variable ranging from a maximum of 418 feet at Hudson's Bay-Pan American South Island River M-41 to zero where the carbonate grades into the open marine shale of the overlying Fort Simpson and partially equivalent Horn River formations. The irregular edge of the Slave Point platform is shown on Plate 4 extending east from Arrowhead River to Trout River. This platform edge can be traced further eastward to Great Slave Lake and southward to the Kotcho Lake and Evie Lake areas of northeastern British Columbia.

Dolomitized reefs occur along irregularities of the platform edge and produce gas at Hudson's Bay-Pan American South Island River M-41 and in the Kotcho Lake, Petitot River and Evie Lake fields of northeastern British Columbia. Slave Point production at Celibeta is due to local structural closure and favorable organic porosity in reef and reef-flank limestone (cross-section D-D'). The encouraging Slave Point gas shows at Pure-Pan American Trainor Lake C-39 may be caused by structure but more probably can be attributed to up-dip shale-out of uppermost Slave Point limestone into the overlying Fort Simpson.

Three general areas within the mapped area are considered favorable for Slave Point dolomitized reef gas or oil accumulations.

At Trout River, about 30 miles northeast of Trout Lake, sharp irregularities along the Slave Point platform are a suitable site for reef development.

At South Island River the reef was penetrated by Hudson's Bay-Pan American M-41. The three wells between M-41 and Trout Lake penetrated dense off-reef limestones along the western margin of the Horn River shale re-entrant. It appears possible from the Slave Point lithologies in these three wells that the productive dolomite reef at M-41 could extend north-northwest another ten or fifteen miles and that a second reef may lie en-echelon to it near the south edge of Trout Lake.

At Arrowhead River, Home-Signal-CSP Celibeta wells Nos. 1, 2, 5 and 6 penetrated very organic reef and reef flank limestones. Home-Signal-CSP Celibeta No. 7 penetrated an off-reef, or platform-edge, sequence of dense calcilutite and sparse calcarenite suggesting the Celibeta limestone reef is separated from the reef anticipated further northwest in the vicinity of Permits 4611 and 4612. In the latter area British American-Texaco Arrowhead N-2 penetrated a Slave Point section consisting of dense calcilutite and cryptocrystalline platform-edge limestone. The operator's second test, B-76, located seven miles southeast of N-2, penetrated a radically different Slave Point section. The upper 210 feet at B-76 consisted of coarsely fragmental, slightly dolomitic limestone underlain by 118 feet of dense calcilutite. The detritus and abundant coral, stromatoporoid and amphipora in the upper 210 feet is indicative of a reef-flank facies related to an eastern reef buildup. At Imperial-Sun Arrowhead Aurora M-47 the Slave Point-Pine Point contact was picked at 7,255 feet on a dense dolomitic micro-pyritic calcilutite. The overlying 78 feet of Slave Point is anomalously rich in coral, bulbous stromatoporoid and amphipora imbedded in a very coarse calcarenite and breccia. The abundance of organic material and detritus suggests Aurora M-47 is located on the north edge of the anticipated reef.

Middle Devonian

East and southeast of the Arrowhead River area the contact between the Upper and Middle Devonian is easily picked on the unconformity at the base of the Watt Mountain formation. The typical green waxy pyritic shales of this formation are difficult to recognize in the Arrowhead River area. They have been identified in British American-Texaco Arrowhead B-76 and in several wells in the Celibeta, Island River and Trout River areas. The characteristic Watt Mountain electric-log pick is normally identifiable except where the unit is replaced by the Horn River shale facies. There is no question that an unconformity exists at the base of the Watt Mountain from the Presquile barrier reef trend southeast into north-central Alberta. Northwest and basinward from the Presquile barrier reef there may or may not be an unconformity between Upper and Middle Devonian.

In the Trainor Lake area an argillaceous limestone at the top of the Middle Devonian is correlated with the Sulfur Point formation of northwestern Alberta. The limestone probably represents a fore-reef tongue from the upper Presquile. The limestone grades into Horn River shale along the re-entrant between Trout and Trainor Lakes. West of the re-entrant carbonates at the same stratigraphic position are included in the Pine Point formation.

The Pine Point formation is a basinward facies of the Presquile and Keg River formations of the Great Slave Lake area, northwestern Alberta and northeastern British Columbia. It grades from coarsely crystalline vuggy reefoid dolomite through detrital reef-flank limestone and dense off-reef calcilutite into the open marine Horn River shale facies. The Pine Point is completely replaced by Horn River shale at Briggs Turkey Lake No. 1 located within the re-entrant which enters the map area south of Fort Simpson and extends on southward into northeastern British Columbia. Southwest of the Celibeta-Arrowhead River-Mattson Creek trend the Pine Point grades rapidly into Horn River shale of the Liard geosyncline (Plate 6).

Pine Point dolomitized reefs occur at South Island River and Celibeta. As demonstrated by Plates 6 and 7 southern Trout Lake, Arrowhead River and Netla are considered favorable localities for similar reef development.

At the south edge of Trout Lake, Pan American-Home-CSP North Island River O-12 penetrated a Pine Point section containing an anomalously high percentage of fragmental limestone. The detritus was probably shed from a reef located west of O-12 which may be a northward continuation of the South Island River reef or a separate reef on strike with South Island River.

Logs of the four control wells for the anticipated Pine Point reef play at Arrowhead River are shown on cross-section C-C'. British American-Texaco Arrowhead N-2 penetrated a Pine Point section composed mainly of dense calcilutite and cryptocrystalline limestone indicative of a basinward and off-reef facies. There are minor sparse calcarenites with coral fragments near the top and medium crystalline dolomites near the base of the section that are anomalous and, along with the coarsely crystalline dolomite of the basal Lonely Bay platform, suggest nearby reefing. British American-Texaco Arrowhead B-76 penetrated a Pine Point section composed primarily of reef and reef-flank coarse dolomite and dolomitic fragmental limestone. Inter-crystalline dolomite porosity is heavily stained with a black residual pyrobitumen. A drillstem test of the upper Pine Point gave up small amounts of gas and gas-cut mud. Home-Signal-CSP Celibeta No. 7 located southwest of the aforementioned two wells, partially penetrated a Pine Point section composed of medium to coarsely crystalline vuggy reef and reef-flank dolomite interbedded with dense off-reef calcilutite. The reef and reef-flank facies at Celibeta No. 7 may be related to the reef located east of B-76 or to the Celibeta reef whose apex passes through Home-Signal-CSP Celibeta No. 5. Imperial-Sun Arrowhead Aurora M-47 has a Pine Point section composed of dense occasionally bituminous calcilutite and sparse calcarenite. Calcarenites bearing coral, stromatoporoid

and amphipora occur at the top and base of the Pine Point. Aurora M-47 is interpreted to be in a back-reef position relative to the Arrowhead River reef.

At Netla, north of Arrowhead River, Imperial Sun Netla F-7 penetrated a Pine Point section composed of reef-flank calcarenite and off-reef dense calcilutite. Approximately 40 feet of organic porosity in upper reef-flank rocks yielded gas to surface at 6,800 Mcf/d and 385 feet of gas and salt water-cut mud. As demonstrated by Plates 6 and 7 there is a good possibility of a full Pine Point reef development east and northeast of Netla F-7. Imperial-Sun Netla Raven F-73 and I-46 penetrated Pine Point sections composed of very bituminous dense calcilutite and sparse to medium calcarenite. Both sections are very rich in coral, stromatoporoid and amphipora and are interpreted to have been deposited in a restricted environment on the lee side of the postulated Netla and Arrowhead River reefs. Murphy-SOBC Muskeg River No. 1 and Arrowhead River No. 1 are interpreted to be located near to the eastern flank of the Netla reef due to an increase in the amount of fragmental limestone and the introduction of thin finely crystalline dolomite tongues in the Pine Point.

The Lonely Bay formation is a basinward facies equivalent of the Keg River biostrome of northwestern Alberta. It is similar in every respect to its Alberta counterpart in that it serves as the organic platform for reef development in the overlying Pine Point, thickens rapidly toward and beneath the reefs, and is altered to coarsely crystalline vuggy dolomite beneath and around the Pine Point reefs. These facies characteristics are demonstrated by the Lonely Bay thicknesses and gross lithologies given on Plates 5, 6 and 7. The Lonely Bay ranges in thickness from an average of 100 feet in the Trout River area to 195 feet beneath the Celibeta Pine Point reef. It grades into Horn River shale of the Liard geosyncline southwest of the Celibeta-Arrowhead river-Mattson Creek trend. The Lonely Bay is transitional with the overlying Pine Point and underlying Headless formations. Where the Headless is absent the Lonely Bay is underlain by lower Middle Devonian sandstone.

The Headless formation is a facies equivalent of the limy dolomite member of the Keg River biostrome south of Great Slave Lake (cross-section E-E^1). It varies from a dense calcilutite to a finely crystalline dolomite throughout the map area. It attains a maximum thickness of 90 feet in the Netla and Arrowhead River areas. Southwest of the Celibeta-Arrowhead River-Mattson Creek trend the Headless grades into Horn River shale of the Liard geosyncline. The Headless pinches out

locally northeast of Trout Lake (Plate 8). It is transitional with the lower Middle Devonian sandstone. Where the sandstone is absent it unconformably overlies the Chinchaga, Manetoe or Arnica formations.

The lower Middle Devonian sandstone was deposited on the unconformity between the Chinchaga and Headless or Lonely Bay formations in the Trout River area. It is a quartzose detrital sand derived from, and deposited in close proximity to, quartzite rich basement highs. The source for the sandstone of the map area lies southeast of Trout Lake. Here Pan American-Home-CSP North Island River O-12 penetrated a quartzite basement high immediately underlying the Headless. Similar sand halos exist around pre-Headless basement highs in the Great Slave Lake area and are the major objectives of several land plays.

As is evident from the preceding discussion the Horn River formation is a basinward marine shale facies which replaces all formations from the Slave Point to the Headless, inclusive. It ranges in age from lower Upper Devonian to Middle Devonian.

The Nahanni is an ambiguous term applied in most previous reports and well releases to the first Middle Devonian, or older, carbonate encountered beneath the Fort Simpson or Horn River shale. Since the first carbonate may range anywhere from Slave Point to Arnica the term Nahanni has been discarded.

Probable Middle Devonian

Formations beneath the pre-Headless unconformity provisionally assigned to the Middle Devonian include the Manetoe, Chinchaga and Arnica. Due to the paucity of fossils in these rocks the age designation is questionable and all, or a portion, of these formations may be older than Middle Devonian.

The best sections of typical Manetoe occur at British American-Texaco Arrowhead B-76, Shell Liard No. 2 and Home-Signal-CSP Celibeta No. 1. It is a grey to white coarsely crystalline porous dolomite. Douglas and Norris (1961) describe 500 feet of Manetoe on the Iverson anticline north of the map area. At Pan American A-1 Mattson Creek, 658 feet of crystalline dolomite is tentatively included in the Manetoe. Only the upper 200 feet is coarsely crystalline and the lower 458 feet may possibly belong to the transitionally underlying Arnica. The Manetoe is truncated by the Pre-Headless unconformity along the Celibeta-Arrowhead River trend and because of its good reservoir properties must be considered a secondary objective at Arrowhead River.

The Chinchaga formation is composed of cryptocrystalline to dense anhydritic dolomite and anhydrite. It ranges in thickness from zero to 600 feet within the map area. Along the Tathlina shelf it averages about 70 feet in thickness except where it is absent due to erosion, or non-deposition, across local basement highs. In the Fort Simpson area, along the structural depression between the Tathlina shelf and Martin Hills and Horn Plateau highs, the Chinchaga thickens rapidly. Westerol 3A penetrated 600 feet of Chinchaga rocks which included a thick salt section (cross-section A-A^1). West of the Celibeta-Arrowhead River-Mattson Creek trend the Chinchaga grades into dolomite of the Arnica formation.

The Arnica formation is a thick sequence of grey, argillaceous, occasionally silty, dense to finely crystalline and vuggy dolomite deposited as fill in the Liard geosyncline. As demonstrated by cross-section A-A^1 and Plate 8 the upper Arnica grades eastward into the Chinchaga of the Tathlina shelf. The upper Arnica is equivalent to the Chinchaga. The basal dolomites mapped as Arnica may be pre-Chinchaga. The base of the Arnica is provisionally picked at the first occurrence of siliceous dolomite. Using this marker the Arnica has a maximum known thickness of 1,990 feet at Canada Southern Beaver River YT 1-27. Although the Arnica produces gas at Beaver River it does not have sufficient effective porosity within the Arrowhead River area to warrant consideration as a reservoir objective.

At Pan American A-1 Mattson Creek 2,780 feet of sandy anhydritic dolomite underlies the Arnica. These beds are provisionally assigned to the undifferentiated Silurian-Ordovician although they may include some Devonian and possibly Cambrian rocks. They occur only as fill in the Liard geosyncline.

Within the Tathlina shelf the Ordovician Mirage Point is represented by a sequence of red siltstone, shale and anhydrite. The Mirage Point is absent along the Celibeta-Arrowhead River structural high due to non-deposition, or erosion. It has a maximum thickness along the Fort Simpson structural depression of 85 feet. Its thickness is dependent upon basement topography. The Mirage Point is equivalent to the Red Beds formation of northwestern Alberta.

The Old Fort Island sandstone of the Tathlina shelf is probably equivalent to the Granite Wash of northern Alberta. It is a detrital sand derived from the basement and its thickness and distribution are dependent upon basement topography. The maximum known thickness within the map area occurs at Home-Signal-CSP Celibeta No. 1, on the northwest limb of Celibeta anticline.

Basement rocks in the Arrowhead River area consist of an undifferentiated sequence of quartzite, green pyritic argillite, chert and associated diorite, quartz diorite and granite intrusives. The undifferentiated basement includes intrusives as young as pre-Headless.

R. L. Williams

RLW/mk

cc: JTS w/ attachs
RJR w/o attachs
BDP w/o attachs

Freeport Oil w/ attachs
Gridoil Leases w/ attachs

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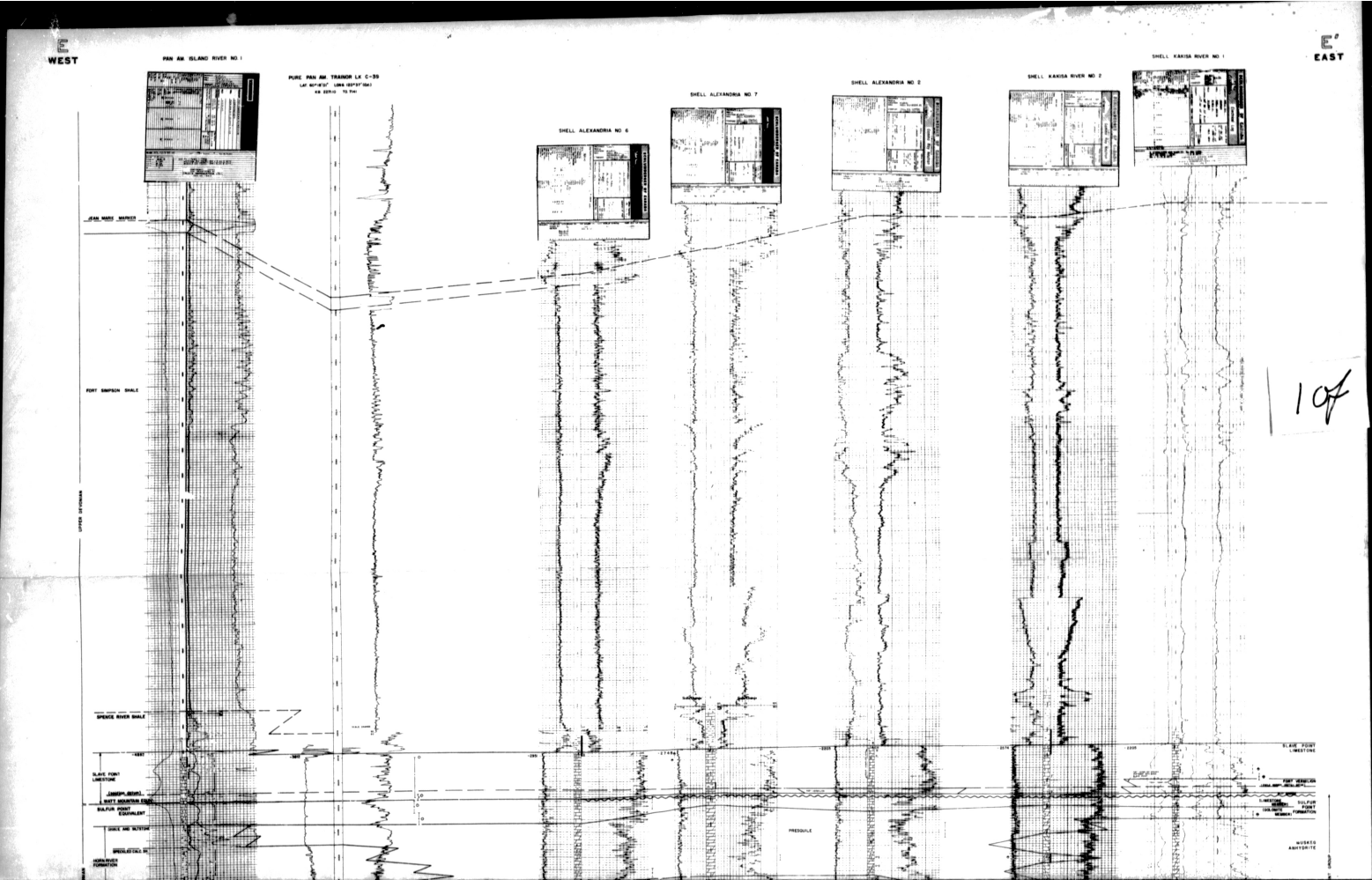
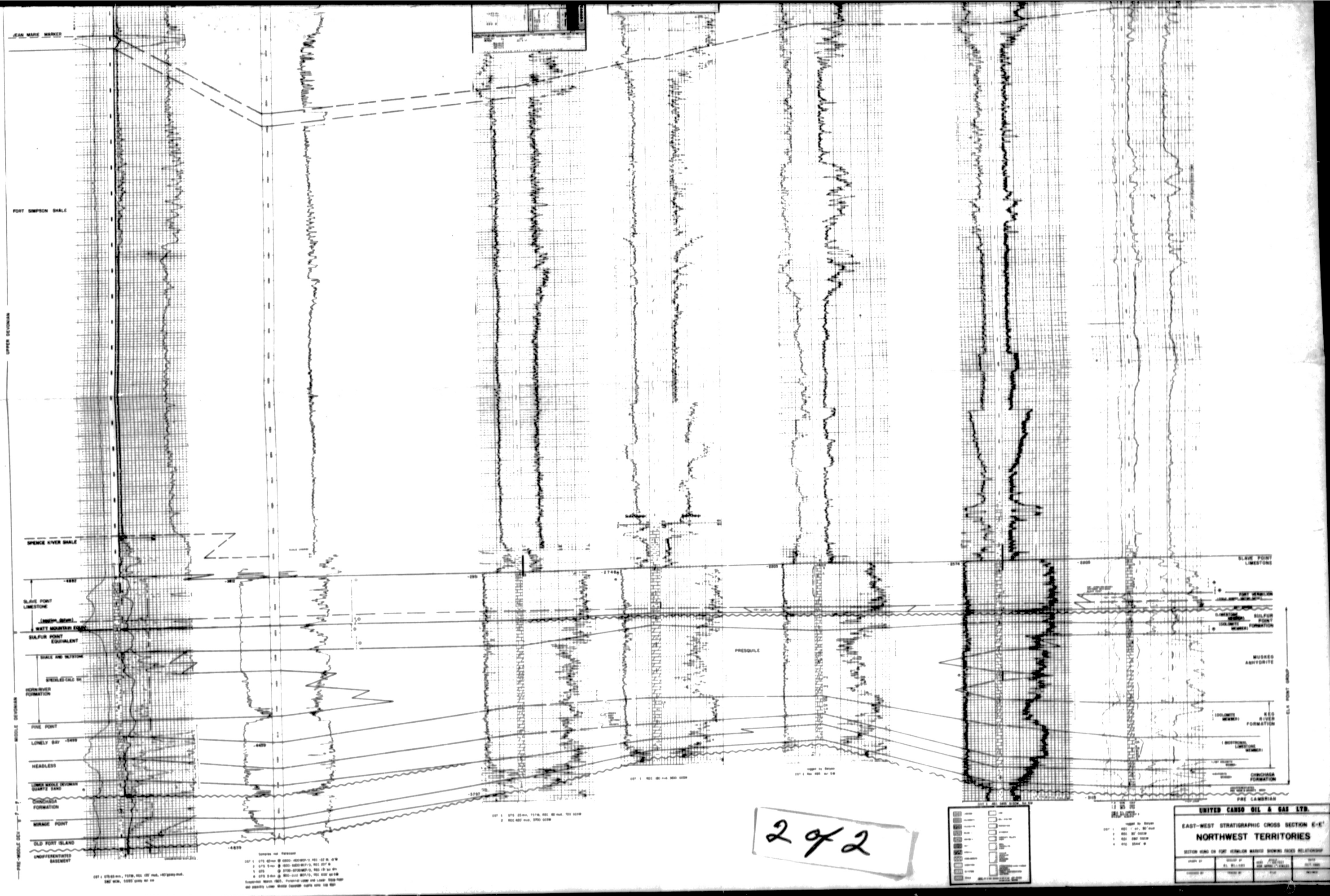

E
WEST
E'
EAST
PAN AM. ISLAND RIVER NO. 1
PURE PAN AM. TRAINOR LK C-35
SHELL ALEXANDRIA NO. 6
SHELL ALEXANDRIA NO. 7
SHELL ALEXANDRIA NO. 2
SHELL KAKISA RIVER NO. 2
SHELL KAKISA RIVER NO. 1
JEAN MARIE MARKER
FORT SIMPSON SHALE
SPENCE RIVER SHALE
SLAVE POINT LIMESTONE
SULFUR POINT EQUIVALENT
SHALE AND ANTRIM
HORN RIVER FORMATION
PRESQU'ILE
SLAVE POINT LIMESTONE
FORT VERMILION MEMBER
LIMESTONE MEMBER
SULFUR POINT FORMATION
MUSKEG ANHYDRITE
UPPER DEVONIAN
107


JEAN MARIE MARKER
FORT SIMPSON SHALE
UPPER DEVONIAN
SPENCE RIVER SHALE
SLAVE POINT LIMESTONE
WATT MOUNTAIN EQUIV.
SULFUR POINT EQUIVALENT
SHALE AND SILTSTONE
SPECKLED CALC. SH.
HORN RIVER FORMATION
MIDDLE DEVONIAN
PINE POINT
LONELY BAY
HEADLESS
LOWER MIDDLE DEVONIAN QUARTZ SAND
CHINCHAGA FORMATION
MIRAGE POINT
OLD FORT ISLAND
UNDIFFERENTIATED BASEMENT
PRE-MIDDLE DEV.
PRESQUILE
SLAVE POINT LIMESTONE
FORT VERMILION
SULFUR POINT FORMATION
MUSKEG ANHYDRITE
ELK POINT GROUP
RED RIVER FORMATION
CHINCHAGA FORMATION
PRE CAMBRIAN
UNITED CANSO OIL & GAS LTD.
EAST-WEST STRATIGRAPHIC CROSS SECTION E-E'
NORTHWEST TERRITORIES
SECTION HUNG ON FORT VERMILION MARKER SHOWING FACIES RELATIONSHIP
OCT. 1965
2 of 2

D
WEST

BEAVER R. AREA

CANADA SOUTHERN ET AL K BEAVER R YT 1-27

CELIBETA AREA

HOME SIGNAL CEP CELIBETA NO 1

HOME SIGNAL CEP CELIBETA NO 2

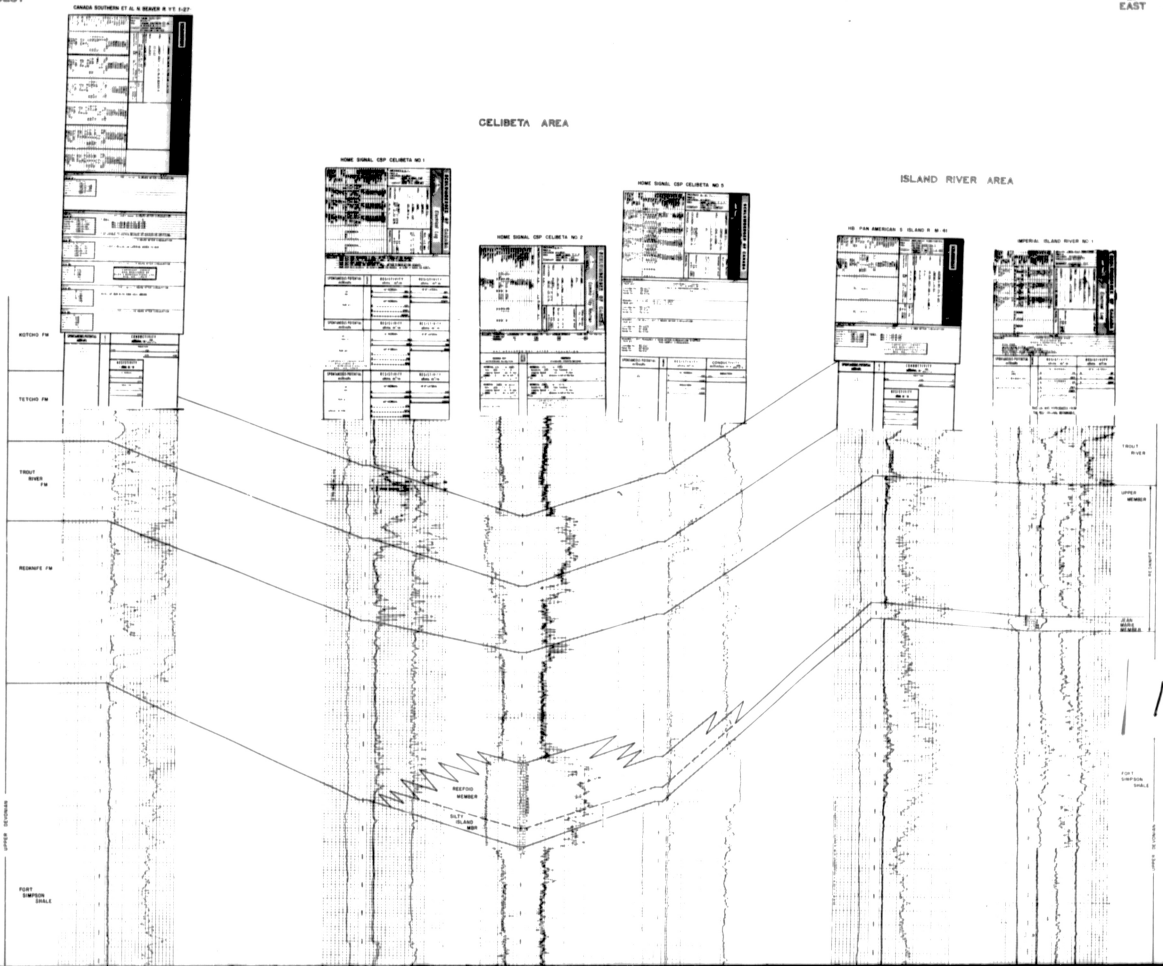
HOME SIGNAL CEP CELIBETA NO 3

ISLAND RIVER AREA

HD PAN AMERICAN S ISLAND R M-41

IMPERIAL ISLAND RIVER NO 1

D'
EAST



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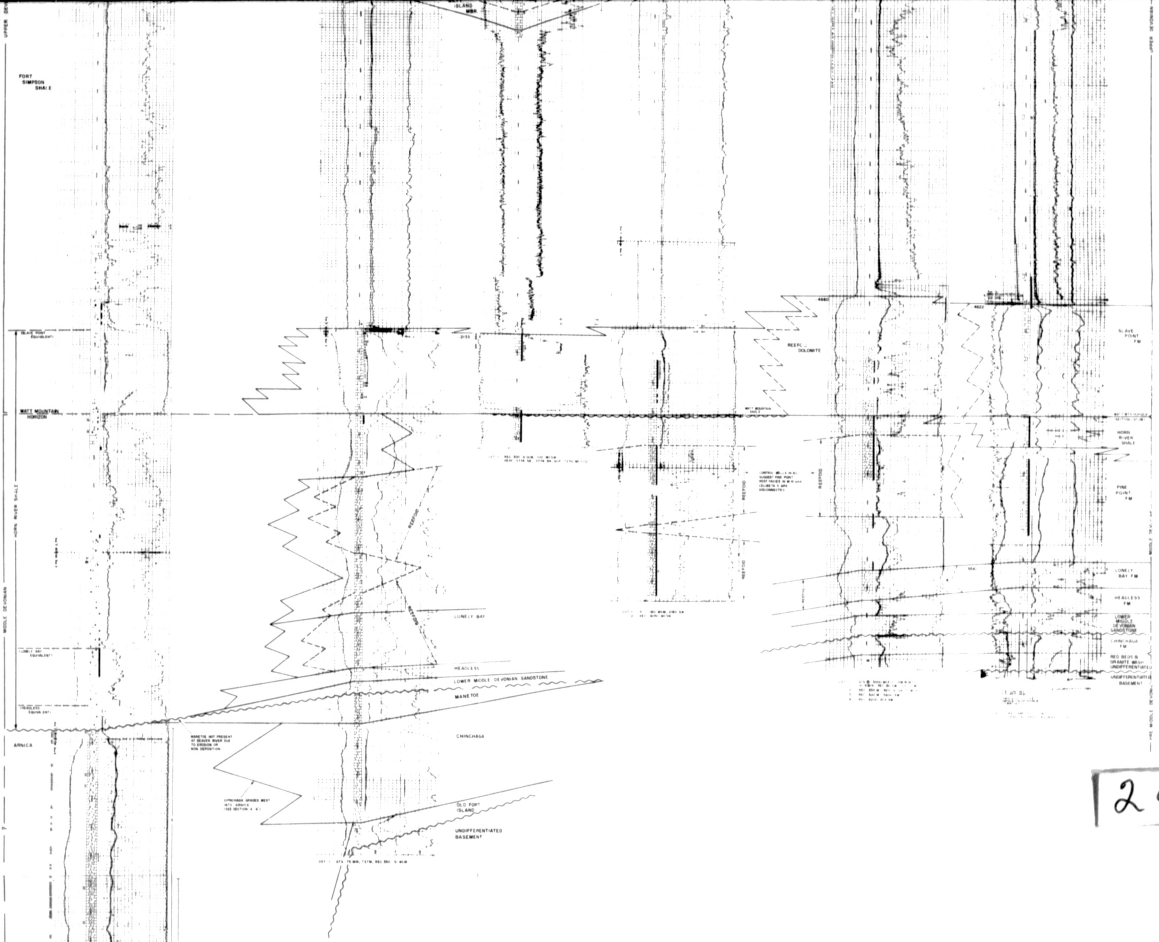
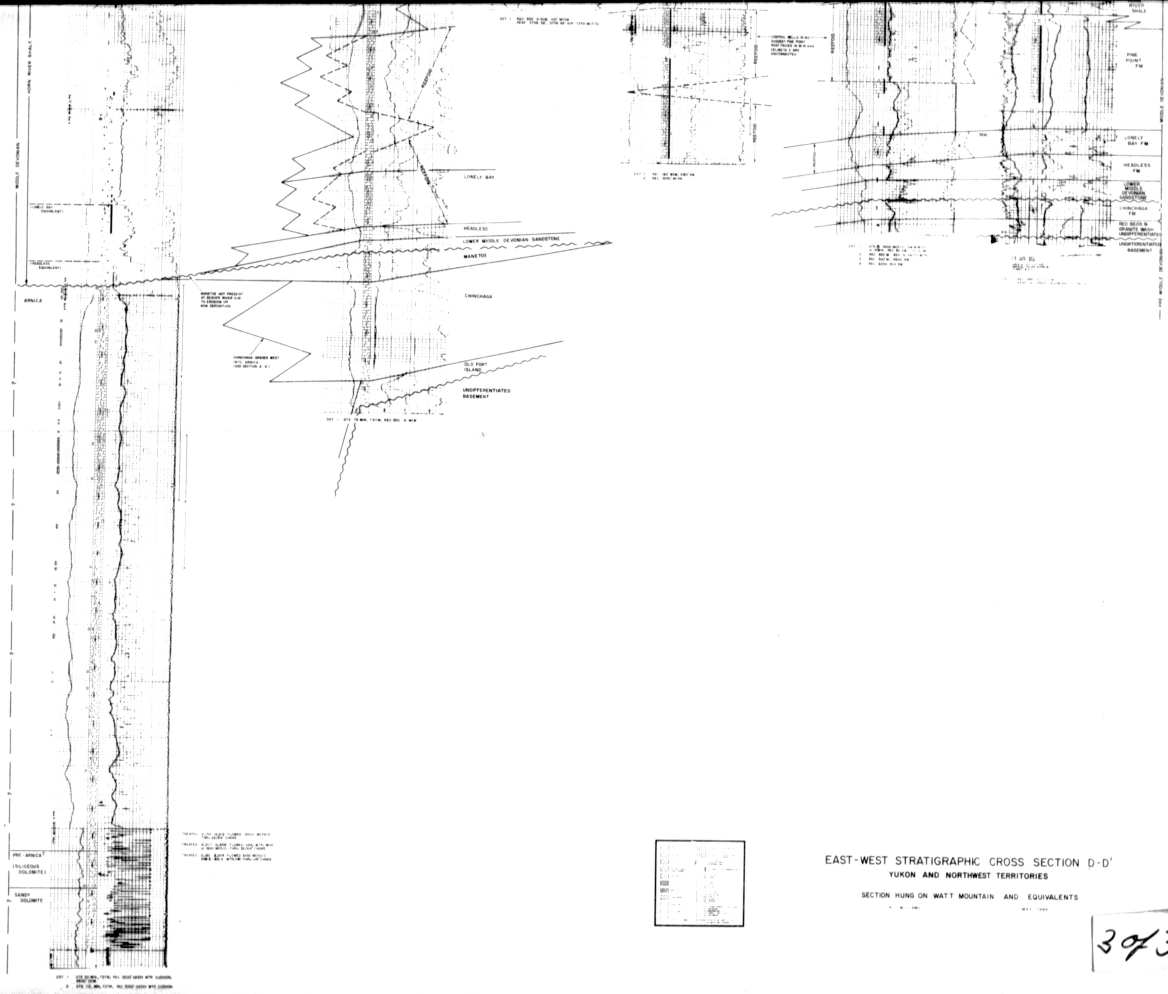

PORT
SIMPSON
SHALE
WATT MOUNTAIN
FORMATION
WORK
RIVER
SHALE
LONELY BAY
HEALEY
LOWER MIDDLE DEVONIAN SANDSTONE
MANETOE
ARNICA
CHINCHAGA
OLD FORT
ISLAND
UNDIFFERENTIATED
BASEMENT
REEF
DOLOMITE
SLAVE
POINT
FM
FINE
POINT
FM
LONELY
BAY FM
HEALEY
FM
UNDIFFERENTIATED
BASEMENT

2 of



EAST-WEST STRATIGRAPHIC CROSS SECTION D-D'

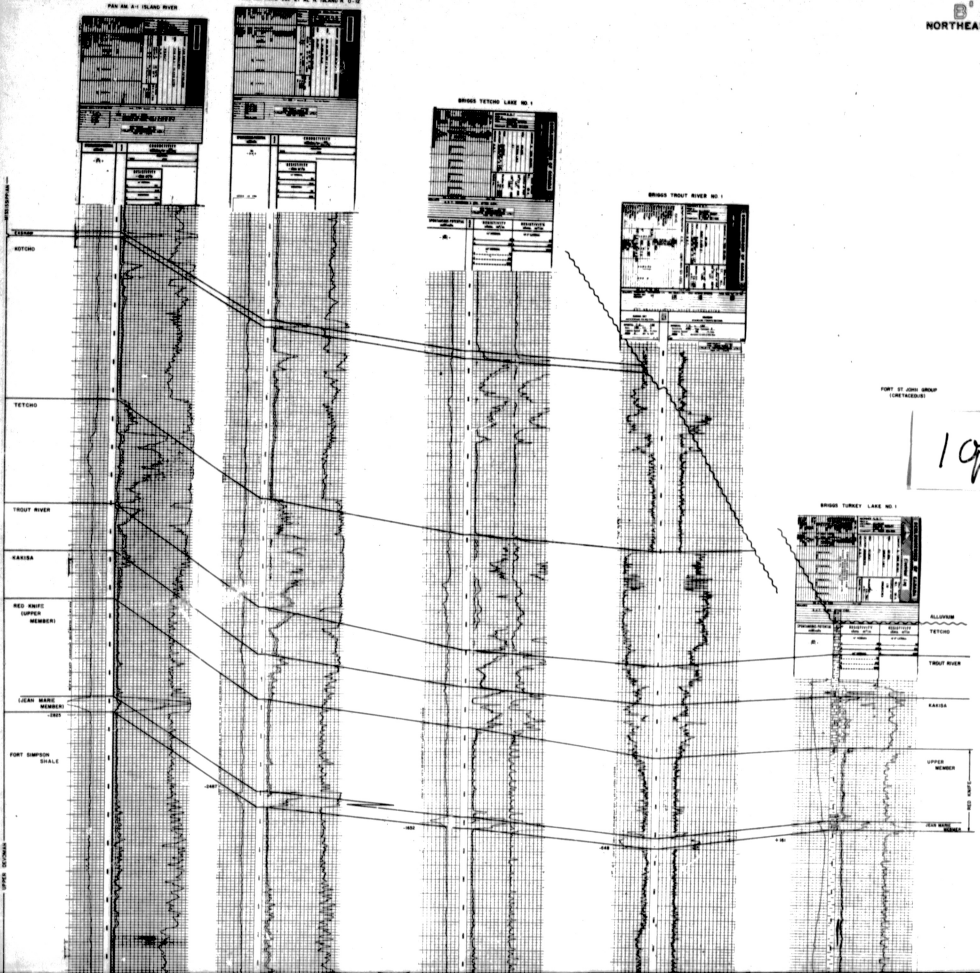
YUKON AND NORTHWEST TERRITORIES

SECTION HUNG ON WATT MOUNTAIN AND EQUIVALENTS

3073

B
SOUTHWEST

B'
NORTHEAST



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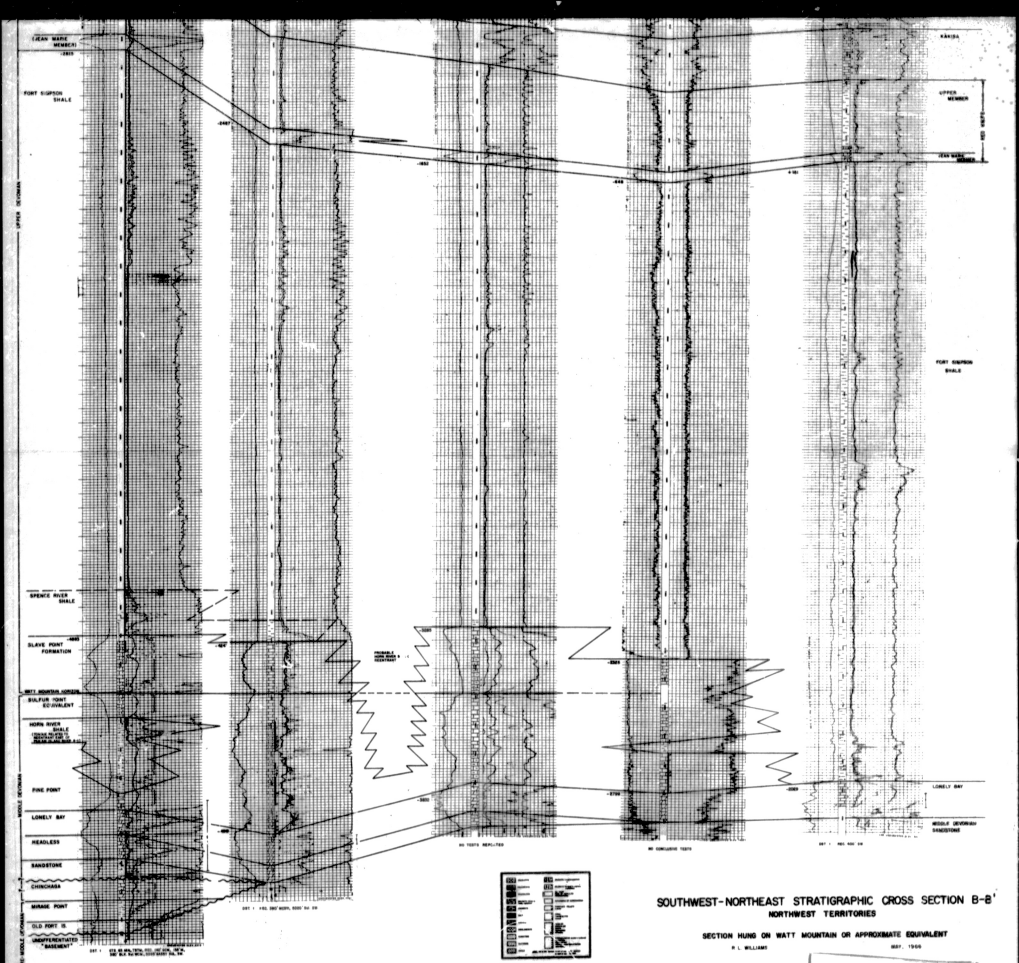


SOUTHWEST-NORTHEAST STRATIGRAPHIC CROSS SECTION B-B'

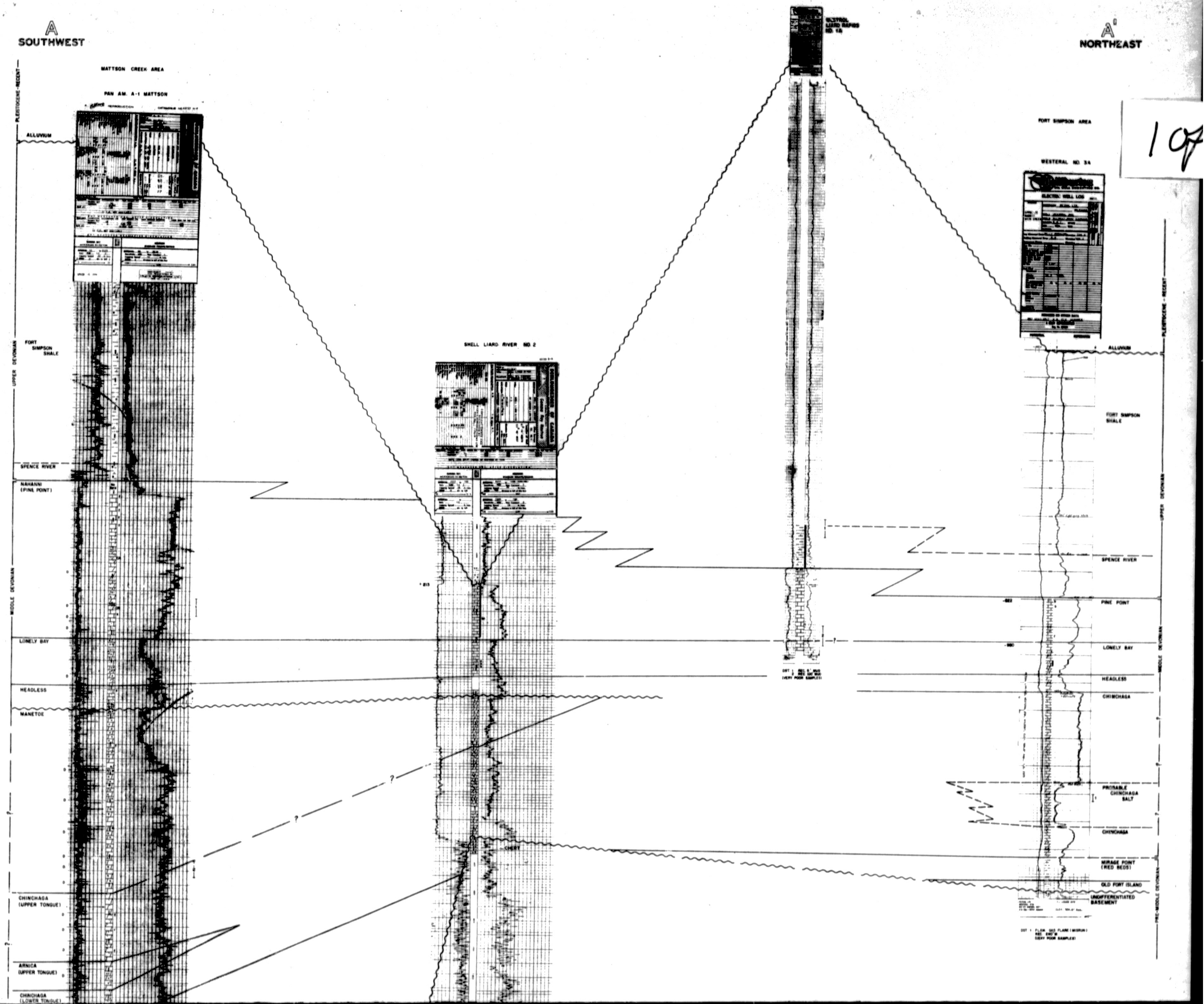
NORTHWEST TERRITORIES

SECTION HUNG ON WATT MOUNTAIN OR APPROXIMATE EQUIVALENT

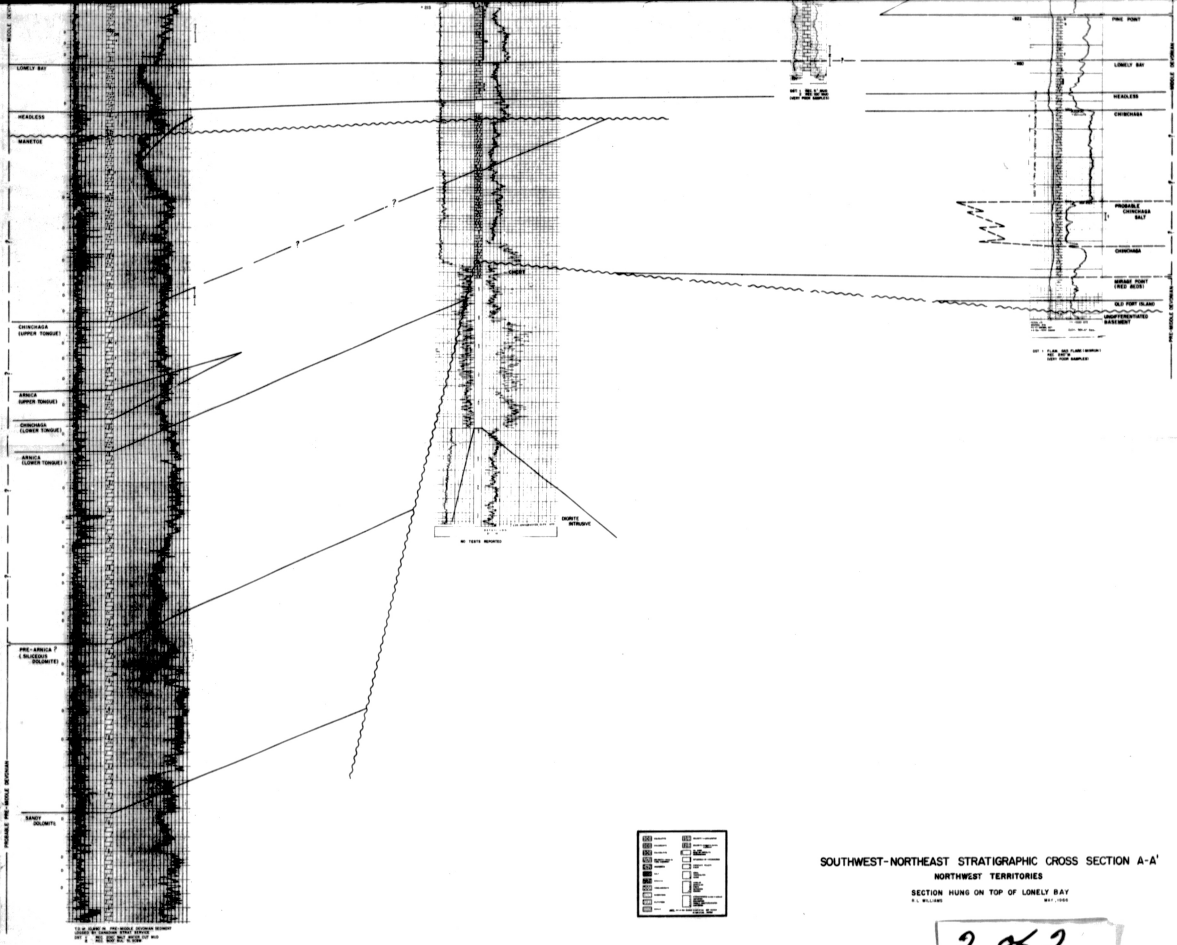
R. L. WILLIAMS

MAY, 1966

2 of 2



A
SOUTHWEST
A'
NORTHEAST
MATTSON CREEK AREA
PAN AM. A-1 MATTSON
SHELL LIARD RIVER NO. 2
FORT SIMPSON AREA
WESTERAL NO. 3A
PLEISTOCENE-RECENT
UPPER DEVONIAN
MIDDLE DEVONIAN
PRE-MIDDLE DEVONIAN
ALLUVIUM
FORT SIMPSON SHALE
SPENCE RIVER
NAHANNI (PINE POINT)
PINE POINT
LONELY BAY
HEADLESS
MANETOE
CHINCHAGA
CHERT
PROBABLE CHINCHAGA SALT
MIRAGE POINT (RED BEDS)
OLD FORT ISLAND
UNDIFFERENTIATED BASEMENT
CHINCHAGA (UPPER TONGUE)
ARNICA (UPPER TONGUE)
CHINCHAGA (LOWER TONGUE)



SOUTHWEST-NORTHEAST STRATIGRAPHIC CROSS SECTION A-A'

NORTHWEST TERRITORIES

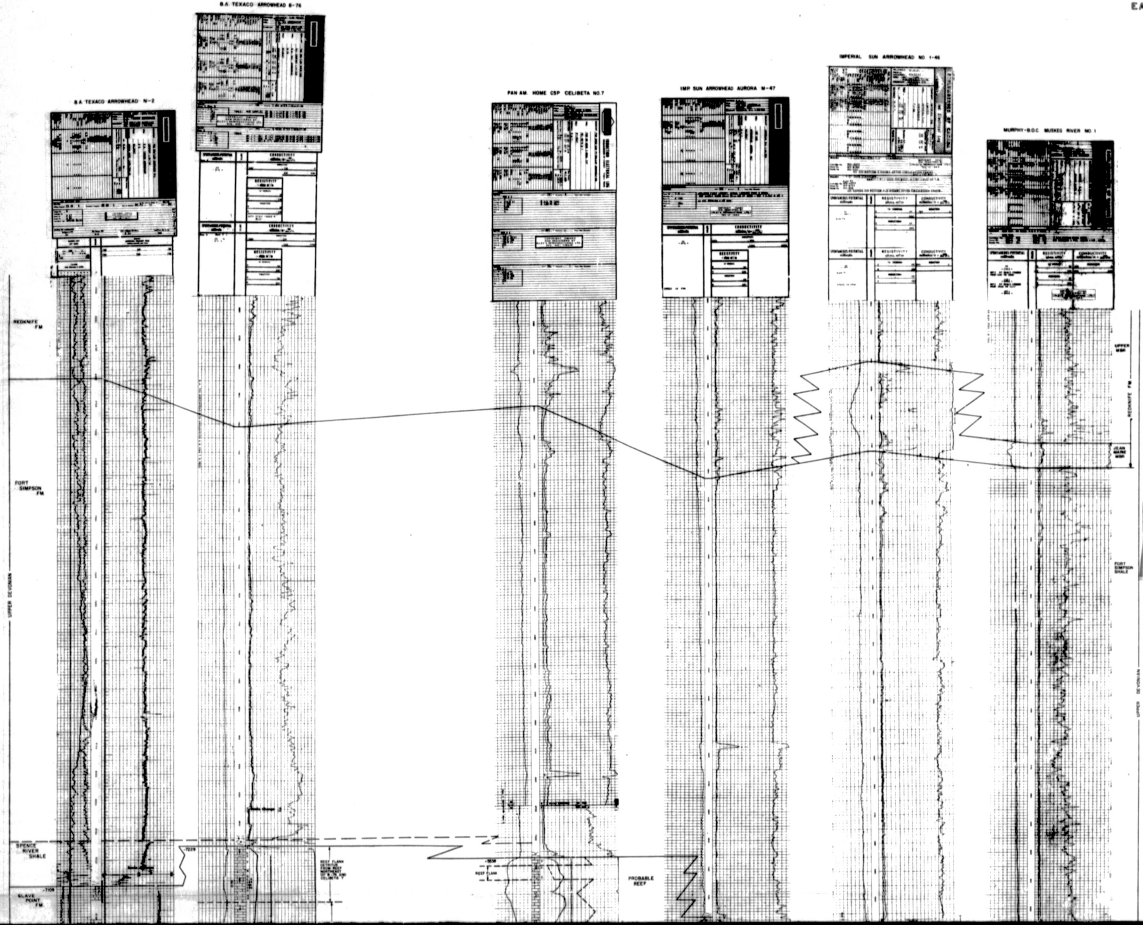
SECTION HUNG ON TOP OF LONELY BAY

R.L. WILLIAMS MAY, 1955

2 of 2

C
WEST

C'
EAST



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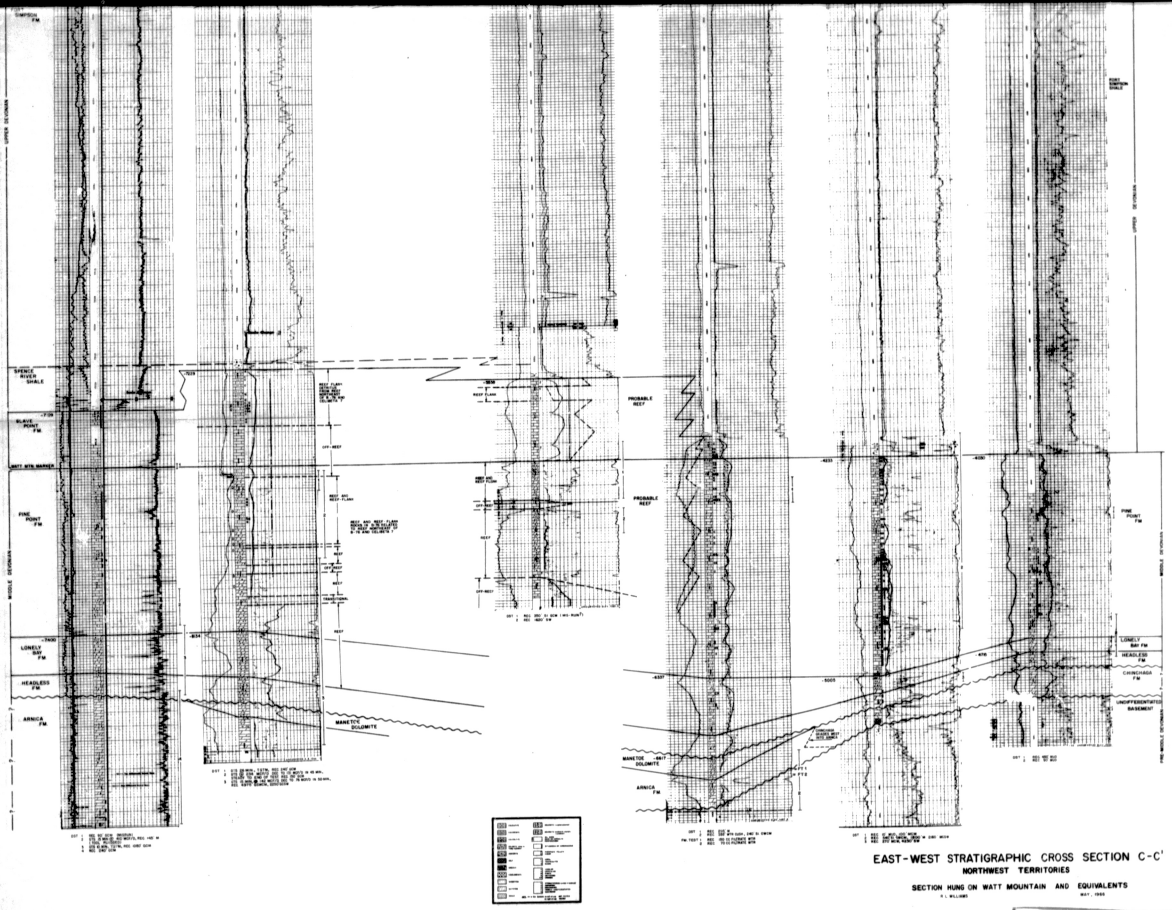


EAST-WEST STRATIGRAPHIC CROSS SECTION C-C'

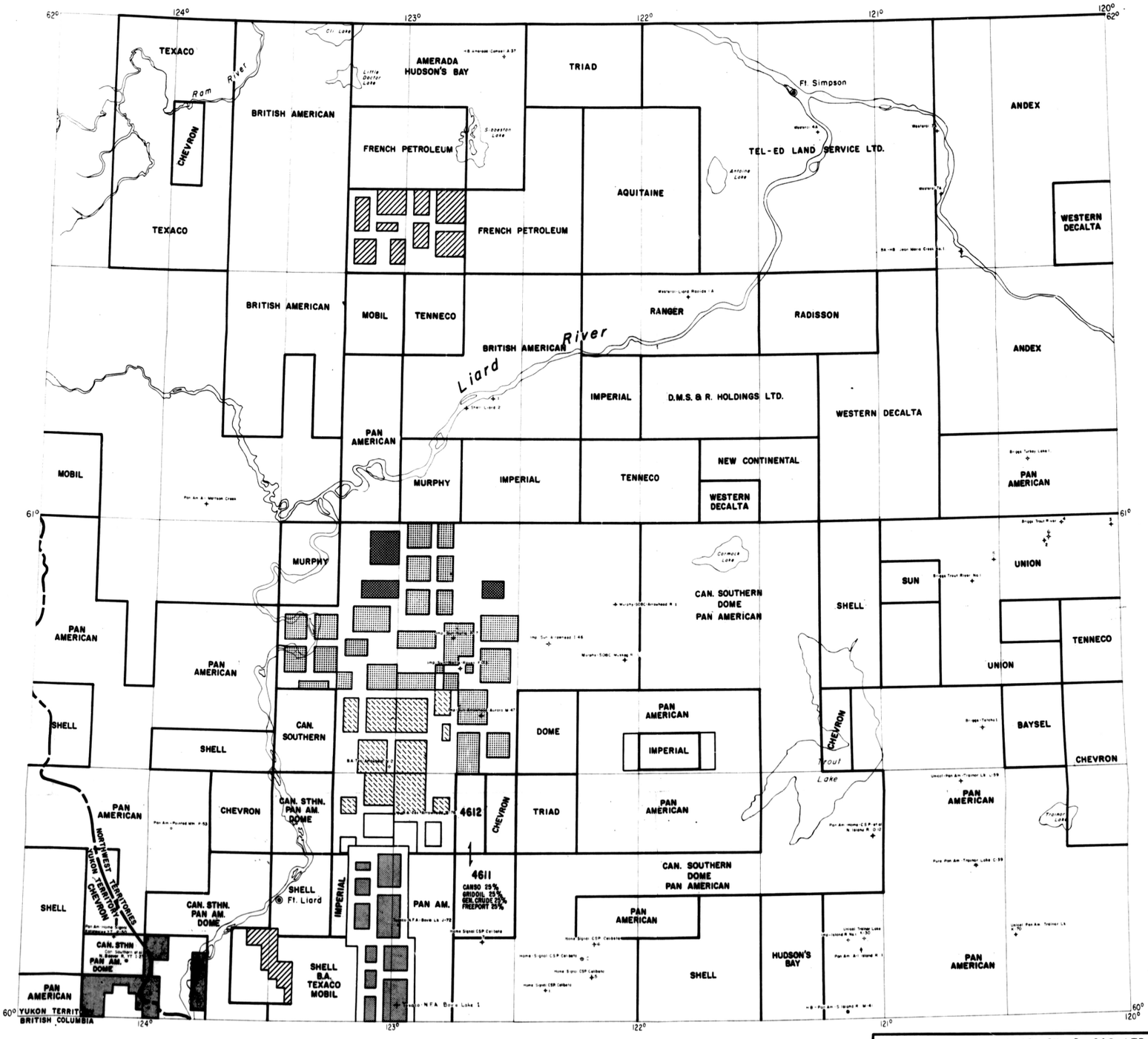
NORTHWEST TERRITORIES

SECTION HUNG ON WATT MOUNTAIN AND EQUIVALENTS

MAY, 1965

T. L. WILLIAMS

2 of 2



P. & N.G. LEASES

- IMPERIAL
- SHELL
- TEXACO
- B.A. & TEXACO
- SHELL-B.A.-TEXACO-MOBIL
- MURPHY & GREAT PLAINS

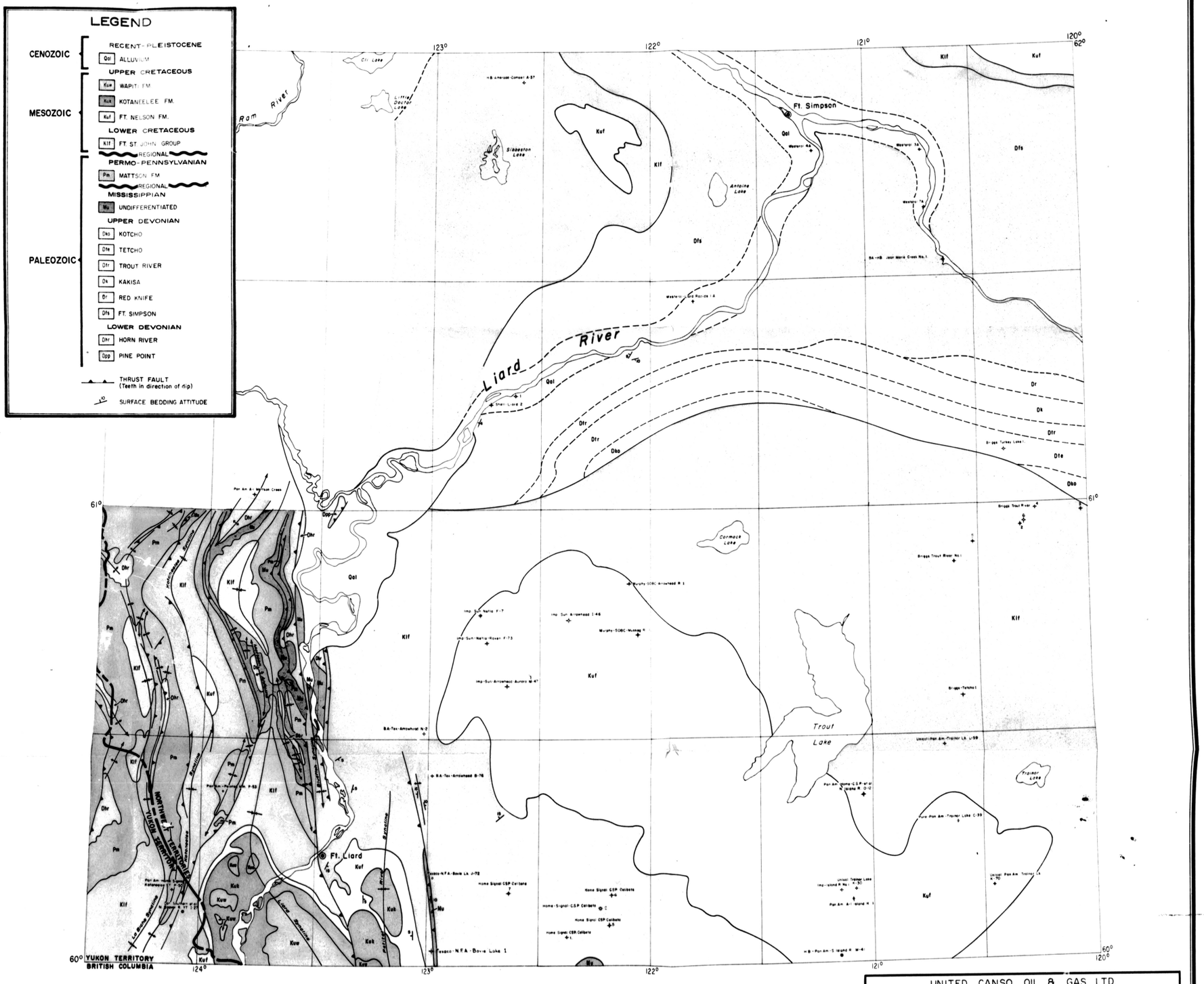
UNITED CANSO OIL & GAS LTD.

ARROWHEAD RIVER AREA NORTHWEST TERRITORIES

LAND MAP

DRAWN BY	GEOLOGY BY	SCALE	DATE
		1" = 8 MILES	MARCH - 1966
CHECKED BY	TRACED BY	FILE	REVISED

PLATE No. I



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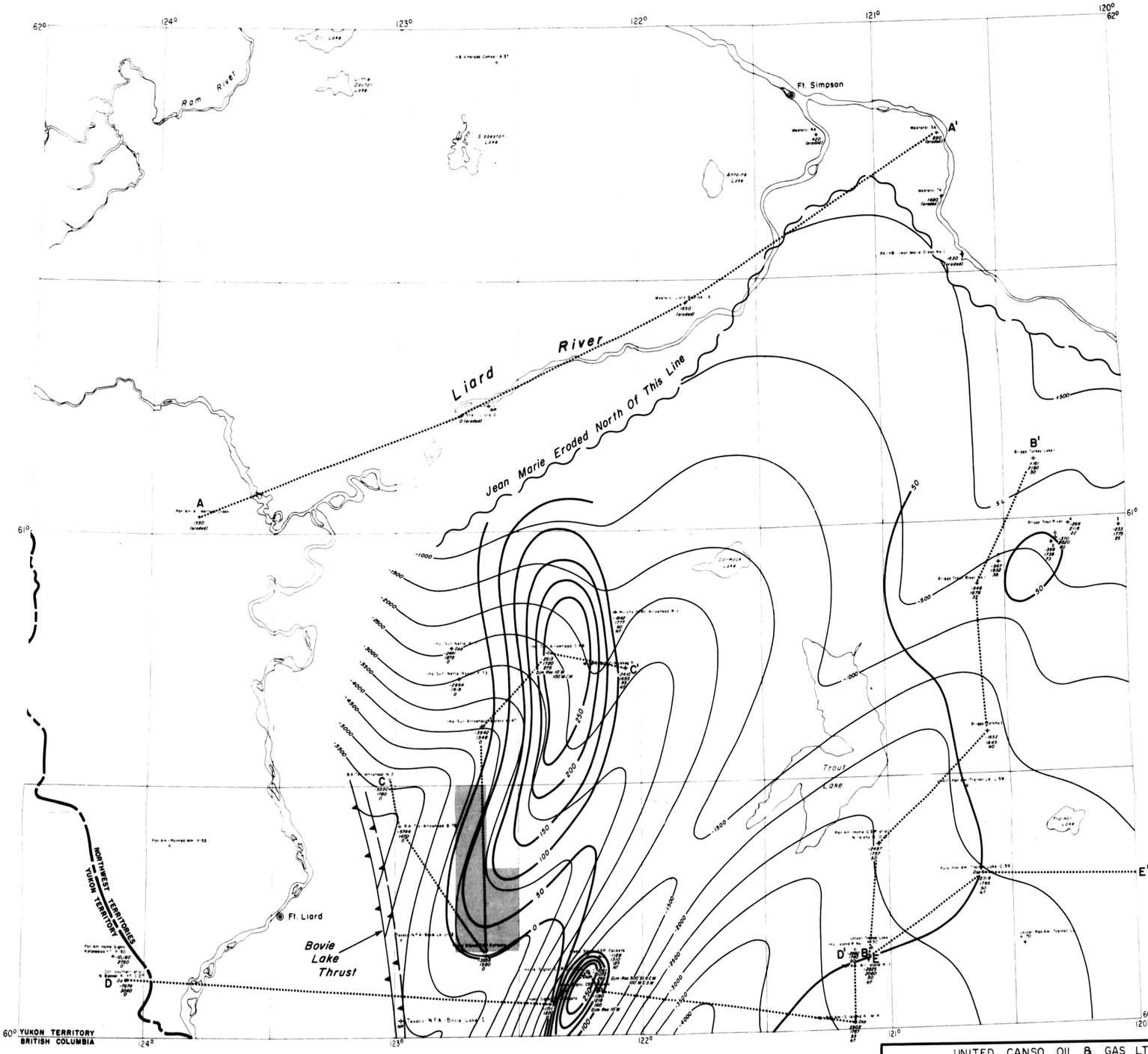
ARROWHEAD RIVER AREA NORTHWEST TERRITORIES

PRELIMINARY GEOLOGY

NOTE: MODIFIED AFTER DOUGLAS (1958), DOUGLAS & NORRIS (1959 & 1960), & STOTT (1960)

DRAWN BY	GEOLOGY BY	SCALE	DATE
	R.L. WILLIAMS	1" = 8 MILES	APRIL, 1966
CHECKED BY	TRACED BY	FILE	REVISED

PLATE No. 2



LEGEND

Datum on Fort Simpson shale
Thickness of Fort Simpson
Thickness of Jean Marie
All of Jean Marie & all or part of Ft. Simpson eroded

SYMBOLS

Dim	Jean Marie
Dfs	Fort Simpson
Dsp	Slave Point
Dpp	Pine Point
Da	Arrica
NP	Not Penetrated
NT	No Tests

A' Section Line

Thrust fault (teeth in direction of dip)

Surface trace

Approximate subsurface trace on top of Fort Simpson

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ARROWHEAD RIVER AREA NORTHWEST TERRITORIES

ISOPACHS OF UPPER DEVONIAN JEAN MARIE MEMBER

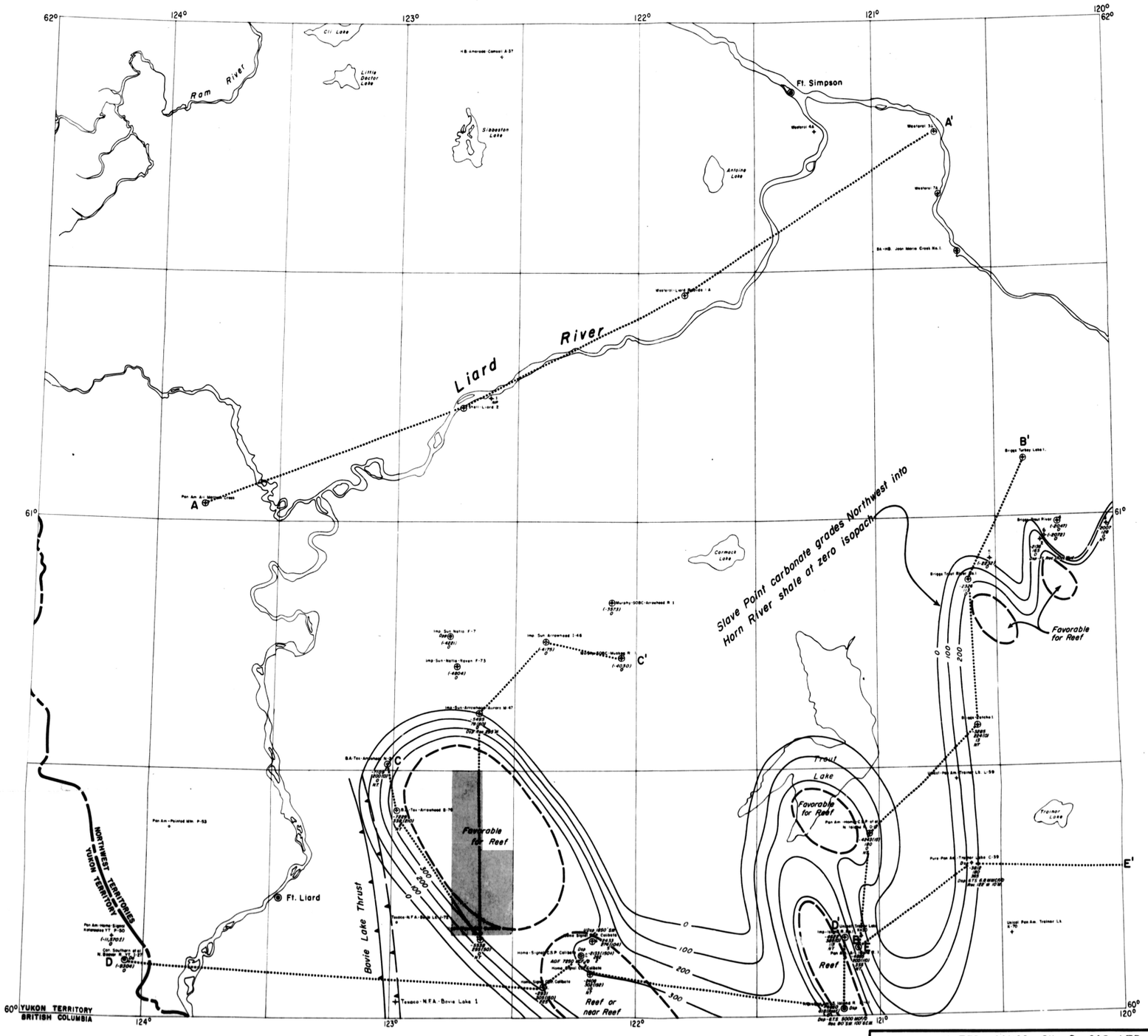
ISOPACH INTERVAL 50'

STRUCTURE CONTOURS ON TOP OF FT. SIMPSON FM.

CONTOUR INTERVAL 500'

DRAWN BY	GEOLOGY BY	SCALE	DATE
	R. L. WILLIAMS	1" = 8 MILES	MAY, 1966
CHECKED BY	TRACED BY	FILE	REVISED

PLATE No. 3



Dsp — Capable of producing or producing formation
Untagged well
Top of Spence River Shale where Slave Point is absent

Logged well
Top of Slave Point
Gross thickness of Slave Point (Net thickness of Slave Point fragmental and/or Reefoid Carbonate.)
Thickness of Horn River Shale and/or Watt Mountain Fm. (Includes Sulfur Point Limestone tongue South & Southeast of Trout Lake)

FORMATION SYMBOLS

Dsp	Slave Point (UDep-Upper)
Dhr	Horn River
Ds	Sulfur Point
Dpp	Pine Point
Da	Arnica

A' — Cross section line

Thrust fault (Teeth in direction of dip)
Surface trace
Approximate subsurface trace on Slave Point Fm.

Approximate outline of dolomitized Slave Point Reef or areas favorable for Reef.

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ARROWHEAD RIVER AREA NORTHWEST TERRITORIES

ISOPACHS OF LOWER UPPER DEVONIAN SLAVE POINT FORMATION

ISOPACH INTERVAL 100'

DRAWN BY	GEOLOGY BY	SCALE	DATE
	R.L. WILLIAMS	1" = 8 MILES	MAY, 1966
CHECKED BY	TRACED BY	FILE	REVISED

PLATE No. 4

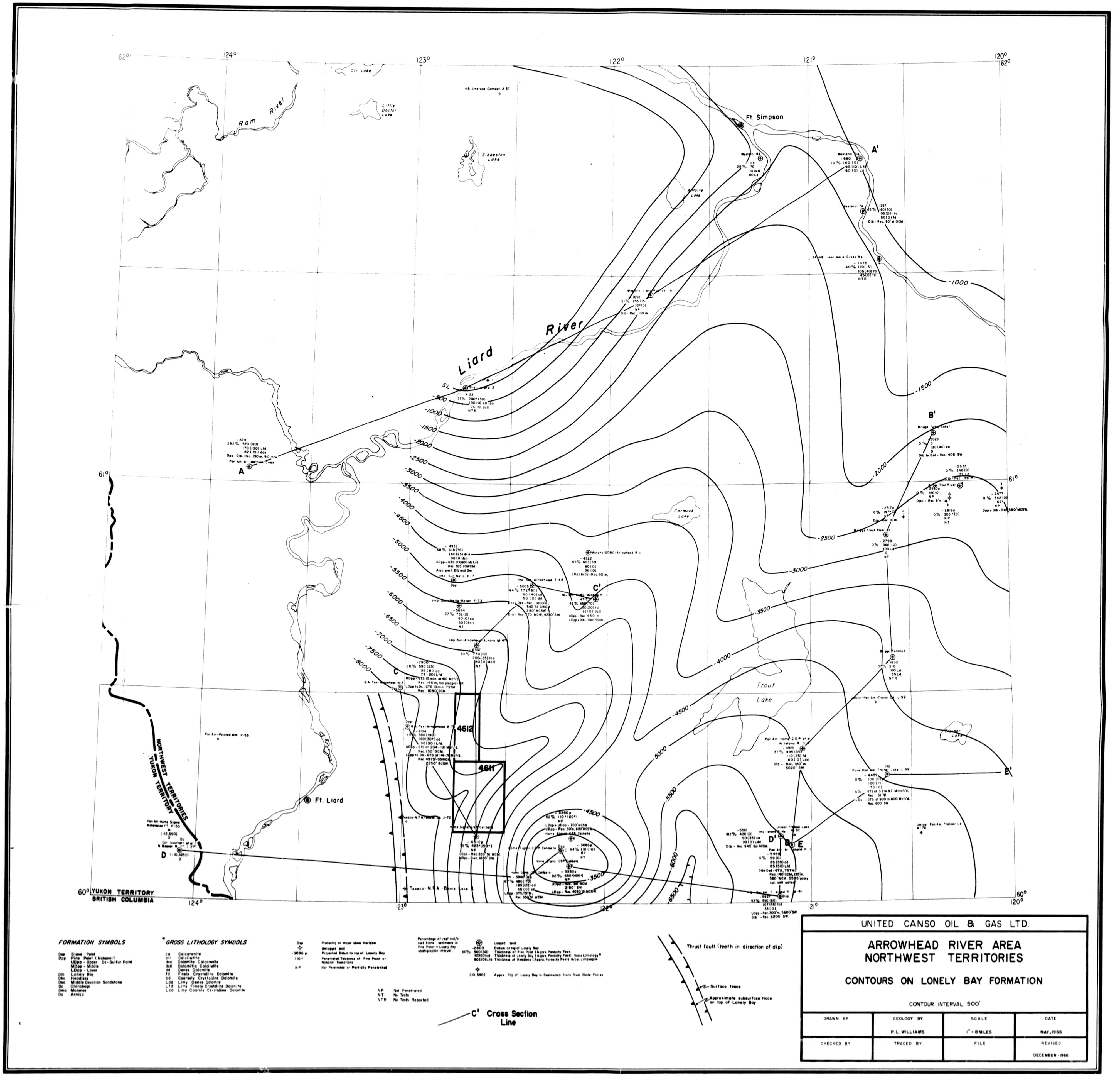
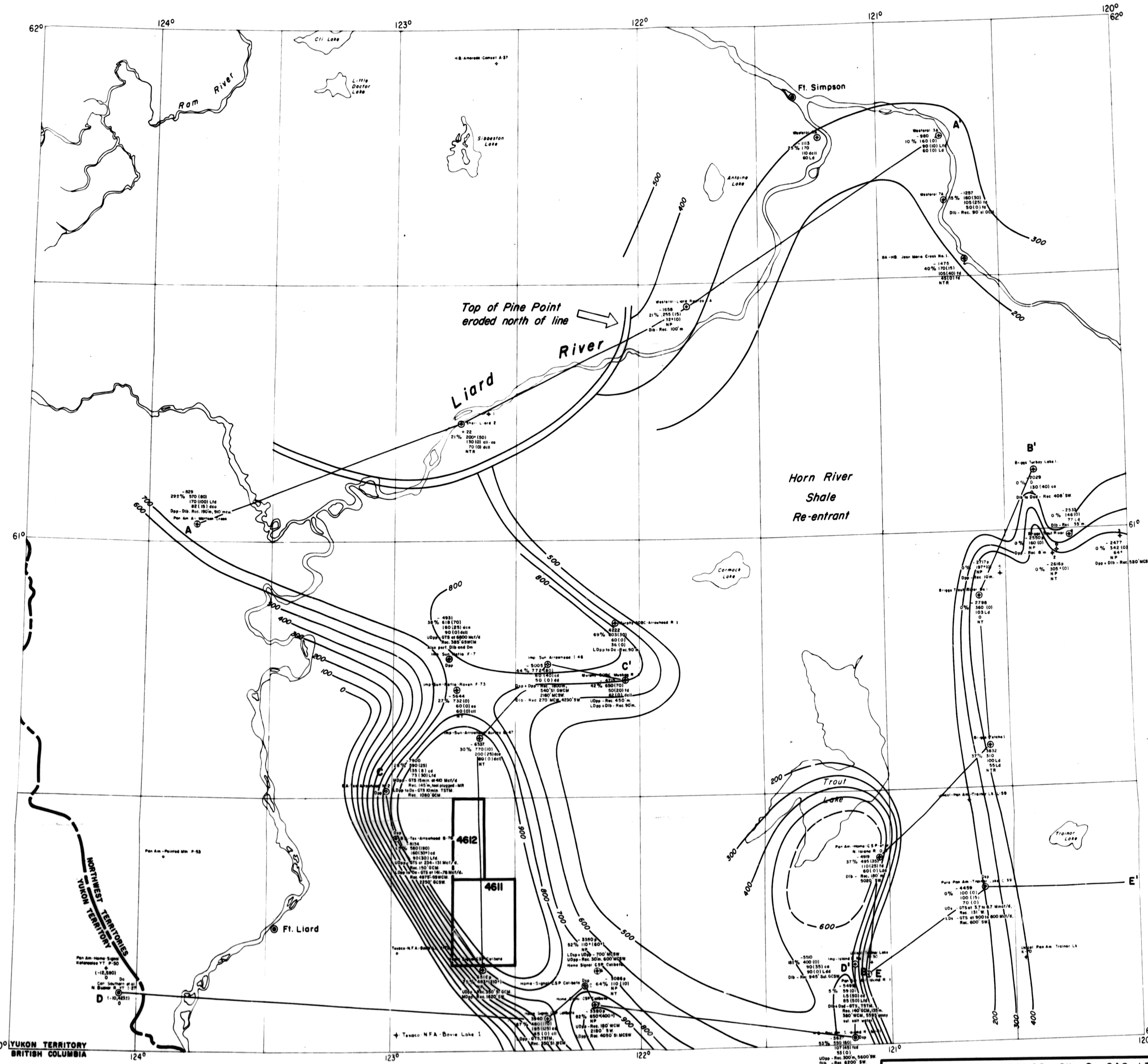

UNITED CANSO OIL & GAS LTD.
ARROWHEAD RIVER AREA
NORTHWEST TERRITORIES
CONTOURS ON LONELY BAY FORMATION
CONTOUR INTERVAL 500'
DRAWN BY
GEOLOGY BY
R.L. WILLIAMS
SCALE
1" = 8 MILES
DATE
MAY, 1966
CHECKED BY
TRACED BY
FILE
REVISED
DECEMBER - 1966
FORMATION SYMBOLS
Dsp Slave Point
Dpp Pine Point (Nahanni)
UDpp - Upper Ds - Sulfur Point
MDpp - Middle
LDpp - Lower
Dlb Lonely Bay
Dhs Headless
Dsd Middle Devonian Sandstone
Dc Chinchaga
Dma Manetoe
Da Arnica
*GROSS LITHOLOGY SYMBOLS
ca Calcarenite
cll Calcilutite
dca Dolomite Calcarenite
dcll Dolomitic Calcilutite
dd Dense Dolomite
fd Finely Crystalline Dolomite
cd Coarsely Crystalline Dolomite
Ldd Limy Dense Dolomite
Lfd Limy Finely Crystalline Dolomite
Lcd Limy Coarsly Crystalline Dolomite
Dsp Producing or major show horizon
Unlogged Well
-3086 p Projected Datum to top of Lonely Bay
110+ Penetrated Thickness of Pine Point or Nahanni Formations
NP Not Penetrated or Partially Penetrated
Percentage of reef and/or reef flank sediments in Pine Point + Lonely Bay stratigraphic interval.
Logged Well
-2800 Datum on top of Lonely Bay
60% 560 (30) Thickness of Pine Point (Apprx. Porosity Feet)
160(60)cd Thickness of Lonely Bay (Apprx. Porosity Feet) Gross Lithology*
90(20)Lfd Thickness of Headless (Apprx. Porosity Feet) Gross Lithology*
(10,590) Apprx. Top of Lonely Bay in Basinward Horn River Shale Facies
NP Not Penetrated
NT No Tests
NTR No Tests Reported
C' Cross Section Line
Thrust fault (teeth in direction of dip)
Surface trace
Approximate subsurface trace on top of Lonely Bay
Ft. Simpson
Liard River
Ram River
Sibbeston Lake
Little Doctor Lake
Carmack Lake
Trout Lake
Ft. Liard
NORTHWEST TERRITORIES
YUKON TERRITORY
BRITISH COLUMBIA
4612
4611

PLATE No. 5



FORMATION SYMBOLS

Dsp Slave Point
Dpp Pine Point (Nahanni)
UDpp - Upper Ds - Sulfur Point
MDpp - Middle
LDpp - Lower
Dlb Lonely Bay
Dhs Headless
Dsd Middle Devonian Sandstone
Dc Chinchaga
Dma Monetoe
Da Arnica

*** GROSS LITHOLOGY SYMBOLS**

ca Calcarenite
cll Calcilutite
dca Dolomite Calcarenite
dcll Dolomitic Calcilutite
dd Dense Dolomite
fd Finely Crystalline Dolomite
cd Coarsely Crystalline Dolomite
Ldd Limy Dense Dolomite
Lfd Limy Finely Crystalline Dolomite
Lcd Limy Coarsly Crystalline Dolomite

Dsp Producing or major show horizon
Unlogged Well
-3086 p Projected Datum to top of Lonely Bay
110+ Penetrated Thickness of Pine Point or Nahanni Formations
NP Not Penetrated or Partially Penetrated

Percentage of reef and/or reef flank sediments in Pine Point + Lonely Bay stratigraphic interval.

60% Logged Well
-2800 Datum on top of Lonely Bay
560 (30) Thickness of Pine Point (Apprx. Porosity Feet)
160(60)cd Thickness of Lonely Bay (Apprx. Porosity Feet) Gross Lithology*
90(20)Lfd Thickness of Headless (Apprx. Porosity Feet) Gross Lithology*

(10,590) Apprx Top of Lonely Bay in Basinward Horn River Shale Facies

NP Not Penetrated
NT No Tests
NTR No Tests Reported

C' Cross Section Line

UNITED CANSO OIL & GAS LTD.

ARROWHEAD RIVER AREA NORTHWEST TERRITORIES

ISOLITH OF COMBINED PINE POINT AND LONELY BAY CARBONATE THICKNESSES

CONTOUR INTERVAL 100'

DRAWN BY	GEOLOGY BY	SCALE	DATE
	R.L. WILLIAMS	1" = 8 MILES	MAY, 1966
CHECKED BY	TRACED BY	FILE	REVISED

PLATE No. 6