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# GENERAL GEOLOGY, GEOMORPHOLOGY

# AND

# FRACTURE ANALYSIS SURVEY

# OF

GEOLOGICAL & EVALUATION
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# P.&N.G. PERMITS 5418 and 5421

# FOR

# MICHIGAN DEVELOPMENTS LTD.

# BY

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# INDEX

## GEOMORPHOLOGY

The Permit Nos. 5418 and 5421 lie on the MacKenzie Plain area of the Northwest Territories, about 7 miles southwest of the junction of the Keele and MacKenzie Rivers. 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 information can be had from the mosaic. The direction of ice movement was obviously northwest-southeast.

The drainage pattern is well defined and the whole area is drained by the Keele River and its tributaries. The Keele River flows to the east through Permit No. 5421. Middle Creek flows north through the mosaic area and joins the Keele within Permit No. 5421. 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 to some degree by glacial action. 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, 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. In 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 area.

## STRATIGRAPHY

Permits 5418 and 5421 are located on the MacKenzie Plain about 7 miles southwest of the confluence of the Keele and MacKenzie Rivers. They lie approximately 17 miles east of the Canyon Ranges of the MacKenzie Mountains and about 12 miles west of the McConnel Range of the Franklin Mountains. The MacKay Range lies about 15 miles northwest of the Permits. Fort Norman is located 40 miles to the north of the Permits while the settlement of Wrigley is some 70 miles southeast of them. The Pre-Cambrian Shield outcrops about 225 miles east of the Permits. Subsurface control is provided by three wells, one of which is Shell Keele River L-4, located about 5 miles north of the Permits in 64°, 23', 37" N., and 125°, 01', 43" W. The other control wells are Imperial Redstone No. 1 which is located 11 miles east of the Permits in 64°, 11', 42" N., and 124°, 38', 19" W. and Shell Cloverleaf I-46, located in 63°, 55', 44" N., and 124°, 52', 39" W., which is about 12 miles south-southeast. The sedimentary section varies in age from Cambrian to Tertiary. Imperial Redstone No. 1, bottomed at 4,874 feet or 374 feet into the Ronning Formation, while the Shell Keele River bottomed at 4,235 feet in the Upper Devonian, Imperial Formation after penetrating 1,948 feet of them. Shell Cloverleaf I-46 bottomed at 11,318 feet after penetrating 5,143 feet of undivided Bear Rock and Ronning sediments. Regional isopachs indicate the area covered by the Permits should be underlain by a minimum of 14,000 feet of sediments. Regional isopach and facies maps along with published

geological reports have been used to outline the general stratigraphic sequence which can be expected to underlie Permits 5418 and 5421.

## CAMBRIAN AND/OR OLDER

### KATHERINE GROUP

The Katherine Group which represents the earliest Paleozoic sediments in this region are named from a section exposed in the Upper Carcajou River area which lies about 75 miles northwest of the Permits. The section exposed consists of interbedded quartzites and black, platey shales. The shales are green, chocolate and black coloured with the black being platey and bituminous. They are contained as interbeds in the quartzites which are generally pink, buff, rusty and white coloured in outcrop. The top of the Katherine is placed at the base of a chocolate coloured shale succession. The base of the Katherine was not seen, leaving the total thickness unknown for this area. To date the Katherine has not been penetrated by any well drilled in this region, which leaves the subsurface section an unknown quantity. While reservoirs are not described in outcrop it must none the less be expected that sand bodies such as offshore bars, beach sands and longshore 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 during the deposition of the sands. A gravity meter and airborne magnetometer survey could be used to

good advantage in locating areas requiring more detailed exploration such as a seismic exploration survey. The bituminous shales described in the Upper Carcajou River exposure should provide an adequate source of hydrocarbons. This section should be considered in any exploratory plans for this area as it could contain major reserves of hydrocarbons. Anticlinal structures could provide an additional trapping mechanism in this area.

## CAMBRIAN

### MACDOUGAL GROUP

The type section of the Macdougal Group is located about 75 miles northwest of Permits 5418 and 5421 in the Dodo Canyon of Macdougal Creek. At the type section the Macdougal is divisable 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. Lithologically the group consists of interbedded limestones, sandstones, reddish coloured gypsum, black, petroliferous shales as well as green, red and chocolate coloured shales. The section mapped by Laudon at Imperial River is about 30 miles northwest of the type section. The Imperial River section is 1,839 feet thick, with the base not exposed, and consists of sandstones, alternating with limestones, gypsum and vari-coloured shales. The basal 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. There is considerable gypsum in the upper shales and Laudon attributes the crinkly

distorted shale beds near the top to gypsum solution with accompanying collapse of the shales. A 146 foot bed of black to dark grey, laminated, algal limestone near the top of the section overlies soft black deepwater shales and is separated from them by an unconformity. The limestone, which is sandy in part, contains calcareous algae which are up to 3 feet in diameter.

The Macdougal at Norman Wells contains a bed of salt 2,000 feet thick which is correlated with the Saline River Formation. The type section of the Saline River Formation lies 2 miles above the junction of the Saline River with the MacKenzie River, which is about 15 miles due east of Permit 5421. The section exposed is 100 feet thick with neither the top nor the base seen. Estimated thickness of the Saline River Formation at the type section is 500 feet. The section exposed consists of red and green shales interbedded in part with gypsum and salt deposits. Salt springs in the area undoubtedly have their source in this formation. The Saline River Formation at the type area is underlain by older beds of Macdougal age and by about 630 feet of the Katherine Group. The Katherine is exposed on Clark Mountain, which is about 25 miles east of Permit 5421 and consists of mainly pink and red quartzite.

The Saline River Formation is a very widespread unit and is believed to be present northwest of Norman Wells as well as south of the type locality for the following reasons:

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

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

3. 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.

4. 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 northwest and southeast of Norman Wells.

Permits 5418 and 5421 will undoubtedlybe underlain by Saline River Salt, however, no reasonable estimate of the thickness present can be made.

Solution of the Saline River Salt creates the possibility of salt structures in the overlying Carbonate banks similar to those found to be productive in southeastern Saskatchewan and at Rainbow Lake in northwestern Alberta. The crinkly distorted shale beds noted by Laudon at Imperial River may be a product of salt

solution rather than gypsum solution as was suggested by him. The algal laminates at Imperial River indicate some organic activity in the Macdougal seas and this coupled with underlying salt structures could give rise to hydrocarbon bearing reservoirs within this sequence. The petroliferous shales within the Macdougal Group should provide adequate source material for the generation of hydrocarbons. Imperial Vermilion Ridge #1, located at 65°, 07', 51" N., and 126°, 05' 00" W., which is about 55 miles north-northwest of Permit 5421 penetrated 3,177 feet of Macdougal beds without reaching the Katherine Group. Shell Blackwater Lake G-52, located in 64°, 01', 20" N., and 122°, 55', 12" W. lies slightly over 60 miles east of the Permits and penetrated 760 feet of Macdougal sediments before stopping. Neither well was drill stem tested in the Cambrian portion of the well bore and to date there have been no reservoirs encountered in wells which have drilled to the Cambrian in this region.

## ORDOVICIAN - SILURIAN

As has been noted by various authors, rocks of Ordovician age have not 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 shales and argillites at outcrops in the Upper Peele River area which lies about 300 miles northwest of the Permits. About 75 miles west of the Permits, near the confluence of the Keele and Twitya Rivers, 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. Some 20 miles northeast of this section the same sandstone was mapped as a 4,500 foot thick unit with only occasional shale partings. The sections described by Helck and Keele from outcrops along with the scattered subsurface control available have been used to establish some regional lithofacies patterns for the Ordovician.

The Upper Peele 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. The shelf edge carbonates are found along the central portion of the MacKenzie Mountains and on the Peele Plateau. To the east 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 probably underlie Permits 5418 and 5421. There is a possibility that the Permits in question may be underlain by reefal shelf edge carbonates. This possibility exists because a long, narrow trend of basinal sediments extends from the Fort McPherson area through Norman Wells and south into the Camsell Basin and Liard Plateau. This trough is mapped as lying about 15 miles west of the Permits, which would put the Permits in a good position to explore for porous shelf edge carbonates.

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 under the name of 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 one named the Franklin Mountain and an upper one named the Mount Kindle. The Franklin Mountain Formation is usually found to consist of limestones and dolomites with abundant irregular shaped chert nodules. The Mount Kindle is generally made up of a sequence of chert poor limestones and dolomites which tend to thin in a southerly and easterly direction. The Ronning Group should be from 3,000 feet to 3,500 feet thick in the area covered by Permits 5418 and 5421, and should consist of clean, finely crystalline, shelf carbonates with abundant chert inclusions and variable degrees of porosity. The possibility for the occurrence of reefal shelf edge carbonates fronting a basinal sequence of shales to the west of them exists in this area much the same way as was outlined earlier for the Ordovician beds. The Imperial Redstone No. 1 well, located in 64°, 11', 42" N., and 124°, 38', 19" W., which lies about 11 miles east of the Permits, penetrated 314 feet of Ronning before it was abandoned. The section consisted of finely crystalline dolomites with variable amounts of anhydrite and gypsum. The section was generally found to contain fine vug and intercrystalline porosity, which was not tested,

presumably due to a lack of shows and probable evaporite plugging of porosity. Imperial Loon Creek No. 2, located in 65°, 07', 20" N., and 126°, 128', 51" W., which is about 63 miles north-northwest of the Permits penetrated 1,270 feet of Ronning. The Ronning was found to consist of mainly white to grey, microcrystalline to granular dolomites with some evaporite plugging. Scattered poor porosity was present throughout, however, no drill stem tests were run and no shows were noted in the samples, however, oil staining has been described in the Upper Ronning group at wells drilled in the Norman Wells area.

The Ronning has been described in outcrop at a number of locations in this region. In the area of Dahadinni River, which is about 25 miles south of Permit 5418, about 330 feet of grey to black dolomites and limestones with thin interbeds of black shale were found lying beneath the brecciated Bear Rock Formation. The base of the Ronning is not exposed at this section. The section at Bear Rock, which is about 40 miles north of Permit 5421, consists of 600 feet of limestones, dolostones and shales with the brecciated sediments of the Bear Rock Formation overlying them and the Macdougal red and green, gypsiferous shales underlying them. The Mount Kindle Formation is apparently not present here. At Mount St. Charles, which lies about 48 miles north-northeast of Permit 5421, the section is mapped as 865 feet of Franklin Mountain Formation, overlain by 480 feet of Mount Kindle carbonates. The Franklin Mountain Formation consists of a lower 200 feet of cavernous limestones overlain by 195 feet of cherty limestone and

grey limestone. This is in turn overlain by 470 feet of grey dolomitic limestone. The base of the Franklin Mountain Formation here is not exactly clear as various workers have placed beds beneath those described above into the Ronning Group also. They consist of gypsum, conglomeratic limestone with black bituminous pebbles and highly bituminous limestones which lithologically would appear to be nearer the description of the Macdougal Group. The basal 210 feet of the Mount Kindle is a dolomitic limestone containing corals of Niagaran age. Overlying them are 90 feet of limestone and chert beds while the upper 180 feet of Mount Kindle is a hard, grey, dolomite which is cherty in the lower part. The section is overlain by the brecciated dolomites of the Bear Rock Formation.

Four miles north of Norman Wells, at Schooner Creek, Stelck mapped a 100 foot section of massive, crystalline, porous limestone containing some coralline fauna. He correlated them with the lower portion of the Mount Kindle Formation. This section can be interpreted as a porous, carbonate bank, or bank edge 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 in this region, it undergoes both facies and thickness changes in the MacKenzie River area.

The trapping conditions which can be outlined for the Ronning in this area are quite varied. A few of the types of

trapping to prospect for are outlined below:

(a) The marked disconformity which separates the Ronning Group from the overlying Bear Rock Formation may have produced erosional features such as scarps, monodnocks and channels, which when scaled by the basal evaporites of the Bear Rock Formation would constitute an effective trap. Leaching should enhance the reservoir properties of the Ronning carbonates.

(b) As mentioned previously, low reef fronts or porous carbonate banks may be present and coupled with the seal provided by the overlying Bear Rock evaporites could present a very extensive trap. Lateral facies changes from porous to semi-evaporitic carbonates could 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 southeast 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 have received an extra fill of sediments over that being deposited where the salt was not removed. Once sedimentation within the sink hole caught up, subsequent sediments would be deposited on a normal sea floor. The second stage in the formation of a Hummingbird type of trap would involve the removal of the salt surrounding the original sink hole 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 adequate 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 of the Bear Rock in exposed sections.

(d) Gentle to tight anticlinal folds possibly coupled with thrust faulting are likely to be present at the Permits in question and could provide sizeable accumulations of hydrocarbons within them.

MIDDLE DEVONIAN

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 40 miles north of Permit 5421 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 dolomitic 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 10 feet of bedded limestone and dolomite breccia.

The Bear Rock is a very widespread formation which undergoes a number of facies changes, grading from open marine basinal shale facies to evaporitic shoreline facies. 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 Peele Plateau areas are the shelf limestone and dolomite facies. In the Peele Plateau they attain a thickness of some 2,000 feet and consist of micritic pellet and micritic skeletal limestones with intervals of finely crystalline, porous dolomite in the lower part. The shelf carbonates are in turn replaced by a relatively narrow belt, about 25 miles wide, of shelf dolomites which appear to be the prelude of the adjacent evaporite sequence. The shelf dolomites are present in the MacKenzie Mountains and extend in a line north through the Fort Good Hope region and south into the Camsell and Nahanni Ranges. Permits 5418 and 5421 are mapped as lying slightly east of the shelf dolomite facies, however control

is such that they may be found to be underlain by the shelf dolomite facies. The shelf dolomitic facies are in turn replaced by an evaporitic sequence along their entire length. This facies change begins to the west and north of Norman Wells and extends southward into northwestern Alberta and northeastern British Columbia. In the Norman Wells area and also in the area covered by the Permits the basal portion of the Bear Rock is commonly evaporitic while the upper portion consists of carbonate breccias. The Imperial Redstone #1 well which lies 11 miles east of the Permits penetrated 1,078 feet of Bear Rock sediments. The upper 300 feet consisted of grey to brown, microcrystalline dolomites with some interbeds of dark brown microcrystalline limestone. Porosity of a fine, vugular and intercrystalline nature was found scattered throughout this section. Traces of dead oil stain were observed in the samples, however, no tests were run over the Bear Rock. The Bear Rock in this well becomes increasingly evaporitic with depth until the basal 375 feet contain quite thick beds of dark grey to brown to white anhydrite interbedded with grey-brown limestones and brown to dark brown dolomites. This lower 780 feet of Bear Rock is essentially dense with only very scattered traces of vugular porosity and dead oil staining being observed.

The evaporite facies of the Bear Rock is equivalent to the Chinchaga Formation of northern Alberta and northeastern British Columbia. 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. Permits 5418 and 5421 are mapped as lying on the northern end of the Camsell Basin. Immediately south of the Permits the Bear Rock isopach undergoes pronounced thickening as evidenced by the Shell Cloverleaf well. The Permits should be in a good position to locate a porous shelf dolomite or shelf edge facies. Some support for this is noted in the Imperial Redstone No. 1 well which had an interbedded sequence of limestones and dolomites which is usually indicative of a zone of mixing activity. This zone is usually found next to carbonate bank buildups.

In the Norman Wells area the Bear Rock carbonates 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. The Atlantic Col. Car Shoals C-31 well, located in 65°, 50', 7.5" N., and 128°, 51', 45" W., which is about 145 miles northwest of the Permits, is located in about the same stratigraphic position as the Permits, i.e., in the shelf dolomite facies near to the evaporite facies. The well had 744 feet of Bear Rock and a drill stem test run over a 13 foot interval near the top of the formation recovered 5 feet of oil, 180 feet of mud and 385 feet of water. A test run over the next 245 feet of Bear Rock

recovered 2,800 feet of water with a chlorinity of 24,000 PPM $CL^-$ indicating the reservoir was not flushed. There was no draw down in reservoir pressures indicating an extensive porous zone. Relatively close to this well Atlantic had previously drilled a well called Atlantic Col Car Beavertail G-26, located in 65°, 55', 25" N., and 128°, 34', 25" W. They ran a number of drill stem tests over the Bear Rock without recovering any formation fluid. The well was cased through the Bear Rock and perforated in it. Swab tests recovered 5 gallons of water with a chlorinity of 4,200 PPM $CL^-$, which is quite obviously not formation fluid. The well was subsequently abandoned, however, the two Atlantic wells serve to illustrate the rapid changes in reservoir properties which can occur in the Bear Rock. They also indicate that the reservoir must be considered as a potential hydrocarbon bearing reservoir in the Norman Wells and surrounding areas. Oil shows were also encountered by Western Decalta at their Rond Lake wells; however, these wells lie some 200 miles north-northwest of the Permits.

The Bear Rock Formation is exposed at numerous outcrops in the Norman Wells region. At the Dahadinni River section, which is about 25 miles south of the Permits, more than 420 feet of typically brecciated dolomites were observed. In addition to the type section at Bear Rock the formation is exposed on Mount St. Charles, which is about 48 miles north-northeast of the Permits.

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 undoubtedly true for the basal portion of the Bear Rock. The Mount St. Charles section may be considered as supporting evidence for the theory proposing 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 unrecognized thrust faults repeating the section, however, neither of these alternatives seems very plausible. The rapid facies changes within the Bear Rock are further evidenced when one compares the section exposed 3 miles north of Mount St. Charles to the exposure on Mount St. Charles. Here the chert beds of the underlying Mt. 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 Formation. The Mount St. Charles section has no evaporites. The difference in thickness between the two exposures is worthy of note also.

HUME FORMATION

Considerable confusion has existed in the literature concerning the relationship of the Ramparts or Hume, Hare Indian and the Kee Scarp Reef. A paper by H. G. Bassett in the Geology of The Arctic Symposium" is probably the most important one to read for 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 subdivided the Ramparts into three members: a lower limestone member, a middle shale member and an upper limestone member. The lower limestone member, 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, and very fossiliferous 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 at this section is 180 feet thick and is mapped as a 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 Bassett in his paper. The section as redefined by Bassett consists of: The Hume Formation which he equates with the Lower Ramparts of G. S. Hume: The Hare Indian which is considered the correlative of the Middle Ramparts shale: 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. The type section 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 and northeastern British Columbia. 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 located 4 miles north of Norman Wells. The Hume here is only 8.5 feet thick, and consists of limestone, black, shaley to slatey and fossiliferous. The basal 1 foot is a conglomerate indicating a disconformable contact with the underlying Bear Rock which is exposed. The Schooner Creek section is overlain by the Hare Indian Shale.

The Hume Formation is generally encountered as a non-porous rock both in outcrop and in the subsurface. The Keg River

Platform of northern Alberta is also normally a non-porous rock, however, it does develop into a marginal shoal along the northern flanks of the Peace River Arch. This marginal shoal is a very porous, granular, reefy dolomite which yields large quantities of water when drill stem tested. The marginal shoal is in turn replaced by a back shoal mud flat which is in turn replaced by shoreline sands. Patch reefs have developed in the mud flats back of the marginal shoal and some free oil has been recovered from drill stem tests run over them; however, to date no commercial wells are present in them. The shoreline sands have been found productive of oil in the general Red Earth - Utikuma Lake area. The facies pattern developed along the north flank of the Peace River Arch should have been repeated along 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.

The Hume has been described at various localities as being very petroliferous in part. This situation is also duplicated in the Keg River Platform of northern Alberta where it is overlain by the productive Keg River Pinnacle and atoll reefs. The Keg River Platform is almost certainly the source of the oil in these prolific reefs. Because of the similarities outlined above any reservoirs developed in the Hume must be considered as prospective hydrocarbon traps. Imperial Redstone No. 1 penetrated 855 feet of Hume sediments which consisted mainly of dark brown microcrystalline, argillaceous limestone with minor amounts of shale and dolomite interbedded with the limestone.

One test was run near the top of the Hume, however, only mud was recovered. The section appears to become increasingly shaley near the contact with the underlying Bear Rock. Imperial Hoosier Ridge No. 1, located in 65°, 24', 15.6" N., and 127°, 37', 13.9" W., lies about 100 miles northwest of the Permits under review and reported gas showings as well as traces of oil from the Hume Formation. The Hume is present at the Dahadinni River outcrop section in a grey to black limestone and dolomitic limestone facies. The section is also exposed at Bear Rock as a shaley limestone facies. The Hume was 658 feet thick in the Shell Cloverleaf 1-46 well. No tests were run in this well.

HARE INDIAN

The contact of the Hare Indian with the underlying Hume Formation 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 predominately shale to predominately limestone. Facies changes thus account for the diachronous nature of the contact as well as being the cause of some of the confusion which has surrounded correlations of the Devonian sediments in this region. The section exposed on Carcajou Ridge, which is about 115 miles northwest of the Permits in question, serves to illustrate this problem. On the south central side of this ridge the Kee Scarp

is 70 feet thick and lies on 21 feet of Hare Indian Shale, while on the northeast flank of the ridge it rests on limestones which are probably a facies equivalent of the Hare Indian Shale. The reef is only 6 feet thick on the west end of Carcajou Ridge. Further west of Carcajou Ridge the Hare Indian attains a thickness approaching 700 feet. The section at Carcajou Ridge 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 described above, it can thin to less than a 100 feet in a few miles. The thickness around Norman Wells is usually about 100 feet, while to the north of Norman Wells in the vicinity of Hoosier Ridge the section in wells drilled ranges from 500 feet to 800 feet. South of Norman Wells around the confluence of the MacKenzie and Redstone Rivers the Hare Indian is about 500 feet thick on the region of isopachs. Imperial Redstone No. 1, which is about 11 miles east of the Permits, penetrated about 600 feet of light to dark green and dark grey, in part silty shales of the Hare Indian Formation. Shell Cloverleaf had 342 feet of Hare Indian.

The relationship between the Kee Scarp Reef and the underlying Hare Indian and Hume Formations appears to be somewhat

analagous to the relationship between the Klua shales and adjacent reefs in the Clarke Lake area of northeastern British Columbia. The Klua shale, which is Middle Devonian, overlies the Keg River Formation and is overlain by the Slave Point Formation of bank carbonates in some wells, however, in others the reef growth initiated in the Keg River has continued on into the Slave Point with little or no interruption. In the latter case no Klua shale was deposited.

KEE SCARP FORMATION

The Kee Scarp Formation as redefined by Bassett 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 mentioned, is diachronous. The Kee Scarp Formation 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 platform or foundation unit is a biohermal 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 varies from zero feet to 350 feet in the Norman Wells area. The greatest overall measured thickness of the 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 Bassett redefined as part of the Imperial Formation.

The platform unit of the Kee Scarp is undoubtedly the correlative of the Upper Ramparts limestone unit mapped by Hume. This fact, as mentioned previously, means the Kee Scarp is a widespread formation since it is not restricted as it was previously to only the reef member. Since the Kee Scarp reef grows upwards from the foundation unit, any well drilled in this region must be considered a potential Kee Scarp producer.

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 Hare Indian thicks which were described under the discussion of that formation have not yet been found to contain reefs, however, they have certainly not been adequately explored either. Regional isopachs indicate Permits 5418 and 5421 are located on the northern margin of a Hare Indian thick and should thus be well located for Kee Scarp reef developments. The Kee Scarp platform in the Imperial Redstone No. 1 well, which is 11 miles east of the Permits is about 35 feet thick. It was not present in Shell Cloverleaf I-46.

The oil in the Norman Wells oil field is trapped in the updip end of a discrete Kee Scarp biohermal reef. The thickness of the reef varies up to a total of 495 feet. Reserves in the reef have been estimated as high as 60 million barrels. The

productive area of the field is placed at 2,600 acres.

CANOL FORMATION

The Canol Formation was defined by Bassett 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 very rarely calcareous, however, it is commonly sulphurous and siliceous. Fossils are very rare in the Canol. The Canol is overlain by the Imperial Formation of Upper Devonian age. It may be the equivalent of the lower part of the Besa River shale of northeastern British Columbia. The Canol thickness ranges from zero feet to 400 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 zero in places while it thickens in the off reef direction, consequently the thickness variation is quite large. The Canol Formation was 235 feet thick in the Imperial Redstone No. 1 well and consisted of grey-brown to brown silty shale and siltstone. It was 435 feet thick in Shell Cloverleaf I-46 and directly overlays the Hare Indian.

UPPER DEVONIAN

IMPERIAL FORMATION

The Imperial Formation was redefined by Bassett 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 Formation 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 lithologies of the Imperial are extremely variable which makes correlations within it very difficult. The thickness of the Imperial may reach more than 3,000 feet where the processes of erosion have not cut very deeply. The Imperial is exposed at the Dahadinni River section south of the Permits. They are also exposed north of the Dahadinni River along the Redstone River where they total about 2,420 feet in thickness. The Imperial in the Imperial Redstone No. 1 well was only 30 feet thick, however. in the Shell Keele River L-4 well, wnich is 5 miles north of the Permits, the Imperial Formation was not fully penetrated, however, the well did penetrate 1,948 feet of them before drilling was stopped. The Imperial in the Keele well was mainly green to brownish-green, calcareous shales with thin interbeds of siltstone, dolomite and marlstone. In the Shell Cloverleaf I-46 well it was 2,255 feet thick and was tested for a recovery of water cut mud. The three control wells are indicative of the magnitude of the sub-cretaceous unconformity in this area.

## CRETACEOUS

### SANS SAULT GROUP

The type section of the Sans Sault Group is along the Mountain River where it joins the MacKenzie River. The name is

derrived from the Sans Sault Rapids which are near the type section. The type section is about 140 miles northwest of the Permits. The Sans Sault is the basal group of Cretaceous sediments which lie directly above the unconformity separating the 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 section consists of shales and sandstones of marine origin. Some beds are quite widespread and form good marker beds. The Sans Sault Group is approximately 1,411 feet thick near the type section, while on the Mountain River, where it cuts through the Imperial Range it is about 3,850 feet thick.

SLATER RIVER FORMATION

The Slater River Formation overlies the Sans Sault Group and 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 numerous beds of bentonite which in outcrop are only 1/8 inch to 1 inch thick. The Slater River also contains a fish scale horizon which is thought to indicate an upper Cretaceous age for the formation. The section is about 1,000 feet thick at the type section. According to Hume, 400 feet of Slater River shales were seen in outcrop on the Keele River south of Norman Wells, but neither the top nor the bottom were seen.

LITTLE BEAR FORMATION

The type section of the Little Bear Formation is found about 75 miles west of Fort Norman on the Little Bear River. The beds consist of sandstone, some conglomerate, sandy shales and coal seams. The beds are not correlatable between areas due to their lenticular nature. The type section is 780 feet thick and contains marine brackish and freshwater fossils.

EAST FORK FORMATION

The East Fork Formation is named from a section exposed on the East Fork of the Little Bear River. The thickness at the type section is 850 feet thick and consists of a series of well stratified, grey, conchoidal and plastic marine shales. There are some thin, limey sandstone members and thin coal seams near the base.

The thickness of Cretaceous sediments which are present in any one place in the general Norman Wells region, including the area under study, is extremely variable. The Shell Keele River L-4 well penetrated approximately 2,170 feet of undivided Cretaceous sediments while the Imperial Redstone No. 1 encountered 1,690 feet of undivided Cretaceous beds. The Shell Keele River L-4 well encountered a 70 foot zone of siltstone, and sandstone with some chert pebble conglomerate at the base of the Cretaceous. The sediments are of marine origin and contain a dead asphaltic stain throughout, however, there was no more than 5 feet of intergranular porosity present which was not tested. The first

50 feet of shales above the basal sand, silt section also contained a dead asphaltic stain in a very dark grey to black to dark brown shale. From 1,470 feet to 1,600 feet in the Shell Keele River well there is a very porous, salt and pepper, medium coarse grained sandstone with kaolinitic and sideritic cement. The sand which is well sorted was tested and a recovery of 960 feet of fresh water was obtained. The well contains similar porous sands at 1,340 feet to 1,375 feet and from 675 feet to 990 feet, but they were not tested. The upper sand contains a fair percentage of chert pebbles and some siderite nodules. The remainder of the Cretaceous in this well consists of thin sandstone and siltstone stringers imbedded in brown to grey-brown to grey shales. From 1,600 feet to 2,220 feet the section is mainly dark grey shale. The Cretaceous section in the Imperial Redstone No. 1 well is mainly composed of dark grey shales with abundant ironstone nodules. The basal 130 feet contains minor, medium to dark grey siltstone stringers, while the upper 450 feet contains some thin beds of sandstone. The sands are salt and pepper, sideritic, medium grained kaolinitic with some poor porosity. A trace of glauconite was observed. There are also numerous thin dark grey siltstone stringers in this interval. The Shell Keele River well certainly has many more porous sands than does the Imperial Redstone well, indicating a shale out of reservoirs between them. The dead staining observed in the basal sand of the Shell Keele River well coupled with the shale out of the sands in an updip direction indicates that the Cretaceous should be carefully evaluated in any wells drilled in the vicinity of Permits 5418 and

5421. Cretaceous beds are exposed along the Keele, Dahadinni and Redstone Rivers, however, the sections are incomplete. The Cretaceous is exposed in the northeastern corner of Permit 5421, north of the Keele River.

## TERTIARY

Tertiary sediments in the Norman Wells area are not subdivided. They consist of conglomerates, gravels, shales, lignites, soft, coarse carbonaceous sands and soft clays. A thickness of 1,600 feet has been mapped on the Little Bear River. The East Fork has lignite beds 8 feet 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. Shell Keele River L-4 had 120 feet of sandstones which were unconsolidated and contained chert, till, pebbles of dolomite, granite and brown shale. The Imperial Redstone No. 1 contained 45 feet of much the same material as the Shell Keele River L-4 well.

## STRUCTURE

The Permits in question are located on the MacKenzie Plain, approximately midway between the MacKenzie Mountains to the west and the Franklin Mountains to the east. The MacKenzie Plain is characterized by many gentle folds and only minor faults. The Permits are crossed by at least two northwest trending synclines, one at the northeast corner of the Permits and the other strikes across Permit 5418 from its northwest corner to a point about 3

miles west of its southeastern corner. Anticlinal structures are not mapped on the acreage, however, two anticlinal folds lying to the northwest may extend onto the acreage. The cover of Tertiary and Cretaceous sediments tend to mask the surface structures on Permits 5418 and 5421, however, it would be very surprising if anticlinal structures could not be found on these Permits by other means.

It is recommended that further evaluation of the Permits under review consist of a gravity meter and an airborne magnetometer survey. They should be of great assistance in outlining the distribution of the Saline River Salt and any salt structures associated with it. The magnetometer may be of help in outlining the present Pre-Cambrian structure. The surface structures should be evaluated by a photo-geological study combined with a surface geological field party.

## 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 5418 and 5421. 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 seem 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 also be expressed as straight valleys or hills or by straight streams where the stream course is controlled by a fracture zone.

### VEGETAL LINEAMENTS

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

## INTERPRETATION OF FRACTURE DATA

The object of Fracture Analysis (Photogeophysics) is to

locate shallow to deep-seated structures 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 two to three 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 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.

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.

## FRACTURE ANALYSIS OF PERMITS 5418 and 5421

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 14,000 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 four 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 has been moderately scarred with glacial grooves and striations and that the direction of ice flow was about North 60 degrees West. 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 a 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 5418 and 5421 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 5418 and 5421 is probably quite small.

There are two areas on the mosaic where the fractures are less intense than the surrounding area.

Some fractures are present within these areas, but they do 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 5418 and 5421 are located on the MacKenzie Plain of the Northwest Territories, about 210 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. PRE-CAMBRIAN TOPOGRAPHY

Basement topography under Permits 5418 and 5421 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 sedimertary rocks is often great. The Granite Wash sand is usually present in the topographic "lows" on the Basement, but absent on the "highs". The Granite Wash is an excellent potential reservoir.

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

Many small faults have been reported by A. W. Norris (1955) in the Basement and immediately overlying rocks and these features could cause closure within the sedimentary units.

2. REEFS

Reefs of any age 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 5418 and 5421. 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 two 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 southeast corner of Permit 5418 and in the northwest corner of Permit 5421.

These Basement high features are most interesting from the oil and gas point of view. The general shape of these features 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 areas are over 1-1/2 miles in width. If a fault caused the fracture "low" the width of the low would be about 1 mile or less.

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. All profiles, A-$A^1$, C-$C^1$ and B-$B^1$ run at right angles to the strike.

Respectfully submitted by:

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WGC:mjh

# REFERENCES


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. - (1922, 1923)

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

Reconnaissance across Northeastern British Columbia and the Geology of the Northern Extension of Franklin Mountains, N.W.T.; Geol. Surv., Canada, Sum. Rept., 1922, pt. B., pp 65 - 87 (1923)

HUME, G. S. - (1954)

The Lower MacKenzie River Area. Northwest Territories, and Yukon. Geol. Surv. Canada, Memoir 273, 1954.

KEELE, Joseph - (1936)

A Reconnaissance across MacKenzie Mountains on the Pelly, Ross, and Gravel Rivers; Geol. Surv. Canada, Pub. 1097, 1910. Formation Names in the MacKenzie River Valley; Science, Vol. 83, No. 2140, pp 14 - 15 (1936).

NAUSS, F.W.

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

STELCK, C.R.

Upper Peele 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 (1959).

BASSETT, H.G.

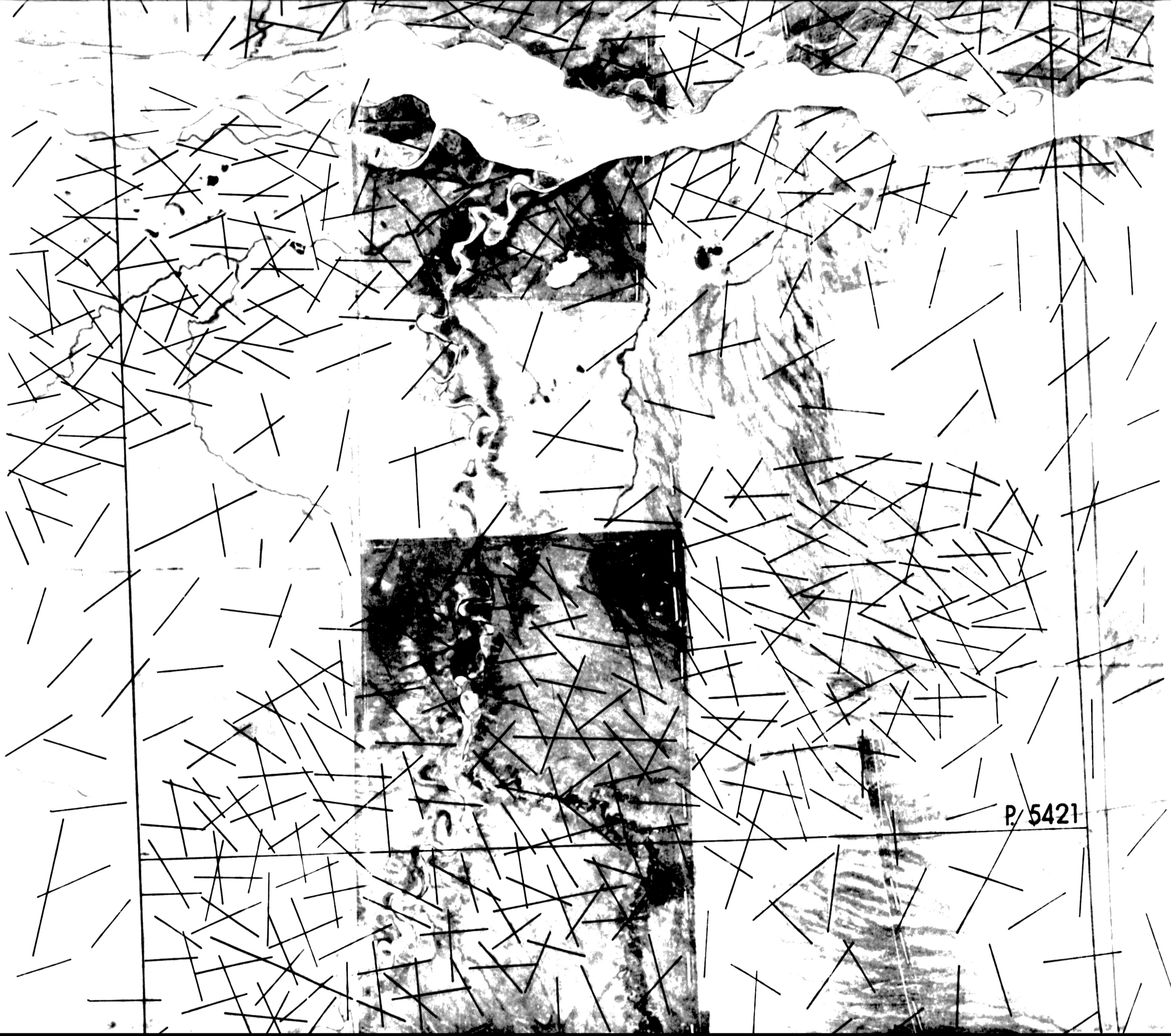
Devonian Stratigraphy, Central MacKenzie River Region, Northwest Territories, Canada, Geology of the Arctic. Vol. 1, pp 481 - 498

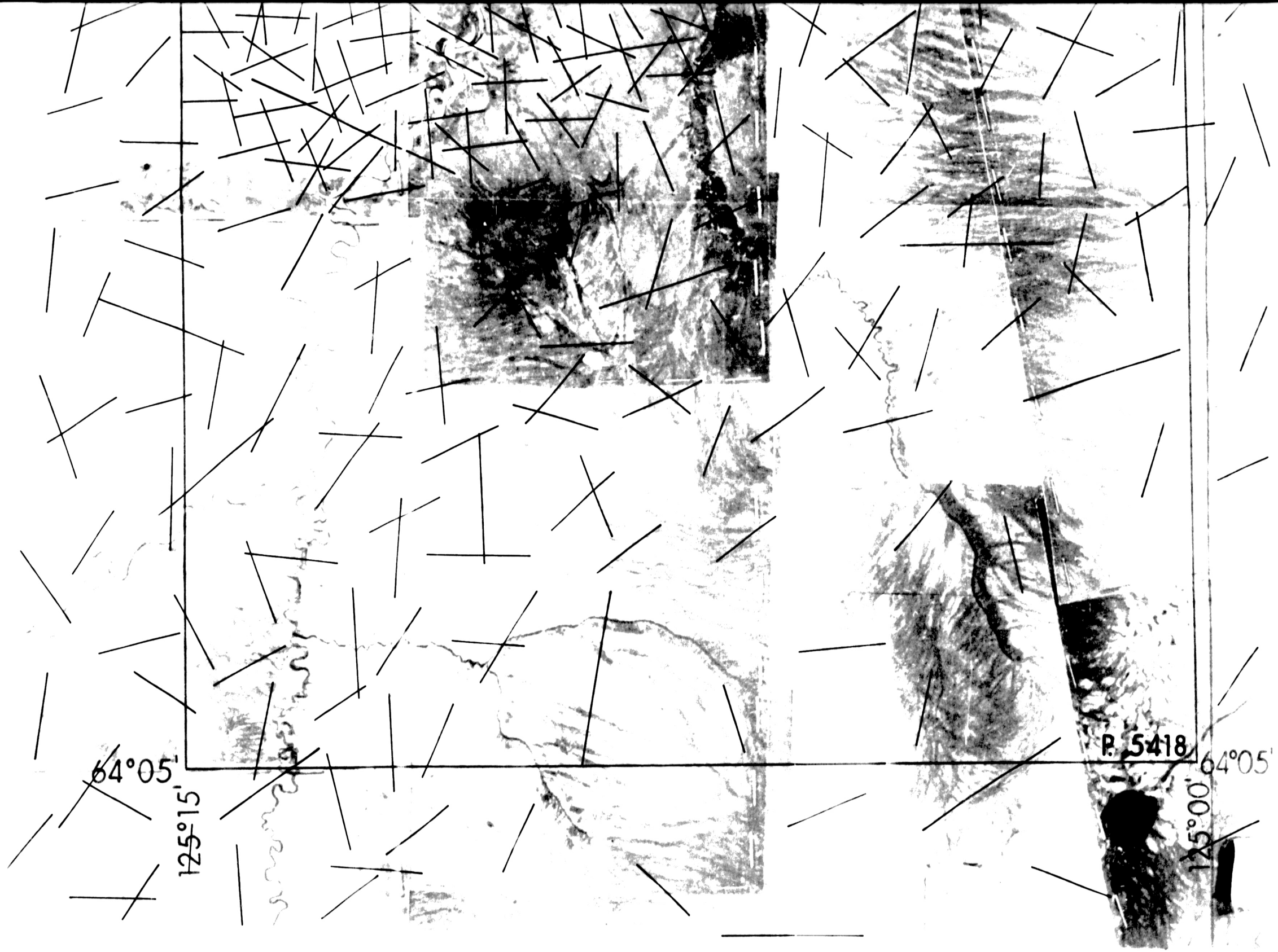
125°15'

64°20'

125°00'

64°20'


P. 5421


P. 5418
64°05'
125°15'
125°00'
64°05'

# MICHIGAN DEVELOPMENTS LTD.

## P. & N.G. PERMITS 5418 & 5421

4 of 4

SCALE IN MILES

1 0 1 2 3

[redacted]

# MICHIGAN DEVELOPMENTS LTD.

## P. & N.G. PERMITS 5418 & 5421

SCALE IN MILES

1 0 1 2 3

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

4 of 4

125°15'

64°20'

125°00'

64°20'

1 of

P. 5421

64°10'

64°10'

2 of

P. 5418

64°05'

125°15'

125°00'

64°05'

# MICHIGAN DEVELOPMENTS LTD.

## P. & N.G. PERMITS 5418 & 5421

## MEGA FRACTURE PATTERN

SCALE IN MILES

1 0 1 2 3

3 of 3

A'

125°15'

64°20'

125°00'

64°20'

A

B'

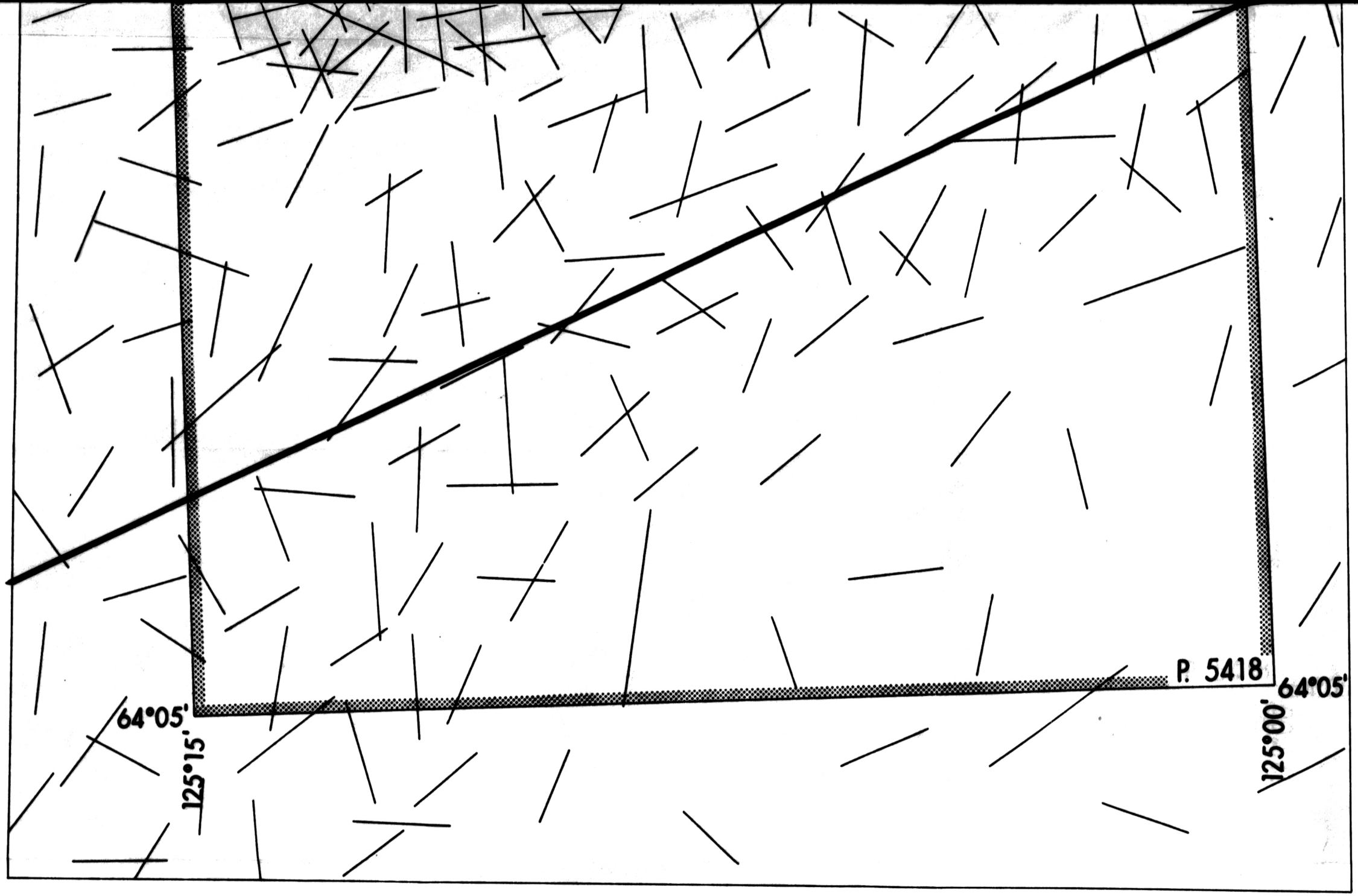
1 of

P. 5421

64°10'

64°10'

C'




# MICHIGAN DEVELOPMENTS LTD.

## P. & N.G. PERMITS 5418 & 5421

## TOTAL FRACTURE PATTERN

SCALE IN MILES

1 0 1 2 3

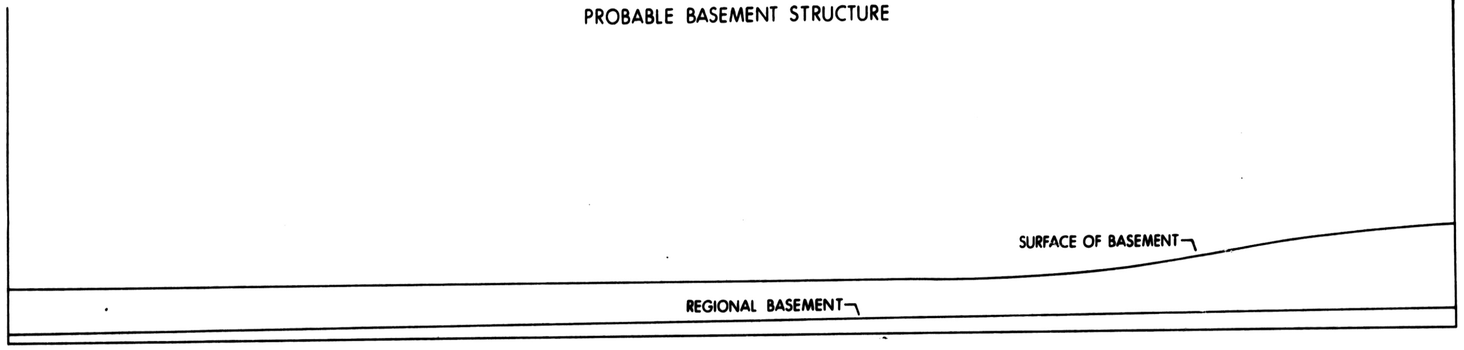
LOW DENSITY | NORMAL DENSITY | HIGH DENSITY

393

B

B'

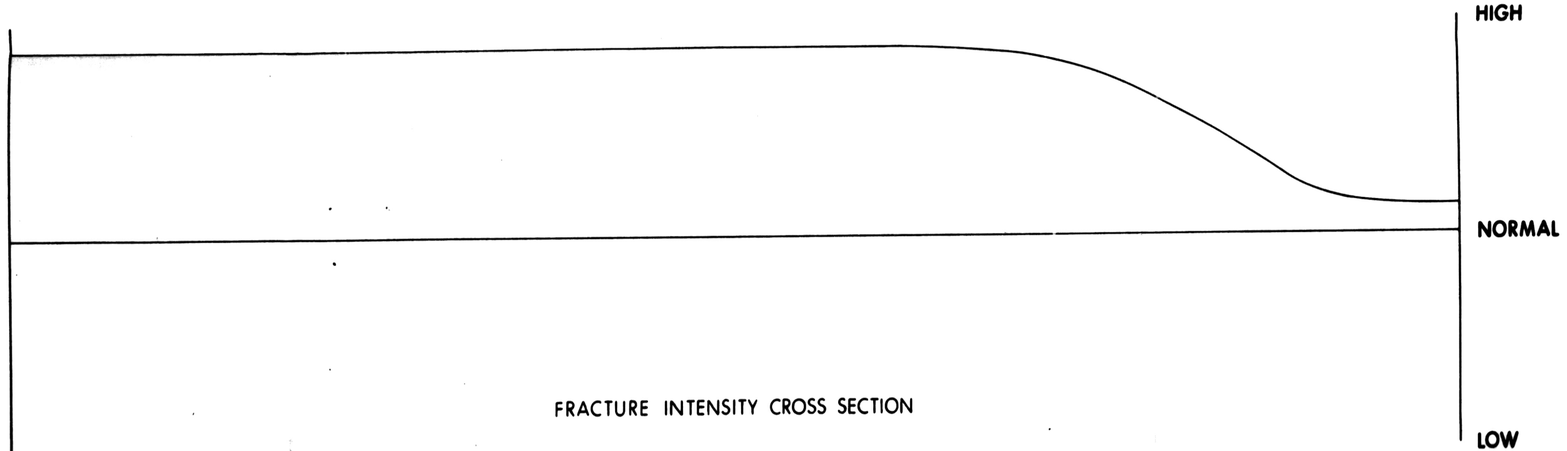
PROBABLE BASEMENT STRUCTURE



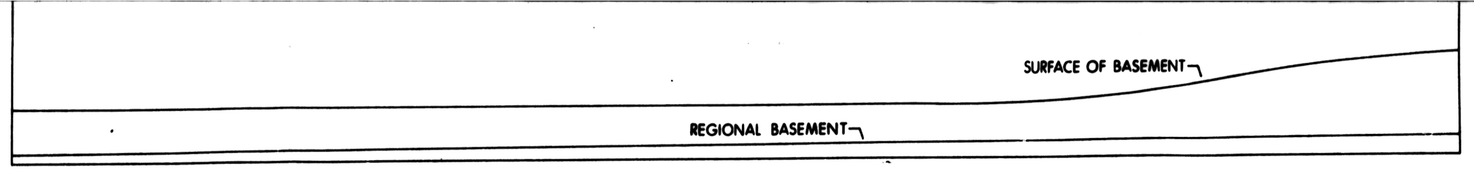


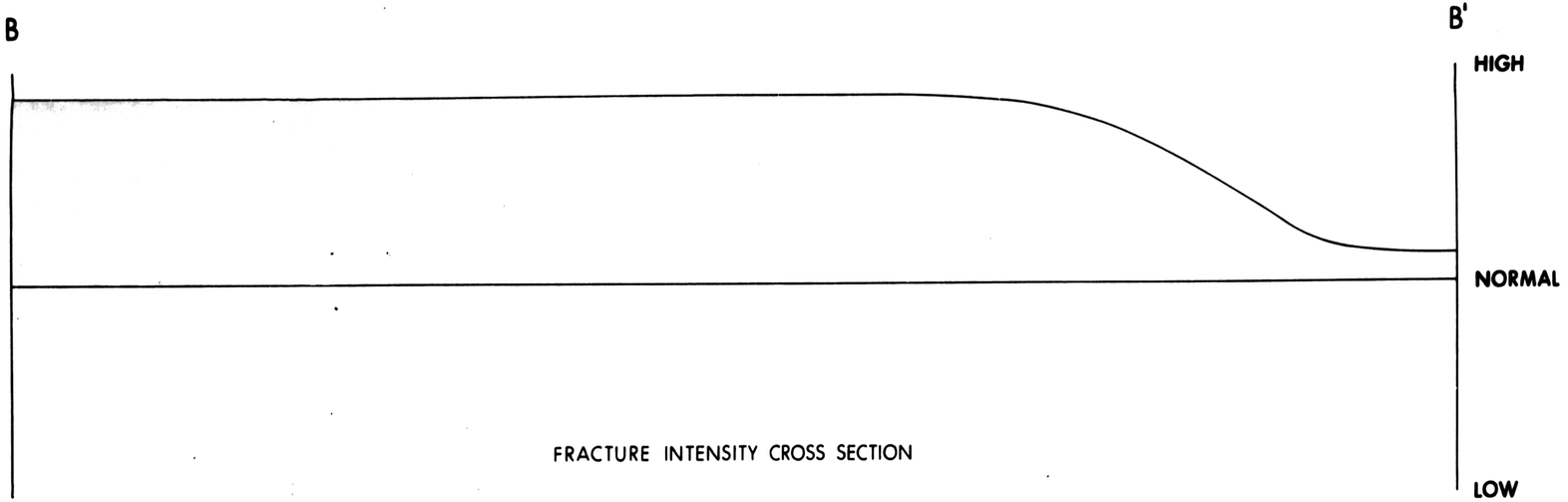

B

B'




FRACTURE INTENSITY CROSS SECTION




FRACTURE INTENSITY CROSS SECTION

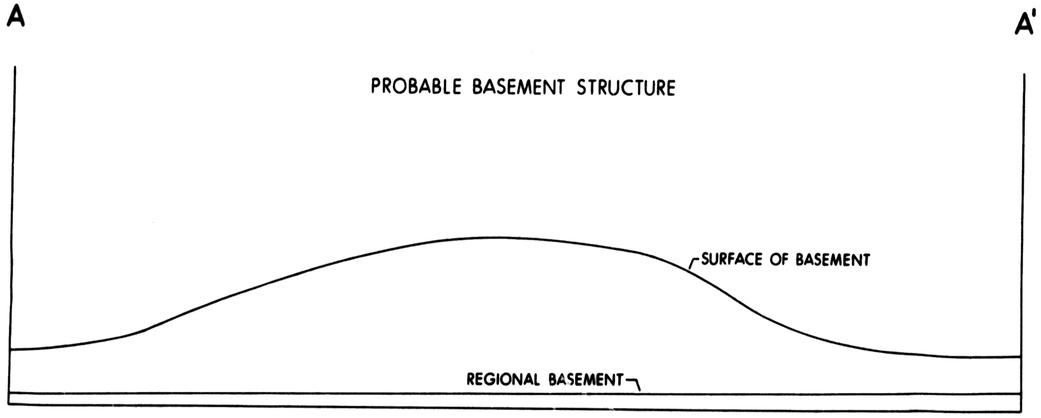
# MICHIGAN DEVELOPMENTS LTD.

## P. & N.G. PERMITS 5418 & 5421

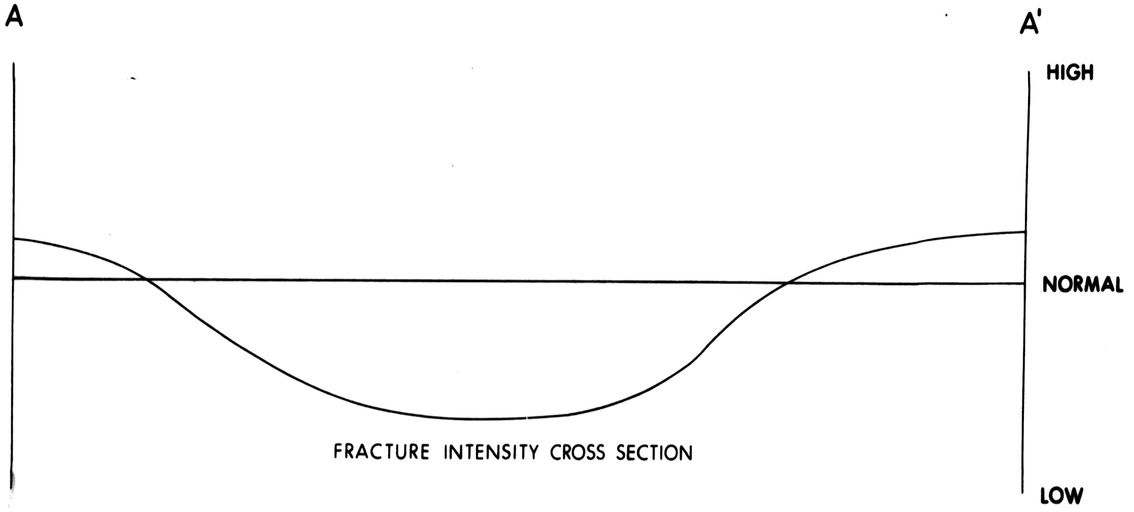
SCALE IN MILES

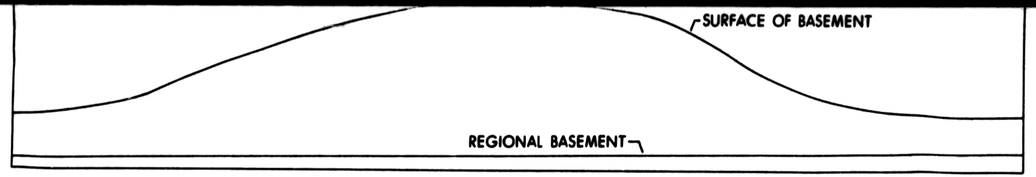
1 0 1 2 3

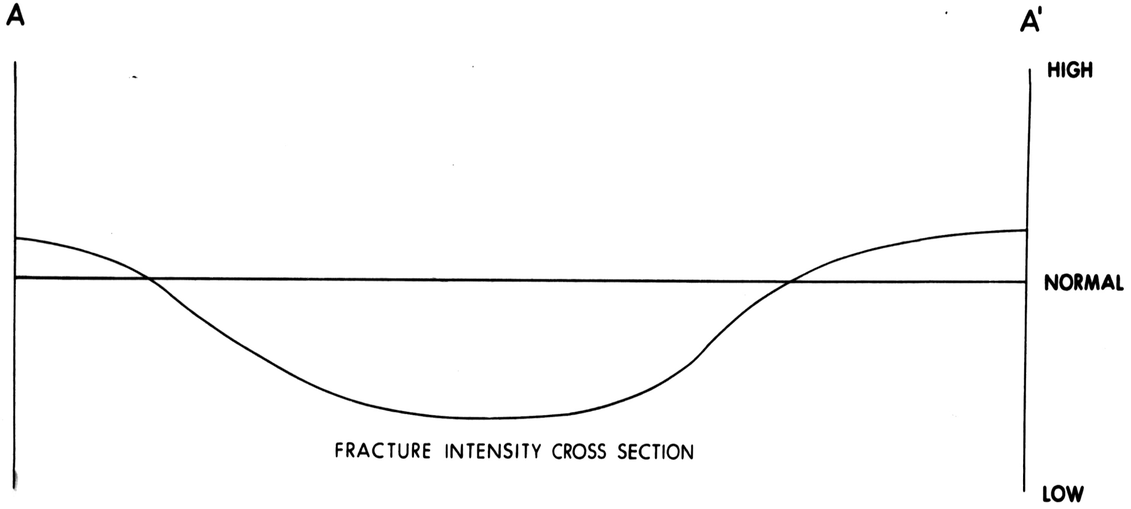
242


A
A'
PROBABLE BASEMENT STRUCTURE
SURFACE OF BASEMENT
REGIONAL BASEMENT




A
A'
HIGH
NORMAL
LOW
FRACTURE INTENSITY CROSS SECTION




FRACTURE INTENSITY CROSS SECTION

# MICHIGAN DEVELOPMENTS LTD.

## P. & N.G. PERMITS 5418 & 5421

SCALE IN MILES

1 0 1 2 3

2 of 2

C

C'

PROBABLE BASEMENT STRUCTURE

SURFACE OF BASEMENT

REGIONAL BASEMENT



C

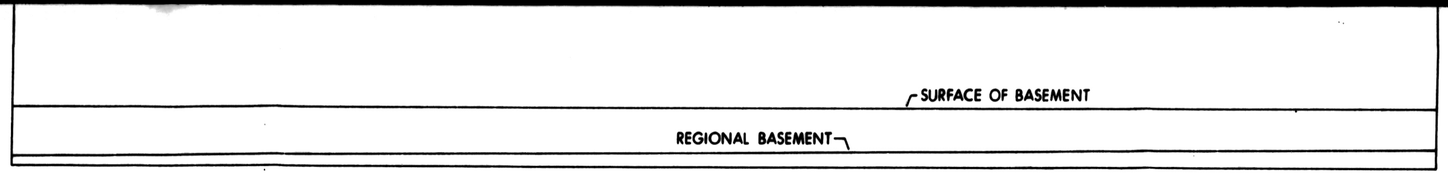
C'

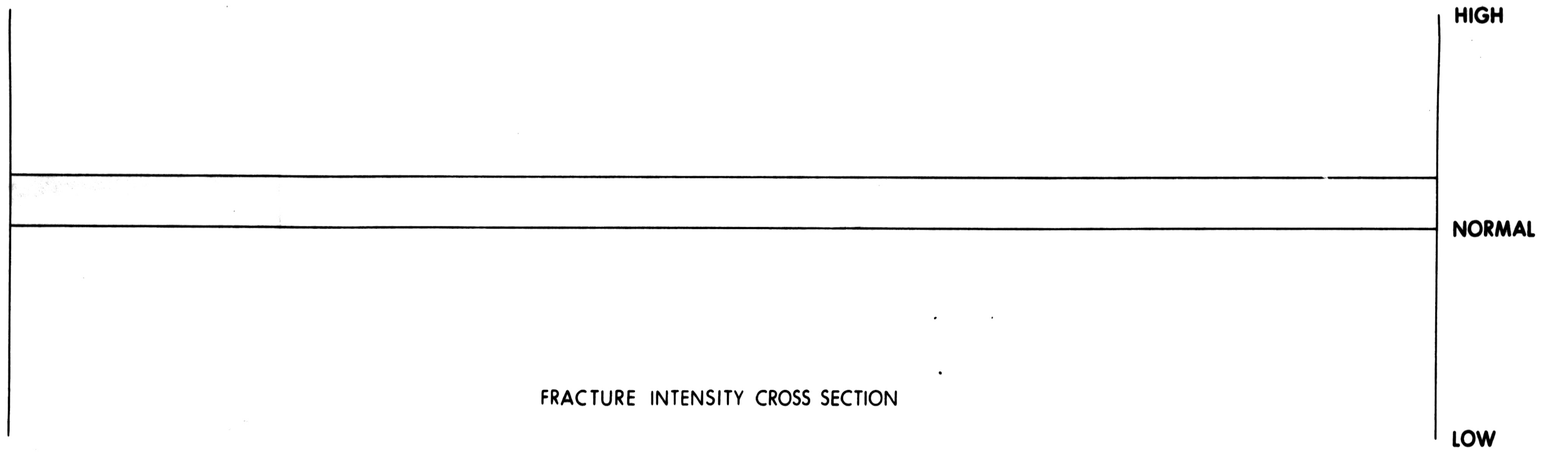
HIGH

NORMAL

FRACTURE INTENSITY CROSS SECTION

LOW




FRACTURE INTENSITY CROSS SECTION

# MICHIGAN DEVELOPMENTS LTD.

## P. & N.G. PERMITS 5418 & 5421

SCALE IN MILES

1 0 1 2 3

KODAK SAFETY FILM