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GENERAL GEOLOGY

&

FRACTURE ANALYSIS SURVEY

of

P. & N. G. PERMIT NO. 5072

for

GROSMONT OIL & GAS LTD.

by

RAYALTA PETROLEUMS LTD.

INTRODUCTION

This report discusses the results of a General Geology and Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permit No. 5072. This Permit is located in the Northwest Territories and is held under the Canada Oil and Gas Land Regulations and is located between 121° 45' to 122° 00' longitude and 64° 20' to 64° 30' latitude. The Permit is 800 miles northwest of Edmonton and 280 miles northwest of Yellowknife. There are no roads near the Permit.

The Yellowknife Highway serves Fort Providence which is 230 miles southeast of the Permit and is the closest road to 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 slopes gently towards the north and total relief does not exceed 100 feet. Great Bear Lake lies 30 miles north of the north boundary of the Permit. The drainage flows to the north via the Johnny Hoe River which flows through the Permit. 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 stands of thin evergreen trees intersperced 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.

STRATIGRAPHY

GENERAL STATEMENT

The stratigraphic discussion presented herewith is based on a study of the area covered by Petroleum and Natural Gas Permit 5059 and Permits 5062 to 5081 inclusive. The north limit of this area is located along the south shore of the Keith Arm of Great Bear Lake and it trends southeast to about 64° 00' - 121° 00'. No wells have been drilled in this area and surface outcrops are rare and widely scattered. Therefore, it has been necessary to study the regional geology of the whole Northwest Territories and make many projections of data and, admittedly, some of these projections are rather long-ranged. However, when combined with such subsurface information as is available an accurate picture of the sedimentary stratigraphy can be presented.

The Permits are on the Interior Plains 40 to 60 miles east of the Franklin Mountains, and about 100 miles west of the Pre-Cambrian Shield outcrop area. The Permits lie about 150 miles east-southeast of the Norman Wells Oil Field which provides most of the nearest well control. The area covered by the above referred Permits is underlain by sediments ranging in age from Cambrian to Tertiary. Regional isopachs indicate about 6,000 feet of sediments should be present under the northern Permits and about 4,500 feet under the southern Permits. Structurally, they should be underlain by homoclinal to gently folded beds. However, since the Northern Franklin Mountains are the result of compressional movements, it would seem likely that the area lying in front of the mountains may have been folded into anticlines of appreciable magnitude. The Pre-Cambrian may have undergone early faulting under the Permits since faulting of this age is quite common in this region. The Basement faults have commonly produced northeast trending lineaments but are generally conceded to have not disturbed the Paleozoic sediments. The Basement faults are generally steeply inclined right-hand faults and as far as is known, the horizontal movement exceeds the vertical movement by a large amount. Some recurrent movement at widely separated times has been noted in the region. Well control east of the acreage concerned is very scarce Regional isopachs and facies maps along with published geological reports have been used to describe the stratigraphic sequence which might be expected to underlie this area.

CAMBRIAN and/or OLDER

KATHERINE GROUP

The Katherine Group which represents the earliest Paleozoic sediments in this region, is named from a section exposed in the Upper Carcajou River area which lies about 150 miles west of the acreage under study. The section exposed consists of interbedded quartzites and black, platy shales. The shales which are black, platy, bituminous as well as green and chocolate coloured, are contained in interbeds within the quartzites. The quartzites are generally pink, buff, rusty and white in outcrop. The top of the Katherine is placed at the base of a choclate coloured shale succession while the base was not seen in outcrop leaving the total thickness unknown for this area. The Katherine Group has not been penetrated by any drill holes in this region to date, which means the subsurface section is unknown. While reservoir beds are not described in outcrop it must be expected that sand bodies such as offshore bars, beach sands and long shore bars will eventually be found in this group of sediments. Similar sands are found to be prolific producers in the Red Earth Creek area of northern Alberta. The delineation of prospective areas for encountering such sands is dependant on a knowledge of present Pre-Cambrian structure as well as its topographical expression, when the sands were being deposited. A gravity meter and airborne magnetometer survey could be used to good advantage in locating areas for more detailed exploration. Source rocks for hydrocarbons should be no problem since the outcrop section previously described would appear to contain an adequate source within its bituminous shales. This section should be considered in any exploratory plans for this area.

CAMBRIAN

MACDOUGAL GROUP

The type section of the Macdougal Group is located about 130 miles west of this area in the Dodo Canyon of the Macdougal River. At the type section the Macdougal is divisible into a number of formations which total 997 feet in thickness. The base is placed at the bottom of a 130 foot thick chocolate brown shale while the top is placed above 50 feet of evenly bedded limestone with shale partings. The lithology is made up of interbedded limestones, sandstones, reddish coloured gypsum, black, petroliferous shales, red and green shales as well as choclate coloured shales. The Imperial River section which was mapped by Laudon lies 30 miles to the northwest of the type section. The section, which is 1,839 feet thick with the base not exposed, consists of alternating sandstones, limestones, gypsum and vari-coloured shales. The lower part consists of sandstones with minor shale interbeds which appear to be a shallow water deposit since they are ripple marked and cross-bedded. The section becomes increasingly shaly upwards The gypsum content is also greater near the top. A 146 foot thick bed of black to dark grey, laminated, algal limestone is located near the top of the section. Calcareous algae up to three feet in diameter are present. At

Norman Wells the Macdougal Group contains a bed of salt 2,000 feet thick which is correlated with the Saline River Formation This salt sect on is believed to be present to the north, west and south of Norman Wells for the following reasons:

1 The Western margin of the Saline River salt is known in the Norman Wells area and a postulated extension of this margin can be made to the north, west and south of Norman Wells

2 The overlying Ronning carbonates are brecciated at exposures in the northern Richardson Mountains west of Inuvik, suggesting salt solution collapse

3 The type section at Saline River which lies 100 miles south of

the Permits under discussion, contains salt as evidenced by the presence of salt springs.

4. Aeromagnetic coverage north of Inuvik has disclosed two features which bear a marked similarity to known salt domes in the Arctic Islands.

5. The gypsum in three diapiric structures which intrude Cretaceous beds on the east margin of the Richardson Mountains west of Inuvik contains evidence of early Paleozoic origin.

Since the Saline River salt is evidently so wide spread it should be present under this area with the eastern edge lying some unknown distance to the east. The solution of this salt creates the possibility of salt structures in the overlying carbonate banks similar to those found to be productive in southeast Saskatchewan and at Rainbow Lake in northwestern Alberta. The algal laminate at Imperial River indicates some organic activity in the Macdougal seas and this coupled with underlying salt features, could give rise to hydrocarbon bearing reservoirs within this sequence. The petroliferous shales within the Macdougal should be adequate source material. The Macdougal has been reached by very few of the wells drilled in this region and no where has it been fully penetrated. Imperial Vermilion Ridge No. 1, drilled 3,177 feet of Macdougal beds without reaching the underlying Katherine Group. To date no reservoirs have been tested in the wells which have drilled to the Macdougal.

ORDOVICIAN-SILURIAN

RONNING FORMATION

Rocks of Ordovician Age have not, as noted by various authors, been definitely identified in this region; however, it seems to be generally accepted that they are present in the Norman Wells region. The contact with the underlying Macdougal is unconformable. Stelck mapped 1,500 feet of shales and argillites at outcrops in the Upper Peel River area, which lies some 300 miles to the west of these Permits. About 150 miles west of the Permits, at the Keele and Twitya River confluence, the Ordovician section was mapped by Keele as 4,000 feet of alternating beds of argillite, dolomite and limestone with 1,500 feet of sandstone overlying and separated from them by a 100 foot thick diabase sill. He mapped this same sandstone 35 miles to the east as being 4,500 feet thick with only occasional shale partings. The sections described in outcrop by Keele and Stelck along with the scattered subsurface control available have been used to establish some regional lithofacies trends for the Ordovician.

The Upper Peel River section is mapped as an open marine basinal sequence of shales and argillites. Flanking this basin are shelf-edge carbonates which are reefal in part. These shelf-edge carbonates are found along the MacKenzie Mountains and on the Peel Plateau. Back of the shelf-edge carbonates are the shelf carbonates proper, which are generally clean, finely crystalline carbonates with variable porosity. They are present over most of the interior plains and should underlie the Permits under discussion.

The distribution of Silurian Age strata covers a much wider area than do the beds of Ordovician Age. Lithologically the Silurian rocks are very similar to the underlying

Ordovician beds and for this reason as well as ease of working with them, they have been grouped together as the Ronning Group. The sedimentary pattern for the Silurian is very similar to that established in the underlying Ordovician. In the Norman Wells area the Ronning Group can be divided into two formations, a lower unit named the Franklin Mountain and an upper unit named the Mount Kindle. The Franklin Mountain Formation is generally composed of limestones and dolomites with abundant irregular shaped chert nodules. The Mount Kindle is usually found to consist of a sequence of chert poor limestones and dolomites which tend to thin in a southerly and easterly direction.

The Franklin Mountain Formation should be approximately 800 feet thick in the area covered by these Permits. It should consist of clean, finely crystalline shelf carbonates with abundant chert inclusions and quite variable degrees of porosity.

At the nearest outcrop section of the Ronning, which is found about 50 miles west of the Permits at Mt St Charles on Great Bear River, the Franklin Mountain Formation is about 865 feet in thickness. The section consists of limestones with the basal 200 feet described as cavernous; about midway in the section is 75 feet of cherty limestone. The upper 470 feet is a grey, dolomitic limestone. The base of the Franklin Formation here is not exactly clear as various workers have included beds beneath those described in the Ronning Group as well. They consist of gypsum, conglomeratic limestone with black, bituminous pebbles and highly bituminous limestones, which seems more like Macdougal to the writer. The Mount Kindle consists of 480 feet of carbonates, the basal 210 feet is a dolomitic limestone containing corals while overlying it are 90 feet of limestone and chert beds. The upper

180 feet is a hard, grey dolomite that is cherty in the lower part. The section is overlain by the Bear Rock brecciated dolomites. The section at Bear Rock near Fort Norman, which is 30 miles west of Mt. St. Charles, consists of 600 feet of limestone, dolomites and shales with the brecciated sediments of the Bear Rock overlying them and the Macdougal red and green, gypsiferous shales underlying them. The Mount Kindle is apparently not present here. Imperial Loon Creek No. 2, in 65° 07' 20" N., and 126° 12' 51" W., which is about 75 miles west of the Permits, penetrated 1,270 feet of Ronning which is close to the same thickness as mapped at Mt. St. Charles. The Loon Creek well found the Ronning to consist mainly of white to grey, micro-crystalline to granular dolomites with some evaporitic plugging. Scattered poor porosity was present throughout; however, no tests were run. Outcrops of the Ronning are found about 200 miles to the northwest of the Permits along the Hare Indian

River. The section consists of 750 feet of limestones, overlain by the Bear Rock with the base not exposed. The section is not identified as Mount Kindle but regionally it should be present at this location.

Stelck mapped 100 feet of massive, crystalline, porous limestones containing some coralline fauna at Schooner Creek, which is four miles north of Norman Wells. He correlated them with the lower portion of the Mount Kindle Formation. This section can be interpreted as a porous, carbonate bank deposit. The Mount Kindle is likely to have a number of these carbonate banks or low transgressive reef fronts in this area, since, as can be seen from the various sections described above, it undergoes both facies changes and thickness changes in this region. Since the Mount Kindle is present on Mt. St. Charles to the east of the Permits, as well as to the north of them it will doubtlessly be present under them. The section may contain carbonate banks or low reefs fringing the eastern shore-line of the Mount Kindle sea. Oil staining has been described in the Upper Ronning Group at wells in the Norman Wells area.

The trapping conditions which can be outlined in this area, are quite varied. A few of these potential traps are outlined below:

(a) The marked disconformity which separates the Ronning Group from the overlying Middle Devonian-Bear Rock Formation may have produced erosional features, such as scarps and monodnocks, which would be sealed by the basal evaporites of the Bear Rock. Leaching should enhance the reservoir properties and make this an effective hydrocarbon trap.

(b) As outlined previously, low reef fronts or carbonate banks may be present and coupled with a seal provided by overlying Bear Rock evaporites could present an extensive trap Lateral facies changes from porous to semi-evaporitic carbonates also provide a potential trap of considerable areal extent.

(c) Selective solution of the underlying Cambrian Saline River salt may give rise to one or two stage salt solution structures such as are found to be productive of oil in the Hummingbird area of south-east Saskatchewan. Partial solution of the salt prior to or during Mount Kindle deposition would have served to provide local elevations on the sea bottom where the salt was not removed. These local elevations would provide the loci for reef and/or carbonate banks to grow on. Traps of the Hummingbird type would involve early local solution of the salt. This may have occurred in late Cambrian or early Ronning time. The depressions created would receive an extra fill of sediments over that being deposited where the salt was not removed. Once sedimentation within the sink caught up, subsequent sediments would be deposited on a normal sea floor. The second stage in the formation of the Hummingbird type trap would involve the removal of the salt surrounding the original sink at some time subsequent to Mount Kindle deposition. This would leave the Mount Kindle reservoirs overlying the site of the original salt solution structurally high. The Bear Rock evaporites should provide an effective reservoir seal. Evidence to support one or two stage salt removal in this region is present in the brecciated nature of the sediments composing the Lower Ronning and Bear Rock sediments in known sections.

(d) Gentle to tight anticlinal folds may have been formed by some of the numerous periods of structural activity which have occurred in this region.

MIDDLE DEVONIAN

BEAR ROCK FORMATION

The Bear Rock Formation overlies the Ronning Group and is separated from it by a marked disconformity. The contact with the overlying Hume (Ramparts) may also be disconformable. The type section is located about 100 miles west of this Permit area at Bear Rock, near Fort Norman. The type section is mapped as two distinct facies, a basal 40 feet to 60 feet of white, gypsiferous, massive lensing dolomite or limestone and an upper 175 feet of breccia composed of brown, dolomit'c limestone boulders set in a matrix of dolomitic limestone. Separating the two facies is a 30 foot section of poorly bedded, dark grey limestone and dolomite. The contact with the overlying Hume (Ramparts) is gradational and consists of a 10 foot interval of bedded limestone and dolomite breccia.

The Bear Rock is a very widespread formation which undergoes a number of faceis changes from open marine basinal shale facies to an evaporitic sequence. The basinal shale facies which is present in the Richardson

Mountains continues southeast along the western side of the MacKenzie Mountains. The basinal shales are flanked by a belt of shelf-edge limestones and dolomites along their eastern side. Porosity is developed within these carbonates. Adjacent to the shelf-edge carbonates and covering much of the Interior Plains and Peel Plateau area are the shelf limestone and dolomite facies. In the Peel Plateau they attain a thickness of some 2,000 feet and consist of micritic, pellet and micitic skeletal limestone with intervals of finely crystalline, porous dolomite in the lower part. The shelf carbonates are in turn replaced by a relatively narrow belt of shelf dolomites. This takes place in the MacKenzie Mountains and extends in a line north through the Fort Good Hope region and south into the Camsell and Nahanni Ranges. The shelf dolomites in turn are replaced by an evaporite facies along their entire length. This facies change begins to the west of Norman Wells. In the Norman

Wells area and also in the area of the Permits under discussion the basal portion of the Bear Rock is commonly evaporitic while the upper portion consists of carbonate breccias. The evaporite facies extends southward into northern Alberta where it is known as the Chinchaga Formation. South of Norman Wells a strong depositional feature called the Camsell Basin occurs. Thickening from 2,000 feet to more than 5,000 feet, accompanied by facies changes from evaporites through shelf carbonates to basinal sediments takes place into this basin. The shelf carbonates are cryptocrystalline to microcrystalline dolomites while the shelf-edge facies is reefal with some of it at least being porous.

The Bear Rock carbonates in the Norman Wells area have been found to be very porous in some wells while in others the porosity has been plugged by anhydrite and gypsum. Considerable bitumin has been encountered in places. Drill stem test results vary from mud recoveries to water flowing to surface. While the wells drilled by Western Decalta at Rond Lake are about 250 miles to the northwest of the Permits under review the oil shows in these wells is significant in that they establish the presence of hydrocarbons in beds of Bear Rock Age. Decalta et al Rond Lake # 2, located in 67° 5' 27" N., and 128° 25' 42" W., lost circulation near the top of the Bear Rock and sulphur water was bailed from this interval. Decalta et al Rond Lake # 1, located in 67° 04' 51" N., and 128° 28' 18" W., flowed sulphurous water on a test conducted about 900 feet below the top of the Bear Rock. Subsequent to the completion of drilling, a plug was set to 1,046 feet. The hole was bailed to 600 feet with oil cut sulphurous water being recovered. Three weeks later the hole was again bailed with oil cut sulphurous water recovered again. Indicative of the stratigraphic trap possibilities, is the fact that the Rond Lake # I we'l was located downdip to the # 2 well and recovered oil cut water near the base of the Bear Rock, while # 2 well only recovered sulphurous water from the top of the formation. The Bear Rock could be placed in trap position by any of the various str ctural conditions outlined in the preceding discussion of the Ronning Group.

The Bear Rock is present in outcrop along the Hare Indian River about 140 miles northwest of the acreage under review. It consists of typical brecciated limestone and gypsum. The brecciated nature of the Bear Rock was previously mentioned as being a probable product of the solution of the Cambrian Saline River salt. A more conventional theory for the origin of the breccia is that it is a product of the sharp disconformity separating the Ronning Group from the overlying Bear Rock Formation. This theory is doubtlessly true for the basal portion of the Bear Rock

Formation. The section exposed on Mt. St. Charles which is about 50 miles west of the subject Permits, may be considered as supporting evidence for the theory that the brecciation of the Bear Rock was caused by the solution of Saline River salt during Bear Rock deposition. The section is described by Williams, as," 340 feet of saccharoidal, coarse grained, brown dolomites...overlain by 1,000 feet of thin bedded, brown dolomites, in part brecciated". The top of the Bear Rock was not seen. In addition to the brecciation well up into the Bear Rock section, the great thickness of sediments mapped as Bear Rock could be considered suggestive of greater subsidence during deposition here than was occurring in adjacent areas. The thickness at Bear Rock, which is the type section, is about 265 feet. The anomalous thickness could also be due to erosional relief, or thrust faults repeating the section and not being recognisable; however, this does not seem very plausible. The rapid facies changes which may be espected within the Bear Rock is evident when the Mt. St. Charles section is compared to an exposure three miles further north. Here the chert beds of the underlying Mount Kindle Formation are overlain by 500 feet of grey gypsum beds that are in turn overlain by limestone beds that are mapped as part of the overlying Hume (Ramparts) Formation. The Mt. St. Charles section has no evaporites. The thickness variation between these two sections is worthy of comparison also.

HUME FORMATION

Considerable confusion has existed in the literature concerning the relationship of the Ramparts or Hume, Hare Indian and Kee Scarp Reef. A paper by H.G. Basset in the Geology of the Arctic Symposium is probably the most important to an understanding of the Middle Devonian geology of this area.

Hume defined the Ramparts Formation as containing all definite Middle Devonian beds in the Norman Wells area as well as in the surrounding area. The base would be placed at the top of the underlying Bear Rock and the top at the contact with the overlying Fort Creek Shales. He divided the Ramparts into three members, a lower limestone member, a middle shale member and an upper limestone member. The lower limestone, which is relatively thin in the Norman Wells area, thickens in a northwest direction. About 60 miles west-northwest of Norman Wells in the Imperial Range on Mountain River the Lower Ramparts is described as 445 feet of limestone, dark grey to black, with irregular black shale partings, very fossiliferous in part (particularly corals) and very petroliferous in part. The Middle Ramparts of this section consists of 700 feet of grey to green shales and limey shales with many thin limestone beds which are commonly conquinoid in the lower part. The Upper Ramparts limestone at this section is 180 feet thick and is mapped as limestone, black to grey-brown, massive, grading to shale at the base. The upper portion consists of limestones, grey to dark grey, massive, with thin black shale partings.

The term Ramparts was discarded by Basset in his paper. The section as re-defined by Basset consists of: The Hume Formation which he equates with the Lower Ramparts of Hume; the Hare Indian, which is considered the correlative of the Middle Ramparts Shale and the Kee Scarp which is correlated with the Upper Ramparts.

The type section of the Hume is located in the MacKenzie Mountains on the east branch of the Hume River where it consists of 400 feet of thinly bedded limestones which are light grey, argillaceous, very fossiliferous and of shallow water origin. The Hume is correlated diachronously with the lower portion of the Keg River Formation of northern Alberta. The correlation is based on ostracod zones within the Hume and Lower Keg River Formations. The Hume has been found as far north as the Anderson River. The thickness of the Hume is quite variable as is readily apparent if the type section is compared to the section at Schooner Creek, which is four miles north of Norman Wells. The Hume here is only 8.5 feet thick and consists of limestone, black, shaly to slaty and fossiliferous. The basal foot is a one foot thick conglomerate indicating a disconformable contact with the underlying Bear Rock.

The Hume Formation is generally encountered as a non-porous rock both in outcrop and in subsurface. The Keg River platform of northern Alberta is also normally a non-porous rock; however, it does develop into marginal shoal along the north flank of the

Peace River Arch. This marginal shoal is very porous, granular, reefy dolomite which yields large quantities of water when drill stem tested. The marginal shoal is in turn replaced by back shoal mud flats, which are the lateral equivalent to shoreline sands. The sands have been found productive of oil in some locales. The facies pattern developed along the north flank of the Peace River Arch should have been repeated in this area long the margins of the Pre-Cambrian Shield. The marginal shoal and the shoreline sands may have been removed by one of the many periods of deep erosion that have occurred in this region; however, the acreage covered by these Permits must be considered as very well placed to evaluate these possibilities.

The Hume has been described at various localities as being very petroliferous in part. This situation is also duplicated in the Keg River platform where it is overlain by the productive Keg River pinnacle reefs in northwestern Alberta. The Keg River platform is almost certainly the source of the oil in these prolific reefs, and because of the similarities outlined above any reservoirs developed in the Hume must be considered as prospective.

HARE INDIAN

The contact of the Hare Indian with the underlying Hume is generally sharp and probably represents a sudden influx of mud into a clean well aerated sea. It appears to represent a mud bank deposit with the source area lying to the northeast, partially filling a large basin. The contact of the Hare Indian with the overlying Kee Scarp is somewhat diachronous, since it is generally placed at the point the section changes from predominant shale to predominant limestone. Facies changes thus account for the diachronous nature of the contact as well as having been the cause of some of the confusion which has surrounded Devonian correlations in this region. The section at Carcajou Ridge serves to illustrate this problem. Carcajou Ridge lies along the Mountain River west of Norman Wells. The section can be mapped as Kee Scarp Reef six to 70 feet thick, overlying 900 feet (plus) of Hume Formation with the intervening Hare Indian Shale going from zero (0) feet to 21 feet in thickness. The section should probably be mapped as containing much more Hare Indian, only as a limestone and shale facies and not strictly as a shale facies in this case. The Hare Indian generally consists of 500 feet to 700 feet of slightly calcareous, light greenish-grey to medium grey, bituminous (in part) shale with abundant micro fossils. However, due to the facies changes, as mentioned above, it can thin to less than 100 feet in a few miles.

The Hare Indian has been recognized as far north as Anderson River, is present at Fort Good Hope as a 700 foot thick interval, and is usually about 100 feet thick at Norman Wells. South of Norman Wells it is again represented by about 500 feet of shale around the confluence of the MacKenzie and Redstone Rivers. Worthy of note is the similarity between the Carcajou River section and the relationship between the Klua Shale and the adjacent reefs in the Clarke Lake area of northeastern British Columbia. Here the Klus Shale which is Middle Devonian, overlies the Keg River Formation in some areas while in others continuous reef growth from Keg River time through Slave Point has allowed no shale deposition

KEE SCARP

The Kee Scarp as redefined by Basset is a widely distributed formation. Ostracods have been used to establish the Kee Scarp as equivalent to the combined Sulphur Point-Slave Point carbonates of northern Alberta. The contact with the underlying Hare Indian shale, as previously noted, is diachronous. The Kee

Scarp in the Norman Wells area consists of a lower platform unit which is about 75 feet to 165 feet thick and lithologically is a bedded limestone with abundant fossils. The platform unit is usually devoid of hydrocarbons. Overlying the foundation unit is a biohernal reef which constitutes the reservoir for the Norman Wells Oil Field. The reef is composed of materials such as corallites, bryozoans and stromatoporoids set in a coral sand matrix. The facies varies widely between wells as would be expected in a true reef. The thickness of the Kee Scarp reef above the platform unit varies from zero (0) feet to 350 feet in the Norman Wells area. The greatest overall measured thickness of Kee Scarp in the area is 495 feet. The Kee Scarp is overlain by the Canol Formation, or, in its absence, the Fort Creek shales which Basset redefined as part of the Imperial Formation.

The oil in the Norman Wells Field is trapped in the updip end of a discrete Kee Scarp reef. The thickness of the reef ranges up to a total of 495 feet. Reserves in the reef have been estimated as high as 60,000,000 barrels while the productive area of the field is placed at 2,600 acres.

The platform unit of the Kee Scarp is undoubtedly the correlative of the Upper Ramparts limestone unit mapped by Hume. This fact, as mentioned above, means the Kee Scarp is a widespread unit. Since the Kee Scarp reef grows upwards from the platform unit any well drilled in this area and any acreage held, must be considered as possibly containing discrete Kee Scarp reefs. Maximum reef growth, regionally, has generally been found on the margins of Hare Indian thicks, however, the presence of them does not ensure Kee Scarp reefs. The margins of the two Hare Indian thicks, which were described under the discussion of that formation, have not yet been found to contain reefs; however, they have not been adequately explored either.

UPPER DEVONIAN

CANOL FORMATION

The Canol Formation was defined by Basset to include the black to very dark brown, non-calcareous, bituminous shales which overlie the Kee Scarp, or, in its absence, the Hare Indian Formation. The Canol is overlain by the Imperial Formation. The Canol may be the equivalent of the lower part of the Bear River shale of northeastern British Columbia. The Canol thickness ranges from zero (0) feet in the Norman Wells area. The thickness varies in relation to the underlying Kee Scarp reef much in the same manner that the Ireton thickness is related to Leduc reefs within the Province of Alberta, I.e. the Canol thins over the reefs to nil in places and thickens in the off-reef direction. The Canol Formation should be present under the Permits in question.

IMPERIAL FORMATION

The Imperial Formation was redefined by Basset to include all beds of Devonian Age overlying the Canol Formation and which are unconformably overlain by Cretaceous strata. He recommended that the term Fort Creek Formation be discontinued as the above definition of the Imperial includes the Fort Creek shales within it. The Imperial consists of a sequence of greenish-grey shales overlain by a series of fine sandstones, siltstones and thin limestone beds. The Imperial is capped at many places by a grey shale sequence. The Imperial is extremely variable in lithologies which makes correlations within it very difficult. The Imperial may reach a thickness of more than 3,000 feet where the processes of erosion have not cut very deeply.

CRETACEOUS

SANS SAULT GROUP

The Sans Sault Group is the basal group of Cretaceous sediments which lie directly above the disconformity separating Cretaceous and Devonian sediments. The top of the Group is usually placed at the base of the first bentonite bed in the overlying thick shale sequence. The sequence consists of shales and sandstones of marine origin. The thickness is about 1,411 feet at the Sans Sault section.

SLATER RIVER FORMATION

The Slater River which overlies the Sans Sault Group, consists of thin bedded, black, friable shales with abundant ironstone concretions. There are also some beds of white and yellow alum and sulphur. Sandstone is only occasionally present. There are many beds of bentonite, which in outcrop are 1/8" to 1" thick. The Slater River

Formation also contains a fish scale horizon which is thought to indicate an upper Cretaceous Age for the formation. This formation is about 1,000 feet thick at the type section.

LITTLE BEAR FORMATION

The type section of this formation is west of Fort Norman on the Little Bear River. The beds consist of sandstone, some conglomerates, sandy shales and coal seams. The beds are not correlatable between areas due to their lenticular nature. The beds are 780 feet thick at their type section and contain marine, brackish and fresh water fossils.

EAST FORK FORMATION

The East Fork Formation is made up of a series of well stratified, grey, conchoidal and plastic marine shales. There are some thin limy sandstone members and thin coal seams near the base. The thickness of this formation is 850 feet at its type locality on the

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The East Fork Formation is made up of a series of well stratified, grey, conchoidal and plastic marine shales. There are some thin limy sandstone members and thin coal seams near the base. The thickness of this formation is 850 feet at its type locality on the

East Fork of the Little Bear River.

The thickness of Cretaceous beds present underlying this Permit area is very difficult to ascertain. C.S. Lord noted coal deposits on Etacho Point which lies about 100 miles due north of the Permits on the west side of Great Bear Lake. The coal which is lignite, is contained in about 1-1/2 miles of outcrops. The outcrops usually contain several seams separated by a few feet of clay, sand, or silt. The width of one seam is from 12 feet to 17 1/2 feet and may be about 7,000 feet in length. The age of the coal is not given, but it may be part of the Little Bear Formation.

The unconformity which underlies the Cretaceous in this area has probably removed much of the Devonian Imperial Formation from the area covered by these Permits. Since subsurface and surface control is so sparce in this area, any prediction of the depth of this erosion is very difficult to make. North of Norman Wells this erosion has in places removed the entire Upper Devonian sequence, leaving the Middle Devonian Formation at subcrop.

TERTIARY

The Tertiary sediments in the Norman Wells area are not subdivided. They consist of conglomerates, gravels, shales, lignites, soft, coarse, carbonaceous sands and soft clays. The Tertiary is exposed south of the Permits under review in the Mt. St. Charles area long the Great Bear River. Plants collected from the exposures along the Great Bear River indicate an Eocene Age. The thickness is approximately 600 feet at these exposures. At exposures on the Little Bear River, 1,600 feet of Tertiary sediments have been mapped. Near the headwaters of the East Fork River beds up to 1,200 feet have been mapped with coal seams eight feet to ten feet thick. The sections mentioned form part of a basin which dips to the south-west in this area.

It is recommended that further evaluation of the Permits under review consist of gravity meter and/or airborne magnetometer surveys. They should be of great assistance in outlining the distribution of the Saline River salt and any salt structures associated with it. The present structure of the Pre-Cambrian Basement could probably be mapped by this method, also, as well as providing a better idea of the drilling depth to it.

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 fractures 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 ever 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 ar vergreen 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.

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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 bed-rock 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 (Photo-geophysics) 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 of error, it has been demonstrated in (plains) 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. 5072

The fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various area of the Permit. The Permit is located in the muskeg area south of Great Bear Lake, Northwest Territories and is many miles from the closest settlement.

The sedimentary section is probably about 5,500 feet 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, Silurian and Devonian sections.

Fractures as plotted on the mosaic show considerable variation in intensity. There are three 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 area is shown in green. The average length of the fractures is about 3,100 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 from southeast to northwest. Many 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. 5072 the statistical mean direction of the axial system is north 45 degrees west and the statistical mean direction of the shear system is north 35 degrees east. A third minc 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 the originate in the upper two-thirds of the sedimentary section. As no azimuth correction is necessary for this study. It has been demonstrated that the low in-

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. 5072 the statistical mean direction of the axial system is north 45 degrees west and the statistical mean direction of the shear system is north 35 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 the originate in the upper two-thirds of the sedimentary section. As 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.5072 is located on the interior plain of the Northwest Territories about 60 miles to the west of the edge of the Pre-Cambrian Shield. The strike of the sedimentary rocks is about north 30 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.

(1) PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permit No.5072 is though to be much the same as it is today 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 gentle folding present over Basement hills These folds are anticlines in every sence 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. DEONVIAN REEFS

Devonian reefs strongly affect the fracture pattern and control the occurrence of gas and oil in the overlying beds. Devonian reefs are present 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. TOPOGRAPHY 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 three areas 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 area of Permit No. 5072.

These Basement high features are most interesting from the oil and gas point of view. The general shape of this feature is such that the causative features must be a hill on the Basement surface. A fault is unlikely as the causative features as the high areas are 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 present around the flanks of the top.

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

Respectfully submitted by:

RAYALTA PETROLEUMS LTD.

William G. Cook

WGC/jp

REFERENCES

BLANCHET, P.H (1957)

"Development of Fracture Analysis as Exploration Method", Amer Assoc. Petrol Geol. Bull., Vol. 41, No. 8, 1748-1759

HAMAN, P.J. (1964)

"Geomechanics Applied to Fracture Analysis on Aerial Photographs", West Canadian Research Publications, Series 2, No. 2

LAUDON, L R (1950)

Imperial River Section MacKenzie Mountains, Northwest Territories, Canada Bull., Amer. Assoc Petrol Geol, Vol 34, No 7, pp. 1565-1577

WILLIAMS, M.Y (1923)

Exploration East of MacKenzie River between Simpson and Wrigley; Geol Surv Canada, Sum. Rept 1921, pt B, pp 56 - 66 (1922)

HUME, G.S. (1953)

The Lower MacKenzie River Area, Northwest Territories and Yukon, Geol Surv Canada, Memoir 273

KEELE, Joseph (1936)

A Reconnaissance across MacKenzie Mountains on the Pelly, Ross and Gravel River; Geol. Surv. Canada, Pub. 1097, 1910

Formation Names in the MacKenzie River Valley; Science, Vol 83, No. 2140, pp 14-15.

NAUSS, A W.

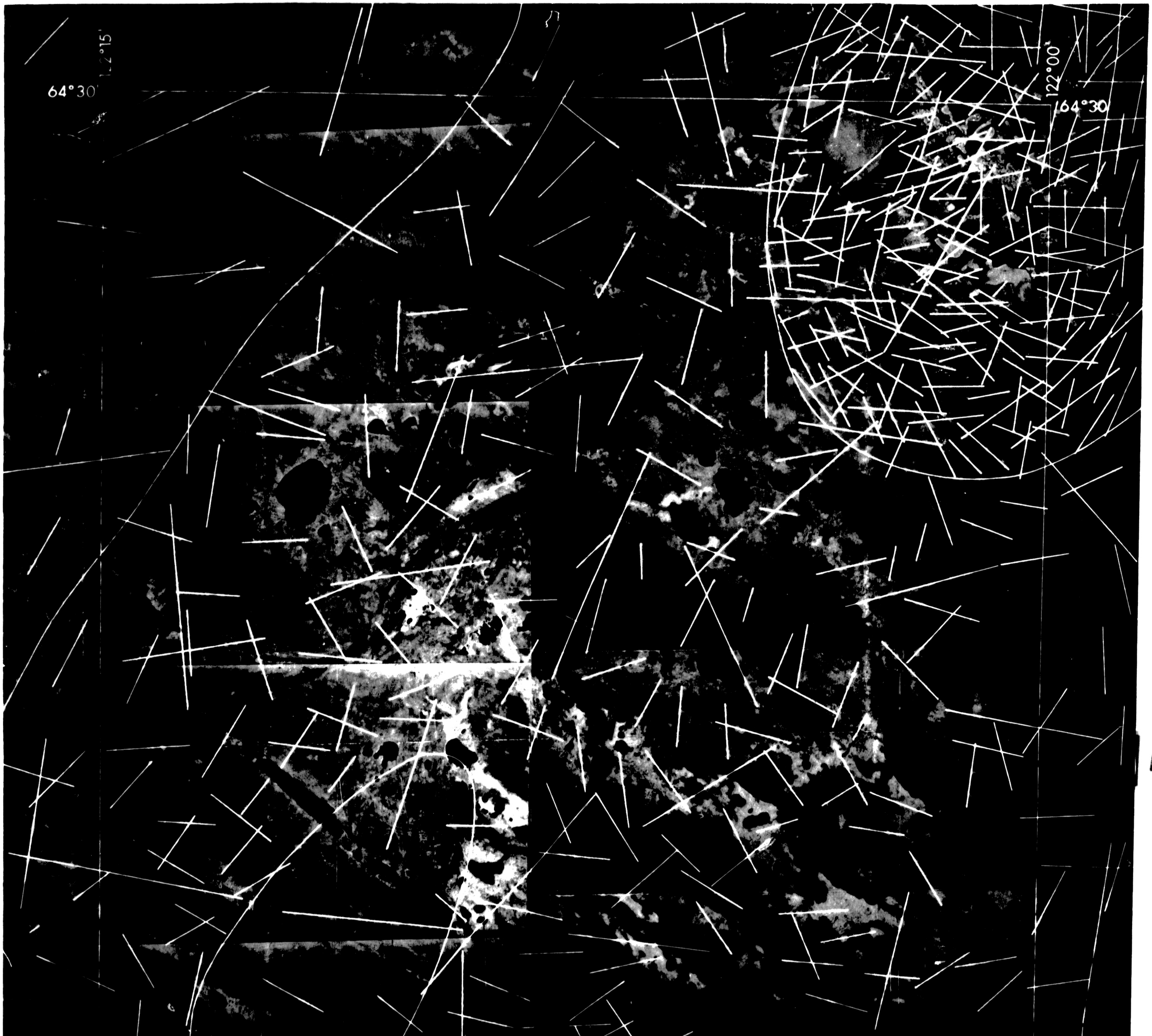
Upper Carcajou - Imperial River Canol Reports Lower MacKenzie River, Canol Reports.

STELCK, C.R

Upper Peel River Canol Reports, Schooner Creek Canol Reports, Carcajou and Little Bear River Divide Area Canol Reports, Bear Rock and Bluefish Creek Canol Reports.

MARTIN, L J. (1959)

Stratigraphy and Depositional Tectonics of North Yukon - Lower MacKenzie Area, Canada, Bull Amer Assoc. Petrol. Geol., Vol, 43, No 10, pp 2399 - 2455



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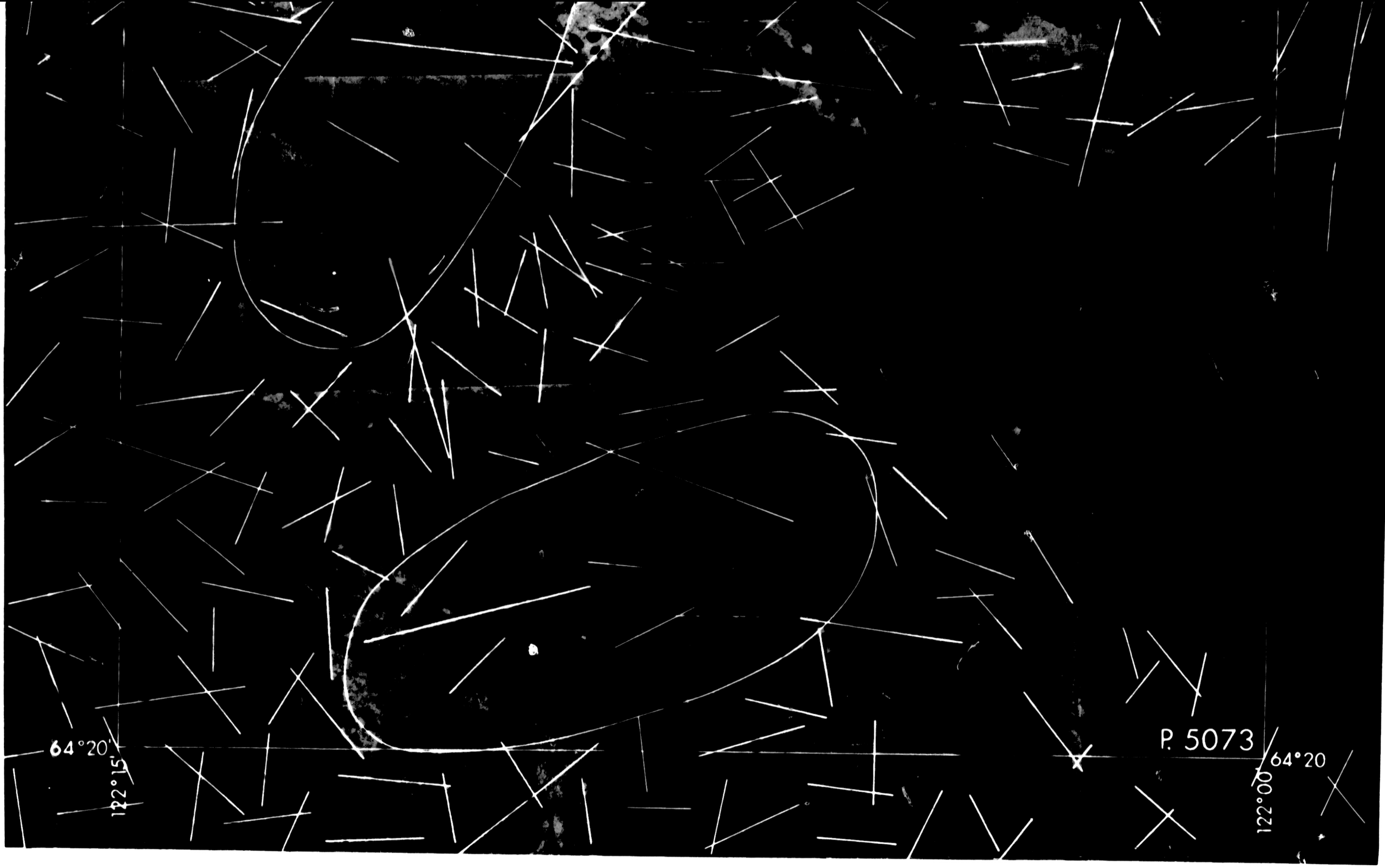

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SCALE IN MILES

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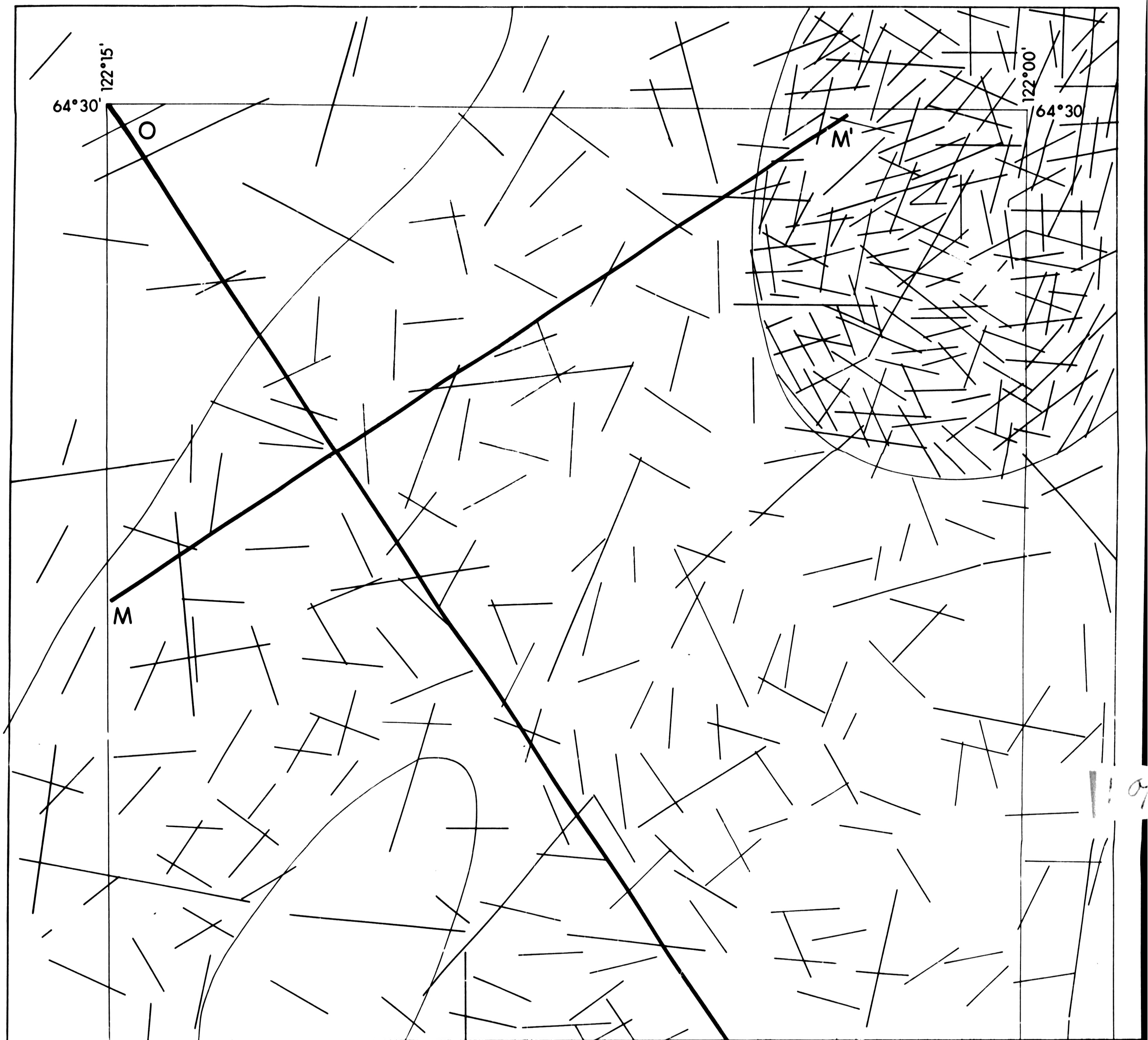
THIS IS AN UNCONTROLLED MOSAIC AND SHOULD NOT BE TAKEN AS AN ACCURATE TOPOGRAPHIC MAP



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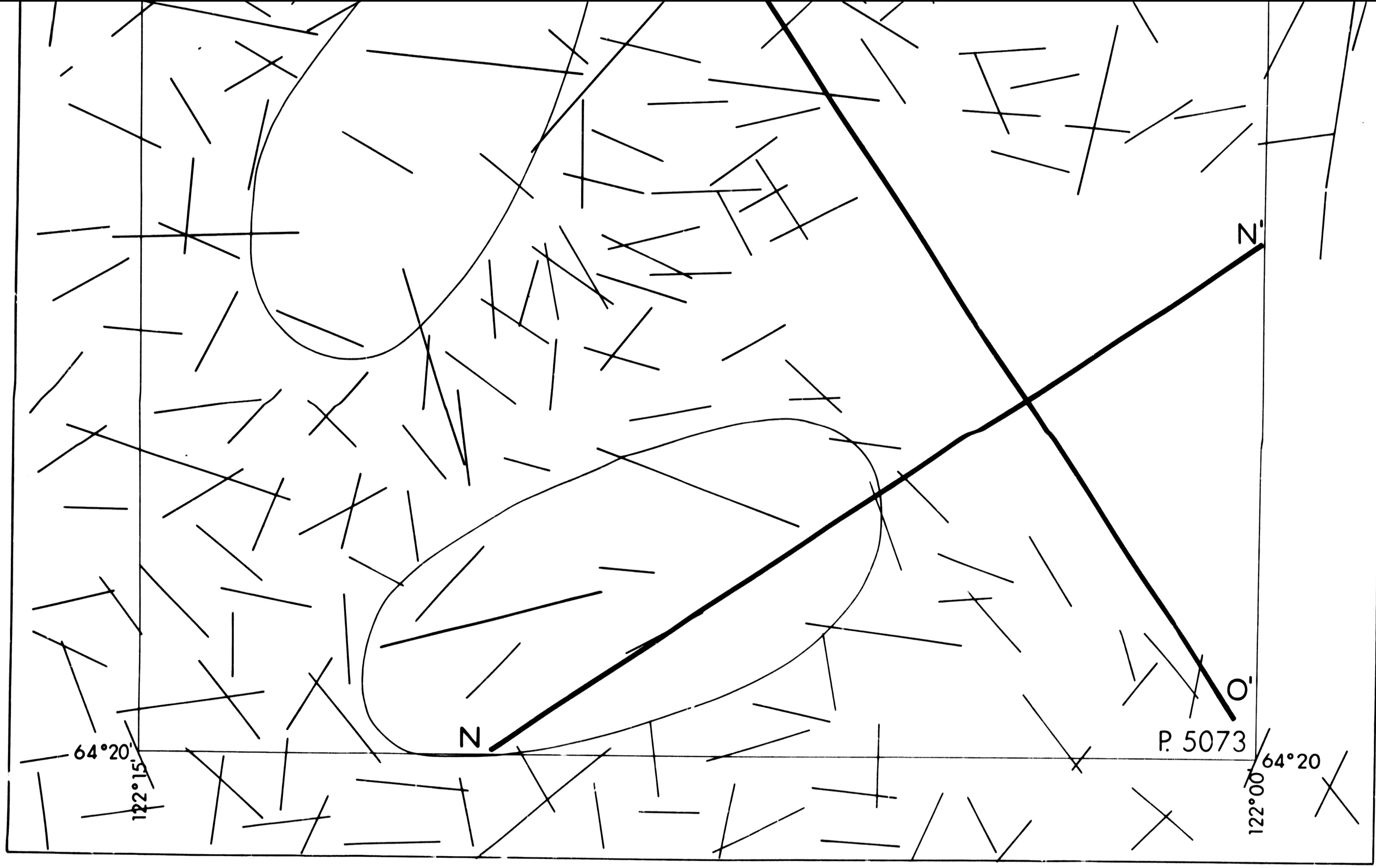

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TOTAL FRACTURE PATTERN

SCALE IN MILES

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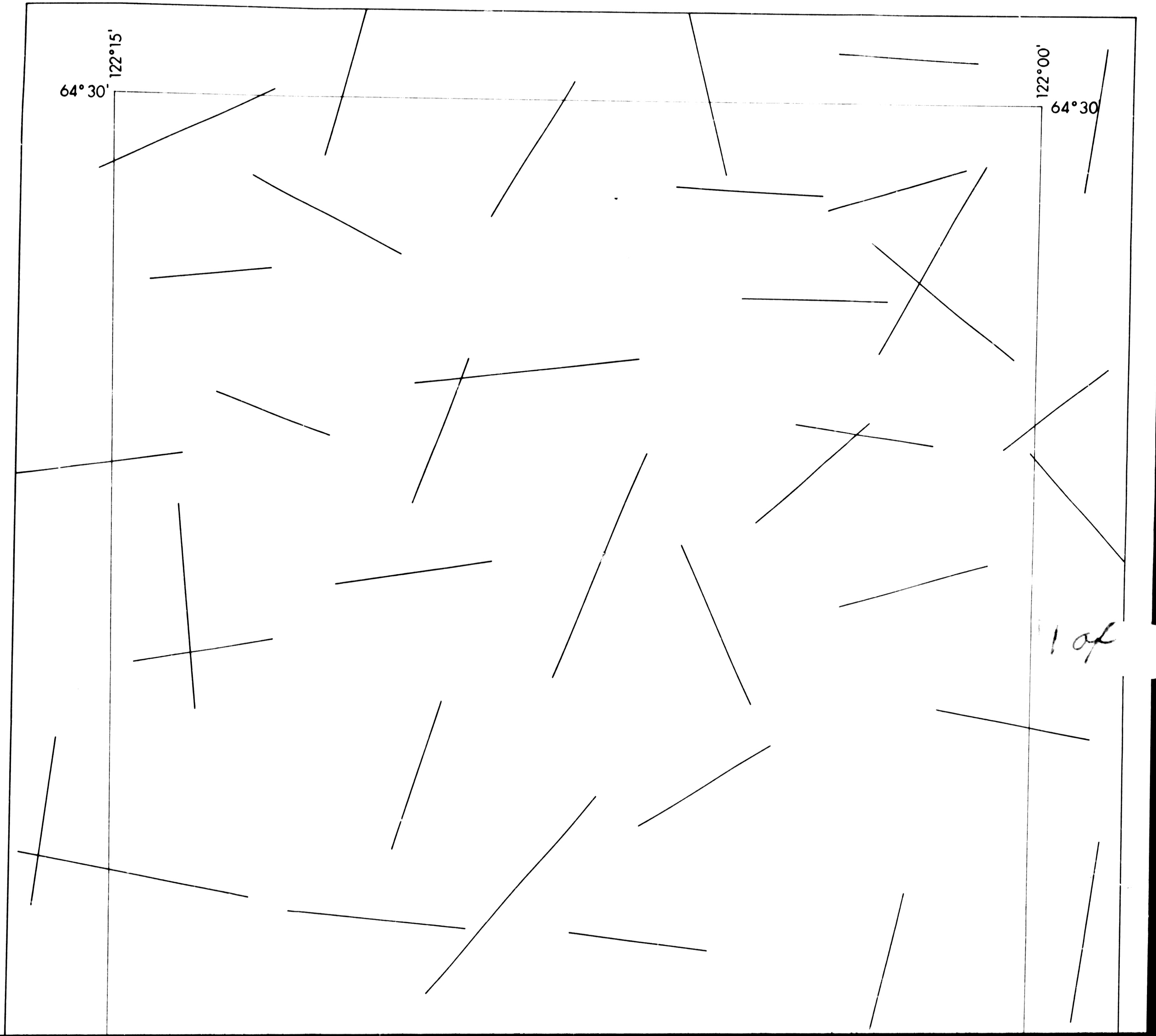
LOW DENSITY

NORMAL DENSITY

HIGH DENSITY



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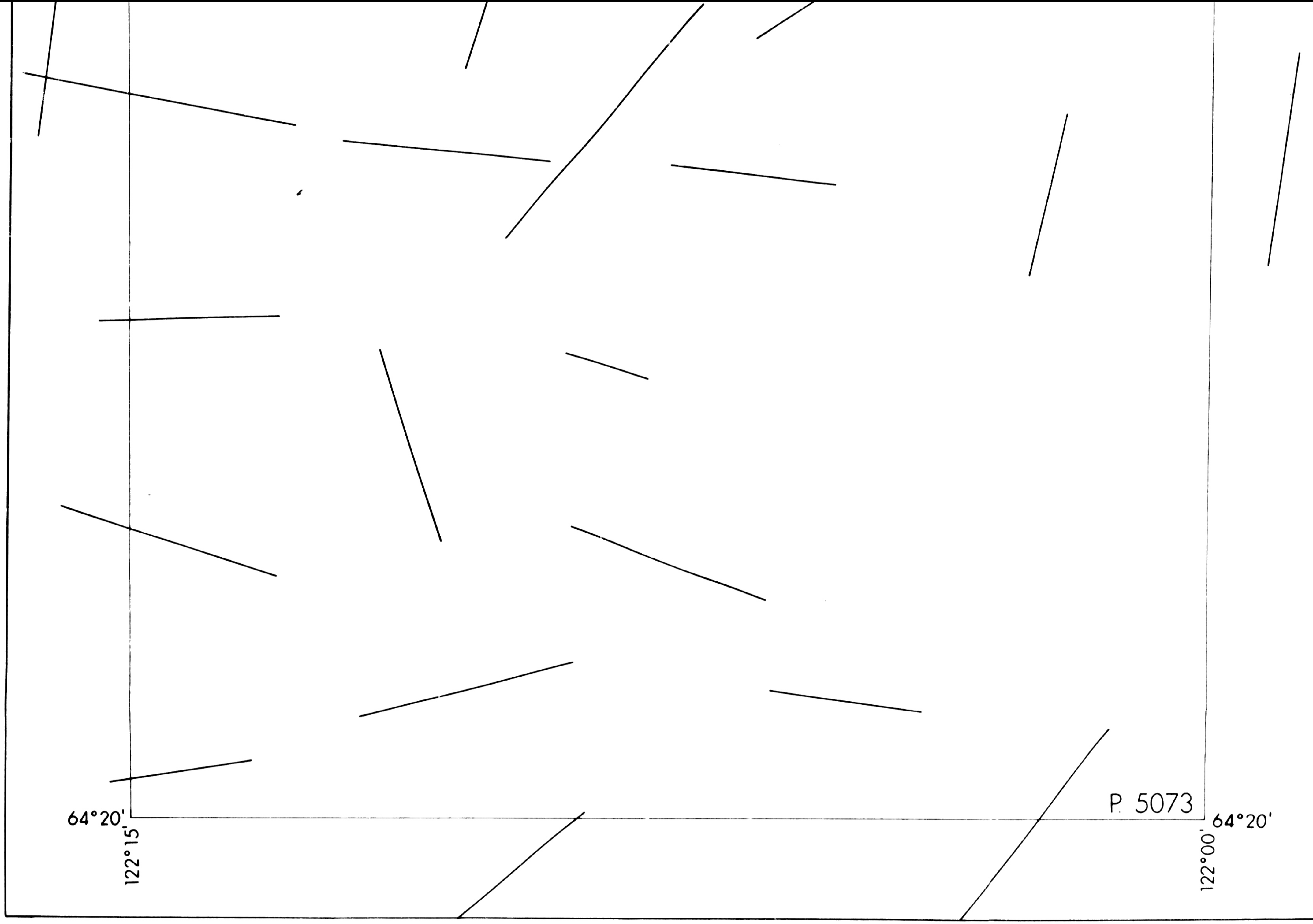

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MEGA FRACTURE PATTERN

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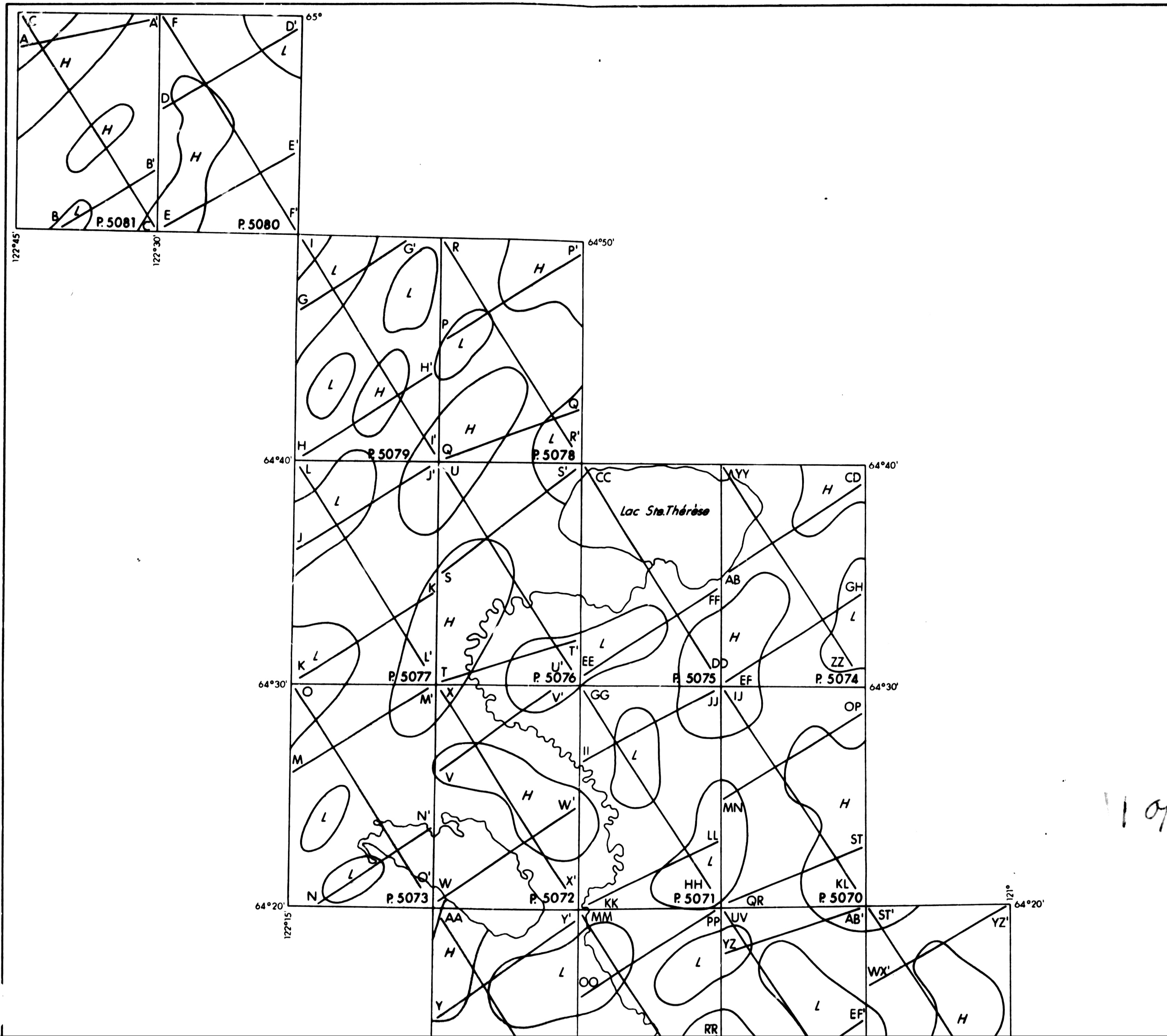
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Lac Ste.Thérèse

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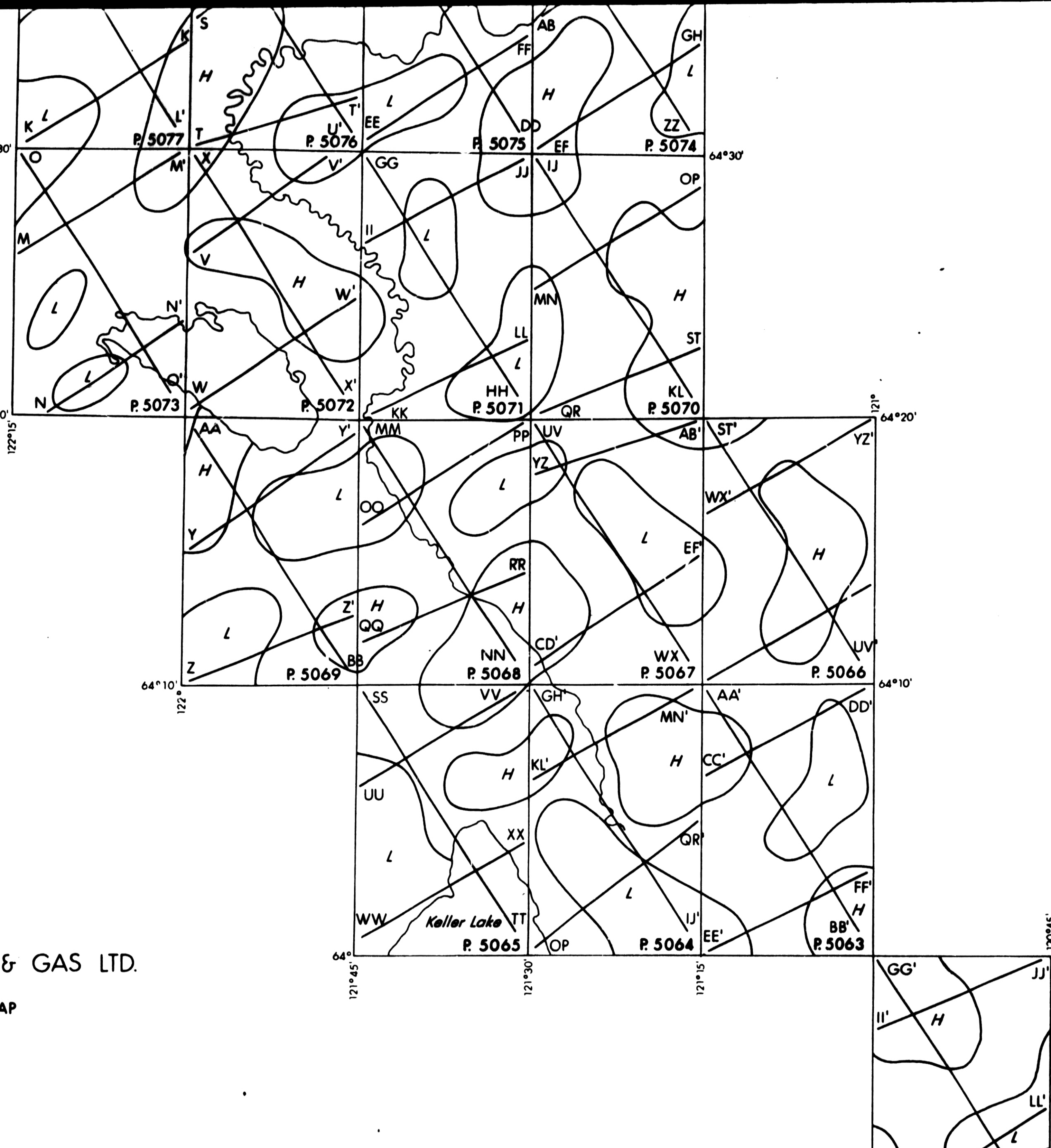

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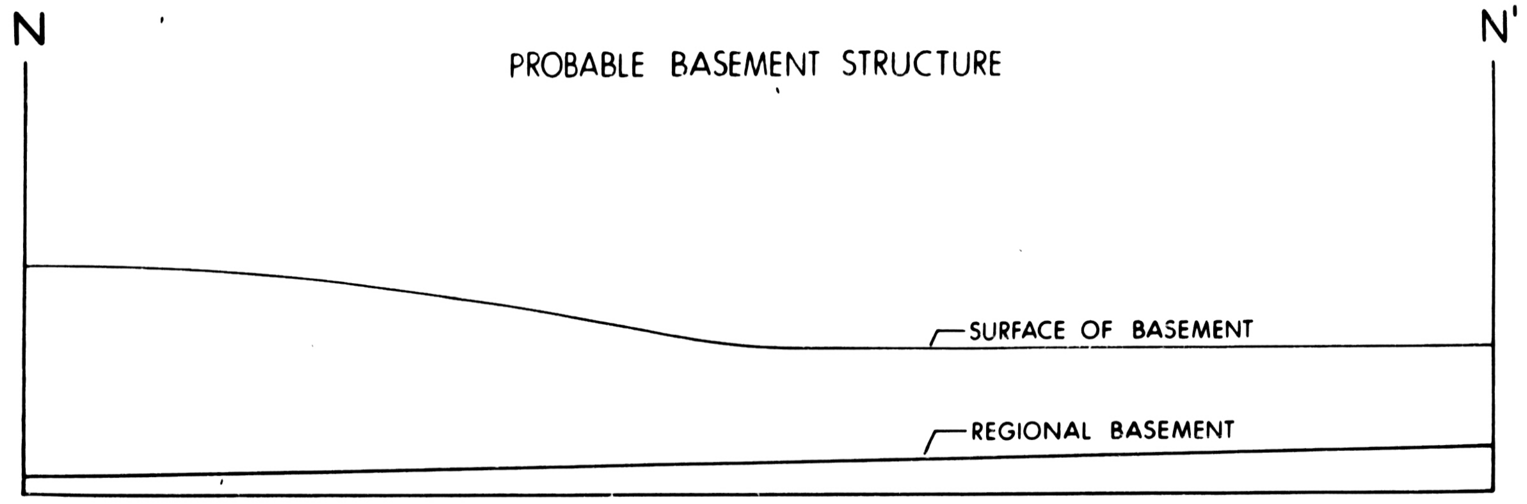
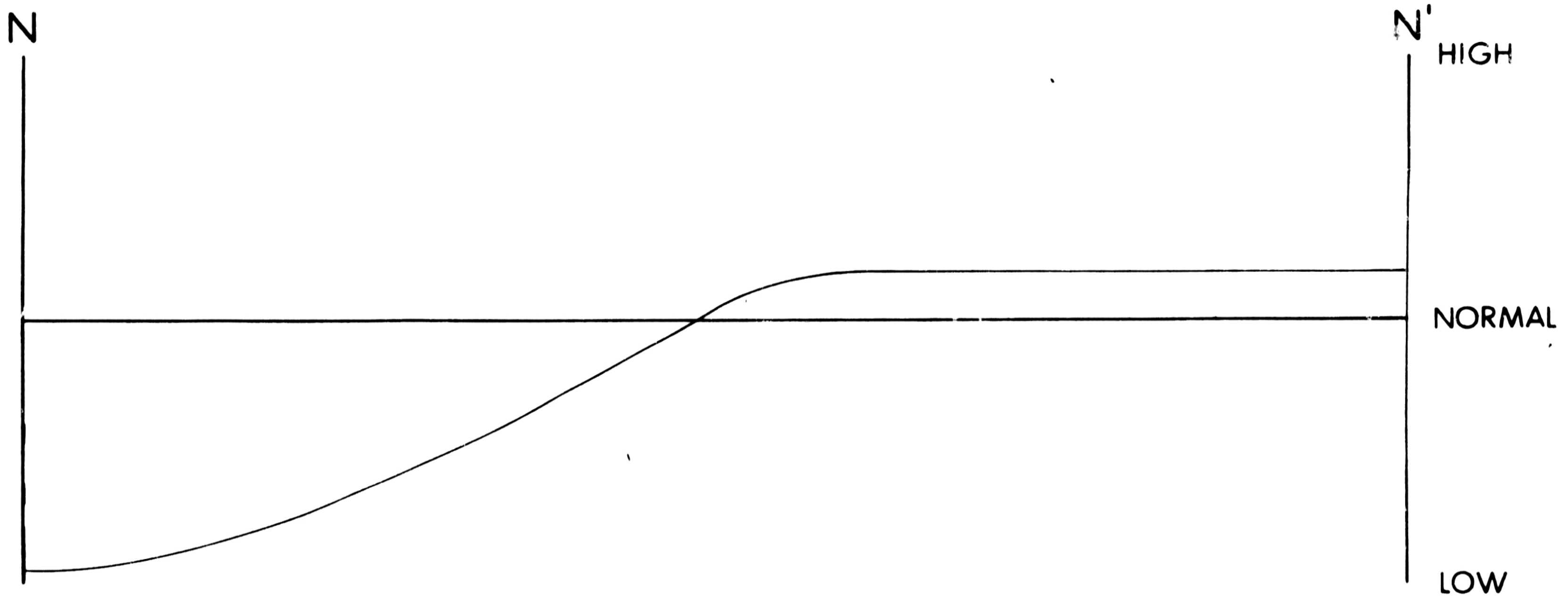
INDEX MAP

2 of 2





FRACTURE INTENSITY CROSS SECTION

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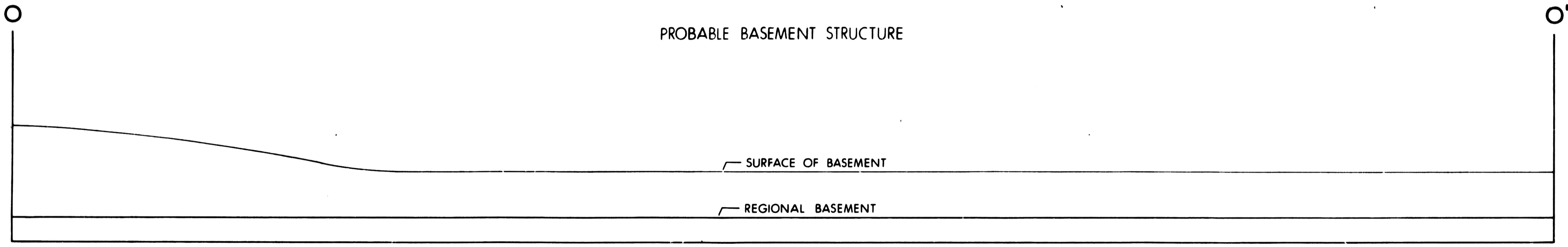

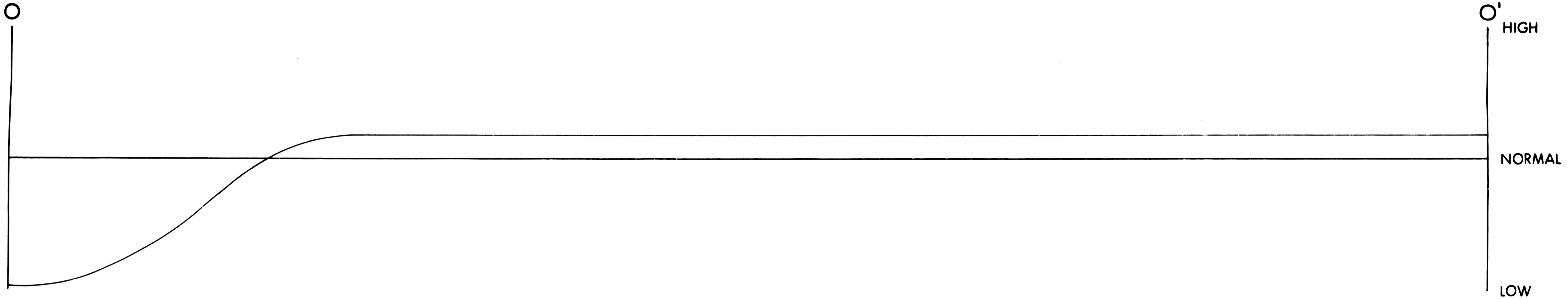

FRACTURE INTENSITY CROSS SECTION

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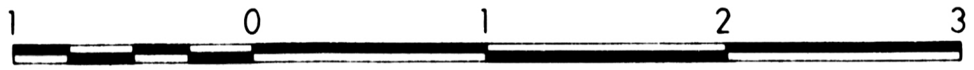

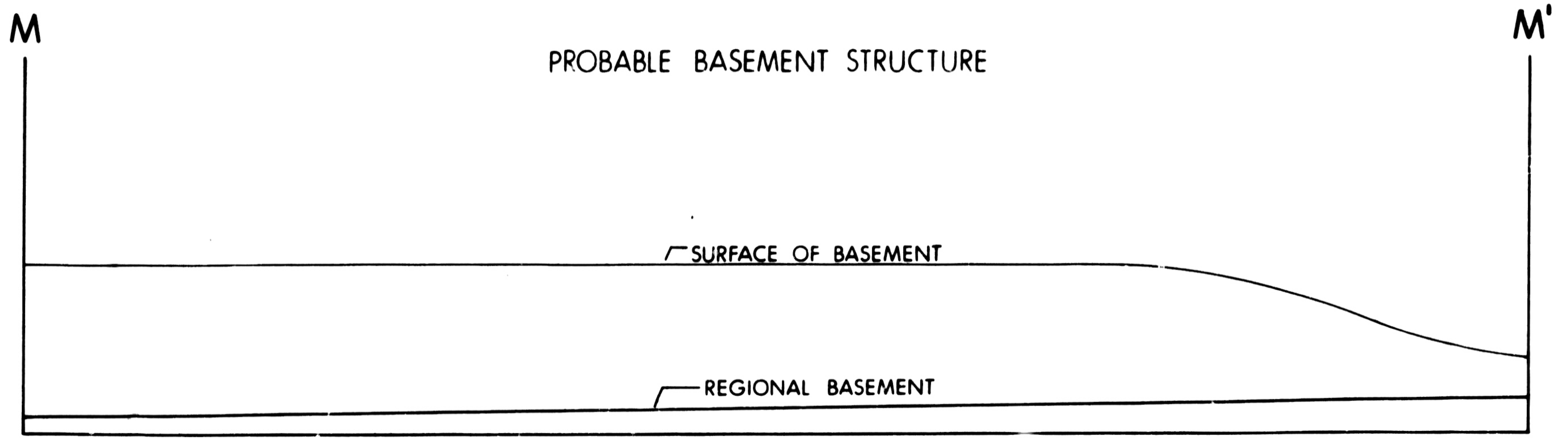

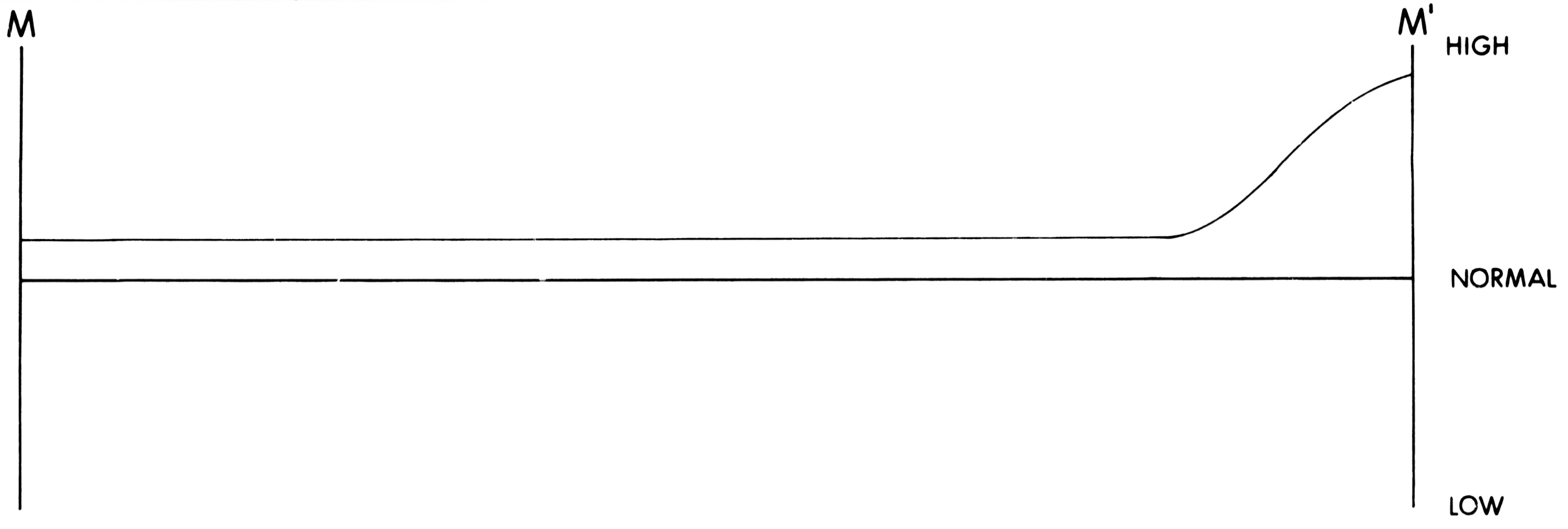

FRACTURE INTENSITY CROSS SECTION

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