BASEMENT LITHOLOGY IN MICHIGAN AS DETERMINED FROM WELL CUTTINGS

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ABSTRACT

This study examines the cuttings from all of the fifteen Precambrian basement tests in the Lower Peninsula of Michigan. The lithologies that are observed are in agreement with lithologies for the various provinces that outcrop around the periphery of the Michigan Basin and can be reasonably extended under the Paleozoic cover using geophysical data. Magnetic susceptibility measurements made on the samples cannot be conclusively related to magnetic data, but one case indicates a correlation with a high magnetic anomaly.

BASEMENT LITHOLOGY IN MICHIGAN

AS DETERMINED FROM WELL CUTTINGS

By

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INTRODUCTION

There has been much discussion on the nature of the basement rocks of the Michigan Basin for a number of years. The rocks considered will be those crystalline and metamorphic rocks covered by the Paleozoic sediments dipping toward the center of the Michigan Basin. Their lithology as encountered in deep drilling through the Paleozoic sediments is related to the rock types typical of the exposed Precambrian provinces surrounding the Michigan Basin. The rocks range in lithology from granite to meta-basalt (greenstone) and quartzite.

The results of the magnetic susceptibility of the rocks as observed in this investigation are related to a magnetic survey of Michigan.

HISTORY OF PREVIOUS INVESTIGATIONS

Although there has been much curiosity about the basement rocks of the Michigan Basin for a good many years, most of the investigations have centered around geophysical interpretive techniques because very little is known from drill holes. The most recent work is that of Kellogg (1971) in his aeromagnetic study of the Lower Peninsula of Michigan, and a gravity and magnetic interpretation by Hinze and Merritt (1969); both of these studies have interpreted broad zones of lithology in the basement. Lidiak (1966) determined lithology and age dates of samples for wells in Washtenaw and Monroe Counties, but the most comprehensive study of covered Precambrian basement rocks of Michigan was by Yettaw (1967), who worked on samples from rocks penetrated by the Security-Thalman #1 well in Berrien County, but with little attempt to tie in data from other wells.

The only other significant source of information is the well logs that are available at the Michigan Geological Survey. These logs have been written, for the most part, by drillers or petroleum geologists and put into the Survey's format without significant change. Some of the samples were looked at by Survey geologists, but not described in detail since they fall below any possible production of oil, and often only the top of the Precambrian was recorded.

The first well to penetrate the basement was drilled in St. Clair County in the late 1920's, and several followed in the 1940's in the eastern part of the State. The Precambrian rock in most of these wells was described as a granite or granite gneiss with one in Washtenaw County being described as a schist. There were some wells drilled in the 1950's into felsic rock in the eastern part of the State and on Beaver Island. In 1964 Consumers Power Company drilled a brine disposal well in St. Clair County which penetrated the Precambrian, and a core was taken. In 1962 the Security-Thallman #1 was drilled in the southwestern part of the State, the only basement test in this area. The Pan American

Drasey #1 was drilled in Presque Isle County in 1967, and the latest Precambrian well was completed in 1970 in Livingston County by the Mobil Oil Corporation. There are a total of 17 basement tests in the Lower Peninsula of Michigan; samples are available for 15, including one core. Other wells drilled in the Michigan Basin penetrating the Precambrian have been drilled in Ohio, Indiana, Wisconsin, and Ontario as well as in the eastern Upper Peninsula.

BASEMENT PROVINCES

It is generally considered that there are four provinces in the basement of the Michigan Basin. A province is defined as an area where the rocks are of similar type, age, and metamorphic grade. Other criteria include similarities in the magnetic and other geophysical characteristics. One of the provinces is the Penokean, which covers the Upper Peninsula and the northern part of the Lower Peninsula. It is described from Wisconsin (Dutton and Bradley (1970)), the western Upper Peninsula, and from Ontario north of Lake Huron. The age dates range from 2.2 to 1.32 b.y. indicating a long range of activity. The rock types run the full range from acid to basic igneous, and there are many types of metamorphic rocks, particularly quartzites, associated with this province.

The Central province covers the largest part of the southern Lower Peninsula and extends into Indiana from western Ohio and thence into Illinois, southern Wisconsin and Iowa. The ages obtained for the rocks of this area average about 1.2 b.y. (Lidiak, et al (1967)). Rock types in this province range from felsic to basic with some metasediments.

Perhaps the best defined province in the basement is the Grenville which occurs in the east and southeast parts of the State. The dates, .9 to 1.1 b.y., obtained by Bass (1960)correlated with what he had found in central and eastern Ohio and into Ontario where the Grenville outcrops. The dates obtained in Michigan agree very well. Most of the Grenville rocks are metamorphic, although there has been some igneous activity. The Grenville in Ontario adjacent to Michigan is mostly metasediments and amphibolites with gneisses present.

The fourth major rock type present in the Michigan Basin is the Keewanawan, but it is not recognized by all geologists because there is no direct lithologic evidence or age dates. The Keewanawan is dated in its outcrop area in the Upper Peninsula and Wisconsin at 1.0 to 1.2 b.y., and therefore is slightly older than the Grenville. Its presence in the Lower Peninsula is indicated only by the Mid-Michigan gravity high and the correlative magnetic anomalies. These have been suspected for some time as being caused by extrusive or intrusive basic igneous rocks, and are continuous with Keewenawan basic extrusives in the type area. It can be seen that the Mid-Michigan anomalies cut across the grain of the gravity and magnetic anomalies of the other provinces, and it can be reasonably said that the rocks causing the anomaly are younger, have higher density and higher magnetic polarization.

The dividing line between the Penokean and Central provinces must fall somewhere across the Lower Peninsula, but on geophysical evidence is difficult to determine. In the north the magnetics show an east-west trend, and the anomalies tend to be of short wavelengths. In the south the trends are similar but seem to curve slightly to the southeast. In the central part of the basin, the depth to the basement reduces the sharpness of any break, and the exact delineation of the two provinces with apparently similar geophysical properties becomes impossible.

The Grenville province's magnetic "finger print" is very clear in the eastern part of the State. The trends all fall into a northeast-southwest pattern that disappears just about at the Livingston-Ingham County line. This trend can be traced down into Ohio and up across Lake Huron into Ontario where Grenville rocks outcrop.

LITHOLOGIC RESULTS

The Michigan Basin in the Upper Peninsula extends from eastern Dickinson County east to the end of the peninsula and then into Manitoulin Island in Lake Huron. In this area there are few basement tests, except for a series of holes around Escanaba. There is only one hole in the eastern part of the peninsula, on Neebish Island. The lithology that is reported for these wells is recorded at the offices of the Michigan Geological Survey at Lansing.

The range of lithologies in this area is great, even where there is not a great deal of space between the wells.

(See Table 1). There is a good correlation of the reported iron formation and the large magnetic anomaly that is located just to the west of Escanaba. The rest of the lithologies that are reported in the western part are granite, greenstone, and other metamorphic rocks such as talc schists.

On Neebish Island the well is reported to have encountered quartzite. There is quartzite outcropping on Manitoulin Island, and it is entirely likely that these rocks are genetically related since Manitoulin is in such close proximity. The samples from the Upper Peninsula were not examined.

The Pan American-Drasey is a very interesting well in that it penetrated two distinct lithologies in the basement. The first is a very clean quartz rock, and the second is a greenstone of basaltic or diabasic origin.

There has been some controversy about the origin of the quartz. Reed (1971) feels that the quartz is so clean that it has to be vein material, but there is only a very small chance that this is the case because it would require a direct hit on a nearly vertical vein to get the 210 feet encountered. The geographical proximity of this well to the quartzites that are encountered in Neebish and Manitoulin Islands, as well as the shapes of some of the intergrowths and the graininess of the cuttings lead to the conclusion that this is a meta-sedimentary quartzite. It is entirely possible that the rock was originally a well washed sandstone with silica cement. Most of the old grain boundaries have been destroyed in recrystallization. (See photos 1 and 2.)

There has not been any controversy as to the origin of the greenstone. It was described in the log that was published by the Michigan Geological Survey as being of basaltic or diabasic origin. This is confirmed, for when a thin section is examined, the plagioclase laths are clearly visible (see photo #3). The other minerals that are seen are chlorite and other types which indicate low grade metamorphism. There is some quartz, but this is a very minor constituent. The extremely fine grain nature of the rock makes further identification impossible.

The other well in the Lower Peninsula that has penetrated possible Penokean rock is located on Beaver Island. There are actually two wells on Beaver Island, both drilled by the McClure Oil Company, but no samples are available for the State Beaver Island #1. The examination of the State Beaver Island #2 indicated a medium grained granite that could have gneissic texture. The magnetic examination shows the samples to fall into the broad range for granite, although at the lower end. This would indicate that there is a low magnetite content in the rock. The age date that is given for the rocks at Beaver Island is only 1.10 b.y. which would fall into the range that is given for the Keewanawan, although granitic rocks of Keewanawan age are uncommon in the outcrop area. There are several possible explanations for the Keewanawan age of this granitic rock. One theory is that the rocks are a product of magmatic differentiation of the more common basic rocks. The fact of the low magnetic susceptibility can be used to support this theory, in that the magnetic minerals have been caught up in the basic rocks and depleted in the later stages of differentiation. (Bass (1964) states that there is an anomalously high amount of Rb in the samples, and he feels that this, along with some fluorite that he saw indicates to him that this is a differentiation product.) Another explanation is that an older (Penokean) granite was metamorphosed by the Keewanawan igneous activity as indicated by the closeness of the gravity and magnetic anomalies, and redated.

The Central province is postulated to run through the southern part of the Lower Peninsula of Michigan and Ohio near the border with Indiana, west through Indiana, Illinois, Wisconsin, and Iowa. The best indication of this province extending into Michigan comes from the magnetic signature of this province in the southern Lower Peninsula. A study by Rudman and Blakely (1965) of an aeromagnetic anomaly in Indiana indicates that there is a great range of susceptibilities in the basement. The range that is published is from 66×10^{-6} e.m.u./cc for a rhyolite in Ohio to 7200×10^{-6} e.m.u./cc. for a basalt in Indiana. In general the values fall into the range of 250×10^{-6} to 400×10^{-6} e.m.u./c.c.. This accounts for the relatively flat magnetic contours except where interrupted by basic rocks of much higher susceptibility. In Wisconsin Dutton and Bradley (1970) have compiled a list of age dates from south to north along the center of the State. There is a trend for the older dates to fall to the north, as would be expected, which indicates a Penokean age for this part. The problem comes in the middle of the State where there is a mixture of dates. This seems to indicate a transition zone of Penokean crust that was intruded by Central province rocks. It is the feeling of Stonehouse (1971) that tectonic activity in Penokean time was early (2.2 to 1.8 b.y.), and the final phase (1.8 to 1.4 b.y.) was not so much orogenic as quiet igneous. Stonehouse (1969) draws the boundary line of the Central province through Michigan south of Saginaw Bay, based on the break in magnetic trends and age dates in Wisconsin to the west. Hinze and Merritt (1969) draw the line through southern Saginaw Bay and use the rationale that the trends and wave lengths of the magnetic anomalies are different. It is the feeling of this author that there is most likely a zone of transition that fills the space between the lines that have been drawn.

The Security-Thalman #1 is an unusual well in that it penetrated 1040 feet of Precambrian rocks. The samples were described by Yettaw (1967) as a medium grained granite that appeared gneissic in part and thus agrees with the lithology type of the Central province. Layton (1970) feels that this could be a zone of deep weathering and that the rock is actually a granite wash; this is difficult to believe because of the great thickness. The main argument used to call the whole section a regolith is the speed at which the drill penetrated the rock. There is an explanation for this when one looks at the cuttings which are very fine and broken up. This condition could be caused by high bit pressure which would result in increased drilling rates. The nature of the rock could be an asset here, too, because of the brittleness of a solid crystalline rock. The quartz in the rock could also act as an abrasive in cutting the softer minerals of the rock. The condition of the mineral grains is too fresh to indicate a regolith. This fact is further substantiated by the fact that good fresh sharp quartz and feldspar grains are found close to the top of the section (see photo). There is some regolith present at the base of the Cambrian sandstone section.

The Grenville rocks are the most drilled and therefore the best defined in the Lower Peninsula of Michigan. The first real proof that the Grenville did extend into Michigan was by Bass (1960) when he dated several wells in eastern Michigan. Along with the wells for which he had age dates in Ohio, Bass was able to set a minimum westward line for the Grenville front. Since then there have been new basement tests drilled, and these confirmed the earlier findings. Hinze and Merritt (1969) placed the Grenville front at about the Livingston-Oakland County line and north-northeastward to Saginaw Bay, on the basis of preliminary magnetic data. The work of Kellogg (1971) along with the lithologic data for the Mobil-Messmore #1 acquired in this study has brought the Grenville front west to the Ingham-Livingston County line, then trending northeast. The Grenville is marked by a magnetic lineation to the northeast that continues across Lake Huron and into Ontario into the rock outcrop area. In southeast Michigan the Grenville is an area of broad magnetic lows with only a few highs. One high is in southern Wayne County and is penetrated by the Sturman-Chapman #1, as can be seen in Table 2. The magnetic susceptibility is on the high side for a granite. There is another magnetic anomaly located on the western boundary of St. Clair County and one in the Howell area, which is the major anomaly of southeast Michigan.

The general lithology that has been observed in the Grenville of Ontario is made up of calcareous and argillaceous metasediments, basic volcanics, granitic gneiss, and both basic and acid intrusives with the last predominating. In Ohio the basement lithology is typically a granite gneiss with some basic rocks. In southern Michigan the main lithology is also a granitic gneiss with some altered basic rocks.

Samples from the St. Clair Oil and Gas-Hurst #1, the first basement well drilled in Michigan, were in very bad condition due to the rusting of contaminating steel. It is for this reason that the magnetic susceptibility was not run and that biotite was the only mineral that could be clearly identified.

The Bernhardt-Puzzuoli #1 a few miles to the south is a more recent well, and therefore the samples were in better condition. The basement rock here is a gneiss with bands of quartz-rich rock, and others that run very high in biotite and plagioclase. Often the biotite bands were also rich in magnetite causing a sharp increase in susceptibility. This well is drilled on the edge of a magnetic gradient that appears to increase into Canada. The area to the west of the well is magnetically very "flat", indicating a low susceptibility contrast between rocks in this area.

Continuing to the south along the east boundary of Michigan the next well that is encountered is the Marathon-Woodhaven #1, drilled as a brine disposal well in 1967. This well is on the north flank of the magnetic anomaly that is located in southern Wayne and northern Monroe Counties. The rock is a granite gneiss, but the magnetic susceptibility is not particularly high; however, the anomaly could result from local rocks such as are sampled in the Sturman-Chapman #1 or something deeper. The Chapman well is interesting in that it has a very well developed regolith just above the basement rock. The percentage of minerals in the regolith interval is almost identical to that seen in the solid rock, the difference being in the weathering of the mineral grains. The feldspars are fractured and broken along cleavage planes, and the corners have been rounded and the surfaces clouded by weathering alteration. The quartz grains are rounded and slightly frosted, and many of the ferro-magnesian minerals are rusted or entirely absent. The results can be seen in Table 2. It is unfortunate that only 1.5 feet of basement were penetrated for it would be interesting to see what effect depth would have on composition and magnetic susceptibility.

The Furgison and Garrison-Shimp #1 sample is best described as an intermediate gneiss because of both lithologic and magnetic considerations. The lithologic examination indicates several bands that are very rich in chlorite and therefore were probably mafic materials that were altered, while the quartz-feldspar bands were not altered. The feldspars appear to be at least 50 percent plagioclase, and probably more in the chlorite rich bands. Bass (1965) x-rayed the green minerals from this well and concluded that they were iron-rich chlorite mixed with biotite and muscovite. This study did not disclose any muscovite because of extremely fine grain size.

Beck-Sancrant #1 well has penetrated more basement than any in Michigan, over 1900 feet. There are no samples at all from the Middle Ordovician down to the top of the basement, and therefore the drillers top must be believed. There are good samples for several hundred feet into the basement, and then none for over 1500 feet, with a few samples from the bottom 50 feet which are contaminated. The rock is a granite gneiss that is rich in quartz, but some of the quartz as usual comes from up hole caving, as indicated by the very worn condition of the grains. The volume of the samples that were saved is so small that accurate measurement of the magnetic susceptibility was not attempted.

Granite is encountered in the Eckert-Taylor #1 a few miles to the north. The percentages of minerals in this well are the closest to a "text book" granite that was encountered. This perhaps means that this is a plutonic rock rather than a metamorphic one. It is also possible that this rock was cut with less bit pressure, and therefore there was less crushing and better retention of the feldspars in the samples.

It is evident from the sample descriptions that rocks from the basement are rather uniform in appearance, and this is confirmed by the flat low magnetic character. Moving to the west, the rocks become more diverse.

The Colvin-Meinzinger #1 samples again indicate a granitic rock. This is one of the wells dated by Lidiak (1966) at 1.05 b.y. The samples in this well were badly contaminated by drill steel and the susceptibility was not run.

An interesting fact to be noted at this time is that all of these wells mentioned above fall between 0 and 250 gammas on the aeromagnetic map of the Lower Peninsula of Michigan. The wells that will be discussed from here on all fall above the 250 gamma contour although the susceptibilities of some of the samples are very low, reflecting that the rocks in the immediate vicinity of the well did not contribute significantly to the anomaly.

The Chamness-Tory #1 and the Colvin-Voss #1 are only a few miles apart and bottom in similar types of rock, rich in biotite and chlorite. In the case of the Tory well there is considerable contamination from up hole, and previous work (Michigan Geologic Survey log and Lidiak) has described the rock as a granite (?). The Voss well has been dated at .95 b.y. It is possible that these rocks are related to the rocks that cause the Howell anomaly; however, they do resemble the rocks from the Shimp well, which is not close to a magnetic high.

The most recent well to penetrate the basement in Michigan is the Mobil-Messmore #1 that was drilled in Livingston County in 1970. The cuttings and stubs for this well were available, and therefore thin sections were prepared. The lithology from the cuttings appeared to be an intermediate gneiss because of the textures and minerals present. The magnetic susceptibility is unexpectedly low in this rock, averaging only 55.37×10^{-6} e.m.u./c.c. When the thin sections were studied, it became apparent that the rock was made up of more than 80 percent plagioclase that was analysed by the twin angle method and shown to be oligoclase or andesine. The crystals are very small and very few are twinned except for some of the relict grains. There are difinite metamorphic structures seen in thin section as grains of opaque mineral flow around relict grains in response to stresses applied during the recrystallization. Turner and Weiss (1963) define this as a schistose texture, but since the whole rock cannot be seen, it will be considered a gneiss because of the lack of micaceous minerals. The opaque mineral is hematite rather than magnetite, and there is some leucoxene and some sphene present; quartz less than 5 percent in any sample and in most samples less than 2 percent. A few grains of pyroxene and some flakes of biotite occur, but all are minor when compared to the amounts of plagioclase and hematite. The lack of magnetite and ferromagnesian minerals tends to suggest oxidation before recrystallization, but this remains to be proved. An age date is being run at this time and is not yet available.

The only core taken in the Michigan Basin from the basement is from the Consumers Power Company-Brine disposal #1 in St. Clair County. It was loaned for the purpose of this study by the subsurface laboratory of the University of Michigan. The core chips were also studied, and it was found that they came from where the core was broken along joint planes and where alteration was heaviest. Within about 3/4 of an inch on either side of the break chlorite was predominant. The rock as a whole is a highly altered gneiss of intermediate to mafic composition. The most common minerals are chlorite, biotite, and plagioclase with some potash feldspar, quartz, pyroxene, hematite, and leucoxene. The core was washed and examined both wet and dry with a 10x hand lens and then 9 one-inch diameter cores were cut from the core as shown, to facilitate magnetic susceptibility measurements; the magnetic susceptibility is even lower than that found in the Messmore well. Finally thin sections were prepared from six of the smaller cores.

CONCLUSIONS

1) Lithologies consistent with those found in the outcrop area of the Penokean province are found in Presque Isle County and on Beaver Island, in the Lower Peninsula and all throughout the Upper Peninsula. Age dates not consistent are attributed to Keewanawan intrusion. The southern province boundary may therefore occur on a line from Manistee to Tawas City as suggested by geophysical data.

2) Rock that is consistent with the lithologies found in the Central province occurs in Berrien County.

3) Rock types that agree with what is found in the outcrop area of the western Grenville province are found in southeast Michigan east and southeast of a line from the Ohio border, along the Ingham-Livingston County line and through Saginaw Bay City.

4) Nothing new can be said about possible Keewanawan rocks at this time.

SUGGESTIONS FOR FURTHER INVESTIGATION

The best suggestion for further work is to have more basement tests drilled in areas of scientific interest. These could be best defined by geophysics. The strong anomalies of the Mid-Michigan gravity high would be an ideal place to start so that one could obtain both lithological and age date data.

Other areas of strong interest include the transition area in the center of the basin. The depth to the top of the basement in this area makes any such test highly unlikely, however. The area of the Albion-Scipio trend is interesting in that it has been postulated that movement in the basement is the cause of the fracture related dolomite that is the oil trap. Just to have samples from any of these locations would add much to what we know, for the spacing of wells is now so wide that any correlation is impossible.

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APPENDIX

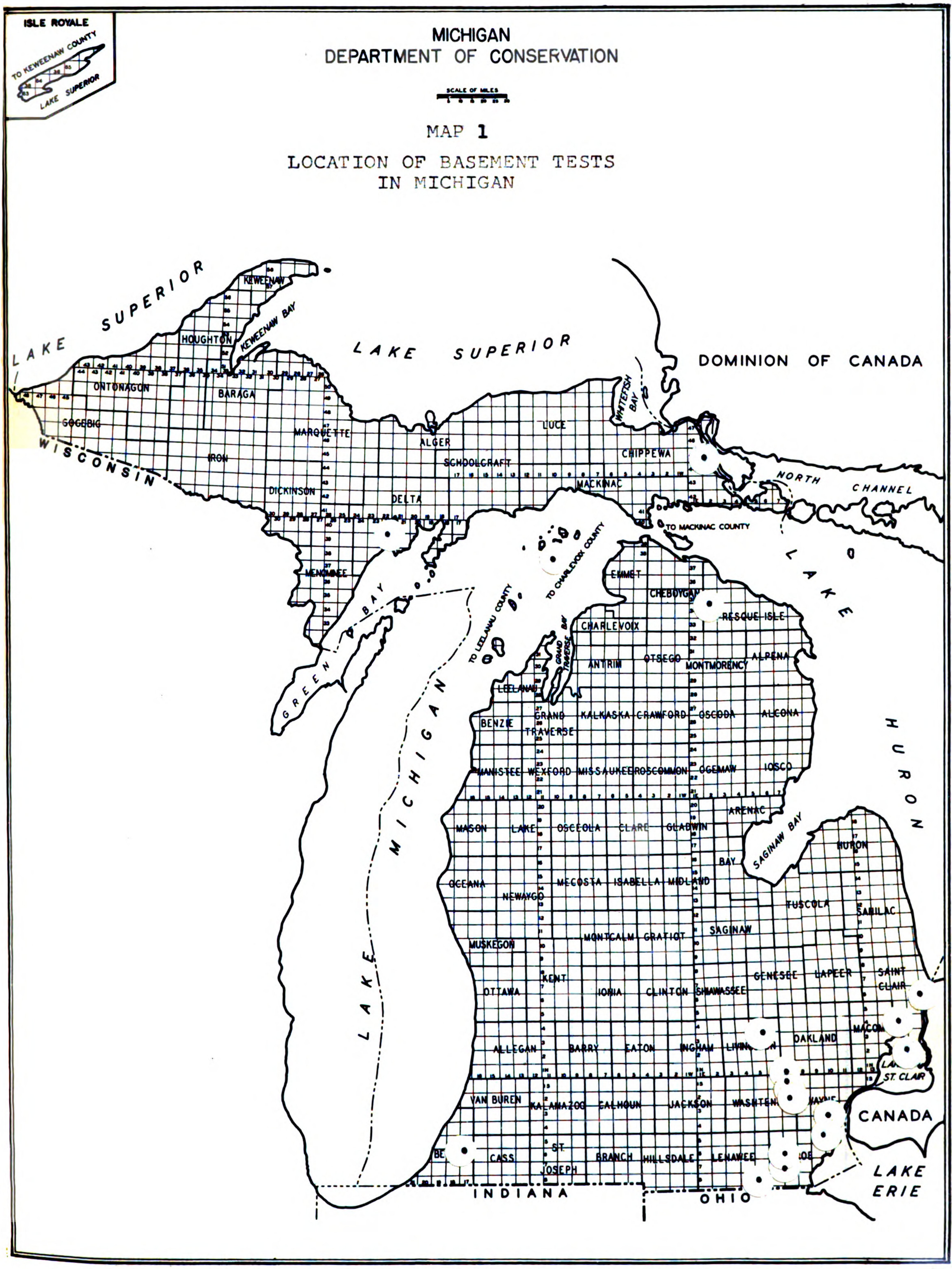
MICHIGAN
DEPARTMENT OF CONSERVATION
SCALE OF MILES
MAP 1
LOCATION OF BASEMENT TESTS
IN MICHIGAN
ISLE ROYALE
TO KEWEENAW COUNTY
LAKE SUPERIOR
LAKE SUPERIOR
DOMINION OF CANADA
NORTH CHANNEL
WISCONSIN
KEWEENAW
HOUGHTON
KEWEENAW BAY
ONTONAGON
BARAGA
GOGEBIC
MARQUETTE
IRON
ALGER
LUCE
WHITEFISH BAY
CHIPPEWA
SCHOOLCRAFT
MACKINAC
DICKINSON
DELTA
MENOMINEE
TO MACKINAC COUNTY
TO CHARLEVOIX COUNTY
TO LEELANAU COUNTY
GREEN BAY
GRAND TRAVERSE BAY
LAKE HURON
EMMET
CHEBOYGAN
PRESQUE ISLE
CHARLEVOIX
ANTRIM
OTSEGO
MONTMORENCY
ALPENA
LEELANAU
BENZIE
GRAND TRAVERSE
KALKASKA
CRAWFORD
OSCODA
ALCONA
MANISTEE
WEXFORD
MISSAUKEE
ROSCOMMON
OGEMAW
IOSCO
ARENAC
MASON
LAKE
OSCEOLA
CLARE
GLADWIN
SAGINAW BAY
HURON
BAY
OCEANA
NEWAYGO
MECOSTA
ISABELLA
MIDLAND
TUSCOLA
SANILAC
MUSKEGON
MONTCALM
GRATIOT
SAGINAW
LAKE MICHIGAN
KENT
GENESEE
LAPEER
SAINT CLAIR
OTTAWA
IONIA
CLINTON
SHIAWASSEE
ALLEGAN
BARRY
EATON
INGHAM
OAKLAND
MACOMB
LAKE ST. CLAIR
VAN BUREN
KALAMAZOO
CALHOUN
JACKSON
WAYNE
CANADA
CASS
ST. JOSEPH
BRANCH
HILLSDALE
LENAWEE
LAKE ERIE
INDIANA
OHIO

TABLE 1

Upper Peninsula

Penokean Province

Well Name and Location (S-T-R)	Depth	Lithology	Type of Sample	Age Date b.y.	Magnetic Susceptibility x 10^6 emu/cc
Neebish Well (34-45N-2E)	810	Conglomerate Quartzite			
Escanaba & Lake Superior Rail Road (18-39N-22W)	790	Greenstone Talc Schist			
Stephenson Company (18-39N-22W)	860	Red & Green Slate and Schist			
Chicago & Northwestern Rail Road (29-39N-22W)	855	Talc Schist			
Escanaba Iron Range Exploration Company (28-39N-21W)		Negaunee-Vulcan Iron Formation			
Schemmel (8-39N-21W)	530	Quartzite			
A. E. Neff (31-42N-20W)		Greenstone			

TABLE 1
(cont.)

Escanaba Brewing Co. (31-39N-22W)		Iron Formation			
No name given (30-39N-22W)		Granite			
Department of Conservation (6-40N-29W)		Granite (Gneiss)			
		NORTHERN LOWER PENINSULA			
Pan American-Drasey #1 (29-35N-2E)	5710	Sandstone, slightly feldspathic			
	5910	Quartzite	RC		Ave. 363.58
	5940	Meta-Basalt, Greenstone			Ave. 2213.93 S.D.=715.86
McClure-State, Beaver Island #2 (6-37N-10W)	4745	Sandstone	RC	1.1	
	4800	Granite			
		CENTRAL PROVINCE			
Security-Thalmann #1 (10-6S-17W)	4606	Sandstone	RC		
	5647.5	Granite			

TABLE 2

GRENVILLE PROVINCE

Well Name and Location (S-T-R)	Depth	Lithology	Type of Sample	Age Date b.y.	Magnetic Susceptibility x10^{6} emu/cc
St. Clair Oil & Gas-Hurst #1 (26-5N-16E)	4730 4740	Sandstone Granite	CTC	1.02	N.R. Contaminated with Steel
Bernhardt-Puzzuoli #1 (3-2N-16E)	4152 4188	Sandstone Granite	RC		Ave. 1773.26 S.D.=572.35 Max. 2605.86 7 Samples Min. 980.70
Marathon-Woodhaven #1 (22-4S-10E)	3710 3755	Sandstone with arkose at base Granite	RC		Ave. 688.71 S.D.=359.26 Max. 1092.96 9 Samples Min. 252.22
Sturman-Chapman #1 (29-5S-10E)	3366 3375 3376.5	Sandstone Regolith Granite	RC		Regolith=1092.78 Basement=2521.80
Furgison & Garrison-Shimp #1(16-7S-6E)	3637 3671	Sandstone Granite-Intermediate Gneiss	RC		Ave. 1279.70 S.D.=905.57 Max. 2745.96 5 Samples Min. 560.40
Beck-Sancrant #1 (19-7S-7E)	3627 5495	Sandstone Granite	CTC		N.R. Samples too small
Eckert-Taylor #1 (32-8S-7E)	3875 3900	Sandstone with regolith in basal 10' Granite	RC		N.R.Samples too small

TABLE 2 Cont.

Colvin-Meinzinger #1 (12-2S-7E)	5670 5692	Sandstone with some Regolith at base Granite	CTC	1.05	N.R. Contaminated
Chamness-Tory Comm.#1 (27-1S-7E)	6071 6082	Sandstone Chlorite-Biotite Schist	CTC		N.R. Contaminated with steel
Colvin-Voss #1 (16-1S-7E)	6368 6410	Sandstone Chlorite-Biotite Schist	CTC	0.95	N.R. Contaminated with steel
Mobil-Messmore #1 (11-3N-5E)	7160 7589	Sandstone slightly Feldspathic Granodiorite - Diorite Gneiss	RC	N/A	Ave. 55.37 S.D.=40.68 Max. 140.12 22 Samples Min. 0.00
Consumers Power Co. Brine Disposal #1 (31-4N-15E)	4605 4634	Sandstone* Intermediate to Mafic Gneiss	CC to 4615.5 Core		Ave. 49.25 S.D.=20.52 Max. 65.67 10 Samples Min. 21.89

Key to Tables: CTC=Cable Tool Cuttings; RC=Rotary Cuttings; CC=Core Chips
N/A=Not Available; N.R.=Not Run (reason)

McClure Oil Company
State, Beaver Island #2
(6-37N-10W)

Depth	Rock Type	Description
4720-4740	Sandstone	Quartz, clear-pink, frosted, rounded 90%; slightly feldspathic in lower pt.
4740-4745	Sandstone	As above with increase of feldspar to 20%
4745-4800	Granite	Quartz, clear,angular 25%; Feldspar, clean, fresh 60%; Some more mafics at base indicated by rust and magnetite grains, some Epidote present

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Pan American Oil Company
Drasey #1
(29-35N-2E)

5600-5720	Sandstone	Quartz, rounded, frosted; Feldspar up to 10% in some intervals; show of Pyrite and some rust; some possible Chalcopyrite at 5680-90
5720-5880	Quartzite	Quartz, clear, angular cuttings some grainyness visible in larger peices, Bands with some pyrite alternating with bands without sulphides
5880-5910	Quartzite	As above with dark minerals and some Feldspar grains
5910-5940	Greenstone Meta-Basalt	Plagioclase lathes, Chlorite visible Some Pyroxenes, Amphiboles possible

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Security Oil and Gas Company
Thalmann #1

For detailed log refer to Yettaw (1967)
Samples spot checked for acuracy and found to agree

St. Clair Oil and Gas Company
Hurst #1
(26-5N-16E)

Very poor samples due to rusting of contaminating drill steel. Biotite can be seen clearly but the other minerals are coated with a thick coat of rust. The ammount of Biotite indicates a Gneiss of a Schist. Grain size is also very fine due to the use of cable tools

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Bernhardt
Puzzuoli #1
(3-2N-16E)

4142-4152	Sandstone	Quartz, rounded, frosted, some Biotite at base
4152-4188	Quartz-Biotite Gneiss	Quartz 70+%, clear and angular throughout interval with some bands as high as 85% quartz; Biotite most common accessory with bands of 20% biotite, very few Feldspar grains seen, some of the samples have rusty clumps of grains where identification is impossible

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Marathon
Woodhaven #1
(22-4S-10E)

3650-3660	Arkose	About equal amounts of Quartz and Feldspars with 20% Magnetite, Magnetic susceptibility =6277.49×10^{-6} emu/cc
3660-3670	Arkose	As above with dramatic decrease in Magnetite to less than 5%
3670-3710	Sandstone	Quartz, medium to fine grained, rounded, frosted very little Feldspar
3710-3755	Granite	Quartz, clear, angular 30%; Potash Feldspar, angular, fresh 50%; Mafics (Biotite, Magnetite, Amphiboles) 20% Slight show of chlorite, Feldspars zoned at base of section

Sturman
Chapman #1
(29-5S-10E)

3299-3366	Sandstone	Quartz, clear to frosted, rounded, slight show of feldspars
3366-3375	"Granite Wash"	Quartz, slightly rounded, Feldspars cleaved and surfaces cloudy with alteration, rounded; some Magnetite
3375-3376.5	Granite	Quartz 70% (some from above); Feldspar and Mafics

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Furgison and Garrison
Shimp #1
(16-7S-6E)

3626-3634	Sandstone	Quartz, rounded, frosted, fine grained 90%; Some Biotite and Magnetite present
3634-3642	Sandstone, Regolith, Granite	Quartz, 90%, some fresh some as above; Chlorite 2%; some Feldspars and Biotite (Published log reports precambrian top at 3637)
3642-3655	Gneiss	Quartz 70%; Chlorite 5-15%; small garnets possible at top of section; rest of sample is Feldspars
3655-3657	Gneiss	Quartz, 60%; Chlorite; altered Feldspars, some feldspar textures seen in the chlorite
3657-3671	Gneiss	Quartz, 60%; Biotite,10%; Chlorite,10% Feldspar and others 20%; minor variations, samples rusty at bottom with possible steel contamination

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Beck
Sancrant #1
(19-7S-7E)

3595-3627	"Granite Wash"	Quartz and Feldspar, weathered, possible Cambrian or Precambrian
3627-3895	Granite Gneiss	Quartz 50-90%; Feldspars, Chlorite, Biotite, and show of pyrite and "Jasper" Cuttings fine to very fine

Beck
Sancrant #1
(cont.)

3895-3900	Gneiss	As above with sericite
3900-4025	Gneiss	As above without sericite, but with more Chlorite; some Magnetite, show of amphibole
4025-4030	Granite Gneiss	Quartz; Potash Feldspar; Plagioclase; Biotite; Amphibole; Magnetite; Coarse cuttings, slight foliation visible
4030-4140	Granite Gneiss	As above, fine cuttings with mostly Quartz and very little other minerals
4140-5385	No Samples	
5385-5495	Gneiss	Samples coated with rust from Drill steel, not able to obtain a good discription

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Eckert
Taylor #1
(32-8S-7E)

3836-3855	Sandstone	Quartz, rounded, frosted 95%
3855-3875	Arkose or "Granite Wash"	Quartz, as above 60% to 30% at base; Feldspar, cleaved, blocky, with rounded corners, surface alteration
3875-3900	Granite	Quartz 30%; Feldspar 50%; Accessories 20%; Drills finer than above and peices show breaking across mineral boundaries some possible weathering in top 4 feet

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Colvin and Associates
Meinzinger #1
(12-2S-7E)

5670-5673	Sandstone	Quartz, drills very fine
5673-5692	Granite	Quartz, some from above 60% Potash Feldspars clearly visible

Chamness
Tory Comm. #1
(27-1S-7E)

5993-6071	Sandstone	Quartz, rounded, pink-white
6071-	Chlorite-Biotite Schist	Sample mostly Quartz from above, with Biotite the most common accessory; some Feldspar and some Chlorite showing alteration in larger pieces

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Colvin
Voss #1
(16-1S-7E)

6321-6368	Sandstone	Quartz, rounded, frosted
6368-6410	Chlorite-Biotite Schist	Sample mostly Quartz from above; Biotite; Chlorite, some larger pieces showing slikensides?; show of Muscovite and Feldspar

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Mobil
Messmore #1
(11-3N-5E)

7100-7140	Sandstone	Arkosic; Quartz and Feldspar, weathered
7140-7160	No Sample	
7160-7589	Granodiorite Diorite Gneiss	Plagioclase; Hematite; show Quartz; Pyroxene; Biotite; Leucoxene; Sphene Called a gneiss because of textures seen in thin section

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Consumers Power Company
Brine Disposal #1
(31-4N-15E)

4615.5 4616.5	Intermediate to Mafic Gneiss	Mostly Plagioclase with Hornblende needles, some injected material, broken at 16.5 with 40^{o} dip with slikensides and much alteration to chlorite

Consumers Power Company
Brine Disposal #1
(cont.)

4616.5 17.3	Intermediate to Mafic Gneiss	As above with more injected material Very Fine Grained, broken along foliation at 45°
4617.3 18.0		Bands of potash rich Feldspars and bands of Biotite, Hornblende, and Plagioclase; bottom broken at 60° dip with alteration Chlorite
4618.0 18.7		Gneiss with 2.5"band of altered Biotite grading to gray, Minor Calcite vains perpendicular to foliation
4618.7 19.8		As above bottom broken at 45°
4619.8 22.5		As above broken at 90° to axis
4622.5 24.0		As above with slight inorease in mafics foliation at 55°
4624.0 24.6		As above with band of diorite-pegmatite? cutting across foliation(see photo)
4624.6 25.5		As above, core badly broken with no control
4625.5 26.2		Top broken at 50° dip and 80° rotation from previous breaks, strong alteration slikensides present
4626.2 27.0		Feldspars 70%; Mafics 20-30%; Quartz less than 10%
4627.0 28.0		As above, becoming more mafic at base
4628.0 29.3		Intermediate and mafic bands
4629.3 30.0		Biotite-Chlorite band, slight foliation homogeneous with minor Calcite and Quartz
4630.0 34.0		Fine grained dark rock, mostly Chlorite vains parallel to above foliation

Pan American Oil Company

Drasey #1

Depth	Magnetic Susceptibility ($x10^{+6}$ emu/cc)
5600-10	1373.20
10-20	616.54
20-30	420.37
30-40	252.22
40-50	364.31
50-60	224.20
60-70	532.46
70-80	420.37
80-90	336.29
5690-5700	616.54
5700-10	364.31
10-20	224.20
Quartzite Section	
20-30	140.12
30-40	182.16
40-50	112.10
50-60	392.34
60-70	504.44
70-80	168.15
80-90	84.07
5790-5800	168.15
5800-10	84.07
10-20	448.39
20-30	196.17
30-40	560.49
40-50	588.51
50-60	280.24
60-70	504.44
70-80	392.34
80-90	896.78
5890-5900	672.59
5900-10	532.47
Greenstone Section	
10-20	1457.27
20-30	2185.91
30-40	1933.69
5940 circ 30	2101.84
5940 circ 60	3390.96

Consumers Power Company

Brine Disposal #1

Depth	Magnetic Susceptibility (x10^{6} emu/cc)
4616.1	65.67
4617.5	32.13
4620.2	38.31
4624.3	43.78
4626.6	21.89
4627.3	49.26
4628.1	60.20
4629.8	65.67
4634.0	43.78

Bernhardt

Puzzouli #1

4135-38	896.64
38-42	1092.78
42-48	1653.18
48-52	2381.70
precambrian	
52-58	1737.24
58-62	1737.24
62-66	1457.04
66-72	2605.86
72-79	1457.04
79-83	980.74
83-88	2437.74

Marathon
Woodhaven #1

3670-80	812.71
80-90	1429.25
3690-3700	896.78
3700-10	476.42
Precambrian	
10-15	700.16
15-20	1092.96
20-25	980.86
25-30	980.86
35-35	252.22
35-40	532.47
40-45	532.47
45-50	588.51
50-55	532.47

Sturman
Chapman #1

3299-3310	280.20	
3310-15	560.40	
15-23	392.28	
23-30	308.22	
30-42	1457.04	
42-55	840.60	
55-66	560.40	
66-75	1092.78	
75-76.5	2521.80	

Furgison & Garrison
Shimp #1

3626-34	840.60	
34-42	2241.60	(Transition, Basement 37)
42-45	560.40	
45-55	Sample too small	
55-57	756.54	
57-62	1401.00	
62-67.5	700.50	
67.5-71	2745.96	(Poss. Steel contamination)

Mobil
Messmore #1

7360-70	56.05
70-80	28.02
80-90	70.06
7390-7400	28.02
7400-10	56.05
10-20	28.02
30-40	140.12
40-50	14.01
50-60	14.01
60-70	42.04
70-80	14.01
80-90	0.00
7490-7500	112.10
7500-10	42.04
10-20	84.07
20-30	28.02
30-40	112.10
40-50	56.05
50-60	14.01
60-70	98.09
70-80	56.05
80-89	126.11

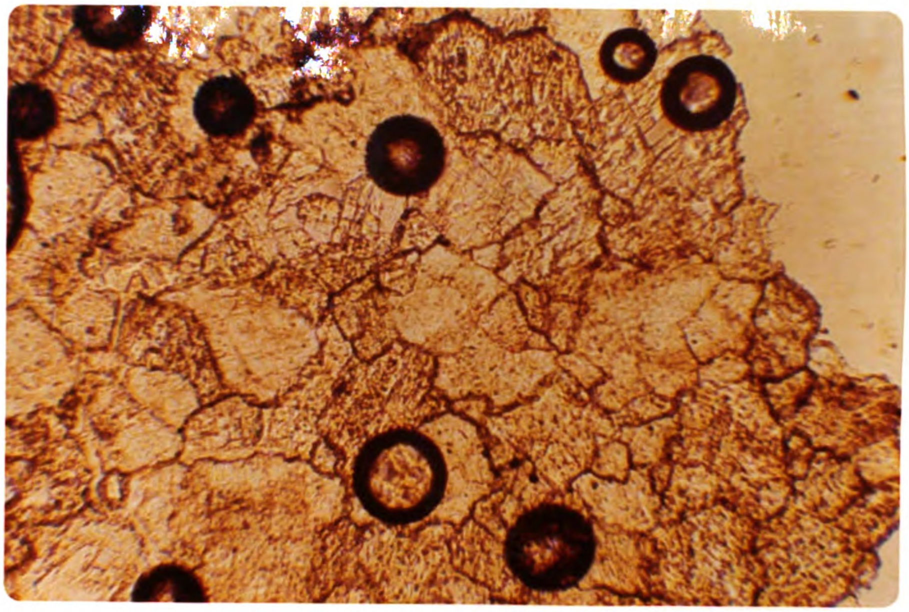

Photo 1: Thin section of Quartzite from Pan American Oil Co.-Drasey #1. Plane polarized light

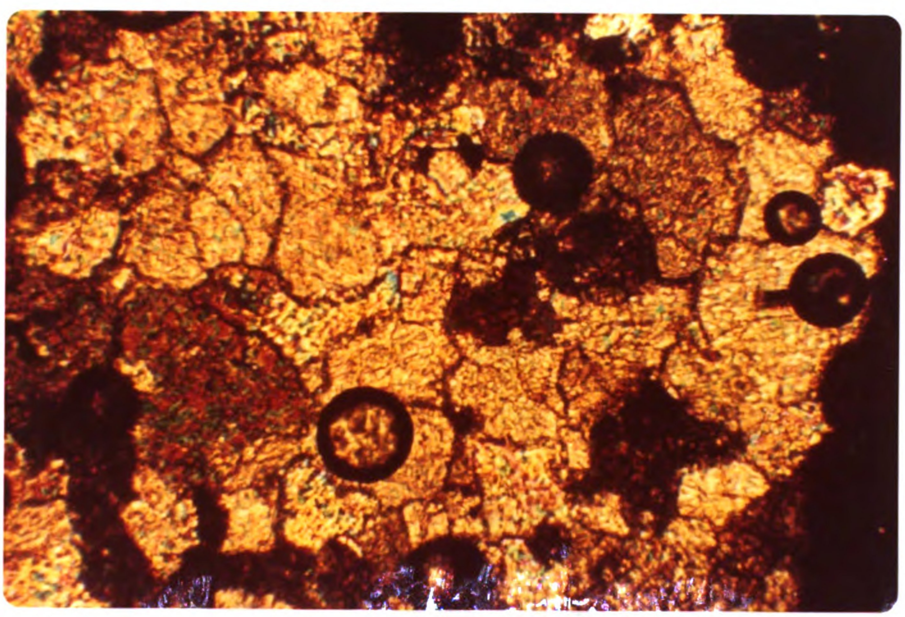

Photo 2: Thin section of Quartzite from Pan american Oil Co.-Drasey #1. Crossed Nicols

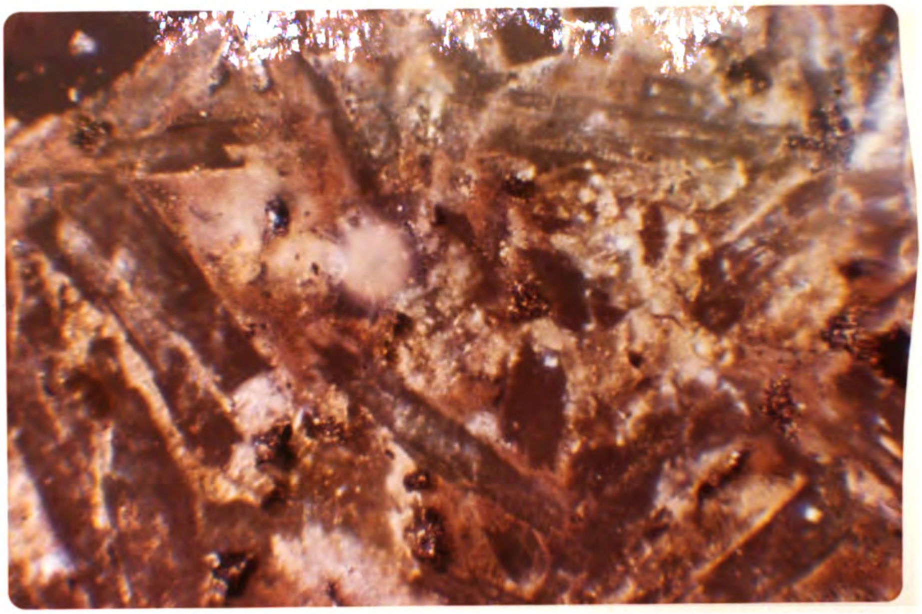

Photo 3: Polished section of Meta-Basalt from the Pan American-Drasey #1. Reflected Light

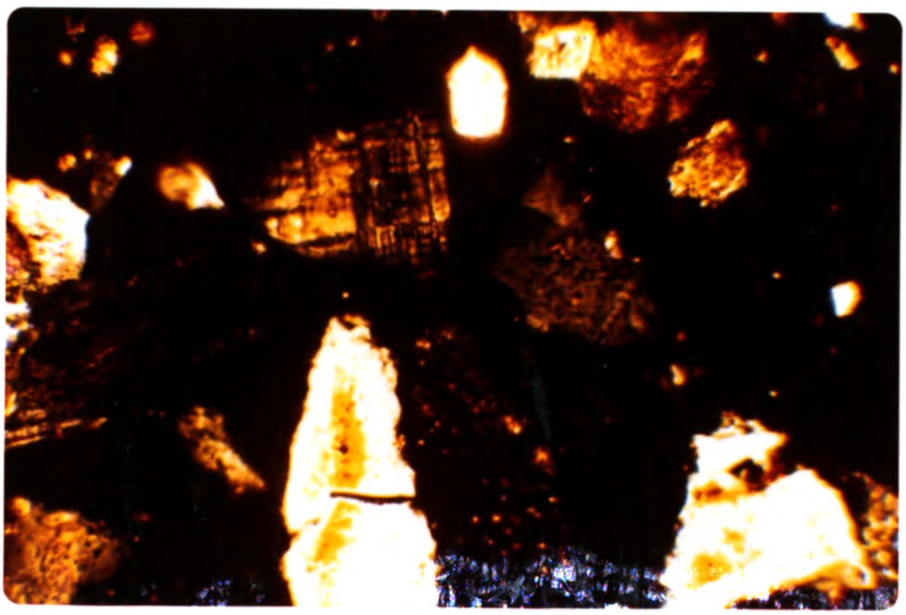

Photo 4: Thin Section of Quartz and Microcline from the Security-Thalmann #1. Crossed Nicols (Overly thick)

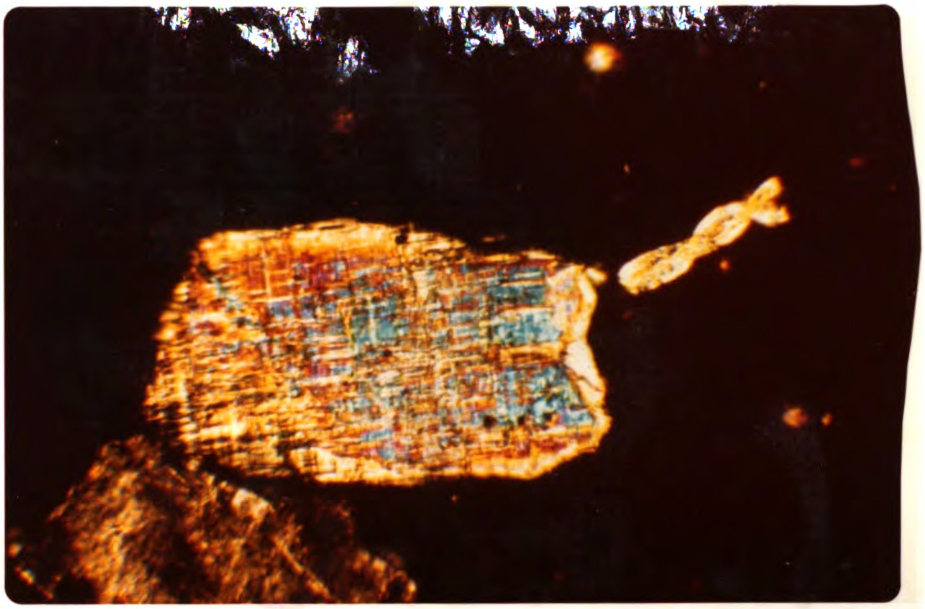

Photo 5: Microcline from the Security-Thalmann #1. Crossed Nicols (Section too Thick)

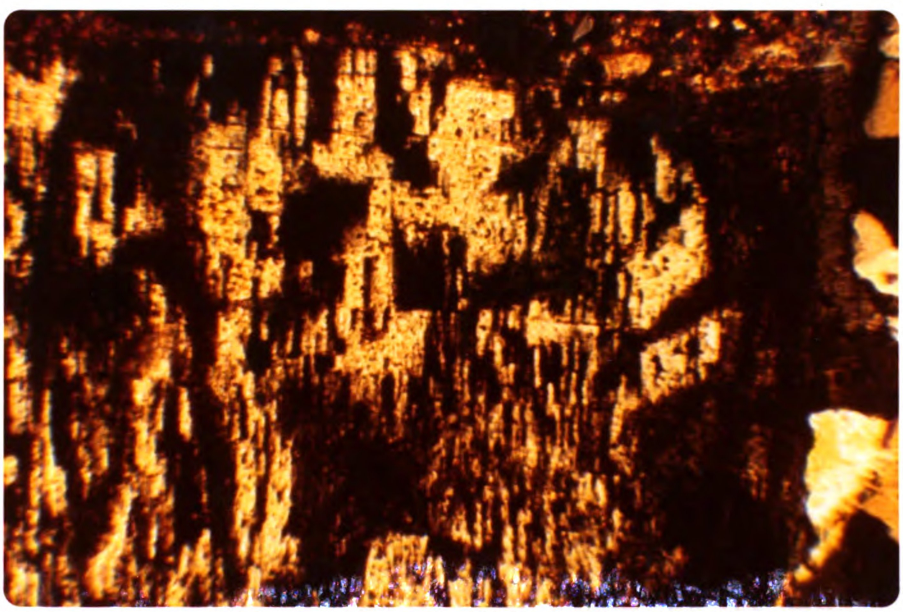

Photo 6: Albite twins in a relect grain from the Mobil-Messmore #1. Crossed Nicols

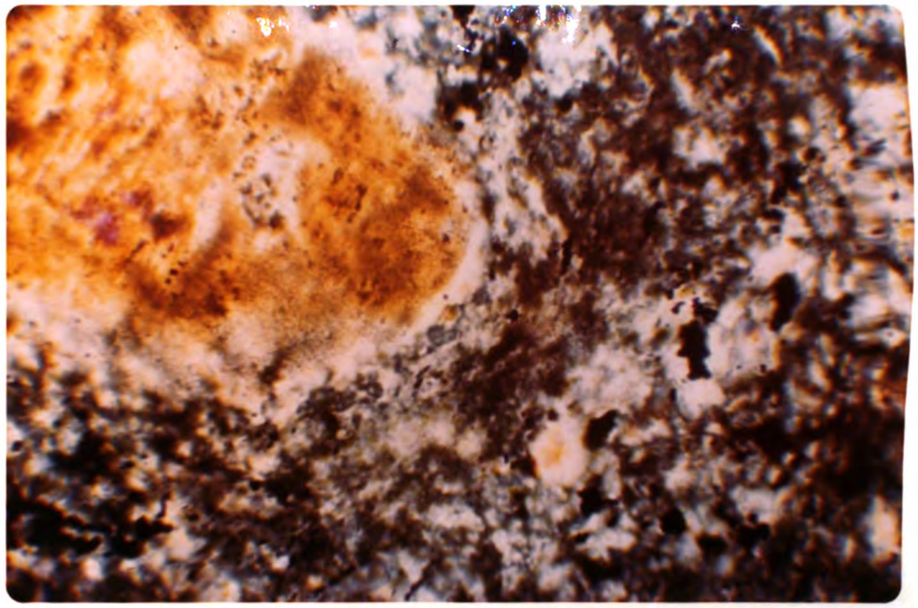

Photo 7: Thin section of rock from the Mobil-Messmore#1 showing flow structures around a relect grain. Crossed Nicols

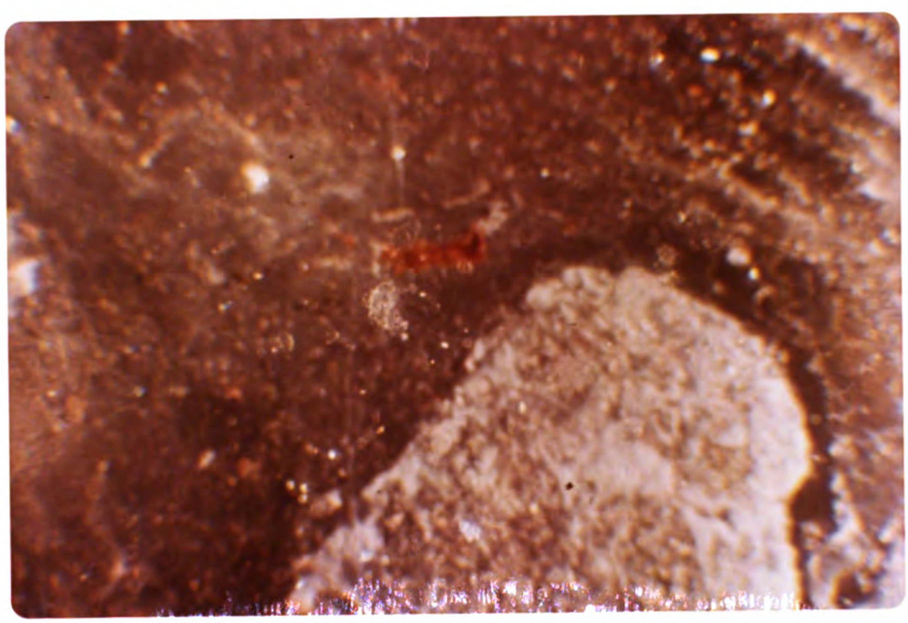

Photo 8: Polished section of same area as Photo 7 under reflected light.

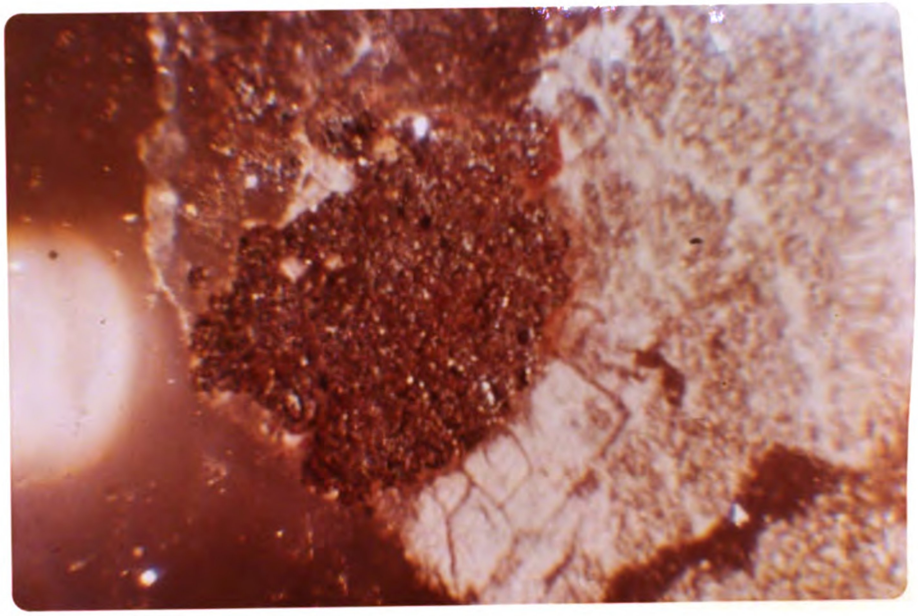

Photo 9: Polished section of rock from the Mobil-Messmore #1 showing large mass of Hematite with Feldspar grains. Reflected light.

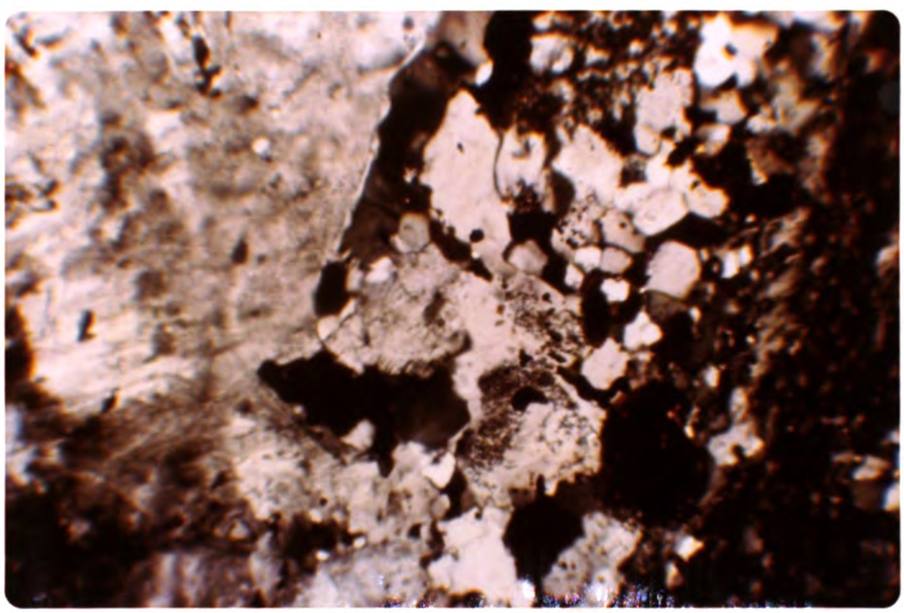

Photo 10: Thin section from the Mobil-Messmore #1 showing cataclastic texture of the Feldspar grains

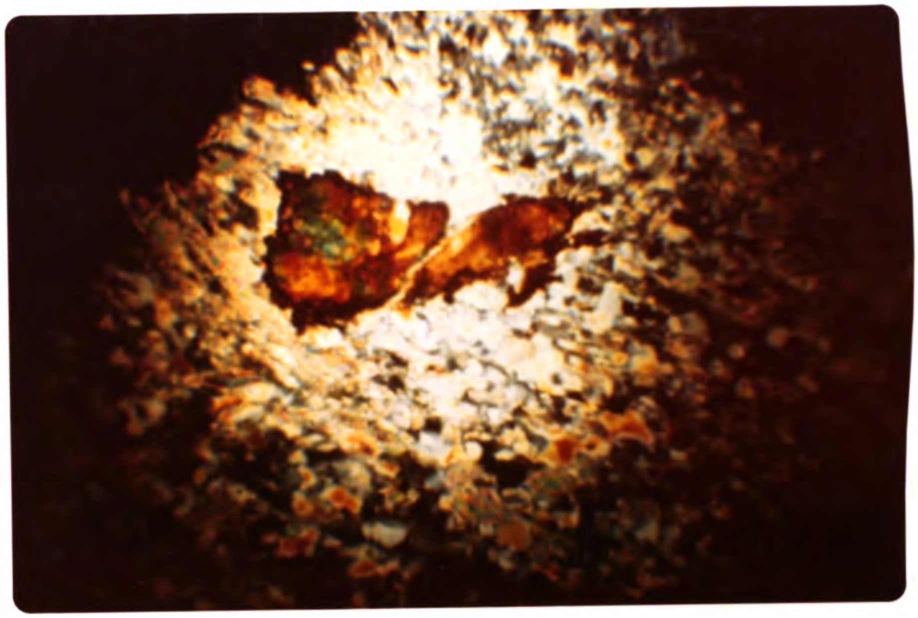

Photo 11: Biotite grain with other fero-magnesian mineral grains from the Mobil-Messmore #1.

Photo 12: Section of core from the Consumers Power-Brine Disposal #1. Note band of injected material cutting across foliation

Photo 13:- Section of core from the Consumers Power - Brine Disposal #1. Note heavy alteration along broken face and how the angle of break is equal to the foliation

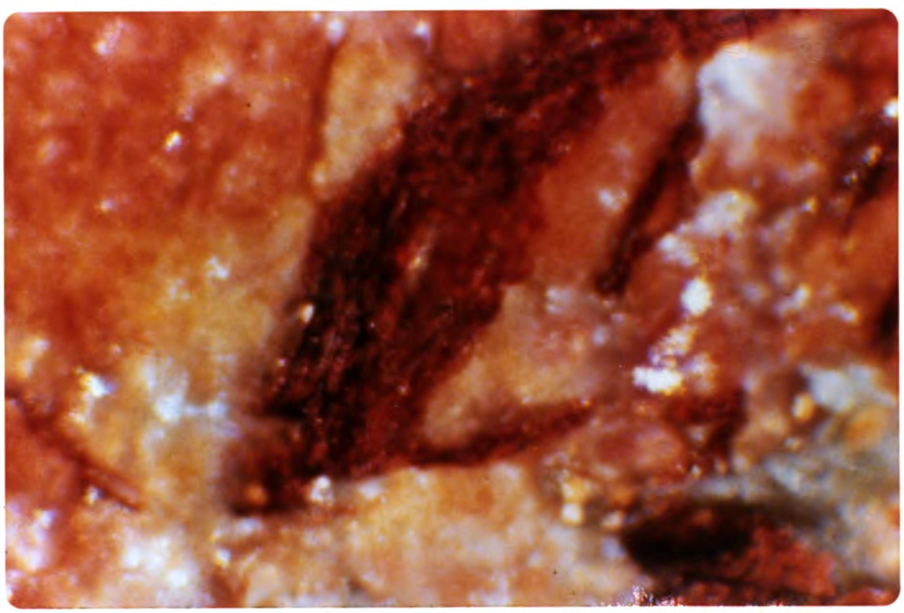

Photo 14: Altered Biotite and Feldspar in reflected light from Consumers Power-Brine Disposal #1

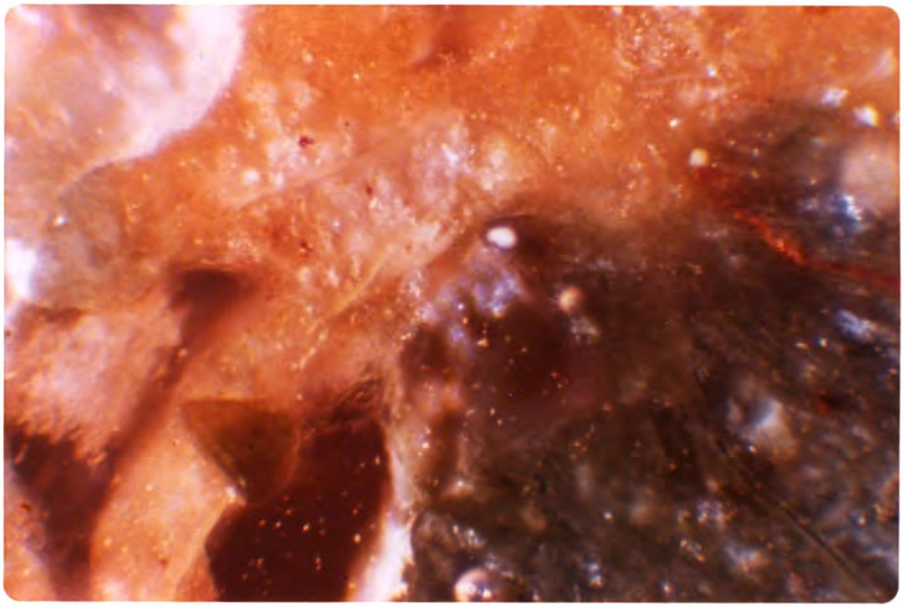

Photo 15: Chlorite and Feldspar in the Consumers Power-Brine Disposal #1. Reflected Light

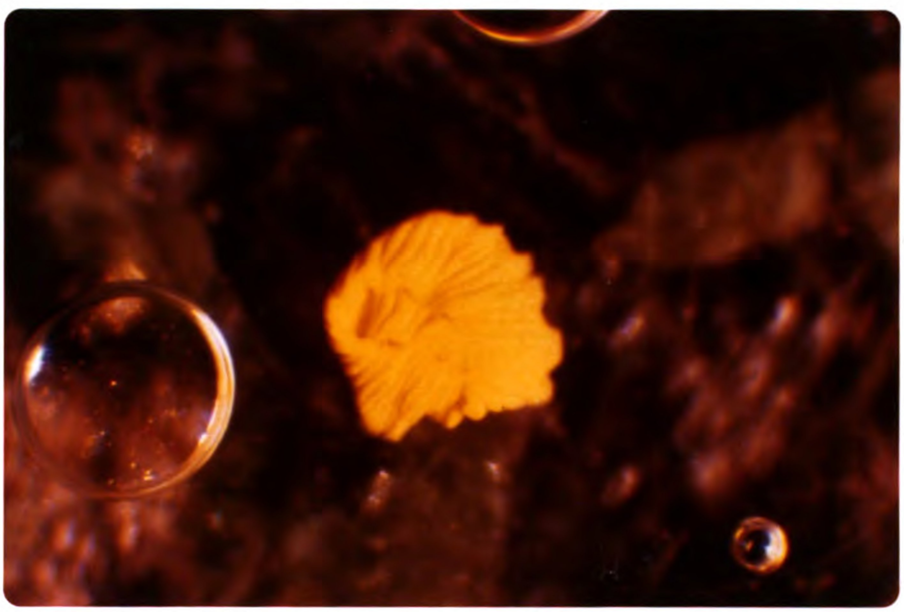

Photo 16: An unusual yellow grain of Leucoxene from the Consumers Power-Brine Disposal #1. Reflected Light.