GENERAL GEOLOGY, GEOMORPHOLOGY

AND

FRACTURE ANALYSIS SURVEY

OF

P. & N. G. PERMITS 5301 and 5302
LAC BELOT AREA, N.W.T.

FOR

PARIS INVESTMENTS LIMITED

BY

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INDEX

GEOMORPHOLOGY

The Permit Numbers 5301 and 5302 lie on the interior plains area of the Northwest Territories about 60 miles southwest of the edge of the PreCambrian Shield. The area was completely glaciated during Wisconsin time as is shown by the abundance of glacial landforms and by modification of the bedrock surface. These glacial features are not so dominant as to obliterate all other surface forms and features and much non-glacial geological information can be had from the mosaic. The direction of ice movement was obviously northwest southeast.

The drainage pattern is not well defined in this area but, in general, the drainage is to the west towards the Hare Indian River. Within the mosaic the south area drainage is all internal towards Tunago Lake and the lake itself does not have any drainage. The northeast part is drained by the Hare Indian River. Many of these small streams are intermittant and hold water only during the spring. The general drainage pattern is dendritic but it has been greatly altered by the glacial affects and the many lakes. It does not appear to be controlled by any subsurface feature.

There are no topographic forms present which indicate any geological feature.

GLACIAL FEATURES

The surface of the area has been modified on a very large scale by the passage of the glaciers and their subsequent melting. The bedrock itself, however, probably did not exert any influence on the ice flow pattern or the direction and pattern flow of the meltwater streams. There is a possibility that the strong lineations were present before glaciation and that the glacial flow simply took the line of least resistance and followed pre-existing lineations. This net effect would be an accentuation of the pre-glacial trends.

Small moraine belts are present throughout nearly all of the mosaic area. Nearly all of these are maturely dissected but the typical knob and kettle topography remains. The kettle lakes are very small compared to other lakes in the area often the small depressions contain no water at all. The knob hills are usually low and well rounded. The moraines are not as large or as conspicuous as those in the Province of Alberta.

Scattered throughout the moraine are countless drumlinoid forms. These are formed near the edge of the moving glacial ice and are parallel to the direction of movement of the ice. They are usually less than 50 feet high and several hundred feet in length. True drumlins are a distinct, easily recognised shape, but in this area post glacial erosion has obliterated most of these features and no "drumlin fields" are present.

Drumlins are almost always composed of glacial till material and in their uneroded state are good indicators of the direction of ice flow. Many are present in the northeast corner of the mosaic.

Transverse ridge is the term applied to all drift ridges formed at right angles to the direction of ice flow. Many of these features are present throughout the two permits and good examples can be seen in the area east of Tunago Lake. They are characterized by being short in length and are seldom more than a few tens of feet in height. These features often occur as small ridges in drumlin-fields and are at right angles to the long axis of the drumlins. On aerial photographs the transverse ridges give the terrain a cross-hatched appearance.

Ice block ridges are usually seen in glaciated areas but none can be seen on this mosaic. If they were once present they have been removed by erosion. Typically they are small ridges which surround or nearly surround irregularly shaped depressions. These ridges were formed in cracks between ice blocks into which ablation material was sloughed as the individual ice blocks melted.

Perhaps the most striking glacial feature anywhere is the esker. These are long sinuous ridges of gravel and till laid down by sub-glacial drainage streams. Some can be traced for astonishing distances - over 200 miles on the Canadian Shield.

They roughly parallel the direction of the ice flow. Within the mosaic area several short eskers can be identified but post glacial erosion seems to have removed most evidence of their existence. Esker streams often erode channels through the bedrock where the bedrock forms a slight high between two low areas.

STRATIGRAPHY

Permits 5301 and 5302 which are covered in some part by Tunago Lake and other lakes are geographically located on the interior plains about 15 miles northwest of Great Bear Lake and 150 miles west of the PreCambrian Shield. They are also 50 to 60 miles due north of the Franklin Mountains and can therefore be expected to be underlain by homoclinal to gently folded sediments. The sedimentary sequence ranges in age from early Cambrian to upper Devonian which is in turn overlain by a thin veneer of Cretaceous and Tertiary sediments. Regional isopachs indicate a sedimentary thickness of about 6,500 feet should be present in this area. Well control in this area is very sparce, the nearest being at Rond Lake, where Western Decalta drilled five shallow tests in 1960. These tests are located approximately 80 miles northwest of the area under discussion.

CAMBRIAN AND OR OLDER

KATHERINE GROUP

The earliest Paleozoic sediments encountered in this area consist of a series of interbedded quartzites and black plately shales. The quartzites are generally pink, white, buff and rusty with interbedded black, bituminous plately shales and occasional chocolate brown and green shales. The thickness of this group is undetermined for this area, however, the top usually placed at the base of a succession of chocolate brown shales. Reservoir beds have not been noted in this succession but the possibility of shoreline sands and off shore sand bars should be noted.

MACDOUGAL GROUP

In the Norman Wells area the Macdougal group was described by Nauss (3) from Macdougal Creek exposures as 997 feet of interbedded limestones, chocolate colored, black petroliferous, red and green shales, reddish colored gypsum and sandstones. At Imperial River, about 70 miles to the northwest, Laudon (4) has described a succession of beds 1,839 feet thick, consisting again of interbedded limestones, gypsum, vari-colored shales, and sandstones, however, at the top of this sequence he has described a 146 foot unit of "green, black, tan and grey shales carrying in part much gypsum and some algal limestone layers". At Norman Wells a salt layer 2,000 feet thick is named, the Saline River Formation and is correlated with the Macdougal group. Northwest of Norman Wells the presence of salt is deduced from the following evidence:

1. Overlying Ronning carbonates are brecciated at exposures in the northern Richardson Mountains west of Inuvik suggesting salt solution collapse.

2. The west margin of the Cambrian salt is known in the Norman Wells area and a postulated extension of this margin can

be made to the northwest and south of Norman Wells.

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

4. 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. The Saline River salt may reasonably be expected to extend under Permits 5301 and 5302 with the eastern margin lying some unknown distance towards the PreCambrian Shield. The solution of these salts sets up the possibility of salt structures in the overlying carbonate banks similar to these found to be productive in southeast Saskatchewan and at Rainbow Lake in northwest Alberta. The algal limestone described by Laudon (4) at Imperial River indicated some organic activity in the Cambrian Seas and coupled with underlying

salt features could give rise to patch reefs throughout the area. The sandstones described in outcrop coupled with the petroliferous shales may give rise to hydrocarbon bearing reservoirs within this sequence, however, it is difficult to imagine them being found in the same locale as the Saline River Formation.

ORDOVICIAN - SILURIAN

As has been noted by Hume (5), Ordovician rocks have not been definitely recognized in this area although a number of authors have suggested beds of this age are present in the Norman Wells area. Some 200 miles to the west of the subject permits, outcrops of shales and argillites 1,500 feet thick have been mapped by Stelck (6). Approximately 200 miles south-southwest at the junction of the Recle and Twitya Rivers confluence Keele (7) noted that 4,000 feet of alternating beds of argillite, dolomite and limestone are overlain by about 1,500 feet of sandstone lying on a diabase sill 100 feet thick. Some 35 miles to the east he describes this sandstone as being about 4,500 feet thick with only occasional shale partings. The sandstones described by Keele are not expected to occur in this area. The sections described by Stelck and Keele coupled with sparce subsurface control help establish a regional sedimentary sequence which finds the permits being discussed underlain by clean, finely crystalline shelf carbonates with variable porosity. The shelf carbonates are present over most of the Interior Plains, and Franklin Mountains. On the Peel Plateau and along the MacKenzie Mountains, they are bordered by shelf edge carbonates which are reefal in part. The shelf edge carbonates are in turn replaced by the basinal shales and argillites described by Stelck.

Silurian strata are more widely distributed throughout this area than rocks of Ordovician age, however, the sedimentary pattern established in the Ordovician continued on throughout most of Silurian time. Due to the lithological similarities between the Ordovician and Silurian they have, for practical purpose, been lumped together and named the Ronning Group. West of the Permits they have been found in outcrop along the Hare Indian River in a number of places, the nearest lying some 30 miles from the Permits under discussion. They have been mapped as 750 feet of limestones with neither the top nor the bottom of these beds being observed, however, the Bear Rock Formation of brecciated limestones and gypsum was found overlying them. The Ronning in the Norman Wells area generally can be divided into two units. The lower unit, which has been named the Franklin Mountain Formation, generally consists of limestones and dolomites with abundant irregular chert nodules. The upper unit, named the Mount Kindle Formation, generally consists of a sequence of chert poor limestones and dolomites which tend to thin out in a southerly and easterly direction. The Franklin Mountain Formation in the vicinity of Permits 5301 and 5302 will probably be found to consist of about 1,000 feet of clean, finely crystalline shelf carbonates with abundant chert inclusions and have variable porosity. North of Norman Wells the lower part of the Mount Kindle Formation has been mapped in outcrop as a 100 foot thick sequence of massive, crystalline, porous limestone containing a coralline, fauna. Coupling this outcrop section with the regional thickening of the Mount Kindle in a northerly and westerly direction from Norman Wells, a series of porous carbonate banks or low relief transgressive reef fronts may be postulated. Permits 5301 and 5302 are well located with respect to this type of facies. Regionally the Mount Kindle should be about 500 feet in thickness over the permit area.

The Upper Ronning has been found to have oil stained porous dolomites in wells drilled at Norman Wells, thus proving that the formation cannot be overlooked as a potential hydrocarbon bearing reservoir in any wells drilled in the MacKenzie district. The variety of trapping conditions which may be expected to occur in the vicinity of the subject permits are as follows:

(a) The marked disconformity separating the Ronning Group from the overlying Bear Rock formation may be expected to give rise to erosional features, such as Scarps and Monodnocks, which, when sealed by the overlying gypsum and/or anhydrite of the Bear Rock would constitute an effective trap.

(b) Reef fronts and/or porous carbonate bank facies, as outlined above, may be capped by the Bear Rock Evaporites and change facies laterally into tight carbonates of Ronning age.

(c) Selective Solution of the underlying Cambrian Saline River salt may give rise to one or two stage solution structures such as are found to be productive in the Hummingbird area of southeast Saskatchewan. Partial solution of this salt prior to, or during, Mount Kindle sedimentation would have served to give rise to local elevations on sea bottom where the salt was not removed, thus providing, the loci for reef and/or porous carbonate banks. Traps of the Hummingbird type would involve early local solution of salt, say in late Cambrian or early Ronning time. The depressions created would receive increased sedimentation over that being deposited where the salt was not removed. Once sedimentation within the depression caught up, subsequent sediments would be deposited on a normal sea bottom. The trap would then be created by solution of the remaining salt at some time subsequent to Mount Kindle deposition, which would leave the Mount Kindle reservoirs overlying the site of original salt solution, structurally high and hopefully sealed by overlying Bear Rock Evaporites. Evidence for two stage salt removal is found in the nature of the brecciated sediments in lower Ronning and Bear Rock sediments in the outcrop sections.

(d) Anticlinal structures have probably been formed by some of the numerous periods of structural activity which have occured in this area.

MIDDLE DEVONIAN

BEAR ROCK FORMATION

The type section of the Bear Rock Formation is at Bear Rock, Fort Norman, where it has been mapped with two distinct facies. The lower 40 to 60 feet consists of non-bedded gypsiferous, massive dolomite or limestone which is overlain by 30 feet of dark grey, poorly bedded limestone or dolomite. This is in turn overlain by 175 feet of breccia of brown dolomitic limestone boulders set in a matrix of dolomitic limestone. The contact with the overlying Ramparts Formation is gradational and consists of 10 feet of bedded limestone and dolomite breccia. Regionally, the Bear Rock undergoes a facies change from shelf carbonates to evaporitic sequence. In the Peel Plateau Basin the Bear Rock Formation which is of early and middle Devonian age, consists of some 2,000 feet of micritic pellet and micritic skeletal limestone with intervals of finely crystalline, porous dolomite in the lower portion. In the vicinity of Norman Wells a facies change to evaporites takes place. The evaporite sequence extends southwestwards into Alberta where it is known as the Chinchaga Formation. A strong depositional feature called Camsell Basin occurs to the south of Norman Wells. Thickening from 2,000 to more than 5,000 feet accompanied by a facies change from evaporites through shelf carbonates to basinal sediments, takes place into this basin. In this area the shelf carbonates are cryptocrystalline to microcrystalline dolomite. The shelf edge facies is reefal and some of it, at least, is porous.

The shelf carbonate facies of the Peel Plateau basin extends northeastwards to the outcrop belt. The line marking the beginning of the facies change from shelf carbonates to evaporites passes just to the west of Permits 5301 and 5302. As was noted by Hume (5), the Bear Rock has been found to be very porous in some wells drilled in this area while in others the original pore space has been infilled by anhydrite and gypsum. In places it has been found to contain considerable bitumin. 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 Bear Rock top. 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 again being recovered. Since Rond Lake #1 was located down dip to the #2 well and recovered oil cut water near the base of the Bear Rock, while #2 only recovered sulphurous water from the top of the Bear Rock, it seems likely that the wells have tested separate reservoirs with the separation being provided by facies change. Permits 5301 and 5302 lie 50 miles east of these wells where the Bear Rock should have become more evaporitic. This fact, coupled with moving in an updip direction, could provide the necessary conditions for trapping oil within the Bear Rock sediments. Hydrocarbon traps within the Bear Rock would likely be provided by any of the various structural conditions outlined in the preceding discussion of the Ronning Group. The Bear Rock is seen in outcrop along the Hare Indian River, which lies west of Permits 5301 and 5302. As was noted in the discussion of the Ronning Group the nearest exposure to the acreage in question lies 20 miles west, where neither top nor bottom of the section is exposed. The section exposed consists of typical brecciated limestone and gypsum.

The brecciated nature of the Bear Rock was previously mentioned as possibly being a product of the removal of underlying Cambrian Saline River salt. A more conventional theory of the origin of the breccia is that it is a product of the sharp disconformity separating the Ronning Group and the overlying Bear Rock. This is no doubt true for the basal portion of the Bear Rock formation, however, the section exposed on Mount Charles, which is 34 miles east of Fort Norman, may be considered as support for removal of underlying salt during Bear Rock deposition. The section is described by Williams (8), 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 into the Bear Rock section, the great thickness of sediments mapped as Bear Rock is anomalous and suggestive of greater subsidence during deposition than is found in the adjacent areas. The section at Norman Wells varies between 200 and 500 feet in thickness. It is possible, of course, that in addition to the thrust fault which formed Mount Charles, other thrusts have repeated the Bear Rock and have not been recognized by workers in the area; however, this does not seem likely. Evidence of the rapid facies changes taking place within the Bear Rock is found when the Mount Charles section, (in which no evaporites are described) is compared to an exposure 3 miles farther north. Here, the chert beds of the underlying Mount Kindle formation are overlain by 500 feet of gray gypsum beds which is in turn overlain by limestone beds that are mapped as part of the overlying Ramparts formation.

RAMPARTS FORMATION

Hume (5) referred to all definite Middle Devonian beds in the Norman Wells area, as well as surrounding areas, as the Ramparts Formation. He divided the Ramparts into three members, a lower Ramparts limestone member, and a middle Ramparts shale member, and an upper Ramparts limestone member. The lower limestone is relatively thin in the Norman Wells area, however, it thickens in a northwest direction about 60 miles west-northwest of Norman Wells in the Imperial Range, or 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 at this section consists of 700 feet of grey to green shales and limey shales with many thin limestone beds which are commonly coquinoid in the lower part. The upper Ramparts limestone member at this section is 180 feet thick and is mapped as limestone, black to grey-brown, massive, grading to shale at the base. It is also petroliferous. The upper portion consists of limestone; grey to dark grey, massive and with thin black shale partings. Numerous other exposures of Ramparts are described in the literature dealing with the area. Regionally the shale content of the Ramparts increases in a northerly and westerly direction. The section at Schooner Creek, 4 miles north of Norman Wells was mapped by Stelck (6) as 8.5 feet of lower Ramparts, 231 feet of middle Ramparts shale member and 102 feet of upper Ramparts limestone member. Further north and for many miles down stream along the MacKenzie River the Middle Devonian sections are dominantly shale. North of the MacKenzie River, shales alone are present along the Anderson River. These shales continue for more than 50 miles downstream. South of Norman Wells the three-fold division of the Ramparts formation is not very easily applied as the carbonate members develop at the expense of the Middle shale member. The Ramparts formation under present usage is called the Hume formation. The Hume Formation equates with the Lower portion of the Keg River Formation of northwestern Alberta. This correlation is based on ostracod zones within the Lower Keg River and Hume formations. One is tempted to note the similarity between the petroliferous nature of the Hume in the Norman Wells area and petroliferous nature of the Keg River platform underlying the productive reefs at Rainbow Lake and North Zama. The Hume appears to generally be encountered as a non-porous rock both in outcrop and in subsurface. This is also generally true of the Keg River platform, with the exception being found along the flanks of the Peace River Arch where it is found in a marginal shoal facies. Here it is a very porous granular, reefy dolomite and has yielded large quantities of water when tested. The possibility that such a sequence may be found in the area between Norman Wells and the PreCambrian Shield should not be discounted; however, it should be borne in mind that the marginal shoal may have been removed by one of the many periods of erosion that have occured in this area. The Ramparts or Hume was observed in outcrop, south of Permit 5301 and 5302 along the Hare Indian River which indicates that the formation is present on the permits in question. Approximately 300 feet of Hume was encountered in the wells drilled by Western Decalta at Rond Lake, some 80 miles northwest of the permits under discussion. Drilling depth to the Hume of course varied with the topography but was generally around 500 feet. No tests were conducted of this formation by Western Decalta at these wells.

HARE INDIAN-KEESCARP

The Hume, over large areas, is overlain by a shale sequence of relatively uniform thickness. The thickness varies generally between 500 and 700 feet, however, it thins rapidly from this thickness to less than 100 feet in the space of a few miles. In some outcrop sections. this shale sequence, which is termed the Hare Indian Formation, has been found to be absent with the overlying Kee Scarp Reef lying directly on the underlying Hume Formation. One such location is found at the Carcajou Ridge section which is exposed along the Mountain River west of Norman Wells. Here, the reef, which is from 6 feet to 70 feet thick, overlies 900 feet (plus) of Hume Formation. At this section the Hare Indian shale is observed to go from 21 feet to zero (0) feet in thickness. This situation is similar to that found in the Clarke Lake area of northeast British Columbia where the Klua shale, of Middle Devonian age, overlies the Keg River Formation in some areas, but in others continuous reef growth from Keg River through to and including the Slave Point has allowed no shale deposition. The Hare Indian Formation is believed to be a mud bank deposit, with the source area lying to the northeast, partially filling a large basin. The Hare Indian thins regionally, into the Norman Wells area, to 100 feet or less in thickness. North of Norman Wells, centering around Fort Good Hope, the Hare Indian has thickened to over 700 feet. This sequence thins towards the Peel Plateau to the west, and also towards this acreage. South of Norman Wells a thick Hare Indian sequence is again present. Thisk thick centers about the confluence of the MacKenzie and Redstone Rivers. The sequence here is 500 feet or more in thickness.

The Kee Scarp carbonate is late Middle Devonian in age. Ostracods have been used to establish the Kee Scarp as equivalent to the combined Sulphur Point - Slave Point carbonates of northwestern Alberta. As noted previously, the Kee Scarp of Norman Wells rests on the Hare Indian Formation. The Kee Scarp is the reservoir of the Norman Wells Oil Field. The oil is trapped in the updip end of a discrete reef. On a regional basis the maximum reef growth is confined to the margins of thick Hare Indian Shale. However, its presence does not ensure Kee Scarp development. The margins of the two Hare Indian thicks referred to previously have not been found to contain Kee Scarp reefs as yet, but the areas have not been adequately explored and prospects for finding them must be considered good.

The Kee Scarp reef in wells at Norman Wells is found to consist of a reef platform 75 to 125 feet thick composed of bedded limestones which usually contain abundant fossils and is generally barren. This foundation unit is overlain by true reef materials, such as corallites, bryozoans and stromatoporoids set in a coral sand matrix. There is a wide variation in the reef facies encountered from well to well as would be expected in a reef. The thickness of reef ranges up to 400 feet (plus). Reserves of oil within the reef have been placed as high as 60,000,000 barrels with a productive area of 2,600 acres.

UPPER DEVONIAN

The Fort Creek Formation consists of a thick shale sequence which rests on the Kee Scarp reefs, or in its absence, on the Hume Formation. This shale is correlated with the Fort Simpson Shale of northwestern Alberta. At Norman Wells the basal Fort Creek Shale is a highly bituminous shale which varies in thickness in relation to the underlying Kee Scarp reef, i.e. it thickens away from the reef. The Fort Creek is, of course, variable in thickness because of the Kee Scarp reef, however, thicknesses up to 1,200 feet are present in this area.

IMPERIAL FORMATION

The Imperial Formation consists of greenish-grey shales and greenish sandstones which reach a maximum thickness of more than 2,000 feet in this general area. The sandstone is irregularly distributed within the formation and correlations are difficult. This formation correlates with the Wabamun - Winterburn groups of Alberta.

CRETACEOUS

The Cretaceous in the Norman Wells area disconformably overlies the older Devonian beds. Erosion of these older formations is very pronounced and causes a wide variation in thickness of the underlying beds. North of Norman Wells this erosion has in places stripped away the entire upper Devonian sequence, leaving the Middle Devonian formations at subcrops. Since subsurface control, as well as outcrop data, is so sparce in the vicinity of Permits 5301 and 5302 any attempt to estimate the depth of erosion that has occurred here is extremely hazardous. However, in light of the outcrops along the Hare Indian River which, as has been mentioned before, lies 30 miles to the west, and the drilling depths reported by Western Decalta from their Rond Lake wells, 80 miles to the northwest, an estimate may be made. The best guess is that the erosion may have cut as deeply as the Middle Devonian Hume Formation. However, there is a possibility that some Fort Creek is left, and consequently a possibility that Kee Scarp reefs are present and preserved. As was noted in the discussion of Hare Indian - Kee Scarp, these reefs develop along the margins of Hare Indian thicks. Indications are that such a margin is trending in this direction.

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 type section of the Sans Sault Group is composed of essentially shales and sandstones of marine origin and contains all Cretaceous strata up to the first bentonite bed. The thickness of the sections, which is located at Sans Sault Rapids, approximately 65 miles southwest of the Permits in question is estimated at 1,411 feet.

SLATER RIVER FORMATION

This formation is composed of thin bedded, black, friable shales with abundant concretionary layers of ironstone nodules. It contains some thin sandstones, seams of alum, and sulphur. It has abundant thin bands of bentonite. The thickness of this unit is about 1,000 feet.

LITTLE BEAR FORMATION

The type section is on the Little Bear River where the strata are composed of sandstone, some conglomerate and sandy shales. Coal seam bedding is lenticular and very local in nature. A thickness of about 780 feet has been given to this formation.

EAST FORK FORMATION

The East Fork section consists of a series of well bedded conchoidal, plastic marine shale, grey in color. Its thickness at the type locality, one the East Fork of the Little Bear River, is 850 feet. It contains minor sandstone lenses and a thin coal seam.

Sparce surface and subsurface control also makes the prediction of the stratigraphic thickness of Cretaceous beds present at Permits 5301 and 5302 difficult. Regionally it would seem likely that there is little more than a thin veneer of the Sans Sault Group present.

TERTIARY

A thickness of 1,600 feet of Tertiary beds have been mapped on the Little Bear River. The beds consist of soft, coarse, carbonaceous sands, gravels, conglomerates, shales and lignites. The East Fork has lignite beds 8 to 10 feet thick at its headwaters while along both sides of its valley for 18 miles the high hills and valley sides are made up of Tertiary strata up to 1,200 feet thick. These two outcrops seem to form part of a basin which dips to the southwest. If this is the case it would indicate that very little Tertiary age sediments will be found over Permits 5301 and 5302.

Further evaluation of the Permits in question should consist of a gravity meter survey in order to try and outline the present salt distribution within the Cambrian Saline River

Formation. An airborne magnetometer survey may also be of some use in delineating PreCambrian Basement structures as well as the drilling depth to it.

FRACTURE ANALYSIS

This section of the report discusses the results of a Detailed Fracture Analysis Survey carried out within, and in the immediate vicinity of, Petroleum and Natural Gas Permits 5301 and 5302. An aerial mosaic (scale 1.65 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 or 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 DISCUSSION

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 must 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 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 be also 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 the clumps of trees as well as 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/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 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 PERMITS 5301 and 5302

The Fracture pattern as shown on the enclosed mosaic and maps shows a great variation in intensity over various areas of the Permits. The two permits are located in the muskeg area east of the MacKenzie River and are hundreds of miles from the closest settlement.

The sedimentary section is about 6,000 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 are three areas where the fracture intensity is greater than normal and there are two areas 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 southeast. 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 Permits 5301 and 5302 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 Reservation 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 and thus any anomaly under Permits 5301 and 5302 is probably quite small.

There are two 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.

STRUCTURE

Petroleum and Natural Gas Permits 5301 and 5302 are located on the interior plains of the Northwest Territories about 80 miles to the west of the edge of the PreCambrian Shield. The strike of the sedimentary rocks is about North 40 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. PRECAMBRIAN TOPOGRAPHY

Basement topography under Permits 5301 and 5302 is thought 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 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 form traps for oil or gas.

Many small faults have been reported by A. W. Noriss (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. However, it is unlikely that any reefs are present in the area of Permits 5301 and 5302. The only platform from which they could grow is the Keg River equivalent and so far, no evidence of reefing has been found in this area.

3. TECTONIC FOLDING AND FAULTING

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

4. TOPOGRAPHIC RELIEF ON AN INTRA-SEDIMENTARY

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 two areas 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. 5301 as well as in the southeast corner of Permit No. 5302.

Of these two Basement high features the one to the northeast is the 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 on 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. Area three could be caused by a Basement fault.

Three 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. Two profiles $A-A^1$ and $B-B^1$ run at right angles to the strike of the Basement while the third $C-C^1$ is parallel to strike.

Respectfully submitted by:

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WGC:mjh

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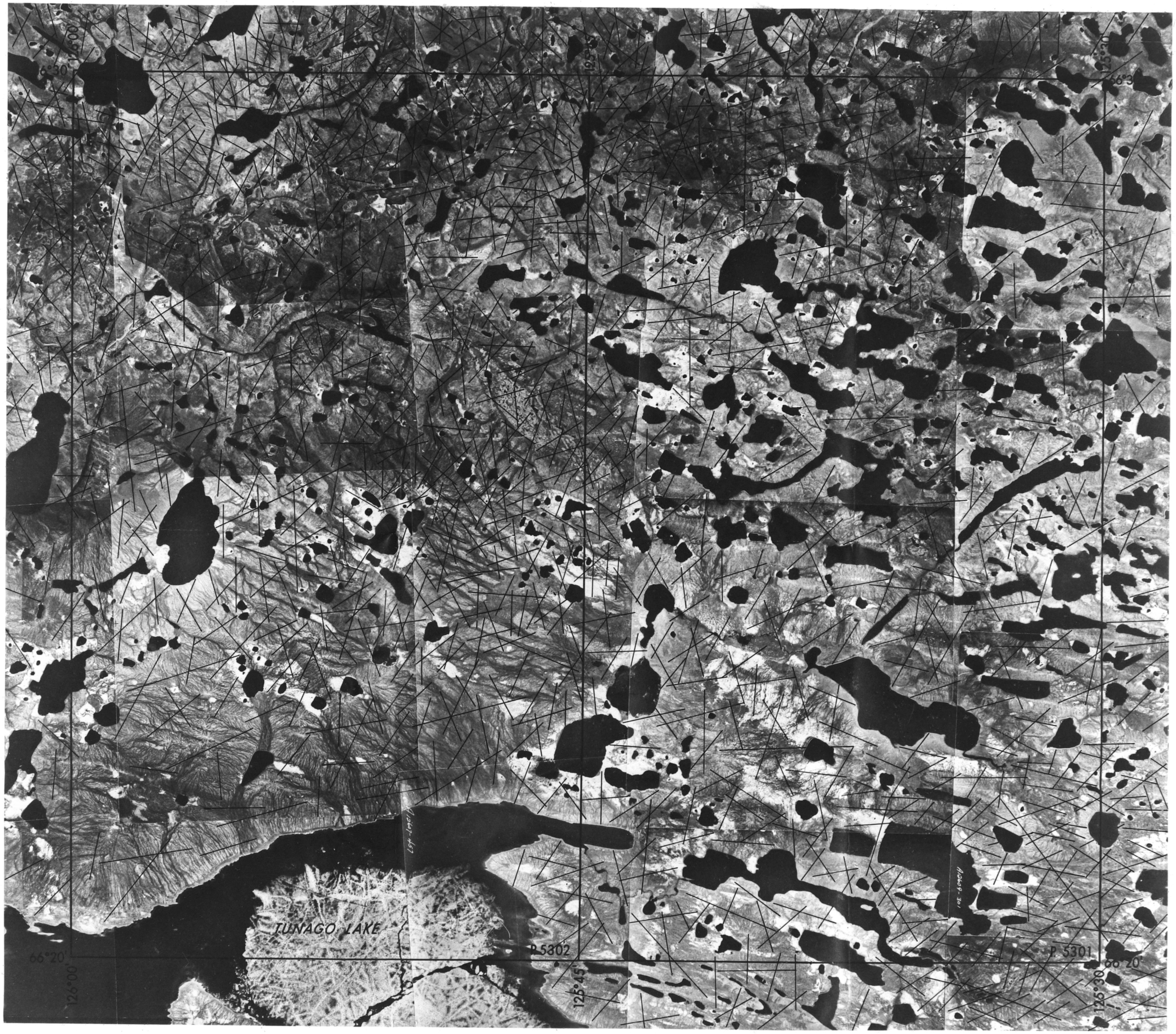

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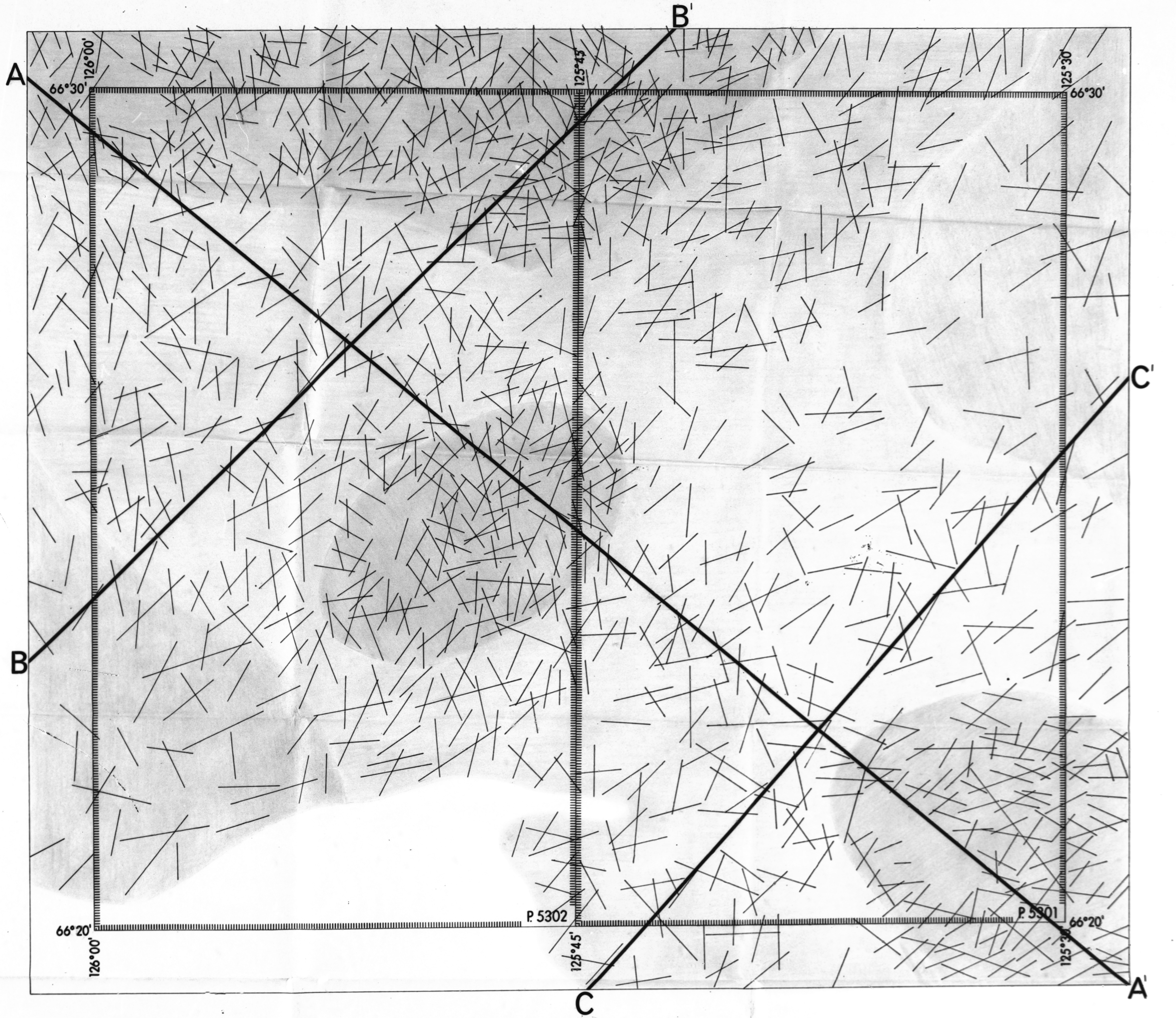
P. & N.G. PERMITS 5301 & 5302

SCALE IN MILES

1 0 1 2 3

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



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P. & N.G. PERMITS 5301 & 5302

TOTAL FRACTURE PATTERN

689-2-6-2

SCALE IN MILES

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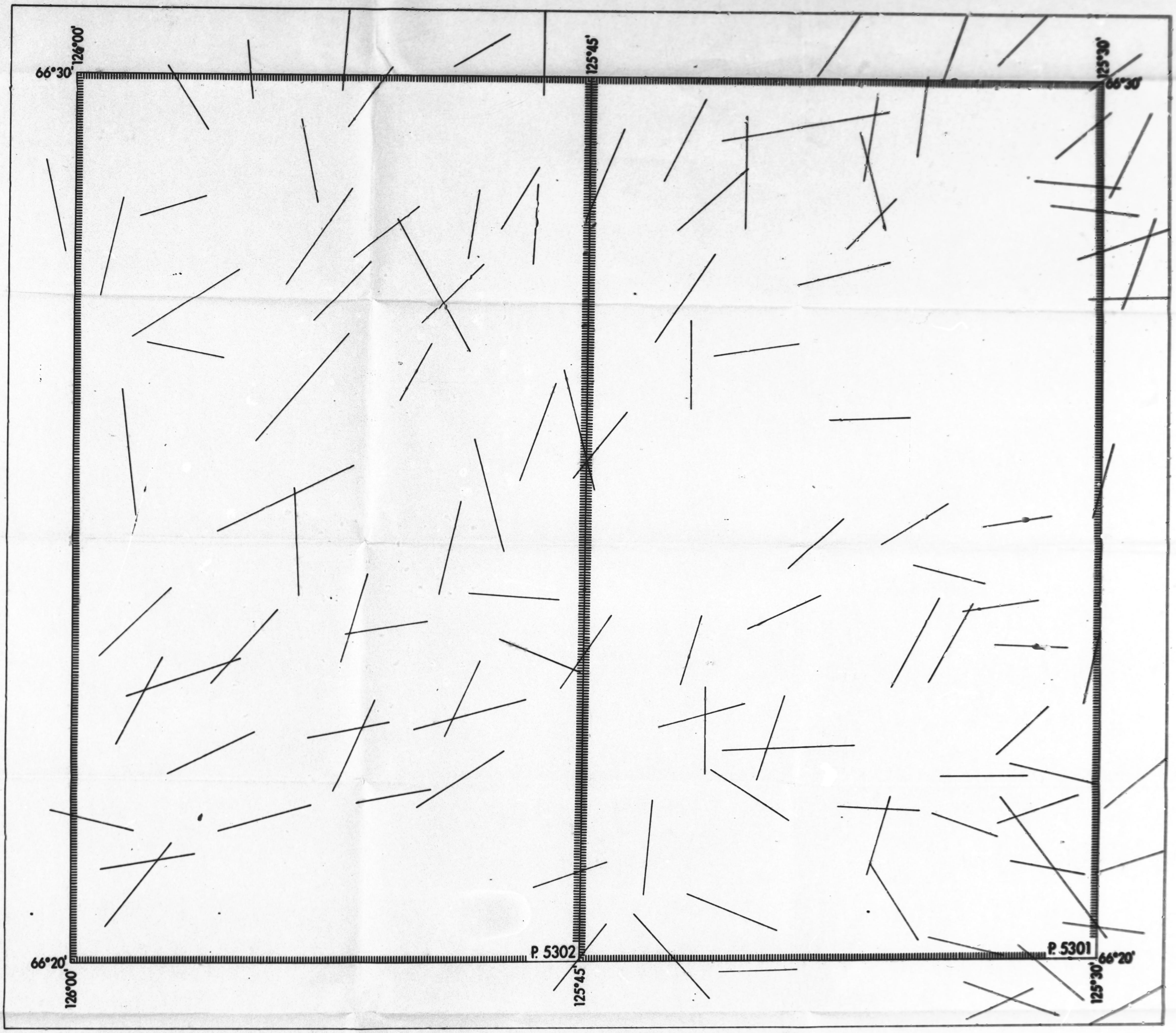
LOW DENSITY

NORMAL DENSITY

HIGH DENSITY



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P. & N.G. PERMITS 5301 & 5302

MEGA FRACTURE PATTERN

SCALE IN MILES

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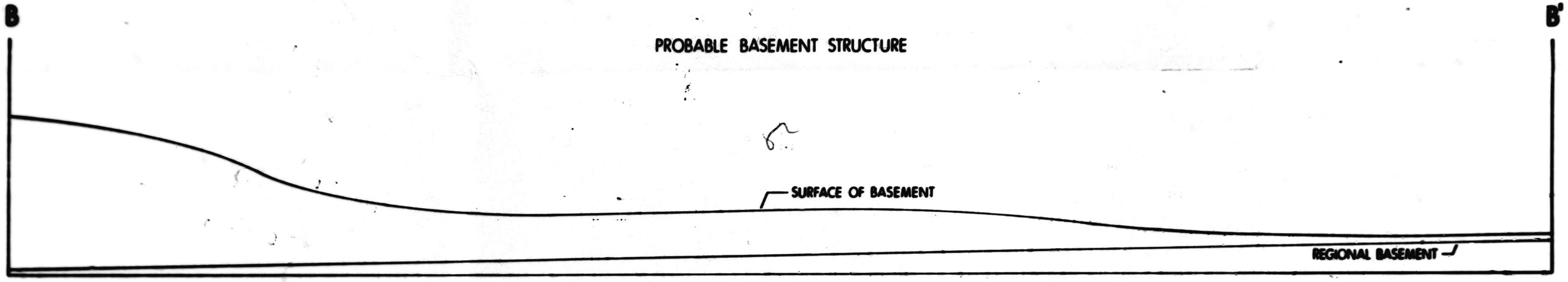

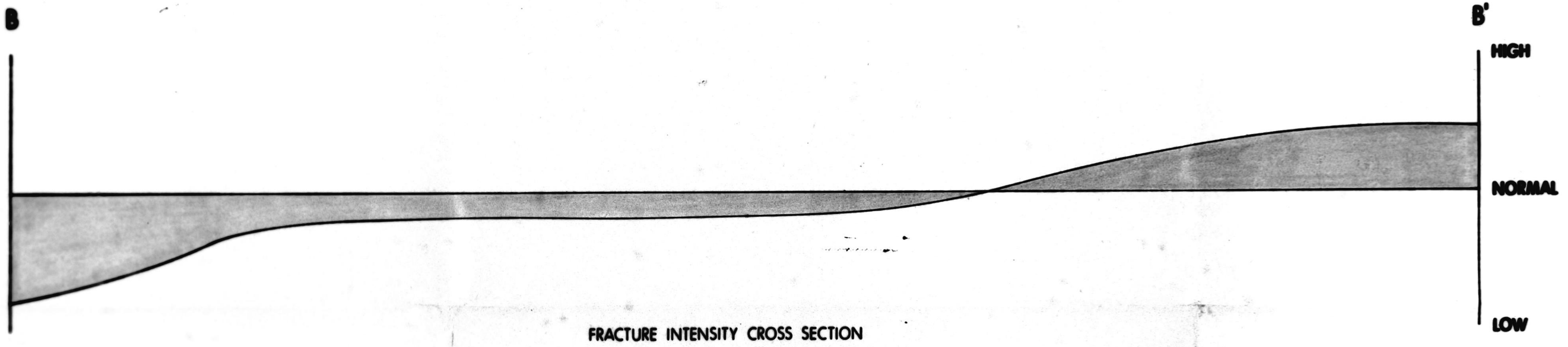

FRACTURE INTENSITY CROSS SECTION

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P. & N.G. PERMITS 5301 & 5302

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SCALE IN MILES

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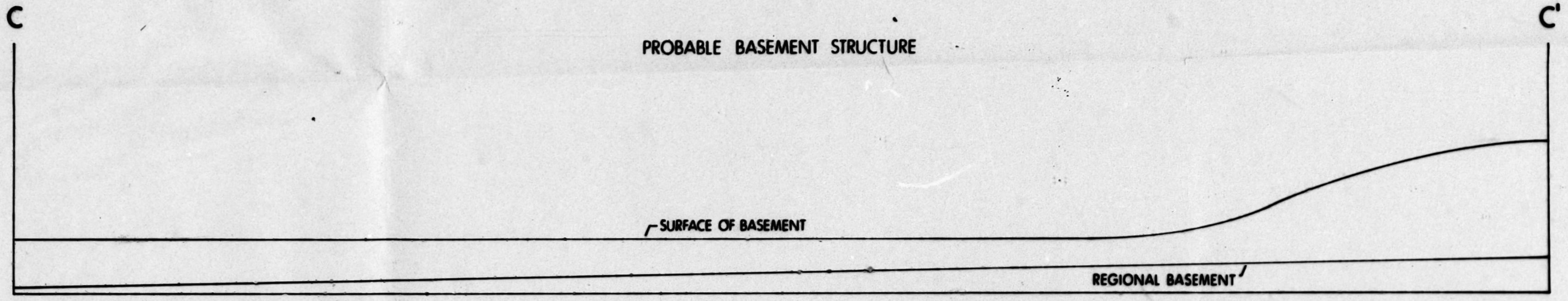

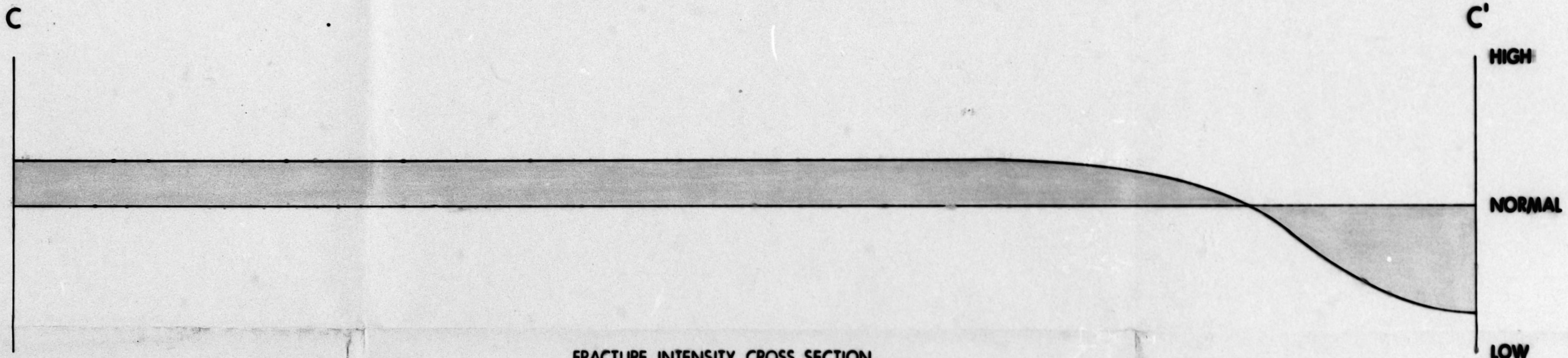

FRACTURE INTENSITY CROSS SECTION

PARIS INVESTMENTS LIMITED

P. & N.G. PERMITS 5301 & 5302

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SCALE IN MILES

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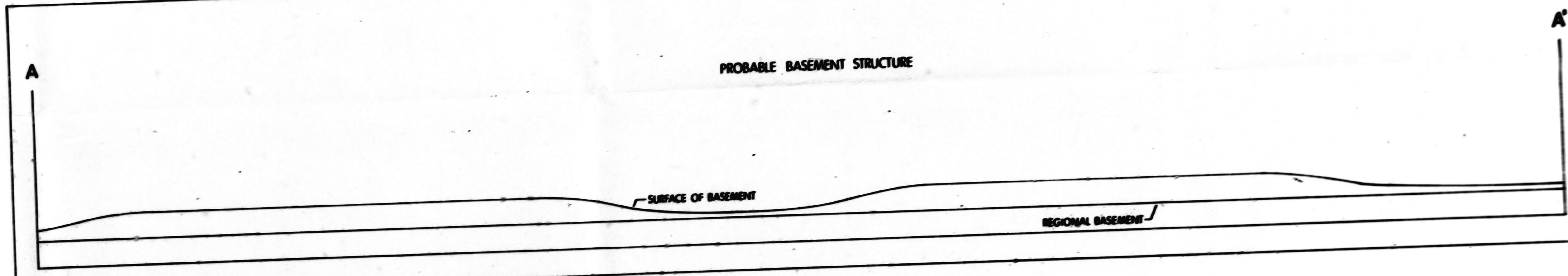

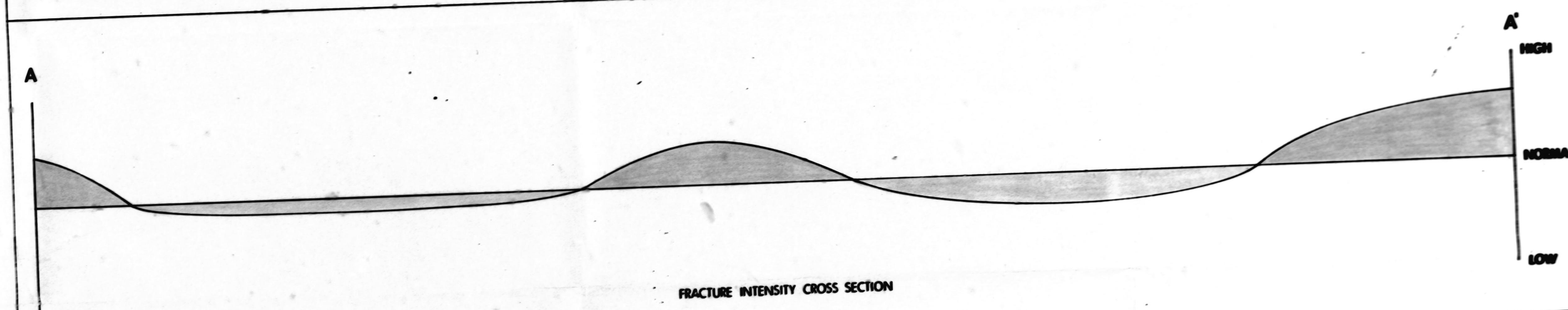

FRACTURE INTENSITY CROSS SECTION

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SCALE IN MILES