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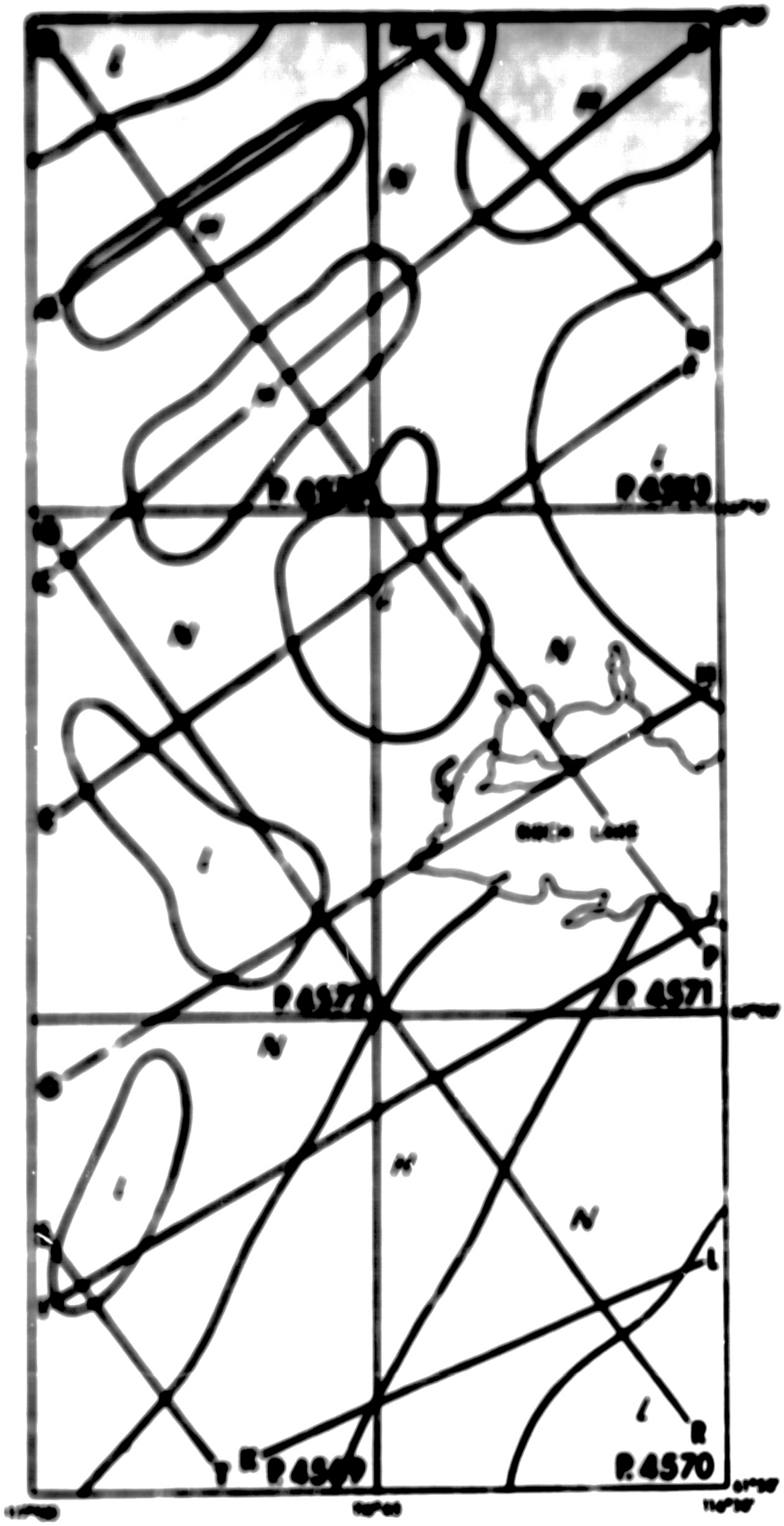

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INDEX MAP

INTRODUCTION

This report discusses the results of a Fracture Analysis Survey carried out and within, the immediate vicinity of, Petroleum & Natural Gas Permit No. 4569. This Permit is located in the Northwest Territories and is held under the Canada Oil and Gas Land Regulation and is located between 116° 45' to 117° 00' longitude and 61° 50' to 62° 00' latitude. The Permit is 600 miles north of Edmonton and 80 miles southwest of Yellowknife.

The Yellownife Highway is about five miles southeast of the Permit and this is the only road which passes through the area. Access to the Permit itself is by helicopter or on foot during the summer or by vehicle during the months when the ground is frozen. However, there are no roads in the area and considerable road construction would be required to reach any particular area.

The surface of the Permit is quite flat-lying and total relief does not exceed 40 feet. There is no developed drainage pattern within this area but there are many irregularly shaped large and small intermittent lakes present. A layer of very soft muskeg covers this part of the Northwest Territories and this muskeg is so soft that it is impassable to all but specialized vehicles.

Vegetation consists of thick stands of thin evergreen trees interspersed with many open areas. These open areas are covered by muskeg grass and scrub deciduous growth. The evergreen trees show up as a medium gray tone on the mosaic and the open areas are a lighter gray. A few small patches of deciduous trees are present.

There is no topographic form or aerial photo feature present which immediately suggests the presence of any geologic structure.

The results of this survey are illustrated on the Total Fracture Map, the Mega Fracture Map plus the mosaic with the fractures superimposed. In addition there are four hypothetical cross-sections. All the above can be found in the folder at the back of this report.

STRATIGRAPHY

The sedimentary section under Petroleum & Natural Gas Permit No. 6160 is about 3,400 feet thick and the Ordovician, Devonian and Cretaceous systems are represented. An unconformity is present between the Ordovician and Devonian systems, (between the Chedabucto Lake formation and the Chinchaga formation) and another is present between the Devonian and the Cretaceous. The Ordovician is mostly clastics with some amount of carbonate while the Devonian section is composed of evaporite and carbonate rocks. The Cretaceous is composed of clastics.

ORDOVICIAN

The Ordovician section is about 630 feet thick and is divided into the Old Fort Island, La Martre Falls and Chedabucto Lake formations. The section is mostly carbonates with dolomite and tiny dolomite being the dominant rock type. A sandstone unit occurs at the base of the section.

OLD FORT ISLAND FORMATION

The Old Fort Island formation is the oldest Paleozoic rock unit present in the area north and northwest of Great Slave Lake. The unit is probably a "Granite Wash" type of deposit and where exposed in outcrops consists essentially of sandstone. Norris (1962) describes the unit as "consisting of thin to thick bedded, fine to coarse grained, vari-colored but mainly white, friable, quartzose sandstone, some thin beds of greenish gray and dusky red siltstone; and occasional laminae and partings of green shale". The sandstones are usually porous and often friable. Norris's description of this unit sounds very similar to the present writer's description of the Granite Wash formation as present in the Red Earth Oil Field in Township 87, Range 8, West of the Fifth Meridian (Alberta).

As the Old Fort Island Formation has yielded no fossils as yet its exact age is unknown and a similar age problem exists with the Granite Wash in northern Alberta. However, both formations appear to be conformable with the overlying beds and both are often confined to topographic low areas on the Pre-Cambrian Shield. The age of the Old Fort Island formation is, therefore, probably Middle Ordovician, but older than the La Matre Falls formation. The sandstone beds of this unit are an excellent potential reservoir.

LA MATRE FALLS FORMATION

The LaMatre Falls formation is 300 to 350 feet thick in the region under discussion, and consists of red and green shale, fine to coarse grained sandstone and silty to sandy dolomite. The base of the La Matre Falls is often an argillaceous silty, oolitic limestone with some sandy and conglomeratic dolomite and sandstone. Gypsum and salt are also often present.

The shales are platy, fissile and are vari-colored with red and green being the most common color, but pinks, brown and gray also being present, silty to sandy and at times slightly dolomitic. The sandstone beds are medium to light gray, and fine to coarse grained. Where the sandstone lies directly on the Pre-Cambrian Shield it is often arkosic and in this area it is a "Granite Wash". Grapholit's remains, date this formation as Middle Ordovician. The sandstone and dolomite members of this formation are good potential reservoir horizons.

CHEDABUCTO LAKE FORMATION

The Chedabucto Lake formation is about 200 to 250 feet thick in the vicinity of the Permit and the unit consists of massive, cliff-forming dolomites some of which are sandy and conglomeratic. Norris (1962) describes the formation ......"consists of a thick bedded to massive, highly resistant, scarp-forming, fine grained, granular, in places minutely vuggy, medium brown dolomite, commonly weathering a pale orange or orange-brown in the south, and a yellowish brown and gray in the north". Purple mottling is common and chert is often present. The age of the Chedabucto Lake formation is Upper Ordovician. The reservoir possibilities of this unit in the subsurface do not appear to be great as only minor vugs are reported from the surface exposures. This formation is overlain unconformably by the Middle Devonian System and the Chinchaga formation of the Middle Devonian is the overlying unit.

DEVONIAN

The Devonian section is about 1,075 feet thick and consists of the Chinchaga formation plus units which are equivalent to the Keg River and Muskeg formations. The exact sequence present is unknown due to a lack of wells in the area plus the lack of surface knowledge in this northern area. In addition, the Middle Devonian succession in this area is very complex and many abrupt lithologic changes are present. The Chinchaga formation is recognized as a map-able unit but the units above the Chinchaga cannot be correlated to the northern Alberta type section area.

CHINCHAGA FORMATION

The Chinchaga is about 325 feet thick and in this area the unit consists of evaporites, some minor dolomite plus some dolomite and limestone breccia. The Chinchaga unconformably overlies the Chedabucto Lake formation and is conformably overlain by younger Middle Devonian beds. Norris (1965) states " The Chinchaga formation is mostly gypsum ......easily eroded and does not produce good outcrops. The gypsum is generally white, or banded light to dark gray, and weathers to a material of soft, powder, or putty-like consistency when moistened. In places the gypsum beds are contorted and brecciated. One of the more complete sequences of the lower beds of the Chinchaga ....consist (s) of thickly bedded to massive, pale brown, extremely vuggy, gypsiferous limestone, succeeded by a poorly exposed interval of thinly bedded, light gray weathering limestone, and overlain by massive, cliff-forming pale brown limestone. Within a distance of about 10 miles ......there lower beds change to gypsum and brecciated gypsum". Brecciated gypsum and carbonate beds are present through the entire section in the area north of Great Slave Lake.

KEG RIVER EQUIVALENT

The section which correlates with the Keg River formation is called the Lonely Bay formation.

[illegible] describes the lower part of the [illegible] formation as [illegible] dark brown aphanitic to [illegible] limestone, thinly bedded light gray fine grained to aphanitic limestone [illegible] brown [illegible], thin bedded light olive gray to medium gray, fine grained limestone, medium bedded aphanitic slightly dolomitic limestone and thinly bedded [illegible] brown slightly argillaceous limestone. A younger section is described as consisting of [illegible] dark to medium brown fine grained to [illegible] limestone overlain by irregularly thin bedded medium brown fine grained to aphanitic limestone interbedded with nodular limestone.

[illegible] FORMATION EQUIVALENT

In the area south of [illegible] Lake [illegible] unit present which corresponds to the [illegible] of northwestern Alberta. It is up to [illegible] feet thick in the area and is composed of a lower 100 feet of bituminous shale; a middle 175 feet of green calcareous shale; and an upper member up to 225 feet thick which consists of gray to white reefal dolomite. This upper member correlates to the Presqu'ile reef of the Pine Point area.

Fracture intensity contrasts could reflect the edge of the Presqu'ile reef or where there is rapid change in lithology within the section.

CRETACEOUS

The Cretaceous sediments are about 400 to 800 feet thick depending on surface elevation. The thicker sections are present under the hills.

Lithologically the section consists of dark gray, concretionary, gypsiferous shales. These shales are Lower Cretaceous in age and are probably equivalent to the Peace River and Spirit River formations of northern Alberta.

TERTIARY

A thin layer of glacial clay, sand boulders and till lies on the surface of the map area. The thickness of these deposits varies from place to place but probably does not exceed 100 feet.

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 [illegible] and [illegible] fractured is the basic premise on which is built the [illegible] technique known as Fracture Analysis. A Fracture is defined as "[illegible] photographs".

Fracturing is largely caused by [illegible]

[illegible]

(a) [illegible]

(b) [illegible]

(c) [illegible]

[illegible]

[illegible]

system is applied by any method recording all [illegible] subtle irregularities in the velocity of a certain type of linear feature and the alternative presentation of the data as contoured intensity maps or by 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 photo-analyst 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 orthographic 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, [illegible] system and the [illegible] system. In both systems the fractures are [illegible] and in general the two systems are at approximately right angles to each other.

Because of [illegible] limiting factors [illegible] Surveys have a lower order of reliability than [illegible] Surveys. [illegible] surface conditions affect the [illegible]. In areas covered by [illegible] and [illegible] the fracture count is [illegible]. Cultivated areas [illegible] a lower count than adjacent [illegible]. Consequently a difference in [illegible] in fracture count (F/t) 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 of 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. 4949

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 north of the Great Slave Lake and is many 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 Devonian 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 3,000 feet and both macro 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 heavily scarred with glacial grooves and striations and that the direction of ice flow was about north 60 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. 6149 the statistical mean direction of the axial system is north 30 degrees west and the statistical mean direction of the shear system is north 55 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 Figure is [illegible] [illegible] to 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 and thus the anomaly [illegible] the low incidence area in Figure [illegible] [illegible] is probably quite small.

There is this 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 4569 is located on the interior plain of the Northwest Territories about 55 miles to the west of the edge of the Pre-Cambrian Shield. The strike of the sedimentary rocks is about north 25 degrees west and the units dip to the southwest at a few tens of feet per mile.

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. 4569 is thought to be much the same as it is to-day along the southwest 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.

Many small faults have been reported by A.W. Norris (1965) in the Basement and immediately overlying rocks and these features could cause closure within the sedimentary units.

(2) DEVONIAN REEFS

Devonian Reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. Small Middle Devonian reefs are present just west of this Permit and others could well be present under the subject area.

(3) TECTONIC FOLDING & FAULTING

The presence of tectonic folds is very unlikely, but some normal faulting is probably 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 areas are 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. 4160.

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.

Four hypothetical structure cross-sections accompany this report and reference to them will show how Basement "highs" are inferred to be present beneath areas of low fracture intensity. Three profiles run at right angles to the strike of the Basement while the fourth is parallel to strike.

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William C. Cook

WOC/jp

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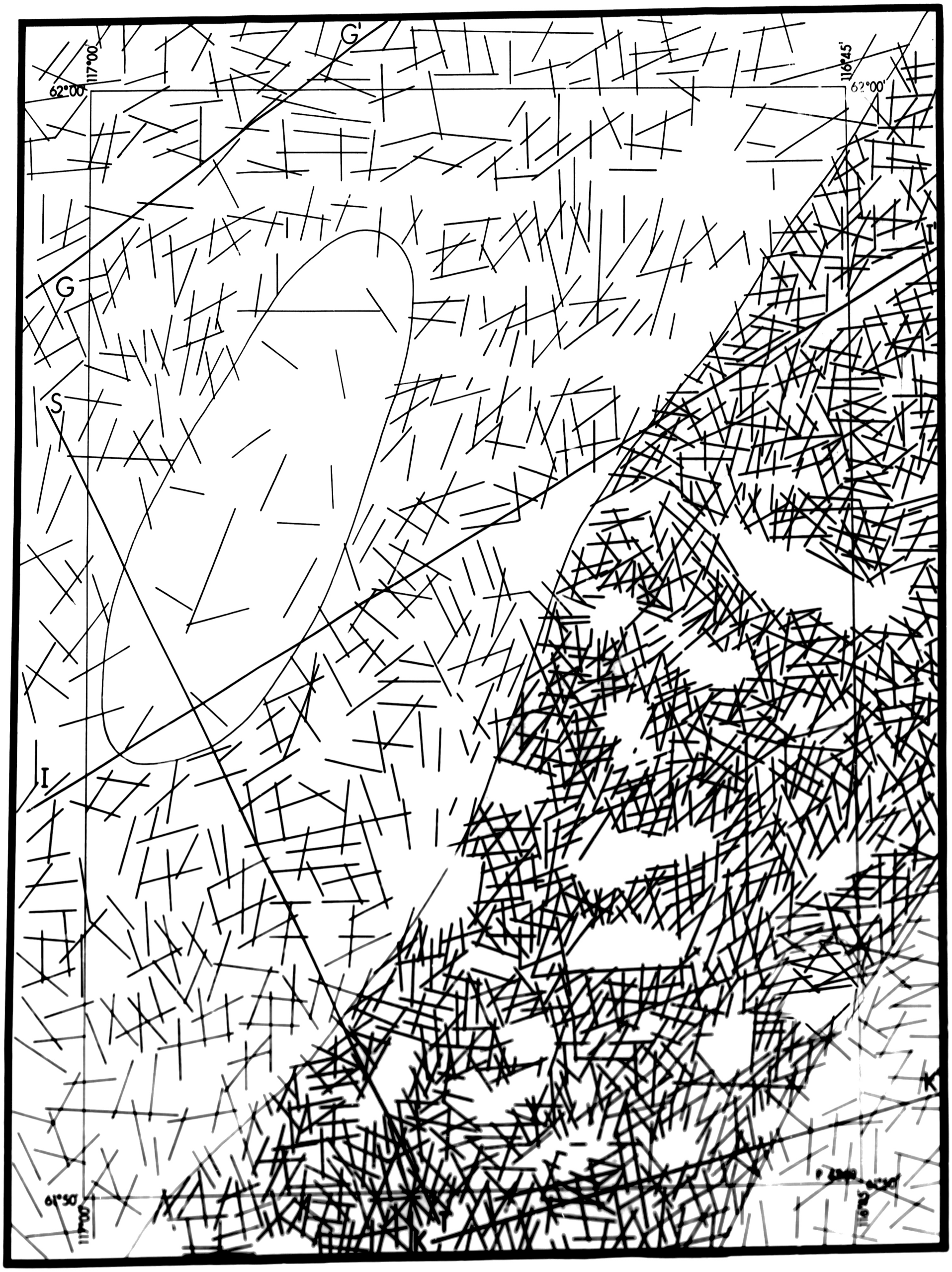
SCALE IN MILES



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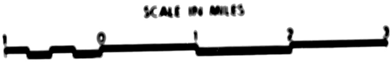
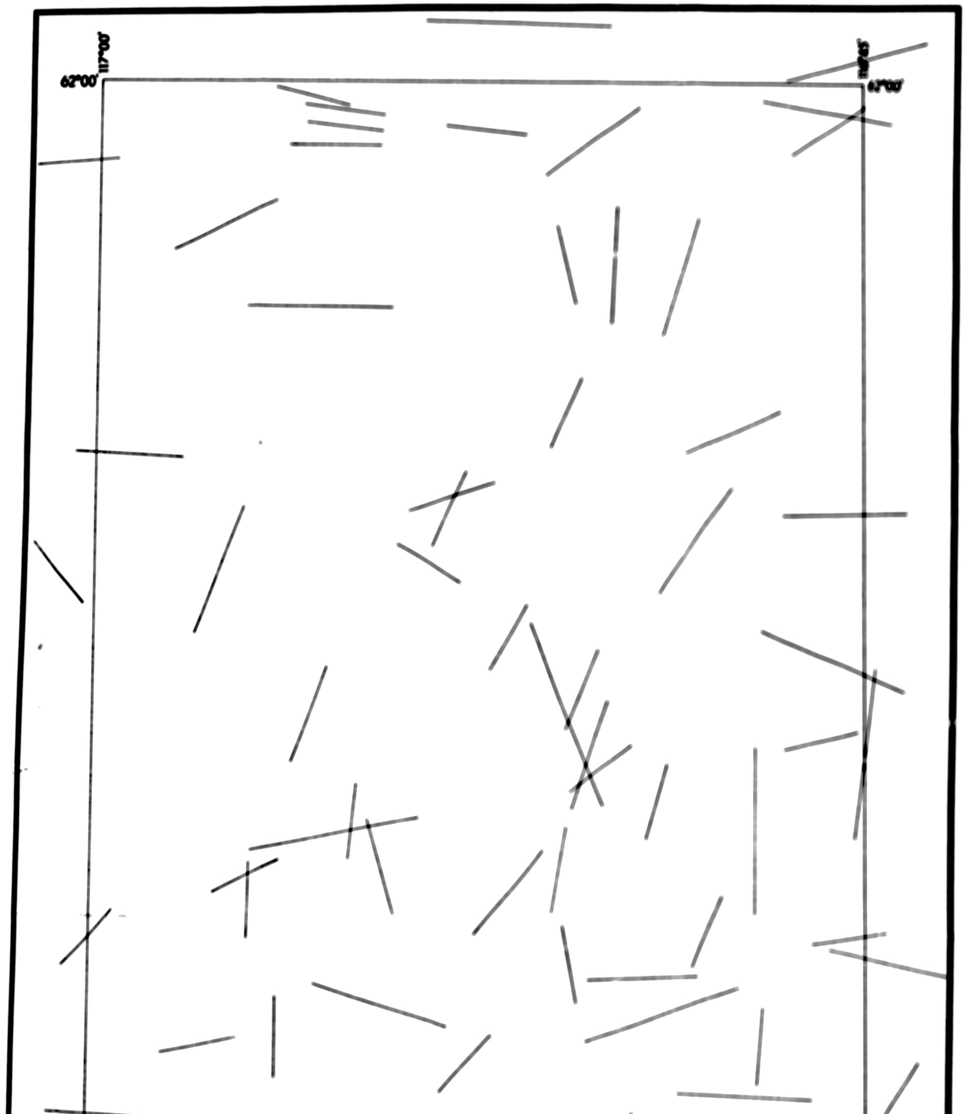
TOTAL FRACTURE PATTERN

SCALE IN MILES





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MEGA FRACTURE PATTERN

SCALE IN MILES

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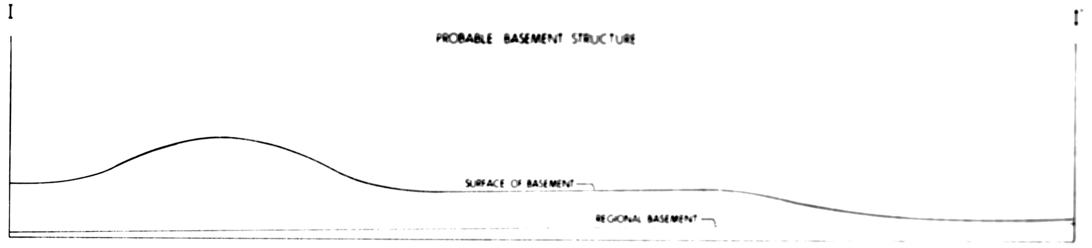

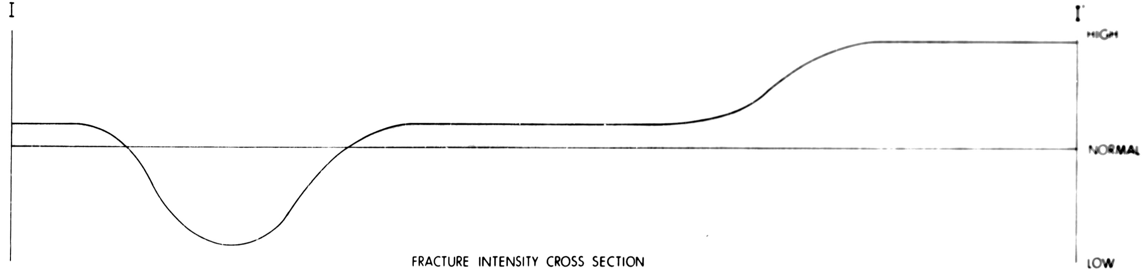

FRACTURE INTENSITY CROSS SECTION

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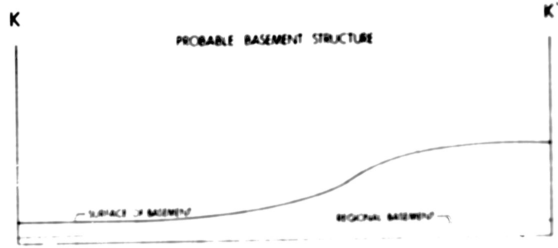

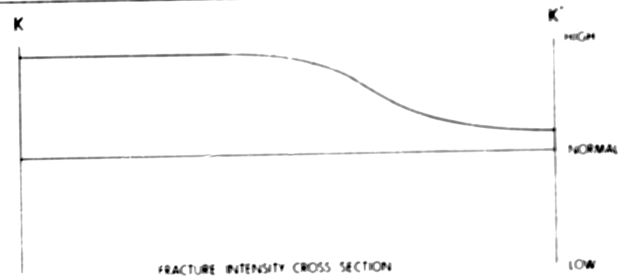

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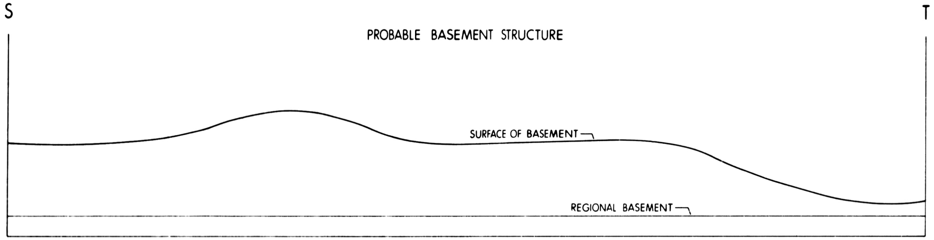

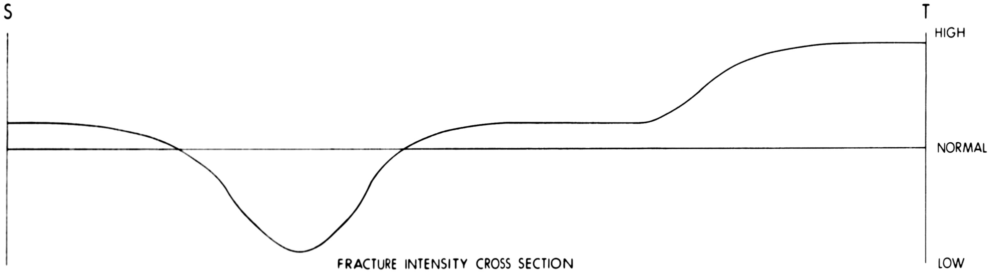

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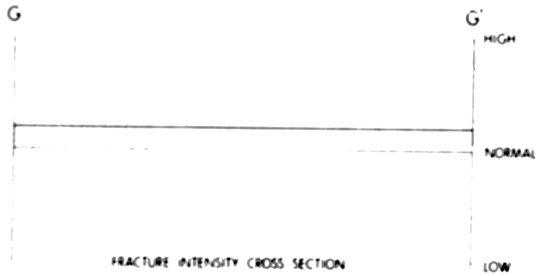

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