Exploration

Permit

No. 47

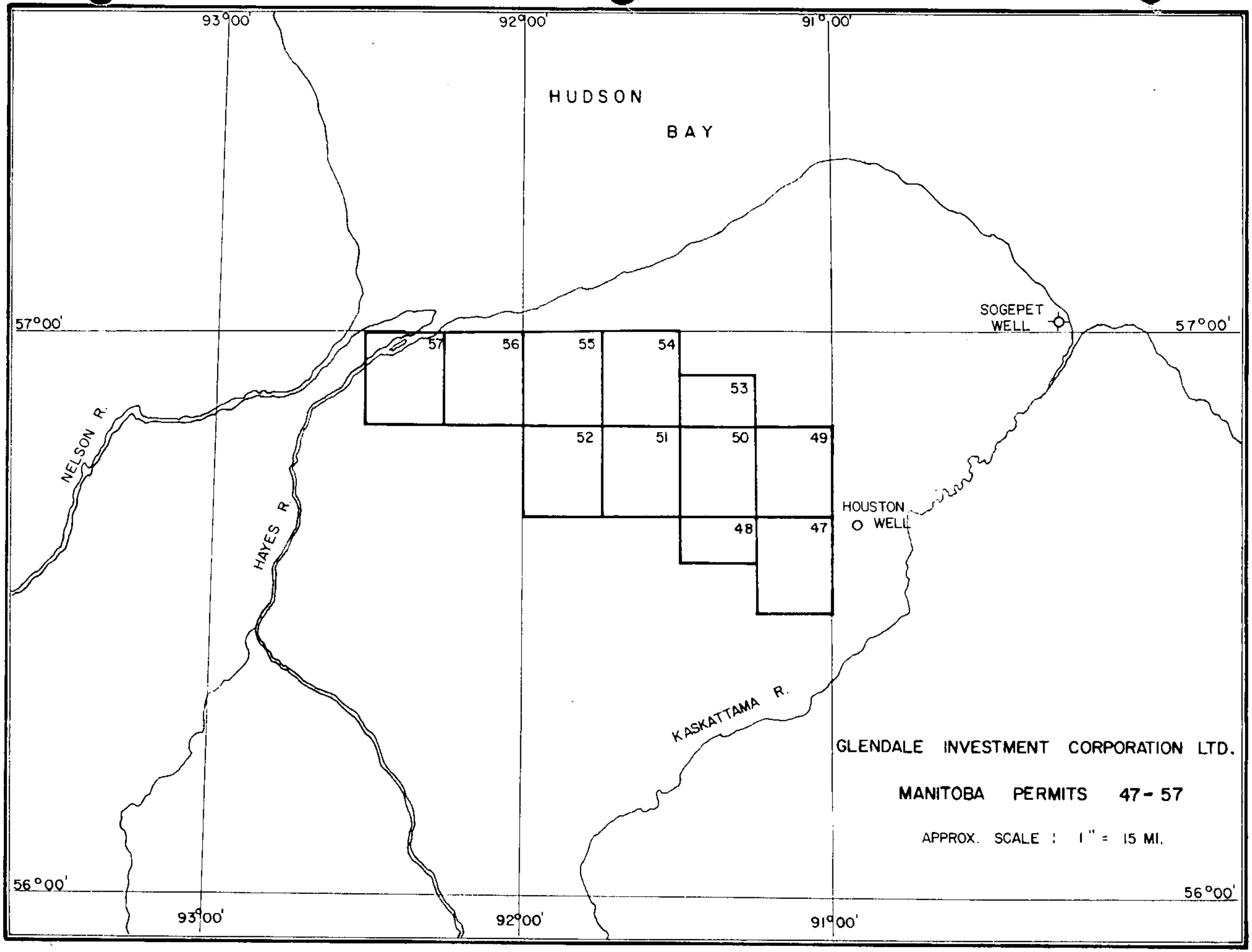
INTRODUCTION

This report discusses the results of a study of the General Geology, Stratigraphy and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 47, Manitoba. This permit is located between 56° 30' - 56° 40' latitude and 91° 00' - 91° 15' longitude. This is in the Hudson's Bay area of northeast Manitoba approximately 540 air miles north-northeast of Winnipeg. There are no roads within the area and the use of an aircraft is required to reach the area.

The stratigraphic discussion is based on information contained in published reports and on the limited data available from well control.

The Fracture Analysis Survey locates topographic highs and lows on the Basement surface. Areas of Basement "highs" are of great interest as it is felt that much reef growth (which is known to be present) is centered, or at least concentrated, over areas of Basement "highs".

Areas of Basement "lows" are of interest as Granite Wash sands tend to accumulate and attain considerable thickness in these "lows". Reefs and Granite Wash sands are probably the two principal reservoir horizons in this area.



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SOGEPET WELL
HOUSTON WELL
NELSON R.
HAYES R.
KASKATTAMA R.
GLENDALE INVESTMENT CORPORATION LTD.
MANITOBA PERMITS 47 - 57
APPROX. SCALE : 1" = 15 MI.

STRATIGRAPHY

The subject acreage, which is located one to 50 miles south of the Hudson Bay shoreline near York Factory in Manitoba, is primarily covered by muskeg with numerous small rivers, and streams present. Access to the area is provided by the Canadian National Railway line running into Port Nelson and also by ocean ships to the same point. Subsurface control will be provided by the Sogepet-Aquitane-Kaskattama # I well when it is released. It is located some 30 miles east of the northeast corner of the acreage. Recently Houston et al Comeault Sth Prov. # I, located at about 56° 40' and 90° 52' has been licenced. This location, which is some 5 miles east of the acreage, will provide additional valuable subsurface information about this area. Outcrop information is extremely scarce in this area with only some talus being noted near York Factory along the north side of the acreage and along the Kaskattama River, which lies along the south and east side of the acreage. The main outcrop data has to be projected into this area from sections found on the Severn River, which is 110 miles southeast

of the acreage. The Nelson River which is approximately 50 miles northwest of the acreage is another outcrop area. Ordovician rocks are exposed along Gods River, 30 miles south of the western portion of the area under discussion. Beds ranging in age from Upper Ordovician to Upper Silurian are expected to be present beneath the land under review.

ORDOVICIAN

BAD CACHE RAPIDS GROUP

PORTAGE CHUTE FORMATION

The type section of the Portage Chute formation is located on the Churchill River, 100 miles northwest of the acreage. Outcrops are also present on the Nelson River approximately 50 miles west of the area, as well as on the Sachigo and Severn Rivers which lie to the south. The formation was defined by Nelson as overlying peneplaned Pre-Cambrian rocks, and in turn being conformably overlain by the Surprise Creek formation. The Portage Chute formation, which is 75 feet thick at the type section, consists of a four foot basal quartz sandstone which is generally quite uniform, tight and calcareous. This sand is also

present at the other outcrop sections mentioned above. The sand grades upwards into grey to buff, weathering light grey, partially dolomitic, microcrystalline, laminated limestones. Skeletal debris is quite abundant. At the type section the limestone section is 71 feet thick. The thickness of the Portage Chute formation on the Nelson River is approximately 25 feet, while at the Severn River exposures it is only about ten feet thick. The formation dips easterly with an increasing rate of dip as one proceeds basinward along the outcrop sections. Fossils consist mainly of a variety of corals and molluscans with some trilobites present. The limestone takes on a nodular appearance in weathered sections.

SURPRISE CREEK FORMATION

The type section of the Surprise Creek formation was defined by Nelson as being located at Surprise Creek on the Churchill River. It is also present at the Nelson River section but not further south. Nelson considered the Surprise Creek formation as late Ordovician in age. The type section consists of 63 1/2 feet of thinly bedded, light yellowish grey, micro to cryptocrystalline limestone. It ranges from slightly dolomitic, to dolomitic, and contains some lenses of chert. The Surprise Creek formation is disting-

uished from the underlying Portage Chute formation by its lack of organic fragments, and by its smooth weathering characteristics, as opposed to the nodular weathering of the Portage Chute formation. The exposures at Nelson River are poor and not easily correlated with the type section, but, they appear to be lithologically similar to the type section. The thickness is a minimum 30 feet and the fauna is composed mainly of brachiopods. The combined thickness of the Surprise Creek formation and Portage Chute formation at the Selco-Pennycutaway # 1, drill hole, which lies about 17 miles west of the acreage, was 300 $\pm$, indicating a rapid thickening of this group in a basinward direction.

CHURCHILL RIVER GROUP

CAUTION CREEK FORMATION

The type section of the Caution Creek formation is also found on the Churchill River. The type section was defined by Nelson to consist of a basal 18 foot bed of mainly grey to yellowish grey weathering, cryptocrystalline, slightly dolomite limestone, containing shell fragments. This

is overlain by an 18 foot bed of grey to brown weathering, crypto to microcrystalline, slightly dolomitic limestone with little organic remains. This bed weathers into smooth layers, whereas, the lower bed weathers into uneven rubbly beds. The uppermost bed consists of six feet of grey, earthly weathering, micro to cryptocrystalline, slightly dolomitic limestone which has a nodular appearance on a weathered surface. The fauna consists of brachiopods, corals, and molluscans. The Caution Creek formation apparently does not outcrop on the Nelson River, but, it should be present in the subsurface of the subject acreage.

CHASM CREEK FORMATION

The Chasm Creek formation is found both along the Churchill and Nelson Rivers with the Churchill sections being the better one. The Chasm is also exposed at Gods River, some 30 miles south of the acreage. The Chasm is fairly similar to the underlying Caution Creek formation and is in conformable contact with it. At the type section it is about 180 feet thick. The basal 55 feet is a light yellowish grey to buff, microcrystalline, slightly dolomitic

limestone grading to an iron rich dolomite. It is very resistant and weathers to a yellow and orange massive bed. This unit is overlain by about 100 feet of light grey, crypto to microcrystalline, slightly dolomitic to dolomitic limestone. The unit contains abundant fine organic fragments. Overlying this unit is a 5 to 15 foot thick bed of light grey, cryptocrystalline, dolomitic limestone which contains no organic material but has fine intercalations of finely fragmented limestone beds. The uppermost unit is ten to 20 feet thick, and is a light grey weathering, very dolomitic, microcrystalline unit which is strongly fucoidal. On the Nelson River the Chasm Creek section is a minimum of 15 feet thick with the maximum thickness unknown. It is lithologically similar to the type section as is the 38 foot thick section found on Gods River. The Chasm Creek formation contains a fauna comprised of corals, cephalopods and some brachiopods.

RED HEAD RAPIDS FORMATION

The Red Head Rapids formation is the uppermost Ordovician sediment found in this region and tye type section is located on the Churchill River where it overlies the Churchill River Group. The formation is a minimum of 42

feet thick with the maximum thickness unknown. Nelson notes that this formation may be Silurian in age. The lower 25 feet consist of light yellow, microcrystalline dolomitic which weathers a distinctive orange color. No fossils are present in this bed. The upper 17 feet is composed of grey to yellowish grey, microcrystalline dolomite, partially vuggy, which weathers to a grey color. This bed is also quite unfossiliferous. The Red Head Rapids is not present in outcrop on the Nelson, Gods, or Severn Rivers, but, it should be present in the subsurface of the acreage.

SILURIAN

PORT NELSON FORMATION

The type section of the Port Nelson formation is located on the Nelson River some 47 miles west of the acreage under review. The section exposed is 24 feet thick and consists of interbeds of brecciated dolomite, dolomite, and shaly dolomite. The dolomite is generally a gray micro to cryptocrystalline to occasionally granular rock with minor porosity. It contains a coral fauna and

is placed in the Middle Silurian. In the James Bay area a drill hole encountered 110+ feet of this formation. This unit should be found at subcrop under the southwestern portion of the acreage.

SEVERN RIVER FORMATION

The type section of this formation is found on the Severn River some 110 miles southeast of the acreage. The minimum thickness at the type section is 42 feet with the maximum unknown. The section consists of a basal 13 foot light grey, micro to cryptocrystalline limestone with rare vuggy porosity, and a suggestion of algal material. The middle unit consists of 4 feet of light yellowish grey, to orange buff, micro to finely crystalline algal limestone with good vuggy porosity. The upper unit is a 25 foot thick bed of cream to buff, partly microcrystalline to finely crystalline, chalky and partly organic limestone. Fine to coarse organic debris is present as well as beds of oolitic material. The Severn River formation appears to be present near Churchill in similar facies plus the notable fact that it has a strong bituminous odour from a fresh break in this area. This formation should also be present at subcrop under the southwest portion of the acreage.

EKWAN RIVER FORMATION

The type section of this formation is on the Ekwan River, which is in the James Bay area and lies some 350 miles southeast of the area under consideration. The section is from 73 to 88 feet thick and consists of grey, fine grained, partially cherty limestone containing corals and stromatoporoids. The section on Severn River is a minmum 37 feet thick with the maximum unknown. The basal 20 feet is composed of light medium brown, microcrystalline limestone with fine to coarse fossil fragments, some chert nodules and some oolitic material. The fossils consist of stromatoporoids, corals, brachiopods and cephalopods. Some poor intercrystalline and vuggy porosity is present. The middle 11 feet consists of yellowish brown, microcrystalline partially dolomitic, chalky limestone with some thin fragmental beds and rare brachiopods. The upper 6 feet is a light greyish brown, to creamy, microcrystalline limestone which is very highly and coarsely fragmental. The top section contains poor to good porosity. The Ekwan River formation is also exposed along the shore of Hudson Bay from the Mouth of Owl River to a point some 20 miles south of Cape Churchill. The Ekwan should be found to

subcrop along the western and central position of the subject acreage.

ATTAWAPISKAT FORMATION

The type section is located on the Attawapiskat River which lies some 40 miles south of the Ekwan River type section in the James Bay area. The formation outcrops on the Ekwan River, Severn River and along the tidal flats south from Cape Churchill.

The Ekwan River outcrop section consists of 54 feet of fine grained, thin bedded, coral reef limestone. Nelson has described a reefal and possible off reef facies for the Attawapiskat formation in general. The reef facies has a minimum thickness of 25 feet and is a cream, to orange cream, to buff, microcrystalline, fragmental limestone with corals and stromatoporoids being common. Porosity grades from tight to excellent and is vuggy. Nelson feels that some of the well bedded reefs are suggestive of biostromes, while other oval, domal reefs are believed to be bioherms. He noted a gassy odour at one location.

The off-reef facies is a minimum of 16 feet thick with uniform beds of cream, to partly yellowish cream, to grey microcrystalline limestone. There are abundant coarse granular, bioclastic beds which have excellent intergranular porosity which could be post reef deposits. The Attawapiskat outcrops south of Cape Churchill range in thickness from 25 to 50 feet in thickness, with both facies present and they are seen to grade laterally from one to the other. This formation should be at subcrop through the central portion of the acreage.

KENOGAMI RIVER FORMATION

The Kenogami River formation which has only been found in outcrop, in the James Bay represents the youngest Silurian found in the Hudson Bay Basin. The formation consists of an alternating series of shale, siltstone, sandstone, dolomite, silty dolomite, shaly limestone, and limestone. The colours mainly range from buff to grey, but, reds and greens are the colours of the clastics. The outcrop section has a minimum thickness of 300 feet while a well drilled on Puskwuine Point in James Bay had a thickness of 862 feet. The Kenogami River formation is

expected to subcrop along the eastern half of the acreage under review.

DEVONIAN

Rocks of Devonian age are not expected to be present under the area covered by the permit, however, they should be present at subcrop east of the acreage, at and near the Sogepet-Aquitaine-Kaskattama # 1 well where total depth was reached at 2,941 feet in granite.

CRETACEOUS

Rocks of Cretaceous age are know only in the James Bay area and are not expected to be present under the permits.

FRACTURE ANALYSIS

This section of the report discusses the results of a Detailed Fracture Analysis Survey carried out on the area under discussion. An aerial mosaic (scale 1.5 inches equals approximately 1 mile) made from Dominion Government aerial photographs accompanies this report. These same photographs were examined stereoscopically and the fractures plotted on the individual photographs, then transferred to the mosaic for analysis.

The theory that the earth's crust is abundantly and methodically fractured is the basic premise on which is built the exploration technique known as Fracture Analysis. A Fracture is defined as"...generally abundant, natural lineation discernible on aerial photographs".

Fracturing is largely caused by external stresses on the surface. The most important are:

(a) earth tides

(b) radial acceleration of the earth along its radius vector.

(c) a gradual decrease of the
earth's rate of rotation.

As stated above, the earth is systematically fractured and the fracture system would approach symmetry if the crust were homogeneous. It is considered that irregularities are caused by regional heterogeneous conditions within the earth's crust. Local departures from the norm are caused by structural or stratigraphic anomalies.

The term "photogeophysics" was introduced by Blanchet (1956) and deals with mapping, analysis and interpretation of fracture traces as recorded on aerial photographs. In a more general way "photogeophysics" can be defined as the methodical statistical analysis of linear features seen on aerial photographs and this system is applied by any method recording all observable lineations, or the totality of a certain type of linear feature, and the statistical presentation of the data on contoured intensity maps of dry plotting the fractures directly on the mosaic.

In this report a megafracture is longer than one mile and a microfracture is shorter than one mile.

GENERAL STATEMENT

ORIGIN OF FRACTURES

Fracturing is largely caused by external stresses on the earth, although internal stresses may play some minor roll. The most important of these external forces are the diurnal earth tides due to the gravitational effects of the sun and moon; the change in radial acceleration of the earth along its radius vector and the gradual decrease in the earth's rate of rotation. The endless rhythemic action of these earth tides is probably the principal cause of the systematic fracture system seen over most of the world, even though the amplitude of these tides is only 9-13 inches. The fractures are most likely generated by the process of fatigue as the end result of these stresses which are repeated regularly over millions and millions of years. Metals fatigue in the same manner when subjected to continual vibration.

In general the initiating forces which generate fractures must have continued for a very long time and

the process involved are continuous and are probably active at the present time. Furthermore, Mollard (1957) states, "The mechanism required to reflect lineaments to ground surface must be reasonably simple, for simple patterns are produced on diverse topography and in diverse types and depths of surficial deposits that overlie different kinds of relatively flat-lying sedimentary rocks of varying thickness. The mechanism producing the lineament pattern must persist over extensive and widespread belts of the earth's outer shell; that is today, the engendering mechanism in fact be world wide".

External forces such as earth tides obviously fit these parameters. Some internal forces may also apply such as the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

In general it can be said that fracture patterns are caused by either internal forces or external forces.

If the forces are internal the result would be different orientation of the fracture systems in areas of similar tectonic history but different position. If the forces are external the orientation of the fracture arrangement should have world wide similarity. However, stable areas such as the masses of the continents may develop fracture patterns due to external forces and tectonically active areas may develop their own pattern due to internal forces.

If joints form early in the history of a sediment then systematic joints must be successively younger upwards through the section and the joint pattern is imposed on each new layer of sediments when they have become consolidated enough to fracture. This upward propagation is caused by the fatigue caused by stress, which in turn is caused by diurnal earth tides.

EXPRESSION OF FRACTURE

Fractures have been observed in aerial photographs from every climate and on every continent in the world. They are expressed as topographic relief, vegetation

differences and soil tonal differences.

TOPOGRAPHIC RELIEF LINEAMENTS

A common type are relief lineaments which can be manifested by a change (usually abrupt) of topographic elevation on either side of a relatively straight line. They may also be expressed as straight valleys or hills or by straight streams where the stream course is controlled by a fracture zone.

VEGETAL LINEAMENTS

Vegetal lineaments are the most common in the parkland and muskeg areas of western Canada and many excellent examples of fractures can be seen on almost any aerial photograph of northern Saskatchewan, Alberta or British Columbia. Straight lines of both deciduous and evergreen trees as well as scrub growth are universally visible. However, the most common vegetal lineament seen by this writer is a straight "edge" to a clump of trees or bushes. In many cases these fractures control the size and

shape of cultivated fields. Excellent examples of this latter expression of fractures are present in the western part of the Peace River district.

SOIL TONAL LINEAMENTS

These reflect differentiation in soil moisture and general ground water conditions. These are common in the southern parts of Alberta and Saskatchewan, especially near large rivers.

Surface investigations have shown that fractures are associated with bedrock joints; however, in glaciated areas such as western Canada, the photoanalyst must take care to establish the direction of ice flow over an area before he begins to statistically plot and analyse the fractures. Most areas in western Canada show an abundance of grooves and flutes caused by the glacier and these must not be mistaken for fracture traces caused by subsurface structural conditions. In parts of the Lloydminster area of eastern Alberta the glacial scars are so deeply impressed on the surface that fracture analysis is at best difficult and

often impossible.

INTERPRETATION OF FRACTURE DATA

The object of Fracture Analysis (Photogeophysics) is to locate shallow to deep-seated structural and stratigraphic anomalies. The actual count of fractures per unit area is made and values are contoured on a "Fracture Intensity Map". In areas of known reefs the fracture intensity is 2-3 times greater on the flanks of the reef than directly above the reef.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general the two systems are at approximate right angles to each other.

Because of certain inherent limiting factors, Structure Incidence Surveys have a lower order of reliability than Detailed Fracture Analysis Surveys. To some extent at least, surface conditions affect the fracture count. In areas

covered by lakes, sloughs and rivers, the fracture count is zero. Cultivated areas generally yield a lower count than adjacent virgin territory. Consequently, a difference or contrast in fracture count (F/I) between two points may be in part due to structure, but, also due in part to different surface conditions. To some extent, this can be compensated for by applying appropriate weightings to the observed counts, but over or under corrections may result.

Nevertheless, in spite of these sources or error, it has been demonstrated in (plains) areas where abundant subsurface control is available, that the incidence of fracturing is considerably above normal in the surrounding area immediately out from the steepest part of the flanks of the structure. This is in contrast with a low or normal incidence over the crestal area, and also to a normal incidence off structure.

FRACTURE ANALYSIS OF PERMIT NO. 47

The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permit. The Permit is located in the muskeg area south of Hudson's Bay and is hundreds of miles from the closest settlement.

The sedimentary section is probably about 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There is one area where the fracture intensity is greater than normal and there is one area where the fracture intensity is less than normal. The high intensity areas are shown in red and the low intensity areas are shown in green. The average length of the fractures is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to mention the glacial problem in this area.

Reference to the mosaic will show that the area is moderately scarred with glacial grooves and striations and that the direction of ice flow was about north 30 degrees east. Some of these grooves are so deeply impressed on the surface that they control the shape of the lakes and of tree growth in the area. In any area such as this the photoanalyst is faced with the difficult problem of eliminating the glacial scars from the fracture pattern without creating false anomalies. The removal of all fractures from a 10 - 12 degree arc in any area will create fracture anomalies and it requires delicate weighting of the whole pattern to adjust for these effects.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general, the two systems are at approximate right angles to each other. Within Petroleum & Natural Gas Permit No. 47, the statistical mean direction of the axial system is north 40 degrees west and the statistical mean direction of the shear system is north 30 degrees east. A third minor system, here termed the sub-axial system, trends nearly north-south.

No regional fractures of great length can be seen and as these are conceded to originate within the Basement, it is assumed that all fractures plotted on the mosaic originate within the sedimentary section. Furthermore, as the fractures are short for this area it is very likely that they originate in the upper two-thirds of the sedimentary section. As the surface of the Permit is relatively flat-lying no azimuth correction is necessary for this study. It has been demonstrated that the low incidence anomalies on a mosaic are considerably larger than the subsurface feature which causes them. Because the high incidence area on Permit No. 47 occurs at the edge of the mosaic it is difficult to estimate the size of the causative feature.

There is one area on the mosaic where the fractures are less intense than the surrounding area. Some fractures are always present within these areas but they usually have a lower incidence than the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the in the next section of this report.

STRUCTURE

Petroleum and Natural Gas Permit No. 47 is located on the coastal plain on the south shore of Hudson's Bay 70 miles north of the edge of the Pre-Cambrian Shield.

Structural features which could be present and which could cause the low incidence anomalies mentioned in this report are discussed in order of probability.

(1) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No. 47 is thought to be much the same as it is today along the north edge of the Shield. Low rounded hills separated by gentle to abrupt valleys are seen on the Shield and these features are undoubtedly present under the subject Permit. The effect of this Basement relief on the overlying sedimentary rocks is often great. The Granite Wash sand is usually present in the topographic "lows" on the Basement but absent on the "highs". The Granite Wash is an excellent potential reservoir.

Further effects of Basement topography on beds higher than the Granite Wash is the gentle folding present over Basement hills. These folds are anticlines in every sense and could form traps for oil or gas.

(2) REEFS

Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. However, only small reefs have been found in outcrops near the Permit and such small masses as these probably do not greatly affect the fracture pattern.

(3) TECTONIC FOLDING AND FAULTING

The presence of tectonic folds is very unlikely, but some normal faulting could be present.

(4) TOPOGRAPHIC RELIEF ON AN INTRA-SEDIMENTARY UNCONFORMITY

Unconformity, is a possible source of fracture intensity anomalies, but within the Permit area it is unlikely that the relief on any unconformities within the sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there is one area of "high" fracture intensity, and one area of "low" fracture intensity (green). The general interpretation is that the low fracture intensity area is underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is high in the northeast corner of Permit No. 47.

This Basement high feature is most interesting from the oil and gas point of view. The general shape of this feature is such that the causative feature must be a hill on the Basement surface. A fault is unlikely as the causative feature as the high area is over one and one-half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Granite Wash sand is probably absent on the top of this high fracture area, but will probably be present along the flanks of this feature.

Respectfully submitted by:

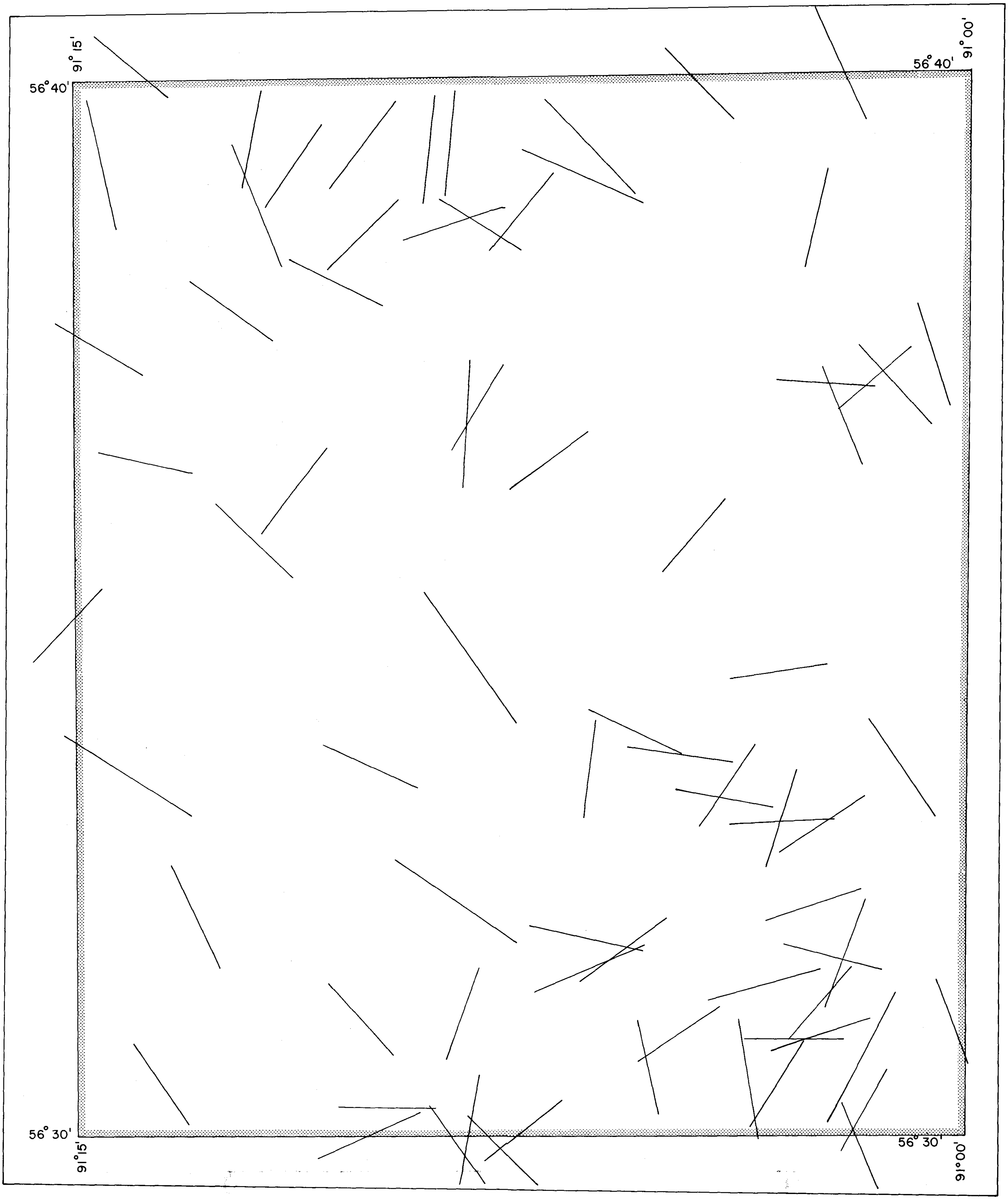
RAYALTA PETROLEUMS LTD.

William G. Cook

WGC/jp

REFERENCES

NELSON S.J. &	1966: Geology of Hudson Bay Basin, Bull. Can. Petrol. Geol., Vol. 14, No. 4, pp. 520-578.
BOSTOCK H.H. CUMMING L.M. NORFORD B.S. NORRIS A.W. PRICE L.L. STANDFORD B.V.	Geology Hudson Bay Lowlands, Map 17-.1967, Geol. Surv. Can.
BLANCHET P.H.	1957: "Development of Fracture Analysis as Exploration Method", Amer. Assoc. Petrol. Geol. Bull., Vol. 41, No. 8, 1748-59
HAMAN P.J.	1964: "Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2



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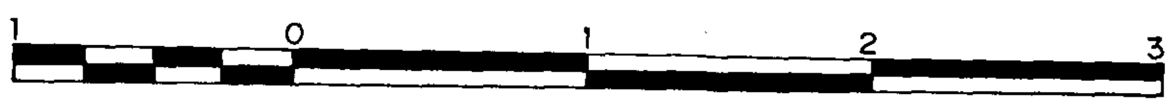
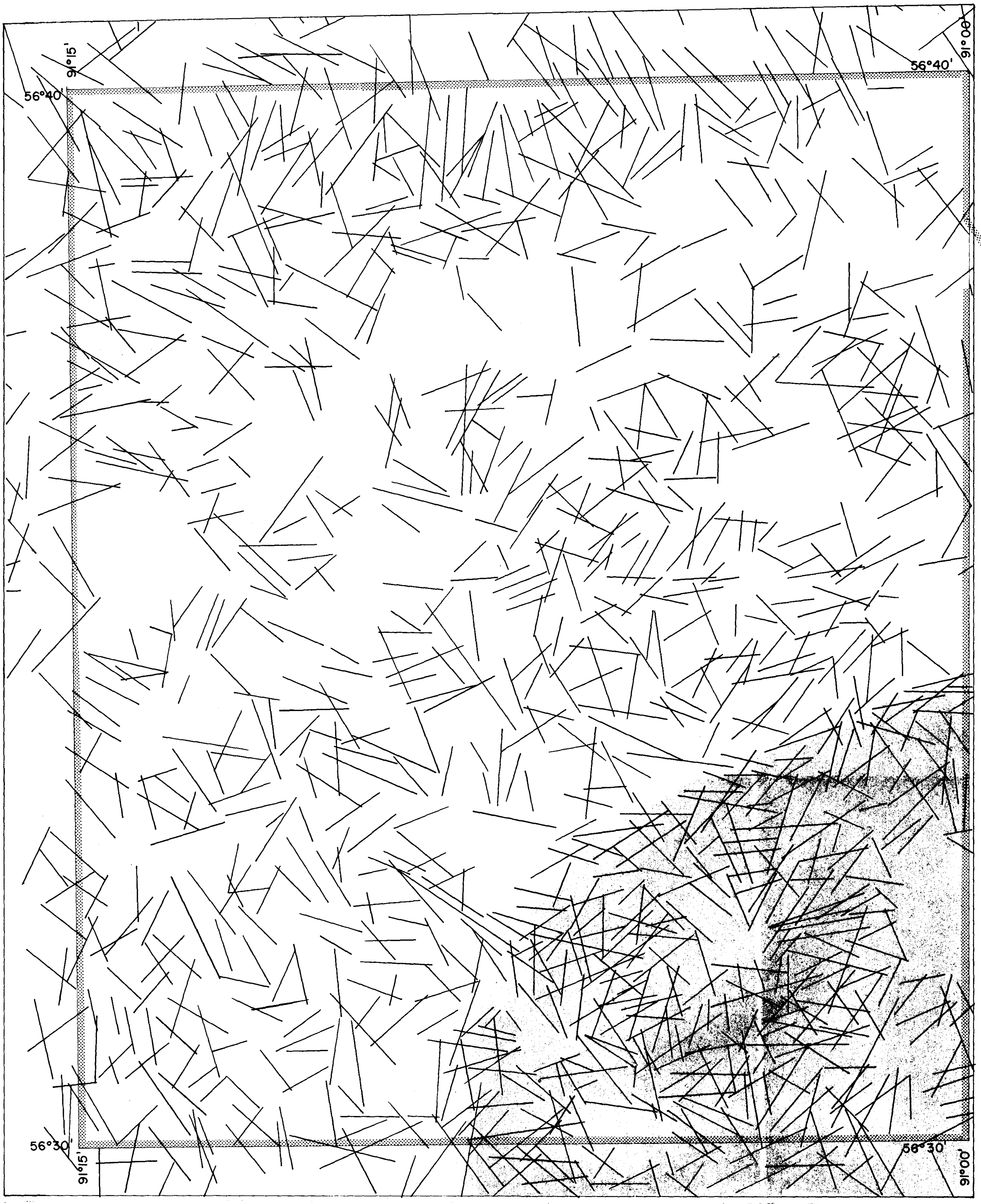
P. & N. G. PERMIT No. 47

MEGA FRACTURE PATTERN

SCALE : 1.5" = 1 MI.





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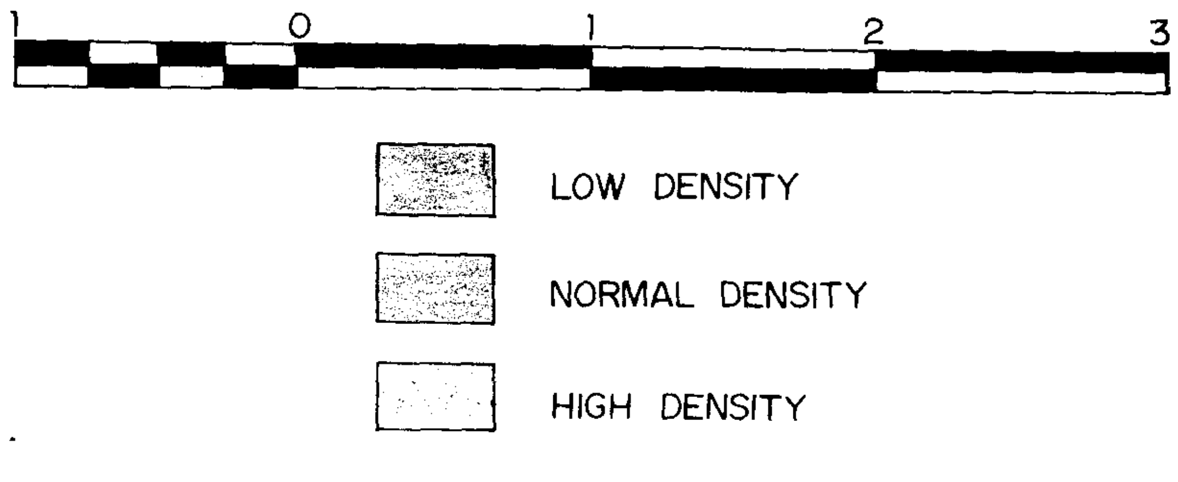
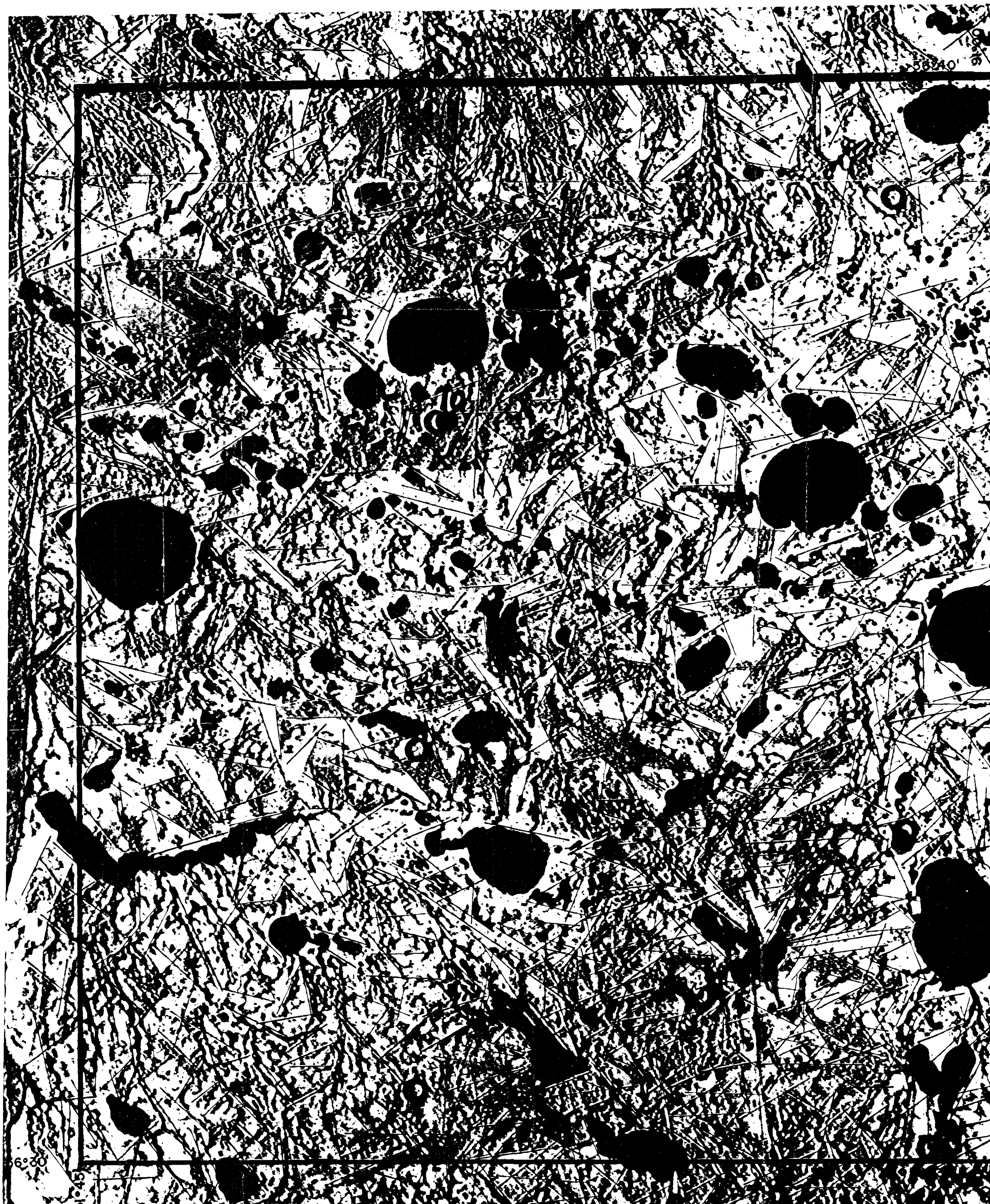
P. & N. G. PERMIT NO. 47

TOTAL FRACTURE PATTERN

SCALE : 1.5" = 1 mi.





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P. & N. G. PERMIT NO. 47

HUDSON'S BAY LOWLANDS

MANITOBA

SCALE : 1.5" = 1 MI.

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THIS IS A UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN ACCURATE TOPOGRAPHIC MAP.

Exploration Permit No. 48

INTRODUCTION

This report discusses the results of a study of the General Geology, Stratigraphy and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 48, Manitoba. This permit is located between 56° 35' - 56° 40' latitude and 91° 15' - 91° 30' longitude. This is in the Hudson's Bay area of northeast Manitoba approximately 540 air miles north-northwest of Winnipeg. There are no roads within the area and the use of an aircraft is required to reach the area.

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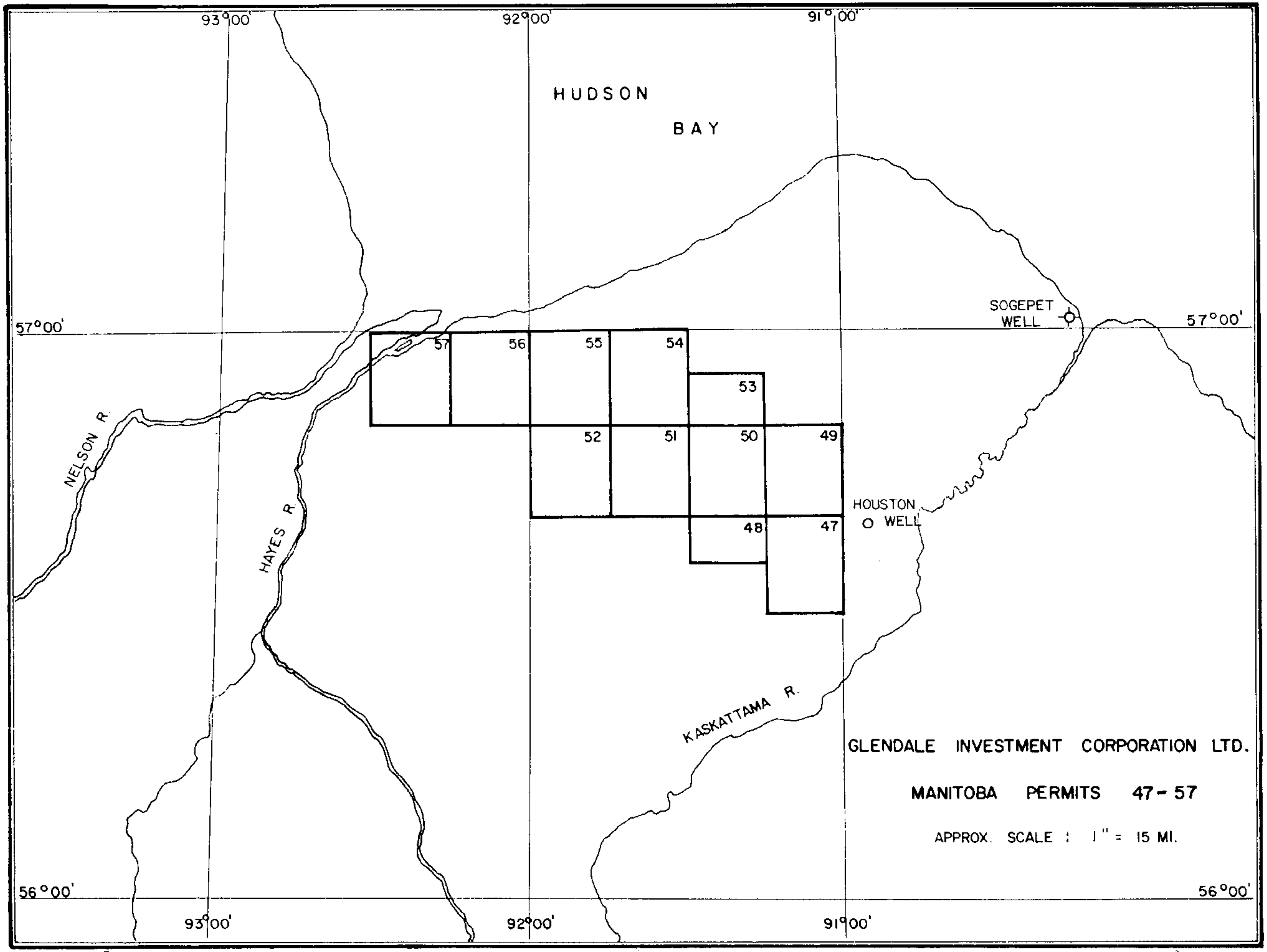

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GLENDALE INVESTMENT CORPORATION LTD.
MANITOBA PERMITS 47 - 57
APPROX. SCALE : 1" = 15 MI.

STRATIGRAPHY

The subject acreage, which is located one to 50 miles south of the Hudson Bay shoreline near York Factory in Manitoba, is primarily covered by muskeg with numerous small rivers, and streams present. Access to the area is provided by the Canadian National Railway line running into Port Nelson and also by ocean ships to the same point. Subsurface control will be provided by the Sogepet-Aquitane-Kaskattama # I well when it is released. It is located some 30 miles east of the northeast corner of the acreage. Recently Houston et al Comeault Sth Prov. # I, located at about 56° 40' and 90° 52' has been licenced. This location, which is some 5 miles east of the acreage, will provide additional valuable subsurface information about this area. Outcrop information is extremely scarce in this area with only some talus being noted near York Factory along the north side of the acreage and along the Kaskattama River, which lies along the south and east side of the acreage. The main outcrop data has to be projected into this area from sections found on the Severn River, which is 110 miles southeast

of the acreage. The Nelson River which is approximately 50 miles northwest of the acreage is another outcrop area. Ordovician rocks are exposed along Gods River, 30 miles south of the western portion of the area under discussion. Beds ranging in age from Upper Ordovician to Upper Silurian are expected to be present beneath the land under review.

ORDOVICIAN

BAD CACHE RAPIDS GROUP

PORTAGE CHUTE FORMATION

The type section of the Portage Chute formation is located on the Churchill River, 100 miles northwest of the acreage. Outcrops are also present on the Nelson River approximately 50 miles west of the area, as well as on the Sachigo and Severn Rivers which lie to the south. The formation was defined by Nelson as overlying peneplaned Pre-Cambrian rocks, and in turn being conformably overlain by the Surprise Creek formation. The Portage Chute formation, which is 75 feet thick at the type section, consists of a four foot basal quartz sandstone which is generally quite uniform, tight and calcareous. This sand is also

present at the other outcrop sections mentioned above. The sand grades upwards into grey to buff, weathering light grey, partially dolomitic, microcrystalline, laminated limestones. Skeletal debris is quite abundant. At the type section the limestone section is 71 feet thick. The thickness of the Portage Chute formation on the Nelson River is approximately 25 feet, while at the Severn River exposures it is only about ten feet thick. The formation dips easterly with an increasing rate of dip as one proceeds basinward along the outcrop sections. Fossils consist mainly of a variety of corals and molluscans with some trilobites present. The limestone takes on a nodular appearance in weathered sections.

SURPRISE CREEK FORMATION

The type section of the Surprise Creek formation was defined by Nelson as being located at Surprise Creek on the Churchill River. It is also present at the Nelson River section but not further south. Nelson considered the Surprise Creek formation as late Ordovician in age. The type section consists of 63 1/2 feet of thinly bedded, light yellowish grey, micro to cryptocrystalline limestone. It ranges from slightly dolomitic, to dolomitic, and contains some lenses of chert. The Surprise Creek formation is disting-

uished from the underlying Portage Chute formation by its lack of organic fragments, and by its smooth weathering characteristics, as opposed to the nodular weathering of the Portage Chute formation. The exposures at Nelson River are poor and not easily correlated with the type section, but, they appear to be lithologically similar to the type section. The thickness is a minimum 30 feet and the fauna is composed mainly of brachiopods. The combined thickness of the Surprise Creek formation and Portage Chute formation at the Selco-Pennycutaway # 1, drill hole, which lies about 17 miles west of the acreage, was 300 $\pm$, indicating a rapid thickening of this group in a basinward direction.

CHURCHILL RIVER GROUP

CAUTION CREEK FORMATION

The type section of the Caution Creek formation is also found on the Churchill River. The type section was defined by Nelson to consist of a basal 18 foot bed of mainly grey to yellowish grey weathering, cryptocrystalline, slightly dolomite limestone, containing shell fragments. This

is overlain by an 18 foot bed of grey to brown weathering, crypto to microcrystalline, slightly dolomitic limestone with little organic remains. This bed weathers into smooth layers, whereas, the lower bed weathers into uneven rubbly beds. The uppermost bed consists of six feet of grey, earthly weathering, micro to cryptocrystalline, slightly dolomitic limestone which has a nodular appearance on a weathered surface. The fauna consists of brachiopods, corals, and molluscans. The Caution Creek formation apparently does not outcrop on the Nelson River, but, it should be present in the subsurface of the subject acreage.

CHASM CREEK FORMATION

The Chasm Creek formation is found both along the Churchill and Nelson Rivers with the Churchill sections being the better one. The Chasm is also exposed at Gods River, some 30 miles south of the acreage. The Chasm is fairly similar to the underlying Caution Creek formation and is in conformable contact with it. At the type section it is about 180 feet thick. The basal 55 feet is a light yellowish grey to buff, microcrystalline, slightly dolomitic

limestone grading to an iron rich dolomite. It is very resistant and weathers to a yellow and orange massive bed. This unit is overlain by about 100 feet of light grey, crypto to microcrystalline, slightly dolomitic to dolomitic limestone. The unit contains abundant fine organic fragments. Overlying this unit is a 5 to 15 foot thick bed of light grey, cryptocrystalline, dolomitic limestone which contains no organic material but has fine intercalations of finely fragmented limestone beds. The uppermost unit is ten to 20 feet thick, and is a light grey weathering, very dolomitic, microcrystalline unit which is strongly fucoidal. On the Nelson River the Chasm Creek section is a minimum of 15 feet thick with the maximum thickness unknown. It is lithologically similar to the type section as is the 38 foot thick section found on Gods River. The Chasm Creek formation contains a fauna comprised of corals, cephalopods and some brachiopods.

RED HEAD RAPIDS FORMATION

The Red Head Rapids formation is the uppermost Ordovician sediment found in this region and tye type section is located on the Churchill River where it overlies the Churchill River Group. The formation is a minimum of 42

feet thick with the maximum thickness unknown. Nelson notes that this formation may be Silurian in age. The lower 25 feet consist of light yellow, microcrystalline dolomitic which weathers a distinctive orange color. No fossils are present in this bed. The upper 17 feet is composed of grey to yellowish grey, microcrystalline dolomite, partially vuggy, which weathers to a grey color. This bed is also quite unfossiliferous. The Red Head Rapids is not present in outcrop on the Nelson, Gods, or Severn Rivers, but, it should be present in the subsurface of the acreage.

SILURIAN

PORT NELSON FORMATION

The type section of the Port Nelson formation is located on the Nelson River some 47 miles west of the acreage under review. The section exposed is 24 feet thick and consists of interbeds of brecciated dolomite, dolomite, and shaly dolomite. The dolomite is generally a gray micro to cryptocrystalline to occasionally granular rock with minor porosity. It contains a coral fauna and

is placed in the Middle Silurian. In the James Bay area a drill hole encountered 110+ feet of this formation. This unit should be found at subcrop under the southwestern portion of the acreage.

SEVERN RIVER FORMATION

The type section of this formation is found on the Severn River some 110 miles southeast of the acreage. The minimum thickness at the type section is 42 feet with the maximum unknown. The section consists of a basal 13 foot light grey, micro to cryptocrystalline limestone with rare vuggy porosity, and a suggestion of algal material. The middle unit consists of 4 feet of light yellowish grey, to orange buff, micro to finely crystalline algal limestone with good vuggy porosity. The upper unit is a 25 foot thick bed of cream to buff, partly microcrystalline to finely crystalline, chalky and partly organic limestone. Fine to coarse organic debris is present as well as beds of oolitic material. The Severn River formation appears to be present near Churchill in similar facies plus the notable fact that it has a strong bituminous odour from a fresh break in this area. This formation should also be present at subcrop under the southwest portion of the acreage.

EKWAN RIVER FORMATION

The type section of this formation is on the Ekwan River, which is in the James Bay area and lies some 350 miles southeast of the area under consideration. The section is from 73 to 88 feet thick and consists of grey, fine grained, partially cherty limestone containing corals and stromatoporoids. The section on Severn River is a minmum 37 feet thick with the maximum unknown. The basal 20 feet is composed of light medium brown, microcrystalline limestone with fine to coarse fossil fragments, some chert nodules and some oolitic material. The fossils consist of stromatoporoids, corals, brachiopods and cephalopods. Some poor intercrystalline and vuggy porosity is present. The middle 11 feet consists of yellowish brown, microcrystalline partially dolomitic, chalky limestone with some thin fragmental beds and rare brachiopods. The upper 6 feet is a light greyish brown, to creamy, microcrystalline limestone which is very highly and coarsely fragmental. The top section contains poor to good porosity. The Ekwan River formation is also exposed along the shore of Hudson Bay from the Mouth of Owl River to a point some 20 miles south of Cape Churchill. The Ekwan should be found to

subcrop along the western and central position of the subject acreage.

ATTAWAPISKAT FORMATION

The type section is located on the Attawapiskat River which lies some 40 miles south of the Ekwan River type section in the James Bay area. The formation outcrops on the Ekwan River, Severn River and along the tidal flats south from Cape Churchill.

The Ekwan River outcrop section consists of 54 feet of fine grained, thin bedded, coral reef limestone. Nelson has described a reefal and possible off reef facies for the Attawapiskat formation in general. The reef facies has a minimum thickness of 25 feet and is a cream, to orange cream, to buff, microcrystalline, fragmental limestone with corals and stromatoporoids being common. Porosity grades from tight to excellent and is vuggy. Nelson feels that some of the well bedded reefs are suggestive of biostromes, while other oval, domal reefs are believed to be bioherms. He noted a gassy odour at one location.

The off-reef facies is a minimum of 16 feet thick with uniform beds of cream, to partly yellowish cream, to grey microcrystalline limestone. There are abundant coarse granular, bioclastic beds which have excellent intergranular porosity which could be post reef deposits. The Attawapiskat outcrops south of Cape Churchill range in thickness from 25 to 50 feet in thickness, with both facies present and they are seen to grade laterally from one to the other. This formation should be at subcrop through the central portion of the acreage.

KENOGAMI RIVER FORMATION

The Kenogami River formation which has only been found in outcrop, in the James Bay represents the youngest Silurian found in the Hudson Bay Basin. The formation consists of an alternating series of shale, siltstone, sandstone, dolomite, silty dolomite, shaly limestone, and limestone. The colours mainly range from buff to grey, but, reds and greens are the colours of the clastics. The outcrop section has a minimum thickness of 300 feet while a well drilled on Puskwuine Point in James Bay had a thickness of 862 feet. The Kenogami River formation is

expected to subcrop along the eastern half of the acreage under review.

DEVONIAN

Rocks of Devonian age are not expected to be present under the area covered by the permit, however, they should be present at subcrop east of the acreage, at and near the Sogepet-Aquitaine-Kaskattama # I well where total depth was reached at 2,941 feet in granite.

CRETACEOUS

Rocks of Cretaceous age are know only in the James Bay area and are not expected to be present under the permits.

FRACTURE ANALYSIS

This section of the report discusses the results of a Detailed Fracture Analysis Survey carried out on the area under discussion. An aerial mosaic (scale 1.5 inches equals approximately 1 mile) made from Dominion Government aerial photographs accompanies this report. These same photographs were examined stereoscopically and the fractures plotted on the individual photographs, then transferred to the mosaic for analysis.

The theory that the earth's crust is abundantly and methodically fractured is the basic premise on which is built the exploration technique known as Fracture Analysis. A Fracture is defined as"...generally abundant, natural lineation discernible on aerial photographs".

Fracturing is largely caused by external stresses on the surface. The most important are:

(a) earth tides

(b) radial acceleration of the earth along its radius vector.

(c) a gradual decrease of the earth's rate of rotation.

As stated above, the earth is systematically fractured and the fracture system would approach symmetry if the crust were homogeneous. It is considered that irregularities are caused by regional heterogeneous conditions within the earth's crust. Local departures from the norm are caused by structural or stratigraphic anomalies.

The term "photogeophysics" was introduced by Blanchet (1956) and deals with mapping, analysis and interpretation of fracture traces as recorded on aerial photographs. In a more general way "photogeophysics" can be defined as the methodical statistical analysis of linear features seen on aerial photographs and this system is applied by any method recording all observable lineations, or the totality of a certain type of linear feature, and the statistical presentation of the data on contoured intensity maps of dry plotting the fractures directly on the mosaic.

In this report a megafracture is longer than one mile and a microfracture is shorter than one mile.

GENERAL STATEMENT

ORIGIN OF FRACTURES

Fracturing is largely caused by external stresses on the earth, although internal stresses may play some minor roll. The most important of these external forces are the diurnal earth tides due to the gravitational effects of the sun and moon; the change in radial acceleration of the earth along its radius vector and the gradual decrease in the earth's rate of rotation. The endless rhythemic action of these earth tides is probably the principal cause of the systematic fracture system seen over most of the world, even though the amplitude of these tides is only 9-13 inches. The fractures are most likely generated by the process of fatigue as the end result of these stresses which are repeated regularly over millions and millions of years. Metals fatigue in the same manner when subjected to continual vibration.

In general the initiating forces which generate fractures must have continued for a very long time and

the process involved are continuous and are probably active at the present time. Furthermore, Mollard (1957) states, "The mechanism required to reflect lineaments to ground surface must be reasonably simple, for simple patterns are produced on diverse topography and in diverse types and depths of surficial deposits that overlie different kinds of relatively flat-lying sedimentary rocks of varying thickness. The mechanism producing the lineament pattern must persist over extensive and widespread belts of the earth's outer shell; that is today, the engendering mechanism in fact be world wide".

External forces such as earth tides obviously fit these parameters. Some internal forces may also apply such as the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

In general it can be said that fracture patterns are caused by either internal forces or external forces.

If the forces are internal the result would be different orientation of the fracture systems in areas of similar tectonic history but different position. If the forces are external the orientation of the fracture arrangement should have world wide similarity. However, stable areas such as the masses of the continents may develop fracture patterns due to external forces and tectonically active areas may develop their own pattern due to internal forces.

If joints form early in the history of a sediment then systematic joints must be successively younger upwards through the section and the joint pattern is imposed on each new layer of sediments when they have become consolidated enough to fracture. This upward propagation is caused by the fatigue caused by stress, which in turn is caused by diurnal earth tides.

EXPRESSION OF FRACTURE

Fractures have been observed in aerial photographs from every climate and on every continent in the world. They are expressed as topographic relief, vegetation

differences and soil tonal differences.

TOPOGRAPHIC RELIEF LINEAMENTS

A common type are relief lineaments which can be manifested by a change (usually abrupt) of topographic elevation on either side of a relatively straight line. They may also be expressed as straight valleys or hills or by straight streams where the stream course is controlled by a fracture zone.

VEGETAL LINEAMENTS

Vegetal lineaments are the most common in the parkland and muskeg areas of western Canada and many excellent examples of fractures can be seen on almost any aerial photograph of northern Saskatchewan, Alberta or British Columbia. Straight lines of both deciduous and evergreen trees as well as scrub growth are universally visible. However, the most common vegetal lineament seen by this writer is a straight "edge" to a clump of trees or bushes. In many cases these fractures control the size and

shape of cultivated fields. Excellent examples of this latter expression of fractures are present in the western part of the Peace River district.

SOIL TONAL LINEAMENTS

These reflect differentiation in soil moisture and general ground water conditions. These are common in the southern parts of Alberta and Saskatchewan, especially near large rivers.

Surface investigations have shown that fractures are associated with bedrock joints; however, in glaciated areas such as western Canada, the photoanalyst must take care to establish the direction of ice flow over an area before he begins to statistically plot and analyse the fractures. Most areas in western Canada show an abundance of grooves and flutes caused by the glacier and these must not be mistaken for fracture traces caused by subsurface structural conditions. In parts of the Lloydminster area of eastern Alberta the glacial scars are so deeply impressed on the surface that fracture analysis is at best difficult and

often impossible.

INTERPRETATION OF FRACTURE DATA

The object of Fracture Analysis (Photogeophysics) is to locate shallow to deep-seated structural and stratigraphic anomalies. The actual count of fractures per unit area is made and values are contoured on a "Fracture Intensity Map". In areas of known reefs the fracture intensity is 2-3 times greater on the flanks of the reef than directly above the reef.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general the two systems are at approximate right angles to each other.

Because of certain inherent limiting factors, Structure Incidence Surveys have a lower order of reliability than Detailed Fracture Analysis Surveys. To some extent at least, surface conditions affect the fracture count. In areas

covered by lakes, sloughs and rivers, the fracture count is zero. Cultivated areas generally yield a lower count than adjacent virgin territory. Consequently, a difference or contrast in fracture count (F/I) between two points may be in part due to structure, but, also due in part to different surface conditions. To some extent, this can be compensated for by applying appropriate weightings to the observed counts, but over or under corrections may result.

Nevertheless, in spite of these sources or error, it has been demonstrated in (plains) areas where abundant subsurface control is available, that the incidence of fracturing is considerably above normal in the surrounding area immediately out from the steepest part of the flanks of the structure. This is in contrast with a low or normal incidence over the crestal area, and also to a normal incidence off structure.

FRACTURE ANALYSIS OF PERMIT NO. 48

The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permit. The Permit is located in the muskeg area south of Hudson's Bay and is hundreds of miles from the closest settlement.

The sedimentary section is probably about 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There is one area where the fracture intensity is greater than normal and there is one area where the fracture intensity is less than normal. The high intensity area is shown in red and the low intensity area is shown in green. The average length of the fractures is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to mention the glacial problem in this area.

Reference to the mosaic will show that the area is moderately scarred with glacial grooves and striations and that the direction of ice flow was about north 30 degrees east. Some of these grooves are so deeply impressed on the surface that they control the shape of the lakes and of tree growth in the area. In any area such as this the photoanalyst is faced with the difficult problem of eliminating the glacial scars from the fracture pattern without creating false anomalies. The removal of all fractures from a 10 - 12 degree arc in any area will create fracture anomalies and it requires delicate weighting of the whole pattern to adjust for these effects.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general, the two systems are at approximate right angles to each other. Within Petroleum and Natural Gas Permit No. 48 the statistical mean direction of the axial system is north 40 degrees west and the statistical mean direction of the shear system is north 30 degrees east. A third minor system, here termed the sub-axial system, trends nearly north-south.

No regional fractures of great length can be seen and as these are conceded to originate within the Basement, it is assumed that all fractures plotted on the mosaic originate within the sedimentary section. Furthermore, as the fractures are short for this area it is very likely that they originate in the upper two-thirds of the sedimentary section. As the surface of the Permit is relatively flat-lying no azimuth correction is necessary for this study. It has been demonstrated that the low incidence anomalies on a mosaic are considerably larger than the subsurface feature which causes them. Because the high incidence area on Permit No. 48 occurs at the edge of the mosaic it is difficult to estimate the size of the causative feature.

There is one area on the mosaic where the fractures are less intense than the surrounding area. Some fractures are always present within these areas but they usually have a lower incidence than the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the next section of this report.

STRUCTURE

Petroleum and Natural Gas Permit No. 48 is located on the coastal plain on the south shore of Hudson Bay about 70 miles north of the edge of the Pre-Cambrian Shield.

Structural features which could be present and which could cause the low incidence anomalies mentioned in this report are discussed in order of probability.

(1) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No. 48 is thought to be much the same as it is today along the north edge of the Shield. Low rounded hills separated by gentle to abrupt valleys are seen on the Shield and these features are undoubtedly present under the subject Permit. The effect of this Basement relief on the overlying sedimentary rocks is often great. The Granite Wash sand is usually present in the topographic "lows" on the Basement but absent on the "highs". The Granite Wash is an excellent potential reservoir.

Further effects of Basement topography on beds higher than the Granite Wash is the gentle folding present over Basement hills. These folds are anticlines in every sense and could form traps for oil or gas.

(2) REEFS

Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. However, only small reefs have been found in outcrops near the Permit and such small masses as these probably do not greatly affect the fracture pattern.

(3) TECTONIC FOLDING AND FAULTING

The presence of tectonic folds is very unlikely, but some normal faulting could be present.

(4) TOPOGRAPHIC RELIEF ON AN INTRA-SEDIMENTARY UNCONFORMITY

Unconformity, is a possible source of fracture intensity anomalies, but within the Permit area it is unlikely that the relief on any unconformities within the sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there is one area of "high" fracture intensity, and one area of "low" fracture intensity (green). The general interpretation is that the low fracture intensity area is underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is high in the east part of Permit No. 48.

This Basement high feature is most interesting from the oil and gas point of view. The general shape of this feature is such that the causative feature must be a hill on the Basement surface. A fault is unlikely as the causative feature as the high area is over one and one - half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Granite Wash sand is probably absent on the top of this high fracture area, but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Cook

WGC/jp

REFERENCES

NELSON S.J. & — 1966: Geology of Hudson Bay Basin, Bull. Can. Petrol. Geol., Vol. 14, No. 4, pp. 520-578.

BOSTOCK H.H.
CUMMING L.M.
NORFORD B.S.
NORRIS A.W. — Geology Hudson Bay Lowlands, Map 17-.1967, Geol. Surv. Can.
PRICE L.L.
STANDFORD B.V.

BLANCHET P.H. — 1957: "Development of Fracture Analysis as Exploration Method", Amer. Assoc. Petrol. Geol. Bull., Vol. 41, No. 8, 1748-59

HAMAN P.J. — 1964: "Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2

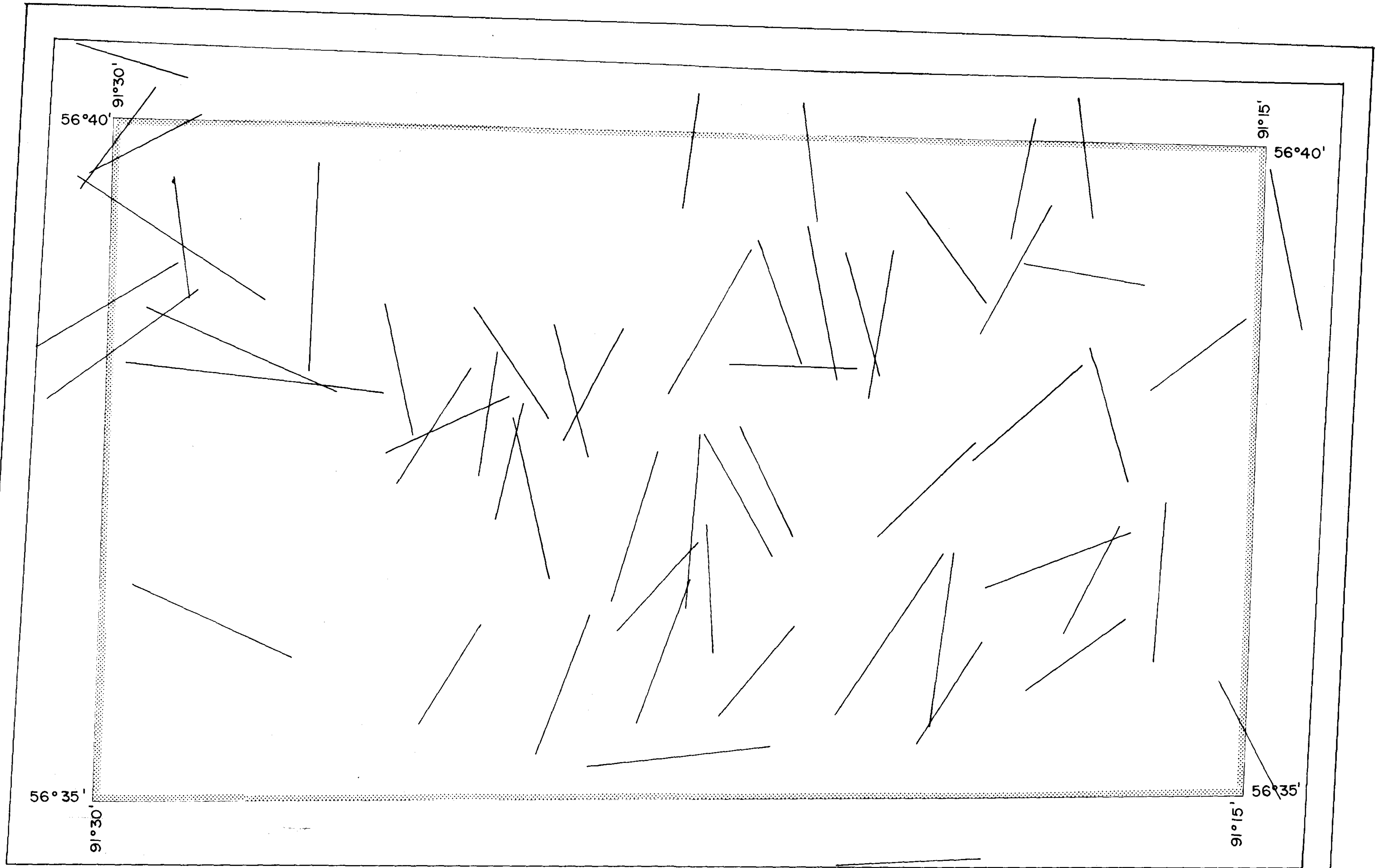
Granite Wash sand is probably absent on the top of this Basement topographic high; but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

WILLIAM G. CROOK
Photoanalyst, P. Geol.

WGC/jp



GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 48

MEGA FRACTURE PATTERN

SCALE : 1.5" = 1 MI.

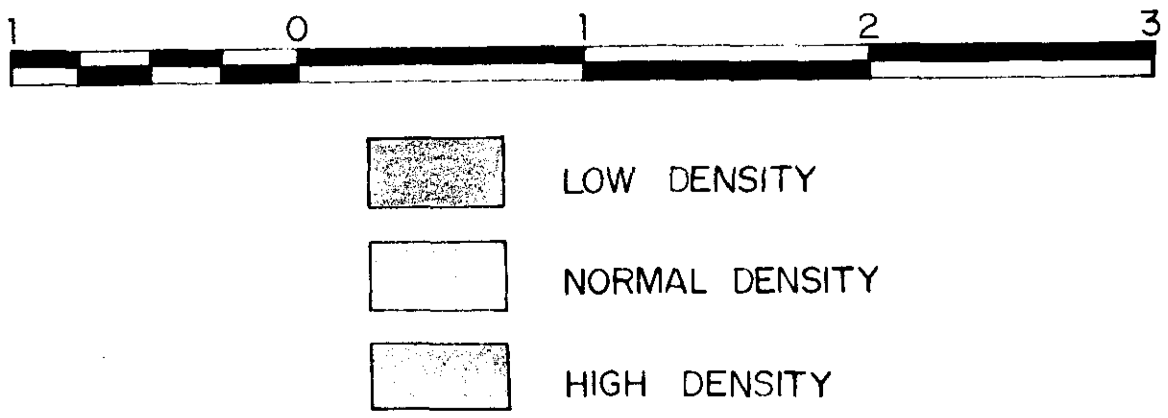
1 0 1 2 3

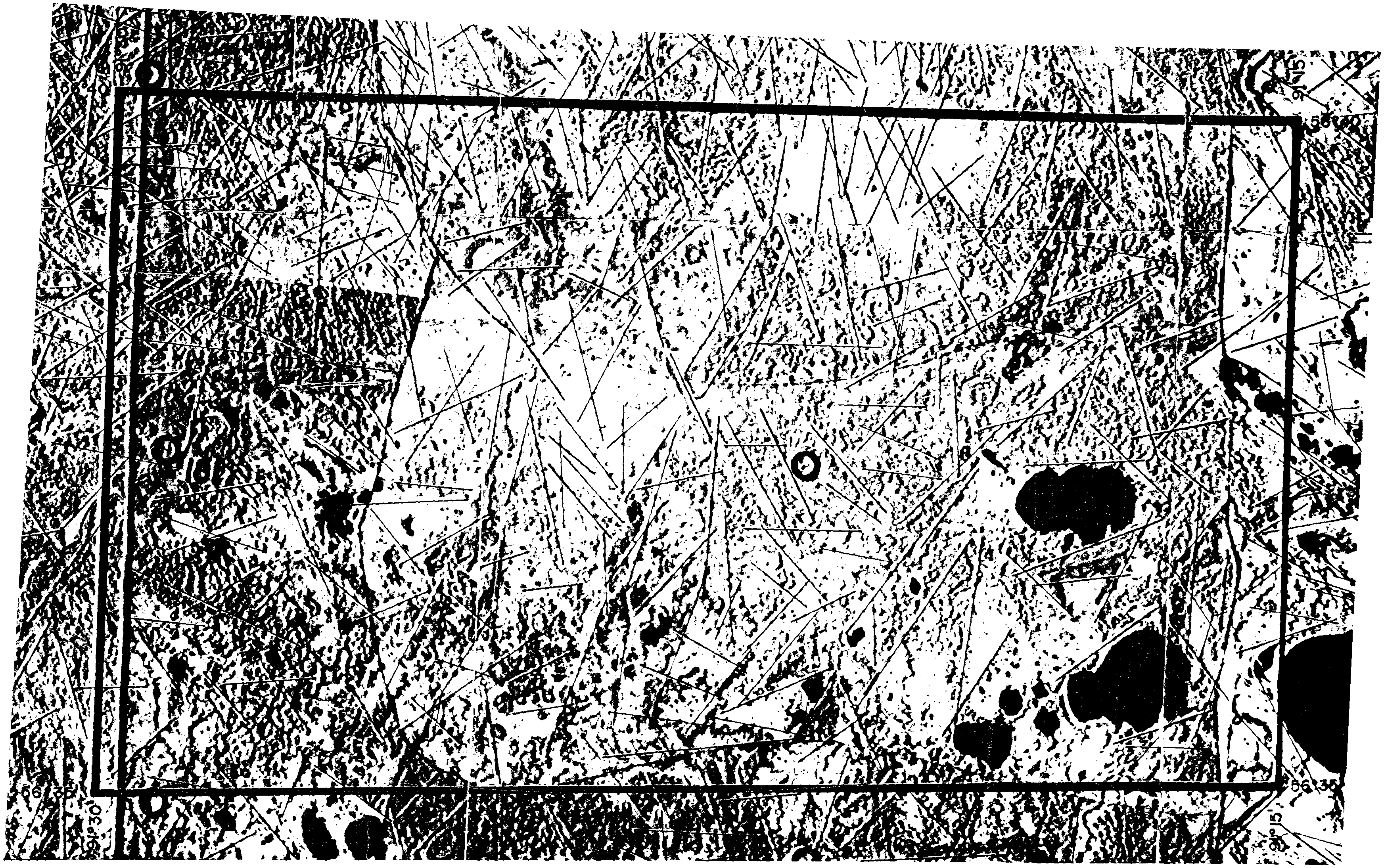
GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 48

TOTAL FRACTURE PATTERN

SCALE : 1.5" = 1 mi.





GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT NO. 48

HUDSON'S BAY LOWLANDS

MANITOBA

SCALE : 1.5" = 1 MI.

1 0 1 2 3

THIS IS A UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN ACCURATE TOPOGRAPHIC MAP.

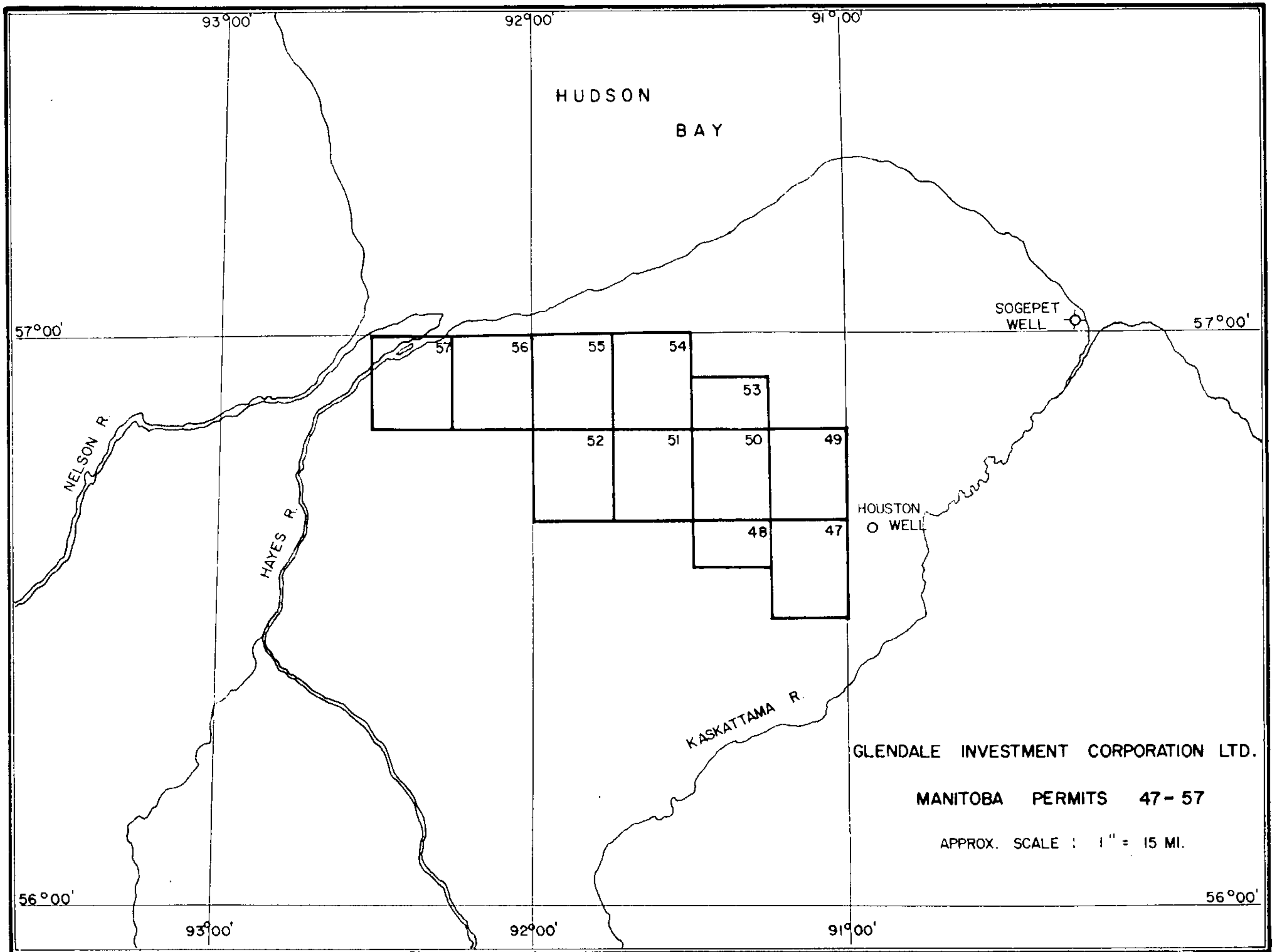
Exploration
Permit
No. 49

INTRODUCTION

This report discusses the results of a study of the General Geology, Stratigraphy and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 49, Manitoba. This permit is located between 56° 40' - 56° 50' latitude and 91° 00' - 91° - 15' longitude. This is in the Hudson's Bay area of northeast Manitoba approximately 540 air miles north-northwest of Winnipeg. There are no roads within the area and the use of an aircraft is required to reach the area.

The stratigraphic discussion is based on information contained in published reports and on the limited data available from well control.

The Fracture Analysis Survey locates topographic highs and lows on the Basement surface. Areas of Basement "highs" are of great interest as it is felt that much reef growth (which is known to be present) is centered, or at least concentrated, over areas of Basement "highs".



93°00'
92°00'
91°00'
HUDSON
BAY
57°00'
SOGEPET
WELL
57°00'
NELSON R.
HAYES R.
57
56
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HOUSTON
WELL
KASKATTAMA R.
GLENDALE INVESTMENT CORPORATION LTD.
MANITOBA PERMITS 47 - 57
APPROX. SCALE : 1" = 15 MI.
56°00'
56°00'
93°00'
92°00'
91°00'

Areas of Basement "lows" are of interest as Granite Wash sands tend to accumulate and attain considerable thickness in these "lows". Reefs and Granite Wash sands are probably the two principal reservoir horizons in this area.

STRATIGRAPHY

The subject acreage, which is located one to 50 miles south of the Hudson Bay shoreline near York Factory in Manitoba, is primarily covered by muskeg with numerous small rivers, and streams present. Access to the area is provided by the Canadian National Railway line running into Port Nelson and also by ocean ships to the same point. Subsurface control will be provided by the Sogepet-Aquitane-Kaskattama # 1 well when it is released. It is located some 30 miles east of the northeast corner of the acreage. Recently Houston et al Comeault Sth Prov. # 1, located at about 56° 40' and 90° 52' has been licenced. This location, which is some 5 miles east of the acreage, will provide additional valuable subsurface information about this area. Outcrop information is extremely scarce in this area with only some talus being noted near York Factory along the north side of the acreage and along the Kaskattama River, which lies along the south and east side of the acreage. The main outcrop data has to be projected into this area from sections found on the Severn River, which is 110 miles southeast

of the acreage. The Nelson River which is approximately 50 miles northwest of the acreage is another outcrop area. Ordovician rocks are exposed along Gods River, 30 miles south of the western portion of the area under discussion. Beds ranging in age from Upper Ordovician to Upper Silurian are expected to be present beneath the land under review.

ORDOVICIAN

BAD CACHE RAPIDS GROUP

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The type section of the Portage Chute formation is located on the Churchill River, 100 miles northwest of the acreage. Outcrops are also present on the Nelson River approximately 50 miles west of the area, as well as on the Sachigo and Severn Rivers which lie to the south. The formation was defined by Nelson as overlying peneplaned Pre-Cambrian rocks, and in turn being conformably overlain by the Surprise Creek formation. The Portage Chute formation, which is 75 feet thick at the type section, consists of a four foot basal quartz sandstone which is generally quite uniform, tight and calcareous. This sand is also

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SURPRISE CREEK FORMATION

The type section of the Surprise Creek formation was defined by Nelson as being located at Surprise Creek on the Churchill River. It is also present at the Nelson River section but not further south. Nelson considered the Surprise Creek formation as late Ordovician in age. The type section consists of 63 1/2 feet of thinly bedded, light yellowish grey, micro to cryptocrystalline limestone. It ranges from slightly dolomitic, to dolomitic, and contains some lenses of chert. The Surprise Creek formation is disting-

uished from the underlying Portage Chute formation by its lack of organic fragments, and by its smooth weathering characteristics, as opposed to the nodular weathering of the Portage Chute formation. The exposures at Nelson River are poor and not easily correlated with the type section, but, they appear to be lithologically similar to the type section. The thickness is a minimum 30 feet and the fauna is composed mainly of brachiopods. The combined thickness of the Surprise Creek formation and Portage Chute formation at the Selco-Pennycutaway # 1, drill hole, which lies about 17 miles west of the acreage, was 300 $\pm$, indicating a rapid thickening of this group in a basinward direction.

CHURCHILL RIVER GROUP

CAUTION CREEK FORMATION

The type section of the Caution Creek formation is also found on the Churchill River. The type section was defined by Nelson to consist of a basal 18 foot bed of mainly grey to yellowish grey weathering, cryptocrystalline, slightly dolomite limestone, containing shell fragments. This

is overlain by an 18 foot bed of grey to brown weathering, crypto to microcrystalline, slightly dolomitic limestone with little organic remains. This bed weathers into smooth layers, whereas, the lower bed weathers into uneven rubbly beds. The uppermost bed consists of six feet of grey, earthly weathering, micro to cryptocrystalline, slightly dolomitic limestone which has a nodular appearance on a weathered surface. The fauna consists of brachiopods, corals, and molluscans. The Caution Creek formation apparently does not outcrop on the Nelson River, but, it should be present in the subsurface of the subject acreage.

CHASM CREEK FORMATION

The Chasm Creek formation is found both along the Churchill and Nelson Rivers with the Churchill sections being the better one. The Chasm is also exposed at Gods River, some 30 miles south of the acreage. The Chasm is fairly similar to the underlying Caution Creek formation and is in conformable contact with it. At the type section it is about 180 feet thick. The basal 55 feet is a light yellowish grey to buff, microcrystalline, slightly dolomitic

limestone grading to an iron rich dolomite. It is very resistant and weathers to a yellow and orange massive bed. This unit is overlain by about 100 feet of light grey, crypto to microcrystalline, slightly dolomitic to dolomitic limestone. The unit contains abundant fine organic fragments. Overlying this unit is a 5 to 15 foot thick bed of light grey, cryptocrystalline, dolomitic limestone which contains no organic material but has fine intercalations of finely fragmented limestone beds. The uppermost unit is ten to 20 feet thick, and is a light grey weathering, very dolomitic, microcrystalline unit which is strongly fucoidal. On the Nelson River the Chasm Creek section is a minimum of 15 feet thick with the maximum thickness unknown. It is lithologically similar to the type section as is the 38 foot thick section found on Gods River. The Chasm Creek formation contains a fauna comprised of corals, cephalopods and some brachiopods.

RED HEAD RAPIDS FORMATION

The Red Head Rapids formation is the uppermost Ordovician sediment found in this region and tye type section is located on the Churchill River where it overlies the Churchill River Group. The formation is a minimum of 42

feet thick with the maximum thickness unknown. Nelson notes that this formation may be Silurian in age. The lower 25 feet consist of light yellow, microcrystalline dolomitic which weathers a distinctive orange color. No fossils are present in this bed. The upper 17 feet is composed of grey to yellowish grey, microcrystalline dolomite, partially vuggy, which weathers to a grey color. This bed is also quite unfossiliferous. The Red Head Rapids is not present in outcrop on the Nelson, Gods, or Severn Rivers, but, it should be present in the subsurface of the acreage.

SILURIAN

PORT NELSON FORMATION

The type section of the Port Nelson formation is located on the Nelson River some 47 miles west of the acreage under review. The section exposed is 24 feet thick and consists of interbeds of brecciated dolomite, dolomite, and shaly dolomite. The dolomite is generally a gray micro to cryptocrystalline to occasionally granular rock with minor porosity. It contains a coral fauna and

is placed in the Middle Silurian. In the James Bay area a drill hole encountered 110+ feet of this formation. This unit should be found at subcrop under the southwestern portion of the acreage.

SEVERN RIVER FORMATION

The type section of this formation is found on the Severn River some 110 miles southeast of the acreage. The minimum thickness at the type section is 42 feet with the maximum unknown. The section consists of a basal 13 foot light grey, micro to cryptocrystalline limestone with rare vuggy porosity, and a suggestion of algal material. The middle unit consists of 4 feet of light yellowish grey, to orange buff, micro to finely crystalline algal limestone with good vuggy porosity. The upper unit is a 25 foot thick bed of cream to buff, partly microcrystalline to finely crystalline, chalky and partly organic limestone. Fine to coarse organic debris is present as well as beds of oolitic material. The Severn River formation appears to be present near Churchill in similar facies plus the notable fact that it has a strong bituminous odour from a fresh break in this area. This formation should also be present at subcrop under the southwest portion of the acreage.

EKWAN RIVER FORMATION

The type section of this formation is on the Ekwan River, which is in the James Bay area and lies some 350 miles southeast of the area under consideration. The section is from 73 to 88 feet thick and consists of grey, fine grained, partially cherty limestone containing corals and stromatoporoids. The section on Severn River is a minmum 37 feet thick with the maximum unknown. The basal 20 feet is composed of light medium brown, microcrystalline limestone with fine to coarse fossil fragments, some chert nodules and some oolitic material. The fossils consist of stromatoporoids, corals, brachiopods and cephalopods. Some poor intercrystalline and vuggy porosity is present. The middle 11 feet consists of yellowish brown, micro-crystalline partially dolomitic, chalky limestone with some thin fragmental beds and rare brachiopods. The upper 6 feet is a light greyish brown, to creamy, microcrystalline limestone which is very highly and coarsely fragmental. The top section contains poor to good porosity. The Ekwan River formation is also exposed along the shore of Hudson Bay from the Mouth of Owl River to a point some 20 miles south of Cape Churchill. The Ekwan should be found to

subcrop along the western and central position of the subject acreage.

ATTAWAPISKAT FORMATION

The type section is located on the Attawapiskat River which lies some 40 miles south of the Ekwan River type section in the James Bay area. The formation outcrops on the Ekwan River, Severn River and along the tidal flats south from Cape Churchill.

The Ekwan River outcrop section consists of 54 feet of fine grained, thin bedded, coral reef limestone. Nelson has described a reefal and possible off reef facies for the Attawapiskat formation in general. The reef facies has a minimum thickness of 25 feet and is a cream, to orange cream, to buff, microcrystalline, fragmental limestone with corals and stromatoporoids being common. Porosity grades from tight to excellent and is vuggy. Nelson feels that some of the well bedded reefs are suggestive of biostromes, while other oval, domal reefs are believed to be bioherms. He noted a gassy odour at one location.

The off-reef facies is a minimum of 16 feet thick with uniform beds of cream, to partly yellowish cream, to grey microcrystalline limestone. There are abundant coarse granular, bioclastic beds which have excellent intergranular porosity which could be post reef deposits. The Attawapiskat outcrops south of Cape Churchill range in thickness from 25 to 50 feet in thickness, with both facies present and they are seen to grade laterally from one to the other. This formation should be at subcrop through the central portion of the acreage.

KENOGAMI RIVER FORMATION

The Kenogami River formation which has only been found in outcrop, in the James Bay represents the youngest Silurian found in the Hudson Bay Basin. The formation consists of an alternating series of shale, siltstone, sandstone, dolomite, silty dolomite, shaly limestone, and limestone. The colours mainly range from buff to grey, but, reds and greens are the colours of the clastics. The outcrop section has a minimum thickness of 300 feet while a well drilled on Puskwuine Point in James Bay had a thickness of 862 feet. The Kenogami River formation is

expected to subcrop along the eastern half of the acreage under review.

DEVONIAN

Rocks of Devonian age are not expected to be present under the area covered by the permit, however, they should be present at subcrop east of the acreage, at and near the Sogepet-Aquitaine-Kaskattama # I well where total depth was reached at 2,941 feet in granite.

CRETACEOUS

Rocks of Cretaceous age are know only in the James Bay area and are not expected to be present under the permits.

FRACTURE ANALYSIS

This section of the report discusses the results of a Detailed Fracture Analysis Survey carried out on the area under discussion. An aerial mosaic (scale 1.5 inches equals approximately 1 mile) made from Dominion Government aerial photographs accompanies this report. These same photographs were examined stereoscopically and the fractures plotted on the individual photographs, then transferred to the mosaic for analysis.

The theory that the earth's crust is abundantly and methodically fractured is the basic premise on which is built the exploration technique known as Fracture Analysis. A Fracture is defined as "...generally abundant, natural lineation discernible on aerial photographs".

Fracturing is largely caused by external stresses on the surface. The most important are:

(a) earth tides

(b) radial acceleration of the earth along its radius vector.

(c) a gradual decrease of the earth's rate of rotation.

As stated above, the earth is systematically fractured and the fracture system would approach symmetry if the crust were homogeneous. It is considered that irregularities are caused by regional heterogeneous conditions within the earth's crust. Local departures from the norm are caused by structural or stratigraphic anomalies.

The term "photogeophysics" was introduced by Blanchet (1956) and deals with mapping, analysis and interpretation of fracture traces as recorded on aerial photographs. In a more general way "photogeophysics" can be defined as the methodical statistical analysis of linear features seen on aerial photographs and this system is applied by any method recording all observable lineations, or the totality of a certain type of linear feature, and the statistical presentation of the data on contoured intensity maps of dry plotting the fractures directly on the mosaic.

In this report a megafracture is longer than one mile and a microfracture is shorter than one mile.

GENERAL STATEMENT

ORIGIN OF FRACTURES

Fracturing is largely caused by external stresses on the earth, although internal stresses may play some minor roll. The most important of these external forces are the diurnal earth tides due to the gravitational effects of the sun and moon; the change in radial acceleration of the earth along its radius vector and the gradual decrease in the earth's rate of rotation. The endless rhythemic action of these earth tides is probably the principal cause of the systematic fracture system seen over most of the world, even though the amplitude of these tides is only 9-13 inches. The fractures are most likely generated by the process of fatigue as the end result of these stresses which are repeated regularly over millions and millions of years. Metals fatigue in the same manner when subjected to continual vibration.

In general the initiating forces which generate fractures must have continued for a very long time and

the process involved are continuous and are probably active at the present time. Furthermore, Mollard (1957) states, "The mechanism required to reflect lineaments to ground surface must be reasonably simple, for simple patterns are produced on diverse topography and in diverse types and depths of surficial deposits that overlie different kinds of relatively flat-lying sedimentary rocks of varying thickness. The mechanism producing the lineament pattern must persist over extensive and widespread belts of the earth's outer shell; that is today, the engendering mechanism in fact be world wide".

External forces such as earth tides obviously fit these parameters. Some internal forces may also apply such as the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

In general it can be said that fracture patterns are caused by either internal forces or external forces.

If the forces are internal the result would be different orientation of the fracture systems in areas of similar tectonic history but different position. If the forces are external the orientation of the fracture arrangement should have world wide similarity. However, stable areas such as the masses of the continents may develop fracture patterns due to external forces and tectonically active areas may develop their own pattern due to internal forces.

If joints form early in the history of a sediment then systematic joints must be successively younger upwards through the section and the joint pattern is imposed on each new layer of sediments when they have become consolidated enough to fracture. This upward propagation is caused by the fatigue caused by stress, which in turn is caused by diurnal earth tides.

EXPRESSION OF FRACTURE

Fractures have been observed in aerial photographs from every climate and on every continent in the world. They are expressed as topographic relief, vegetation

differences and soil tonal differences.

TOPOGRAPHIC RELIEF LINEAMENTS

A common type are relief lineaments which can be manifested by a change (usually abrupt) of topographic elevation on either side of a relatively straight line. They may also be expressed as straight valleys or hills or by straight streams where the stream course is controlled by a fracture zone.

VEGETAL LINEAMENTS

Vegetal lineaments are the most common in the parkland and muskeg areas of western Canada and many excellent examples of fractures can be seen on almost any aerial photograph of northern Saskatchewan, Alberta or British Columbia. Straight lines of both deciduous and evergreen trees as well as scrub growth are universally visible. However, the most common vegetal lineament seen by this writer is a straight "edge" to a clump of trees or bushes. In many cases these fractures control the size and

shape of cultivated fields. Excellent examples of this latter expression of fractures are present in the western part of the Peace River district.

SOIL TONAL LINEAMENTS

These reflect differentiation in soil moisture and general ground water conditions. These are common in the southern parts of Alberta and Saskatchewan, especially near large rivers.

Surface investigations have shown that fractures are associated with bedrock joints; however, in glaciated areas such as western Canada, the photoanalyst must take care to establish the direction of ice flow over an area before he begins to statistically plot and analyse the fractures. Most areas in western Canada show an abundance of grooves and flutes caused by the glacier and these must not be mistaken for fracture traces caused by subsurface structural conditions. In parts of the Lloydminster area of eastern Alberta the glacial scars are so deeply impressed on the surface that fracture analysis is at best difficult and

often impossible.

INTERPRETATION OF FRACTURE DATA

The object of Fracture Analysis (Photogeophysics) is to locate shallow to deep-seated structural and stratigraphic anomalies. The actual count of fractures per unit area is made and values are contoured on a "Fracture Intensity Map". In areas of known reefs the fracture intensity is 2-3 times greater on the flanks of the reef than directly above the reef.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general the two systems are at approximate right angles to each other.

Because of certain inherent limiting factors, Structure Incidence Surveys have a lower order of reliability than Detailed Fracture Analysis Surveys. To some extent at least, surface conditions affect the fracture count. In areas

covered by lakes, sloughs and rivers, the fracture count is zero. Cultivated areas generally yield a lower count than adjacent virgin territory. Consequently, a difference or contrast in fracture count (F/I) between two points may be in part due to structure, but, also due in part to different surface conditions. To some extent, this can be compensated for by applying appropriate weightings to the observed counts, but over or under corrections may result.

Nevertheless, in spite of these sources or error, it has been demonstrated in (plains) areas where abundant subsurface control is available, that the incidence of fracturing is considerably above normal in the surrounding area immediately out from the steepest part of the flanks of the structure. This is in contrast with a low or normal incidence over the crestal area, and also to a normal incidence off structure.

FRACTURE ANALYSIS OF PERMIT NO. 49

The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permit. The Permit is located in the muskeg area south of Hudson's Bay and is hundreds of miles from the closest settlement.

The sedimentary section is about 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There is one area where the fracture intensity is greater than normal and there is one area where the fracture intensity is less than normal. The high intensity area is shown in red and the low intensity area is shown in green. The average length of the fractures is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to mention the glacial problem in this area.

Reference to the mosaic will show that the area is moderately scarred with glacial grooves and striations and that the direction of ice flow was about north 30 degrees east. Some of these grooves are so deeply impressed on the surface that they control the shape of the lakes and of tree growth in the area. In any area such as this the photoanalyst is faced with the difficult problem of eliminating the glacial scars from the fracture pattern without creating false anomalies. The removal of all fractures from a 10 - 12 degree arc in any area will create fracture anomalies and it requires delicate weighting of the whole pattern to adjust for these effects.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general, the two systems are at approximate right angles to each other. Within Petroleum & Natural Gas Permit No. 49 the statistical mean direction of the axial systems is north 40 degrees west and the statistical mean direction of the shear system is north 30 degrees east. A third minor system, here termed the sub-axial system, trends nearly north-south.

No regional fractures of great length can be seen and as these are conceded to originate within the Basement, it is assumed that all fractures plotted on the mosaic originate within the sedimentary section. Furthermore, as the fractures are short for this area it is very likely that they originate in the upper two-thirds of the sedimentary section. As the surface of the Permit is relatively flat-lying no azimuth correction is necessary for this study. It has been demonstrated that the low incidence anomalies on a mosaic are considerably larger than the subsurface feature which causes them.

There is one area on the mosaic where the fractures are less intense than the surrounding area. Some fractures are always present within these areas but they usually have a lower incidence than the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the next section of this report.

STRUCTURE

Petroleum and Natural Gas Permit No. 49 is located on the coastal plain on the south shore of Hudson's Bay about 70 miles north of the edge of the Pre-Cambrian Shield.

Structural features which could be present and which could cause the low incidence anomalies mentioned in this report are discussed in order of probability.

(1) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No. 49 is thought to be much the same as it is today along the north edge of the Shield. Low rounded hills separated by gentle to abrupt valleys are seen on the Shield and these features are undoubtedly present under the subject Permit. The effect of this Basement relief on the overlying sedimentary rocks is often great. The Granite Wash sand is usually present in the topographic "lows" on the Basement but absent on the "highs". The Granite Wash is an excellent potential reservoir.

Further effects of Basement topography on beds higher than the Granite Wash is the gentle folding present over Basement hills. These folds are anticlines in every sense and could form traps for oil or gas.

(2) REEFS

Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. However, only small reefs have been found in outcrops near the Permit and such small masses as these probably do not greatly affect the fracture pattern.

(3) TECTONIC FOLDING AND FAULTING

The presence of tectonic folds is very unlikely, but some normal faulting could be present.

(4) TOPOGRAPHIC RELIEF ON AN INTRA-SEDIMENTARY UNCONFORMITY

Unconformity, is a possible source of frature intensity anomalies, but within the Permit area it is unlikely that the relief on any unconformities within the sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there is one area of "high" fracture intensity, and one area of "low" fracture intensity (green). The general interpretation is that the low fracture intensity area is underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is high in the southwest part of Permit No. 49.

This Basement high feature is most interesting from the oil and gas point of view. The general shape of this feature is such that the causative feature must be a hill on the Basement surface. A fault is unlikely as the causative feature as the high area is over one and one-half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Granite Wash sand is probably absent on the top of this high fracture area, but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Crook

WGC/jp

REFERENCES

NELSON S.J. & — 1966: Geology of Hudson Bay Basin, Bull. Can. Petrol. Geol., Vol. 14, No. 4, pp. 520-578.

BOSTOCK H.H.
CUMMING L.M.
NORFORD B.S.
NORRIS A.W.
PRICE L.L.
STANDFORD B.V.
— Geology Hudson Bay Lowlands, Map 17-.1967, Geol. Surv. Can.

BLANCHET P.H. — 1957: "Development of Fracture Analysis as Exploration Method", Amer. Assoc. Petrol. Geol. Bull., Vol. 41, No. 8, 1748-59

HAMAN P.J. — 1964: "Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2

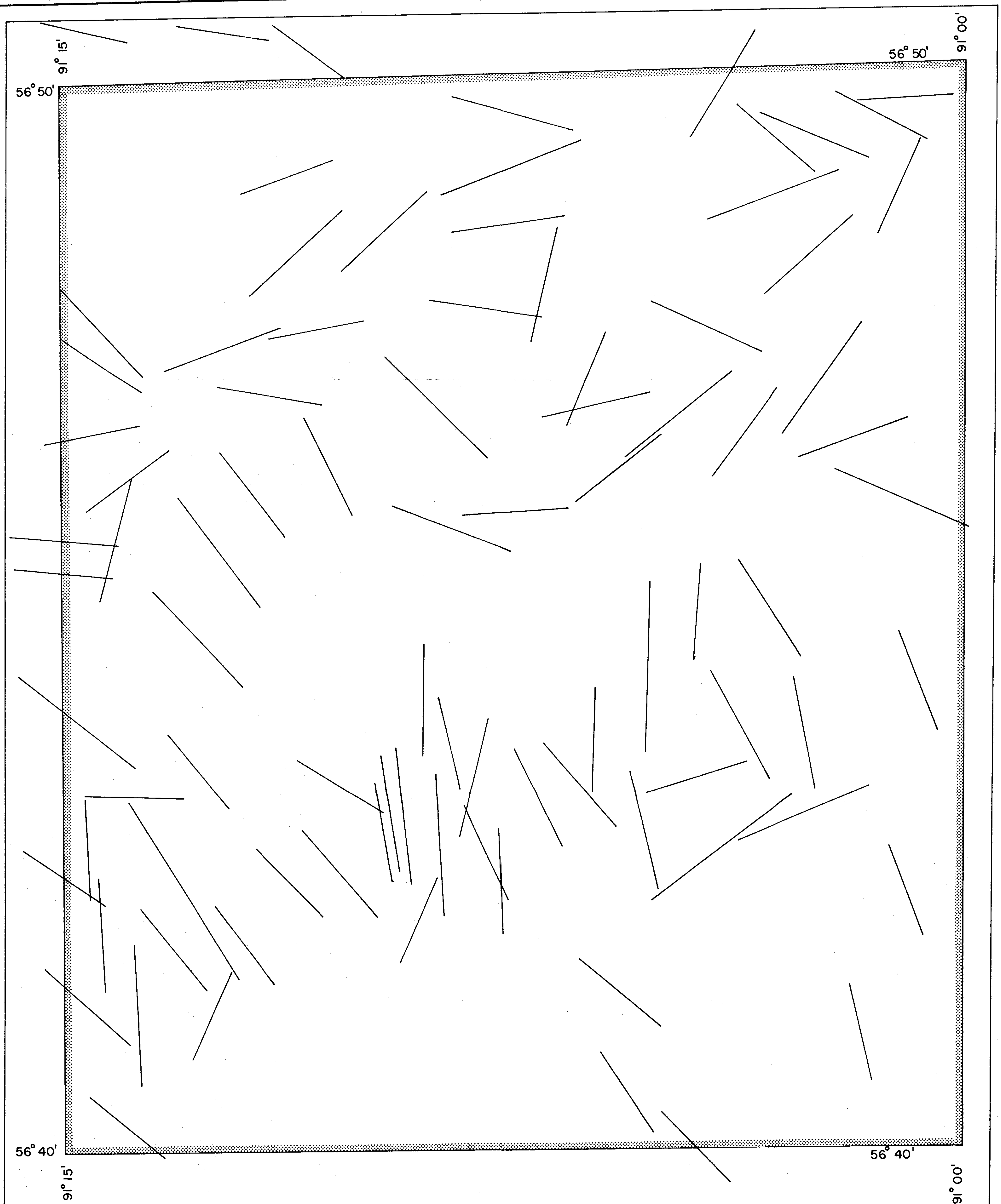
Granite Wash sand is probably absent on the top of this Basement topographic high; but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

WILLIAM G. CROOK
Photoanalyst, P. Geol.

WGC/jp

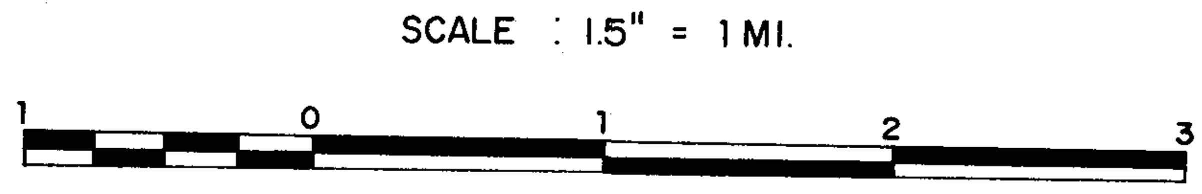


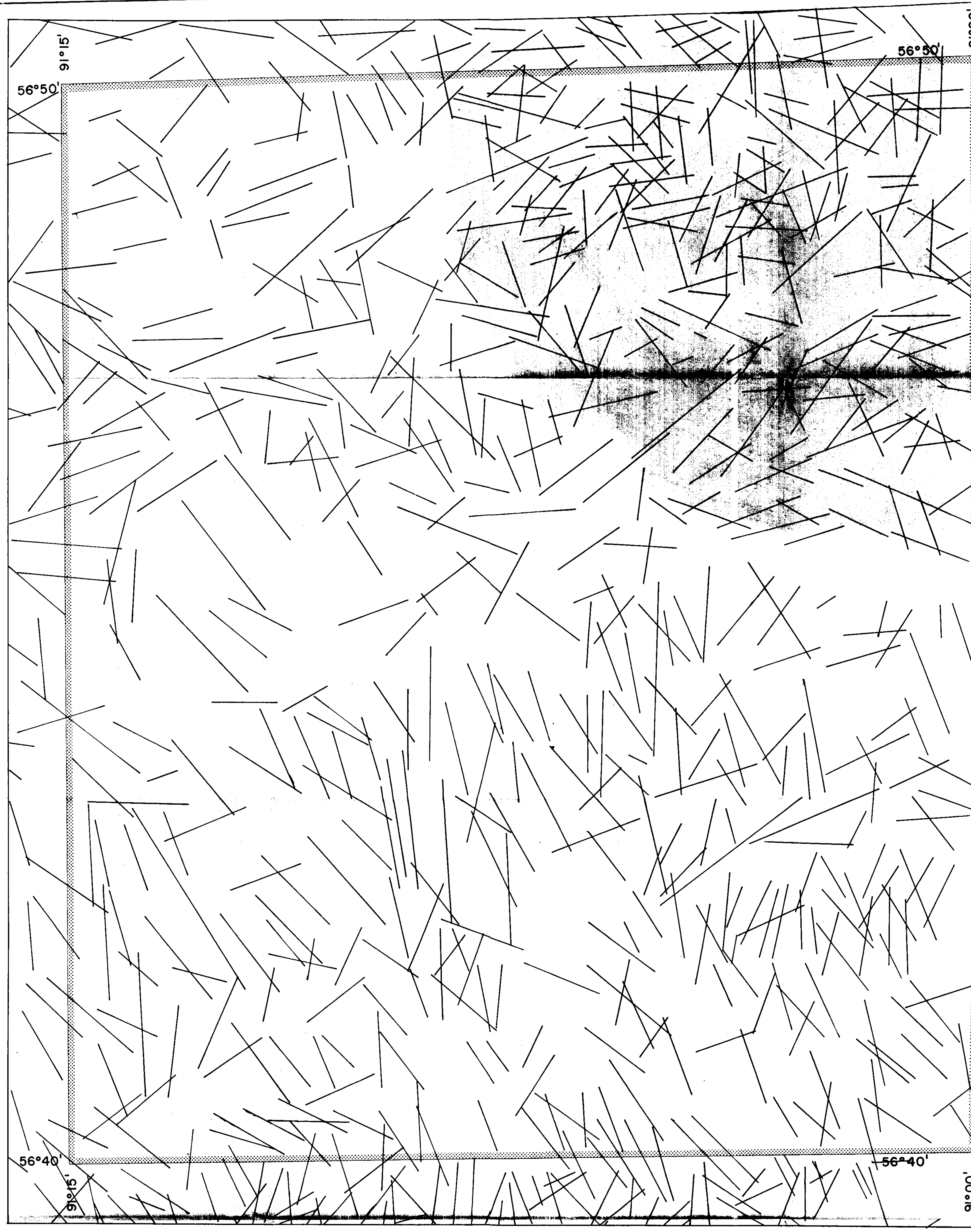
GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 49

MEGA FRACTURE PATTERN

SCALE : 1.5" = 1 MI.



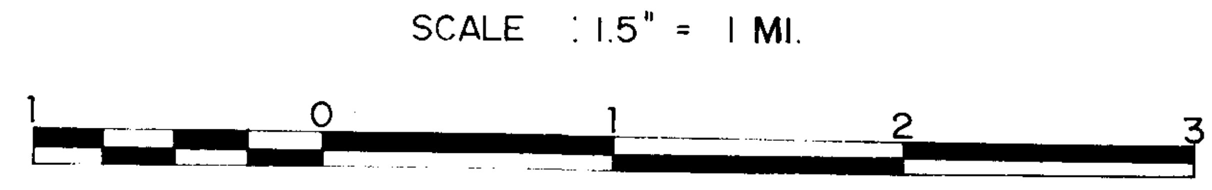


GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 49

TOTAL FRACTURE PATTERN

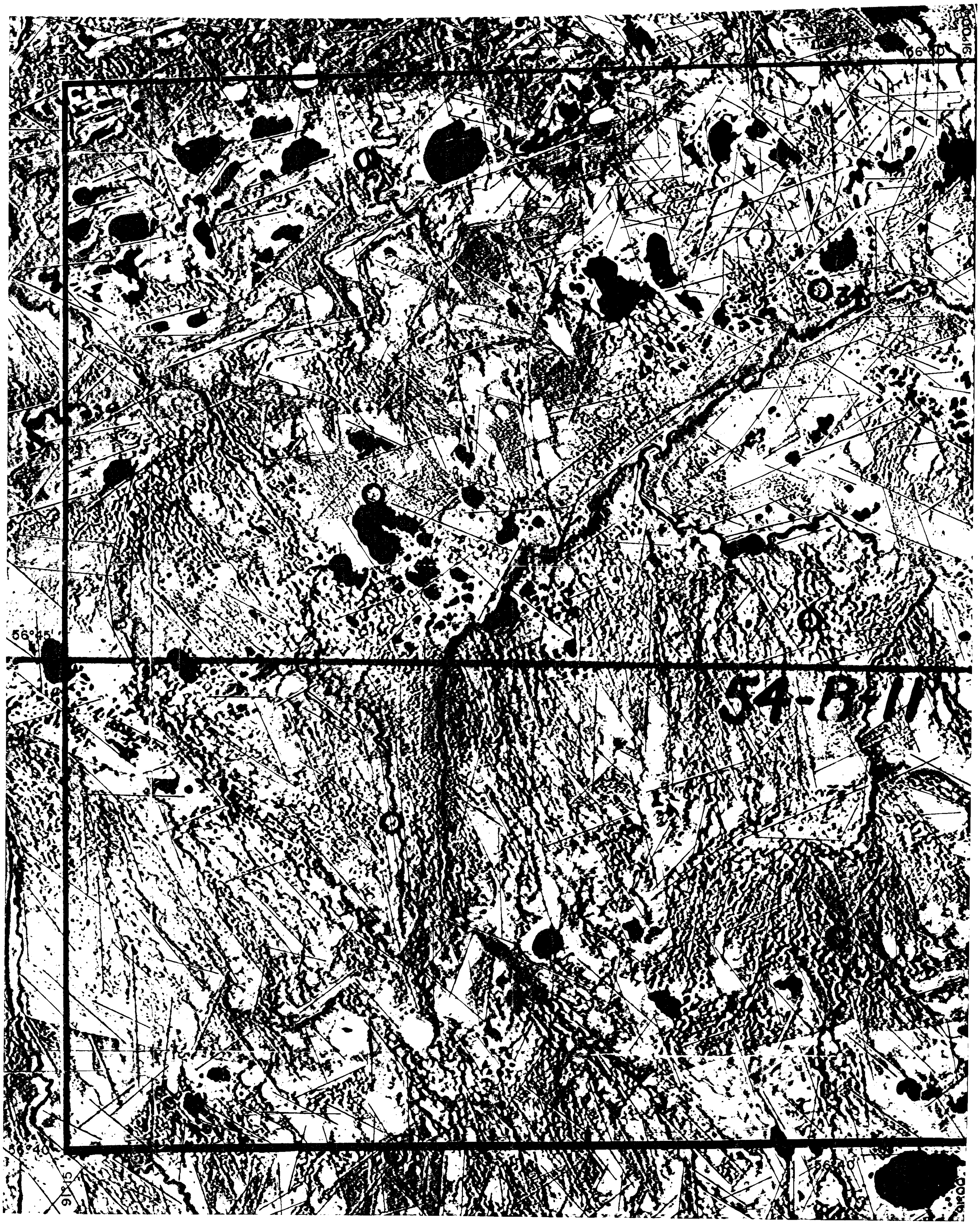
SCALE : 1.5" = 1 MI.



LOW DENSITY

NORMAL DENSITY

HIGH DENSITY



GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT NO. 49

HUDSON'S BAY LOWLANDS

MANITOBA

SCALE : 1.5" = 1 MI.

1 0 1 2 3

THIS IS A UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN

ACCURATE TOPOGRAPHIC MAP.

Exploration
Permit
No. 50

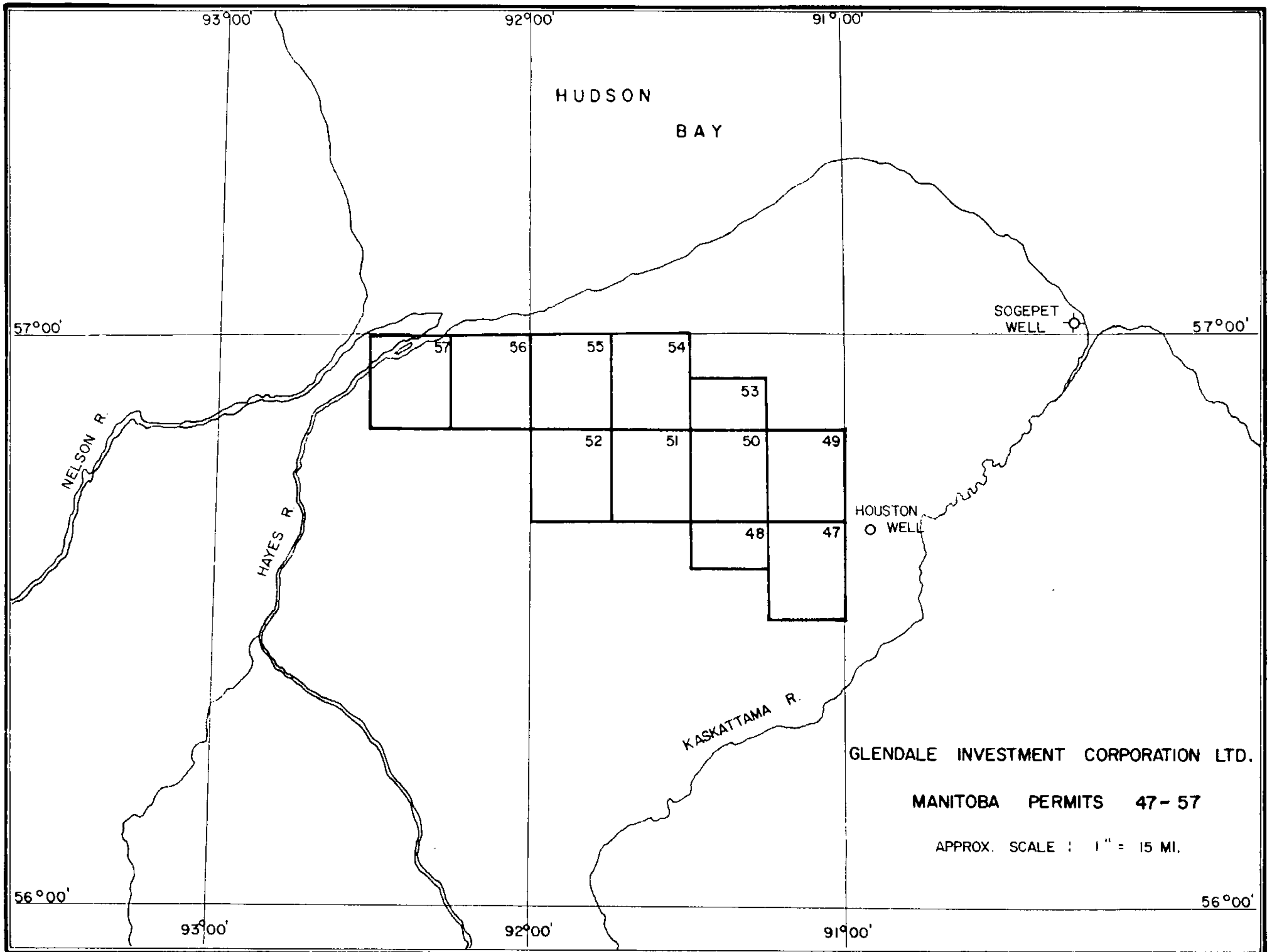
INTRODUCTION

This report discusses the results of a study of the General Geology, Stratigraphy and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 50, Manitoba. This permit is located between 56° 40' - 56° 50' latitude and 91° 15' - 91° 30' longitude. This is in the Hudson's Bay area of northeast Manitoba approximately 540 air miles north-northwest of Winnipeg. There are no roads within the area and the use of an aircraft is required to reach the area.

The stratigraphic discussion is based on information contained in published reports and on the limited data available from well control.

The Fracture Analysis Survey locates topographic highs and lows on the Basement surface. Areas of Basement "highs" are of great interest as it is felt that much reef growth (which is known to be present) is centered, or at least concentrated, over areas of Basement "highs".

Areas of Basement "lows" are of interest as Granite Wash sands tend to accumulate and attain considerable thickness in these "lows". Reefs and Granite Wash sands are probably the two principal reservoir horizons in this area.


93°00'
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56°00'
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GLENDALE INVESTMENT CORPORATION LTD.
MANITOBA PERMITS 47 - 57
APPROX. SCALE : 1" = 15 MI.

STRATIGRAPHY

The subject acreage, which is located one to 50 miles south of the Hudson Bay shoreline near York Factory in Manitoba, is primarily covered by muskeg with numerous small rivers, and streams present. Access to the area is provided by the Canadian National Railway line running into Port Nelson and also by ocean ships to the same point. Subsurface control will be provided by the Sogepet-Aquitane-Kaskattama # 1 well when it is released. It is located some 30 miles east of the northeast corner of the acreage. Recently Houston et al Comeault Sth Prov. # 1, located at about 56° 40' and 90° 52' has been licenced. This location, which is some 5 miles east of the acreage, will provide additional valuable subsurface information about this area. Outcrop information is extremely scarce in this area with only some talus being noted near York Factory along the north side of the acreage and along the Kaskattama River, which lies along the south and east side of the acreage. The main outcrop data has to be projected into this area from sections found on the Severn River, which is 110 miles southeast

of the acreage. The Nelson River which is approximately 50 miles northwest of the acreage is another outcrop area. Ordovician rocks are exposed along Gods River, 30 miles south of the western portion of the area under discussion. Beds ranging in age from Upper Ordovician to Upper Silurian are expected to be present beneath the land under review.

ORDOVICIAN

BAD CACHE RAPIDS GROUP

PORTAGE CHUTE FORMATION

The type section of the Portage Chute formation is located on the Churchill River, 100 miles northwest of the acreage. Outcrops are also present on the Nelson River approximately 50 miles west of the area, as well as on the Sachigo and Severn Rivers which lie to the south. The formation was defined by Nelson as overlying peneplaned Pre-Cambrian rocks, and in turn being conformably overlain by the Surprise Creek formation. The Portage Chute formation, which is 75 feet thick at the type section, consists of a four foot basal quartz sandstone which is generally quite uniform, tight and calcareous. This sand is also

present at the other outcrop sections mentioned above. The sand grades upwards into grey to buff, weathering light grey, partially dolomitic, microcrystalline, laminated limestones. Skeletal debris is quite abundant. At the type section the limestone section is 71 feet thick. The thickness of the Portage Chute formation on the Nelson River is approximately 25 feet, while at the Severn River exposures it is only about ten feet thick. The formation dips easterly with an increasing rate of dip as one proceeds basinward along the outcrop sections. Fossils consist mainly of a variety of corals and molluscans with some trilobites present. The limestone takes on a nodular appearance in weathered sections.

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The type section of the Surprise Creek formation was defined by Nelson as being located at Surprise Creek on the Churchill River. It is also present at the Nelson River section but not further south. Nelson considered the Surprise Creek formation as late Ordovician in age. The type section consists of 63 1/2 feet of thinly bedded, light yellowish grey, micro to cryptocrystalline limestone. It ranges from slightly dolomitic, to dolomitic, and contains some lenses of chert. The Surprise Creek formation is disting-

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CHASM CREEK FORMATION

The Chasm Creek formation is found both along the Churchill and Nelson Rivers with the Churchill sections being the better one. The Chasm is also exposed at Gods River, some 30 miles south of the acreage. The Chasm is fairly similar to the underlying Caution Creek formation and is in conformable contact with it. At the type section it is about 180 feet thick. The basal 55 feet is a light yellowish grey to buff, microcrystalline, slightly dolomitic

limestone grading to an iron rich dolomite. It is very resistant and weathers to a yellow and orange massive bed. This unit is overlain by about 100 feet of light grey, crypto to microcrystalline, slightly dolomitic to dolomitic limestone. The unit contains abundant fine organic fragments. Overlying this unit is a 5 to 15 foot thick bed of light grey, cryptocrystalline, dolomitic limestone which contains no organic material but has fine intercalations of finely fragmented limestone beds. The uppermost unit is ten to 20 feet thick, and is a light grey weathering, very dolomitic, microcrystalline unit which is strongly fucoidal. On the Nelson River the Chasm Creek section is a minimum of 15 feet thick with the maximum thickness unknown. It is lithologically similar to the type section as is the 38 foot thick section found on Gods River. The Chasm Creek formation contains a fauna comprised of corals, cephalopods and some brachiopods.

RED HEAD RAPIDS FORMATION

The Red Head Rapids formation is the uppermost Ordovician sediment found in this region and tye type section is located on the Churchill River where it overlies the Churchill River Group. The formation is a minimum of 42

feet thick with the maximum thickness unknown. Nelson notes that this formation may be Silurian in age. The lower 25 feet consist of light yellow, microcrystalline dolomitic which weathers a distinctive orange color. No fossils are present in this bed. The upper 17 feet is composed of grey to yellowish grey, microcrystalline dolomite, partially vuggy, which weathers to a grey color. This bed is also quite unfossiliferous. The Red Head Rapids is not present in outcrop on the Nelson, Gods, or Severn Rivers, but, it should be present in the subsurface of the acreage.

SILURIAN

PORT NELSON FORMATION

The type section of the Port Nelson formation is located on the Nelson River some 47 miles west of the acreage under review. The section exposed is 24 feet thick and consists of interbeds of brecciated dolomite, dolomite, and shaly dolomite. The dolomite is generally a gray micro to cryptocrystalline to occasionally granular rock with minor porosity. It contains a coral fauna and

is placed in the Middle Silurian. In the James Bay area a drill hole encountered 110+ feet of this formation. This unit should be found at subcrop under the southwestern portion of the acreage.

SEVERN RIVER FORMATION

The type section of this formation is found on the Severn River some 110 miles southeast of the acreage. The minimum thickness at the type section is 42 feet with the maximum unknown. The section consists of a basal 13 foot light grey, micro to cryptocrystalline limestone with rare vuggy porosity, and a suggestion of algal material. The middle unit consists of 4 feet of light yellowish grey, to orange buff, micro to finely crystalline algal limestone with good vuggy porosity. The upper unit is a 25 foot thick bed of cream to buff, partly microcrystalline to finely crystalline, chalky and partly organic limestone. Fine to coarse organic debris is present as well as beds of oolitic material. The Severn River formation appears to be present near Churchill in similar facies plus the notable fact that it has a strong bituminous odour from a fresh break in this area. This formation should also be present at subcrop under the southwest portion of the acreage.

EKWAN RIVER FORMATION

The type section of this formation is on the Ekwan River, which is in the James Bay area and lies some 350 miles southeast of the area under consideration. The section is from 73 to 88 feet thick and consists of grey, fine grained, partially cherty limestone containing corals and stromatoporoids. The section on Severn River is a minmum 37 feet thick with the maximum unknown. The basal 20 feet is composed of light medium brown, microcrystalline limestone with fine to coarse fossil fragments, some chert nodules and some oolitic material. The fossils consist of stromatoporoids, corals, brachiopods and cephalopods. Some poor intercrystalline and vuggy porosity is present. The middle 11 feet consists of yellowish brown, microcrystalline partially dolomitic, chalky limestone with some thin fragmental beds and rare brachiopods. The upper 6 feet is a light greyish brown, to creamy, microcrystalline limestone which is very highly and coarsely fragmental. The top section contains poor to good porosity. The Ekwan River formation is also exposed along the shore of Hudson Bay from the Mouth of Owl River to a point some 20 miles south of Cape Churchill. The Ekwan should be found to

subcrop along the western and central position of the subject acreage.

ATTAWAPISKAT FORMATION

The type section is located on the Attawapiskat River which lies some 40 miles south of the Ekwan River type section in the James Bay area. The formation outcrops on the Ekwan River, Severn River and along the tidal flats south from Cape Churchill.

The Ekwan River outcrop section consists of 54 feet of fine grained, thin bedded, coral reef limestone. Nelson has described a reefal and possible off reef facies for the Attawapiskat formation in general. The reef facies has a minimum thickness of 25 feet and is a cream, to orange cream, to buff, microcrystalline, fragmental limestone with corals and stromatoporoids being common. Porosity grades from tight to excellent and is vuggy. Nelson feels that some of the well bedded reefs are suggestive of biostromes, while other oval, domal reefs are believed to be bioherms. He noted a gassy odour at one location.

The off-reef facies is a minimum of 16 feet thick with uniform beds of cream, to partly yellowish cream, to grey microcrystalline limestone. There are abundant coarse granular, bioclastic beds which have excellent intergranular porosity which could be post reef deposits. The Attawapiskat outcrops south of Cape Churchill range in thickness from 25 to 50 feet in thickness, with both facies present and they are seen to grade laterally from one to the other. This formation should be at subcrop through the central portion of the acreage.

KENOGAMI RIVER FORMATION

The Kenogami River formation which has only been found in outcrop, in the James Bay represents the youngest Silurian found in the Hudson Bay Basin. The formation consists of an alternating series of shale, siltstone, sandstone, dolomite, silty dolomite, shaly limestone, and limestone. The colours mainly range from buff to grey, but, reds and greens are the colours of the clastics. The outcrop section has a minimum thickness of 300 feet while a well drilled on Puskwuine Point in James Bay had a thickness of 862 feet. The Kenogami River formation is

expected to subcrop along the eastern half of the acreage under review.

DEVONIAN

Rocks of Devonian age are not expected to be present under the area covered by the permit, however, they should be present at subcrop east of the acreage, at and near the Sogepet-Aquitaine-Kaskattama # I well where total depth was reached at 2,941 feet in granite.

CRETACEOUS

Rocks of Cretaceous age are know only in the James Bay area and are not expected to be present under the permits.

FRACTURE ANALYSIS

This section of the report discusses the results of a Detailed Fracture Analysis Survey carried out on the area under discussion. An aerial mosaic (scale 1.5 inches equals approximately 1 mile) made from Dominion Government aerial photographs accompanies this report. These same photographs were examined stereoscopically and the fractures plotted on the individual photographs, then transferred to the mosaic for analysis.

The theory that the earth's crust is abundantly and methodically fractured is the basic premise on which is built the exploration technique known as Fracture Analysis. A Fracture is defined as"...generally abundant, natural lineation discernible on aerial photographs".

Fracturing is largely caused by external stresses on the surface. The most important are:

(a) earth tides

(b) radial acceleration of the earth along its radius vector.

(c) a gradual decrease of the earth's rate of rotation.

As stated above, the earth is systematically fractured and the fracture system would approach symmetry if the crust were homogeneous. It is considered that irregularities are caused by regional heterogeneous conditions within the earth's crust. Local departures from the norm are caused by structural or stratigraphic anomalies.

The term "photogeophysics" was introduced by Blanchet (1956) and deals with mapping, analysis and interpretation of fracture traces as recorded on aerial photographs. In a more general way "photogeophysics" can be defined as the methodical statistical analysis of linear features seen on aerial photographs and this system is applied by any method recording all observable lineations, or the totality of a certain type of linear feature, and the statistical presentation of the data on contoured intensity maps of dry plotting the fractures directly on the mosaic.

In this report a megafracture is longer than one mile and a microfracture is shorter than one mile.

GENERAL STATEMENT

ORIGIN OF FRACTURES

Fracturing is largely caused by external stresses on the earth, although internal stresses may play some minor roll. The most important of these external forces are the diurnal earth tides due to the gravitational effects of the sun and moon; the change in radial acceleration of the earth along its radius vector and the gradual decrease in the earth's rate of rotation. The endless rhythemic action of these earth tides is probably the principal cause of the systematic fracture system seen over most of the world, even though the amplitude of these tides is only 9-13 inches. The fractures are most likely generated by the process of fatigue as the end result of these stresses which are repeated regularly over millions and millions of years. Metals fatigue in the same manner when subjected to continual vibration.

In general the initiating forces which generate fractures must have continued for a very long time and

the process involved are continuous and are probably active at the present time. Furthermore, Mollard (1957) states, "The mechanism required to reflect lineaments to ground surface must be reasonably simple, for simple patterns are produced on diverse topography and in diverse types and depths of surficial deposits that overlie different kinds of relatively flat-lying sedimentary rocks of varying thickness. The mechanism producing the lineament pattern must persist over extensive and widespread belts of the earth's outer shell; that is today, the engendering mechanism in fact be world wide".

External forces such as earth tides obviously fit these parameters. Some internal forces may also apply such as the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

In general it can be said that fracture patterns are caused by either internal forces or external forces.

If the forces are internal the result would be different orientation of the fracture systems in areas of similar tectonic history but different position. If the forces are external the orientation of the fracture arrangement should have world wide similarity. However, stable areas such as the masses of the continents may develop fracture patterns due to external forces and tectonically active areas may develop their own pattern due to internal forces.

If joints form early in the history of a sediment then systematic joints must be successively younger upwards through the section and the joint pattern is imposed on each new layer of sediments when they have become consolidated enough to fracture. This upward propagation is caused by the fatigue caused by stress, which in turn is caused by diurnal earth tides.

EXPRESSION OF FRACTURE

Fractures have been observed in aerial photographs from every climate and on every continent in the world. They are expressed as topographic relief, vegetation

differences and soil tonal differences.

TOPOGRAPHIC RELIEF LINEAMENTS

A common type are relief lineaments which can be manifested by a change (usually abrupt) of topographic elevation on either side of a relatively straight line. They may also be expressed as straight valleys or hills or by straight streams where the stream course is controlled by a fracture zone.

VEGETAL LINEAMENTS

Vegetal lineaments are the most common in the parkland and muskeg areas of western Canada and many excellent examples of fractures can be seen on almost any aerial photograph of northern Saskatchewan, Alberta or British Columbia. Straight lines of both deciduous and evergreen trees as well as scrub growth are universally visible. However, the most common vegetal lineament seen by this writer is a straight "edge" to a clump of trees or bushes. In many cases these fractures control the size and

shape of cultivated fields. Excellent examples of this latter expression of fractures are present in the western part of the Peace River district.

SOIL TONAL LINEAMENTS

These reflect differentiation in soil moisture and general ground water conditions. These are common in the southern parts of Alberta and Saskatchewan, especially near large rivers.

Surface investigations have shown that fractures are associated with bedrock joints; however, in glaciated areas such as western Canada, the photoanalyst must take care to establish the direction of ice flow over an area before he begins to statistically plot and analyse the fractures. Most areas in western Canada show an abundance of grooves and flutes caused by the glacier and these must not be mistaken for fracture traces caused by subsurface structural conditions. In parts of the Lloydminster area of eastern Alberta the glacial scars are so deeply impressed on the surface that fracture analysis is at best difficult and

often impossible.

INTERPRETATION OF FRACTURE DATA

The object of Fracture Analysis (Photogeophysics) is to locate shallow to deep-seated structural and stratigraphic anomalies. The actual count of fractures per unit area is made and values are contoured on a "Fracture Intensity Map". In areas of known reefs the fracture intensity is 2-3 times greater on the flanks of the reef than directly above the reef.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general the two systems are at approximate right angles to each other.

Because of certain inherent limiting factors, Structure Incidence Surveys have a lower order of reliability than Detailed Fracture Analysis Surveys. To some extent at least, surface conditions affect the fracture count. In areas

covered by lakes, sloughs and rivers, the fracture count is zero. Cultivated areas generally yield a lower count than adjacent virgin territory. Consequently, a difference or contrast in fracture count (F/I) between two points may be in part due to structure, but, also due in part to different surface conditions. To some extent, this can be compensated for by applying appropriate weightings to the observed counts, but over or under corrections may result.

Nevertheless, in spite of these sources or error, it has been demonstrated in (plains) areas where abundant subsurface control is available, that the incidence of fracturing is considerably above normal in the surrounding area immediately out from the steepest part of the flanks of the structure. This is in contrast with a low or normal incidence over the crestal area, and also to a normal incidence off structure.

FRACTURE ANALYSIS OF PERMIT NO. 50

The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permits. The Permit is located in the muskeg area south of Hudson Bay and is hundreds of miles from the closest settlement.

The sedimentary section is probably about 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There is one area where the fracture intensity is greater than normal and there is one area where the fracture intensity is less than normal. The high intensity area is shown in red and the low intensity area is shown in green. The average length of the fractures is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to mention the glacial problem in this area.

Reference to the mosaic will show that the area is moderately scarred with glacial grooves and striations and that the direction of ice flow was about north 30 degrees east. Some of these grooves are so deeply impressed on the surface that they control the shape of the lakes and of tree growth in the area. In any area such as this the photoanalyst is faced with the difficult problem of eliminating the glacial scars from the fracture pattern without creating false anomalies. The removal of all fractures from a 10-12 degree arc in any area will create fracture anomalies and it requires delicate weighting of the whole pattern to adjust for these effects.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general, the two systems are at approximate right angles to each other. Within Petroleum & Natural Gas Permit No. 50 the statistical mean direction of the axial system is north 40 degrees west and the statistical mean direction of the shear system is north 30 degrees east. A third minor system, here termed the sub-axial system, trends nearly north-south.

No regional fractures of great length can be seen and as these are conceded to originate within the Basement, it is assumed that all fractures plotted on the mosaic originate within the sedimentary section. Furthermore, as the fractures are short for this area it is very likely that they originate in the upper two-thrids of the sedimentary section. As the surface of the Permit is relatively flat-lying no azimuth correction is necessary for this study. It has been demonstrated that the low incidence anomalies on a mosaic are considerably larger than the subsurface feature which causes them.

There is one area on the mosaic where the fractures are less intense than the surrounding area. Some fractures are always present within these areas but they usually have a lower incidence than the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the next section of this report.

STRUCTURE

Petroleum and Natural Gas Permit No. 50 is located on the coastal plain on the south shore of Hudson Bay, 70 miles north of the edge of the Pre-Cambrian Shield.

Structural features which could be present and which could cause the low incidence anomalies mentioned in this report are discussed in order of probability.

(1) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No. 50 is thought to be much the same as it is today along the north edge of the Shield. Low rounded hills separated by gentle to abrupt valleys are seen on the Shield and these features are undoubtedly present under the subject Permit. The effect of this Basement relief on the overlying sedimentary rocks is often great. The Granite Wash sand is usually present in the topographic "lows" on the Basement but absent on the "highs". The Granite Wash is an excellent potential reservoir.

Further effects of Basement topography on beds higher than the Granite Wash is the gentle folding present over Basement hills. These folds are anticlines in every sense and could form traps for oil or gas.

(2) <u>REEFS</u>

Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. However, only small reefs have been found in outcrops near the Permit and such small masses as these probably do not greatly affect the fracture pattern.

(3) <u>TECTONIC FOLDING AND FAULTING</u>

The presence of tectonic folds is very unlikely, but some normal faulting could be present.

(4) TOPOGRAPHIC RELIEF ON AN INTRA-SEDIMENTARY UNCONFORMITY

Unconformity, is a possible source of fracture intensity anomalies, but within the Permit area it is unlikely that the relief on any unconformities within the sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there is one area of "high" fracture intensity, and one area of "low" fracture intensity (green). The general interpretation is that the low fracture intensity area is underlain by topographic highs on Basement. With this established, the deduction is that the Basement is high in the north and east side of Permit No. 50.

This Basement high feature is most interesting form the oil and gas point of view. The general shape of this feature is such that the causative feature must be a hill on the Basement surface. A fault is unlikely as the causative feature as the high area is over one and one-half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Granite Wash sand is probably absent on the top of this high fracture area, but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Crook

WGC/jp

REFERENCES

NELSON S.J. &	1966: Geology of Hudson Bay Basin, Bull. Can. Petrol. Geol., Vol. 14, No. 4, pp. 520-578.
BOSTOCK H.H. CUMMING L.M. NORFORD B.S. NORRIS A.W. PRICE L.L. STANDFORD B.V.	Geology Hudson Bay Lowlands, Map 17-.1967, Geol. Surv. Can.
BLANCHET P.H.	1957: "Development of Fracture Analysis as Exploration Method", Amer. Assoc. Petrol. Geol. Bull., Vol. 41, No. 8, 1748-59
HAMAN P.J.	1964: "Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2

Granite Wash sand is probably absent on the top of this Basement topographic high; but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

WILLIAM G. CROOK
Photoanalyst, P. Geol.

WGC/jp

GLENDALE INVESTMENT CORPORATION LTD.

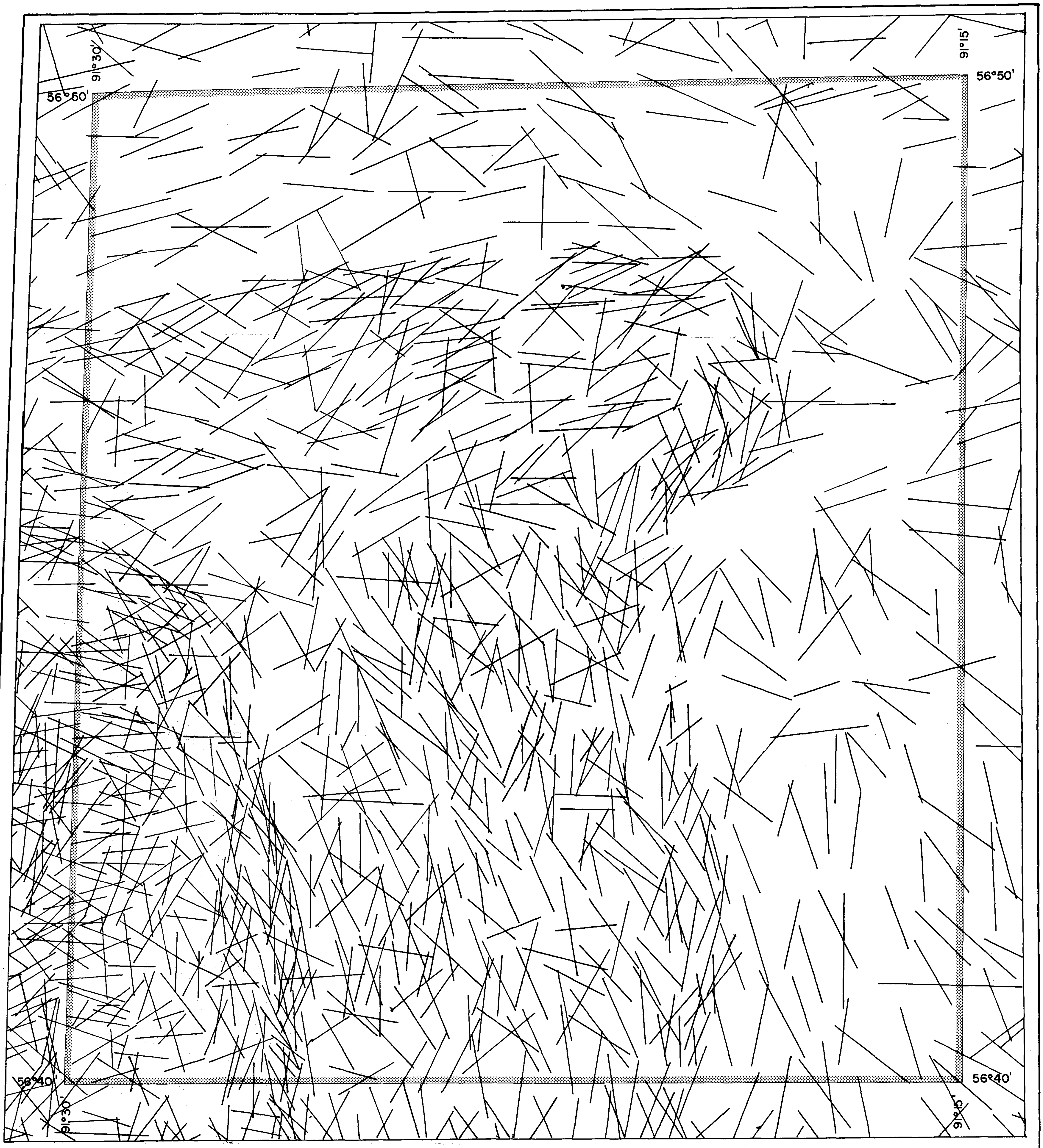
P. & N.G. PERMIT NO. 50

HUDSON'S BAY LOWLANDS
MANITOBA

SCALE: 1.5" = 1 MI.

1 0 1 2 3

THIS IS A UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN ACCURATE TOPOGRAPHIC MAP.

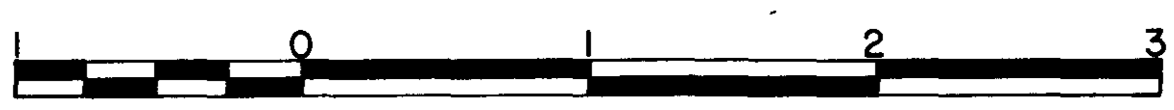


GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT NO. 50

TOTAL FRACTURE PATTERN

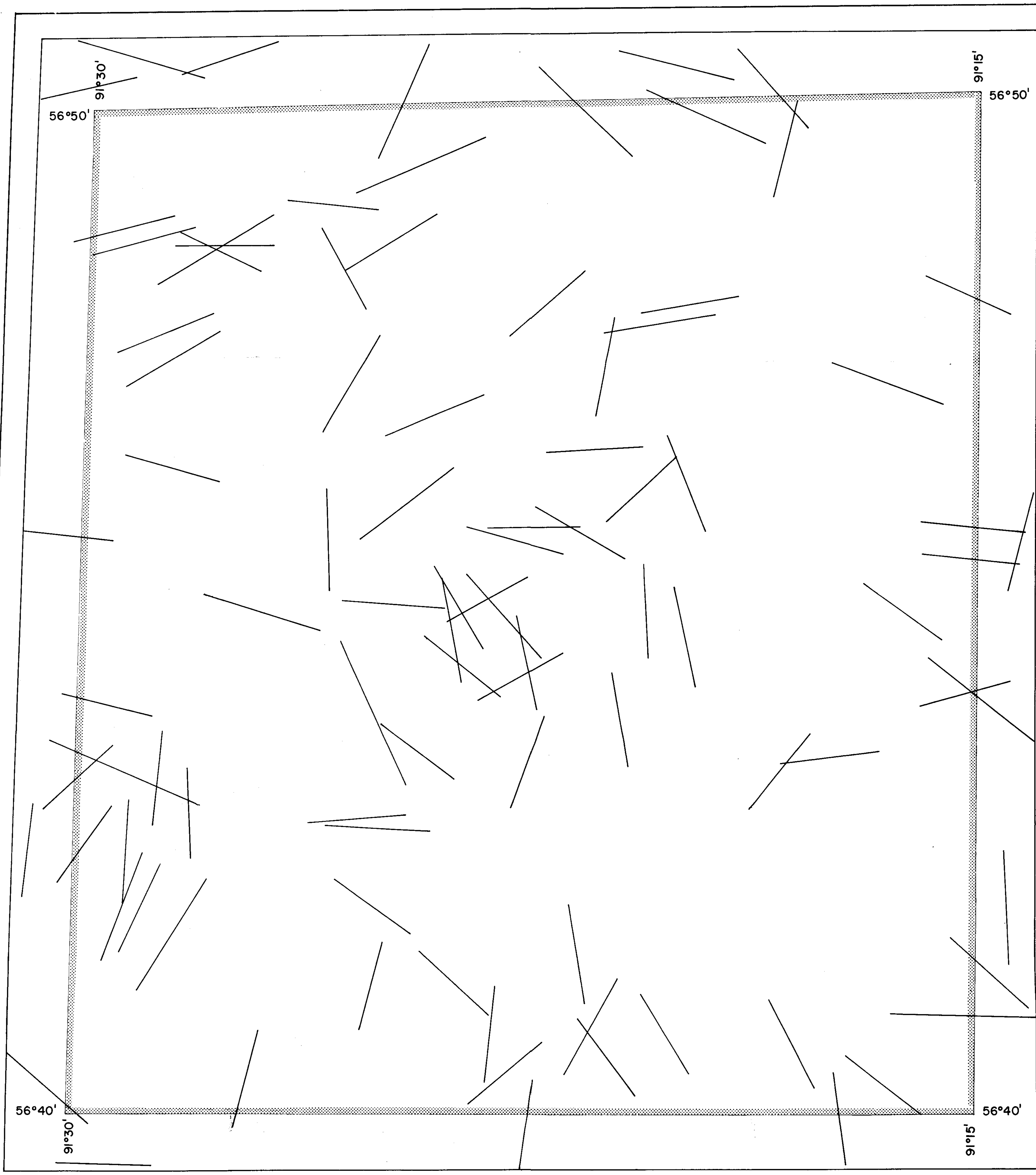
SCALE : 1.5" = 1 MI.



LOW DENSITY

NORMAL DENSITY

HIGH DENSITY

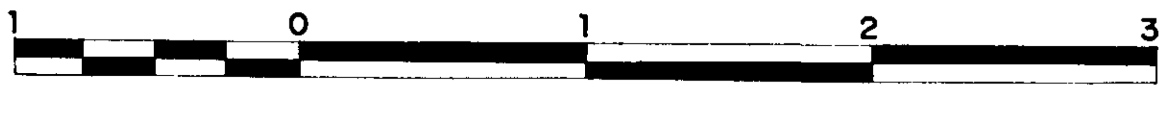


GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 50

MEGA FRACTURE PATTERN

SCALE : 1.5" = 1 MI.



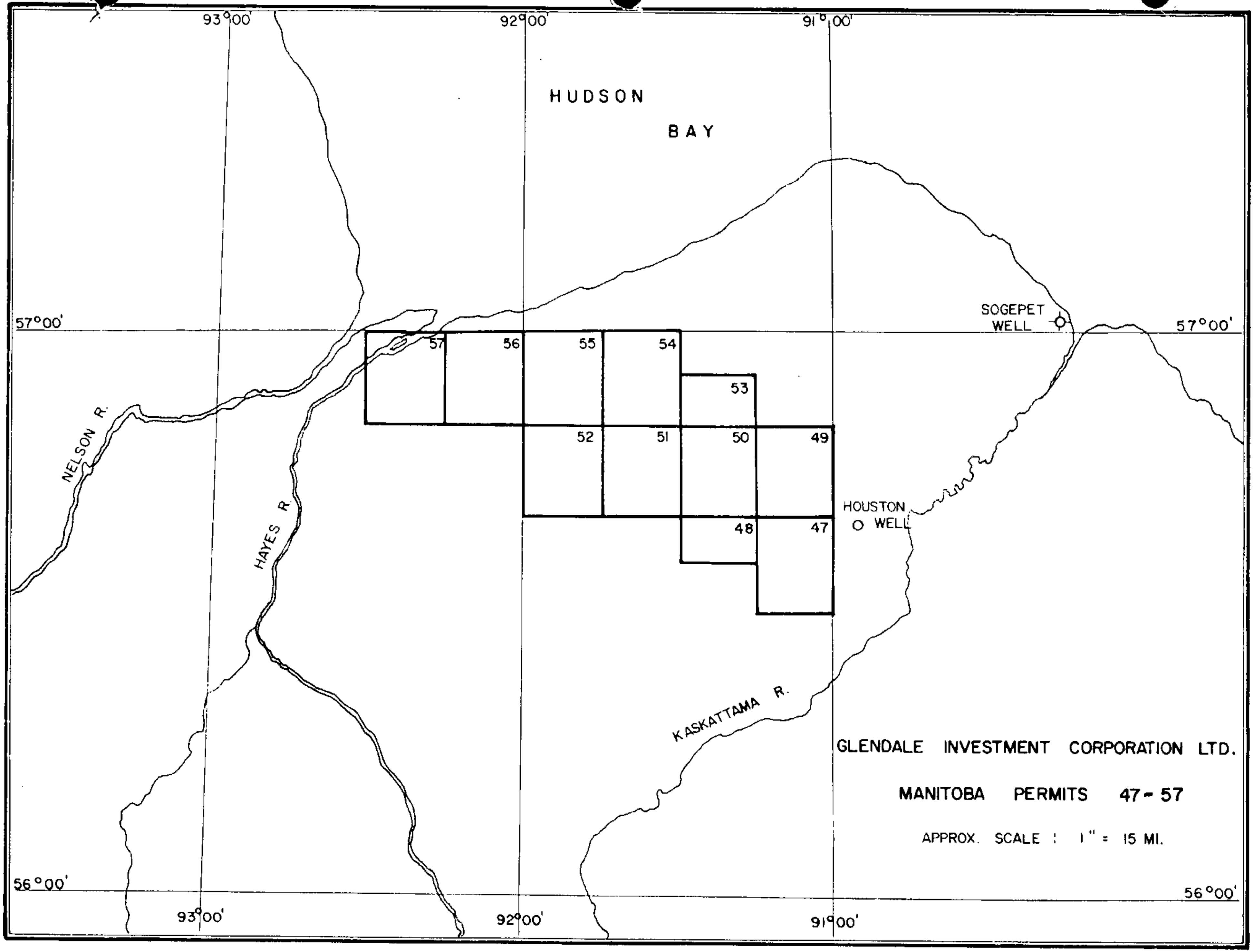
Exploration Permit No. 51

INTRODUCTION

This report discusses the results of a study of the General Geology, Stratigraphy and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 51, Manitoba. This permit is located between 56° 40' - 56° 50' latitude and 91° 30' - 91° 45' longitude. This is in the Hudson's Bay area of northeast Manitoba approximately 540 air miles north-northwest of Winnipeg. There are no roads within the area and the use of an aircraft is required to reach the area.

The stratigraphic discussion is based on information contained in published reports and on the limited data available from well control.

The Fracture Analysis Survey locates topographic highs and lows on the Basement surface. Areas of Basement "highs" are of great interest as it is felt that much reef growth (which is known to be present) is centered, or at least concentrated, over areas of Basement "highs".



HUDSON
BAY
93°00'
92°00'
91°00'
57°00'
56°00'
SOGEPET WELL
HOUSTON WELL
NELSON R.
HAYES R.
KASKATTAMA R.
57
56
55
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47
GLENDALE INVESTMENT CORPORATION LTD.
MANITOBA PERMITS 47 - 57
APPROX. SCALE : 1" = 15 MI.

Areas of Basement "lows" are of interest as Granite Wash sands tend to accumulate and attain considerable thickness in these "lows". Reefs and Granite Wash sands are probably the two principal reservoir horizons in this area.

STRATIGRAPHY

The subject acreage, which is located one to 50 miles south of the Hudson Bay shoreline near York Factory in Manitoba, is primarily covered by muskeg with numerous small rivers, and streams present. Access to the area is provided by the Canadian National Railway line running into Port Nelson and also by ocean ships to the same point. Subsurface control will be provided by the Sogepet-Aquitane-Kaskattama # 1 well when it is released. It is located some 30 miles east of the northeast corner of the acreage. Recently Houston et al Comeault Sth Prov. # 1, located at about 56° 40' and 90° 52' has been licenced. This location, which is some 5 miles east of the acreage, will provide additional valuable subsurface information about this area. Outcrop information is extremely scarce in this area with only some talus being noted near York Factory along the north side of the acreage and along the Kaskattama River, which lies along the south and east side of the acreage. The main outcrop data has to be projected into this area from sections found on the Severn River, which is 110 miles southeast

of the acreage. The Nelson River which is approximately 50 miles northwest of the acreage is another outcrop area. Ordovician rocks are exposed along Gods River, 30 miles south of the western portion of the area under discussion. Beds ranging in age from Upper Ordovician to Upper Silurian are expected to be present beneath the land under review.

ORDOVICIAN

BAD CACHE RAPIDS GROUP

PORTAGE CHUTE FORMATION

The type section of the Portage Chute formation is located on the Churchill River, 100 miles northwest of the acreage. Outcrops are also present on the Nelson River approximately 50 miles west of the area, as well as on the Sachigo and Severn Rivers which lie to the south. The formation was defined by Nelson as overlying peneplaned Pre-Cambrian rocks, and in turn being conformably overlain by the Surprise Creek formation. The Portage Chute formation, which is 75 feet thick at the type section, consists of a four foot basal quartz sandstone which is generally quite uniform, tight and calcareous. This sand is also

present at the other outcrop sections mentioned above. The sand grades upwards into grey to buff, weathering light grey, partially dolomitic, microcrystalline, laminated limestones. Skeletal debris is quite abundant. At the type section the limestone section is 71 feet thick. The thickness of the Portage Chute formation on the Nelson River is approximately 25 feet, while at the Severn River exposures it is only about ten feet thick. The formation dips easterly with an increasing rate of dip as one proceeds basinward along the outcrop sections. Fossils consist mainly of a variety of corals and molluscans with some trilobites present. The limestone takes on a nodular appearance in weathered sections.

SURPRISE CREEK FORMATION

The type section of the Surprise Creek formation was defined by Nelson as being located at Surprise Creek on the Churchill River. It is also present at the Nelson River section but not further south. Nelson considered the Surprise Creek formation as late Ordovician in age. The type section consists of 63 1/2 feet of thinly bedded, light yellowish grey, micro to cryptocrystalline limestone. It ranges from slightly dolomitic, to dolomitic, and contains some lenses of chert. The Surprise Creek formation is disting-

uished from the underlying Portage Chute formation by its lack of organic fragments, and by its smooth weathering characteristics, as opposed to the nodular weathering of the Portage Chute formation. The exposures at Nelson River are poor and not easily correlated with the type section, but, they appear to be lithologically similar to the type section. The thickness is a minimum 30 feet and the fauna is composed mainly of brachiopods. The combined thickness of the Surprise Creek formation and Portage Chute formation at the Selco-Pennycutaway # 1, drill hole, which lies about 17 miles west of the acreage, was 300 $\pm$, indicating a rapid thickening of this group in a basinward direction.

CHURCHILL RIVER GROUP

CAUTION CREEK FORMATION

The type section of the Caution Creek formation is also found on the Churchill River. The type section was defined by Nelson to consist of a basal 18 foot bed of mainly grey to yellowish grey weathering, cryptocrystalline, slightly dolomite limestone, containing shell fragments. This

is overlain by an 18 foot bed of grey to brown weathering, crypto to microcrystalline, slightly dolomitic limestone with little organic remains. This bed weathers into smooth layers, whereas, the lower bed weathers into uneven rubbly beds. The uppermost bed consists of six feet of grey, earthly weathering, micro to cryptocrystalline, slightly dolomitic limestone which has a nodular appearance on a weathered surface. The fauna consists of brachiopods, corals, and molluscans. The Caution Creek formation apparently does not outcrop on the Nelson River, but, it should be present in the subsurface of the subject acreage.

CHASM CREEK FORMATION

The Chasm Creek formation is found both along the Churchill and Nelson Rivers with the Churchill sections being the better one. The Chasm is also exposed at Gods River, some 30 miles south of the acreage. The Chasm is fairly similar to the underlying Caution Creek formation and is in conformable contact with it. At the type section it is about 180 feet thick. The basal 55 feet is a light yellowish grey to buff, microcrystalline, slightly dolomitic

limestone grading to an iron rich dolomite. It is very resistant and weathers to a yellow and orange massive bed. This unit is overlain by about 100 feet of light grey, crypto to microcrystalline, slightly dolomitic to dolomitic limestone. The unit contains abundant fine organic fragments. Overlying this unit is a 5 to 15 foot thick bed of light grey, cryptocrystalline, dolomitic limestone which contains no organic material but has fine intercalations of finely fragmented limestone beds. The uppermost unit is ten to 20 feet thick, and is a light grey weathering, very dolomitic, microcrystalline unit which is strongly fucoidal. On the Nelson River the Chasm Creek section is a minimum of 15 feet thick with the maximum thickness unknown. It is lithologically similar to the type section as is the 38 foot thick section found on Gods River. The Chasm Creek formation contains a fauna comprised of corals, cephalopods and some brachiopods.

RED HEAD RAPIDS FORMATION

The Red Head Rapids formation is the uppermost Ordovician sediment found in this region and tye type section is located on the Churchill River where it overlies the Churchill River Group. The formation is a minimum of 42

feet thick with the maximum thickness unknown. Nelson notes that this formation may be Silurian in age. The lower 25 feet consist of light yellow, microcrystalline dolomitic which weathers a distinctive orange color. No fossils are present in this bed. The upper 17 feet is composed of grey to yellowish grey, microcrystalline dolomite, partially vuggy, which weathers to a grey color. This bed is also quite unfossiliferous. The Red Head Rapids is not present in outcrop on the Nelson, Gods, or Severn Rivers, but, it should be present in the subsurface of the acreage.

SILURIAN

PORT NELSON FORMATION

The type section of the Port Nelson formation is located on the Nelson River some 47 miles west of the acreage under review. The section exposed is 24 feet thick and consists of interbeds of brecciated dolomite, dolomite, and shaly dolomite. The dolomite is generally a gray micro to cryptocrystalline to occasionally granular rock with minor porosity. It contains a coral fauna and

is placed in the Middle Silurian. In the James Bay area a drill hole encountered 110+ feet of this formation. This unit should be found at subcrop under the southwestern portion of the acreage.

SEVERN RIVER FORMATION

The type section of this formation is found on the Severn River some 110 miles southeast of the acreage. The minimum thickness at the type section is 42 feet with the maximum unknown. The section consists of a basal 13 foot light grey, micro to cryptocrystalline limestone with rare vuggy porosity, and a suggestion of algal material. The middle unit consists of 4 feet of light yellowish grey, to orange buff, micro to finely crystalline algal limestone with good vuggy porosity. The upper unit is a 25 foot thick bed of cream to buff, partly microcrystalline to finely crystalline, chalky and partly organic limestone. Fine to coarse organic debris is present as well as beds of oolitic material. The Severn River formation appears to be present near Churchill in similar facies plus the notable fact that it has a strong bituminous odour from a fresh break in this area. This formation should also be present at subcrop under the southwest portion of the acreage.

EKWAN RIVER FORMATION

The type section of this formation is on the Ekwan River, which is in the James Bay area and lies some 350 miles southeast of the area under consideration. The section is from 73 to 88 feet thick and consists of grey, fine grained, partially cherty limestone containing corals and stromatoporoids. The section on Severn River is a minmum 37 feet thick with the maximum unknown. The basal 20 feet is composed of light medium brown, microcrystalline limestone with fine to coarse fossil fragments, some chert nodules and some oolitic material. The fossils consist of stromatoporoids, corals, brachiopods and cephalopods. Some poor intercrystalline and vuggy porosity is present. The middle 11 feet consists of yellowish brown, microcrystalline partially dolomitic, chalky limestone with some thin fragmental beds and rare brachiopods. The upper 6 feet is a light greyish brown, to creamy, microcrystalline limestone which is very highly and coarsely fragmental. The top section contains poor to good porosity. The Ekwan River formation is also exposed along the shore of Hudson Bay from the Mouth of Owl River to a point some 20 miles south of Cape Churchill. The Ekwan should be found to

subcrop along the western and central position of the subject acreage.

ATTAWAPISKAT FORMATION

The type section is located on the Attawapiskat River which lies some 40 miles south of the Ekwan River type section in the James Bay area. The formation outcrops on the Ekwan River, Severn River and along the tidal flats south from Cape Churchill.

The Ekwan River outcrop section consists of 54 feet of fine grained, thin bedded, coral reef limestone. Nelson has described a reefal and possible off reef facies for the Attawapiskat formation in general. The reef facies has a minimum thickness of 25 feet and is a cream, to orange cream, to buff, microcrystalline, fragmental limestone with corals and stromatoporoids being common. Porosity grades from tight to excellent and is vuggy. Nelson feels that some of the well bedded reefs are suggestive of biostromes, while other oval, domal reefs are believed to be bioherms. He noted a gassy odour at one location.

The off-reef facies is a minimum of 16 feet thick with uniform beds of cream, to partly yellowish cream, to grey microcrystalline limestone. There are abundant coarse granular, bioclastic beds which have excellent intergranular porosity which could be post reef deposits. The Attawapiskat outcrops south of Cape Churchill range in thickness from 25 to 50 feet in thickness, with both facies present and they are seen to grade laterally from one to the other. This formation should be at subcrop through the central portion of the acreage.

KENOGAMI RIVER FORMATION

The Kenogami River formation which has only been found in outcrop, in the James Bay represents the youngest Silurian found in the Hudson Bay Basin. The formation consists of an alternating series of shale, siltstone, sandstone, dolomite, silty dolomite, shaly limestone, and limestone. The colours mainly range from buff to grey, but, reds and greens are the colours of the clastics. The outcrop section has a minimum thickness of 300 feet while a well drilled on Puskwuine Point in James Bay had a thickness of 862 feet. The Kenogami River formation is

expected to subcrop along the eastern half of the acreage under review.

DEVONIAN

Rocks of Devonian age are not expected to be present under the area covered by the permit, however, they should be present at subcrop east of the acreage, at and near the Sogepet-Aquitaine-Kaskattama # I well where total depth was reached at 2,941 feet in granite.

CRETACEOUS

Rocks of Cretaceous age are know only in the James Bay area and are not expected to be present under the permits.

FRACTURE ANALYSIS

This section of the report discusses the results of a Detailed Fracture Analysis Survey carried out on the area under discussion. An aerial mosaic (scale 1.5 inches equals approximately 1 mile) made from Dominion Government aerial photographs accompanies this report. These same photographs were examined stereoscopically and the fractures plotted on the individual photographs, then transferred to the mosaic for analysis.

The theory that the earth's crust is abundantly and methodically fractured is the basic premise on which is built the exploration technique known as Fracture Analysis. A Fracture is defined as"...generally abundant, natural lineation discernible on aerial photographs".

Fracturing is largely caused by external stresses on the surface. The most important are:

(a) earth tides

(b) radial acceleration of the earth along its radius vector.

(c) a gradual decrease of the earth's rate of rotation.

As stated above, the earth is systematically fractured and the fracture system would approach symmetry if the crust were homogeneous. It is considered that irregularities are caused by regional heterogeneous conditions within the earth's crust. Local departures from the norm are caused by structural or stratigraphic anomalies.

The term "photogeophysics" was introduced by Blanchet (1956) and deals with mapping, analysis and interpretation of fracture traces as recorded on aerial photographs. In a more general way "photogeophysics" can be defined as the methodical statistical analysis of linear features seen on aerial photographs and this system is applied by any method recording all observable lineations, or the totality of a certain type of linear feature, and the statistical presentation of the data on contoured intensity maps of dry plotting the fractures directly on the mosaic.

In this report a megafracture is longer than one mile and a microfracture is shorter than one mile.

GENERAL STATEMENT

ORIGIN OF FRACTURES

Fracturing is largely caused by external stresses on the earth, although internal stresses may play some minor roll. The most important of these external forces are the diurnal earth tides due to the gravitational effects of the sun and moon; the change in radial acceleration of the earth along its radius vector and the gradual decrease in the earth's rate of rotation. The endless rhythemic action of these earth tides is probably the principal cause of the systematic fracture system seen over most of the world, even though the amplitude of these tides is only 9-13 inches. The fractures are most likely generated by the process of fatigue as the end result of these stresses which are repeated regularly over millions and millions of years. Metals fatigue in the same manner when subjected to continual vibration.

In general the initiating forces which generate fractures must have continued for a very long time and

the process involved are continuous and are probably active at the present time. Furthermore, Mollard (1957) states, "The mechanism required to reflect lineaments to ground surface must be reasonably simple, for simple patterns are produced on diverse topography and in diverse types and depths of surficial deposits that overlie different kinds of relatively flat-lying sedimentary rocks of varying thickness. The mechanism producing the lineament pattern must persist over extensive and widespread belts of the earth's outer shell; that is today, the engendering mechanism in fact be world wide".

External forces such as earth tides obviously fit these parameters. Some internal forces may also apply such as the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

In general it can be said that fracture patterns are caused by either internal forces or external forces.

If the forces are internal the result would be different orientation of the fracture systems in areas of similar tectonic history but different position. If the forces are external the orientation of the fracture arrangement should have world wide similarity. However, stable areas such as the masses of the continents may develop fracture patterns due to external forces and tectonically active areas may develop their own pattern due to internal forces.

If joints form early in the history of a sediment then systematic joints must be successively younger up-wards through the section and the joint pattern is imposed on each new layer of sediments when they have become consolidated enough to fracture. This upward propagation is caused by the fatigue caused by stress, which in turn is caused by diurnal earth tides.

EXPRESSION OF FRACTURE

Fractures have been observed in aerial photographs from every climate and on every continent in the world. They are expressed as topographic relief, vegetation

differences and soil tonal differences.

TOPOGRAPHIC RELIEF LINEAMENTS

A common type are relief lineaments which can be manifested by a change (usually abrupt) of topographic elevation on either side of a relatively straight line. They may also be expressed as straight valleys or hills or by straight streams where the stream course is controlled by a fracture zone.

VEGETAL LINEAMENTS

Vegetal lineaments are the most common in the parkland and muskeg areas of western Canada and many excellent examples of fractures can be seen on almost any aerial photograph of northern Saskatchewan, Alberta or British Columbia. Straight lines of both deciduous and evergreen trees as well as scrub growth are universally visible. However, the most common vegetal lineament seen by this writer is a straight "edge" to a clump of trees or bushes. In many cases these fractures control the size and

shape of cultivated fields. Excellent examples of this latter expression of fractures are present in the western part of the Peace River district.

SOIL TONAL LINEAMENTS

These reflect differentiation in soil moisture and general ground water conditions. These are common in the southern parts of Alberta and Saskatchewan, especially near large rivers.

Surface investigations have shown that fractures are associated with bedrock joints; however, in glaciated areas such as western Canada, the photoanalyst must take care to establish the direction of ice flow over an area before he begins to statistically plot and analyse the fractures. Most areas in western Canada show an abundance of grooves and flutes caused by the glacier and these must not be mistaken for fracture traces caused by subsurface structural conditions. In parts of the Lloydminster area of eastern Alberta the glacial scars are so deeply impressed on the surface that fracture analysis is at best difficult and

often impossible.

INTERPRETATION OF FRACTURE DATA

The object of Fracture Analysis (Photogeophysics) is to locate shallow to deep-seated structural and stratigraphic anomalies. The actual count of fractures per unit area is made and values are contoured on a "Fracture Intensity Map". In areas of known reefs the fracture intensity is 2-3 times greater on the flanks of the reef than directly above the reef.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general the two systems are at approximate right angles to each other.

Because of certain inherent limiting factors, Structure Incidence Surveys have a lower order of reliability than Detailed Fracture Analysis Surveys. To some extent at least, surface conditions affect the fracture count. In areas

covered by lakes, sloughs and rivers, the fracture count is zero. Cultivated areas generally yield a lower count than adjacent virgin territory. Consequently, a difference or contrast in fracture count (F/I) between two points may be in part due to structure, but, also due in part to different surface conditions. To some extent, this can be compensated for by applying appropriate weightings to the observed counts, but over or under corrections may result.

Nevertheless, in spite of these sources or error, it has been demonstrated in (plains) areas where abundant subsurface control is available, that the incidence of fracturing is considerably above normal in the surrounding area immediately out from the steepest part of the flanks of the structure. This is in contrast with a low or normal incidence over the crestal area, and also to a normal incidence off structure.

FRACTURE ANALYSIS OF PERMIT NO. 51

The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permit. The Permit is located in the muskeg area along the south shore of Hudson Bay and is hundreds of miles from the closest settlement.

The sedimentary section is about 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There are two areas where the fractures intensity is greater than normal and there is one area where the fracture intensity is less than normal. The high intensity areas are shown in red and the low intensity area is shown in green. The average length of the fractures is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to mention the glacial problem in this area.

Reference to the mosaic will show that the area is moderately scarred with glacial grooves and striations and that the direction of ice flow was about north 20 degrees east. Some of these grooves are so deeply impressed on the surface that they control the shape of the lakes and of tree growth in the area. In any area such as this the photoanalyst is faced with the difficult problem of eliminating the glacial scars from the fracture pattern without creating false anomalies. The removal of all fractures from a 10 - 12 degree arc in any area will create fracture anomalies and it requires delicate weighting of the whole pattern to adjust for these effects.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general, the two systems are at approximate right angles to each other. Within Petroleum & Natural Gas Permit No. 51 the statistical mean direction of the axial system is north 40 degrees west and the statistical mean direction of the shear system is north 30 degrees east. A third minor system, here termed the sub-axial system, trends nearly north-south.

No regional fractures of great length can be seen and as these are conceded to originate within the Basement, it is assumed that all fractures plotted on the mosaic originate within the sedimentary section. Furthermore, as the fractures are short for this area it is very likely that they originate in the upper two-thirds of the sedimentary section. As the surface of the Permit is relatively flat-lying no azimuth correction is necessary for this study. It has been demonstrated that the low incidence anomalies on a mosaic are considerably larger than the subsurface feature which causes them.

There is one area on the mosaic where the fractures are less intense that the surrounding area. Some fractures are always present within these areas but they usually have a lower incidence than the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the next section of this report.

STRUCTURE

Petroleum and Natural Gas Permit No. 51 is located on the coastal plain on the south shore of Hudson's Bay, 70 miles north of the edge of the Pre-Cambrian Shield.

Structural features which could be present and which could cause the low incidence anomalies mentioned in this report are discussed in order of probability.

(1) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No. 51 is though to be much the same as it is today along the edge of the Shield. Low rounded hills separated by gentle to abrupt valleys are seen on the Shield and these features are undoubtedly present under the subject Permit. The effect of this Basement relief on the overlying sedimentary rocks is often great. The Granite Wash sand is usually present in the topographic "lows" on the Basement but absent on the "highs". The Granite Wash is an excellent potential reservoir.

Further effects of Basement topography on beds higher than the Granite Wash is the gentle folding present over Basement hills. These folds are anticlines in every sense and could form traps for oil or gas.

(2) REEFS

Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. However, only small reefs have been found in outcrops near the Permit and such small masses as these probably do not greatly affect the fracture pattern.

(3) TECTONIC FOLDING AND FAULTING

The presence of tectonic folds is very unlikely, but some normal faulting could be present.

(4) TOPOGRAPHIC RELIEF ON AN INTRA-SEDIMENTARY UNCONFORMITY

Unconformity, is a possible source of fracture intensity anomalies, but within the Permit area it is unlikely that the relief on any unconformities within the sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there are two areas of "high" fracture intensity, and one area of "low" fracture intensity (green). The general interpretation is that the low fracture intensity area is underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is high in the north part of Permit No. 51.

This Basement high feature is most interesting from the oil and gas point of view. The general shape of this feature is such that the causative feature must be a hill on the Basement surface. A fault is unlikely as the causative feature as the high area is over one and one-half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Granite Wash sand is probably absent on the top of this high fracture area, but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Crook

WGC/jp

REFERENCES

NELSON S.J. & — 1966: Geology of Hudson Bay Basin, Bull. Can. Petrol. Geol., Vol. 14, No. 4, pp. 520-578.

BOSTOCK H.H.	
CUMMING L.M.	
NORFORD B.S.	Geology Hudson Bay Lowlands,
NORRIS A.W.	Map 17-.1967, Geol. Surv. Can.
PRICE L.L.	
STANDFORD B.V.	

BLANCHET P.H. — 1957: "Development of Fracture Analysis as Exploration Method", Amer. Assoc. Petrol. Geol. Bull., Vol. 41, No. 8, 1748-59

HAMAN P.J. — 1964: "Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2

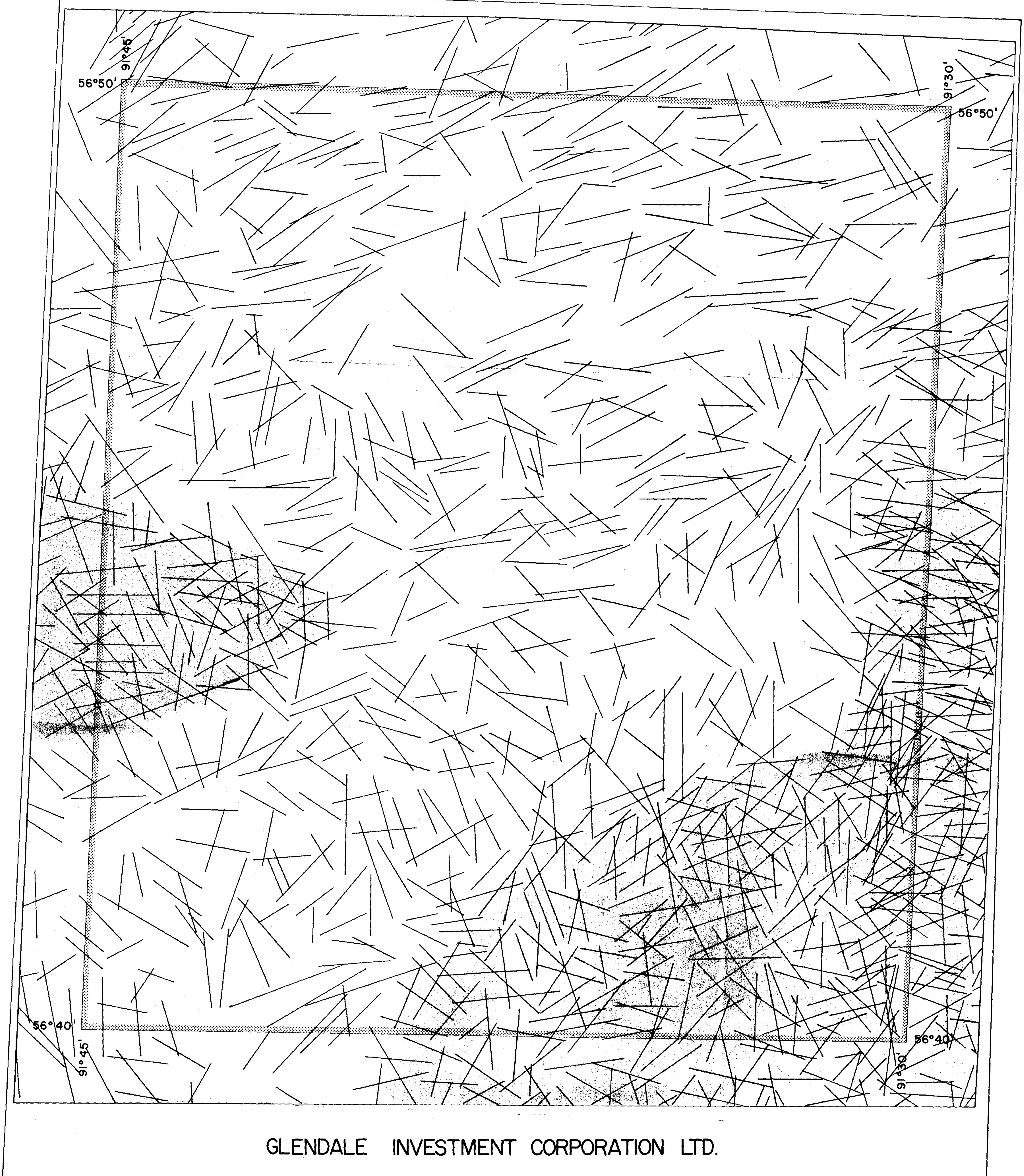
Granite Wash sand is probably absent on the top of this Basement topographic high; but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

WILLIAM G. CROOK
Photoanalyst, P. Geol.

WGC/jp

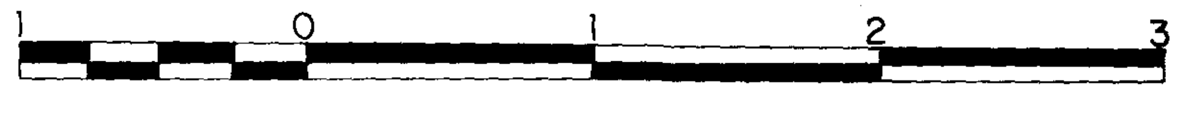


GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT NO. 51

TOTAL FRACTURE PATTERN

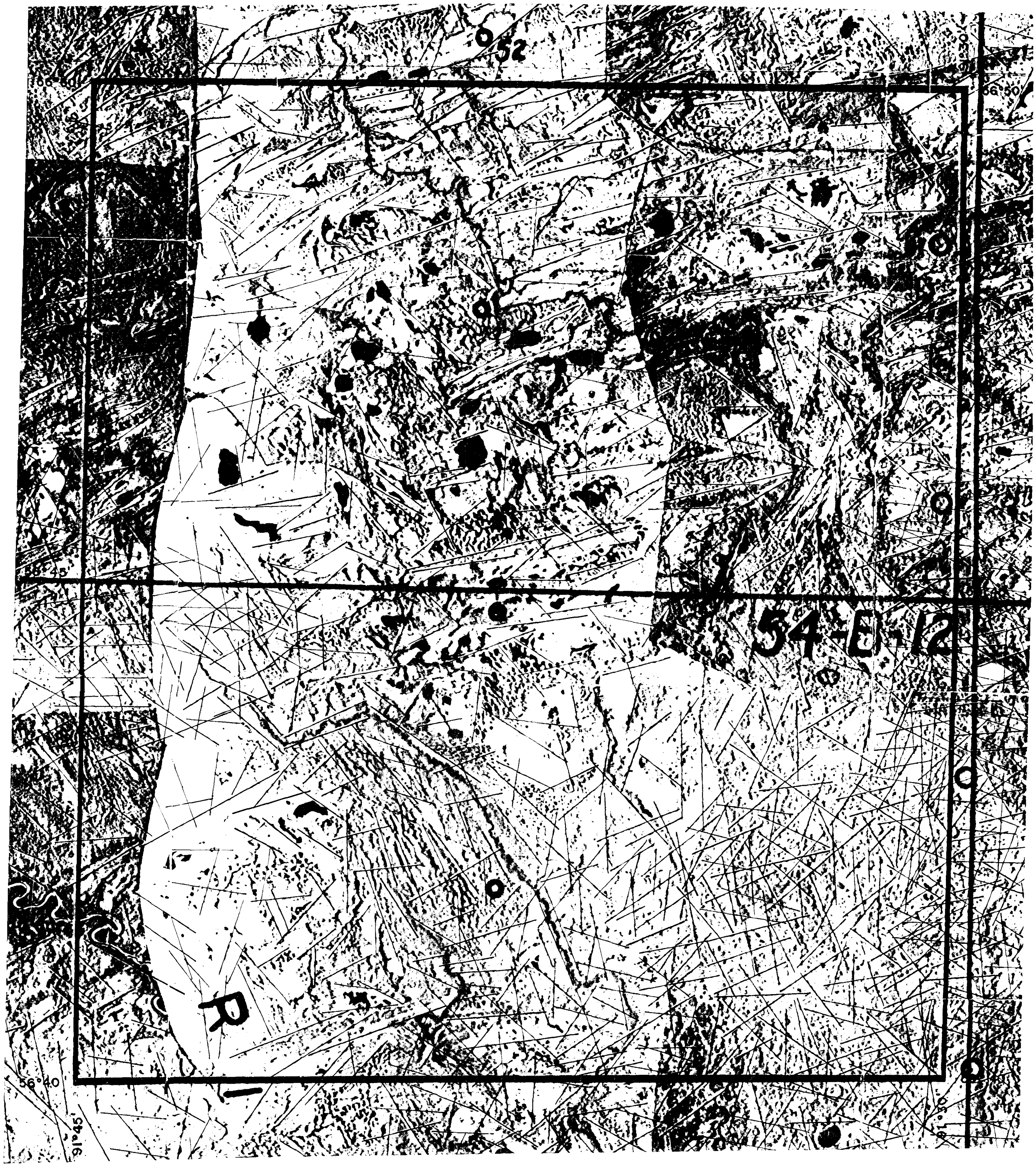
SCALE : 1.5" = 1 MI.



LOW DENSITY

NORMAL DENSITY

HIGH DENSITY



GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT NO. 51

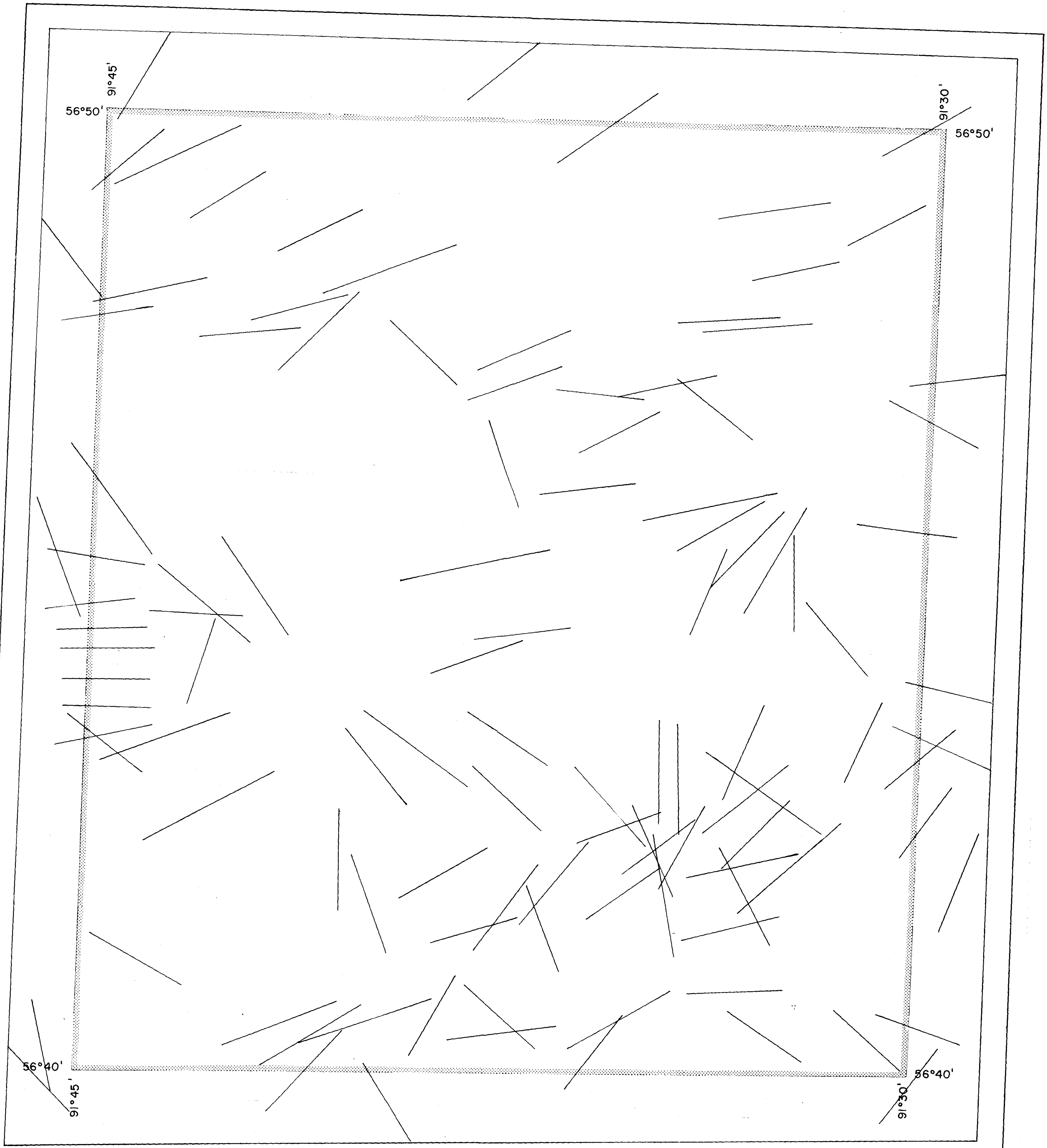
HUDSON'S BAY LOWLANDS

MANITOBA

SCALE: 1.5" = 1 MI.

1 0 1 2 3

THIS IS A UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN ACCURATE TOPOGRAPHIC MAP

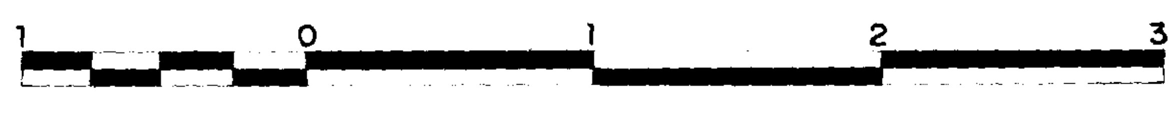


GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 51

MEGA FRACTURE PATTERN

SCALE : 1.5" = 1 MI.



Exploration Permit

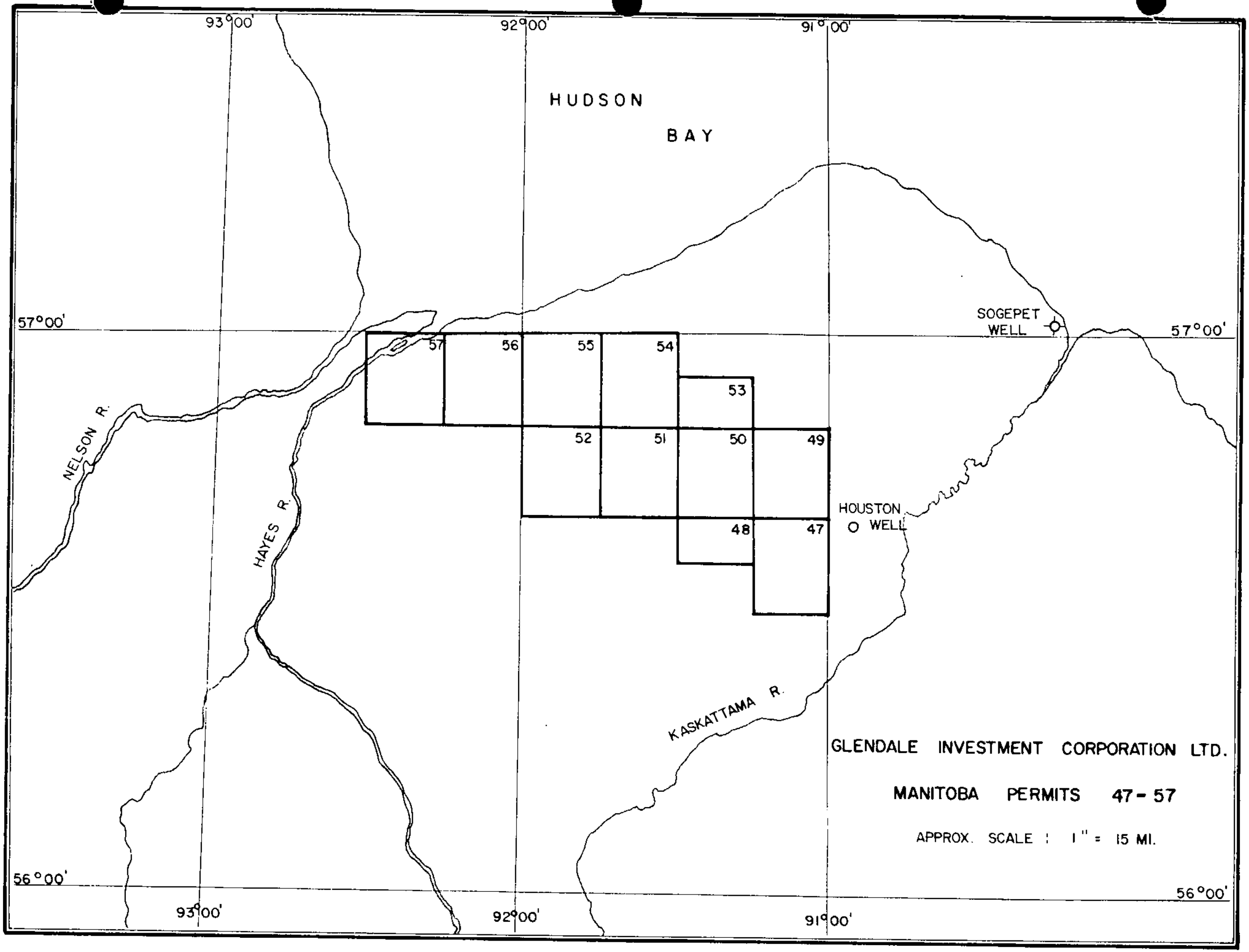
No. 52

INTRODUCTION

This report discusses the results of a study of the General Geology, Stratigraphy and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 52, Manitoba. This permit is located between 56° 40' - 56° 50' latitude and 91° 45' - 92° 00' longitude. This is in the Hudson's Bay area of northeast Manitoba approximately 540 air miles north-northwest of Winnipeg. There are no roads within the area and the use of an aircraft is required to reach the area.

The stratigraphic discussion is based on information contained in published reports and on the limited data available from well control.

The Fracture Analysis Survey locates topographic highs and lows on the Basement surface. Areas of Basement "highs" are of great interest as it is felt that much reef growth (which is known to be present) is centered, or at least concentrated, over areas of Basement "highs".



93°00'
92°00'
91°00'
HUDSON
BAY
57°00'
SOGEPET
WELL
57°00'
57
56
55
54
53
52
51
50
49
HOUSTON
WELL
48
47
NELSON R.
HAYES R.
KASKATTAMA R.
GLENDALE INVESTMENT CORPORATION LTD.
MANITOBA PERMITS 47 - 57
APPROX. SCALE : 1" = 15 MI.
56°00'
56°00'
93°00'
92°00'
91°00'

Areas of Basement "lows" are of interest as Granite Wash sands tend to accumulate and attain considerable thickness in these "lows". Reefs and Granite Wash sands are probably the two principal reservoir horizons in this area.

STRATIGRAPHY

The subject acreage, which is located one to 50 miles south of the Hudson Bay shoreline near York Factory in Manitoba, is primarily covered by muskeg with numerous small rivers, and streams present. Access to the area is provided by the Canadian National Railway line running into Port Nelson and also by ocean ships to the same point. Subsurface control will be provided by the Sogepet-Aquitane-Kaskattama # 1 well when it is released. It is located some 30 miles east of the northeast corner of the acreage. Recently Houston et al Comeault Sth Prov. # 1, located at about 56° 40' and 90° 52' has been licenced. This location, which is some 5 miles east of the acreage, will provide additional valuable subsurface information about this area. Outcrop information is extremely scarce in this area with only some talus being noted near York Factory along the north side of the acreage and along the Kaskattama River, which lies along the south and east side of the acreage. The main outcrop data has to be projected into this area from sections found on the Severn River, which is 110 miles southeast

of the acreage. The Nelson River which is approximately 50 miles northwest of the acreage is another outcrop area. Ordovician rocks are exposed along Gods River, 30 miles south of the western portion of the area under discussion. Beds ranging in age from Upper Ordovician to Upper Silurian are expected to be present beneath the land under review.

ORDOVICIAN

BAD CACHE RAPIDS GROUP

PORTAGE CHUTE FORMATION

The type section of the Portage Chute formation is located on the Churchill River, 100 miles northwest of the acreage. Outcrops are also present on the Nelson River approximately 50 miles west of the area, as well as on the Sachigo and Severn Rivers which lie to the south. The formation was defined by Nelson as overlying peneplaned Pre-Cambrian rocks, and in turn being conformably overlain by the Surprise Creek formation. The Portage Chute formation, which is 75 feet thick at the type section, consists of a four foot basal quartz sandstone which is generally quite uniform, tight and calcareous. This sand is also

present at the other outcrop sections mentioned above. The sand grades upwards into grey to buff, weathering light grey, partially dolomitic, microcrystalline, laminated limestones. Skeletal debris is quite abundant. At the type section the limestone section is 71 feet thick. The thickness of the Portage Chute formation on the Nelson River is approximately 25 feet, while at the Severn River exposures it is only about ten feet thick. The formation dips easterly with an increasing rate of dip as one proceeds basinward along the outcrop sections. Fossils consist mainly of a variety of corals and molluscans with some trilobites present. The limestone takes on a nodular appearance in weathered sections.

SURPRISE CREEK FORMATION

The type section of the Surprise Creek formation was defined by Nelson as being located at Surprise Creek on the Churchill River. It is also present at the Nelson River section but not further south. Nelson considered the Surprise Creek formation as late Ordovician in age. The type section consists of 63 1/2 feet of thinly bedded, light yellowish grey, micro to cryptocrystalline limestone. It ranges from slightly dolomitic, to dolomitic, and contains some lenses of chert. The Surprise Creek formation is disting-

uished from the underlying Portage Chute formation by its lack of organic fragments, and by its smooth weathering characteristics, as opposed to the nodular weathering of the Portage Chute formation. The exposures at Nelson River are poor and not easily correlated with the type section, but, they appear to be lithologically similar to the type section. The thickness is a minimum 30 feet and the fauna is composed mainly of brachiopods. The combined thickness of the Surprise Creek formation and Portage Chute formation at the Selco-Pennycutaway # 1, drill hole, which lies about 17 miles west of the acreage, was 300 $\pm$, indicating a rapid thickening of this group in a basinward direction.

CHURCHILL RIVER GROUP

CAUTION CREEK FORMATION

The type section of the Caution Creek formation is also found on the Churchill River. The type section was defined by Nelson to consist of a basal 18 foot bed of mainly grey to yellowish grey weathering, cryptocrystalline, slightly dolomite limestone, containing shell fragments. This

is overlain by an 18 foot bed of grey to brown weathering, crypto to microcrystalline, slightly dolomitic limestone with little organic remains. This bed weathers into smooth layers, whereas, the lower bed weathers into uneven rubbly beds. The uppermost bed consists of six feet of grey, earthly weathering, micro to cryptocrystalline, slightly dolomitic limestone which has a nodular appearance on a weathered surface. The fauna consists of brachiopods, corals, and molluscans. The Caution Creek formation apparently does not outcrop on the Nelson River, but, it should be present in the subsurface of the subject acreage.

CHASM CREEK FORMATION

The Chasm Creek formation is found both along the Churchill and Nelson Rivers with the Churchill sections being the better one. The Chasm is also exposed at Gods River, some 30 miles south of the acreage. The Chasm is fairly similar to the underlying Caution Creek formation and is in conformable contact with it. At the type section it is about 180 feet thick. The basal 55 feet is a light yellowish grey to buff, microcrystalline, slightly dolomitic

limestone grading to an iron rich dolomite. It is very resistant and weathers to a yellow and orange massive bed. This unit is overlain by about 100 feet of light grey, crypto to microcrystalline, slightly dolomitic to dolomitic limestone. The unit contains abundant fine organic fragments. Overlying this unit is a 5 to 15 foot thick bed of light grey, cryptocrystalline, dolomitic limestone which contains no organic material but has fine intercalations of finely fragmented limestone beds. The uppermost unit is ten to 20 feet thick, and is a light grey weathering, very dolomitic, microcrystalline unit which is strongly fucoidal. On the Nelson River the Chasm Creek section is a minimum of 15 feet thick with the maximum thickness unknown. It is lithologically similar to the type section as is the 38 foot thick section found on Gods River. The Chasm Creek formation contains a fauna comprised of corals, cephalopods and some brachiopods.

RED HEAD RAPIDS FORMATION

The Red Head Rapids formation is the uppermost Ordovician sediment found in this region and tye type section is located on the Churchill River where it overlies the Churchill River Group. The formation is a minimum of 42

feet thick with the maximum thickness unknown. Nelson notes that this formation may be Silurian in age. The lower 25 feet consist of light yellow, microcrystalline dolomitic which weathers a distinctive orange color. No fossils are present in this bed. The upper 17 feet is composed of grey to yellowish grey, microcrystalline dolomite, partially vuggy, which weathers to a grey color. This bed is also quite unfossiliferous. The Red Head Rapids is not present in outcrop on the Nelson, Gods, or Severn Rivers, but, it should be present in the subsurface of the acreage.

SILURIAN

PORT NELSON FORMATION

The type section of the Port Nelson formation is located on the Nelson River some 47 miles west of the acreage under review. The section exposed is 24 feet thick and consists of interbeds of brecciated dolomite, dolomite, and shaly dolomite. The dolomite is generally a gray micro to cryptocrystalline to occasionally granular rock with minor porosity. It contains a coral fauna and

is placed in the Middle Silurian. In the James Bay area a drill hole encountered 110+ feet of this formation. This unit should be found at subcrop under the southwestern portion of the acreage.

SEVERN RIVER FORMATION

The type section of this formation is found on the Severn River some 110 miles southeast of the acreage. The minimum thickness at the type section is 42 feet with the maximum unknown. The section consists of a basal 13 foot light grey, micro to cryptocrystalline limestone with rare vuggy porosity, and a suggestion of algal material. The middle unit consists of 4 feet of light yellowish grey, to orange buff, micro to finely crystalline algal limestone with good vuggy porosity. The upper unit is a 25 foot thick bed of cream to buff, partly microcrystalline to finely crystalline, chalky and partly organic limestone. Fine to coarse organic debris is present as well as beds of oolitic material. The Severn River formation appears to be present near Churchill in similar facies plus the notable fact that it has a strong bituminous odour from a fresh break in this area. This formation should also be present at subcrop under the southwest portion of the acreage.

EKWAN RIVER FORMATION

The type section of this formation is on the Ekwan River, which is in the James Bay area and lies some 350 miles southeast of the area under consideration. The section is from 73 to 88 feet thick and consists of grey, fine grained, partially cherty limestone containing corals and stromatoporoids. The section on Severn River is a minmum 37 feet thick with the maximum unknown. The basal 20 feet is composed of light medium brown, microcrystalline limestone with fine to coarse fossil fragments, some chert nodules and some oolitic material. The fossils consist of stromatoporoids, corals, brachiopods and cephalopods. Some poor intercrystalline and vuggy porosity is present. The middle 11 feet consists of yellowish brown, microcrystalline partially dolomitic, chalky limestone with some thin fragmental beds and rare brachiopods. The upper 6 feet is a light greyish brown, to creamy, microcrystalline limestone which is very highly and coarsely fragmental. The top section contains poor to good porosity. The Ekwan River formation is also exposed along the shore of Hudson Bay from the Mouth of Owl River to a point some 20 miles south of Cape Churchill. The Ekwan should be found to

subcrop along the western and central position of the subject acreage.

ATTAWAPISKAT FORMATION

The type section is located on the Attawapiskat River which lies some 40 miles south of the Ekwan River type section in the James Bay area. The formation outcrops on the Ekwan River, Severn River and along the tidal flats south from Cape Churchill.

The Ekwan River outcrop section consists of 54 feet of fine grained, thin bedded, coral reef limestone. Nelson has described a reefal and possible off reef facies for the Attawapiskat formation in general. The reef facies has a minimum thickness of 25 feet and is a cream, to orange cream, to buff, microcrystalline, fragmental limestone with corals and stromatoporoids being common. Porosity grades from tight to excellent and is vuggy. Nelson feels that some of the well bedded reefs are suggestive of biostromes, while other oval, domal reefs are believed to be bioherms. He noted a gassy odour at one location.

The off-reef facies is a minimum of 16 feet thick with uniform beds of cream, to partly yellowish cream, to grey microcrystalline limestone. There are abundant coarse granular, bioclastic beds which have excellent intergranular porosity which could be post reef deposits. The Attawapiskat outcrops south of Cape Churchill range in thickness from 25 to 50 feet in thickness, with both facies present and they are seen to grade laterally from one to the other. This formation should be at subcrop through the central portion of the acreage.

KENOGAMI RIVER FORMATION

The Kenogami River formation which has only been found in outcrop, in the James Bay represents the youngest Silurian found in the Hudson Bay Basin. The formation consists of an alternating series of shale, siltstone, sandstone, dolomite, silty dolomite, shaly limestone, and limestone. The colours mainly range from buff to grey, but, reds and greens are the colours of the clastics. The outcrop section has a minimum thickness of 300 feet while a well drilled on Puskwuine Point in James Bay had a thickness of 862 feet. The Kenogami River formation is

expected to subcrop along the eastern half of the acreage under review.

DEVONIAN

Rocks of Devonian age are not expected to be present under the area covered by the permit, however, they should be present at subcrop east of the acreage, at and near the Sogepet-Aquitaine-Kaskattama # I well where total depth was reached at 2,941 feet in granite.

CRETACEOUS

Rocks of Cretaceous age are know only in the James Bay area and are not expected to be present under the permits.

FRACTURE ANALYSIS

This section of the report discusses the results of a Detailed Fracture Analysis Survey carried out on the area under discussion. An aerial mosaic (scale 1.5 inches equals approximately 1 mile) made from Dominion Government aerial photographs accompanies this report. These same photographs were examined stereoscopically and the fractures plotted on the individual photographs, then transferred to the mosaic for analysis.

The theory that the earth's crust is abundantly and methodically fractured is the basic premise on which is built the exploration technique known as Fracture Analysis. A Fracture is defined as"...generally abundant, natural lineation discernible on aerial photographs".

Fracturing is largely caused by external stresses on the surface. The most important are:

(a) earth tides

(b) radial acceleration of the earth along its radius vector.

(c) a gradual decrease of the earth's rate of rotation.

As stated above, the earth is systematically fractured and the fracture system would approach symmetry if the crust were homogeneous. It is considered that irregularities are caused by regional heterogeneous conditions within the earth's crust. Local departures from the norm are caused by structural or stratigraphic anomalies.

The term "photogeophysics" was introduced by Blanchet (1956) and deals with mapping, analysis and interpretation of fracture traces as recorded on aerial photographs. In a more general way "photogeophysics" can be defined as the methodical statistical analysis of linear features seen on aerial photographs and this system is applied by any method recording all observable lineations, or the totality of a certain type of linear feature, and the statistical presentation of the data on contoured intensity maps of dry plotting the fractures directly on the mosaic.

In this report a megafracture is longer than one mile and a microfracture is shorter than one mile.

GENERAL STATEMENT

ORIGIN OF FRACTURES

Fracturing is largely caused by external stresses on the earth, although internal stresses may play some minor roll. The most important of these external forces are the diurnal earth tides due to the gravitational effects of the sun and moon; the change in radial acceleration of the earth along its radius vector and the gradual decrease in the earth's rate of rotation. The endless rhythemic action of these earth tides is probably the principal cause of the systematic fracture system seen over most of the world, even though the amplitude of these tides is only 9-13 inches. The fractures are most likely generated by the process of fatigue as the end result of these stresses which are repeated regularly over millions and millions of years. Metals fatigue in the same manner when subjected to continual vibration.

In general the initiating forces which generate fractures must have continued for a very long time and

the process involved are continuous and are probably active at the present time. Furthermore, Mollard (1957) states, "The mechanism required to reflect lineaments to ground surface must be reasonably simple, for simple patterns are produced on diverse topography and in diverse types and depths of surficial deposits that overlie different kinds of relatively flat-lying sedimentary rocks of varying thickness. The mechanism producing the lineament pattern must persist over extensive and widespread belts of the earth's outer shell; that is today, the engendering mechanism in fact be world wide".

External forces such as earth tides obviously fit these parameters. Some internal forces may also apply such as the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

In general it can be said that fracture patterns are caused by either internal forces or external forces.

If the forces are internal the result would be different orientation of the fracture systems in areas of similar tectonic history but different position. If the forces are external the orientation of the fracture arrangement should have world wide similarity. However, stable areas such as the masses of the continents may develop fracture patterns due to external forces and tectonically active areas may develop their own pattern due to internal forces.

If joints form early in the history of a sediment then systematic joints must be successively younger upwards through the section and the joint pattern is imposed on each new layer of sediments when they have become consolidated enough to fracture. This upward propagation is caused by the fatigue caused by stress, which in turn is caused by diurnal earth tides.

EXPRESSION OF FRACTURE

Fractures have been observed in aerial photographs from every climate and on every continent in the world. They are expressed as topographic relief, vegetation

differences and soil tonal differences.

TOPOGRAPHIC RELIEF LINEAMENTS

A common type are relief lineaments which can be manifested by a change (usually abrupt) of topographic elevation on either side of a relatively straight line. They may also be expressed as straight valleys or hills or by straight streams where the stream course is controlled by a fracture zone.

VEGETAL LINEAMENTS

Vegetal lineaments are the most common in the parkland and muskeg areas of western Canada and many excellent examples of fractures can be seen on almost any aerial photograph of northern Saskatchewan, Alberta or British Columbia. Straight lines of both deciduous and evergreen trees as well as scrub growth are universally visible. However, the most common vegetal lineament seen by this writer is a straight "edge" to a clump of trees or bushes. In many cases these fractures control the size and

shape of cultivated fields. Excellent examples of this latter expression of fractures are present in the western part of the Peace River district.

SOIL TONAL LINEAMENTS

These reflect differentiation in soil moisture and general ground water conditions. These are common in the southern parts of Alberta and Saskatchewan, especially near large rivers.

Surface investigations have shown that fractures are associated with bedrock joints; however, in glaciated areas such as western Canada, the photoanalyst must take care to establish the direction of ice flow over an area before he begins to statistically plot and analyse the fractures. Most areas in western Canada show an abundance of grooves and flutes caused by the glacier and these must not be mistaken for fracture traces caused by subsurface structural conditions. In parts of the Lloydminster area of eastern Alberta the glacial scars are so deeply impressed on the surface that fracture analysis is at best difficult and

often impossible.

INTERPRETATION OF FRACTURE DATA

The object of Fracture Analysis (Photogeophysics) is to locate shallow to deep-seated structural and stratigraphic anomalies. The actual count of fractures per unit area is made and values are contoured on a "Fracture Intensity Map". In areas of known reefs the fracture intensity is 2-3 times greater on the flanks of the reef than directly above the reef.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general the two systems are at approximate right angles to each other.

Because of certain inherent limiting factors, Structure Incidence Surveys have a lower order of reliability than Detailed Fracture Analysis Surveys. To some extent at least, surface conditions affect the fracture count. In areas

covered by lakes, sloughs and rivers, the fracture count is zero. Cultivated areas generally yield a lower count than adjacent virgin territory. Consequently, a difference or contrast in fracture count (F/I) between two points may be in part due to structure, but, also due in part to different surface conditions. To some extent, this can be compensated for by applying appropriate weightings to the observed counts, but over or under corrections may result.

Nevertheless, in spite of these sources or error, it has been demonstrated in (plains) areas where abundant subsurface control is available, that the incidence of fracturing is considerably above normal in the surrounding area immediately out from the steepest part of the flanks of the structure. This is in contrast with a low or normal incidence over the crestal area, and also to a normal incidence off structure.

FRACTURE ANALYSIS OF PERMIT NO. 52

The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permit. The Permit is located in the muskeg area south of Hudson Bay and is hundreds of miles from the closest settlement.

The sedimentary section is probably about 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There is one area where the fracture intensity is greater than nomral and there is one area where the fracture intensity is less than normal. The high intensity area is shown in red and the low intensity area is shown in green. The average length of the fractures is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to mention the glacial problem in this area.

Reference to the mosaic will show that the area is moderately scarred with glacial grooves and striations and that the direction of ice flow was about north 30 degrees east. Some of these grooves are so deeply impressed on the surface that they control the shape of the lakes and of tree growth in the area. In any area such as this the photoanalyst is faced with the difficult problem of eliminating the glacial scars from the fracture pattern without creating false anomalies. The removal of all fractures from a 10 - 12 degree arc in any area will create fracture anomalies and it requires delicate weighting of the whole pattern to adjust for these effects.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general, the two systems are at approximate right angles to each other. Within Petroleum & Natural Gas Permit No. 52 the statistical mean direction of the axial system is north 40 degrees west and the statistical mean direction of the shear system is north 30 degrees east. A third minor system, here termed the sub-axial system, trends nearly north-south.

No regional fractures of great length can be seen and as these are conceded to originate within the Basement, it is assumed that all fractures plotted on the mosaic originate within the sedimentary section. Furthermore, as the fractures are short for this area it is very likely that originate in the upper two-thirds of the sedimentary section. As the surface of the Permit is relatively flat-lying no azimuth correction is necessary for this study. It has been demonstrated that the low incidence anomalies on a mosaic are considerably larger than the subsurface feature which causes them.

There is one area on the mosaic where the fractures are less intense that the surrounding area. Some fractures are always present within these areas but they usually have a lower incidence than the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the next section of this report.

STRUCTURE

Petroleum and Natural Gas Permit No. 52 is located on the coastal plain on the south shore of Hudson Bay about 70 miles north of the edge of the Pre-Cambrian Shield.

Structural features which could be present and which could cause the low incidence anomalies mentioned in this report are discussed in order of probability.

(I) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No. 52 is thought to be much the same as it is today along the north edge of the Shield. Low rounded hills separated by gentle to abrupt valleys are seen on the Shield and these features are undoubtedly present under the subject Permit. The effect of this Basement relief on the overlying sedimentary rocks is often great. The Granite Wash sand is usually present in the topographic "lows" on the Basement but absent on the "highs". The Granite Wash is an excellent potential reservoir.

Further effects of Basement topography on beds higher than the Granite Wash is the gentle folding present over Basement hills. These folds are anticlines in every sense and could form traps for oil or gas.

(2) REEFS

Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. However, only small reefs have been found in outcrops near the Permit and such small masses as these probably do not greatly affect the fracture pattern.

(3) TECTONIC FOLDING AND FAULTING

The presence of tectonic folds is very unlikely, but some normal faulting could be present.

(4) TOPOGRAPHIC RELIEF ON AN INTRA-SEDIMENTARY UNCONFORMITY

Unconformity, is a possible source of fracture intensity anomalies, but within the Permit area it is unlikely that the relief on any unconformities within the sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there is one area of "high" fracture intensity, and one area of "low" fracture intensity (green). The general interpretation is that the low fracture intensity area is underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is high in the northeast corner of Permit No. 52.

This Basement high feature is most interesting from the oil and gas point of view. The general shape of this feature is such that the causative feature must be a hill on the Basement surface. A fault is unlikely as the causative feature as the high area is over one and one-half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Granite Wash sand is probably absent on the top of this high fracture area, but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Crook

WGC/jp

REFERENCES

NELSON S.J. & — 1966: Geology of Hudson Bay Basin, Bull. Can. Petrol. Geol., Vol. 14, No. 4, pp. 520-578.

BOSTOCK H.H.
CUMMING L.M.
NORFORD B.S.
NORRIS A.W. — Geology Hudson Bay Lowlands, Map 17-.1967, Geol. Surv. Can.
PRICE L.L.
STANDFORD B.V.

BLANCHET P.H. — 1957: "Development of Fracture Analysis as Exploration Method", Amer. Assoc. Petrol. Geol. Bull., Vol. 41, No. 8, 1748-59

HAMAN P.J. — 1964: "Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2

Granite Wash sand is probably absent on the top of this Basement topographic high; but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

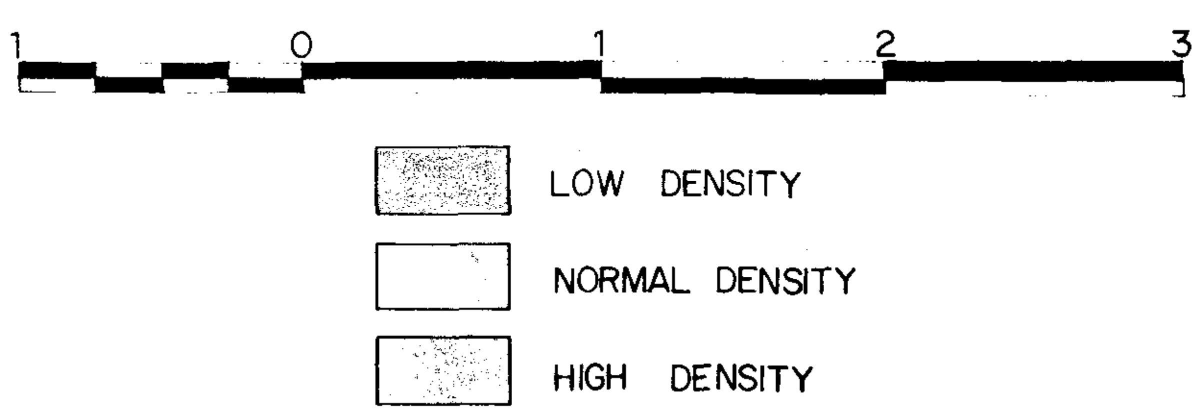
WILLIAM G. CROOK
Photoanalyst, P. Geol.

WGC/jp

GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 52

TOTAL FRACTURE PATTERN



GLENDALE INVESTMENT CORPORATION LTD.

P. & N. G. PERMIT NO. 52

HUDSON'S BAY LOWLANDS

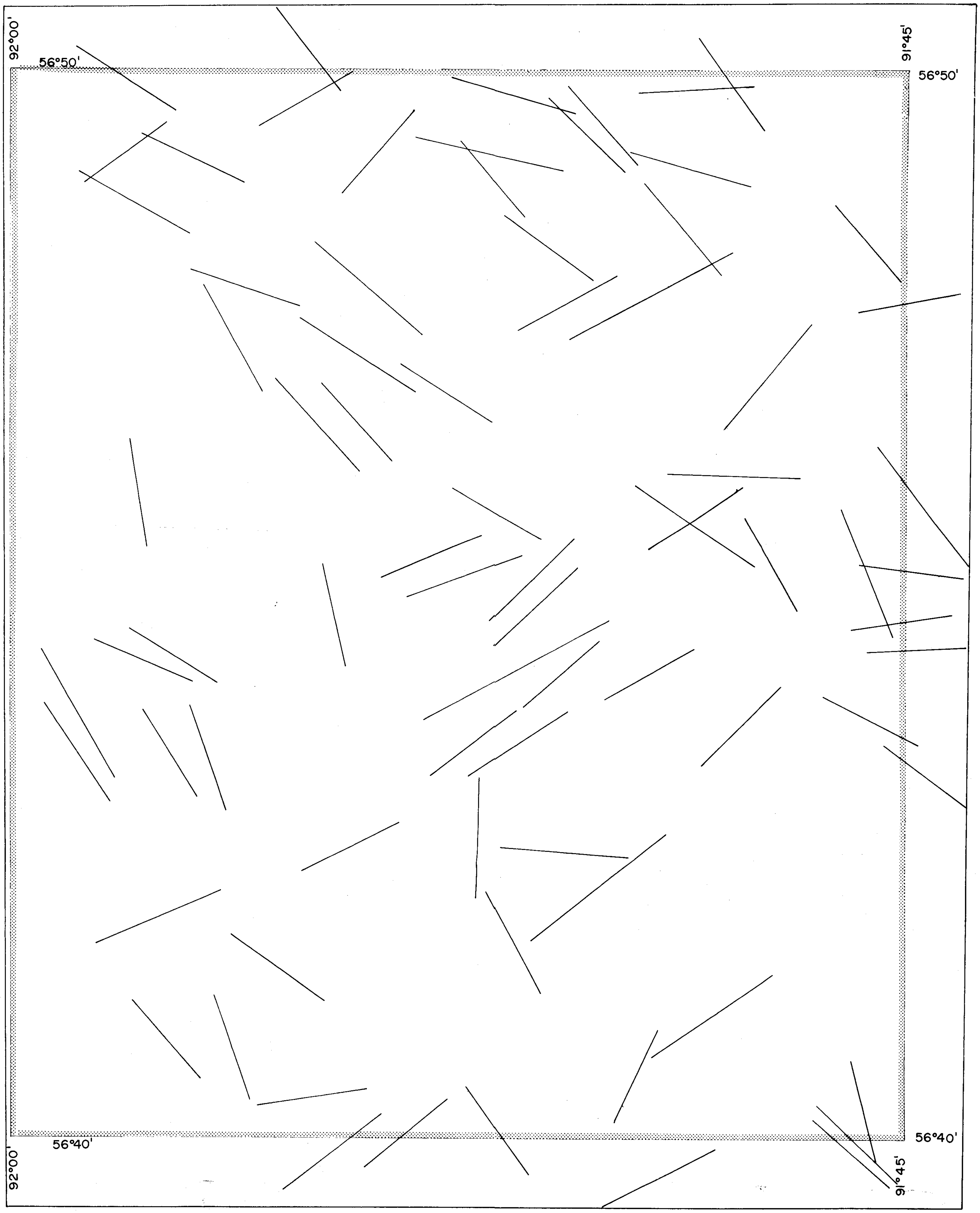
MANITOBA

SCALE : 1.5" = 1 MI.

1 0 1 2 3

THIS IS A UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN

ACCURATE TOPOGRAPHIC MAP.

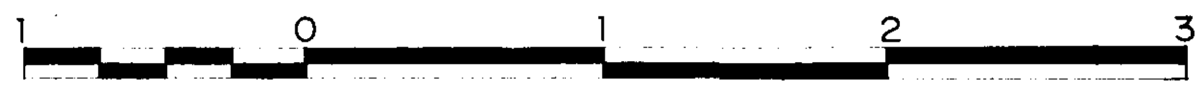


GLENDALE INVESTMENT CORPORATION LTD.

P. & N. G. PERMIT No. 52

MEGA FRACTURE PATTERN

SCALE : 1.5" = 1 MI.



Exploration
Permit
No. 53

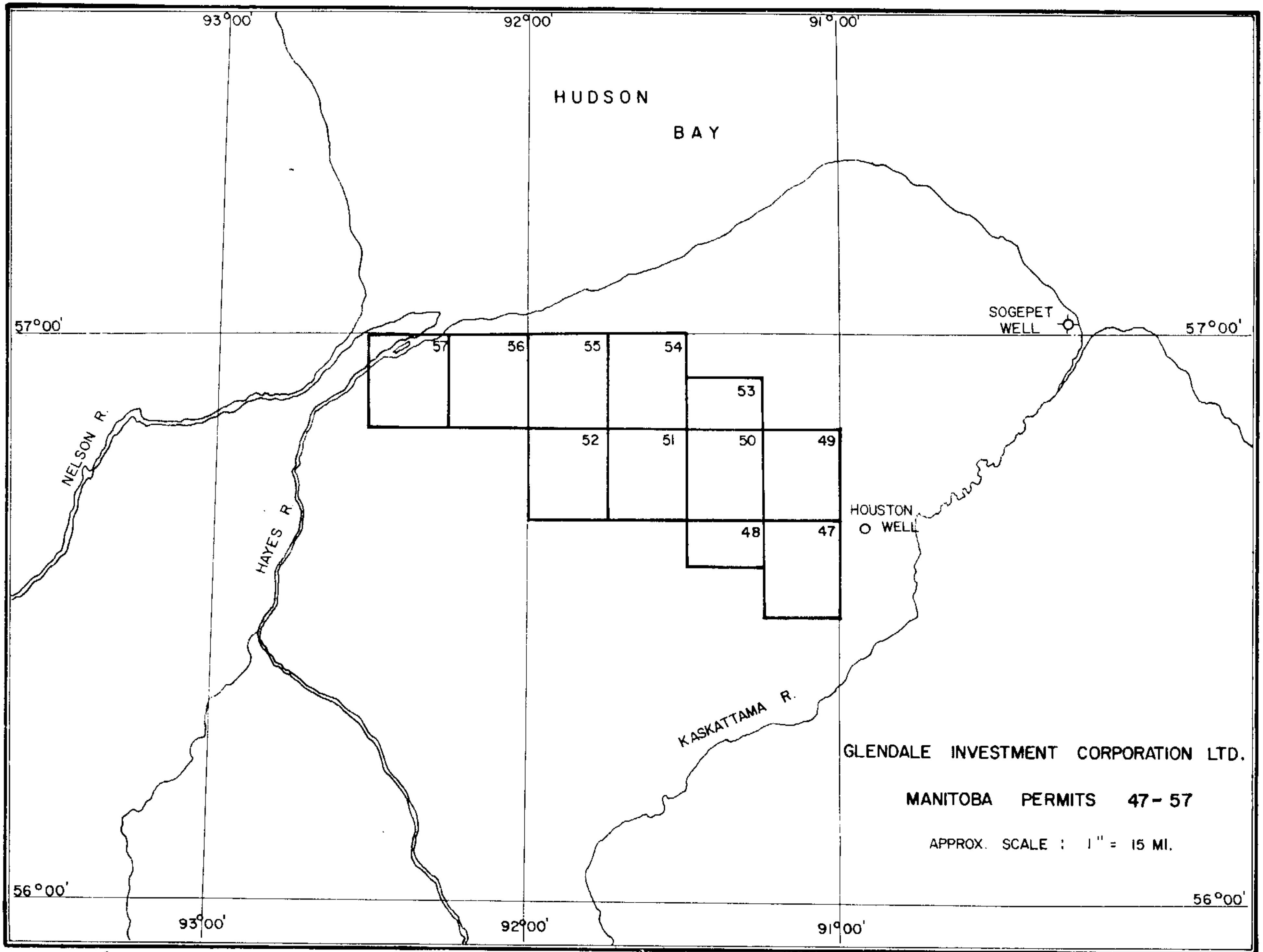
INTRODUCTION

This report discusses the results of a study of the General Geology, Stratigraphy and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 53, Manitoba. This permit is located between 56° 50' - 56° 55' latitude and 91° 15' - 91° 30' longitude. This is in the Hudson's Bay area of northeast Manitoba approximately 540 air miles north-northwest of Winnipeg. There are no roads within the area and the use of an aircraft is required to reach the area.

The stratigraphic discussion is based on information contained in published reports and on the limited data available from well control.

The Fracture Analysis Survey locates topographic highs and lows on the Basement surface. Areas of Basement "highs" are of great interest as it is felt that much reef growth (which is known to be present) is centered, or at least concentrated, over areas of Basement "highs".

Areas of Basement "lows" are of interest as Granite Wash sands tend to accumulate and attain considerable thickness in these "lows". Reefs and Granite Wash sands are probably the two principal reservoir horizons in this area.



93°00'
92°00'
91°00'
HUDSON
BAY
57°00'
SOGEPET
WELL
57
56
55
54
53
52
51
50
49
48
47
NELSON R.
HAYES R.
HOUSTON
WELL
KASKATTAMA R.
GLENDALE INVESTMENT CORPORATION LTD.
MANITOBA PERMITS 47 - 57
APPROX. SCALE : 1" = 15 MI.
56°00'

STRATIGRAPHY

The subject acreage, which is located one to 50 miles south of the Hudson Bay shoreline near York Factory in Manitoba, is primarily covered by muskeg with numerous small rivers, and streams present. Access to the area is provided by the Canadian National Railway line running into Port Nelson and also by ocean ships to the same point. Subsurface control will be provided by the Sogepet-Aquitane-Kaskattama # I well when it is released. It is located some 30 miles east of the northeast corner of the acreage. Recently Houston et al Comeault Sth Prov. # 1, located at about 56° 40' and 90° 52' has been licenced. This location, which is some 5 miles east of the acreage, will provide additional valuable subsurface information about this area. Outcrop information is extremely scarce in this area with only some talus being noted near York Factory along the north side of the acreage and along the Kaskattama River, which lies along the south and east side of the acreage. The main outcrop data has to be projected into this area from sections found on the Severn River, which is 110 miles southeast

of the acreage. The Nelson River which is approximately 50 miles northwest of the acreage is another outcrop area. Ordovician rocks are exposed along Gods River, 30 miles south of the western portion of the area under discussion. Beds ranging in age from Upper Ordovician to Upper Silurian are expected to be present beneath the land under review.

ORDOVICIAN

BAD CACHE RAPIDS GROUP

PORTAGE CHUTE FORMATION

The type section of the Portage Chute formation is located on the Churchill River, 100 miles northwest of the acreage. Outcrops are also present on the Nelson River approximately 50 miles west of the area, as well as on the Sachigo and Severn Rivers which lie to the south. The formation was defined by Nelson as overlying peneplaned Pre-Cambrian rocks, and in turn being conformably overlain by the Surprise Creek formation. The Portage Chute formation, which is 75 feet thick at the type section, consists of a four foot basal quartz sandstone which is generally quite uniform, tight and calcareous. This sand is also

present at the other outcrop sections mentioned above. The sand grades upwards into grey to buff, weathering light grey, partially dolomitic, microcrystalline, laminated limestones. Skeletal debris is quite abundant. At the type section the limestone section is 71 feet thick. The thickness of the Portage Chute formation on the Nelson River is approximately 25 feet, while at the Severn River exposures it is only about ten feet thick. The formation dips easterly with an increasing rate of dip as one proceeds basinward along the outcrop sections. Fossils consist mainly of a variety of corals and molluscans with some trilobites present. The limestone takes on a nodular appearance in weathered sections.

SURPRISE CREEK FORMATION

The type section of the Surprise Creek formation was defined by Nelson as being located at Surprise Creek on the Churchill River. It is also present at the Nelson River section but not further south. Nelson considered the Surprise Creek formation as late Ordovician in age. The type section consists of 63 1/2 feet of thinly bedded, light yellowish grey, micro to cryptocrystalline limestone. It ranges from slightly dolomitic, to dolomitic, and contains some lenses of chert. The Surprise Creek formation is disting-

uished from the underlying Portage Chute formation by its lack of organic fragments, and by its smooth weathering characteristics, as opposed to the nodular weathering of the Portage Chute formation. The exposures at Nelson River are poor and not easily correlated with the type section, but, they appear to be lithologically similar to the type section. The thickness is a minimum 30 feet and the fauna is composed mainly of brachiopods. The combined thickness of the Surprise Creek formation and Portage Chute formation at the Selco-Pennycutaway # 1, drill hole, which lies about 17 miles west of the acreage, was 300 $\pm$, indicating a rapid thickening of this group in a basinward direction.

CHURCHILL RIVER GROUP

CAUTION CREEK FORMATION

The type section of the Caution Creek formation is also found on the Churchill River. The type section was defined by Nelson to consist of a basal 18 foot bed of mainly grey to yellowish grey weathering, cryptocrystalline, slightly dolomite limestone, containing shell fragments. This

is overlain by an 18 foot bed of grey to brown weathering, crypto to microcrystalline, slightly dolomitic limestone with little organic remains. This bed weathers into smooth layers, whereas, the lower bed weathers into uneven rubbly beds. The uppermost bed consists of six feet of grey, earthly weathering, micro to cryptocrystalline, slightly dolomitic limestone which has a nodular appearance on a weathered surface. The fauna consists of brachiopods, corals, and molluscans. The Caution Creek formation apparently does not outcrop on the Nelson River, but, it should be present in the subsurface of the subject acreage.

CHASM CREEK FORMATION

The Chasm Creek formation is found both along the Churchill and Nelson Rivers with the Churchill sections being the better one. The Chasm is also exposed at Gods River, some 30 miles south of the acreage. The Chasm is fairly similar to the underlying Caution Creek formation and is in conformable contact with it. At the type section it is about 180 feet thick. The basal 55 feet is a light yellowish grey to buff, microcrystalline, slightly dolomitic

limestone grading to an iron rich dolomite. It is very resistant and weathers to a yellow and orange massive bed. This unit is overlain by about 100 feet of light grey, crypto to microcrystalline, slightly dolomitic to dolomitic limestone. The unit contains abundant fine organic fragments. Overlying this unit is a 5 to 15 foot thick bed of light grey, cryptocrystalline, dolomitic limestone which contains no organic material but has fine intercalations of finely fragmented limestone beds. The uppermost unit is ten to 20 feet thick, and is a light grey weathering, very dolomitic, microcrystalline unit which is strongly fucoidal. On the Nelson River the Chasm Creek section is a minimum of 15 feet thick with the maximum thickness unknown. It is lithologically similar to the type section as is the 38 foot thick section found on Gods River. The Chasm Creek formation contains a fauna comprised of corals, cephalopods and some brachiopods.

RED HEAD RAPIDS FORMATION

The Red Head Rapids formation is the uppermost Ordovician sediment found in this region and tye type section is located on the Churchill River where it overlies the Churchill River Group. The formation is a minimum of 42

feet thick with the maximum thickness unknown. Nelson notes that this formation may be Silurian in age. The lower 25 feet consist of light yellow, microcrystalline dolomitic which weathers a distinctive orange color. No fossils are present in this bed. The upper 17 feet is composed of grey to yellowish grey, microcrystalline dolomite, partially vuggy, which weathers to a grey color. This bed is also quite unfossiliferous. The Red Head Rapids is not present in outcrop on the Nelson, Gods, or Severn Rivers, but, it should be present in the subsurface of the acreage.

SILURIAN

PORT NELSON FORMATION

The type section of the Port Nelson formation is located on the Nelson River some 47 miles west of the acreage under review. The section exposed is 24 feet thick and consists of interbeds of brecciated dolomite, dolomite, and shaly dolomite. The dolomite is generally a gray micro to cryptocrystalline to occasionally granular rock with minor porosity. It contains a coral fauna and

is placed in the Middle Silurian. In the James Bay area a drill hole encountered 110+ feet of this formation. This unit should be found at subcrop under the southwestern portion of the acreage.

SEVERN RIVER FORMATION

The type section of this formation is found on the Severn River some 110 miles southeast of the acreage. The minimum thickness at the type section is 42 feet with the maximum unknown. The section consists of a basal 13 foot light grey, micro to cryptocrystalline limestone with rare vuggy porosity, and a suggestion of algal material. The middle unit consists of 4 feet of light yellowish grey, to orange buff, micro to finely crystalline algal limestone with good vuggy porosity. The upper unit is a 25 foot thick bed of cream to buff, partly microcrystalline to finely crystalline, chalky and partly organic limestone. Fine to coarse organic debris is present as well as beds of oolitic material. The Severn River formation appears to be present near Churchill in similar facies plus the notable fact that it has a strong bituminous odour from a fresh break in this area. This formation should also be present at subcrop under the southwest portion of the acreage.

EKWAN RIVER FORMATION

The type section of this formation is on the Ekwan River, which is in the James Bay area and lies some 350 miles southeast of the area under consideration. The section is from 73 to 88 feet thick and consists of grey, fine grained, partially cherty limestone containing corals and stromatoporoids. The section on Severn River is a minmum 37 feet thick with the maximum unknown. The basal 20 feet is composed of light medium brown, microcrystalline limestone with fine to coarse fossil fragments, some chert nodules and some oolitic material. The fossils consist of stromatoporoids, corals, brachiopods and cephalopods. Some poor intercrystalline and vuggy porosity is present. The middle 11 feet consists of yellowish brown, microcrystalline partially dolomitic, chalky limestone with some thin fragmental beds and rare brachiopods. The upper 6 feet is a light greyish brown, to creamy, microcrystalline limestone which is very highly and coarsely fragmental. The top section contains poor to good porosity. The Ekwan River formation is also exposed along the shore of Hudson Bay from the Mouth of Owl River to a point some 20 miles south of Cape Churchill. The Ekwan should be found to

subcrop along the western and central position of the subject acreage.

ATTAWAPISKAT FORMATION

The type section is located on the Attawapiskat River which lies some 40 miles south of the Ekwan River type section in the James Bay area. The formation outcrops on the Ekwan River, Severn River and along the tidal flats south from Cape Churchill.

The Ekwan River outcrop section consists of 54 feet of fine grained, thin bedded, coral reef limestone. Nelson has described a reefal and possible off reef facies for the Attawapiskat formation in general. The reef facies has a minimum thickness of 25 feet and is a cream, to orange cream, to buff, microcrystalline, fragmental limestone with corals and stromatoporoids being common. Porosity grades from tight to excellent and is vuggy. Nelson feels that some of the well bedded reefs are suggestive of biostromes, while other oval, domal reefs are believed to be bioherms. He noted a gassy odour at one location.

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(c) a gradual decrease of the earth's rate of rotation.

As stated above, the earth is systematically fractured and the fracture system would approach symmetry if the crust were homogeneous. It is considered that irregularities are caused by regional heterogeneous conditions within the earth's crust. Local departures from the norm are caused by structural or stratigraphic anomalies.

The term "photogeophysics" was introduced by Blanchet (1956) and deals with mapping, analysis and interpretation of fracture traces as recorded on aerial photographs. In a more general way "photogeophysics" can be defined as the methodical statistical analysis of linear features seen on aerial photographs and this system is applied by any method recording all observable lineations, or the totality of a certain type of linear feature, and the statistical presentation of the data on contoured intensity maps of dry plotting the fractures directly on the mosaic.

In this report a megafracture is longer than one mile and a microfracture is shorter than one mile.

GENERAL STATEMENT

ORIGIN OF FRACTURES

Fracturing is largely caused by external stresses on the earth, although internal stresses may play some minor roll. The most important of these external forces are the diurnal earth tides due to the gravitational effects of the sun and moon; the change in radial acceleration of the earth along its radius vector and the gradual decrease in the earth's rate of rotation. The endless rhythemic action of these earth tides is probably the principal cause of the systematic fracture system seen over most of the world, even though the amplitude of these tides is only 9-13 inches. The fractures are most likely generated by the process of fatigue as the end result of these stresses which are repeated regularly over millions and millions of years. Metals fatigue in the same manner when subjected to continual vibration.

In general the initiating forces which generate fractures must have continued for a very long time and

the process involved are continuous and are probably active at the present time. Furthermore, Mollard (1957) states, "The mechanism required to reflect lineaments to ground surface must be reasonably simple, for simple patterns are produced on diverse topography and in diverse types and depths of surficial deposits that overlie different kinds of relatively flat-lying sedimentary rocks of varying thickness. The mechanism producing the lineament pattern must persist over extensive and widespread belts of the earth's outer shell; that is today, the engendering mechanism in fact be world wide".

External forces such as earth tides obviously fit these parameters. Some internal forces may also apply such as the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

In general it can be said that fracture patterns are caused by either internal forces or external forces.

If the forces are internal the result would be different orientation of the fracture systems in areas of similar tectonic history but different position. If the forces are external the orientation of the fracture arrangement should have world wide similarity. However, stable areas such as the masses of the continents may develop fracture patterns due to external forces and tectonically active areas may develop their own pattern due to internal forces.

If joints form early in the history of a sediment then systematic joints must be successively younger upwards through the section and the joint pattern is imposed on each new layer of sediments when they have become consolidated enough to fracture. This upward propagation is caused by the fatigue caused by stress, which in turn is caused by diurnal earth tides.

EXPRESSION OF FRACTURE

Fractures have been observed in aerial photographs from every climate and on every continent in the world. They are expressed as topographic relief, vegetation

differences and soil tonal differences.

TOPOGRAPHIC RELIEF LINEAMENTS

A common type are relief lineaments which can be manifested by a change (usually abrupt) of topographic elevation on either side of a relatively straight line. They may also be expressed as straight valleys or hills or by straight streams where the stream course is controlled by a fracture zone.

VEGETAL LINEAMENTS

Vegetal lineaments are the most common in the parkland and muskeg areas of western Canada and many excellent examples of fractures can be seen on almost any aerial photograph of northern Saskatchewan, Alberta or British Columbia. Straight lines of both deciduous and evergreen trees as well as scrub growth are universally visible. However, the most common vegetal lineament seen by this writer is a straight "edge" to a clump of trees or bushes. In many cases these fractures control the size and

shape of cultivated fields. Excellent examples of this latter expression of fractures are present in the western part of the Peace River district.

SOIL TONAL LINEAMENTS

These reflect differentiation in soil moisture and general ground water conditions. These are common in the southern parts of Alberta and Saskatchewan, especially near large rivers.

Surface investigations have shown that fractures are associated with bedrock joints; however, in glaciated areas such as western Canada, the photoanalyst must take care to establish the direction of ice flow over an area before he begins to statistically plot and analyse the fractures. Most areas in western Canada show an abundance of grooves and flutes caused by the glacier and these must not be mistaken for fracture traces caused by subsurface structural conditions. In parts of the Lloydminster area of eastern Alberta the glacial scars are so deeply impressed on the surface that fracture analysis is at best difficult and

often impossible.

INTERPRETATION OF FRACTURE DATA

The object of Fracture Analysis (Photogeophysics) is to locate shallow to deep-seated structural and stratigraphic anomalies. The actual count of fractures per unit area is made and values are contoured on a "Fracture Intensity Map". In areas of known reefs the fracture intensity is 2-3 times greater on the flanks of the reef than directly above the reef.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general the two systems are at approximate right angles to each other.

Because of certain inherent limiting factors, Structure Incidence Surveys have a lower order of reliability than Detailed Fracture Analysis Surveys. To some extent at least, surface conditions affect the fracture count. In areas

covered by lakes, sloughs and rivers, the fracture count is zero. Cultivated areas generally yield a lower count than adjacent virgin territory. Consequently, a difference or contrast in fracture count (F/I) between two points may be in part due to structure, but, also due in part to different surface conditions. To some extent, this can be compensated for by applying appropriate weightings to the observed counts, but over or under corrections may result.

Nevertheless, in spite of these sources or error, it has been demonstrated in (plains) areas where abundant subsurface control is available, that the incidence of fracturing is considerably above normal in the surrounding area immediately out from the steepest part of the flanks of the structure. This is in contrast with a low or normal incidence over the crestal area, and also to a normal incidence off structure.

FRACTURE ANALYSIS OF PERMIT NO. 53

The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permit. The Permit is located in the muskeg area south of Hudson's Bay and is hundreds of miles from the closest settlement.

The sedimentary section is probably about 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There is one area where the fracture intensity is greater than normal and there is one area where the fracture intensity is less than normal. The high intensity area is shown in red and the low intensity area is shown in green. The average length of the fractures is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to men tion the glacial problem in this area.

Reference to the mosaic will show that the area moderately scarred with glacial grooves and striations and that the direction of ice flow was about north 30 degrees east. Some of these grooves are so deeply impressed on the surface that they control the shape of the lakes and of tree growth in the area. In any area such as this the photo-analyst is faced with the difficult problem of eliminating the glacial scars from the fracture pattern without creating false anomalies. The removal of all fractures from a 10 - 12 degree arc in any area will create fracture anomalies and it requires delicate weighting of the whole pattern to adjust for these effects.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general, the two systems are at approximate right angles to each other. Within Petroleum & Natural Gas Permit No. 53 the statistical mean direction of the axial system is north 40 degrees west and the statistical mean direction of the shear system is north 30 degrees east. A third minor system, here termed the sub-axial system, trends nearly north-south.

No regional fractures of great length can be seen and as these are conceded to originate within the sedimentary section. Furthermore, as the fractures are short for this area it is very likely that they originate in the upper two-thirds of the sedimentary section. As the surface of the Permit is relatively flat-lying no azimuth correction is necessary for this study. It has been deomonstrated that the low incidence anomalies on a mosaic are considerably larger than the subsurface feature which causes them. Because the high incidence area on Permit No. 53 occurs at the edge of the mosaic it is difficult to estimate the size of the causative feature.

There is one area on the mosaic where the fractures are less intense than the surrounding area. Some fractures are always present within these areas but they usually have a lower incidence that the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the next section of this report.

STRUCTURE

Petroleum and Natural Gas Permit No. 53 is located on the coastal plain on the south shore of Hudson's Bay, 70 miles north of the edge of the Pre-Cambrian Shield.

Structural features which could be present and which could cause the low incidence anomalies mentioned in this report are discussed in order of probability.

(I) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No. 53 is thought to be much the same as it is today along the north edge of the Shield. Low rounded hills separated by gentle to abrupt valleys are seen on the Shield and these features are undoubtedly present under the subject Permit. The effect of this Basement relief on the overlying sedimentary rocks is often great. The Granite Wash sand is usually present in the topographic "lows" on the Basement but absent on the "highs". The Granite Wash is an excellent potential reservoir.

Further effects of Basement topography on beds higher than the Granite Wash is the gentle folding present over Basement hills. These folds are anticlines in every sense and could form traps for oil or gas.

(2) REEFS

Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. However, only small reefs have been found in outcrops near the Permit and such small masses as these probably do not greatly affect the fracture pattern.

(3) TECTONIC FOLDING AND FAULTING

The presence of tectonic folds is very unlikely, but some normal faulting could be present.

(4) TOPOGRAPHIC RELIEF ON AN INTRA-SEDIMENTARY UNCONFORMITY

Unconformity, is a possible source of fracture intensity anomalies, but within the Permit area it is unlikely that the relief on any unconformities within the

sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there is one area of "high" fracture intensity, and one area of "low" fracture intensity (green). The general interpretation is that the low fracture intensity area is underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is high in the south part of Permit No. 53.

This Basement high feature is most interesting from the oil and gas point of view. The general shape of this feature is such that the causative feature must be a hill on the Basement surface. A fault is unlikely as the causative feature as the high area is over one and one-half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Granite Wash sand is probably absent on the top of this high fracture area, but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Crook

WGC/jp

REFERENCES

NELSON S.J. & — 1966: Geology of Hudson Bay Basin, Bull. Can. Petrol. Geol., Vol. 14, No. 4, pp. 520-578.

BOSTOCK H.H.
CUMMING L.M.
NORFORD B.S.
NORRIS A.W. — Geology Hudson Bay Lowlands, Map 17-.1967, Geol. Surv. Can.
PRICE L.L.
STANDFORD B.V.

BLANCHET P.H. — 1957: "Development of Fracture Analysis as Exploration Method", Amer. Assoc. Petrol. Geol. Bull., Vol. 41, No. 8, 1748-59

HAMAN P.J. — 1964: "Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2

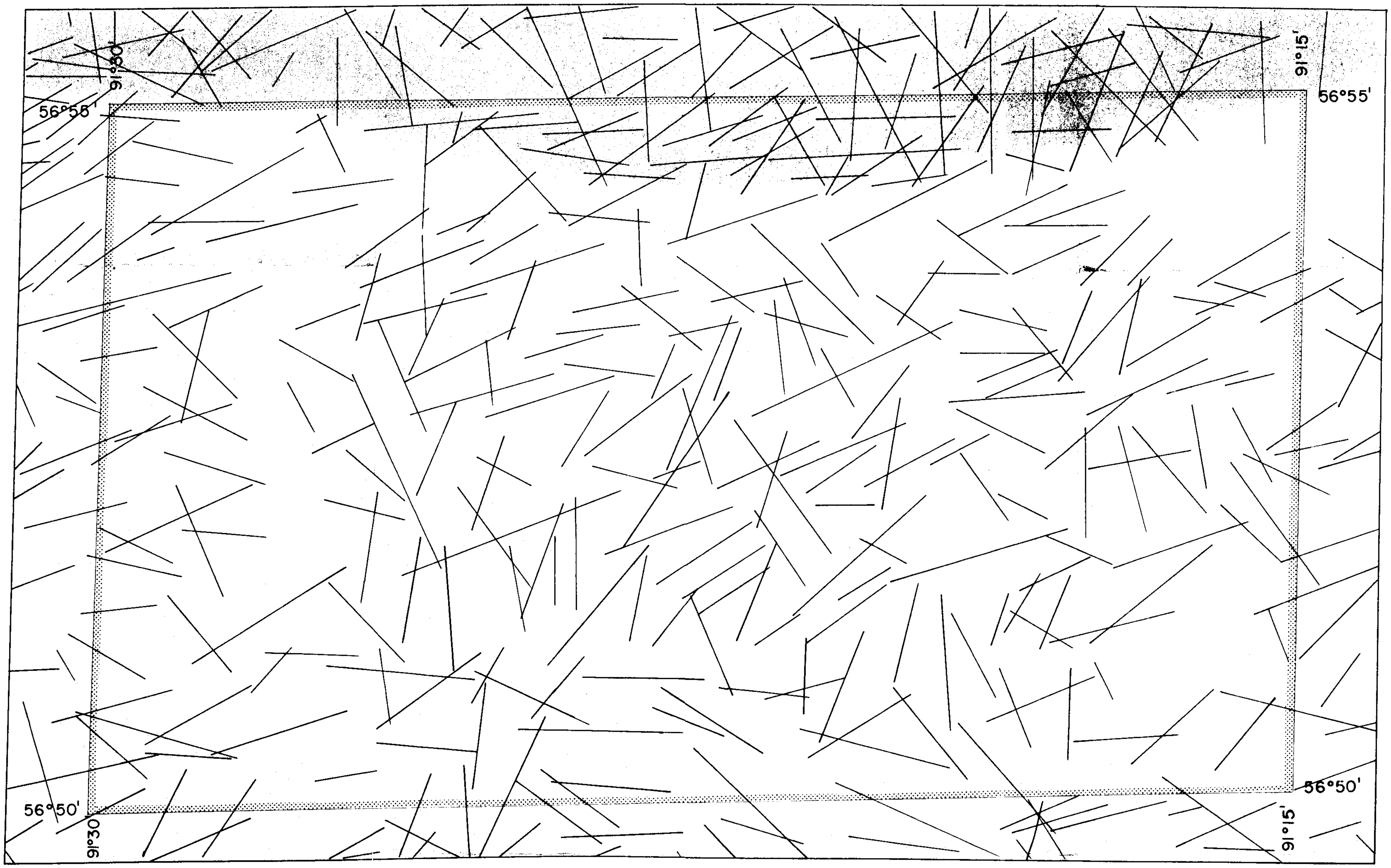
Granite Wash sand is probably absent on the top of this Basement topographic high; but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

WILLIAM G. CROOK
Photoanalyst, P. Geol.

WGC/jp

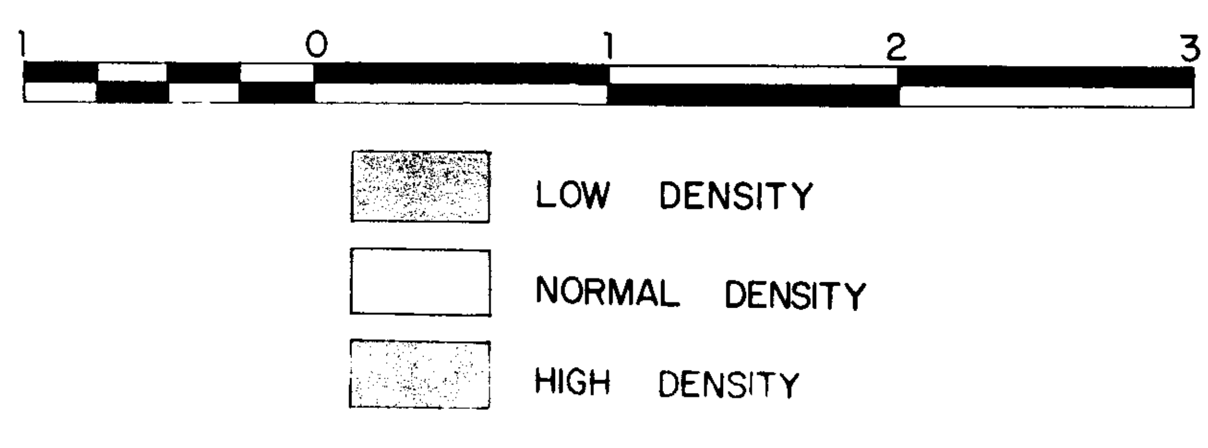


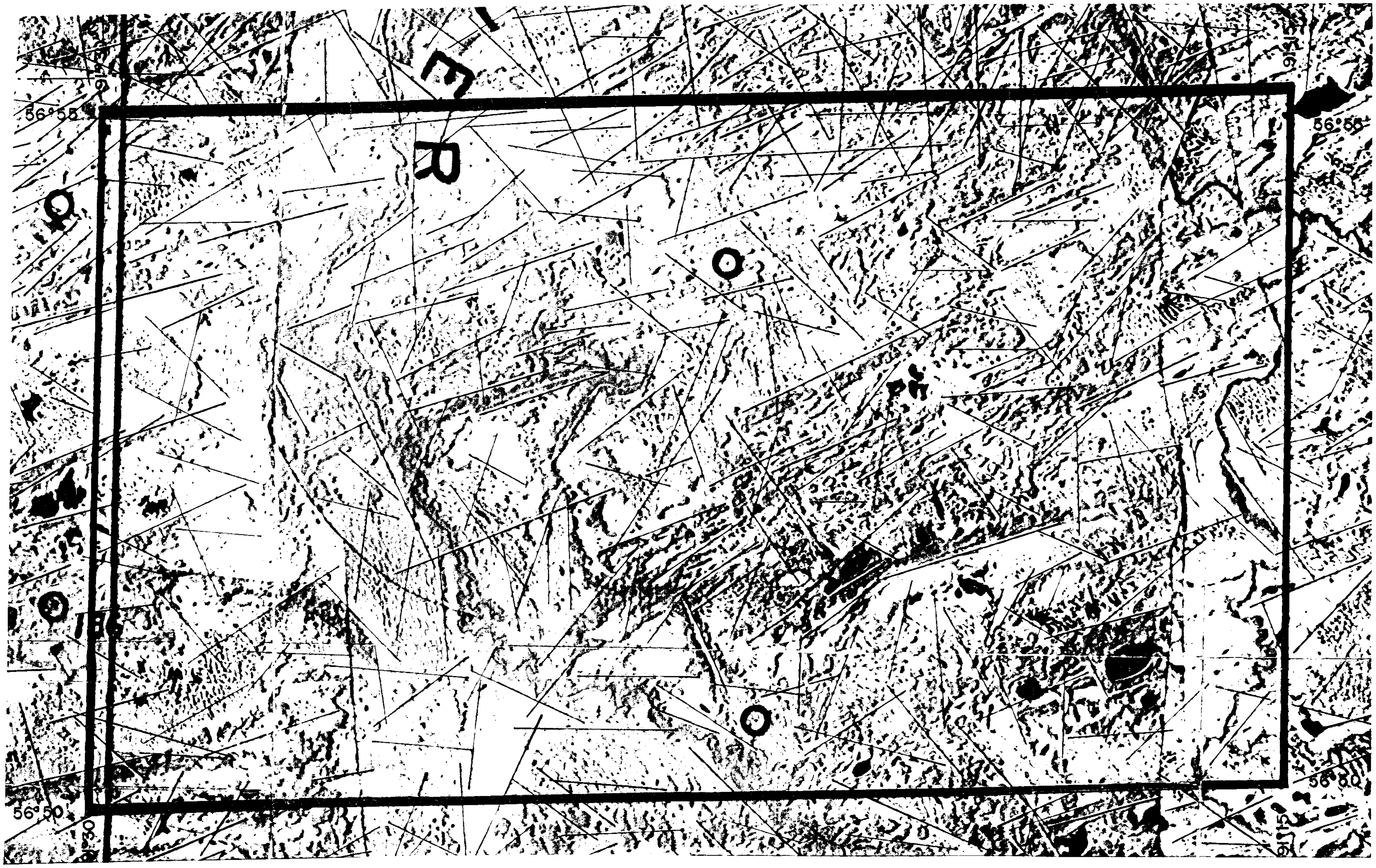
GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 53

TOTAL FRACTURE PATTERN

SCALE : 1.5" = 1 MI.





GLENDALE INVESTMENT CORPORATION LTD.

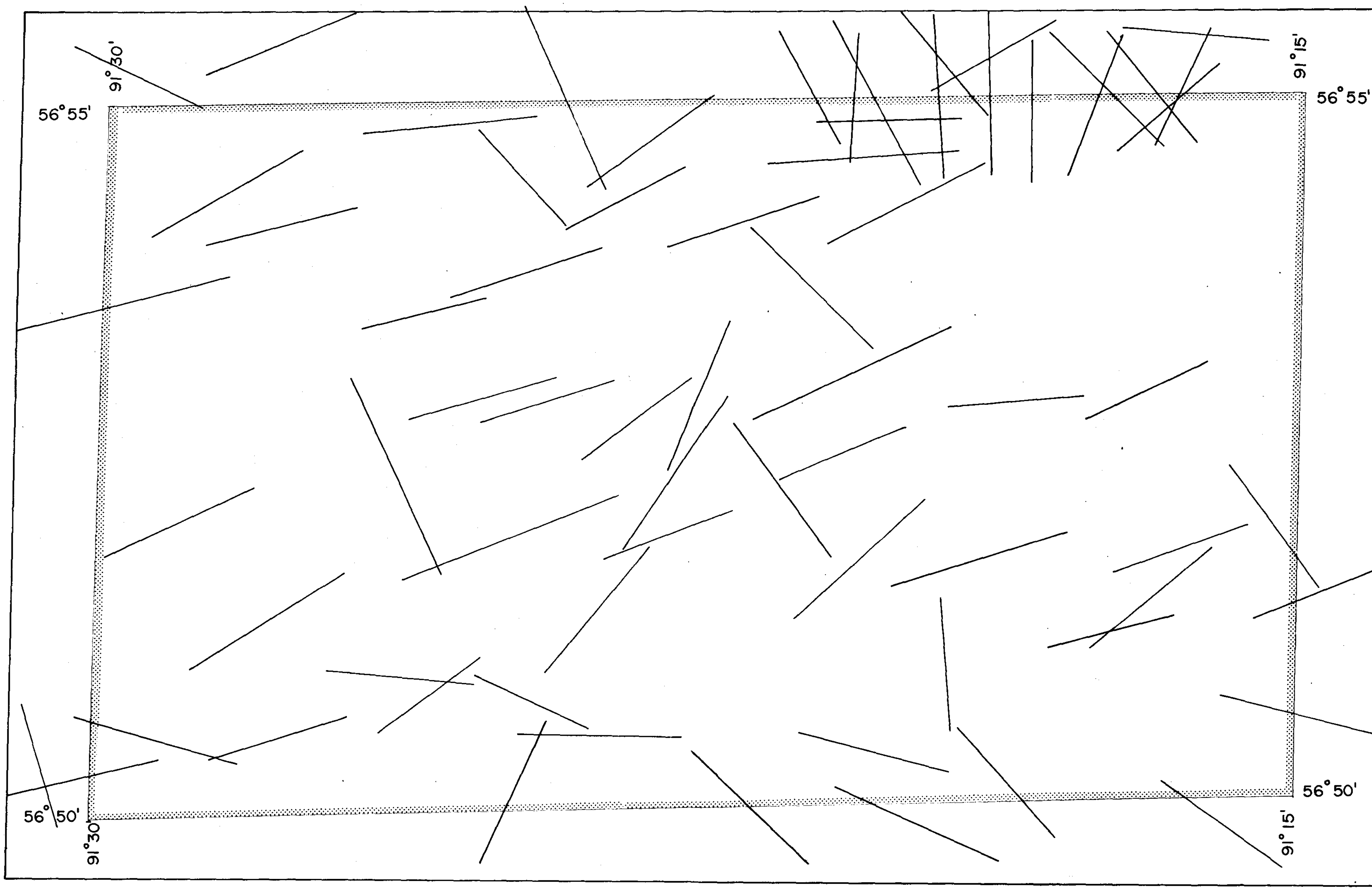
P. & N.G. PERMIT No. 53

HUDSON'S BAY LOWLANDS

MANITOBA

SCALE : 1.5" = 1 MI.

THIS IS A UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN ACCURATE TOPOGRAPHIC MAP.

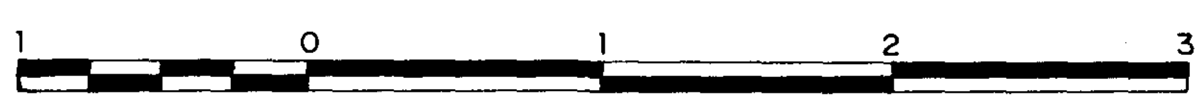


GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 53

MEGA FRACTURE PATTERN

SCALE : 1.5" = 1 MI.



Exploration Permit No. 54

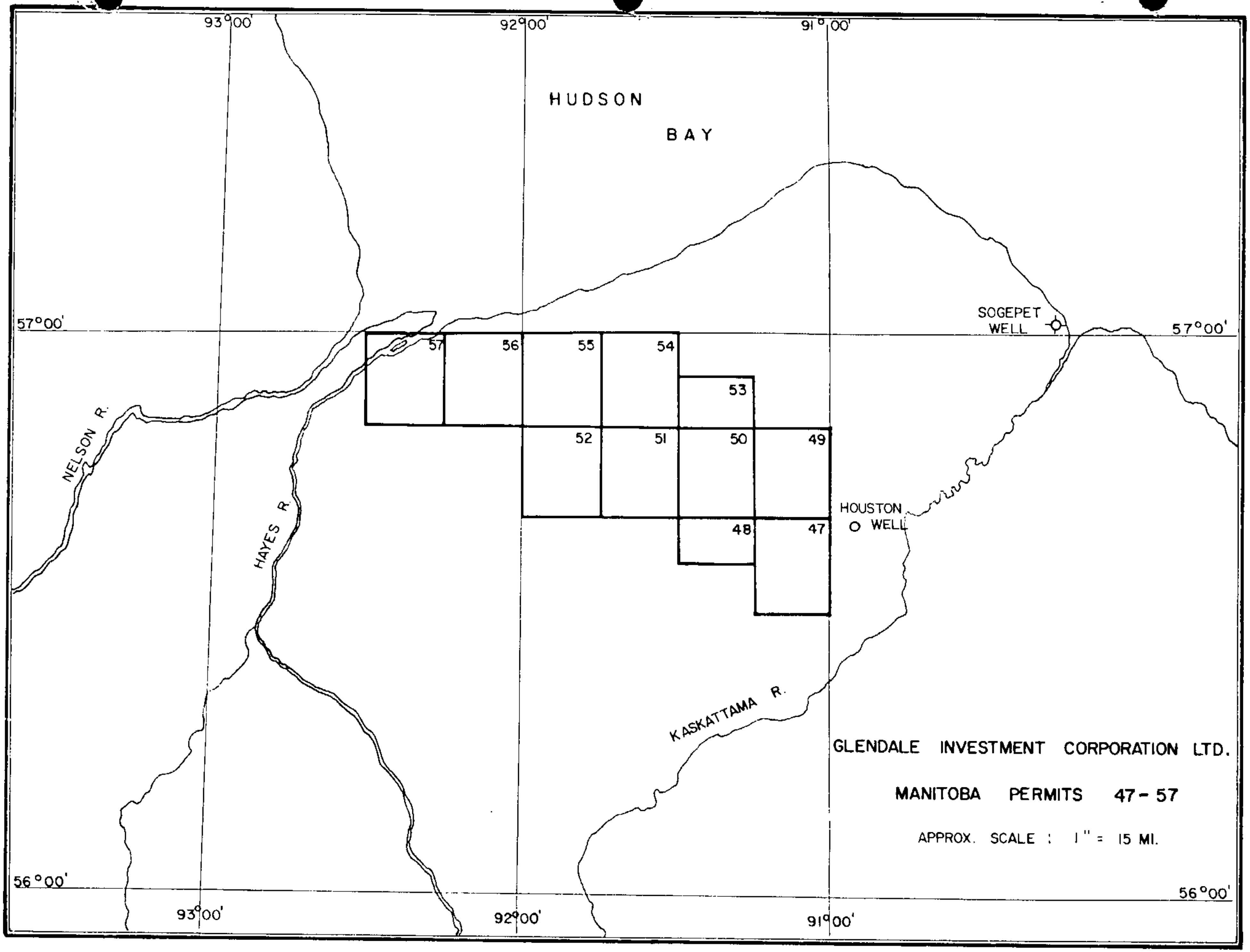
INTRODUCTION

This report discusses the results of a study of the General Geology, Stratigraphy and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 54, Manitoba. This permit is located between 56° 50' - 57° 00' latitude and 91° 30' - 91° 45' longitude. This is in the Hudson's Bay area of northeast Manitoba approximately 540 air miles north-northwest of Winnipeg. There are no roads within the area and the use of an aircraft is required to reach this area.

The stratigraphic discussion is based on information contained in published reports and on the limited data available from well control.

The Fracture Analysis Survey locates topographic highs and lows on the Basement surface. Areas of Basement "highs" are of great interest as it is felt that much reef growth (which is known to be present) is centered, or at least concentrated, over areas of Basement "highs".

Areas of Basement "lows" are of interest as Granite Wash sands tend to accumulate and attain considerable thickness in these "lows". Reefs and Granite Wash sands are probably the two principal reservoir horizons in this area.



93°00'
92°00'
91°00'
HUDSON
BAY
57°00'
SOGEPET
WELL
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56
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54
53
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50
49
48
47
NELSON R.
HAYES R.
HOUSTON
WELL
KASKATTAMA R.
GLENDALE INVESTMENT CORPORATION LTD.
MANITOBA PERMITS 47 - 57
APPROX. SCALE : 1" = 15 MI.
56°00'
56°00'
93°00'
92°00'
91°00'

STRATIGRAPHY

The subject acreage, which is located one to 50 miles south of the Hudson Bay shoreline near York Factory in Manitoba, is primarily covered by muskeg with numerous small rivers, and streams present. Access to the area is provided by the Canadian National Railway line running into Port Nelson and also by ocean ships to the same point. Subsurface control will be provided by the Sogepet-Aquitane-Kaskattama # I well when it is released. It is located some 30 miles east of the northeast corner of the acreage. Recently Houston et al Comeault Sth Prov. # I, located at about 56° 40' and 90° 52' has been licenced. This location, which is some 5 miles east of the acreage, will provide additional valuable subsurface information about this area. Outcrop information is extremely scarce in this area with only some talus being noted near York Factory along the north side of the acreage and along the Kaskattama River, which lies along the south and east side of the acreage. The main outcrop data has to be projected into this area from sections found on the Severn River, which is 110 miles southeast

of the acreage. The Nelson River which is approximately 50 miles northwest of the acreage is another outcrop area. Ordovician rocks are exposed along Gods River, 30 miles south of the western portion of the area under discussion. Beds ranging in age from Upper Ordovician to Upper Silurian are expected to be present beneath the land under review.

ORDOVICIAN

BAD CACHE RAPIDS GROUP

PORTAGE CHUTE FORMATION

The type section of the Portage Chute formation is located on the Churchill River, 100 miles northwest of the acreage. Outcrops are also present on the Nelson River approximately 50 miles west of the area, as well as on the Sachigo and Severn Rivers which lie to the south. The formation was defined by Nelson as overlying peneplaned Pre-Cambrian rocks, and in turn being conformably overlain by the Surprise Creek formation. The Portage Chute formation, which is 75 feet thick at the type section, consists of a four foot basal quartz sandstone which is generally quite uniform, tight and calcareous. This sand is also

present at the other outcrop sections mentioned above. The sand grades upwards into grey to buff, weathering light grey, partially dolomitic, microcrystalline, laminated limestones. Skeletal debris is quite abundant. At the type section the limestone section is 71 feet thick. The thickness of the Portage Chute formation on the Nelson River is approximately 25 feet, while at the Severn River exposures it is only about ten feet thick. The formation dips easterly with an increasing rate of dip as one proceeds basinward along the outcrop sections. Fossils consist mainly of a variety of corals and molluscans with some trilobites present. The limestone takes on a nodular appearance in weathered sections.

SURPRISE CREEK FORMATION

The type section of the Surprise Creek formation was defined by Nelson as being located at Surprise Creek on the Churchill River. It is also present at the Nelson River section but not further south. Nelson considered the Surprise Creek formation as late Ordovician in age. The type section consists of 63 1/2 feet of thinly bedded, light yellowish grey, micro to cryptocrystalline limestone. It ranges from slightly dolomitic, to dolomitic, and contains some lenses of chert. The Surprise Creek formation is disting-

uished from the underlying Portage Chute formation by its lack of organic fragments, and by its smooth weathering characteristics, as opposed to the nodular weathering of the Portage Chute formation. The exposures at Nelson River are poor and not easily correlated with the type section, but, they appear to be lithologically similar to the type section. The thickness is a minimum 30 feet and the fauna is composed mainly of brachiopods. The combined thickness of the Surprise Creek formation and Portage Chute formation at the Selco-Pennycutaway # 1, drill hole, which lies about 17 miles west of the acreage, was 300 $\pm$, indicating a rapid thickening of this group in a basinward direction.

CHURCHILL RIVER GROUP

CAUTION CREEK FORMATION

The type section of the Caution Creek formation is also found on the Churchill River. The type section was defined by Nelson to consist of a basal 18 foot bed of mainly grey to yellowish grey weathering, cryptocrystalline, slightly dolomite limestone, containing shell fragments. This

is overlain by an 18 foot bed of grey to brown weathering, crypto to microcrystalline, slightly dolomitic limestone with little organic remains. This bed weathers into smooth layers, whereas, the lower bed weathers into uneven rubbly beds. The uppermost bed consists of six feet of grey, earthly weathering, micro to cryptocrystalline, slightly dolomitic limestone which has a nodular appearance on a weathered surface. The fauna consists of brachiopods, corals, and molluscans. The Caution Creek formation apparently does not outcrop on the Nelson River, but, it should be present in the subsurface of the subject acreage.

CHASM CREEK FORMATION

The Chasm Creek formation is found both along the Churchill and Nelson Rivers with the Churchill sections being the better one. The Chasm is also exposed at Gods River, some 30 miles south of the acreage. The Chasm is fairly similar to the underlying Caution Creek formation and is in conformable contact with it. At the type section it is about 180 feet thick. The basal 55 feet is a light yellowish grey to buff, microcrystalline, slightly dolomitic

limestone grading to an iron rich dolomite. It is very resistant and weathers to a yellow and orange massive bed. This unit is overlain by about 100 feet of light grey, crypto to microcrystalline, slightly dolomitic to dolomitic limestone. The unit contains abundant fine organic fragments. Overlying this unit is a 5 to 15 foot thick bed of light grey, cryptocrystalline, dolomitic limestone which contains no organic material but has fine intercalations of finely fragmented limestone beds. The uppermost unit is ten to 20 feet thick, and is a light grey weathering, very dolomitic, microcrystalline unit which is strongly fucoidal. On the Nelson River the Chasm Creek section is a minimum of 15 feet thick with the maximum thickness unknown. It is lithologically similar to the type section as is the 38 foot thick section found on Gods River. The Chasm Creek formation contains a fauna comprised of corals, cephalopods and some brachiopods.

RED HEAD RAPIDS FORMATION

The Red Head Rapids formation is the uppermost Ordovician sediment found in this region and tye type section is located on the Churchill River where it overlies the Churchill River Group. The formation is a minimum of 42

feet thick with the maximum thickness unknown. Nelson notes that this formation may be Silurian in age. The lower 25 feet consist of light yellow, microcrystalline dolomitic which weathers a distinctive orange color. No fossils are present in this bed. The upper 17 feet is composed of grey to yellowish grey, microcrystalline dolomite, partially vuggy, which weathers to a grey color. This bed is also quite unfossiliferous. The Red Head Rapids is not present in outcrop on the Nelson, Gods, or Severn Rivers, but, it should be present in the subsurface of the acreage.

SILURIAN

PORT NELSON FORMATION

The type section of the Port Nelson formation is located on the Nelson River some 47 miles west of the acreage under review. The section exposed is 24 feet thick and consists of interbeds of brecciated dolomite, dolomite, and shaly dolomite. The dolomite is generally a gray micro to cryptocrystalline to occasionally granular rock with minor porosity. It contains a coral fauna and

is placed in the Middle Silurian. In the James Bay area a drill hole encountered 110+ feet of this formation. This unit should be found at subcrop under the southwestern portion of the acreage.

SEVERN RIVER FORMATION

The type section of this formation is found on the Severn River some 110 miles southeast of the acreage. The minimum thickness at the type section is 42 feet with the maximum unknown. The section consists of a basal 13 foot light grey, micro to cryptocrystalline limestone with rare vuggy porosity, and a suggestion of algal material. The middle unit consists of 4 feet of light yellowish grey, to orange buff, micro to finely crystalline algal limestone with good vuggy porosity. The upper unit is a 25 foot thick bed of cream to buff, partly microcrystalline to finely crystalline, chalky and partly organic limestone. Fine to coarse organic debris is present as well as beds of oolitic material. The Severn River formation appears to be present near Churchill in similar facies plus the notable fact that it has a strong bituminous odour from a fresh break in this area. This formation should also be present at subcrop under the southwest portion of the acreage.

EKWAN RIVER FORMATION

The type section of this formation is on the Ekwan River, which is in the James Bay area and lies some 350 miles southeast of the area under consideration. The section is from 73 to 88 feet thick and consists of grey, fine grained, partially cherty limestone containing corals and stromatoporoids. The section on Severn River is a minmum 37 feet thick with the maximum unknown. The basal 20 feet is composed of light medium brown, microcrystalline limestone with fine to coarse fossil fragments, some chert nodules and some oolitic material. The fossils consist of stromatoporoids, corals, brachiopods and cephalopods. Some poor intercrystalline and vuggy porosity is present. The middle ll feet consists of yellowish brown, micro-crystalline partially dolomitic, chalky limestone with some thin fragmental beds and rare brachiopods. The upper 6 feet is a light greyish brown, to creamy, microcrystalline limestone which is very highly and coarsely fragmental. The top section contains poor to good porosity. The Ekwan River formation is also exposed along the shore of Hudson Bay from the Mouth of Owl River to a point some 20 miles south of Cape Churchill. The Ekwan should be found to

subcrop along the western and central position of the subject acreage.

ATTAWAPISKAT FORMATION

The type section is located on the Attawapiskat River which lies some 40 miles south of the Ekwan River type section in the James Bay area. The formation outcrops on the Ekwan River, Severn River and along the tidal flats south from Cape Churchill.

The Ekwan River outcrop section consists of 54 feet of fine grained, thin bedded, coral reef limestone. Nelson has described a reefal and possible off reef facies for the Attawapiskat formation in general. The reef facies has a minimum thickness of 25 feet and is a cream, to orange cream, to buff, microcrystalline, fragmental limestone with corals and stromatoporoids being common. Porosity grades from tight to excellent and is vuggy. Nelson feels that some of the well bedded reefs are suggestive of biostromes, while other oval, domal reefs are believed to be bioherms. He noted a gassy odour at one location.

The off-reef facies is a minimum of 16 feet thick with uniform beds of cream, to partly yellowish cream, to grey microcrystalline limestone. There are abundant coarse granular, bioclastic beds which have excellent intergranular porosity which could be post reef deposits. The Attawapiskat outcrops south of Cape Churchill range in thickness from 25 to 50 feet in thickness, with both facies present and they are seen to grade laterally from one to the other. This formation should be at subcrop through the central portion of the acreage.

KENOGAMI RIVER FORMATION

The Kenogami River formation which has only been found in outcrop, in the James Bay represents the youngest Silurian found in the Hudson Bay Basin. The formation consists of an alternating series of shale, siltstone, sandstone, dolomite, silty dolomite, shaly limestone, and limestone. The colours mainly range from buff to grey, but, reds and greens are the colours of the clastics. The outcrop section has a minimum thickness of 300 feet while a well drilled on Puskwuine Point in James Bay had a thickness of 862 feet. The Kenogami River formation is

expected to subcrop along the eastern half of the acreage under review.

DEVONIAN

Rocks of Devonian age are not expected to be present under the area covered by the permit, however, they should be present at subcrop east of the acreage, at and near the Sogepet-Aquitaine-Kaskattama # I well where total depth was reached at 2,941 feet in granite.

CRETACEOUS

Rocks of Cretaceous age are know only in the James Bay area and are not expected to be present under the permits.

FRACTURE ANALYSIS

This section of the report discusses the results of a Detailed Fracture Analysis Survey carried out on the area under discussion. An aerial mosaic (scale 1.5 inches equals approximately 1 mile) made from Dominion Government aerial photographs accompanies this report. These same photographs were examined stereoscopically and the fractures plotted on the individual photographs, then transferred to the mosaic for analysis.

The theory that the earth's crust is abundantly and methodically fractured is the basic premise on which is built the exploration technique known as Fracture Analysis. A Fracture is defined as"...generally abundant, natural lineation discernible on aerial photographs".

Fracturing is largely caused by external stresses on the surface. The most important are:

(a) earth tides

(b) radial acceleration of the earth along its radius vector.

(c) a gradual decrease of the earth's rate of rotation.

As stated above, the earth is systematically fractured and the fracture system would approach symmetry if the crust were homogeneous. It is considered that irregularities are caused by regional heterogeneous conditions within the earth's crust. Local departures from the norm are caused by structural or stratigraphic anomalies.

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External forces such as earth tides obviously fit these parameters. Some internal forces may also apply such as the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

In general it can be said that fracture patterns are caused by either internal forces or external forces.

If the forces are internal the result would be different orientation of the fracture systems in areas of similar tectonic history but different position. If the forces are external the orientation of the fracture arrangement should have world wide similarity. However, stable areas such as the masses of the continents may develop fracture patterns due to external forces and tectonically active areas may develop their own pattern due to internal forces.

If joints form early in the history of a sediment then systematic joints must be successively younger upwards through the section and the joint pattern is imposed on each new layer of sediments when they have become consolidated enough to fracture. This upward propagation is caused by the fatigue caused by stress, which in turn is caused by diurnal earth tides.

EXPRESSION OF FRACTURE

Fractures have been observed in aerial photographs from every climate and on every continent in the world. They are expressed as topographic relief, vegetation

differences and soil tonal differences.

TOPOGRAPHIC RELIEF LINEAMENTS

A common type are relief lineaments which can be manifested by a change (usually abrupt) of topographic elevation on either side of a relatively straight line. They may also be expressed as straight valleys or hills or by straight streams where the stream course is controlled by a fracture zone.

VEGETAL LINEAMENTS

Vegetal lineaments are the most common in the parkland and muskeg areas of western Canada and many excellent examples of fractures can be seen on almost any aerial photograph of northern Saskatchewan, Alberta or British Columbia. Straight lines of both deciduous and evergreen trees as well as scrub growth are universally visible. However, the most common vegetal lineament seen by this writer is a straight "edge" to a clump of trees or bushes. In many cases these fractures control the size and

shape of cultivated fields. Excellent examples of this latter expression of fractures are present in the western part of the Peace River district.

SOIL TONAL LINEAMENTS

These reflect differentiation in soil moisture and general ground water conditions. These are common in the southern parts of Alberta and Saskatchewan, especially near large rivers.

Surface investigations have shown that fractures are associated with bedrock joints; however, in glaciated areas such as western Canada, the photoanalyst must take care to establish the direction of ice flow over an area before he begins to statistically plot and analyse the fractures. Most areas in western Canada show an abundance of grooves and flutes caused by the glacier and these must not be mistaken for fracture traces caused by subsurface structural conditions. In parts of the Lloydminster area of eastern Alberta the glacial scars are so deeply impressed on the surface that fracture analysis is at best difficult and

often impossible.

INTERPRETATION OF FRACTURE DATA

The object of Fracture Analysis (Photogeophysics) is to locate shallow to deep-seated structural and stratigraphic anomalies. The actual count of fractures per unit area is made and values are contoured on a "Fracture Intensity Map". In areas of known reefs the fracture intensity is 2-3 times greater on the flanks of the reef than directly above the reef.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general the two systems are at approximate right angles to each other.

Because of certain inherent limiting factors, Structure Incidence Surveys have a lower order of reliability than Detailed Fracture Analysis Surveys. To some extent at least, surface conditions affect the fracture count. In areas

covered by lakes, sloughs and rivers, the fracture count is zero. Cultivated areas generally yield a lower count than adjacent virgin territory. Consequently, a difference or contrast in fracture count (F/I) between two points may be in part due to structure, but, also due in part to different surface conditions. To some extent, this can be compensated for by applying appropriate weightings to the observed counts, but over or under corrections may result.

Nevertheless, in spite of these sources or error, it has been demonstrated in (plains) areas where abundant subsurface control is available, that the incidence of fracturing is considerably above normal in the surrounding area immediately out from the steepest part of the flanks of the structure. This is in contrast with a low or normal incidence over the crestal area, and also to a normal incidence off structure.

FRACTURE ANALYSIS OF PERMIT NO. 54

The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permit. The Permit is located in the muskeg area south of Hudson Bay and is hundreds of miles from the closest settlement.

The sedimentary section is probably 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There is one area where the fracture intensity is greater than normal and there is one area where the fracture intensity is less than normal. The high intensity area is shown in red and the low intensity area is shown in green. The average length of the fracture is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to mention the glacial problem in this area.

Reference to the mosaic will show that the area is moderately scarred with glacial grooves and striations and that the direction of ice flow was about north 30 degrees east. Some of these grooves are so deeply impressed on the surface that they control the shape of the lakes and of tree growth in the area. In any area such as this the photoanalyst is faced with the difficult problem of eliminating the glacial scars from the fracture pattern without creating false anomalies. The removal of all fractures from a 10-12 degree arc in any area will create fracture anomalies and it requires delicate weighting of the whole pattern to adjust for these effects.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general, the two systems are at approximate right angles to each other. Within Petroleum & Natural Gas Permit No. 54 the statistical mean direction of the axial system is north 40 degrees west and the statistical mean direction of the shear system is north 30 degrees east. A third minor system, here termed the sub-axial system, trends nearly north-south.

No regional fractures of great length can be seen and as these are conceded to originate within the Basement, it is assumed that all fractures plotted on the mosaic originate within the sedimentary section. Furthermore, as the fractures are short for this area it is very likely that they originate in the upper two-thirds of the sedimentary section. As the surface of the Permit is relatively flat-lying no azimuth correction is necessary for this study. It has been demonstrated that the low incidence anomalies on a mosaic are considerably larger than the subsurface feature which causes them.

There is one area on the mosaic where the fractures are less intense than the surrounding area. Some fractures are always present within these areas, but they usually have a lower incidence than the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the next section of this report.

STRUCTURE

Petroleum and Natural Gas Permit No. 54 is located on the coastal plain on the south shore of Hudson's Bay about 70 miles north of the edge of the Pre-Cambrian Shield.

Structural features which could be present and which could cause the low incidence anomalies mentioned in this report are discussed in order of probability.

(I) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No. 54 is thought to be much the same as it is today along the north edge of the Shield. Low rounded hills separated by gentle to abrupt valleys are seen on the Shield and these features are undoubtedly present under the subject Permit. The effect of this Basement relief on the overlying sedimentary rocks is often great. The Granite Wash sand is usually present in the topographic "lows" on the Basement but absent on the "highs". The Granite Wash is an excellent potential reservoir.

Further effects of Basement topography on beds higher than the Granite Wash is the gentle folding present over Basement hills. These folds are anticlines in every sense and could from traps for oil and gas.

(2) REEFS

Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. However, only small reefs have been found in outcrops near the Permit and such small masses as these probably do not greatly affect the fracture pattern.

(3) TECTONIC FOLDING AND FAULTING

The presence of tectonic folds is very unlikely, but some normal faulting could be present.

(4) TOPOGRAPHIC REFLIEF ON AN INTRA-SEDIMENTARY UNCONFORMITY

Unconformity, is a possible source of fracture intensity anomalies, but within the Permit area it is unlikely that the relief on any unconformities within the sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there is one area of "high" fracture intensity, and one area of "low" fracture intensity (green). The general interpretation is that the low fracture intensity area is underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is high in the southwest part of Permit No. 54.

This Basement high feature is most interesting from the oil and gas point of view. The general shape of this feature is such that the causative feature must be a hill on the Basement surface. A fault is unlikely as the causative feature as the high area is over one and one-half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Granite Wash sand is probably absent on the top of this high fracture area, but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Crook

WGC/jp

REFERENCES

NELSON S.J. & — 1966: Geology of Hudson Bay Basin, Bull. Can. Petrol. Geol., Vol. 14, No. 4, pp. 520-578.

BOSTOCK H.H.
CUMMING L.M.
NORFORD B.S.
NORRIS A.W. — Geology Hudson Bay Lowlands, Map 17-.1967, Geol. Surv. Can.
PRICE L.L.
STANDFORD B.V.

BLANCHET P.H. — 1957: "Development of Fracture Analysis as Exploration Method", Amer. Assoc. Petrol. Geol. Bull., Vol. 41, No. 8, 1748-59

HAMAN P.J. — 1964: "Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2

Granite Wash sand is probably absent on the top of this Basement topographic high; but will probably be present along the flanks of this feature.

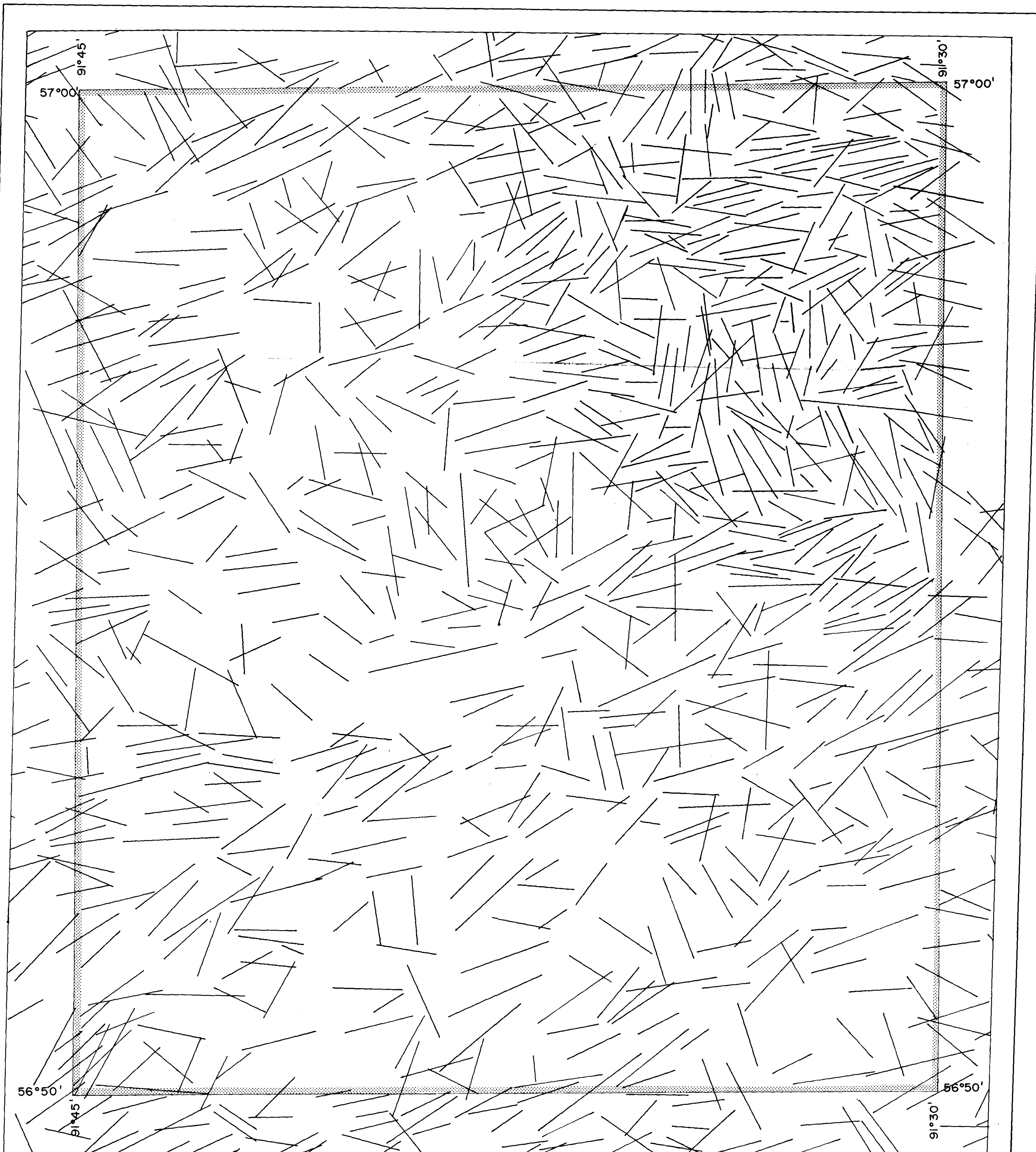
Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Crook

WILLIAM G. CROOK
Photoanalyst, P. Geol.

WGC/jp



GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT NO. 54

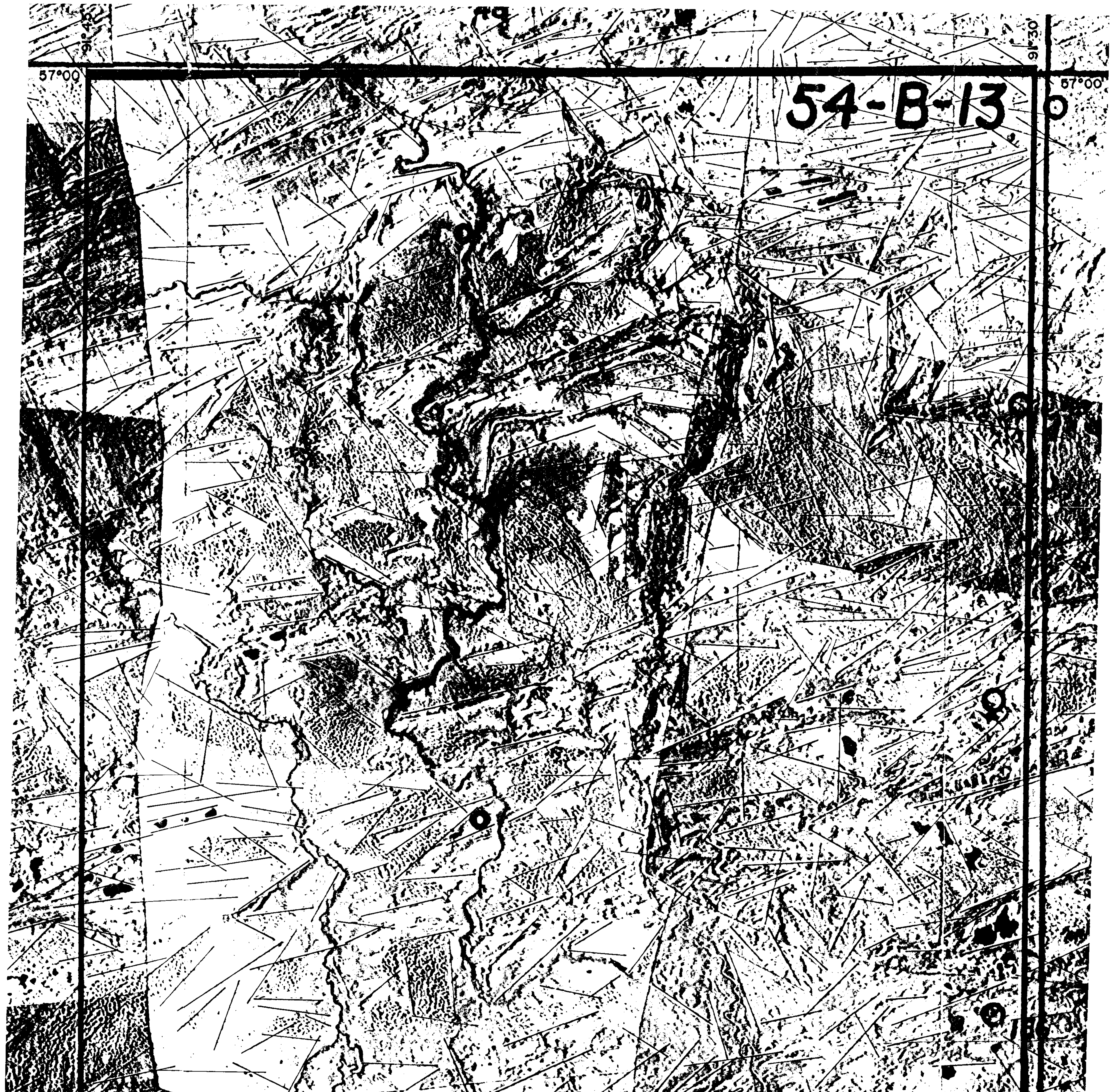
TOTAL FRACTURE PATTERN

SCALE: 1.5" = 1 MI.

LOW DENSITY

NORMAL DENSITY

HIGH DENSITY



GLENDALE INVESTMENT CORPORATION LTD.

P.& N.G. PERMIT No. 54

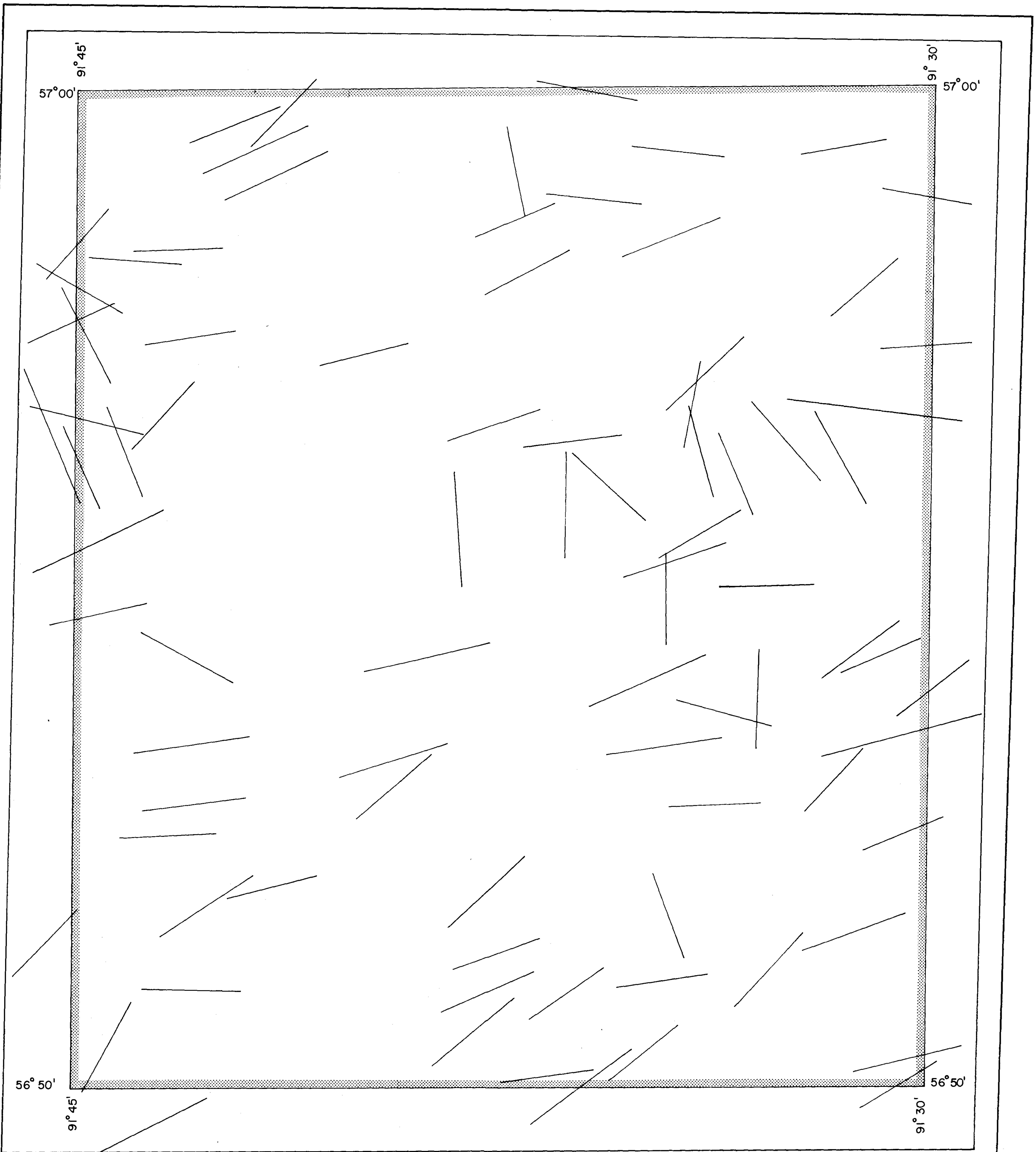
HUDSON'S BAY LOWLANDS

MANITOBA

SCALE : 1.5" = 1MI.

1 0 1 2 3

THIS IS A UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN ACCURATE TOPOGRAPHIC MAP.



GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 54

MEGA FRACTURE PATTERN

SCALE 1.5" = 1 MI.

Exploration
Permit
No. 55

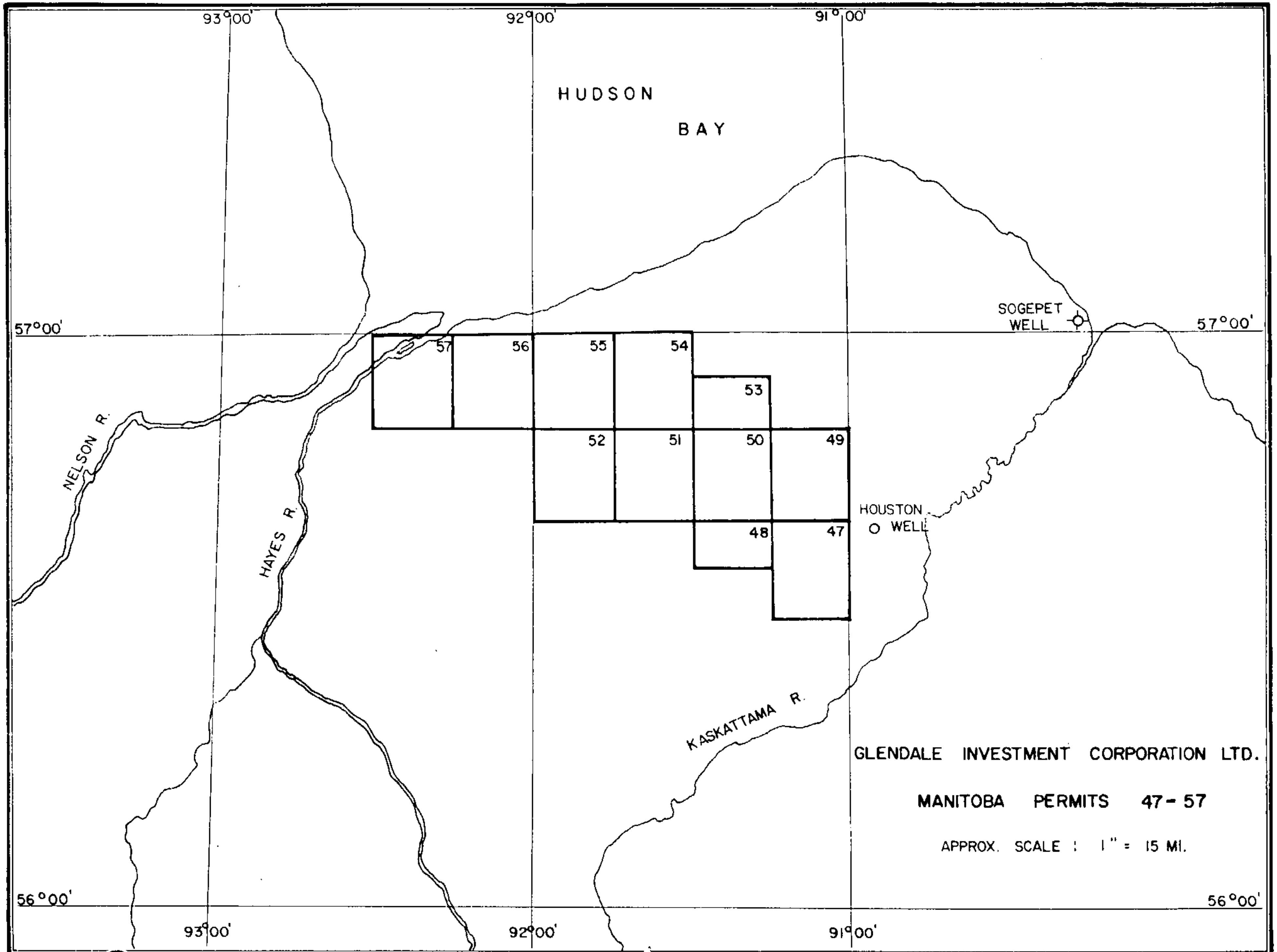
INTRODUCTION

This report discusses the results of a study of the General Geology and Stratigraphy and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 55, Manitoba. This permit is located between 56° 50' - 57° 00' latitude and 91° 45' - 92° 00' longitude. This is in the Hudson's Bay area of northeast Manitoba approximately 540 air miles north-northwest of Winnipeg. There are no roads within the area and the use of an aircraft is required to reach the area.

The stratigraphic discussion is based on information contained in published reports and on the limited data available from well control.

The Fracture Analysis Survey locates topographic highs and lows on the Basement surface. Areas of Basement "highs" are of great interest as it is felt that much reef growth (which is known to be present) is centered, or at least concentrated, over areas of Basement "highs".

Areas of Basement "lows" are of interest as Granite Wash sands tend to accumulate and attain considerable thickness in these "lows". Reefs and Granite Wash sands are probably the two principal reservoir horizons in this area.


93°00'
92°00'
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HUDSON
BAY
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NELSON R.
HAYES R.
KASKATTAMA R.
SOGEPET
WELL
HOUSTON
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GLENDALE INVESTMENT CORPORATION LTD.
MANITOBA PERMITS 47 - 57
APPROX. SCALE : 1" = 15 MI.

STRATIGRAPHY

The subject acreage, which is located one to 50 miles south of the Hudson Bay shoreline near York Factory in Manitoba, is primarily covered by muskeg with numerous small rivers, and streams present. Access to the area is provided by the Canadian National Railway line running into Port Nelson and also by ocean ships to the same point. Subsurface control will be provided by the Sogepet-Aquitane-Kaskattama # I well when it is released. It is located some 30 miles east of the northeast corner of the acreage. Recently Houston et al Comeault Sth Prov. # I, located at about 56° 40' and 90° 52' has been licenced. This location, which is some 5 miles east of the acreage, will provide additional valuable subsurface information about this area. Outcrop information is extremely scarce in this area with only some talus being noted near York Factory along the north side of the acreage and along the Kaskattama River, which lies along the south and east side of the acreage. The main outcrop data has to be projected into this area from sections found on the Severn River, which is 110 miles southeast

of the acreage. The Nelson River which is approximately 50 miles northwest of the acreage is another outcrop area. Ordovician rocks are exposed along Gods River, 30 miles south of the western portion of the area under discussion. Beds ranging in age from Upper Ordovician to Upper Silurian are expected to be present beneath the land under review.

ORDOVICIAN

BAD CACHE RAPIDS GROUP

PORTAGE CHUTE FORMATION

The type section of the Portage Chute formation is located on the Churchill River, 100 miles northwest of the acreage. Outcrops are also present on the Nelson River approximately 50 miles west of the area, as well as on the Sachigo and Severn Rivers which lie to the south. The formation was defined by Nelson as overlying peneplaned Pre-Cambrian rocks, and in turn being conformably overlain by the Surprise Creek formation. The Portage Chute formation, which is 75 feet thick at the type section, consists of a four foot basal quartz sandstone which is generally quite uniform, tight and calcareous. This sand is also

present at the other outcrop sections mentioned above. The sand grades upwards into grey to buff, weathering light grey, partially dolomitic, microcrystalline, laminated limestones. Skeletal debris is quite abundant. At the type section the limestone section is 71 feet thick. The thickness of the Portage Chute formation on the Nelson River is approximately 25 feet, while at the Severn River exposures it is only about ten feet thick. The formation dips easterly with an increasing rate of dip as one proceeds basinward along the outcrop sections. Fossils consist mainly of a variety of corals and molluscans with some trilobites present. The limestone takes on a nodular appearance in weathered sections.

SURPRISE CREEK FORMATION

The type section of the Surprise Creek formation was defined by Nelson as being located at Surprise Creek on the Churchill River. It is also present at the Nelson River section but not further south. Nelson considered the Surprise Creek formation as late Ordovician in age. The type section consists of 63 1/2 feet of thinly bedded, light yellowish grey, micro to cryptocrystalline limestone. It ranges from slightly dolomitic, to dolomitic, and contains some lenses of chert. The Surprise Creek formation is disting-

uished from the underlying Portage Chute formation by its lack of organic fragments, and by its smooth weathering characteristics, as opposed to the nodular weathering of the Portage Chute formation. The exposures at Nelson River are poor and not easily correlated with the type section, but, they appear to be lithologically similar to the type section. The thickness is a minimum 30 feet and the fauna is composed mainly of brachiopods. The combined thickness of the Surprise Creek formation and Portage Chute formation at the Selco-Pennycutaway # 1, drill hole, which lies about 17 miles west of the acreage, was 300 $\pm$, indicating a rapid thickening of this group in a basinward direction.

CHURCHILL RIVER GROUP

CAUTION CREEK FORMATION

The type section of the Caution Creek formation is also found on the Churchill River. The type section was defined by Nelson to consist of a basal 18 foot bed of mainly grey to yellowish grey weathering, cryptocrystalline, slightly dolomite limestone, containing shell fragments. This

is overlain by an 18 foot bed of grey to brown weathering, crypto to microcrystalline, slightly dolomitic limestone with little organic remains. This bed weathers into smooth layers, whereas, the lower bed weathers into uneven rubbly beds. The uppermost bed consists of six feet of grey, earthly weathering, micro to cryptocrystalline, slightly dolomitic limestone which has a nodular appearance on a weathered surface. The fauna consists of brachiopods, corals, and molluscans. The Caution Creek formation apparently does not outcrop on the Nelson River, but, it should be present in the subsurface of the subject acreage.

CHASM CREEK FORMATION

The Chasm Creek formation is found both along the Churchill and Nelson Rivers with the Churchill sections being the better one. The Chasm is also exposed at Gods River, some 30 miles south of the acreage. The Chasm is fairly similar to the underlying Caution Creek formation and is in conformable contact with it. At the type section it is about 180 feet thick. The basal 55 feet is a light yellowish grey to buff, microcrystalline, slightly dolomitic

limestone grading to an iron rich dolomite. It is very resistant and weathers to a yellow and orange massive bed. This unit is overlain by about 100 feet of light grey, crypto to microcrystalline, slightly dolomitic to dolomitic limestone. The unit contains abundant fine organic fragments. Overlying this unit is a 5 to 15 foot thick bed of light grey, cryptocrystalline, dolomitic limestone which contains no organic material but has fine intercalations of finely fragmented limestone beds. The uppermost unit is ten to 20 feet thick, and is a light grey weathering, very dolomitic, microcrystalline unit which is strongly fucoidal. On the Nelson River the Chasm Creek section is a minimum of 15 feet thick with the maximum thickness unknown. It is lithologically similar to the type section as is the 38 foot thick section found on Gods River. The Chasm Creek formation contains a fauna comprised of corals, cephalopods and some brachiopods.

RED HEAD RAPIDS FORMATION

The Red Head Rapids formation is the uppermost Ordovician sediment found in this region and tye type section is located on the Churchill River where it overlies the Churchill River Group. The formation is a minimum of 42

feet thick with the maximum thickness unknown. Nelson notes that this formation may be Silurian in age. The lower 25 feet consist of light yellow, microcrystalline dolomitic which weathers a distinctive orange color. No fossils are present in this bed. The upper 17 feet is composed of grey to yellowish grey, microcrystalline dolomite, partially vuggy, which weathers to a grey color. This bed is also quite unfossiliferous. The Red Head Rapids is not present in outcrop on the Nelson, Gods, or Severn Rivers, but, it should be present in the subsurface of the acreage.

SILURIAN

PORT NELSON FORMATION

The type section of the Port Nelson formation is located on the Nelson River some 47 miles west of the acreage under review. The section exposed is 24 feet thick and consists of interbeds of brecciated dolomite, dolomite, and shaly dolomite. The dolomite is generally a gray micro to cryptocrystalline to occasionally granular rock with minor porosity. It contains a coral fauna and

is placed in the Middle Silurian. In the James Bay area a drill hole encountered 110+ feet of this formation. This unit should be found at subcrop under the southwestern portion of the acreage.

SEVERN RIVER FORMATION

The type section of this formation is found on the Severn River some 110 miles southeast of the acreage. The minimum thickness at the type section is 42 feet with the maximum unknown. The section consists of a basal 13 foot light grey, micro to cryptocrystalline limestone with rare vuggy porosity, and a suggestion of algal material. The middle unit consists of 4 feet of light yellowish grey, to orange buff, micro to finely crystalline algal limestone with good vuggy porosity. The upper unit is a 25 foot thick bed of cream to buff, partly microcrystalline to finely crystalline, chalky and partly organic limestone. Fine to coarse organic debris is present as well as beds of oolitic material. The Severn River formation appears to be present near Churchill in similar facies plus the notable fact that it has a strong bituminous odour from a fresh break in this area. This formation should also be present at subcrop under the southwest portion of the acreage.

EKWAN RIVER FORMATION

The type section of this formation is on the Ekwan River, which is in the James Bay area and lies some 350 miles southeast of the area under consideration. The section is from 73 to 88 feet thick and consists of grey, fine grained, partially cherty limestone containing corals and stromatoporoids. The section on Severn River is a minmum 37 feet thick with the maximum unknown. The basal 20 feet is composed of light medium brown, microcrystalline limestone with fine to coarse fossil fragments, some chert nodules and some oolitic material. The fossils consist of stromatoporoids, corals, brachiopods and cephalopods. Some poor intercrystalline and vuggy porosity is present. The middle ll feet consists of yellowish brown, microcrystalline partially dolomitic, chalky limestone with some thin fragmental beds and rare brachiopods. The upper 6 feet is a light greyish brown, to creamy, microcrystalline limestone which is very highly and coarsely fragmental. The top section contains poor to good porosity. The Ekwan River formation is also exposed along the shore of Hudson Bay from the Mouth of Owl River to a point some 20 miles south of Cape Churchill. The Ekwan should be found to

subcrop along the western and central position of the subject acreage.

ATTAWAPISKAT FORMATION

The type section is located on the Attawapiskat River which lies some 40 miles south of the Ekwan River type section in the James Bay area. The formation outcrops on the Ekwan River, Severn River and along the tidal flats south from Cape Churchill.

The Ekwan River outcrop section consists of 54 feet of fine grained, thin bedded, coral reef limestone. Nelson has described a reefal and possible off reef facies for the Attawapiskat formation in general. The reef facies has a minimum thickness of 25 feet and is a cream, to orange cream, to buff, microcrystalline, fragmental limestone with corals and stromatoporoids being common. Porosity grades from tight to excellent and is vuggy. Nelson feels that some of the well bedded reefs are suggestive of biostromes, while other oval, domal reefs are believed to be bioherms. He noted a gassy odour at one location.

The off-reef facies is a minimum of 16 feet thick with uniform beds of cream, to partly yellowish cream, to grey microcrystalline limestone. There are abundant coarse granular, bioclastic beds which have excellent intergranular porosity which could be post reef deposits. The Attawapiskat outcrops south of Cape Churchill range in thickness from 25 to 50 feet in thickness, with both facies present and they are seen to grade laterally from one to the other. This formation should be at subcrop through the central portion of the acreage.

KENOGAMI RIVER FORMATION

The Kenogami River formation which has only been found in outcrop, in the James Bay represents the youngest Silurian found in the Hudson Bay Basin. The formation consists of an alternating series of shale, siltstone, sandstone, dolomite, silty dolomite, shaly limestone, and limestone. The colours mainly range from buff to grey, but, reds and greens are the colours of the clastics. The outcrop section has a minimum thickness of 300 feet while a well drilled on Puskwuine Point in James Bay had a thickness of 862 feet. The Kenogami River formation is

expected to subcrop along the eastern half of the acreage under review.

DEVONIAN

Rocks of Devonian age are not expected to be present under the area covered by the permit, however, they should be present at subcrop east of the acreage, at and near the Sogepet-Aquitaine-Kaskattama # I well where total depth was reached at 2,941 feet in granite.

CRETACEOUS

Rocks of Cretaceous age are know only in the James Bay area and are not expected to be present under the permits.

FRACTURE ANALYSIS

This section of the report discusses the results of a Detailed Fracture Analysis Survey carried out on the area under discussion. An aerial mosaic (scale 1.5 inches equals approximately 1 mile) made from Dominion Government aerial photographs accompanies this report. These same photographs were examined stereoscopically and the fractures plotted on the individual photographs, then transferred to the mosaic for analysis.

The theory that the earth's crust is abundantly and methodically fractured is the basic premise on which is built the exploration technique known as Fracture Analysis. A Fracture is defined as"...generally abundant, natural lineation discernible on aerial photographs".

Fracturing is largely caused by external stresses on the surface. The most important are:

(a) earth tides

(b) radial acceleration of the earth along its radius vector.

(c) a gradual decrease of the earth's rate of rotation.

As stated above, the earth is systematically fractured and the fracture system would approach symmetry if the crust were homogeneous. It is considered that irregularities are caused by regional heterogeneous conditions within the earth's crust. Local departures from the norm are caused by structural or stratigraphic anomalies.

The term "photogeophysics" was introduced by Blanchet (1956) and deals with mapping, analysis and interpretation of fracture traces as recorded on aerial photographs. In a more general way "photogeophysics" can be defined as the methodical statistical analysis of linear features seen on aerial photographs and this system is applied by any method recording all observable lineations, or the totality of a certain type of linear feature, and the statistical presentation of the data on contoured intensity maps of dry plotting the fractures directly on the mosaic.

In this report a megafracture is longer than one mile and a microfracture is shorter than one mile.

GENERAL STATEMENT

ORIGIN OF FRACTURES

Fracturing is largely caused by external stresses on the earth, although internal stresses may play some minor roll. The most important of these external forces are the diurnal earth tides due to the gravitational effects of the sun and moon; the change in radial acceleration of the earth along its radius vector and the gradual decrease in the earth's rate of rotation. The endless rhythemic action of these earth tides is probably the principal cause of the systematic fracture system seen over most of the world, even though the amplitude of these tides is only 9-13 inches. The fractures are most likely generated by the process of fatigue as the end result of these stresses which are repeated regularly over millions and millions of years. Metals fatigue in the same manner when subjected to continual vibration.

In general the initiating forces which generate fractures must have continued for a very long time and

the process involved are continuous and are probably active at the present time. Furthermore, Mollard (1957) states, "The mechanism required to reflect lineaments to ground surface must be reasonably simple, for simple patterns are produced on diverse topography and in diverse types and depths of surficial deposits that overlie different kinds of relatively flat-lying sedimentary rocks of varying thickness. The mechanism producing the lineament pattern must persist over extensive and widespread belts of the earth's outer shell; that is today, the engendering mechanism in fact be world wide".

External forces such as earth tides obviously fit these parameters. Some internal forces may also apply such as the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

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shape of cultivated fields. Excellent examples of this latter expression of fractures are present in the western part of the Peace River district.

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These reflect differentiation in soil moisture and general ground water conditions. These are common in the southern parts of Alberta and Saskatchewan, especially near large rivers.

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In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general the two systems are at approximate right angles to each other.

Because of certain inherent limiting factors, Structure Incidence Surveys have a lower order of reliability than Detailed Fracture Analysis Surveys. To some extent at least, surface conditions affect the fracture count. In areas

covered by lakes, sloughs and rivers, the fracture count is zero. Cultivated areas generally yield a lower count than adjacent virgin territory. Consequently, a difference or contrast in fracture count (F/l) between two points may be in part due to structure, but, also due in part to different surface conditions. To some extent, this can be compensated for by applying appropriate weightings to the observed counts, but over or under corrections may result.

Nevertheless, in spite of these sources or error, it has been demonstrated in (plains) areas where abundant subsurface control is available, that the incidence of fracturing is considerably above normal in the surrounding area immediately out from the steepest part of the flanks of the structure. This is in contrast with a low or normal incidence over the crestal area, and also to a normal incidence off structure.

FRACTURE ANALYSIS OF PERMIT NO. 55

The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permit. The Permit is located in the muskeg area along the south shore of Hudson Bay and is hundreds of miles from the closest settlement.

The sedimentary section is about 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There are two areas where the fracture intensity is greater than normal and there is one area where the fracture intensity is less than normal. The high intensity areas are shown in red and the low intensity areas are shown in green. The average length of the fractures is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to mention the glacial problem in this area.

Reference to the mosaic will show that the area is moderately scarred with glacial grooves and striations and that the direction of ice flow was about north 20 degrees east. Some of these grooves are so deeply impressed on the surface that they control the shape of the lakes and of tree growth in the area. In any area such as this the photo-analyst is faced with the difficult problem of eliminating the glacial scars from the fracture pattern without creating false anomalies. The removal of all fractures from a 10 - 12 degree arc in any area will create fracture anomalies and it requires delicate weighting on the whole pattern to adjust for these effects.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general, the two systems are at approximate right angles to each other. Within Petroleum & Natural Gas Permit No. 55 the statistical mean direction of the axial system is north 40 degrees west and the statistical mean direction of the shear system is north 30 degrees east. A third minor system, here termed the sub-axial system, trends nearly north-south.

No regional fractures of great length can be seen and as these are conceded to originate within the Basement, it is assumed that all fractures plotted on the mosaic originate within the sedimentary section. Furthermore, as the fractures are short for this area it is very likely that they originate in the upper two-thirds of the sedimentary section. As the surface of the Permit is relatively flat-lying no azimuth correction is necessary for this study. It has been demonstrated that the low incidence anomalies on a mosaic are considerably larger than the subsurface feature which causes them.

There is one area on the mosaic where the fractures are less intense than the surrounding area. Some fractures are always present within these areas but they usually have a lower incidence than the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the next section of this report.

STRUCTURE

Petroleum and Natural Gas Permit No. 55 is located on the coastal plain on the south shore of Hudson Bay about 70 miles north of the edge of the Pre-Cambrian Shield.

Structural features which could be present and which could cause the low incidence anomalies mentioned in this report are discussed in order of probability.

(1) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No. 55 is thought to be much the same as it is today along the north edge of the Shield. Low rounded hills separated by gentle to abrupt valleys are seen on the Shield and these features are undoubtedly present under the subject Permits. The effect of this Basement relief on the overlying sedimentary rocks is often great. The Granite Wash sand is usually present in the topographic "lows" on the Basement but absent on the "highs". The Granite Wash is an excellent potential reservoir.

Further effects of Basement topography on beds higher than the Granite Wash is the gentle folding present over Basement hills. These folds are anticlines in every sense and could from traps for oil and gas.

(2) REEFS

Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. However, only small reefs have been found in outcrops near the Permit and such small masses as these probably do not greatly affect the fracture pattern.

(3) TECTONIC FOLDING AND FAULTING

The presence of tectonic folds is very unlikely, but some normal faulting could be present.

(4) TOPOGRAPHIC RELIEF ON AN INTRA - SEDIMENTARY UNCONFORMITY

Unconformity, is a possible source of fracture intensity anomalies, but within the Permit area it is unlikely that the relief on any unconformities within the

sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there are two areas of "high" fracture intensity, and one area of "low" fracture intensity. The general interpretation is that the "low" fracture intensity areas are underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is low in the area shown in red on the map. There is one area of "high" Basement topography on the Permit.

These Basement high features where present are most interesting from the oil and gas point of view. A fault is unlikely as the causative feature for this high area as the high is over one and one-half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Granite Wash sand is probably absent on the top of this Basement topographic high; but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

WILLIAM G. CROOK
Photoanalyst, P. Geol.

WGC/jp

REFERENCES

NELSON S.J. & — 1966: Geology of Hudson Bay Basin, Bull. Can. Petrol. Geol., Vol. 14, No. 4, pp. 520-578.

BOSTOCK H.H.
CUMMING L.M.
NORFORD B.S.
NORRIS A.W. — Geology Hudson Bay Lowlands, Map 17-.1967, Geol. Surv. Can.
PRICE L.L.
STANDFORD B.V.

BLANCHET P.H. — 1957: "Development of Fracture Analysis as Exploration Method", Amer. Assoc. Petrol. Geol. Bull., Vol. 41, No. 8, 1748-59

HAMAN P.J. — 1964: "Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2

PLEASE INSERT ATTACHED PAGES

(CORRECTED) AS FOLLOWS:

TO BE INSERTED IN

P.&N.G. PERMIT NO. 55

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TWO ATTACHED PAGES

AFTER PAGE WITH PARAGRAPH

BEGINNING " Nevertheless in spite of"

P.&N.G. PERMIT NO. 55

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PAGES OF THIS REPORT.

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BEGINNING "No regional fractures"

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"STRUCTURE"

Granite Wash sand is probably absent on the top of this Basement topographic high; but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Crook

WILLIAM G. CROOK
Photoanalyst, P. Geol.

WGC/jp

Granite Wash sand is probably absent on the top of this high fracture area; but will probably be present along the flanks of this feature. As there are no Basement "high" areas within the Permit the whole of the "normal" area has potential for Granite Wash sand.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Crook

WGC/jp

sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there are two areas of "high" fracture intensity, but no areas of "low" fracture intensity. The general interpretation is that the "low" fracture intensity areas are underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is low in the areas shown in red on the map. There are no areas of "high" Basement topography on the Permit.

These Basement high features where present are most interesting from the oil and gas point of view. A fault is unlikely as the causative feature for these high areas if the high is over one and one-half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

feature which causes them.

There are no areas on the mosaic where the fractures are less intense than the surrounding area. Some fractures are always present within these areas but they usually have a lower incidence than the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the next section of this report.

are shown in red and the normal intensity area is shown in yellow. The average length of the fractures is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to mention the glacial problem in this area.

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The sedimentary section is about 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There are two areas where the fracture intensity is greater than normal but there are no areas where the fracture intensity is less than normal. The high intensity areas

GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 55

HUDSON'S BAY LOWLANDS

MANITOBA

SCALE : 1.5" = 1 MI.

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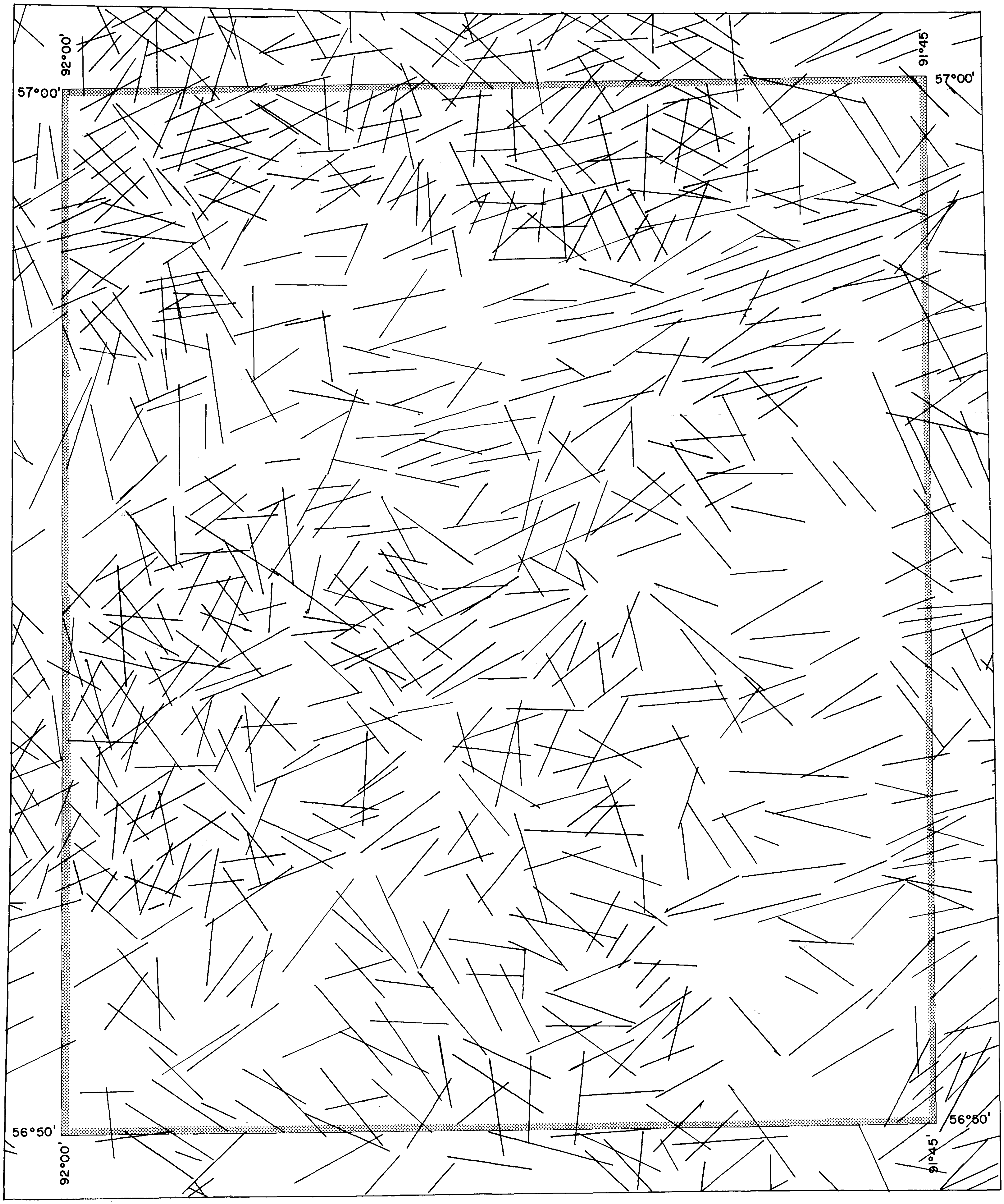
THIS IS A UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN ACCURATE TOPOGRAPHIC MAP.

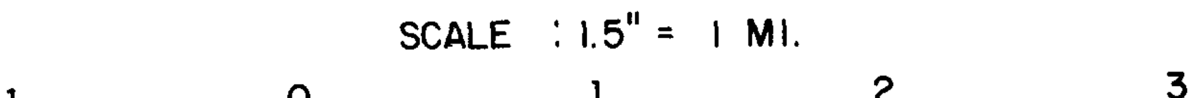


GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 55

TOTAL FRACTURE PATTERN

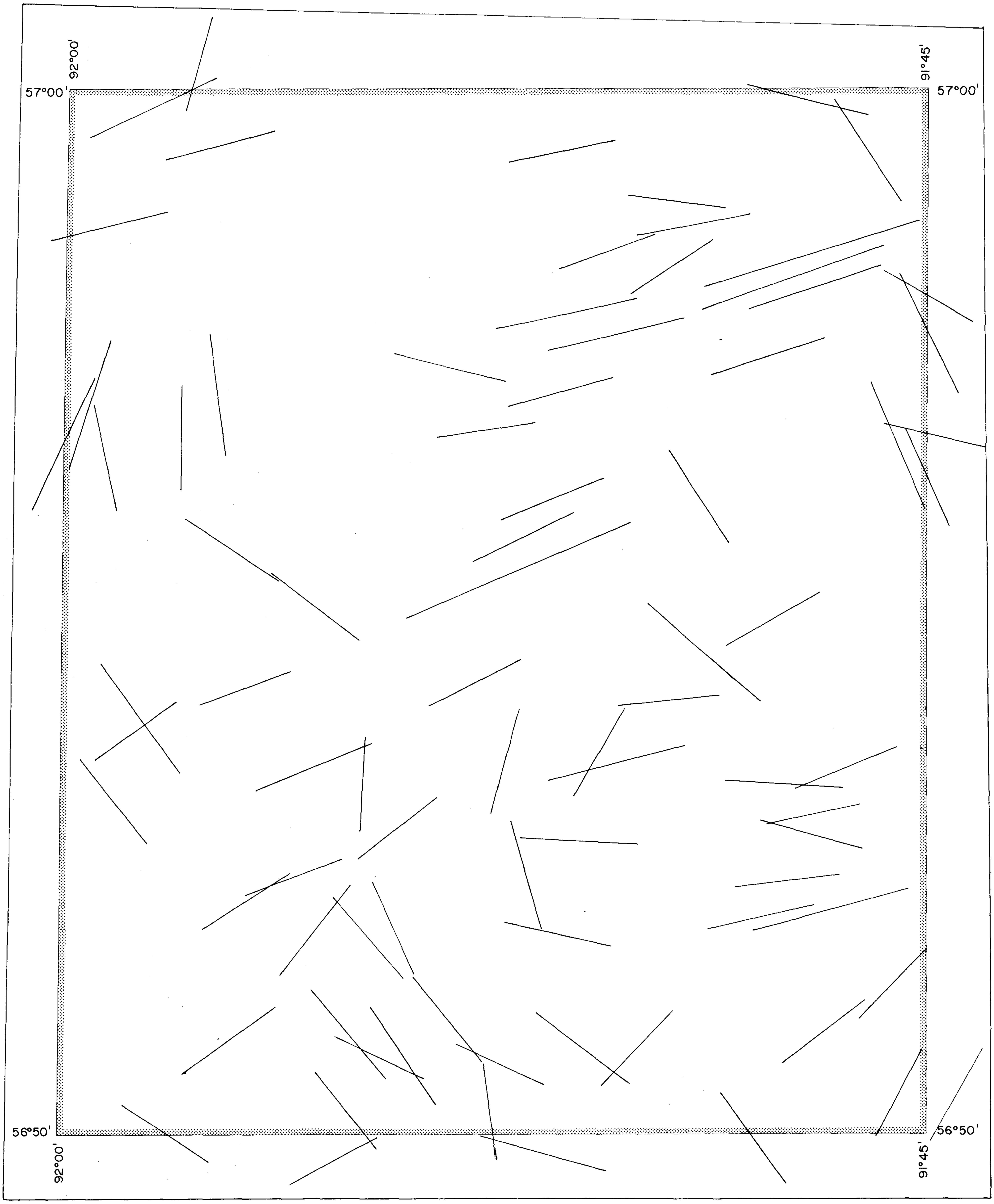
SCALE : 1.5" = 1 MI.



LOW DENSITY

NORMAL DENSITY

HIGH DENSITY



GLENDALE INVESTMENT CORPORATION LTD.

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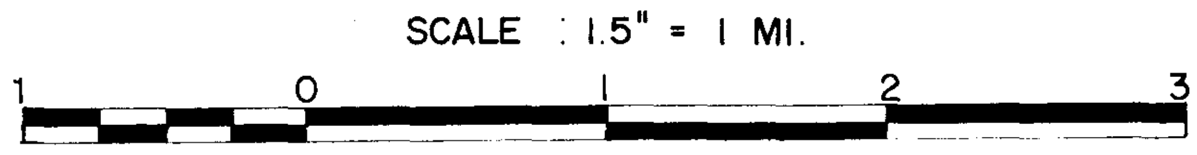
MEGA FRACTURE PATTERN

SCALE : 1.5" = 1 MI.



Exploration
Permit
No. 56

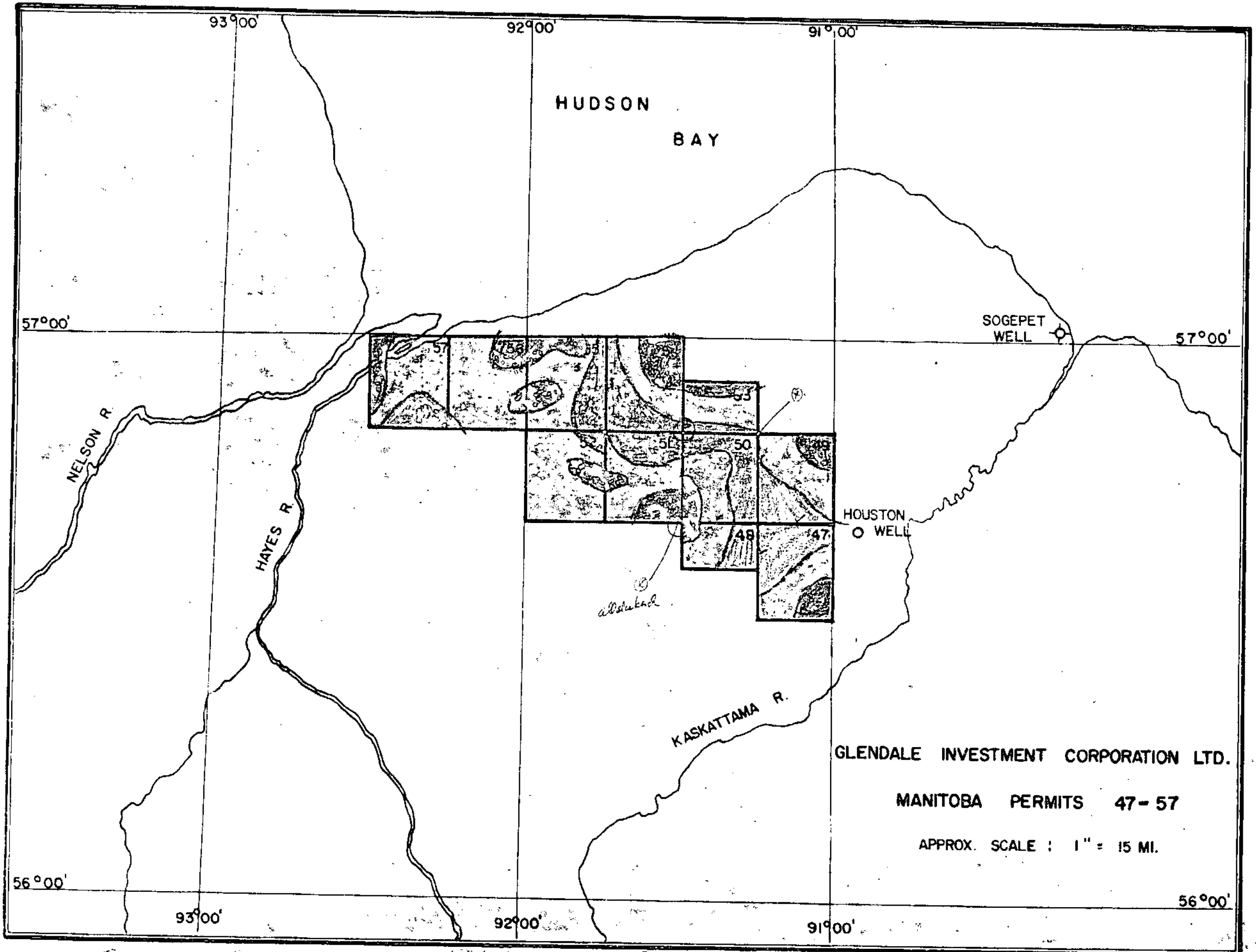
INTRODUCTION

This report discusses the results of a study of the General Geology, Stratigraphy and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 56, Manitoba. This permit is located between 56° 50' - 57° 00' latitude and 92° 00' - 92° 15' longitude. This is in the Hudson's Bay area of northeast Manitoba approximately 540 air miles north-northwest of Winnipeg. There are no roads within the area and the use of an aircraft is required to reach the area.

The stratigraphic discussion is based on information contained in published reports and on the limited data available from well control.

The Fracture Analysis Survey locates topographic highs and lows on the Basement surface. Areas of Basement "highs" are of great interest as it is felt that much reef growth (which is known to be present) is centered, or at least concentrated, over areas of Basement "highs".

Areas of Basement "lows" are of interest as Granite Wash sands tend to accumulate and attain considerable thickness in these "lows". Reefs and Granite Wash sands are probably the two principal reservoir horizons in this area.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NELSON R.
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HOUSTON WELL
KASKATTAMA R.
GLENDALE INVESTMENT CORPORATION LTD.
MANITOBA PERMITS 47 - 57
APPROX. SCALE : 1" = 15 MI.
56°00'
56°00'
93°00'
92°00'
91°00'

STRATIGRAPHY

The subject acreage, which is located one to 50 miles south of the Hudson Bay shoreline near York Factory in Manitoba, is primarily covered by muskeg with numerous small rivers, and streams present. Access to the area is provided by the Canadian National Railway line running into Port Nelson and also by ocean ships to the same point. Subsurface control will be provided by the Sogepet-Aquitane-Kaskattama # 1 well when it is released. It is located some 30 miles east of the northeast corner of the acreage. Recently Houston et al Comeault Sth Prov. # 1, located at about 56° 40' and 90° 52' has been licenced. This location, which is some 5 miles east of the acreage, will provide additional valuable subsurface information about this area. Outcrop information is extremely scarce in this area with only some talus being noted near York Factory along the north side of the acreage and along the Kaskattama River, which lies along the south and east side of the acreage. The main outcrop data has to be projected into this area from sections found on the Severn River, which is 110 miles southeast

of the acreage. The Nelson River which is approximately 50 miles northwest of the acreage is another outcrop area. Ordovician rocks are exposed along Gods River, 30 miles south of the western portion of the area under discussion. Beds ranging in age from Upper Ordovician to Upper Silurian are expected to be present beneath the land under review.

ORDOVICIAN

BAD CACHE RAPIDS GROUP

PORTAGE CHUTE FORMATION

The type section of the Portage Chute formation is located on the Churchill River, 100 miles northwest of the acreage. Outcrops are also present on the Nelson River approximately 50 miles west of the area, as well as on the Sachigo and Severn Rivers which lie to the south. The formation was defined by Nelson as overlying peneplaned Pre-Cambrian rocks, and in turn being conformably overlain by the Surprise Creek formation. The Portage Chute formation, which is 75 feet thick at the type section, consists of a four foot basal quartz sandstone which is generally quite uniform, tight and calcareous. This sand is also

present at the other outcrop sections mentioned above. The sand grades upwards into grey to buff, weathering light grey, partially dolomitic, microcrystalline, laminated limestones. Skeletal debris is quite abundant. At the type section the limestone section is 71 feet thick. The thickness of the Portage Chute formation on the Nelson River is approximately 25 feet, while at the Severn River exposures it is only about ten feet thick. The formation dips easterly with an increasing rate of dip as one proceeds basinward along the outcrop sections. Fossils consist mainly of a variety of corals and molluscans with some trilobites present. The limestone takes on a nodular appearance in weathered sections.

SURPRISE CREEK FORMATION

The type section of the Surprise Creek formation was defined by Nelson as being located at Surprise Creek on the Churchill River. It is also present at the Nelson River section but not further south. Nelson considered the Surprise Creek formation as late Ordovician in age. The type section consists of 63 1/2 feet of thinly bedded, light yellowish grey, micro to cryptocrystalline limestone. It ranges from slightly dolomitic, to dolomitic, and contains some lenses of chert. The Surprise Creek formation is disting-

uished from the underlying Portage Chute formation by its lack of organic fragments, and by its smooth weathering characteristics, as opposed to the nodular weathering of the Portage Chute formation. The exposures at Nelson River are poor and not easily correlated with the type section, but, they appear to be lithologically similar to the type section. The thickness is a minimum 30 feet and the fauna is composed mainly of brachiopods. The combined thickness of the Surprise Creek formation and Portage Chute formation at the Selco-Pennycutaway # 1, drill hole, which lies about 17 miles west of the acreage, was 300 ±, indicating a rapid thickening of this group in a basinward direction.

CHURCHILL RIVER GROUP

CAUTION CREEK FORMATION

The type section of the Caution Creek formation is also found on the Churchill River. The type section was defined by Nelson to consist of a basal 18 foot bed of mainly grey to yellowish grey weathering, cryptocrystalline, slightly dolomite limestone, containing shell fragments. This

is overlain by an 18 foot bed of grey to brown weathering, crypto to microcrystalline, slightly dolomitic limestone with little organic remains. This bed weathers into smooth layers, whereas, the lower bed weathers into uneven rubbly beds. The uppermost bed consists of six feet of grey, earthly weathering, micro to cryptocrystalline, slightly dolomitic limestone which has a nodular appearance on a weathered surface. The fauna consists of brachiopods, corals, and molluscans. The Caution Creek formation apparently does not outcrop on the Nelson River, but, it should be present in the subsurface of the subject acreage.

CHASM CREEK FORMATION

The Chasm Creek formation is found both along the Churchill and Nelson Rivers with the Churchill sections being the better one. The Chasm is also exposed at Gods River, some 30 miles south of the acreage. The Chasm is fairly similar to the underlying Caution Creek formation and is in conformable contact with it. At the type section it is about 180 feet thick. The basal 55 feet is a light yellowish grey to buff, microcrystalline, slightly dolomitic

limestone grading to an iron rich dolomite. It is very resistant and weathers to a yellow and orange massive bed. This unit is overlain by about 100 feet of light grey, crypto to microcrystalline, slightly dolomitic to dolomitic limestone. The unit contains abundant fine organic fragments. Overlying this unit is a 5 to 15 foot thick bed of light grey, cryptocrystalline, dolomitic limestone which contains no organic material but has fine intercalations of finely fragmented limestone beds. The uppermost unit is ten to 20 feet thick, and is a light grey weathering, very dolomitic, microcrystalline unit which is strongly fucoidal. On the Nelson River the Chasm Creek section is a minimum of 15 feet thick with the maximum thickness unknown. It is lithologically similar to the type section as is the 38 foot thick section found on Gods River. The Chasm Creek formation contains a fauna comprised of corals, cephalopods and some brachiopods.

RED HEAD RAPIDS FORMATION

The Red Head Rapids formation is the uppermost Ordovician sediment found in this region and tye type section is located on the Churchill River where it overlies the Churchill River Group. The formation is a minimum of 42

feet thick with the maximum thickness unknown. Nelson notes that this formation may be Silurian in age. The lower 25 feet consist of light yellow, microcrystalline dolomitic which weathers a distinctive orange color. No fossils are present in this bed. The upper 17 feet is composed of grey to yellowish grey, microcrystalline dolomite, partially vuggy, which weathers to a grey color. This bed is also quite unfossiliferous. The Red Head Rapids is not present in outcrop on the Nelson, Gods, or Severn Rivers, but, it should be present in the subsurface of the acreage.

SILURIAN

PORT NELSON FORMATION

The type section of the Port Nelson formation is located on the Nelson River some 47 miles west of the acreage under review. The section exposed is 24 feet thick and consists of interbeds of brecciated dolomite, dolomite, and shaly dolomite. The dolomite is generally a gray micro to cryptocrystalline to occasionally granular rock with minor porosity. It contains a coral fauna and

is placed in the Middle Silurian. In the James Bay area a drill hole encountered 110+ feet of this formation. This unit should be found at subcrop under the southwestern portion of the acreage.

SEVERN RIVER FORMATION

The type section of this formation is found on the Severn River some 110 miles southeast of the acreage. The minimum thickness at the type section is 42 feet with the maximum unknown. The section consists of a basal 13 foot light grey, micro to cryptocrystalline limestone with rare vuggy porosity, and a suggestion of algal material. The middle unit consists of 4 feet of light yellowish grey, to orange buff, micro to finely crystalline algal limestone with good vuggy porosity. The upper unit is a 25 foot thick bed of cream to buff, partly microcrystalline to finely crystalline, chalky and partly organic limestone. Fine to coarse organic debris is present as well as beds of oolitic material. The Severn River formation appears to be present near Churchill in similar facies plus the notable fact that it has a strong bituminous odour from a fresh break in this area. This formation should also be present at subcrop under the southwest portion of the acreage.

EKWAN RIVER FORMATION

The type section of this formation is on the Ekwan River, which is in the James Bay area and lies some 350 miles southeast of the area under consideration. The section is from 73 to 88 feet thick and consists of grey, fine grained, partially cherty limestone containing corals and stromatoporoids. The section on Severn River is a minmum 37 feet thick with the maximum unknown. The basal 20 feet is composed of light medium brown, microcrystalline limestone with fine to coarse fossil fragments, some chert nodules and some oolitic material. The fossils consist of stromatoporoids, corals, brachiopods and cephalopods. Some poor intercrystalline and vuggy porosity is present. The middle ll feet consists of yellowish brown, micro-crystalline partially dolomitic, chalky limestone with some thin fragmental beds and rare brachiopods. The upper 6 feet is a light greyish brown, to creamy, microcrystalline limestone which is very highly and coarsely fragmental. The top section contains poor to good porosity. The Ekwan River formation is also exposed along the shore of Hudson Bay from the Mouth of Owl River to a point some 20 miles south of Cape Churchill. The Ekwan should be found to

subcrop along the western and central position of the subject acreage.

ATTAWAPISKAT FORMATION

The type section is located on the Attawapiskat River which lies some 40 miles south of the Ekwan River type section in the James Bay area. The formation outcrops on the Ekwan River, Severn River and along the tidal flats south from Cape Churchill.

The Ekwan River outcrop section consists of 54 feet of fine grained, thin bedded, coral reef limestone. Nelson has described a reefal and possible off reef facies for the Attawapiskat formation in general. The reef facies has a minimum thickness of 25 feet and is a cream, to orange cream, to buff, microcrystalline, fragmental limestone with corals and stromatoporoids being common. Porosity grades from tight to excellent and is vuggy. Nelson feels that some of the well bedded reefs are suggestive of biostromes, while other oval, domal reefs are believed to be bioherms. He noted a gassy odour at one location.

The off-reef facies is a minimum of 16 feet thick with uniform beds of cream, to partly yellowish cream, to grey microcrystalline limestone. There are abundant coarse granular, bioclastic beds which have excellent intergranular porosity which could be post reef deposits. The Attawapiskat outcrops south of Cape Churchill range in thickness from 25 to 50 feet in thickness, with both facies present and they are seen to grade laterally from one to the other. This formation should be at subcrop through the central portion of the acreage.

KENOGAMI RIVER FORMATION

The Kenogami River formation which has only been found in outcrop, in the James Bay represents the youngest Silurian found in the Hudson Bay Basin. The formation consists of an alternating series of shale, siltstone, sandstone, dolomite, silty dolomite, shaly limestone, and limestone. The colours mainly range from buff to grey, but, reds and greens are the colours of the clastics. The outcrop section has a minimum thickness of 300 feet while a well drilled on Puskwuine Point in James Bay had a thickness of 862 feet. The Kenogami River formation is

expected to subcrop along the eastern half of the acreage under review.

DEVONIAN

Rocks of Devonian age are not expected to be present under the area covered by the permit, however, they should be present at subcrop east of the acreage, at and near the Sogepet-Aquitaine-Kaskattama # I well where total depth was reached at 2,941 feet in granite.

CRETACEOUS

Rocks of Cretaceous age are know only in the James Bay area and are not expected to be present under the permits.

FRACTURE ANALYSIS

This section of the report discusses the results of a Detailed Fracture Analysis Survey carried out on the area under discussion. An aerial mosaic (scale 1.5 inches equals approximately 1 mile) made from Dominion Government aerial photographs accompanies this report. These same photographs were examined stereoscopically and the fractures plotted on the individual photographs, then transferred to the mosaic for analysis.

The theory that the earth's crust is abundantly and methodically fractured is the basic premise on which is built the exploration technique known as Fracture Analysis. A Fracture is defined as "...generally abundant, natural lineation discernible on aerial photographs".

Fracturing is largely caused by external stresses on the surface. The most important are:

(a) earth tides

(b) radial acceleration of the earth along its radius vector.

(c) a gradual decrease of the earth's rate of rotation.

As stated above, the earth is systematically fractured and the fracture system would approach symmetry if the crust were homogeneous. It is considered that irregularities are caused by regional heterogeneous conditions within the earth's crust. Local departures from the norm are caused by structural or stratigraphic anomalies.

The term "photogeophysics" was introduced by Blanchet (1956) and deals with mapping, analysis and interpretation of fracture traces as recorded on aerial photographs. In a more general way "photogeophysics" can be defined as the methodical statistical analysis of linear features seen on aerial photographs and this system is applied by any method recording all observable lineations, or the totality of a certain type of linear feature, and the statistical presentation of the data on contoured intensity maps of dry plotting the fractures directly on the mosaic.

In this report a megafracture is longer than one mile and a microfracture is shorter than one mile.

GENERAL STATEMENT

ORIGIN OF FRACTURES

Fracturing is largely caused by external stresses on the earth, although internal stresses may play some minor roll. The most important of these external forces are the diurnal earth tides due to the gravitational effects of the sun and moon; the change in radial acceleration of the earth along its radius vector and the gradual decrease in the earth's rate of rotation. The endless rhythemic action of these earth tides is probably the principal cause of the systematic fracture system seen over most of the world, even though the amplitude of these tides is only 9-13 inches. The fractures are most likely generated by the process of fatigue as the end result of these stresses which are repeated regularly over millions and millions of years. Metals fatigue in the same manner when subjected to continual vibration.

In general the initiating forces which generate fractures must have continued for a very long time and

the process involved are continuous and are probably active at the present time. Furthermore, Mollard (1957) states, "The mechanism required to reflect lineaments to ground surface must be reasonably simple, for simple patterns are produced on diverse topography and in diverse types and depths of surficial deposits that overlie different kinds of relatively flat-lying sedimentary rocks of varying thickness. The mechanism producing the lineament pattern must persist over extensive and widespread belts of the earth's outer shell; that is today, the engendering mechanism in fact be world wide".

External forces such as earth tides obviously fit these parameters. Some internal forces may also apply such as the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

In general it can be said that fracture patterns are caused by either internal forces or external forces.

If the forces are internal the result would be different orientation of the fracture systems in areas of similar tectonic history but different position. If the forces are external the orientation of the fracture arrangement should have world wide similarity. However, stable areas such as the masses of the continents may develop fracture patterns due to external forces and tectonically active areas may develop their own pattern due to internal forces.

If joints form early in the history of a sediment then systematic joints must be successively younger upwards through the section and the joint pattern is imposed on each new layer of sediments when they have become consolidated enough to fracture. This upward propagation is caused by the fatigue caused by stress, which in turn is caused by diurnal earth tides.

EXPRESSION OF FRACTURE

Fractures have been observed in aerial photographs from every climate and on every continent in the world. They are expressed as topographic relief, vegetation

differences and soil tonal differences.

TOPOGRAPHIC RELIEF LINEAMENTS

A common type are relief lineaments which can be manifested by a change (usually abrupt) of topographic elevation on either side of a relatively straight line. They may also be expressed as straight valleys or hills or by straight streams where the stream course is controlled by a fracture zone.

VEGETAL LINEAMENTS

Vegetal lineaments are the most common in the parkland and muskeg areas of western Canada and many excellent examples of fractures can be seen on almost any aerial photograph of northern Saskatchewan, Alberta or British Columbia. Straight lines of both deciduous and evergreen trees as well as scrub growth are universally visible. However, the most common vegetal lineament seen by this writer is a straight "edge" to a clump of trees or bushes. In many cases these fractures control the size and

shape of cultivated fields. Excellent examples of this latter expression of fractures are present in the western part of the Peace River district.

SOIL TONAL LINEAMENTS

These reflect differentiation in soil moisture and general ground water conditions. These are common in the southern parts of Alberta and Saskatchewan, especially near large rivers.

Surface investigations have shown that fractures are associated with bedrock joints; however, in glaciated areas such as western Canada, the photoanalyst must take care to establish the direction of ice flow over an area before he begins to statistically plot and analyse the fractures. Most areas in western Canada show an abundance of grooves and flutes caused by the glacier and these must not be mistaken for fracture traces caused by subsurface structural conditions. In parts of the Lloydminster area of eastern Alberta the glacial scars are so deeply impressed on the surface that fracture analysis is at best difficult and

often impossible.

INTERPRETATION OF FRACTURE DATA

The object of Fracture Analysis (Photogeophysics) is to locate shallow to deep-seated structural and stratigraphic anomalies. The actual count of fractures per unit area is made and values are contoured on a "Fracture Intensity Map". In areas of known reefs the fracture intensity is 2-3 times greater on the flanks of the reef than directly above the reef.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general the two systems are at approximate right angles to each other.

Because of certain inherent limiting factors, Structure Incidence Surveys have a lower order of reliability than Detailed Fracture Analysis Surveys. To some extent at least, surface conditions affect the fracture count. In areas

covered by lakes, sloughs and rivers, the fracture count is zero. Cultivated areas generally yield a lower count than adjacent virgin territory. Consequently, a difference or contrast in fracture count (F/I) between two points may be in part due to structure, but, also due in part to different surface conditions. To some extent, this can be compensated for by applying appropriate weightings to the observed counts, but over or under corrections may result.

Nevertheless, in spite of these sources or error, it has been demonstrated in (plains) areas where abundant subsurface control is available, that the incidence of fracturing is considerably above normal in the surrounding area immediately out from the steepest part of the flanks of the structure. This is in contrast with a low or normal incidence over the crestal area, and also to a normal incidence off structure.

FRACTURE ANALYSIS OF PERMIT NO. 56

The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permit. The Permit is located in the muskeg area along the south shore of Hudson Bay and is hundreds of miles from the closest settlement.

The sedimentary section is about 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There are two areas where the fracture intensity is greater than normal and there is one area where the fracture intensity is less than normal. The high intensity area is shown in red and the low intensity area is shown in green. The average length of the fractures is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to mention the glacial problem in this area.

Reference to the mosaic will show that the area is moderately scarred with glacial grooves and striations and the direction of ice flow was about north 20 degrees east. Some of these grooves are so deeply impressed on the surface that they control the shape of the lakes and of tree growth in the area. In any area such as this the photoanalyst is faced with the difficult problem of eliminating the glacial scars from the fracture pattern without creating false anomalies. The removal of all fractures from a 10 - 12 degree arc in any area will create fracture anomalies and it requires delicate weighting of the whole pattern to adjust for these effects.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general, the two systems are at approximate right angles to each other. Within Petroleum & Natural Gas

Permit No. 56 the statistical mean direction of the axial system is north 40 degrees west and the statistical mean direction of the shear system is north 30 degrees east. A third minor system, here termed the sub-axial system, trends nearly north-south.

No regional fractures of great length can be seen and as these are conceded to originate within the Basement, it is assumed that all fractures plotted on the mosaic originate within the sedimentary section. Furthermore, as the fractures are short for this area it is very likely that they originate in the upper two-thirds of the sedimentary section. As the surface of the Permit is relatively flat-lying no azimuth correction is necessary for this study. It has been demonstrated that the low incidence anomalies on a mosaic are considerably larger than the subsurface feature which causes them.

There is one area on the mosaic where the fractures are less intense than the surrounding area. Some fractures are always present within these areas but they usually have a lower incidence than the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the next section of this report.

STRUCTURE

Petroleum and Natural Gas Permit No. 56 is located on the coastal plain on the south shore of Hudson Bay about 70 miles north of the edge of the Pre-Cambrian Shield.

Structural features which could be present and which could cause the low incidence anomalies mentioned in this report are discussed in order of probability.

(1) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No. 56 is thought to be much the same as it is today along the north edge of the Shield. Low rounded hills separated by gentle to abrupt valleys are seen on the Shield and these features are undoubtedly present under the subject Permit. The effect of this Basement relief on the overlying sedimentary rocks is often great. The Granite Wash sand is usually present in the topographic "lows" on the Basement but absent on the "highs". The Granite Wash is and excellent potential reservoir.

Further effects of Basement topography on beds higher than the Granite Wash is the gentle folding present over Basement hills. These folds are anticlines in every sense and could form traps for oil and gas.

(2) REEFS

Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. However, only small reefs have been found in outcrops near the Permit and such small masses as these probably do not greatly affect the fracture pattern.

(3) TECTONIC FOLDING AND FAULTING

The presence of tectonic folds is very unlikely, but some normal faulting could be present.

(4) TOPOGRAPHIC RELIEF ON AN INTRA-SEDIMENTARY UNCONFORMITY

Unconformity, is a possible source of fracture intensity anomalies, but within the Permit area it is unlikely that the relief on any unconformities within the sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there are two areas of "high" fracture intensity, and one area of "low" fracture intensity (green). The general interpretation is that the low fracture intensity area is underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is high in the extreme southwest part of Permit No. 56.

This Basement high feature is most interesting from the oil and gas point of view. The general shape of this feature is such that the causative feature must be a hill on the Basement surface. A fault is unlikely as the causative feature as the high area is over one and one-half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Granite Wash sand is probably absent on the top of this high fracture area, but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Cook

WGC/jp

REFERENCES

NELSON S.J. & — 1966: Geology of Hudson Bay Basin, Bull. Can. Petrol. Geol., Vol. 14, No. 4, pp. 520-578.

BOSTOCK H.H.
CUMMING L.M.
NORFORD B.S.
NORRIS A.W.
PRICE L.L.
STANDFORD B.V. — Geology Hudson Bay Lowlands, Map 17-.1967, Geol. Surv. Can.

BLANCHET P.H. — 1957: "Development of Fracture Analysis as Exploration Method", Amer. Assoc. Petrol. Geol. Bull., Vol. 41, No. 8, 1748-59

HAMAN P.J. — 1964: "Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2

Granite Wash sand is probably absent on the top of this Basement topographic high; but will probably be present along the flanks of this feature.

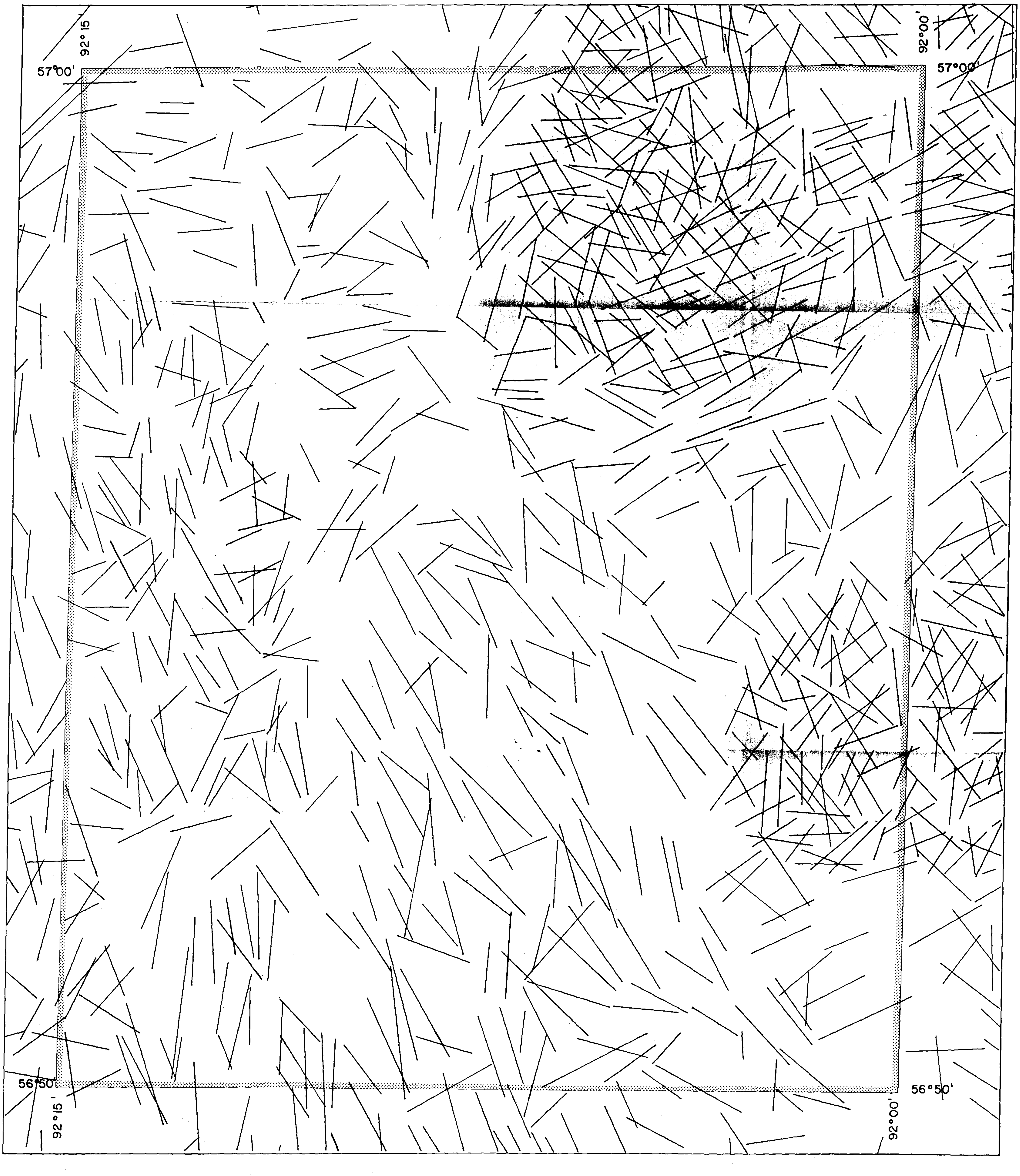
Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Crook

WILLIAM G. CROOK
Photoanalyst, P. Geol.

WGC/jp

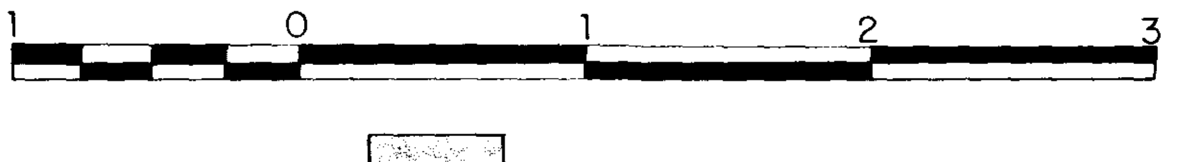


GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 56

TOTAL FRACTURE PATTERN

SCALE : 1.5" = 1 MI.



LOW DENSITY

NORMAL DENSITY

HIGH DENSITY

GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT NO. 56

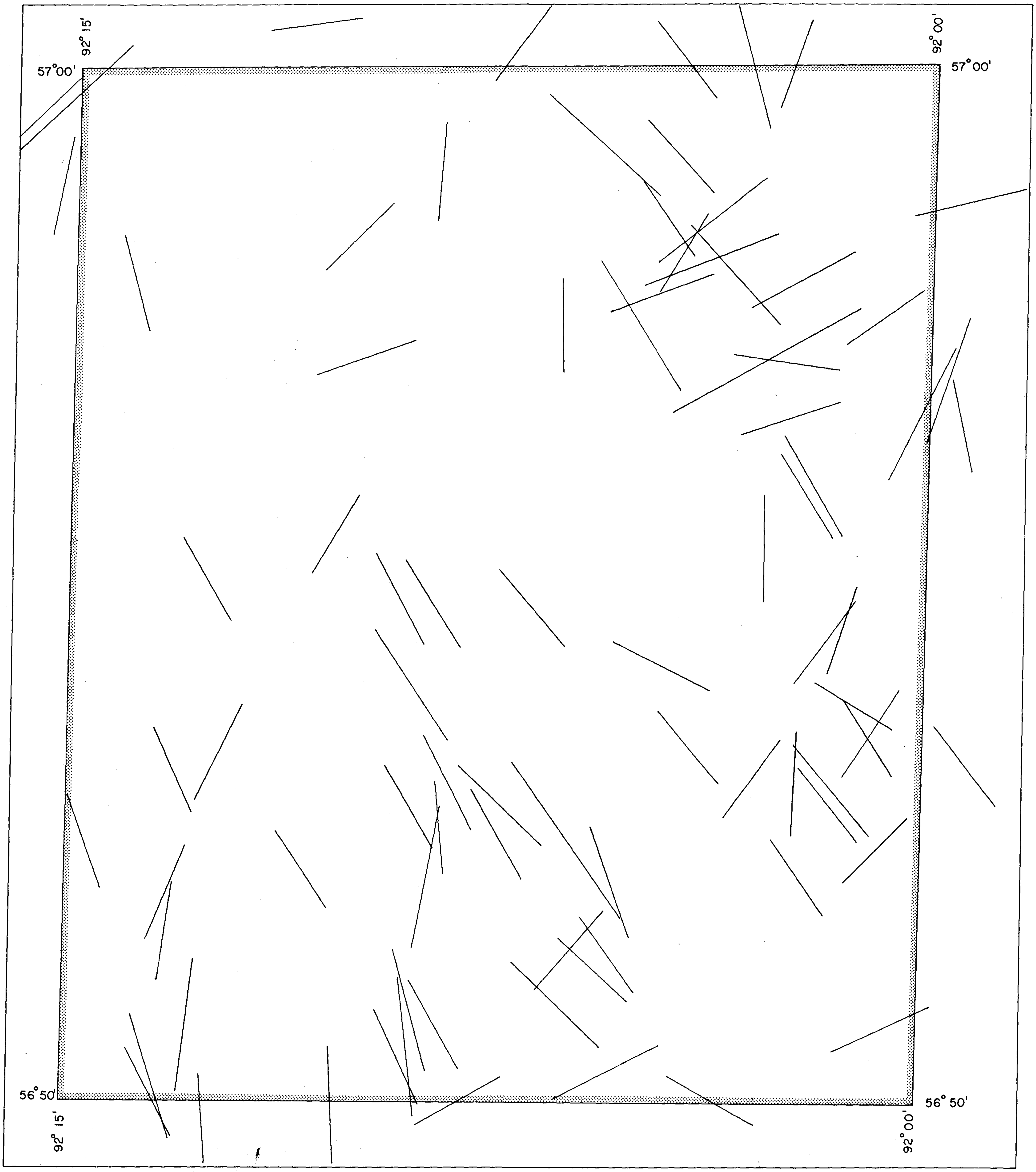
HUDSON'S BAY LOWLANDS

MANITOBA

SCALE: 1.5" = 1 MI.

1 0 1 2 3

THIS IS A UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN ACCURATE TOPOGRAPHIC MAP.



GLENDALE INVESTMENT CORPORATION LTD.

P. & N.G. PERMIT No. 56

MEGA FRACTURE PATTERN

SCALE : 1.5" = 1 MI.

Exploration Permit No. 57

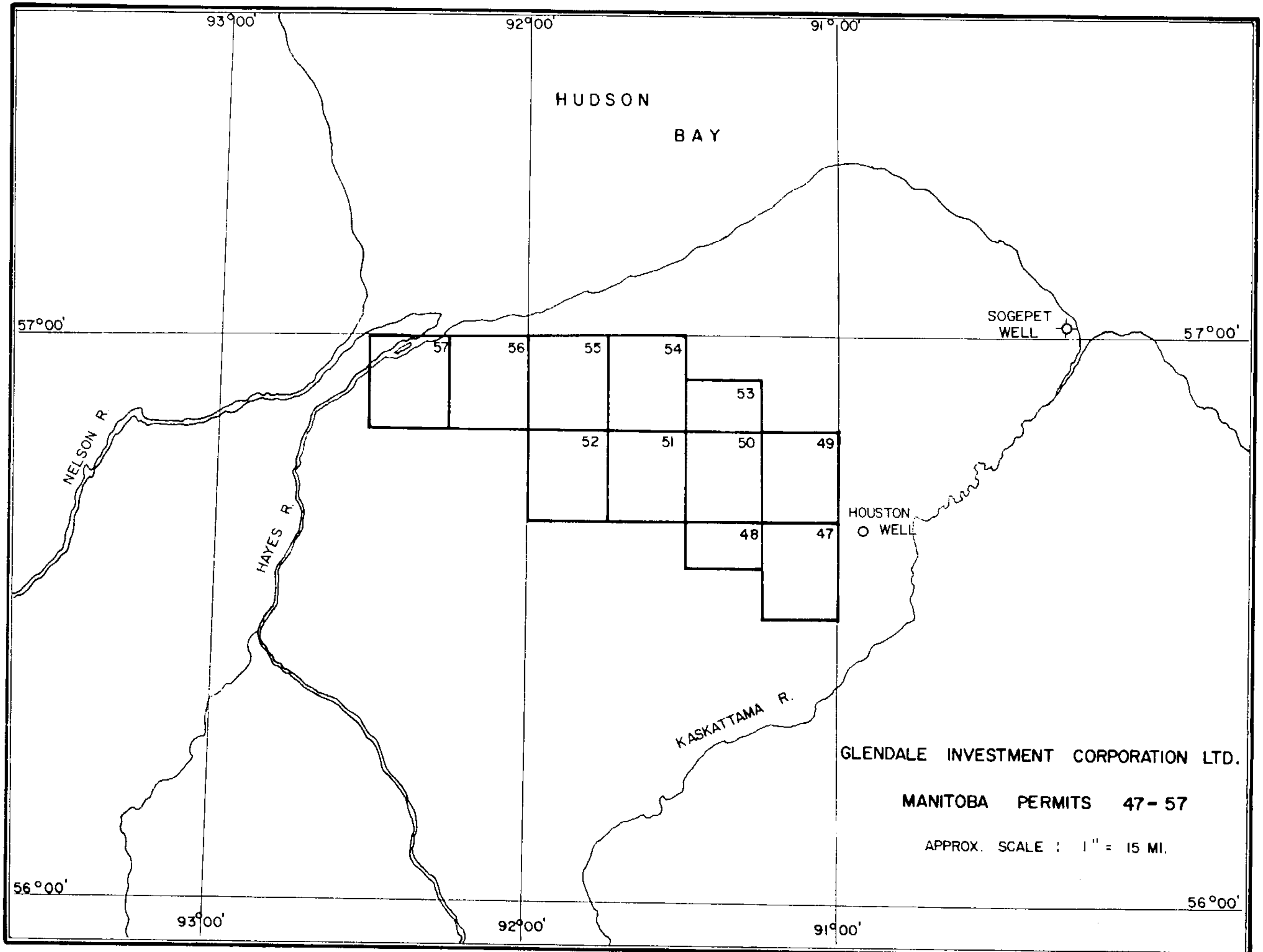
INTRODUCTION

This report discusses the results of a study of the General Geology, Stratigraphy and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 57, Manitoba. This permit is located between 56° 50' - 57° 00' latitude and 92° 15' - 92° 30' longitude. This is in the Hudson's Bay area of northeast Manitoba approximately 540 air miles north-northwest of Winnipeg. There are no roads within the area and the use of an aircraft is required to reach the area.

The stratigraphic discussion is based on information contained in published reports and on the limited data available from well control.

The Fracture Analysis Survey locates topographic highs and lows on the Basement surface. Areas of Basement "highs" are of great interest as it is felt that much reef growth (which is known to be present) is centered, or at least concentrated, over areas of Basement "highs".

Areas of Basement "lows" are of interest as Granite Wash sands tend to accumulate and attain considerable thickness in these "lows". Reefs and Granite Wash sands are probably the two principal reservoir horizons in this area.



GLENDALE INVESTMENT CORPORATION LTD.

MANITOBA PERMITS 47 - 57

APPROX. SCALE : 1" = 15 MI.

STRATIGRAPHY

The subject acreage, which is located one to 50 miles south of the Hudson Bay shoreline near York Factory in Manitoba, is primarily covered by muskeg with numerous small rivers, and streams present. Access to the area is provided by the Canadian National Railway line running into Port Nelson and also by ocean ships to the same point. Subsurface control will be provided by the Sogepet-Aquitane-Kaskattama # I well when it is released. It is located some 30 miles east of the northeast corner of the acreage. Recently Houston et al Comeault Sth Prov. # I, located at about 56° 40' and 90° 52' has been licenced. This location, which is some 5 miles east of the acreage, will provide additional valuable subsurface information about this area. Outcrop information is extremely scarce in this area with only some talus being noted near York Factory along the north side of the acreage and along the Kaskattama River, which lies along the south and east side of the acreage. The main outcrop data has to be projected into this area from sections found on the Severn River, which is 110 miles southeast

of the acreage. The Nelson River which is approximately 50 miles northwest of the acreage is another outcrop area. Ordovician rocks are exposed along Gods River, 30 miles south of the western portion of the area under discussion. Beds ranging in age from Upper Ordovician to Upper Silurian are expected to be present beneath the land under review.

ORDOVICIAN

BAD CACHE RAPIDS GROUP

PORTAGE CHUTE FORMATION

The type section of the Portage Chute formation is located on the Churchill River, 100 miles northwest of the acreage. Outcrops are also present on the Nelson River approximately 50 miles west of the area, as well as on the Sachigo and Severn Rivers which lie to the south. The formation was defined by Nelson as overlying peneplaned Pre-Cambrian rocks, and in turn being conformably overlain by the Surprise Creek formation. The Portage Chute formation, which is 75 feet thick at the type section, consists of a four foot basal quartz sandstone which is generally quite uniform, tight and calcareous. This sand is also

present at the other outcrop sections mentioned above. The sand grades upwards into grey to buff, weathering light grey, partially dolomitic, microcrystalline, laminated limestones. Skeletal debris is quite abundant. At the type section the limestone section is 71 feet thick. The thickness of the Portage Chute formation on the Nelson River is approximately 25 feet, while at the Severn River exposures it is only about ten feet thick. The formation dips easterly with an increasing rate of dip as one proceeds basinward along the outcrop sections. Fossils consist mainly of a variety of corals and molluscans with some trilobites present. The limestone takes on a nodular appearance in weathered sections.

SURPRISE CREEK FORMATION

The type section of the Surprise Creek formation was defined by Nelson as being located at Surprise Creek on the Churchill River. It is also present at the Nelson River section but not further south. Nelson considered the Surprise Creek formation as late Ordovician in age. The type section consists of 63 1/2 feet of thinly bedded, light yellowish grey, micro to cryptocrystalline limestone. It ranges from slightly dolomitic, to dolomitic, and contains some lenses of chert. The Surprise Creek formation is disting-

uished from the underlying Portage Chute formation by its lack of organic fragments, and by its smooth weathering characteristics, as opposed to the nodular weathering of the Portage Chute formation. The exposures at Nelson River are poor and not easily correlated with the type section, but, they appear to be lithologically similar to the type section. The thickness is a minimum 30 feet and the fauna is composed mainly of brachiopods. The combined thickness of the Surprise Creek formation and Portage Chute formation at the Selco-Pennycutaway # 1, drill hole, which lies about 17 miles west of the acreage, was 300 $\pm$, indicating a rapid thickening of this group in a basinward direction.

CHURCHILL RIVER GROUP

CAUTION CREEK FORMATION

The type section of the Caution Creek formation is also found on the Churchill River. The type section was defined by Nelson to consist of a basal 18 foot bed of mainly grey to yellowish grey weathering, cryptocrystalline, slightly dolomite limestone, containing shell fragments. This

is overlain by an 18 foot bed of grey to brown weathering, crypto to microcrystalline, slightly dolomitic limestone with little organic remains. This bed weathers into smooth layers, whereas, the lower bed weathers into uneven rubbly beds. The uppermost bed consists of six feet of grey, earthly weathering, micro to cryptocrystalline, slightly dolomitic limestone which has a nodular appearance on a weathered surface. The fauna consists of brachiopods, corals, and molluscans. The Caution Creek formation apparently does not outcrop on the Nelson River, but, it should be present in the subsurface of the subject acreage.

CHASM CREEK FORMATION

The Chasm Creek formation is found both along the Churchill and Nelson Rivers with the Churchill sections being the better one. The Chasm is also exposed at Gods River, some 30 miles south of the acreage. The Chasm is fairly similar to the underlying Caution Creek formation and is in conformable contact with it. At the type section it is about 180 feet thick. The basal 55 feet is a light yellowish grey to buff, microcrystalline, slightly dolomitic

limestone grading to an iron rich dolomite. It is very resistant and weathers to a yellow and orange massive bed. This unit is overlain by about 100 feet of light grey, crypto to microcrystalline, slightly dolomitic to dolomitic limestone. The unit contains abundant fine organic fragments. Overlying this unit is a 5 to 15 foot thick bed of light grey, cryptocrystalline, dolomitic limestone which contains no organic material but has fine intercalations of finely fragmented limestone beds. The uppermost unit is ten to 20 feet thick, and is a light grey weathering, very dolomitic, microcrystalline unit which is strongly fucoidal. On the Nelson River the Chasm Creek section is a minimum of 15 feet thick with the maximum thickness unknown. It is lithologically similar to the type section as is the 38 foot thick section found on Gods River. The Chasm Creek formation contains a fauna comprised of corals, cephalopods and some brachiopods.

RED HEAD RAPIDS FORMATION

The Red Head Rapids formation is the uppermost Ordovician sediment found in this region and tye type section is located on the Churchill River where it overlies the Churchill River Group. The formation is a minimum of 42

feet thick with the maximum thickness unknown. Nelson notes that this formation may be Silurian in age. The lower 25 feet consist of light yellow, microcrystalline dolomitic which weathers a distinctive orange color. No fossils are present in this bed. The upper 17 feet is composed of grey to yellowish grey, microcrystalline dolomite, partially vuggy, which weathers to a grey color. This bed is also quite unfossiliferous. The Red Head Rapids is not present in outcrop on the Nelson, Gods, or Severn Rivers, but, it should be present in the subsurface of the acreage.

SILURIAN

PORT NELSON FORMATION

The type section of the Port Nelson formation is located on the Nelson River some 47 miles west of the acreage under review. The section exposed is 24 feet thick and consists of interbeds of brecciated dolomite, dolomite, and shaly dolomite. The dolomite is generally a gray micro to cryptocrystalline to occasionally granular rock with minor porosity. It contains a coral fauna and

is placed in the Middle Silurian. In the James Bay area a drill hole encountered 110+ feet of this formation. This unit should be found at subcrop under the southwestern portion of the acreage.

SEVERN RIVER FORMATION

The type section of this formation is found on the Severn River some 110 miles southeast of the acreage. The minimum thickness at the type section is 42 feet with the maximum unknown. The section consists of a basal 13 foot light grey, micro to cryptocrystalline limestone with rare vuggy porosity, and a suggestion of algal material. The middle unit consists of 4 feet of light yellowish grey, to orange buff, micro to finely crystalline algal limestone with good vuggy porosity. The upper unit is a 25 foot thick bed of cream to buff, partly microcrystalline to finely crystalline, chalky and partly organic limestone. Fine to coarse organic debris is present as well as beds of oolitic material. The Severn River formation appears to be present near Churchill in similar facies plus the notable fact that it has a strong bituminous odour from a fresh break in this area. This formation should also be present at subcrop under the southwest portion of the acreage.

EKWAN RIVER FORMATION

The type section of this formation is on the Ekwan River, which is in the James Bay area and lies some 350 miles southeast of the area under consideration. The section is from 73 to 88 feet thick and consists of grey, fine grained, partially cherty limestone containing corals and stromatoporoids. The section on Severn River is a minmum 37 feet thick with the maximum unknown. The basal 20 feet is composed of light medium brown, microcrystalline limestone with fine to coarse fossil fragments, some chert nodules and some oolitic material. The fossils consist of stromatoporoids, corals, brachiopods and cephalopods. Some poor intercrystalline and vuggy porosity is present. The middle ll feet consists of yellowish brown, micro-crystalline partially dolomitic, chalky limestone with some thin fragmental beds and rare brachiopods. The upper 6 feet is a light greyish brown, to creamy, microcrystalline limestone which is very highly and coarsely fragmental. The top section contains poor to good porosity. The Ekwan River formation is also exposed along the shore of Hudson Bay from the Mouth of Owl River to a point some 20 miles south of Cape Churchill. The Ekwan should be found to

subcrop along the western and central position of the subject acreage.

ATTAWAPISKAT FORMATION

The type section is located on the Attawapiskat River which lies some 40 miles south of the Ekwan River type section in the James Bay area. The formation outcrops on the Ekwan River, Severn River and along the tidal flats south from Cape Churchill.

The Ekwan River outcrop section consists of 54 feet of fine grained, thin bedded, coral reef limestone. Nelson has described a reefal and possible off reef facies for the Attawapiskat formation in general. The reef facies has a minimum thickness of 25 feet and is a cream, to orange cream, to buff, microcrystalline, fragmental limestone with corals and stromatoporoids being common. Porosity grades from tight to excellent and is vuggy. Nelson feels that some of the well bedded reefs are suggestive of biostromes, while other oval, domal reefs are believed to be bioherms. He noted a gassy odour at one location.

The off-reef facies is a minimum of 16 feet thick with uniform beds of cream, to partly yellowish cream, to grey microcrystalline limestone. There are abundant coarse granular, bioclastic beds which have excellent intergranular porosity which could be post reef deposits. The Attawapiskat outcrops south of Cape Churchill range in thickness from 25 to 50 feet in thickness, with both facies present and they are seen to grade laterally from one to the other. This formation should be at subcrop through the central portion of the acreage.

KENOGAMI RIVER FORMATION

The Kenogami River formation which has only been found in outcrop, in the James Bay represents the youngest Silurian found in the Hudson Bay Basin. The formation consists of an alternating series of shale, siltstone, sandstone, dolomite, silty dolomite, shaly limestone, and limestone. The colours mainly range from buff to grey, but, reds and greens are the colours of the clastics. The outcrop section has a minimum thickness of 300 feet while a well drilled on Puskwuine Point in James Bay had a thickness of 862 feet. The Kenogami River formation is

expected to subcrop along the eastern half of the acreage under review.

DEVONIAN

Rocks of Devonian age are not expected to be present under the area covered by the permit, however, they should be present at subcrop east of the acreage, at and near the Sogepet-Aquitaine-Kaskattama # I well where total depth was reached at 2,941 feet in granite.

CRETACEOUS

Rocks of Cretaceous age are know only in the James Bay area and are not expected to be present under the permits.

FRACTURE ANALYSIS

This section of the report discusses the results of a Detailed Fracture Analysis Survey carried out on the area under discussion. An aerial mosaic (scale 1.5 inches equals approximately 1 mile) made from Dominion Government aerial photographs accompanies this report. These same photographs were examined stereoscopically and the fractures plotted on the individual photographs, then transferred to the mosaic for analysis.

The theory that the earth's crust is abundantly and methodically fractured is the basic premise on which is built the exploration technique known as Fracture Analysis. A Fracture is defined as"...generally abundant, natural lineation discernible on aerial photographs".

Fracturing is largely caused by external stresses on the surface. The most important are:

(a) earth tides

(b) radial acceleration of the earth along its radius vector.

(c) a gradual decrease of the earth's rate of rotation.

As stated above, the earth is systematically fractured and the fracture system would approach symmetry if the crust were homogeneous. It is considered that irregularities are caused by regional heterogeneous conditions within the earth's crust. Local departures from the norm are caused by structural or stratigraphic anomalies.

The term "photogeophysics" was introduced by Blanchet (1956) and deals with mapping, analysis and interpretation of fracture traces as recorded on aerial photographs. In a more general way "photogeophysics" can be defined as the methodical statistical analysis of linear features seen on aerial photographs and this system is applied by any method recording all observable lineations, or the totality of a certain type of linear feature, and the statistical presentation of the data on contoured intensity maps of dry plotting the fractures directly on the mosaic.

In this report a megafracture is longer than one mile and a microfracture is shorter than one mile.

GENERAL STATEMENT

ORIGIN OF FRACTURES

Fracturing is largely caused by external stresses on the earth, although internal stresses may play some minor roll. The most important of these external forces are the diurnal earth tides due to the gravitational effects of the sun and moon; the change in radial acceleration of the earth along its radius vector and the gradual decrease in the earth's rate of rotation. The endless rhythemic action of these earth tides is probably the principal cause of the systematic fracture system seen over most of the world, even though the amplitude of these tides is only 9-13 inches. The fractures are most likely generated by the process of fatigue as the end result of these stresses which are repeated regularly over millions and millions of years. Metals fatigue in the same manner when subjected to continual vibration.

In general the initiating forces which generate fractures must have continued for a very long time and

the process involved are continuous and are probably active at the present time. Furthermore, Mollard (1957) states, "The mechanism required to reflect lineaments to ground surface must be reasonably simple, for simple patterns are produced on diverse topography and in diverse types and depths of surficial deposits that overlie different kinds of relatively flat-lying sedimentary rocks of varying thickness. The mechanism producing the lineament pattern must persist over extensive and widespread belts of the earth's outer shell; that is today, the engendering mechanism in fact be world wide".

External forces such as earth tides obviously fit these parameters. Some internal forces may also apply such as the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

In general it can be said that fracture patterns are caused by either internal forces or external forces.

If the forces are internal the result would be different orientation of the fracture systems in areas of similar tectonic history but different position. If the forces are external the orientation of the fracture arrangement should have world wide similarity. However, stable areas such as the masses of the continents may develop fracture patterns due to external forces and tectonically active areas may develop their own pattern due to internal forces.

If joints form early in the history of a sediment then systematic joints must be successively younger upwards through the section and the joint pattern is imposed on each new layer of sediments when they have become consolidated enough to fracture. This upward propagation is caused by the fatigue caused by stress, which in turn is caused by diurnal earth tides.

EXPRESSION OF FRACTURE

Fractures have been observed in aerial photographs from every climate and on every continent in the world. They are expressed as topographic relief, vegetation

differences and soil tonal differences.

TOPOGRAPHIC RELIEF LINEAMENTS

A common type are relief lineaments which can be manifested by a change (usually abrupt) of topographic elevation on either side of a relatively straight line. They may also be expressed as straight valleys or hills or by straight streams where the stream course is controlled by a fracture zone.

VEGETAL LINEAMENTS

Vegetal lineaments are the most common in the parkland and muskeg areas of western Canada and many excellent examples of fractures can be seen on almost any aerial photograph of northern Saskatchewan, Alberta or British Columbia. Straight lines of both deciduous and evergreen trees as well as scrub growth are universally visible. However, the most common vegetal lineament seen by this writer is a straight "edge" to a clump of trees or bushes. In many cases these fractures control the size and

shape of cultivated fields. Excellent examples of this latter expression of fractures are present in the western part of the Peace River district.

SOIL TONAL LINEAMENTS

These reflect differentiation in soil moisture and general ground water conditions. These are common in the southern parts of Alberta and Saskatchewan, especially near large rivers.

Surface investigations have shown that fractures are associated with bedrock joints; however, in glaciated areas such as western Canada, the photoanalyst must take care to establish the direction of ice flow over an area before he begins to statistically plot and analyse the fractures. Most areas in western Canada show an abundance of grooves and flutes caused by the glacier and these must not be mistaken for fracture traces caused by subsurface structural conditions. In parts of the Lloydminster area of eastern Alberta the glacial scars are so deeply impressed on the surface that fracture analysis is at best difficult and

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The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permit. The Permit is located in the muskeg area south of Hudson Bay and is hundreds of miles from the closest settlement.

The sedimentary section is about 2,000 feet (plus) thick and several systems are represented. In addition a thin layer of Tertiary glacial till covers nearly all of the area. Potential reservoir horizons are present within both the Ordovician and Silurian sections.

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The average length of the fractures is about 4,000 feet and both mega and micro fractures are present. It is worthy of special note to mention the glacial problem in this area.

Reference to the mosaic will show that the area is moderately scarred with glacial grooves and striations and that the direction of ice flow was about north 30 degrees east. Some of these grooves are so deeply impressed on the surface that they control the shape of the lakes and of tree growth in the area. In any area such as this the photoanalyst is faced with the difficult problem of eliminating the glacial scars from the fracture pattern without creating false anomalies. The removal of all fractures from a 10 - 12 degree arc in any area will create fracture anomalies and it requires delicate weighting of the whole pattern to adjust for these effects.

In any fracture pattern there are two main systems of fractures: the axial system and the shear system. In both systems the fractures are sub-parallel and in general, the two systems are at approximate right angles to each other. Within Petroleum and Natural Gas Permit No. 57 the statistical mean direction of the axial system is north 40 degrees west and the statistical mean direction of the shear system is north 30 degrees east. A third minor system, here termed the sub-axial system, trends nearly north-south.

No regional fractures of great length can be seen and as these are conceded to originate within the Basement, it is assumed that all fractures plotted on the mosaic originate within the sedimentary section. Furthermore, as the fractures are short for this area it is very likely that they originate in the upper two-thirds of the sedimentary section. As the surface of the Permit is relatively flat-lying no azimuth correction is necessary for this study. It has been demonstrated that the low incidence anomalies on a mosaic are considerably larger than the subsurface feature which causes them.

There is one area on the mosaic where the fractures are less intense than the surrounding area.

Some fractures are always present within these areas but they usually have a lower incidence than the surrounding area. These low intensity areas are important and it is quite likely that they are due to some subsurface feature. The type of feature will be discussed in the next section of this report.

STRUCTURE

Petroleum and Natural Gas Permit No. 57 is located on the coastal plain on the south shore of Hudson Bay about 70 miles north of the edge of the Pre-Cambrian Shield.

Structural features which could be present and which could cause the low incidence anomalies mentioned in this report are discussed in order of probability.

(1) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No. 57 is thought to be much the same as it is today along the edge of the Shield. Low rounded hills separated by gentle to abrupt valleys are seen on the Shield and these features are undoubtedly present under the subject Permit. The effect of this Basement relief on the overlying sedimentary rocks is often great. The Granite Wash is usually present in the topographic "lows" on the Basement but absent on the "highs". The

Granite Wash is an excellent potential reservoir.

Further effects of Basement topography on beds higher than the Granite Wash is the gentle folding present over Basement hills. These folds are anticlines in every sense and could form traps for oil or gas.

(2) REEFS

Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. However, only small reefs have been found in outcrops near the Permit and such small masses as these probably do not greatly affect the fracture pattern.

(3) TECTONIC FOLDING AND FAULTING

The presence of tectonic folds is very unlikely, but some normal faulting could be present.

(4) TOPOGRAPHIC RELIEF ON AN INTRA-SEDIMENTARY UNCONFORMITY

Unconformity, is a possible source of fracture intensity anomalies, but within the Permit area it is unlikely that the relief on any unconformities within the sedimentary section is great enough to affect the fracture pattern.

Reference to the Total Fracture Pattern Map which accompanies this report will show that there is one area of "high" fracture intensity, and one area of "low" fracture intensity (green). The general interpretation is that the low fracture intensity area is underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is high in the southeast part of Permit No. 57.

This Basement high feature is most interesting from the oil and gas point of view. The general shape of this feature is such that the causative feature must be a hill on the Basement surface. A fault is unlikely as the causative feature as the high area is over one and one-half miles in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Granite Wash sand is probably absent on the top of this high fracture area, but will probably be present along the flanks of this feature.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Crook

WGC/jp

REFERENCES

NELSON S.J. & — 1966: Geology of Hudson Bay Basin, Bull. Can. Petrol. Geol., Vol. 14, No. 4, pp. 520-578.

BOSTOCK H.H.
CUMMING L.M.
NORFORD B.S.
NORRIS A.W. — Geology Hudson Bay Lowlands, Map 17-.1967, Geol. Surv. Can.
PRICE L.L.
STANDFORD B.V.

BLANCHET P.H. — 1957: "Development of Fracture Analysis as Exploration Method", Amer. Assoc. Petrol. Geol. Bull., Vol. 41, No. 8, 1748-59

HAMAN P.J. — 1964: "Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2

Granite Wash sand is probably absent on the top of this Basement topographic high; but will probably be present along the flanks of this feature.

Respectfully submitted by:

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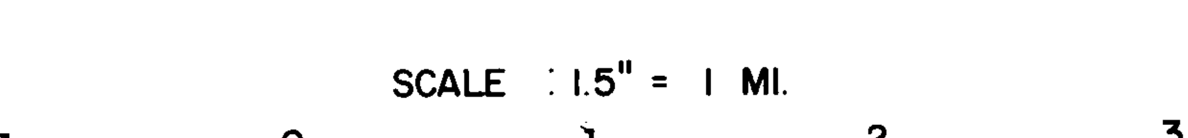
TOTAL FRACTURE PATTERN

SCALE : 1.5" = 1 MI.



LOW DENSITY

NORMAL DENSITY

HIGH DENSITY

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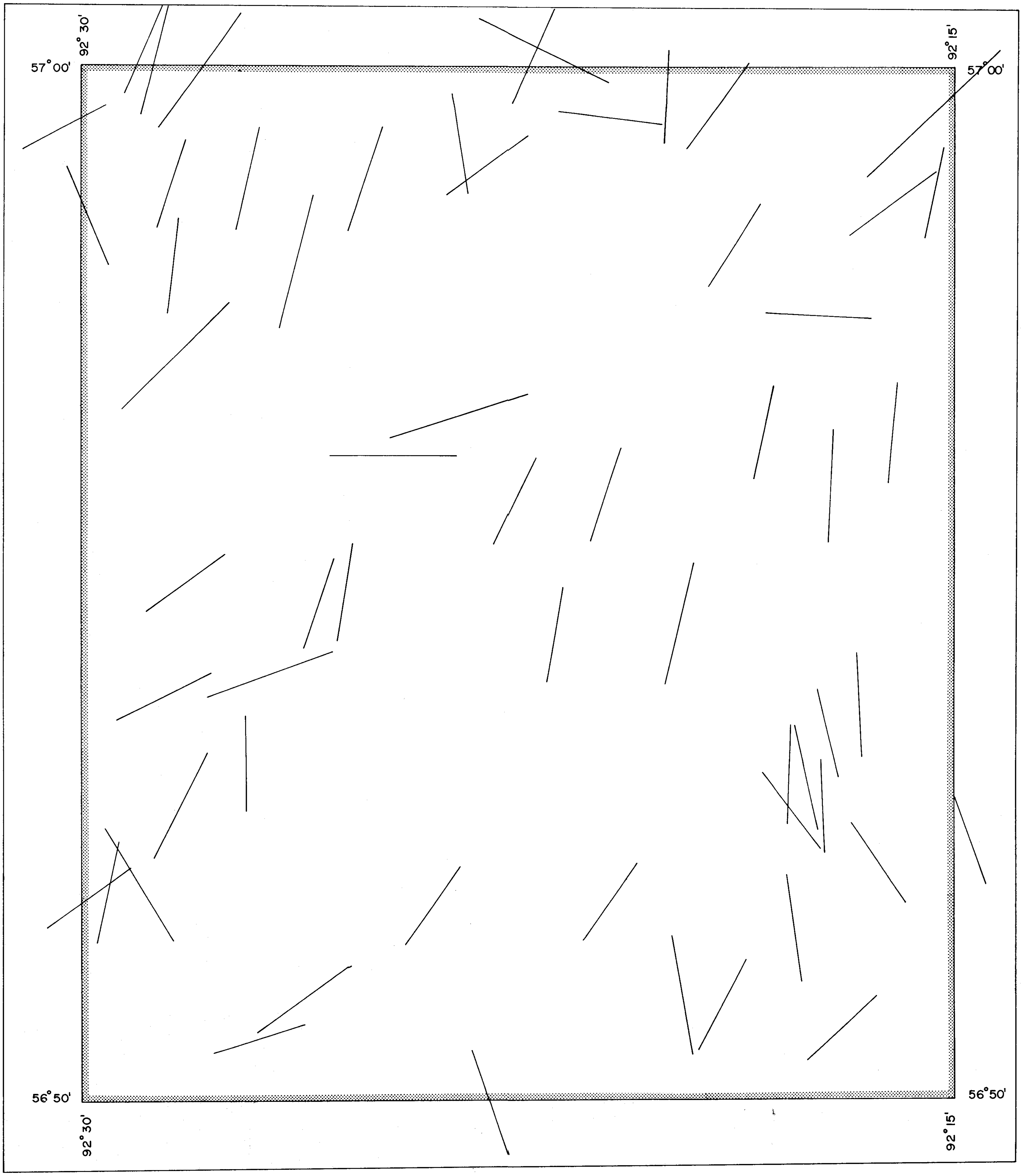
HUDSON'S BAY LOWLANDS

MANITOBA

SCALE: 1.5" = 1 MI.

1 0 1 2 3

THIS IS A UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN ACCURATE TOPOGRAPHIC MAP.



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MEGA FRACTURE PATTERN

SCALE : 1.5" = 1 MI.