GENERAL GEOLOGY, GEOMORPHOLOGY

AND

FRACTURE ANALYSIS SURVEY

OF

P. & N. G. PERMITS 5290 AND 5353

FOR

PARIS INVESTMENTS LTD.

BY

WILLIAM G. CROOK, P. GEOL.

INDEX

GEOMORPHOLOGY

The Permits 5290 and 5353 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 so dominate the surface that little information, other than glacial, can be gleaned from the individual aerial photographs on the mosaic. The direction of ice movement was obviously northwest-southeast.

The drainage pattern is not well defined in this area but, basically most of the lakes drain to the south by the Johnny Hoe River. Within the mosaic area the drainage is confined to small creeks which flow into the various lakes. 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 geologic 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 of 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. The 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 northwest 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 east side of the mosaic. 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 oblation 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 subglacial 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 existance. Esker streams often erode channels through the bedrock where the bedrock forms a slight high between two low areas.

STRATIGRAPHY

The sedimentary section under Permits 5290 and 5353 is about 2,400 feet thick and the Ordovician, Devonian and Cretaceous systems are represented. An unconformity is present between the Ordovician and Devonian systems; between the Chedabucto Lake formation and the Chinchaga formations, and another is present between the Devonian and the Cretaceous. The Ordovician is mostly clastics with some amount of carbonate rocks. The Cretaceous is composed of clastics.

ORDOVICIAN

The Ordovician section is about 650 feet thick and is divided into the Old Fort Island, La Matre Falls and Chedabucto Lake formations. The section is mostly carbonates with dolomite and limy dolomite being the dominant rock type. A sandstone unit occurs at the base of the section.

OLD FORT ISLAND FORMATION

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

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

LA MATRE FALLS FORMATION

The La Matre Falls Formation is 300 to 350 feet thick in the region of Permits 5290 and 5353 and consists of red and green shale, fine to coarse grained sandstone and silty to sandy dolomite. The base of the La Matro Falls is often an argillaceous silty, oolitic limestone with some sandy and conglomeratic dolomite and sandstone. Gypsum and salt are also often present.

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

CHEDABUCTO LAKE FORMATION

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

DEVONIAN

The Devonian section is about 1,075 feet thick and consists of the Chinchaga formation plus units which are equivalent to the Keg River and Muskeg formations. The exact sequence present is unknown due to a lack of wells in the area plus the lack of surface knowledge north of latitude 64° 00'. In addition, the Middle Devonian succession in this area is very complex and many abrupt lithologic changes are present. The Chinchaga formation is recognised as a mapable unit but the units above the Chinchaga cannot be correlated to the northern Alberta type section area.

CHINCHAGA FORMATION

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

Brecciated gypsum and carbonate beds are present throughout the entire section in the area north of Great Slave Lake.

KEG RIVER EQUIVALENT

The section which correlates with the Keg River formation is called the Lonely Bay Formation. Noriss (1963) describes the lower part of the Lonely Bay Formation as ...." massive dark brown aphanitic in part styolitic limestone, thinly bedded lgiht gray fine grained to aphanitic limestone, weathering orange-brown'

irregularly thin bedded light olive gray to medium gray, fine grained limestone medium-bedded aphanitic slightly dolomitic limestone; and thinly bedded pale brown slightly argillaceous limestone. A younger section is described as consisting of ...."massive, dark to medium brown, fine grained, fetid limestone, overlain by irregularly thin-bedded medium brown, fine grained to aphanitic limestone interbedded with nodular limestone".

MUSKEG FORMATION EQUIVALENT

In the area north of Great Slave Lake there are units present which correlates to the Muskeg of northwestern Alberta. It is up to 500 feet thick in this area and is comprised of a lower 100 feetof bituminous shale; a middle 175 feet of green calcareous shale and an upper member up to 225 feet thick which consists of gray to white reefal dolomite. This upper member correlates to the Presqu'ile reef of the Pine Point area.

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

CRETACEOUS

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

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

TERTIRARY

A thin layer of glacial clay, sand boulders and till lies on the surface of the map area. These deposits are extensively discussed elsewhere in this report.

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 5290 and 5353. 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 know 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 the action of deep seated tectonic forces, and the most probable of these is isostatic adjustment. Isostatic rebound following the melting of the glaciers may still be taking place and this will further accentuate fractures present before glaciation.

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

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

EXPRESSION OF FRACTURE

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

TOPOGRAPHIC RELIEF LINEAMENTS

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

VEGETAL LINEAMENTS

Vegetal lineaments are the most common in the parkland and muskeg areas of western Canada and many excellent examples of fractures can be seen on almost any aerial photograph of northern Saskatchewan, Alberta or British Columbia. Straight lines of both deciduous and evergreen trees as well as scrub growth are universally visible. However, the most common vegetal lineament seen by this writer is a straight "edge" to a clump of trees or bushes. In many cases these fractures control the size and shape of 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/1) between two points may be in part due to structure, but, also due in part to different surface conditions. To some extent, this can be compensated for by applying appropriate weightings to the observed counts, but over or under corrections may result.

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

FRACTURE ANALYSIS OF PERMITS 5290 AND 5353

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 2,400 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 and Devonian sections.

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

Reference to the mosaic will show that the area has been deeply 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 5290 and 5353 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 Permits 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 5290 and 5353 is probably quite small.

There is one area on the mosaic where the fractures are less intense than the surrounding area.

Some fractures are present within this area but it does have a lower incidence than the surrounding area. This low intensity area is important and it is quite likely that it is 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 5290 and 5353 are located on the interior plains of the Northwest Territories about 80 miles to the west of the edge of the Pre Cambrian Shield. The strike of the sedimentary rocks is about North 20 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 5290 and 5353 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 from 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 5290 and 5353. 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 FEATURE**

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

Reference to the Total Fracture Pattern Map which accompanies this report will show that there are two areas of "high" fracture intensity and one area of "low" fracture intensity (green). The general interpretation is that the low fracture intensity areas are underlain by topographic highs on the Basement. With this established, the deduction is that the Basement is low in the southeast corner of Permit 5353 as well as in the north-central part of Permit 5290.

The Basement high feature 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 as the high area is over one and one-half mile in width. If a fault caused the fracture "low" the width of the low would be about one mile or less.

Three hypothetical structure cross-sections accompany this report and reference to them will show how Basement "high" is inferred to be present beneath the area of low fracture intensity. In profiles C - C' and B - B' run at right angles to the strike of the Basement while the third A - A' is parallel to strike.

Respectfully submitted by:

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WGC/jp

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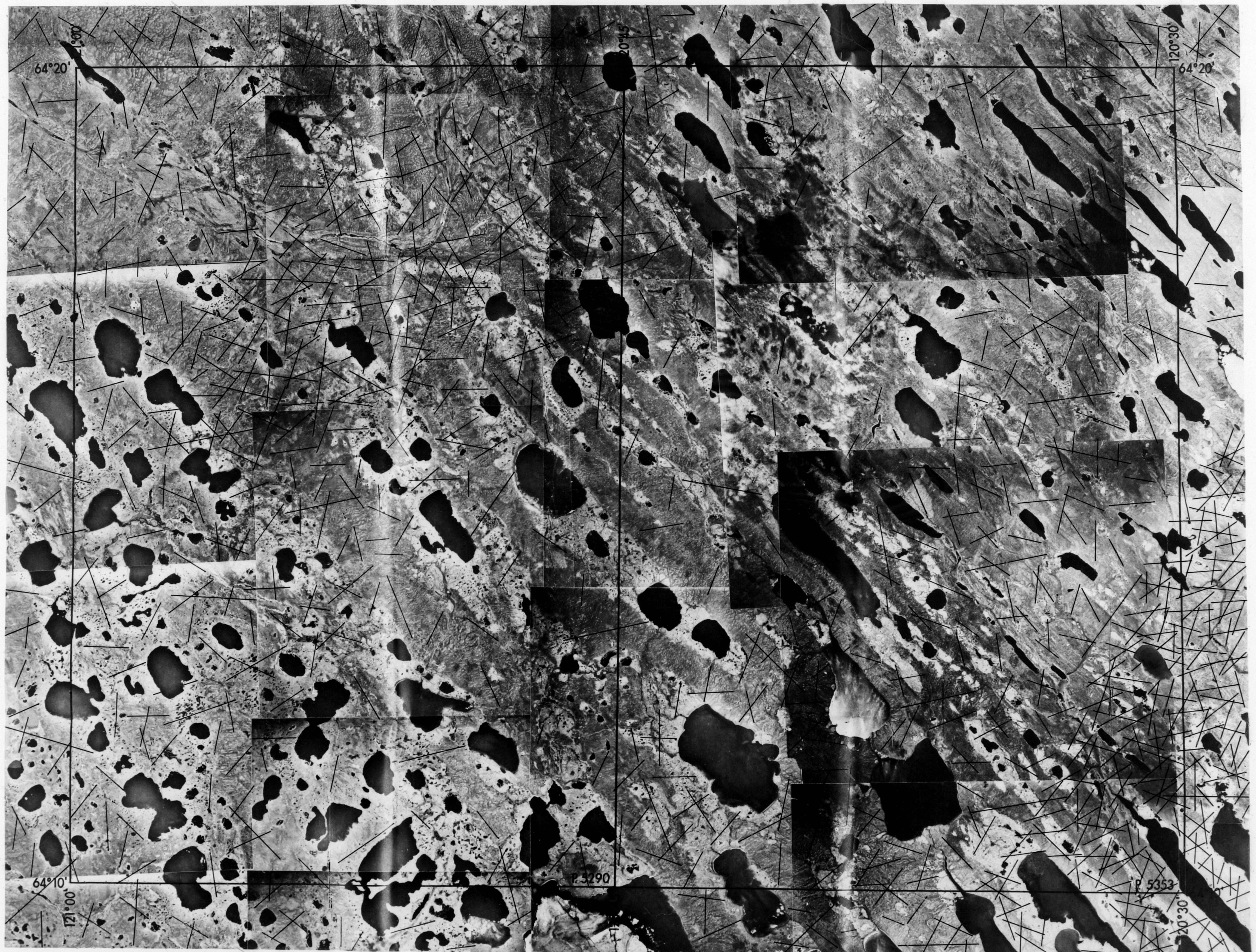


CARILLON DEVELOPMENT CORPORATION LIMITED

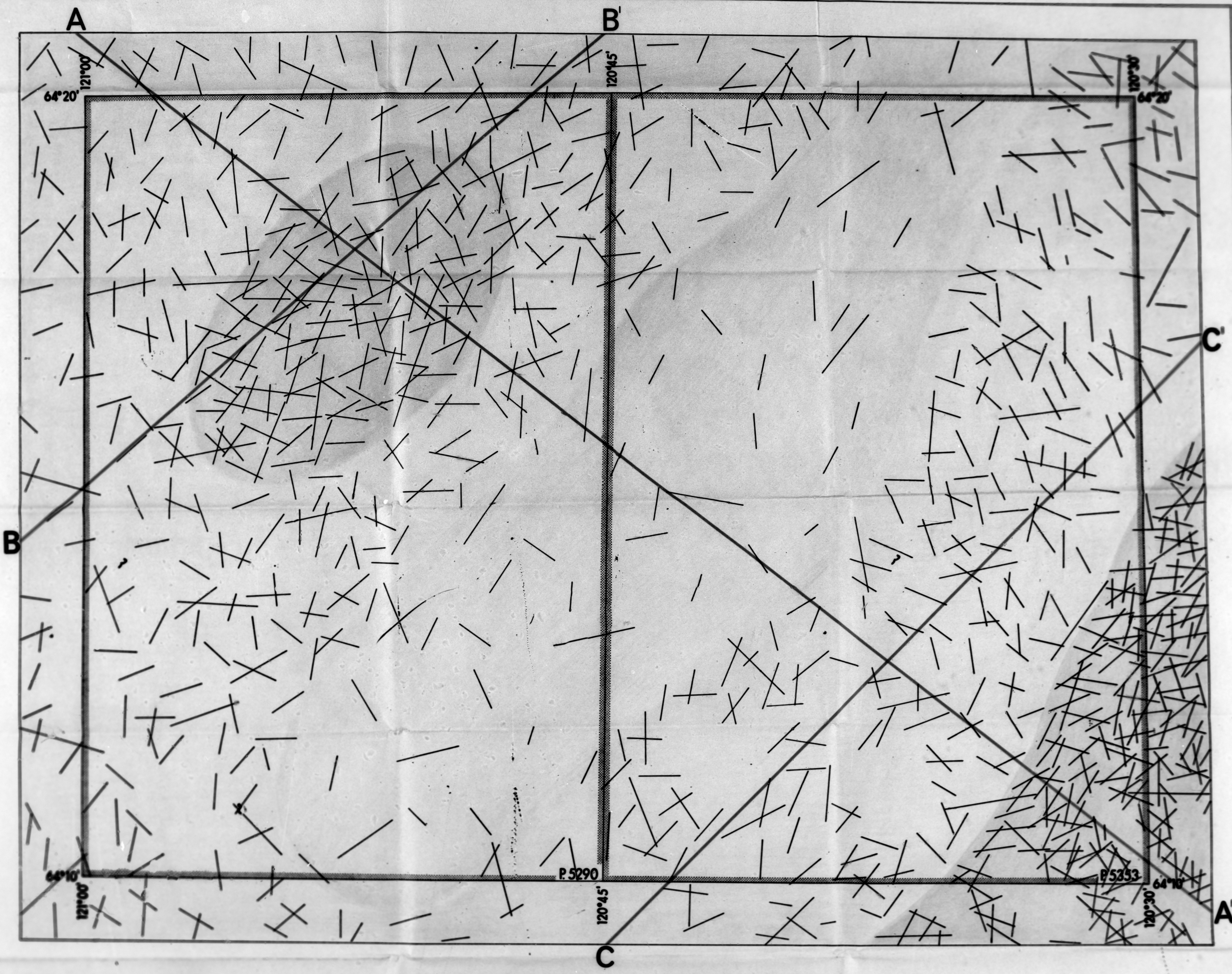
P. & N.G. PERMITS 5290 & 5353

SCALE IN MILES

689-2-6-6

1 0 1 2 3

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



CARILLON DEVELOPMENT CORPORATION LIMITED

P. & N.G. PERMITS 5290 & 5353

TOTAL FRACTURE PATTERN

SCALE IN MILES

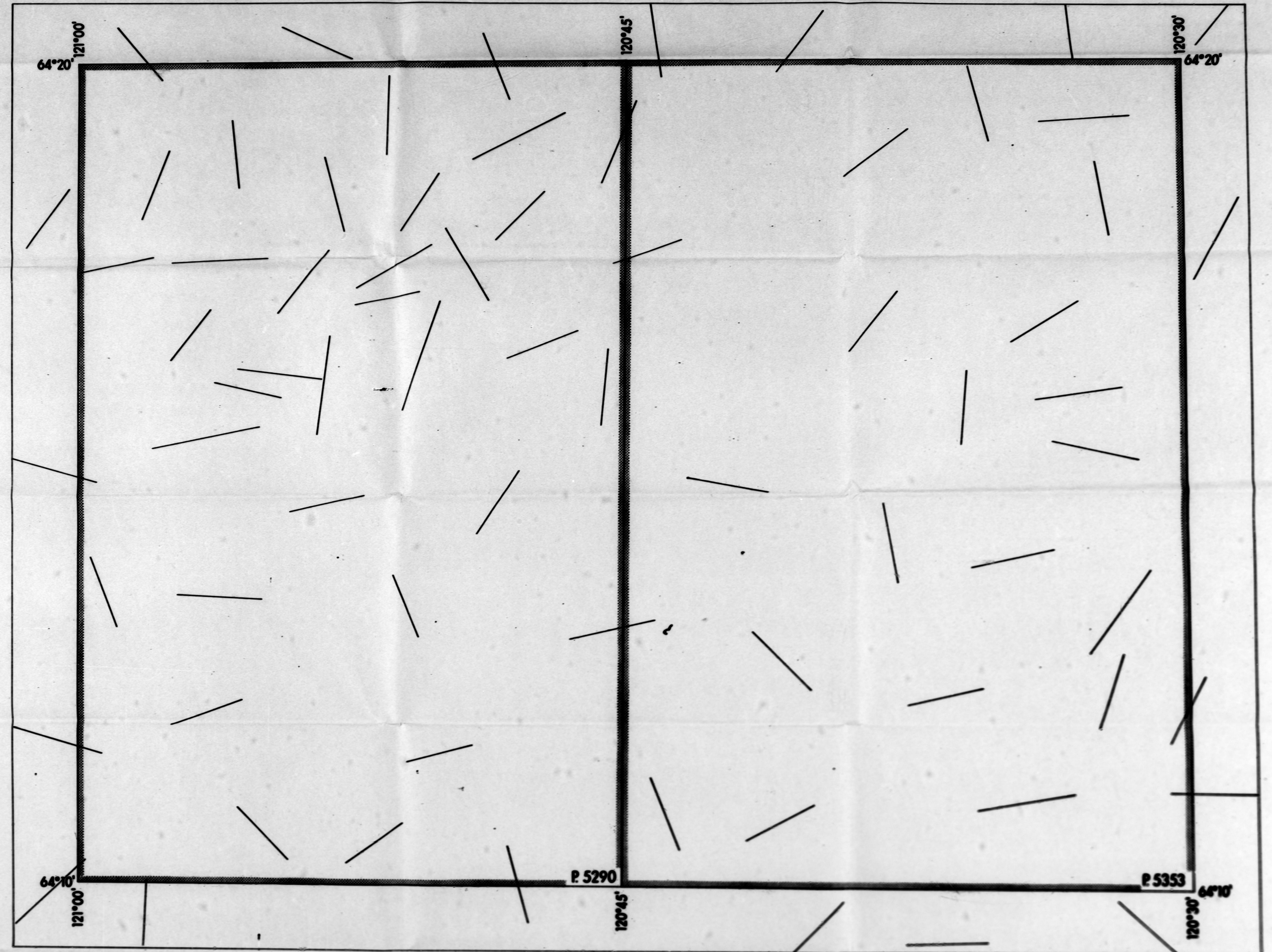
1 0 1 2 3

LOW DENSITY

NORMAL DENSITY

HIGH DENSITY

689-2.6.6



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P. & N.G. PERMITS 5290 & 5353

MEGA FRACTURE PATTERN

689-2-6-6

SCALE IN MILES

1 0 1 2 3

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P. & N.G. PERMITS 5290 & 5353

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SCALE IN MILES

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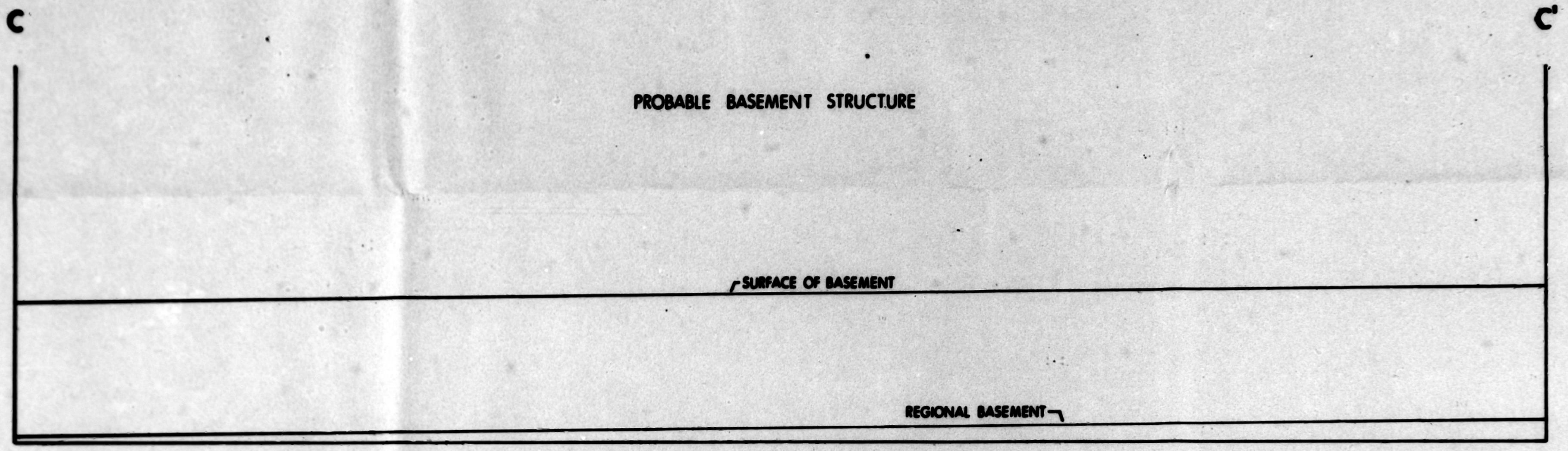

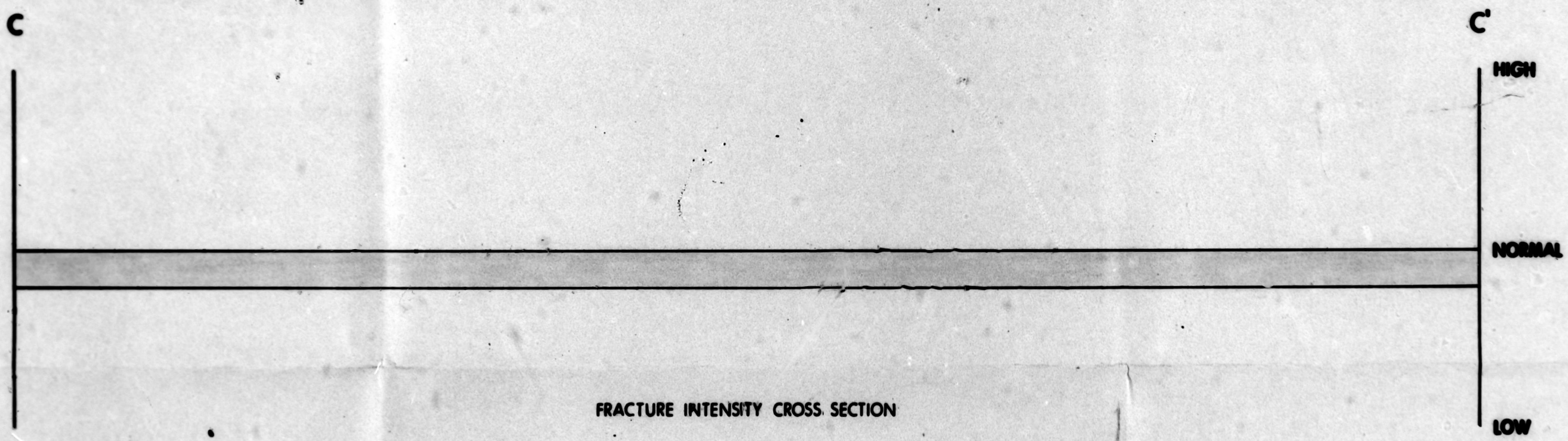

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P. & N.G. PERMITS 5290 & 5353

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SCALE IN MILES

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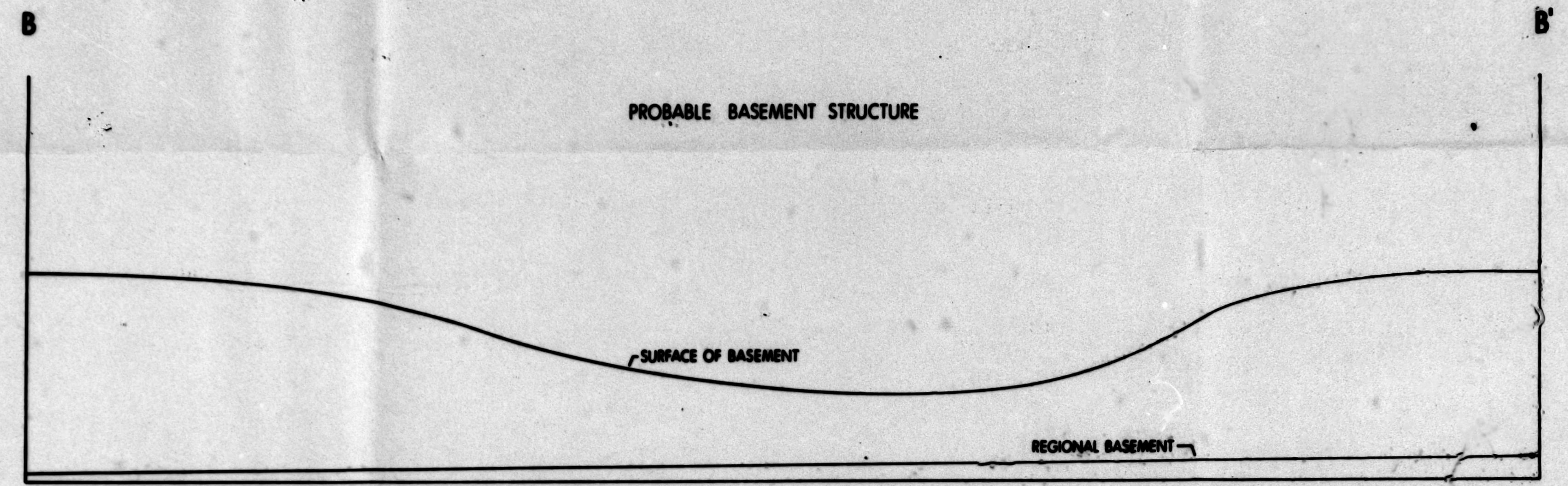

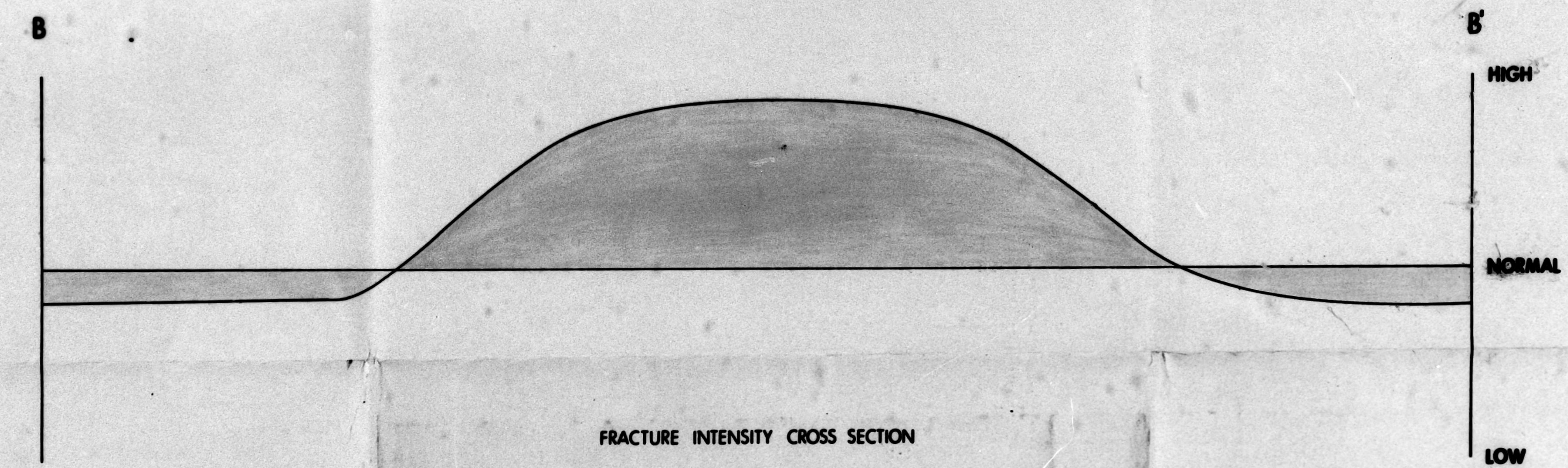

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P. & N.G. PERMITS 5290 & 5353

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SCALE IN MILES

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