AN INVESTIGATION OF THE GEOLOGY OF A PART
OF THE EMO AREA
DISTRICT OF RAINY RIVER, ONTARIO

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ABSTRACT

The geology of the Emo area consists of a terraine of deformed and metamorphosed Archean sedimentary and volcanic rocks invaded by multiple granitic intrusions and several less extensive basic intrusions. A petrographic study of certain units of each of the rock types has been made. The classification, original nature and metamorphism of the sedimentary and volcanic rocks are discussed. The sediments fall into two major divisions: (1) a thick unit of greywacke with interbedded shale, conglomerate and banded iron formation, and (2) a smaller unit of well-bedded calcareous and chloritic siltstones and shales now transformed to hornblende-plagioclase-quartz schists and gneisses. The volcanic rocks consist of a variety of lavas, agglomerates and tuffs. The basic lavas are typical "greenstones" and are largely of basaltic composition. The more acid lavas are predominantly dacites. The structural geology, stratigraphy and conditions of sedimentation are discussed. The intrusive rocks are described with reference to their composition, structure and genesis. An attempt is made to evaluate the role of metasomatism in the formation of the granitic rocks.

CHAPTER I INTRODUCTION

GENERAL STATEMENT

This thesis describes the results of a study of the petrology, structure and genesis of certain rock types found in the Emo area. The study was designed to be as broad as possible in the time available. The project was suggested by Professor H. D. B. Wilson. The area was provided and the field party was equipped by the Ontario Department of Mines. G. L. Fletcher acted as co-leader of the field party and also used part of the area as a source of thesis material. A report on the entire area, written under joint authorship and entitled, "The Geology of the Emo Area, District of Rainy River", is to be published by the Ontario Department of Mines.

LOCATION AND ACCESS

Emo is situated in the Rainy River district of Ontario, 20 miles west of Fort Frances, on the Canadian National Railway between Fort Frances and Winnipeg. The Emo area, as described in this thesis, extends over approximately 320 square miles and includes the Townships of Tait, Mather, Kingsford, Shenston, Dobie, Carpenter, Roseberry, Barwick, Lash and Aylsworth plus parts of adjoining townships. The south boundary of the map-area is marked by the Rainy River.

The main freight line of the Canadian National Railways crosses the southern part of the map-area and daily train service is provided from Winnipeg and Fort William. Stations are located at Emo and Barwick, the two main centers of population. Provincial highways No. 70 and No. 71 cross the area from north to south and from east to west respectively, providing access by automobile from Kenora, Rainy River and Fort Frances. Good gravel roads make all parts of the area easily accessible, and numerous logging trails and survey lines have greatly facilitated field traversing.

TOPOGRAPHY

Relief in the area is low, seldom exceeding 75 feet. The southern parts have large level tracts of thick overburden with small, widely scattered outcrops. The northern parts are slightly more rugged in appearance, having low ridges of outcrops and heavily wooded valleys. Much of the good timber has been cleared as farming land. Unlike most areas in the Canadian Precambrian Shield, lakes of appreciable size are absent and muskegs are comparatively small and dry

Drainage is provided by the Rainy River and its tributaries, principally the Sturgeon and Pinewood Rivers. The drainage system is characterized by numerous small meandering streams, sharply incised in thick surficial deposits. Its pattern does, however, suggest partial control by the structure of the bedrock.

PREVIOUS GEOLOGICAL WORK

Previous to 1952, interest in the Emo area as a mining district was only casual and detailed study of the geology had not been made. Many portions of the area had been staked from time to time and scattered test pits are evidence of early prospecting. A brief reconnaissance survey along the Rainy River was conducted in 1885 by A. C. Lawson of the Geological Survey of Canada. This geology, to a large extent interpretive, is shown on two maps, both on a scale of two miles to one inch, accompanying the "Report on the Geology of the Rainy Lake Region" published in 1887. This Geology was used by T. L. Tanton in compiling map 226A (Kenora Sheet) of the Geological Survey of Canada. The soils and surficial deposits were mapped and studied by W. A. Johnston (1915).

The report of a base metal deposit in the southern part of Dobie Township in 1952 instigated a period of intensive exploration. The area was thoroughly prospected. Aeromagnetic and ground geophysical surveys were made in the southern parts. Deposits of nickel-copper and iron were found but because these were small and of low grade, work in the area ceased, temporarily at least, in the autumn of 1953.

Adjacent to the map-area in Minnesota, bedrock exposure has not been considered sufficient to warrant detailed study. However, a geological sketch map is available from the Minnesota Geological Survey. Also available are total intensity aeromagnetic maps of the following:

(1) Parts of Rouseau and Lake of the Woods counties, Minnesota.

(2) Parts of Lake of the Woods and Beltcami counties, Minnesota.

(3) Northeastern Koochiching county, Minnesota.

(4) Northwestern Koochiching county, Minnesota.

PRESENT STUDY

The survey work on which the present study is based was conducted during the field season of 1953 in response to the interest in the area at that time. A base map on a scale of one quarter inch to one mile was supplied by the Survey Branch, Ontario Department of Lands and Forests. Vertical aerial photographs, on the same scale, in conjunction with pace and compass traverses provided close control for the location of outcrops. Essentially all small scattered outcrops were examined and, in areas of extensive exposure, irregular traverses were performed to give moderately complete coverage.

The geological map of the area is published ona scale of one inch to one mile. A similar map accompanying this thesis (in pocket in back) is on a scale of one half mile to one inch. On both maps, for purposes of clarity, outcrops have been enlarged and their outlines generalized. Groups of outcrops are frequently shown as one.

Division of the area was necessary so that co-leaders of the field party would both have thesis material. It was found impossible to do this simply and fairly on a geographic or geometric basis. Division was made, therefore, on a geological basis. Each man was allotted geological units in such a way as to expose him to a more or less complete suite of the rock types. The units studied by the author are shown in color figure 1. The locations of the representative specimens and of the specimens examined in thin section are shown on the accompanying geological map.

Laboratory work was largely of a petrographic nature. Thin sections were made to give representative coverage of each lithological unit and wherever significant variations were suspected. Rosiwal grain counts were made to determine approximate mineralogical compositions. The staining technique described by Keith (1939) was used to distinguish plagioclase and potash feldspar. Plagioclase composition was determined by the Michel-Levy method on albite twins and by oil immersion methods. Specific gravity measurements were made on specimens of the basic lavas.

GENERAL GEOLOGY

The bedrock in the area is entirely Precambrian in age. The majority of the sedimentary and volcanic rocks were originally assigned to the Keewatin by Lawson (1887). He proposed (1887, p. 102), however, that at least part of the body of sediments and tuffs outcropping in the south part of Aylsworth township is a probable extension of the Coutchiching rocks in the Bear's Passage area of the Rainy Lake region. He stated, with reference to the Coutchiching,

> " . . . . the belt of mica schists . . . extends from the neighborhood of Bear's Passage across Rainy Lake in a W. S. W. direction to Coutchiching and thence down Rainy River. In the direction of its strike, the belt is traceable continuously for twenty-four miles, and it probably continues to the westward, under the post glacial formations of the Rainy River for a distance of at least sixteen miles."

The westward extension into Aylsworth township is shown on Lawson's "Rainy Lake Sheet" and on the "Kenora Sheet" compiled by Tanton.

Under the present study, the volcanics and sediments were found to be severely folded and metamorphosed, seemingly of definite Archean age. Lithologically, the body in Aylsworth township does not compare too closely with the Coutchiching mica schists in the Rainy Lake area. However, in recognition of Lawson's postulations, it has been assigned to the "Coutchiching or Keewatin". The remainder of the volcanics and sediments are "Keewatin-type" and have been assigned to the Keewatin. They have been divided as follows:

(1) The lower sedimentary division consisting of hornblende schists.

(2) The upper sedimentary division consisting of greywacke, iron formation and conglomerate.

(3) Intermediate and acid volcanics

(4) Basic volcanics

The intrusive rocks are all post-Keewatin. Two basic stocks and numerous smaller basic dikes and sills intrude the sediments and volcanics. Granitic masses cut all previously mentioned groups with the exception of one basic intrusion. No definite evidence was found to indicate broadly separated periods of intrusion. Diabase and quartz diabase dikes, representing the youngest igneous rocks in the area, are believed to be Keweenawan in age.

Deposits of clay, sand, gravel and boulders, laid down by continental glaciers, overlie the Precambrian rocks. Bedded clays indicate deposition in post-glacial lakes. These deposits are all Pleistocene age. Recent deposits consist of swamp peat and small amounts of alluvial sand, silt and clay loam deposited along streams.

The geological succession and the lithological units are summarized in the following table.

TABLE 1: Legend

QUATERNARY

RECENT: Peat, alluvial sands, silt, clay-loams.

PLEISTOCENE: Bedded clay-loams, glacial clay, silt, sand, gravel, boulders.

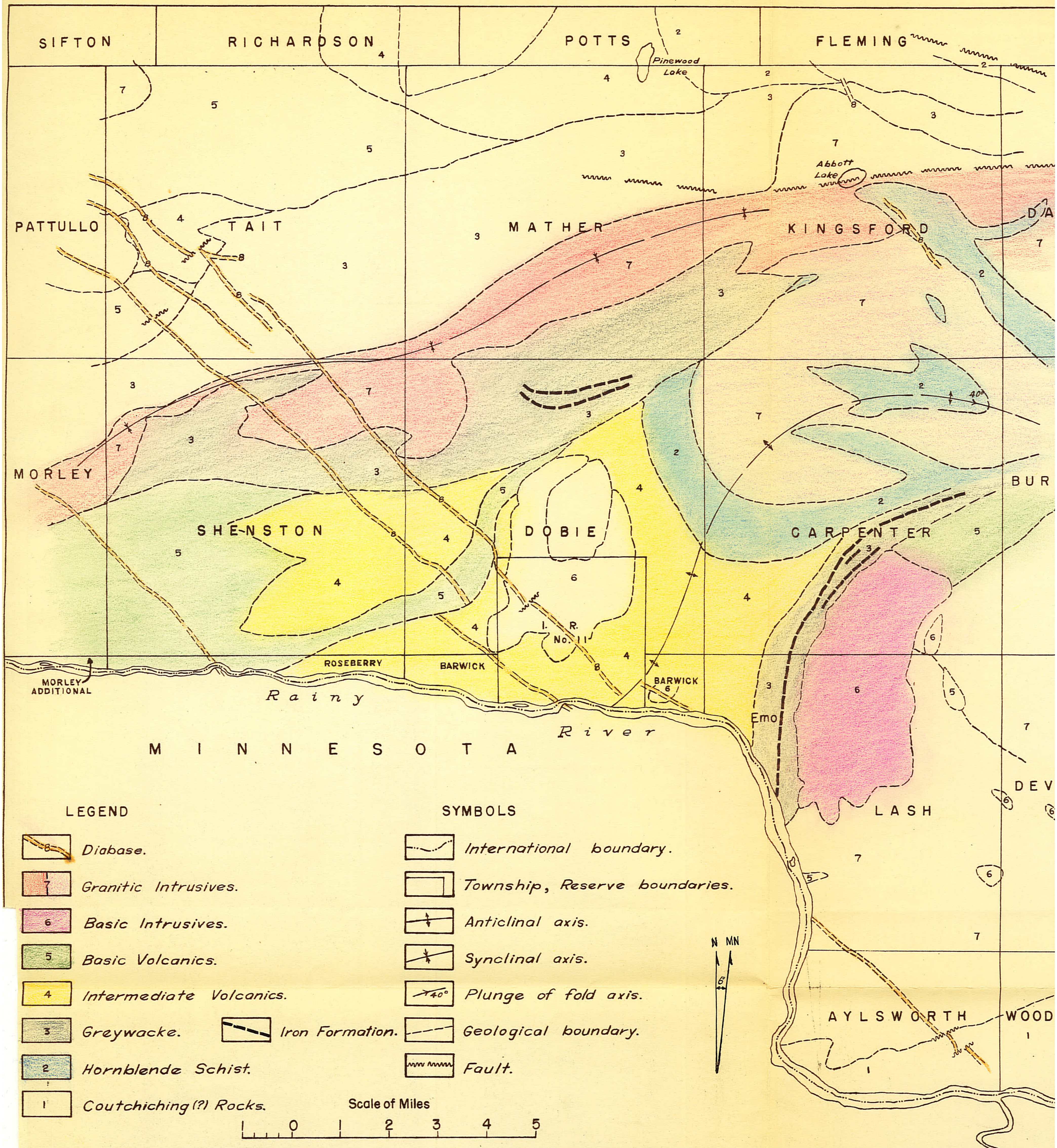


Figure 1. Sketch map of the Emo Area showing the distribution of rocks studied.

PRECAMBRIAN

POST-KEEWATIN

KEWEENAWAN: Quartz diabase dikes

GRANITIC INTRUSIONS:

	Tait intrusion	Pegmatite dikes
	Potts intrusion	Granitic and Ap-
	Lash intrusion	litic dikes.
Chrono-	Devlin intrusion	Quartz Monzonite
logical	Kingsford intrusion	Monzonite
	Shenston-Mather intrusion	Hornblende grano-
	Carpenter intrusion	diorite.
sequence		Granodiorite

BASIC INTRUSIONS:

	Dobie intrusion	Norite
indefinite	Carpenter-Lash intrusion	Hyperathene gabbro
		Diabasic gabbro
		Hornblende diorite

KEEWATIN

Carpenter volcanics

Mather sediments

Dobie-Tait volcanics

Carpenter sediments

COUTCHICHING OR KEEWATIN

Siliceous tuff, biotite and hornblende schist

VOLCANIC DIVISIONS OF THE KEEWATIN BASIC VOLCANICS:

Basalt, pillow basalt, coarse basalt, basalt porphyry, amygdaloidal and vesicular basalt, basic tuff and sediment, basic agglomerate.

INTERMEDIATE AND ACID VOLCANICS:

Dacite, dacite porphyry, quartz latite and rhyolite, intermediate agglomerate, tuff.

SEDIMENTARY DIVISIONS OF THE KEEWATIN:

UPPER DIVISION:

Greywacke and derived biotite schist, conglomerate, iron formation.

LOWER DIVISION:

Hornblende schist, garnetiferous hornblende schist.

CHAPTER II KEEWATIN SEDIMENTARY ROCKS

The sedimentary rocks of the Emo area form two lithologic divisions. These are apparently of two distinct ages and are referred to as the "upper" and "lower" sedimentary divisions.

LOWER SEDIMENTARY DIVISION

Distribution and Structure

The lower sedimentary division is exposed in two parts of the Emo area. Several outcrops occur in the extreme north east portion but these are not considered in this report.

The main body, the one studied for this thesis, forms a belt which extends in a broad arc from the north east corner of Dobie township south and east into the central part of Carpenter township. From here, it continues eastward at a bearing of approximately N70°E beyond the boundary of the map area. North of this belt, several outcrops and numerous inclusions of the same sedimentary formation occur within large granitic masses. The outcrops have been interpreted as representing tongues and remnants of the main band.

The attitude of bedding in almost all parts is vertical to steeply dipping. An east-plunging anticline has been outlined in lots 3 and 4, concession VI, Carpenter township.

Bordering the main arc on its south flank are the greywacke and iron formations of the upper sedimentary division.

On the south east flank, iron formation has been outlined by geophysical work and probably the greywacke is also present. Intermediate and acid volcanics border the arc to the south west. Contacts with the above formations were not found exposed. The concave part of the arc is occupied by granodiorite. Comparatively sharp sedimentary-intrusive contacts are exposed in several places but zones of lit-par-lit are more usual.

Character and Composition

The sediments as observed in the field appear as fine-grained thinly-bedded clastics (see Plate 1). The rock is completely recrystallized. Parallelism of grains is clearly visible but schistosity is not strong. The color of both fresh and weathered surfaces in most of the material is dark-grey. The fresh surface characteristically shows lustrous black hornblende and a banded appearance resulting from fine laminations of feldspathic material. Minor amounts of light brownish sandy material are present in interbands ranging from six inches to one foot in width. These are composed of feldspar, quartz and biotite.

Dark red garnets, probably almandine, are locally prevalent in the hornblende-rich sediments. Most commonly they form concentrated zones and patches or are sparsely scattered as individual porphyroblasts. In some places, they occur

A. Thin-bedded hornblende sedimentary schists showing lenses composed of garnet and hornblende, lot 4, concession IV, Carpenter township.

B. Closer view of the garnetiferous lenses, lot 4, concession IV, Carpenter township.

with coarse-grained hornblende, plagioclase and diopside in lense-like knots. (see Plate 1B) The knots are 3 to 8 inches in length and are elongated parallel the bedding planes.

The sediments near the granitic intrusives do not appear to have suffered exceptional alteration or transformation. Outlines of inclusions and contacts are comparatively sharp. Silicified joints are common, however, and occasionally small amounts of pistachio green epidote alteration are present.

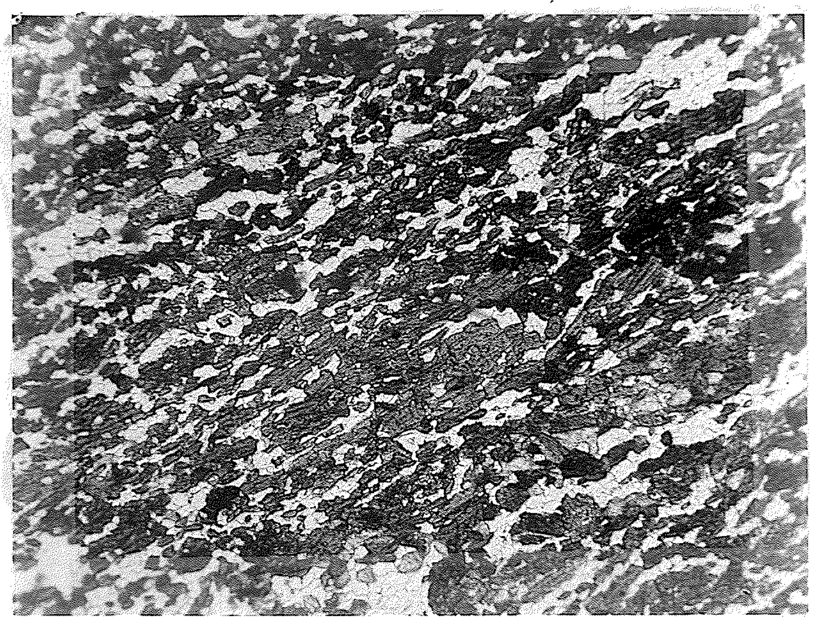
Microscopic Description

Thin sections of the rock reveal a recrystallized xenomorphic texture. Parallelism of grains is weak to moderate. Grain size is uniform ranging from 0.1 to 0.5 mm. The principal mineral constituents are hornblende, plagioclase and quartz. The rock was found to be too variable in composition to lend itself to satisfactory Rosiwal analysis. The estimated compositional range is: 40 to 60 per cent hornblende, 15 to 30 per cent plagioclase and 15 to 25 per cent quartz. Diopside is not present everywhere but makes up 20 per cent of some specimens. Minor constituents are garnet, biotite, calcite, sphene and sulphides. Potash feldspar was not found in appreciable amounts, although small patches of sericite may possibly represent alteration products. Hornblende occurs in small cleavable anhedral prisms and is the most pronouncly aligned mineral in the rock (see Plate 2A). It is strongly pleochroic, dark green to yellowish-green. Plagioclase and quartz form a granular mosaic. The plagioclase is poorly twinned and, in specimens containing diopside, it is strongly saussuritized. Its composition is apparently oligoclase or andesine. The diopside, where present, is concentrated in 1-2 mm bands alternating with hornblende-rich material (see Plate 2B). It is pale green in color and non-pleochroic. The crystals are anhedral. Pyroxene cleavage is moderately developed. The extinction angle is approximately 40 degrees with Z. The garnet, in thin section, is pale pink. It forms poorly developed metacrysts with abundant inclusions of quartz. (see Plate 3A) Biotite is a brown variety and was not found in sections containing diopside. Sphene occurs as sparse wedge-shaped crystals with leucoxene alteration.

The bulk of the sediments of the lower sedimentary division, in their present state, can best be called hornblende schists.

Original Nature

A cursory search of the literature indicated that metamorphosed sediments resembling these hornblende schists evidently are not common in the southwestern part of the Canadian Shield. However, Eskola (1914, pp. 118-121, 140-146) has described diopside-amphibolites and diopside-bearing



A. Hornblende sedimentary schist showing alignment of hornblende. Ordinary light. X25. (Specimen N-56-2)

B. Garnetiferous hornblende schist. Ordinary light. X25. (Specimen F-8-6)

Diopsidic hornblende schist with saussuritized plagioclase. Ordinary light. X25 (Specimen F-10-3) leptite from the Orijavi region of Finland which have much the same character. Of the former he says:

> " . . . The general mineralogical composition of the diopside-amphibolites shows, however, that they have quite a different set of chemical characters and must be considerably richer in lime than the amphibolites proper.
>
> All these features point to the suggestion that the diopside-amphibolites are of sedimentary origin and that they have originated by alteration by metamorphism of a series of calcareous shales, probably mingled with volcanic materials."

Of the latter he states:

> " . . . a fragmental structure and the absence of any features indicative of an igneous origin makes it probable that the rock had been originally a clastic sediment.
>
> On the other hand, the bulk composition is quite typical of an igneous rock and we may assume therefore that it was formed from volcanic ashes and tuffs . . In the vicinity of limestones leptites often contain diopside."

Their clastic nature and a comparison with Eskola's descriptions suggests that the Emo hornblende schists were originally fine sandy or silty sediments with quartz and plagioclase grains in a calcareous shale matrix. Pyroclastic materials were probably a major component. The diopsidic bands were undoubtedly derived of layers exceptionally rich in lime. Chlorite may have been abundant because "sediments rich in chlorite are usually more or less calcareous". (Harker, 1932, p.53)

Garnetiferous Knots

The origin of the previously mentioned garnet-bearing knots or lenses in the sediments is of interest. Pettijohn (1939, p. 766) suggests that similar nodules found in the Thunder Lake area, Ontario were once calcareous concretions. It is noted, however, that in the present examples the bedding planes are warped around the knots rather than abutting against them as might be expected if they were concretions. It seems more probable therefore that they have originated from metamorphism rather than diagenesis. It is suggested that metasomatic action accompanying granitic intrusion has been effective in concentrating lime, magnesia iron and silica in lenses between the bedding planes. Probably all these components, with possible exception of silica, were derived directly from the sediments in view of the fact that these are a readily available source. The conditions imposed were apparently such as to promote growth of large crystals and, to a certain extent, cause a differentiation of mineral phases. Thus rims of almost pure hornblende enclose many of the nodules of garnet, diopside and plagioclase. Slippage and crenulation along bedding planes accompanying major folding may have facilited concentration of the metasomatizing emanations by providing centers of low pressure.

Metamorphism

The constancy of mineralogy and the close proximity of all parts of the lower sedimentary division to granitic intrusives indicate that the metamorphism is a regional type and of uniform grade throughout. As was stated, the rock is completely recrystallized. Its predominant mineral assemblage is hornblende-plagioclase-garnet-diopside-quartz-biotite. The diopsidic parts closely resemble the diopside plagioclase-amphibolites described by Harker (1932, pp. 282-283). The latter represent "the highest grade of metamorphism", i.e. the sillimanite zone. According to Turner and Verhoogen (1951, p. 458), "the sillimanite zone of regional metamorphism is often affected by synchronous intrusion of granite magma". This is believed to have been the setting for the metamorphism of the hornblendic sedimentary schists. Their mineral composition indicates that they belong to the amphibolite metamorphic facies and probably, more specifically, to the garnet-hornblende subfacies as defined by Turner and Verhoogen (1951,pp 458-460). That is, they have been metamorphosed under high temperature and pressure at great depth.

UPPER SEDIMENTARY DIVISION

Distribution and Structure

The main occurrence of the upper sedimentary division is in two parallel steeply dipping bands which extend N70°E. The two bands are believed to represent opposite limbs of a synclinal fold and are divided by an elongated body of granitic rocks.

The south band was studied for this thesis. It underlies the northern parts of Shenston and Dobie township and the southeastern part of Mather township. Its usual width is 8,000 to 12,000 feet. However, this is probably considerably greater than the true thickness of the formation because of abundant lit-par-lit injections and, possibly, because of undetected faults or folds.

An iron formation trending north and east from the town of Emo is also included in the upper sedimentary division.

Character

The three distinguished lithologic units are:

(1) Biotite schists

(2) Conglomerate

(3) Iron formation

Biotite Schists

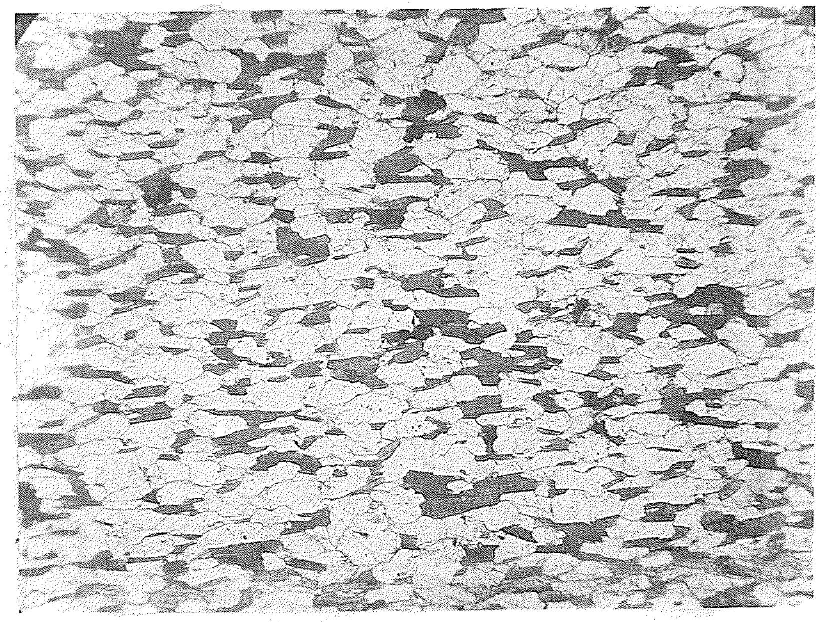
The biotite schists are predominant and make up an estimated 90 per cent of the division. The rock is recrystallized in appearance and is well consolidated. Foliation is pronounced but extreme schistosity is rare. In the field, the fine-grained clastic character of the original sediment is still evident. Bedding is moderate to good. (see Plate 4) The fresh surface is medium grey to brownish-grey in color with some banding due to bedding. The weathered surface is characteristically brownish.

Microscopic Description

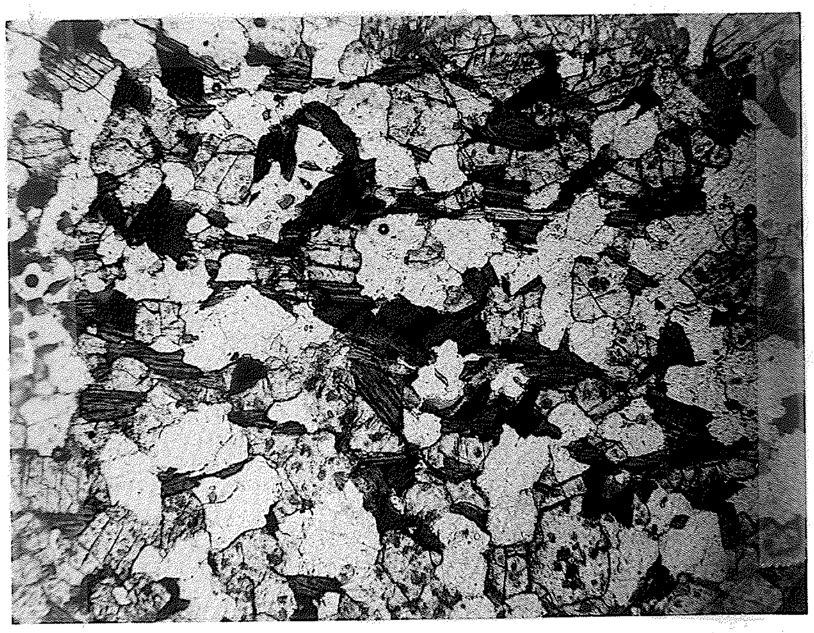
Thin section study revealed a remarkably uniform mineralogical composition, the principle constituents being quartz, plagioclase and biotite. Potash feldspar is conspicuously rare and only small amounts of introduced microcline were observed in specimens from near granitic intrusions. Minor constituents are epidote, garnet, chlorite, muscovite, hornblende, apatite, sulphides and magnetite.

The minerals are evenly distributed, seldom forming clots. Grainsize is uniform in individual specimens, ranging from 0.1 to 0.3 millimeters. The texture is xenomorphic, usually with a parallel alignment of biotite blades (Plate 5A); less common, it has a granular non-oriented appearance. (Plate 5B). Modal analysis gave the following average results: quartz,

Thin-bedded biotite sedimentary schists, lot 4, concession I, Mather township.



A. Biotite-plagioclase-quartz sediments showing uniform character and alignment of biotite blades. Ordinary light. X80. (Specimen N-19-3)



B. Stained thin section of biotite-plagioclase-quartz sediments showing recrystallized granular texture. Ordinary light. X25. (Specimen N-5-9)

25-35 per cent; plagioclase, 40-55 per cent; biotite, 15-25 per cent. The quartz is clear, but frequently strained. Plagioclase is unaltered with good albite twinning. Most commonly, its composition is andesine. Biotite is brown and has strong pleochroism and absorption. In some specimens, it contained minute inclusions of zircon surrounded by pleochroic haloes. The epidote is usually granular, but occasionally occurs in euhedral cleavable crystals. It is yellowish, slightly pleochroic, and has high interference colors. It is usually associated with the biotite and is apparently most abundant near the granitic intrusions. The garnet is a dark red variety. It occurs in poorly formed porphyroblasts with seive-texture due to abundant quartz inclusions.

Conglomerate

The conglomerate consists of pebbles, cobbles and small boulders, ranging from one inch to one foot in diameter, enclosed in a matrix of the typical biotite schists. The clasts are well-rounded and make up an estimated 35 per cent of the total unit. In the field, they all appeared to have the same composition, consisting of a fine-grained, slightly gneissic igneous rock. Their fresh surface is grey, their weathered surface is buff. A stained thin section showed the rock to consist of approximately equal amounts of quartz, plagioclase and biotite with a lesser amount of a potash feldspar, probably microcline. The quartz and feldspar form a microgranular intergrowth through which are aligned minute biotite blades. The rock is probably quartz latite and closely resembles the quartz latite lavas described later under "Intermediate and Acid Volcanics".

Iron Formation

Iron formation occurs in bands trending in a general east-west direction across the northern part of Dobie township and in a belt extending north and east from the town of Emo. It is not exposed, however. The northernmost occurrence has been outlined by ground magnetometer work and has been investigated by four diamond drill holes. The southern belt has been outlined on the map from an aeromagnetic survey map and minor ground geophysical work. Diamond drilling of this formation has also been carried out but the data are not available. The belts are apparently of similar character.

In the core examined from the north belt, the iron formation appeared to be interbedded with the biotite and garnet rich sedimentary schists and gneisses. It consists of thin bands of dark grey iron-rich material alternating with thin white to light grey quartzitic and feldspathic bands. Magnetite is the predominate iron oxide and was the only one observed in polished sections. Small amounts of specular hematite are present, however. Pyrite occurs in rare poorly developed crystals. A thin section revealed the non-opaque minerals to be principally quartz with plagioclase and biotite, as in the schists, plus green hornblende. The texture is xenomorphic granular, completely recrystallized. The grain-size is approximately 0.1 to 0.2 millimeters.

Original Nature

Biotite Schists

The biotite schists and gneisses except for an absence of two feldspars are intermediate between two types described by Harker. These are (1) biotite and garnet granulites and (2) quartzose mica-schists and quartzose-garnet-mica schists. Harker's examples were derived respectively from feldspathic arenaceous sediments and more impure arenites.

The Coutchiching mica schists described by Lawson (1913 pp. 28-35) in the Rainy Lake area are similar in nature although they have greater percentages of quartz and alkali feldspar. On the basis of chemical analysis Lawson believes the schists to be derived from shales.

Grout (1933, p. 994) describes comparable biotite schists in Minnesota. From his figure 7, p. 1003 the mineralogical composition is approximately one third of each of quartz, biotite and combined feldspars plus minor sericite, chlorite, and epidote. The schists were derived by metamorphism of shales and sands induced by granitic intrusions. Of these, Grout says:

> "Analyses of separate beds . . . failed to show as much difference in quartz content as might be expected in sands and shales. The mineral content of the two phases seems to be about the same, though the darker fine clay may have a little more graphite than the coarse material."

He found that color banding was due to a variation in grain-size, the coarse material weathering lighter than the fine clays. Pettijohn, in studying schists originating from grey-wacke and slate, observed:

> "In spite of metamorphism, however, the original differences in grainsize and mineral composition between one bed and another are faithfully retained. Original sands and muds, alternating in thin beds, were converted first to greywacke and slates and then with increasing metamorphism to quartz-biotite schist and paragneiss."

A definite clastic appearance does characterize the biotite schists of the Emo area. The existance of the same schists as the matrix of the conglomerate and the presence of typical greywacke-type texture in the less metamorphosed parts of the northern band described by Fletcher are further indication of an original sandy nature. Shale is probably represented by the finer grained material and apparently accounts for much of the banding. Thus, it is believed that the bulk of the schists were originally feldspathic greywacke with lesser amounts of interbedded shale.

The rarity of potash-feldspar probably indicates that potash was less abundant in the original sediment than sodium. This too is indicative of greywacke. (Pettijohn, 1949, p. 251)

Iron Formation

In discussing Archean iron formations, Pettijohn says:

> " . . Always it is the same well-banded, lean iron poor, crumpled siliceous (originally cherty) interbedded with greywacke type of deposit . . . The Archean iron bearing formations are essentially ferruginous cherts, and their origin is but a phase of the whole chert problem. To the extent that this problem is solved for later times, it is solved for the Archean.
>
> The younger bedded cherts associated with geosynclinal greywacke-greenstone complex contain Radiolaria which most certainly indicate marine origin. A marine origin is therefore implied for the Archean ferruginous cherts."

His description fits that of the iron formation in the Emo area perfectly as far as it is known. The latter does not offer any further answers to the chert problem because of its lack of exposure. Its occurrence and distribution indicate that it is a sedimentary deposit probably laid down in shallow marine waters under the normal conditions of geo-synclinal sedimentation. A restricted basin of deposition of the type suggested by James (1951) may have provided the necessary conditions for precipitation of the iron oxides. The original ferruginous material could have been either magnetite or hematite. Banding is probably retained from original bedding.

Metamorphism

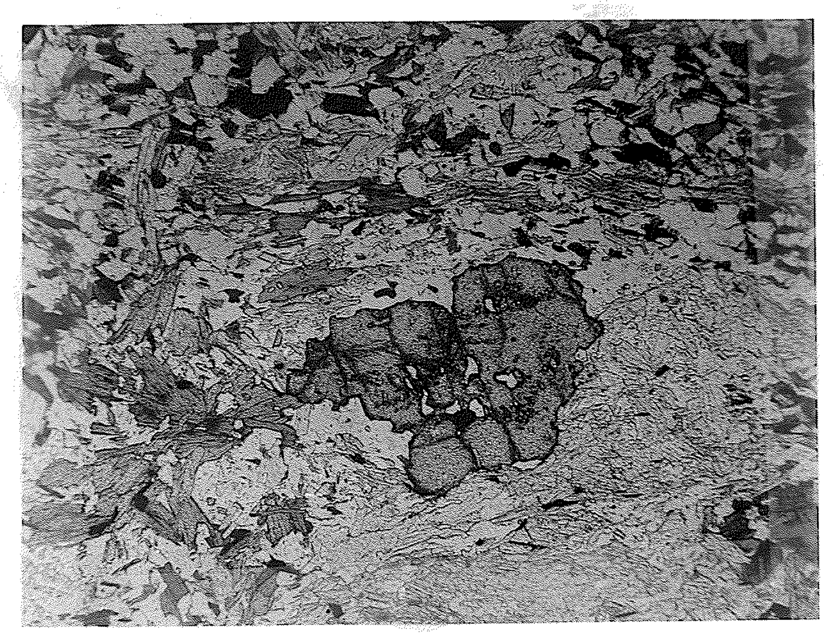
The persistance of the same mineralogy throughout the investigated part of the upper sedimentary division suggests that the metamorphism has been on a regional scale. However, the type of mineralogy does not imply that the grade is uniform throughout. The plagioclase-biotite-quartz-garnet assemblage suggests a medium grade. Because of its comparative simplicity, however, higher grades may be represented. Garnet occurs without a definite pattern of distribution suggesting controlling effects of bulk composition. Biotite although produced at lower grades, may be stable even at high grades if an ample supply of water and other volatiles is available (Harker 1932, p. 57). The absence of potash-feldspar may possibly indicate that extreme grades have not been reached because:

". . . most highly metamorphosed rocks often contain a considerable amount of potash-feldspar, a mineral not found (in rocks of argillaceous composition) in any lower grade of regional metamorphism." (Harker, p. 228)

Specimens collected at various distances from the main granitic masses showed only minor differences. The schists and gneisses nearest the intrusives are generally slightly coarser grained and contain a little more epidote. The increased grainsize may be due to recrystallization but may only be a reflection of original texture. The increase in epidote is probably the result of a local calcareous admixture or addition.

One of the specimens furthest from the granites showed poorly formed garnets closely associated with knots of chlorite and muscovite within otherwise normal biotite schist. (Plate 6A) This association is somewhat anomalous in that garnet is usually formed at the expense of chlorite. It may, however, represent a stage where the metamorphism has just reached the grade of the garnet zone. That is, the garnet had just begun to form but has not developed far enough to replace all the chlorite. Thus, equilibrium had not been reached.

Most of the biotite schists are placed in the amphibolite facies by their mineral assemblage. Near the granitic intrusives they could conceivably belong to either the staurolite-kyanite subfacies or the almandine-diopside-hornblende sub-



A. Biotite schists showing porphyroblastic garnet and clots of chlorite and muscovite. Ordinary light. X25. (Specimen N-12-7)

B. Biotite schists showing "phenocrysts" of plagioclase developed by metasomatic replacement. Ordinary light. X80. (Specimen N-33-3) facies. The latter is most probable because, in these localities, the absence of extreme schistosity and the presence of granulitic textures suggest high temperature and pressure with only subordinate stress. The metamorphic grade evidently decreases away from the intrusives.

In the iron formation, predominant magnetite is characteristic of higher grades.

Lit-par-lit

The zones of lit-par-lit injection shown on the map range from sedimentary material injected with concordant stringers and diklets, largely of quartz monzonite, to slab-like fragments of sediments engulfed in the intrusive rock. The long dimensions of the slabs parallel the original bedding and the gneissosity of the quartz monzonite. Considerable contortion is present although extreme ptygmatic folding is not prevalent. The sedimentary-igneous contacts are, most commonly, relatively sharp although completely gradational contacts do exist.

Small metacrysts of calcic oligoclase (Plate 6B), closely resembling those in the intrusive rock are frequently developed in the sediment. This phenomenon is generally regarded as the result of metasomatic introduction of alkali (Williams et al, 1954, p. 235). It is possible that they represent a straight forward recrystallization of the sediments in an attempt to reach equilibrium with the adjacent crystallizing granitic rock. However, if this were true a slightly more calcic plagioclase might be expected because the sediment is more mafic rich than the granite. Whether this difference in mafic content is sufficient to be significant remains a question.

Other changes in the mineralogy of the sediments are surprisingly slight, especially so in regard to their content of potash feldspar and muscovite. On the other hand, dark mafic-rich bands in the quartz monzonite are believed to indicate assimilation of sedimentary material. Grout (1933, p. 1006) describes injection gneisses along contacts with granitic intrusives as follows:

> " . . . these gneisses are probably developed only by additions of magma --- especially by a somewhat pegmatitic phase of magma.
>
> It seemed clear in the field that all gradations could be found between schist and granite . . The granite in one place near a group of inclusions . . . . is noticable darker than average, and analysis show that it may have assimilated as much as 20 per cent of its weight of the schist."

This same description applies very well to most of the lit-par-lit in the Emo area. It is believed that the effects of assimilation in the granite considerably overshadow those of granitization in the sediments.

CONCLUSIONS

1) The sediments of the lower sedimentary division now exist as diopside-bearing hornblende-plagioclase-quartz schists. They are believed to be derived by regional metamorphism of fine clastic sediments with a clay matrix rich in calcareous and chloritic materials. Volcanic tuffs were probably a major component. The metamorphic grade is approximately that of the sillimanite zone, belonging to almandine-diopside-hornblende subfacies of the amphibolite facies.

2) The upper sedimentary division consists largely of plagioclase-biotite-quartz schists, locally garnetiferous. Originally it probably consisted of feldspathic greywacke with interbedded shale. Its metamorphism is regional and of the amphibolite facies. The grade increases progressing towards the granitic intrusions.

3) The iron formation consists largely of magnetite and quartz and has probably been derived by high medium-grade metamorphism of ferrugnious cherts.

4) Granitization of the sediments has occurred, but only on a minor scale along the borders of the granitic intrusions.

CHAPTER III VOLCANIC ROCKS OF THE KEEWATIN

The volcanic rocks of the Emo are classified as (1) intermediate and acid volcanics and (2) basic volcanics.

INTERMEDIATE AND ACID VOLCANICS

Distribution and Structure

The intermediate and acid volcanics occur in a north and a south group (see figure 1). Only the south or Dobie group was studied for this thesis. It is divided into two belts separated by a band of basic volcanics. The same rock types occur in both belts and they probably represent parts of the same period of volcanism. However, their exact relationship to each other and to the adjacent rock types cannot be definitely established because of poor exposure.

The northernmost belt extends from the east-central part of Shenston township into the central part of Dobie township. Its structural trend is approximately N70°E and the dips of bedding, flow structures and foliation features are steep to vertical.

The southern and larger belt occupies the southeastern half of Dobie township, Barwick township and small portions of Shenston, Roseberry and Carpenter townships. Its trend is in a general north-east direction and dips on flow and bedding structures are near vertical. The belt is believed to occur along the axis of a major anticline and is intruded on its northeast flank by the "Dobie basic intrusion".

Character

The principal lithologic units of intermediate and acid volcanics are:

(1) Lavas, intermediate to acid in composition.

(2) Intermediate agglomerate.

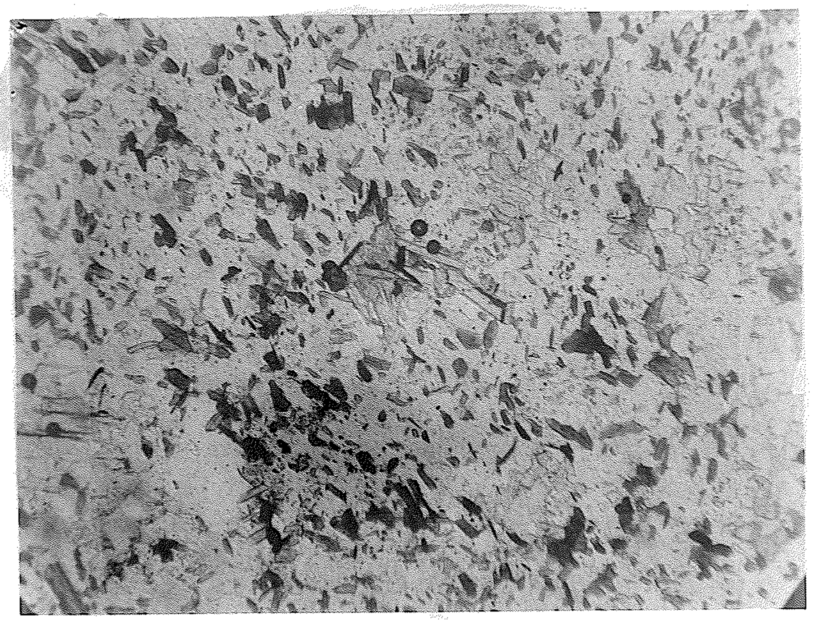
(3) Tuffs.

Intermediate and Acid Lavas

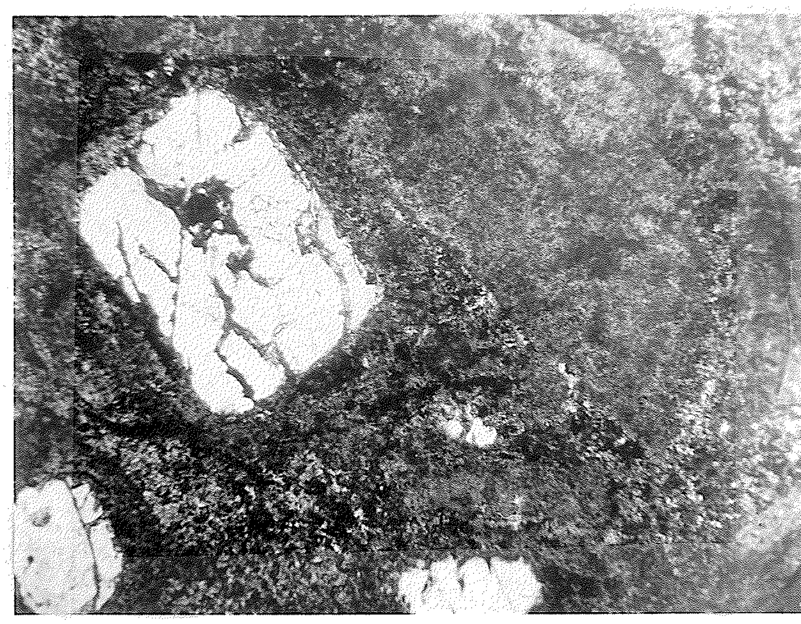
The lavas are largely dacitic in composition with minor amounts of quartz latite and rhyolite. In the field, they all appeared very similar. They are dense, massive and extremely tough. Their fresh surface is light greenish-grey or, less commonly, buff. The weathered surface is a light color, typically creamy-white, buff or brownish. The texture ranges from aphanitic to porphyritic.

The porphyritic material has quartz phenocrysts or "eyes" and feldspar phenocrysts. The matrix is aphanitic. The phenocrysts range from microscopic to five millimeters in size and make up from 5 to 40 per cent of the total rock. Commonly they show a weak irregular alignment due to flow. On the map, this material has been designated as dacite porphyry but quartz porphyry and quartz feldspar porphyry could also be applied as appropriate names.

Microscopic examination shows the dacitic lavas are composed mainly of quartz and plagioclase in approximately equal amounts. Biotite is usually the next most prevalent constituent and makes up from 5 to 40 per cent of the rock. In some specimens hornblende occurs instead of biotite. Less common minerals are muscovite, chlorite, epidote and calcite. Staining shows that potash-feldspar is rare. Plagioclase occurs in a micro-granular intergrowth with quartz in the aphanitic material and in the porphyritic lavas it forms phenocrysts (Plate 7A, B). In the former, it is poorly twinned and because of its fine-grained nature could not be isolated for analysis by oil immersion methods. In the phenocrysts, albite twinning indicate oligoclase. Sericitization is common and moderate saussuritization is developed in some parts, apparently those nearest the "Dobie basic intrusive". The quartz phenocrysts are usually anhedral but in some specimens subhedral crystals are present. They seldom show strain effects. The biotite is a brown pleochroic variety. It forms minute, unoriented blades uniformly distributed throughout the rock. Hornblende occurs in small pleochroic green prisms. In a few places it forms cleavable phenocrysts in the porphyritic lavas. Muscovite apparently occurs only in conjunction with biotite. Characteristically it is present as 1/2 millimeter metacrysts (see Plate 7A). The chlorite is pale green with low birefringence and forms tiny blades, most commonly in specimens containing horn-



A. Fine-grained dacite composed of plagioclase, quartz and biotite with muscovite metacrysts. Ordinary light. X25. (Specimen N-10-2)



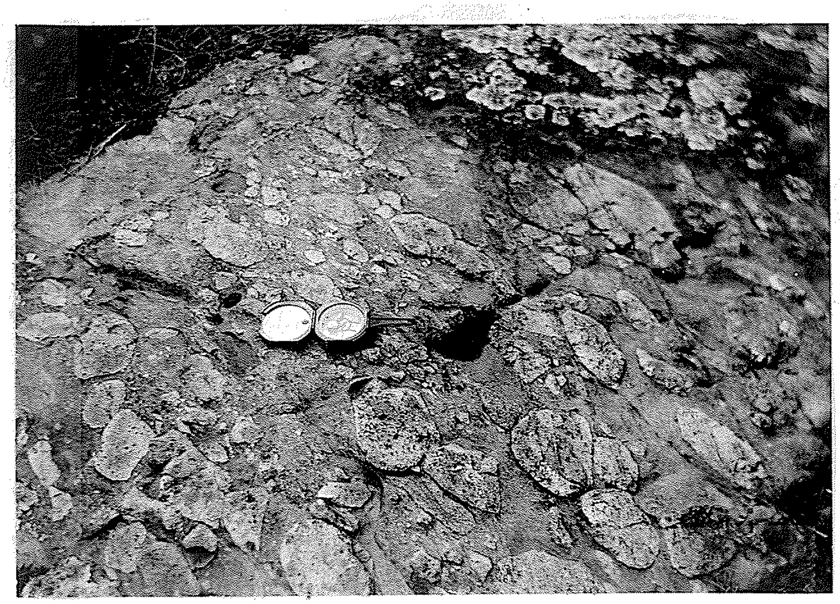
B. Stained thin section showing dacite porphyry with subhedral phenocrysts of quartz and plagioclase. Ordinary light. X25. (Specimen N-65-3) blende. Epidote forms rare granules and calcite appears to be secondary.

The quartz latites and rhyolites are similar in character to the dacite but are much finer grained with more alkali-feldspar. Mafics are even less abundant.

Intermediate Agglomerate

The intermediate agglomerate (see Plate 8), like the lavas, weathers a typical light buff, brown or cream-white. It is intimately associated with the lavas and, in some places, porphyritic lava forms the matrix around the fragments.

The fragments range from one to eight inches in size and some are as large as one foot. They are subangular to subrounded in outline and make up from 10 to 40 per cent of the rock. They are not confined to definite beds but are randomly distributed. All appear to be formed of the same material, a massive fine-grained igneous rock. Thin sections show a composition essentially the same as the lavas, ranging from quartz latite to quartz dacite. The principal constituents are quartz and plagioclase with biotite, hornblende and epidote. Potash-feldspar occurs in varying amounts and where prevalent is accompanied by muscovite. The texture ranges from microcrystalline to poorly porphyritic. Sutured intergrowths of plagioclase and quartz are common. Biotite occurs as tiny brown pleochroic blades and in places has minute inclusions of zircon. Epidote



Intermediate agglomerate with dacite fragments, NE 1/4 section 1, Shenston township.

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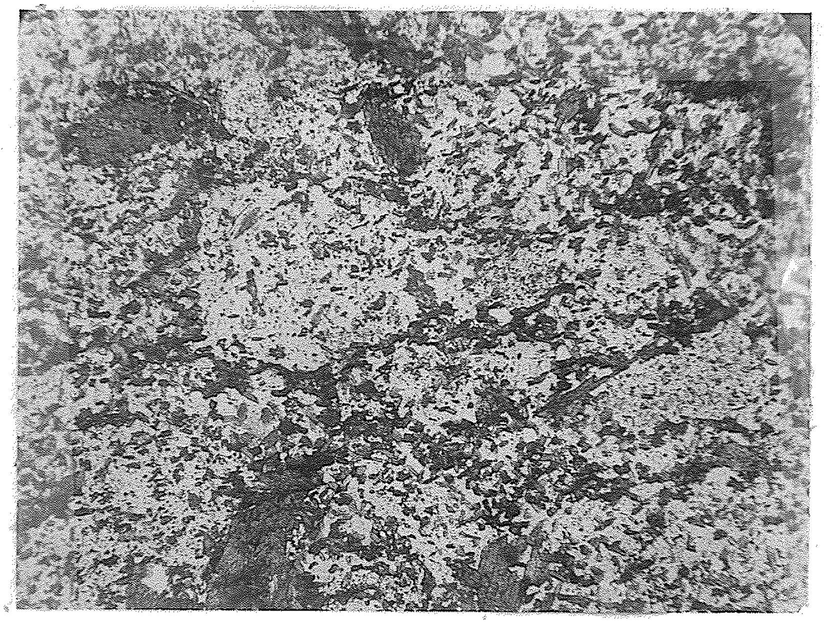
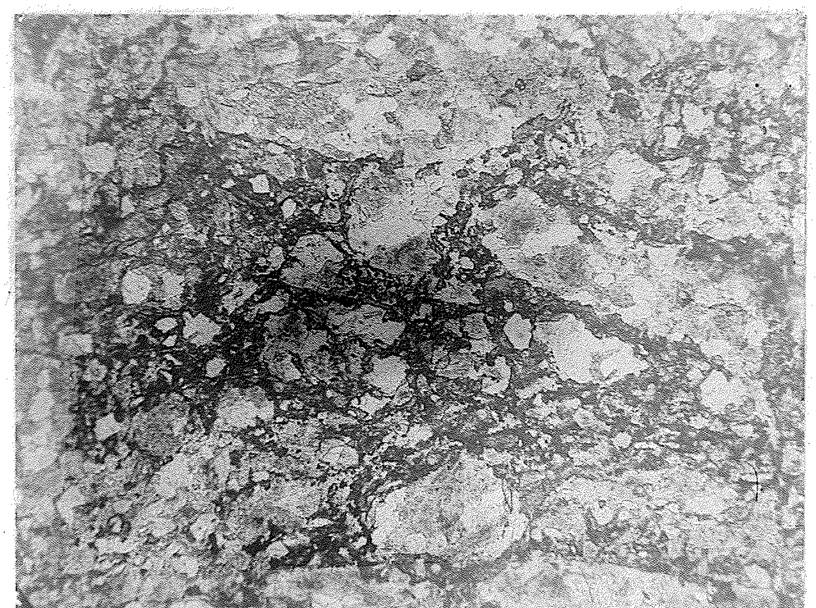
forms rare granules. Hornblende is yellow to brown pleochroic variety and is associated with the biotite.

The matrix is usually greenish-grey in color and is invariably slightly darker than the fragments. It is generally a fine-grained pyroclastic. Bedding is absent or poorly developed. Considerable difficulty was encountered in distinquishing the pyroclastic material from the lavas both in the field and the laboratory.

Under the microscope, most specimens were found to have a completely recrystallized microgranular texture. A few showed 1 to 3 millimeter clastic grains (Plate 9A). In some of the latter the fragments resemble phenocrysts and the material could be called a "porphyritic tuff" (Pettijohn, 1949, p. 265). The composition of the agglomerate matrix is more variable than either the lavas or the larger fragments. It contains a greater percentage of mafic minerals and commonly more than one type. The estimated average composition is 20 per cent quartz, 55 per cent plagioclase and 25 per cent biotite and/or hornblende. The plagioclase is poorly twinned and frequently saussuritized. It is probably oligoclase. Biotite is brown, strongly pleochroic and occurs in tiny blades. Hornblende is usually bluish-green or pale green and shreddy. Locally it forms dark green, strongly pleochroic crystals with good amphibole cleavage. Epidote is associated with the biotite. Muscovite forms 0.5 to 1.0 mill-



A. Recrystallized agglomerate matrix showing outlines of original grains. Dark mineral is hornblende. Ordinary light. X25 (Specimen N-9-3)



B. Tuffaceous material showing pyroclastic texture. Ordinary light. (Specimen F-9-4) imeter poikiloblasts and small amounts of sericite are common to most specimens.

Tuffs

Tuffaceous material is interbedded in small amounts with quartz latite and rhyolite in the northern belt. It is so similar to the pyroclastic matrix of the agglomerate that another description is unnecessary. Plate 9B shows the well developed pyroclastic texture.

Metamorphism

Two principal types of metamorphism are to be suspected in the intermediate and acid volcanics because of their geologic occurrence. One is regional metamorphism, the other is more localized metamorphism caused by the "Dobie basic intrusion". In studying the rocks, however, the cause and the grade were difficult to establish. Good index minerals or mineral assemblages are lacking because of the acidic composition. All combinations of the minerals present were found. Where variations of the mineralogy do occur, slight compositional differences probably are more a controlling factor than the type and grade of metamorphism. For example, in agglomerate from one locality the fragments and matrix contain the same minerals except that biotite occurs in the former whereas the latter have hornblende. In another locality, both have biotite as their only mafic constituent. Furthermore, apparently anomolous features cause added uncertainty. Near Manitou Rapids, tuffaceous material is completely recrystallized and moderately gneissic whereas adjacent porphyritic lavas are little deformed, the quartz phenocrysts even lacking undulatory extinction. The lavas seem to have been less susceptible to recrystallization.

The metamorphism in the northern parts of the volcanics studied is probably regional and of the grade of the garnet zone. This is indicated, as will be discussed later under the heading "Basic Volcanics", by the occurrence of adjacent and interbedded garnetiferous plagioclase-amphibolites. The extreme north-east part of the belt near the lower sedimentary division has possibly been subjected to even higher grades of metamorphism. No definite evidence was found to indicate a decrease southwards in the grade of regional metamorphism.

In the vicinity of the "Dobie basic intrusive" an increased amount of epidote and appreciable saussuritization possibly indicate superimposed contact thermal metamorphism of a lower grade. Combinations of epidote with hornblende or biotite may represent the albite-epidote-amphibolite facies or the grade of the biotite zone. The occurrence of chlorite might represent the chlorite zone in the outer part of the metamorphic aureole. However, it must be emphasized that evidence on which these postulations are based is extremely indefinite. The same mineral combinations are present several miles distant from the intrusive contact as occur within a few hundreds of yards of it. Hence, it is impossible to accurately evaluate the mineralogy or to outline metamorphic isograds.

BASIC VOLCANICS

Distribution and Structure

The basic volcanic rocks outcrop largely in the following parts of the Emo area:

(1) Tait and Richardson townships

(2) Shenston and Dobie townships

(3) The eastern part of Carpenter township

Parts (2) and (3) were studied for this thesis.

The Shenston-Dobie group is shown on the map to underlie the south-western part of Shenston township with a maximum width of about 20,000 feet. It has a 2500 foot wide extension into the central part of Dobie-township. The structural trend is east north-east and the formation dips steeply to vertically in all exposed parts. Undetermined structural complications undoubtedly account for the marked change of thickness. The body is bordered on its extreme north east side by the upper sedimentary division. Elsewhere, it is bordered by and interfingers with intermediate and acid volcanics. The "Dobie basic intrusive" cuts the eastern extension.

The basic volcanics in the eastern part of Carpenter township, strike approximately N70°E and dip steeply. They form a wedge-shaped body narrowing to the east into Burriss township which, in the map-area, has a maximum width of about 8,000 feet. To the north it is bordered by iron formation, on the south-west by the "Carpenter-Lash basic intrusion", and to the south-east by the "Devlin Monzonite".

Character

The two occurrences studied consist of essentially the same types of material. Dark-colored basic lavas predominate with lesser amounts of basic agglomerate, tuff and associated sedimentary material.

Basic Lavas

The basic lavas are relatively fresh in appearance, greenish-grey to dark grey, and weather greenish-grey to brownish grey. They are largely fine-grained to aphanitic, massive or slightly gneissic. Schistose material is developed only locally. Medium to coarse-grained lavas, where present, are characterized by aligned crystals of hornblende, 2 to 7 millimeters in length, which stand out on the weathered surface as a result of differential weathering. Porphyritic lavas occur only in minor amounts. They have 5 to 10 millimeter phenocrysts of white or greenish feldspar enclosed in a fine-grained dark greenish-grey matrix.

The most common flow structures observed in the lavas are pillows. These range in length from a few inches to four feet and are separated by seams of tuffaceous material, 1/4 to 3 inches in thickness. Although they are relatively abundant, the pillows were found to have such poorly developed cusps and such irregular shapes that reliable determinations of tops of flows could rarely be made.

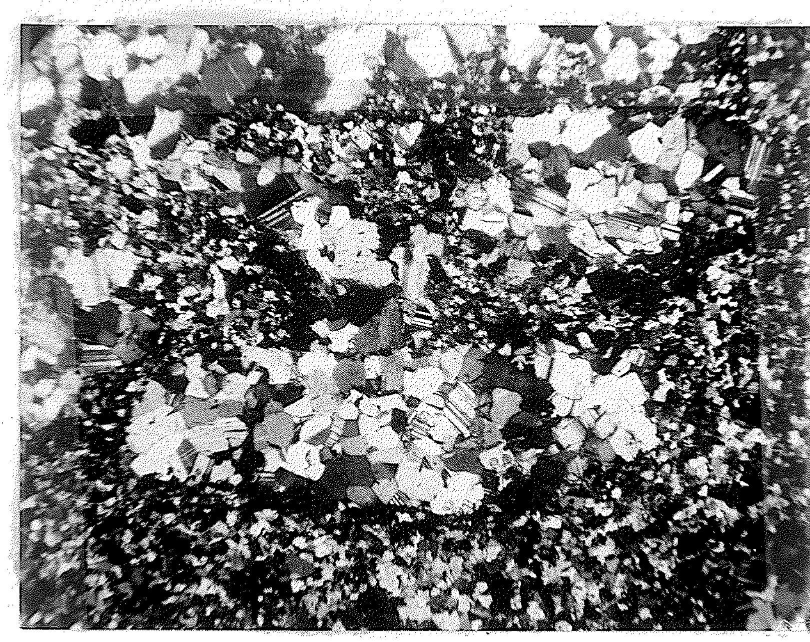
Vesicles and amygdales occur locally, being most abundant in the pillow lavas. The vesicles range in diameter from 1 to 5 millimeters and are frequently elongated. The amygdales consist of white to pinkish calcite.

Microscopic Examination

Thin sections revealed the finer-grained lavas to be highly recrystallized with an xenomorphic granular texture. Some of the medium-grained lava has hypidiomorphic texture. In the porphyritic lava, most of the phenocrysts are reduced to clots of granular crystals but a few subhedral crystals of original plagioclase are preserved (see Plate 10A).

The lavas from the two areas studied are appreciably different mineralogically and are described separately.

The basic lavas in Shenston and Dobie townships are composed principally of hornblende and plagioclase. Quantitatively, the proportions of these minerals vary considerably,



A. Porphyritic basalt showing recrystallized plagioclase phenocrysts. Crossed nicols. X25 (Specimen N-56-5)

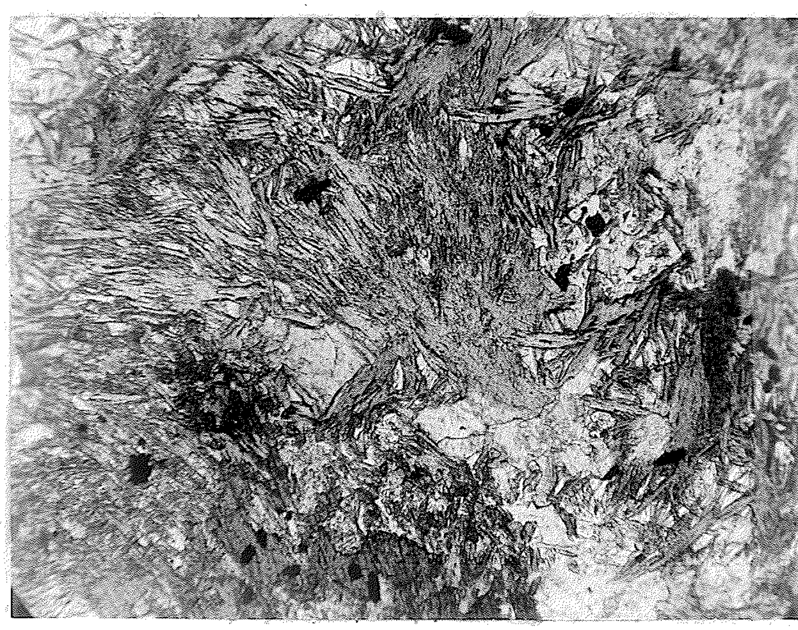
B. Recrystallized basic lava composed of poorly oriented hornblende and plagioclase. Ordinary light. X80. (Specimen F-4-1) hornblende making up from 25 to 75 per cent of the rock. Other minerals occurring in the lavas but found only locally and in small amounts are biotite, garnet, quartz, chlorite, epidote, magnetite, sulphides and calcite.

The hornblende is green or slightly bluish-green and is strongly pleochroic. It forms minute cleavable prismatic crystals. Most commonly these are randomly oriented (see Plate 10B) but, in the sheared and gneissic material they are poorly aligned. The crystals are generally uniformly distributed throughout the rock but in some of the coarse-grained specimens, they form clots which apparently are pseudomorphic in outline.

The plagioclase is largely fresh, recrystallized and granular. Locally, it is saussuritized. Albite twinning is poorly developed but occasional twins in the coarser-grained material indicate a composition of labradorite or, rarely, andesine. Oil immersion analysis of original plagioclase from the porphyritic lava showed a composition of bytownite.

Biotite occurs in brown pleochroic blades. Garnet is dark red in color, forming poorly developed metacrysts with abundant inclusions of hornblende and plagioclase (see Plate 11A). It is evidently most common in the hornblende-rich material and is found in both gneissic and granular lavas. Chlorite is locally present in shreddy masses with low interference colors (see Plate 12B). It is found with epidote and appears

A. Basic lavas showing poorly developed garnet metacryst. Ordinary light. X25 (Specimen N-66-6)



B. Chloritized basic lava. Ordinary light. X80 (Specimen FN-1-6) to be an alteration product of hornblende. In places it is confined to tiny stringers.

The Carpenter basic lavas are also composed largely of hornblende and plagioclase. Augite and diallage are common as is biotite. Sphene, apatite and sulphides are present in accessory amounts. Introduced calcite occurs in some specimens. The plagioclase is granular and completely recrystallized. Saussuritization of phenocrysts is frequently intense. Albite twinning indicates a composition of basic andesine to labradorite. The hornblende forms cleavable anhedral cleavage. It is strongly pleochroic, colors ranging from yellow brown to brownish-green. Absorption is strong. Diallage is pale greenish yellow with good parting and pyroxene cleavage. Biotite is brown and frequently intergrown with brown hornblende. It is the only mineral showing appreciable alignment.

Classification

The basic lavas are typical "Greenstones" either andesitic or basaltic in composition. Distinction between andesite and basalt is usually based upon the plagioclase composition. Grout (1932, p. 92) says:

> " . . . most American petrographers class aphanites bearing andesine as andesite and those with labradorite or bytownite as basalts."

However, recrystallization under metamorphism has probably resulted in a plagioclase composition different from that originally present.

The specific gravities of specimens of the lavas were measured in an attempt to determine their composition and possibly outline different flows. The results are shown in Table 2. Included in the table are the principal minerals in each specimen, listed in order of abundance. Exceptionally abundant minerals are underlined, those in amounts less than 7 per cent are placed in parentheses.

TABLE 2 Specific Gravities of Specimens of Basic Lavas.

Specimen Number	Mineralogy	Specific Gravity
N-66-6	Hornblende-plagioclase-(garnet)	3.11
ND-1-1	Hornblende-plagioclase-(biotite)	3.03
N-10-5	Hornblende-plagioclase-biotite (quartz-garnet)	3.01
FN-3-2	Hornblende-plagioclase	3.01
FN-3-1	Hornblende-plagioclase-quartz	2.99
N-66-3	Hornblende-plagioclase	2.99
F-C-6	Hornblende-plagioclase	2.98
N-33-1	Hornblende-plagioclase-(quartz)	2.96
N-5-2	Hornblende-plagioclase	2.95
FN-1-5	Hornblende-andesine-quartz	2.93
ND-2-2	Hornblende-andesine-biotite-(chlorite)	2.92

TABLE 2 Con't

Specimen Number	Mineralogy	Specific Gravity
N-66-1	Hornblende-labradorite-biotite	2.92
N-65-7	Plagioclase-hornblende-diallage-quartz	2.91
F-4-1		2.87
F-13-4	Bytownite-hornblende-biotite-sericite-(quartz)	2.87
FN-1-6	Plagioclase-chlorite-hornblende-(quartz)	2.86
F-13-5	Bytownite-hornblende-biotite-quartz	2.83
N-10-7	Plagioclase-chlorite-hornblende-biotite-(quartz)	2.80

It is obvious that the specific gravity is a function of mineralogy. Because the latter is largely metamorphic, the method is not satisfactory as a measure of chemical composition. However, it is considered significant that the majority of the values lie within the range of specific gravities for basalts as given by Daly (1933). Furthermore, it is noted that specimens N-13-4 and N-13-5 have original bytownite but are among the least dense specimens. It is therefore believed that the bulk of the lavas are basaltic in composition.

Basic Sediment, Tuff and Agglomerate

Small amounts of dark-colored mafic-rich sedimentary material, in part tuffaceous, and basic agglomerate are associated and interbedded with the basic lavas. This material is most extensive in the Carpenter group and the best exposure is in lot 3, concession III, Carpenter township.

The sediments are fine-grained, clastic in appearance, and have irregular bedding. They are moderately schistose and locally garnetiferous (see Plate 12A). Microscopic examination shows them to be composed mainly of greenish-brown hornblende, diopside, plagioclase and quartz.

The agglomerate consists of fragments of porphyritic basalt and fine grained lava in a matrix of the basic tuffaceous material. The fragments are subangular and range from one to six inches in length. They make up from 10 to 40 per cent of the total rock.

Metamorphism

Dobie-Shenston Group

In this group the mineral assemblages plagioclase-green hornblende and garnet-plagioclase-green hornblende are indicative of regional metamorphism of at least the grade of the garnet zone (Harker, pp. 283-285, 1933). This corresponds to the metamorphism of the bordering "upper sedimentary division". It is noted that the occurrence of garnet in the material richest in hornblende corresponds with Harker's findings. He suggests compositional control and hence the poorly developed character of the garnets probably does not place an upper limit on the grade. However, the presence of epidote suggests that the grade is not higher than the garnet zone.

The character of the calcitic amygdales is regarded as a negative evidence that high grades have not been reached. Harker says of the metamorphism of impure magnesium limestones (1933, p. 258):

> "In the highest grades of metamorphism the aluminous hornblendes, like the non-aluminous, normally give place to diopside and forsterite . . . ."

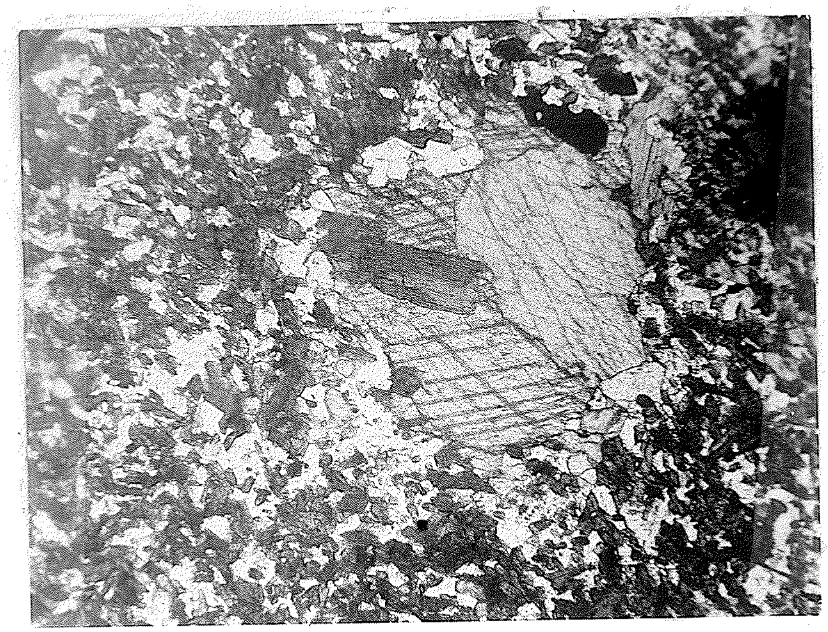
Therefore it might be expected that if high grades were imposed, reaction between the carbonate material of the amygdales and the adjacent hornblende should have occurred resulting in diopside. This phenomenon was observed by Eskola (1914, p. 108). Diopside, however, was not found in the amygdales of the basic lavas in Shenston and Dobie townships (Plate 12B).

The character of the chlorite suggests that it is the result of pneumatolytic alteration.

Carpenter Group

In the Carpenter group of basic volcanics combinations of hornblende, plagioclase and garnet again imply medium or high grades of regional metamorphism. The latter is indicated to be most probable by the presence of brown hornblende (Mason,

A. Garnetiferous basic sediments found associated with the basaltic lavas, lot 3, concession III, Carpenter township.



B. Calcite amygdale in basic lavas. Ordinary light. X25 (Specimen N-66-10)

1952, p. 231), and augite and diallage. Harker (1933) suggests that great hydrostatic pressure is a factor in the development of augite. It is therefore proposed that the metamorphism is of the grade of the sillimanite zone and that it has taken place at considerable depth. Diopside in the tuffaceous materials implies these same conditions. This is also in accordance with the metamorphism of the nearby "lower sedimentary division".

CONCLUSIONS

(1) The volcanic rocks of the Emo area consist of lavas, agglomerates and tuffs which range in composition from acid to basic.

(2) The acid and intermediate volcanics are poor indicators of metamorphic grade. They have probably been subjected to regional metamorphism of the grade of the garnet zone. Local superimposition of thermal metamorphism caused by the "Dobie basic intrusion" and of approximately the albite-epidote-amphibolite facies is suggested.

(3) The typical "greenstone" in the area is largely basaltic lavas.

(4) Regional metamorphism of the grade of the garnet zone is indicated in the basic volcanics of Shenston and Dobie townships.

(5) The basic volcanic rocks in Carpenter township have been subjected to high grades of regional metamorphism, possibly reaching that of the sillimanite zone.

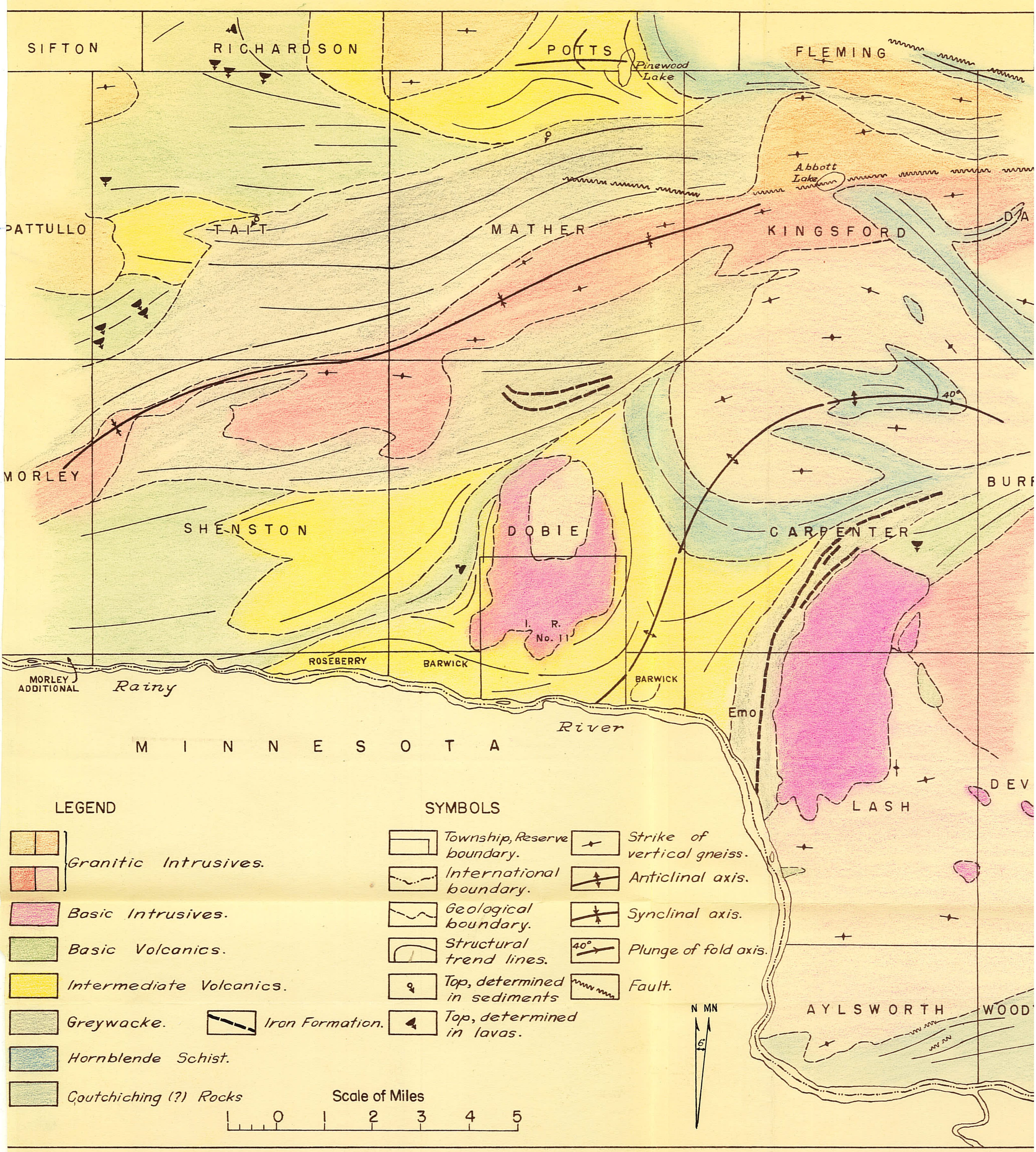


Figure 2. Sketch map showing the structural geology of the Emo Area.

CHAPTER IV STRUCTURE, STRATIGRAPHY AND SEDIMENTATION OF THE KEEWATIN

The interpretation of the structure and stratigraphy in the area has been limited by the sparseness of outcrops. Wherever possible contacts and structural trends have been outlined on the basis of geophysical and drill hole data but in many places their location has been assumed. Tops of beds have been determined primarily from pillow structures in the basic lavas. Determinations based on grainsize gradations and cross-bedding in the sediments could rarely be made because of the obscuring effects of metamorphism and lichen coverings. The attitude of schistosity and bedding are only occasionally suggestive.

A discussion of the structure of the rocks assigned to the Keewatin is in effect a discussion of the structure of the area as a whole because they make up the main sections of sediments and volcanics. Stratigraphic groupings and age sequences are based largely on structural interpretations and, hence, follow accordingly. For purposes of clarity, the entire Emo area is included in the following discussions.

STRUCTURE

Three major folds, two anticlines and a complementary syncline, are indicated within the map-area (see figure 2).

The limbs of these folds are vertical to steeply dipping and the axes of all three trend in an east-west to east north-east direction.

The most southerly fold, an anticline, is exposed with drag folding in lots 3 and 4, concession VI, Carpenter township. From this location the axis apparently trends west and south under areas covered by overburden to a point on the Rainy River approximately two miles west of Emo. In the exposures in Carpenter township the axis plunged approximately 40 degrees to the east. The arc of vertical sediments at the boundary of Dobie and Carpenter townships indicates the axis to be plunging steeply to the south-west. Thus the eastern part of the anticline is believed to be domed.

Only two reliable determinations of tops of beds were made in the limbs of the fold. In the south limb, in lot 3, concession III, Carpenter township pillow lavas indicate tops to the south. Correspondingly, the north limb pillow lavas in lot 9, concession III, Dobie township indicate tops to the north.

The axis of the north anticline trends, as shown on the map, from Pinewood Lake to the south-west corner of Potts township. Its location further west is not known because of the proximity of the fold to the boundary of the map-area. However, the schistosity and flow structures in the volcanic rocks swing from an east-west direction in Mather and Tait townships to a north-south direction in Richardson township indicating that the fold does persist. The pattern of Burditt Lake and other lakes to the North suggest that this fold may be the southern extremity of a much larger fold.

Evidence that the fold is an anticline is not available in the immediate vicinity of the defined part of the axis. However, the top of what is apparently the south limb is indicated to be to south by pillow lavas in Tait and Richardson townships and by sedimentary grainsize gradations in Tait and Mather townships.

The position of the synclinal axis between the two anticlines probably is marked by the band of granitic rocks trending N70^{o}E across Shenston and Mather townships. This is suggested by vertically plunging drag folds in the sediments bordering the intrusion.

STRATIGRAPHY

The treatment of the stratigraphy of the Keewatin follows that used by Satterly (1941). The stratigraphic divisions are based on lithology and are named after the township in which they are best exposed. In the following sequence, the oldest division is at the bottom, the youngest at the top. No definite evidence was found of unconformable contacts.

Carpenter volcanics

Mather sediments

Dobie-Tait volcanics

Carpenter sediments (possibly Coutchiching in age)

Carpenter Sediments

The "Carpenter sediments" consist of the hornblende schists of the lower sedimentary division. As described previously, the main body of these sediments outcrop in Carpenter township and another less known body outcrops in the south-east corner of Potts township. In both areas the sediments are anticlinally folded. Their position indicates that they stratigraphically underlie the intermediate and acid volcanics and that they form the basal units of the Keewatin rocks in the sections exposed by the folding. Thus the two bodies are believed to be equivalent in age and to represent the oldest unit of Keewatin rocks in the map-area.

The Coutchiching originally mapped and defined by Lawson in the Rainy Lake area is a thick series of sedimentary mica schists underlying Keewatin volcanic rocks. The Carpenter sediments have this same stratigraphic position and thus may possibly be Coutchiching in age. However, the hornblende schists do not resemble the mica schists lithologically. Direct correlations cannot be made because of the 20 mile gap between the two map-areas. Hence, the Carpenter sediments are included in the Keewatin.

Dobie-Tait Volcanics

The "Dobie volcanics" are the belt of volcanic rocks extending across the southern parts of Shenston and Dobie townships into the western part of Carpenter township. The "Tait volcanics" are the northern body of basic, intermediate and acid volcanic rocks. The former occur in the north limb of the proposed syncline, the latter in the south limb. Stratigraphically, both are indicated to directly underlie the main body of the upper sedimentary division. Therefore, they are probably equivalent in age. They are indicated to overlie the "Carpenter sediments".

Mather Sediments

The "upper sedimentary division" is best exposed in Mather township and is given the stratigraphic name "Mather sediments". As was discussed previously, the main body of these sediments is a synclinally folded formation composed largely of greywacke and underlain by the Dobie and Tait volcanics. The iron formation interbedded with the greywacke in northern Dobie township is on the north limb of an anticline. The one trending north and east across Carpenter township is in the south limb of the same fold. It is therefore believed that the latter is also part of this stratigraphic unit.

Previous mention has been made of the similarity of the biotite schists in this division and of Lawson's Coutchiching mica schists in the Rainy Lake Area. The implications of this similarity with regards to age relationships and the controversial Coutchiching problem are obvious.

Carpenter Volcanics

The basic volcanic rocks in eastern Carpenter township are called the "Carpenter volcanics". They are indicated to stratigraphically overlie the iron formation by their position in the anticline and by a determination of the direction of tops of flows made in the pillow lavas. Thus, they are probably the youngest group of Keewatin rocks.

SEDIMENTATION

"The Archean sediments of the southern Canadian Shield are mainly greywacke; much conglomerate, a little slate, and still less iron-bearing formation are also present. Excessive thickness, especially of the conglomerates, abundance of graded bedding, rarity of cross-bedding and absence of ripple mark, the greywacke nature of the arenaceous beds, the absence of true quartzites and limestones and scarcity of normal argilleceous sediments, and the association with greenstones and tuffs are all earmarks of a geosynclinal facies of sedimentation. The deposits are much like the rapidly accumulated "Flysch" sediments of later eras."(Pettijohn, 1943, p. 926)

The Keewatin rocks of the Emo area are extremely well satisfied by this description. The Carpenter sediments were probably derived largely of tuffaceous material and deposited in shallow marine waters. The volcanics, greywacke, iron formation and conglomerate are all typical Archean deposits. It is therefore concluded that geosynclinal sedimentation has resulted in the Precambrian sedimentary and volcanic rocks of the Emo area.

CHAPTER V POST - KEEWATIN INTRUSIONS - BASIC INTRUSIONS

The principal basic intrusions are two stocks, one in the central part of Dobie township, the other in Lash and Carpenter townships. The latter was studied for this thesis. Smaller bodies of hornblende diorite and hornblende gabbro are common to the area and some of these were examined in detail.

CARPENTER-LASH INTRUSION

Dimensions

The Carpenter-Lash basic intrusion has the maximum dimensions of 30,000 by 12,000 feet and is elongated in a north-south direction. Exposure is poor, particularly in Lash township, and although the intrusive boundaries have been outlined with the help of an aeromagnetic map their location is still much in doubt. Immediately to the east of the main body is a smaller mass, apparently of the same material, engulfed in granitic rocks.

Character

The intrusion is fine-to medium-grained and equigranular throughout. It is massive except in the border outcrops where weak gneissosity is developed. The fresh surface of the rock is dark greenish-grey and the weathered surface is grey to brownish-grey. In general, the feldspars are medium grey but in the coarser material pale greenish plagioclase contrasts with the darker mafics.

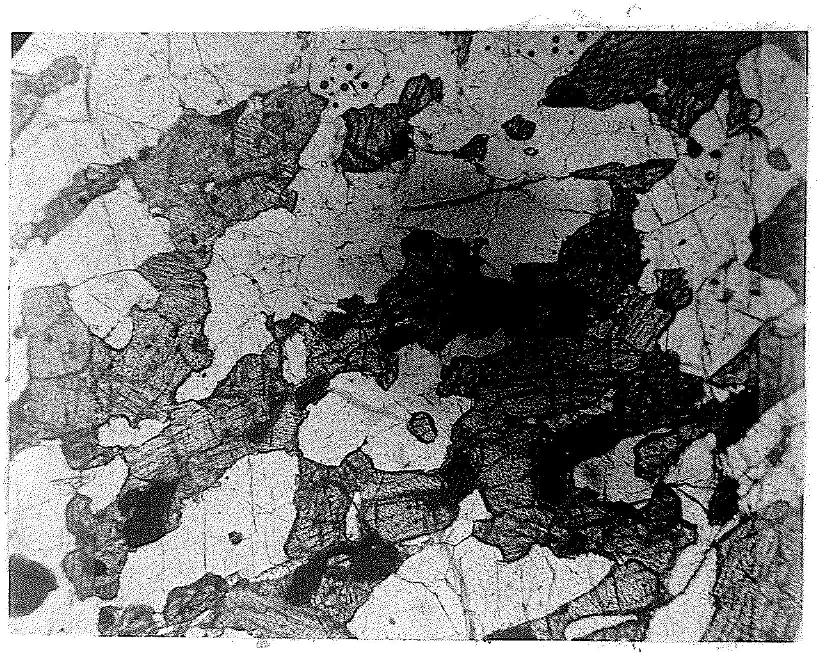
Microscopic examination showed the unaltered specimens to have a hypidiomorphic granular texture (Plate 13A). The gneissic materials have irregular alignment of mineral grains. Grain size ranges from 0.1 to 4 millimeters and is most commonly 0.5 to 2 millimeters.

The approximate compositional range was shown by Rosiwal analysis to be 50-65 per cent plagioclase, 15-25 per cent hypersthene. Varying degrees of alteration of the pyroxenes has taken place (Plate 14A, B), uralite being absent from some specimens and making up 20 per cent of others. The plagioclase ranges from andesine to labradorite (Ab_{45} - Ab_{60}), as indicated by albite twinning. It forms subhedral laths and is frequently moderately sericitized or saussuritized. Hypersthene has faint pink to greyish-green pleochroism. Augite is pale green and cleavable. Commonly it is twinned. Diallage has typical basal parting.

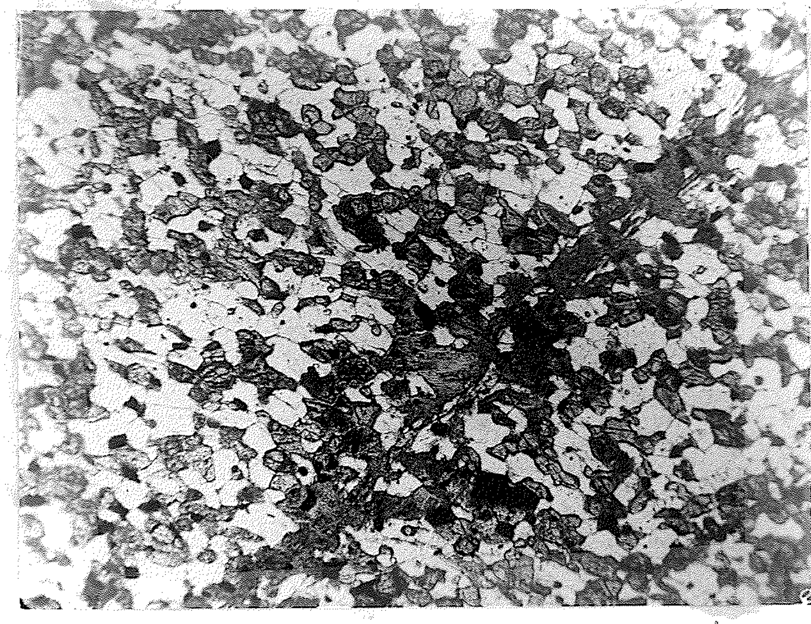
The bulk of the intrusive rock is, by Johannsen's classification (1937, p. 238), hyperite or hypersthene gabbro.

Structure

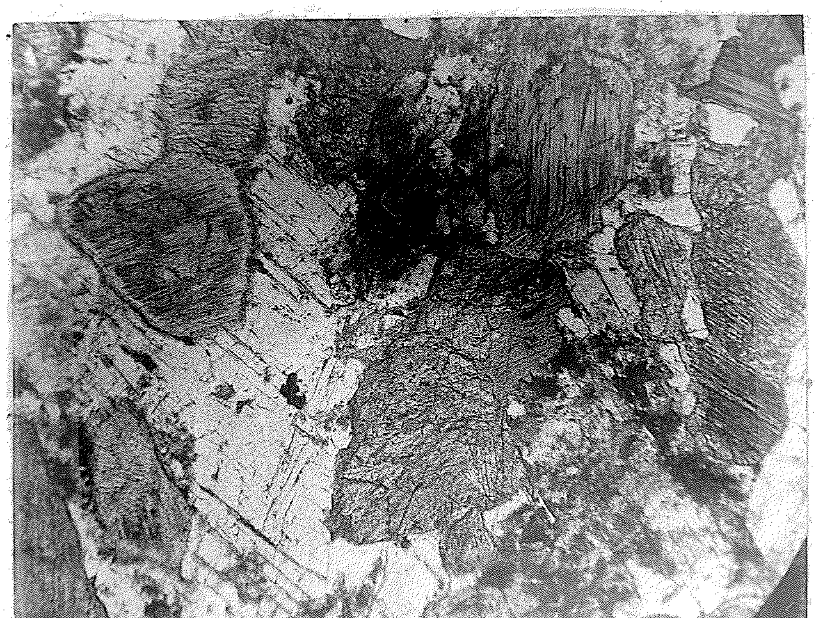
A complete structural study of the intrusion is impossible because of the poor exposure. As was mentioned previously, the rock in the border outcrops shows a gneissic alignment of



Hypersthene gabbro showing typical texture. Pyroxenes are hypersthene and diallage (with basal parting). Ordinary light. X25 (Specimen N-46-1)



A. Fine-grained hypersthene gabbro with uralite veinlet. Ordinary light. X25 (Specimen N-46-2)



B. Highly uralitized hypersthene gabbro. Ordinary light. X25 (Specimen N-38-2) crystals. This is believed to be a primary effect brought about by intrusion. The Dobie basic intrusion shows compositional zoning and to some extent textural zoning. In the Carpenter-Lash intrusion, definite zoning could not be established. The plagioclase composition varies at random. Neither the quantities of the different pyroxenes nor the total pyroxene content show a discernible pattern. Grain-size ranged from fine to medium in all parts. Alteration does not appear to be characteristic of any particular part. Thus, the intrusion is evidently randomly heterogeneous within comparatively small limits.

Genesis

The Lash-Carpenter intrusion does not show evidence of being anything but the product of normal crystallization of a basic magma. Textural relationships of minerals indicate that hypersthene was the first mineral to crystallize. Later its place in the crystallization sequence was taken by augite and/or diallage. Evidently plagioclase began to form about this same time. Uralitization is probably a late magmatic or deuteric effect.

Local primary gneissosity suggests that the magma was emplaced when at least partially crystallized.

The field evidence for the relative age of the intrusive is as follows:

(1) In lot 3, concession II, Carpenter township, the intrusive truncates the "Carpenter basic volcanics".

(2) In lot 3, concession I, Carpenter township, it is cut by dikes and apophyses of the "Devlin monzonite intrusion" which outcrops extensively to the east.

(3) In the rock cut along Provincial Highway No. 71 in the SW 1/4, section 33, Lash township, fragments of hypersthene gabbro are included in the "Lash quartz monzonite intrusion".

Thus, the intrusion is younger than the volcanic-sedimentary complex and older than at least two of the granitic bodies. Hence it is probably an ophiolitic type of intrusion related to the orogeny in the area.

HORNBLENDE DIORITE AND HORNBLENDE GABBRO

Minor dikes, sills and other irregular intrusive bodies cutting the sediments and volcanics are common throughout the area. Xenoliths of the same type of material are found in the granitic intrusions. Although the intrusions usually strike in a north-east direction, they are very unlike the typical Keweenawan diabase dikes in their structural characteristics. The largest single exposure is 1600 feet by 600 feet. Most commonly the dikes and sills range from one to 20 feet in width and are not traceable for more than several hundred feet. The xenolithic masses seldom exceed 20 feet in length.

Character

Specimens from the various masses are appreciably different. In general, the rock is dark greenish-grey and commonly shows dark ferromagnesium minerals surrounded by whitish feldspars. Medium-to coarse-grained material is most prevalent. The majority of the bodies are massive, only the smaller intrusions showing regional schistosity. Linear gneissosity is rare. Recrystallization is complete in most of the material, and xenomorphic texture being developed.

The principal mineral constituents are hornblende and plagioclase but these occur in widely varying proportions. Biotite, quartz, epidote, chlorite, sphene and sulphides are present in lesser amounts.

Hornblende occurs in two forms. In the western part of the area it is predominantly a shreddy green uralitic variety. In the east, it is strongly pleochroic, yellowish-brown to dark greenish-brown. It has good amphibole cleavage and forms subhedral crystals, aggregated together to appear as black phenocrysts in hand specimen.

Plagioclase is considerably recrystallized and most commonly is transformed into a granular mosaic around the other minerals. In some of the uralitized specimens original plagioclase still exists but it is highly saussuritized or sericitized. Albite twinning is poorly developed but a composition of andesine (Ab_{55} - Ab_{65}) is indicated. The recrystallized material is commonly labradorite.

The rock is classified as hornblende diorite and hornblende gabbro. Some of the material corresponds to spessartite, a form of lamprophyre, i.e., a dark dike rock with porphyritic or panidiomorphic texture in which euhedral hornblende crystals and andesine feldspar are characteristic (Williams et al, 1954, pp. 84-88).

Origin and Genesis

A few of the dikes may represent feeders for the basic lavas. Others are probably related to the two basic stocks. Their discontinuous character suggests that emplacement was not under tensional conditions as with the later diabases but, rather, that it accompanied folding.

Brownish hornblende in the eastern parts of the area is probably indicative of high grades of metamorphism caused by later granitic intrusion. The occurrence of inclusions of the dike rock in the granites support this idea. In the west, the uralite may be a result of regional metamorphism in some dikes and of deuteric alteration in others. The latter are most probably younger than the granites and may be related to the Dobie intrusive.

KEWEENAWAN DIABASE DIKES

Character

Diabase and quartz diabase form near-vertical dikes cutting all other Precambrian rock formations in the Emo area. The distribution of outcrops indicate the dikes have remarkable continuity in the direction N45°W. Two dikes are apparently continuous for distances of more than 20 miles and several others have been traced for 5 miles. The major dikes range in width from 100 to 300 feet. Smaller dikes, several inches to 6 feet in width are common.

A characteristic feature in the structure of the dikes are two or more sets of cooling joints developed normal to the walls thus dividing the dike in columns or slabs. Glacial plucking of these columns has resulted in a hummocky appearance along the strike of the dike (see Plate 15A). This effect in the large dikes is often clearly visible in aerial photographs.

The dike rock is dark greenish-grey in color and characteristically weathers brown. The dikes are fine-grained along the margins, becoming medium to coarse-grained in the central portions.

Microscopic Description

Microscopic examination shows an approximate composition

Keweenawan quartz diabase dike cutting granodiorite and showing hummocky effect due to jointing, lot 9, concession III, Dance township.

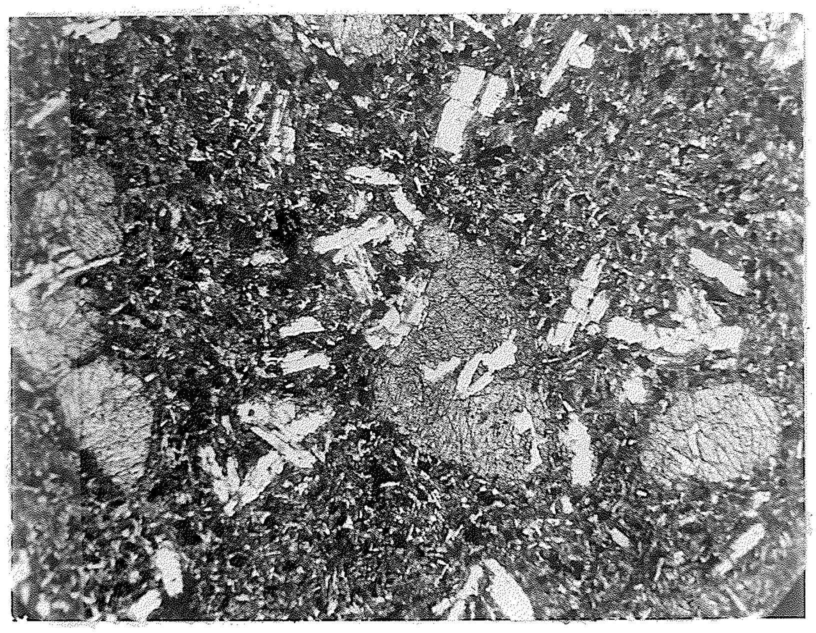
of 35-45 per cent augite, 50-60 per cent labradorite and 1-3 per cent magnetite. The augite-plagioclase ratio is greatest in the fine-grained material. Interstitial quartz may or may not be present and never occurs in amounts exceeding 10 per cent. Diabasic or intergranular texture is well developed throughout (Plate 16A). Labradorite (Ab_{45} - Ab_{50}) occurs in fresh well-twinned laths with random orientation. The augite forms anhedral crystals within the plagioclase network. In some places it forms subhedral phenocrysts in a matrix of fine-grained diabase (Plate 16B). Locally uralitization is moderate. Magnetite is finely disseminated and is significant in that it is the cause of aeromagnetic anomolies observed over the dikes.

Genesis

The dikes have evidently crystallized passively from a magma as evidenced by their sharp boundaries, marginal chilling effects and lack of orientation of crystals. The magma was probably of mafic-rich basaltic composition.

Intrusion of the dikes has obviously taken place under tensional conditions probably resulting from broad crustal warping. This is indicated by the continuity of the dikes in one direction and by dilationary effects observed along the margins of the dikes. A resultant feature of tensional emplacement common to the dikes is offset without actual severance. Many of the faults indicated on the map where offset

A. Medium-grained diabase showing typical. Ordinary light. X25 (Specimen FN-1-1)



B. Diabase showing augite phenocrysts. Ordinary light X25 (Specimen N-4-2) of the dikes is considerable, are undoubtedly only a modification of this phenomenon. Others, however, are probably faults which have moved after the emplacement either as new or pre-existing fault-planes. An example of these is in the central part of Manitou Rapids Indian Reserve, where the fault was outlined by an electromagnetic "cross-over" and the shear zone was observed in diamond drill core.

CHAPTER VI POST KEEWATIN INTRUSIVES: GRANITIC INTRUSIONS

Seven granitic intrusions in the Emo area have been named. Several small bodies are not distinguished. Within the map-area individual intrusions are stocks and bosses. Combined they form masses of batholithic dimensions. Boundaries between different intrusions are poorly defined and age relationships are obscure.

The composition of the granitic rocks ranges from quartz monzonite to granodiorite and is rarely as basic as quartz diorite. True granites are almost non-existant. On the map, four different compositional groups are denoted by symbols. Dikes are classified as pegmatitic or granitic and aplitic.

For this thesis, two of the intrusions were studied in detail. These are the "Carpenter intrusion" and the "Shenston-Mather intrusion".

CARPENTER INTRUSION

The Carpenter intrusion underlies the northern third of Carpenter township and the southern third of Kingsford township. It occupies the centre of the domal structure in the Carpenter sediments and is bordered on the south and west by these sediments. It is bordered on the north by the Shenston-Mather intrusion and extends beyond the eastern boundary of the map-area.

Character

The appearance of the intrusion is the same overall. It is fine-to medium-grained and its color is light grey to pinkish-grey. Gneissosity is moderate and results from alignment of layers and flakes of biotite. Locally, particularly near contacts with sedimentary material, a non-uniform appearance is developed with abundant mafic-rich streaks in the normal intrusive rock. Contortion of gneissosity and abundant injections of quartzose and feldspathic materials give added effect to the heterogeneity. The actual contacts with the sediments are comparatively sharp.

Composition

The rock has a remarkably simple mineralogy, being composed of quartz, plagioclase, microcline and biotite. Minor constituents, accessory minerals and alteration products are extremely rare. The results of Rosiwal analyses of stained thin sections and slabs are shown on a Q-Pl-Or diagram in figure 3, and on a Q-F-M diagram in figure 4. Because of the close similarity of all specimens from the intrusion it is very probable that more analyses would give results corresponding closely with those already obtained. The bulk of the material is granodiorite.

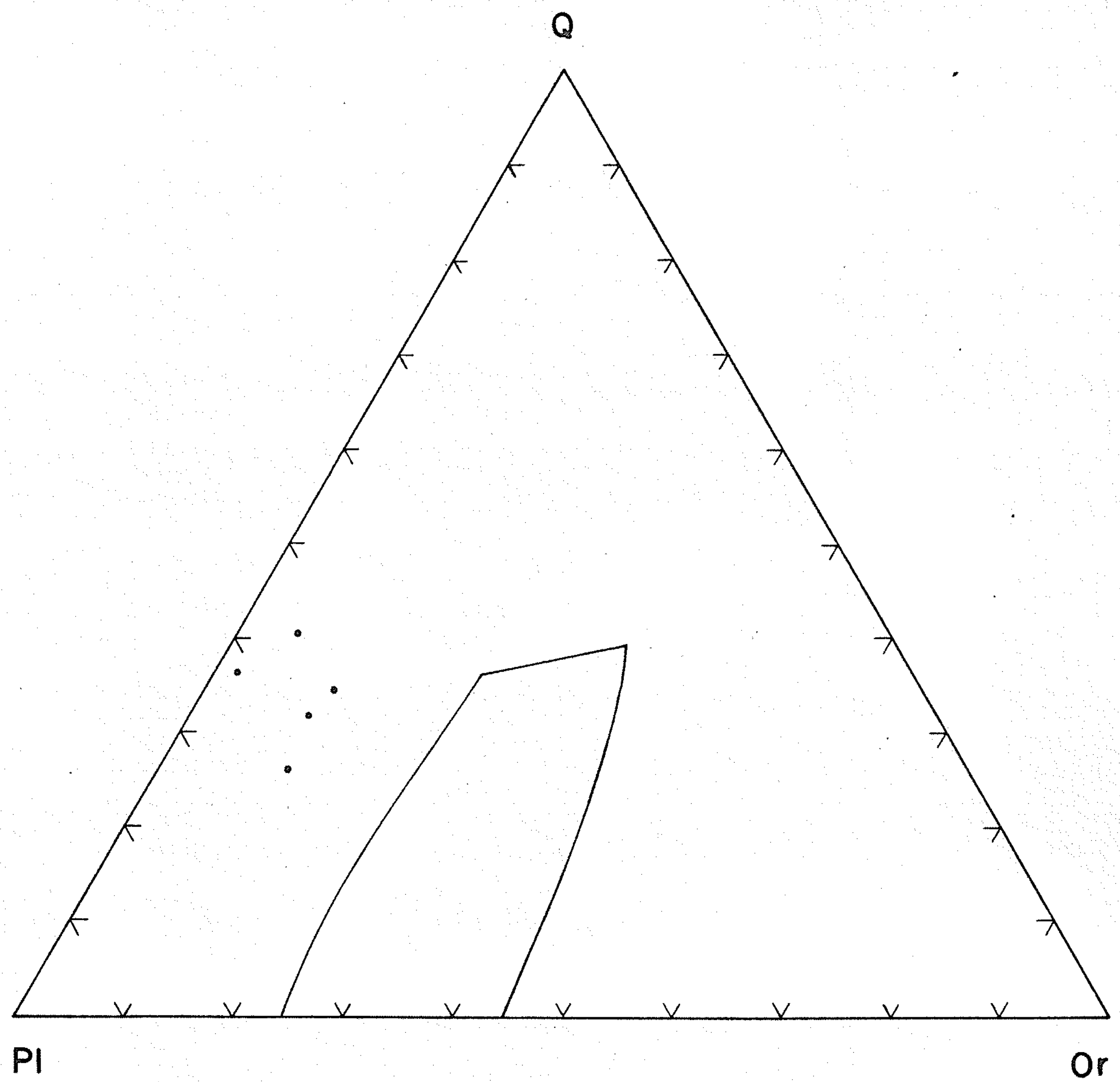


FIGURE 3. Volume percent recalculated to 100 of quartz (Q), plagioclase (Pl), and potash feldspar (Or) in thin sections of the Carpenter granitic intrusive.

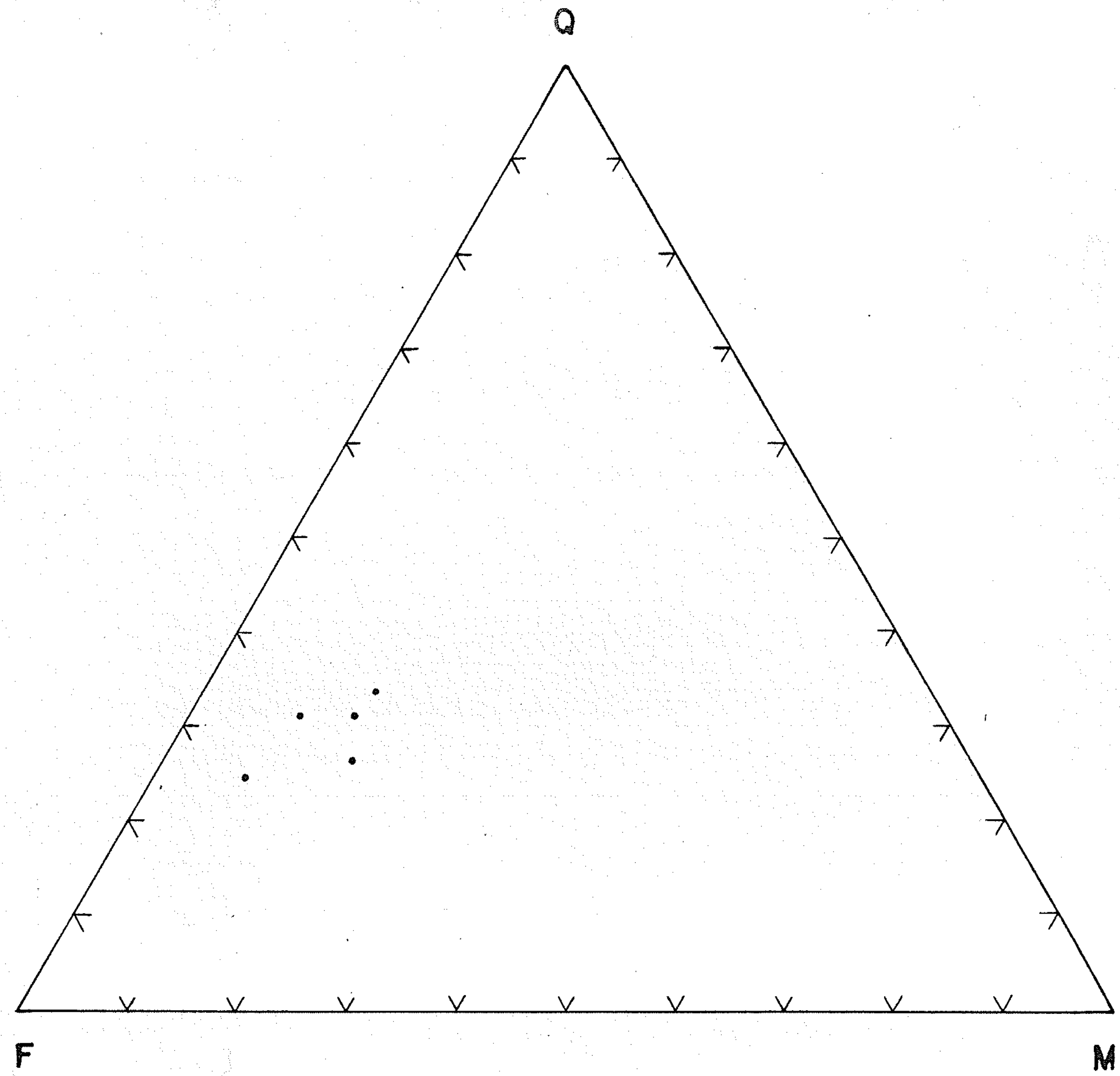


FIGURE 4. Volume percent of quartz (Q), total feldspar (F), and dark minerals (M) in thin sections of the Carpenter granitic intrusive.

Microscopic Description

The quartz and feldspars form an xenomorphic granular intergrowth through which brown biotite blades are aligned. The quartz shows slight strain shadows. The plagioclase is fresh and moderately twinned, both albite and carlsbad types being present. Its composition is indicated to by oligoclase (Ab_{73} - Ab_{82}) by oil immersion analysis. The microcline has typical cross-hatch twinning.

Structure

The intrusion does not appear to be zoned, the same texture and composition being generally persistant. The trend of the gneissosity is the most distinctive structural feature. As seen on the map, it conforms with the outline of the domal structure in the surrounding sediments. In the field conformability with the sediments was observed on a small scale and drag-folds in the sediments are frequently duplicated in the adjacent intrusive rocks. Lit-par-lit injection is common but the boundaries of the injections are usually well defined.

Genesis

Determination of the extent of granitization is a major problem in this and other granitic bodies in the area. The close correspondence of planar features in the granodiorite and the bordering sediments may point to a replacement origin. However, the hornblende schists are the only sedimentary material observed inthe vicinity. Their transformation to granodiorite would require extremely large amounts of chemical exchange. Therefore, if this material was replaced, extensive gradational zones might be expected. These, however, do not exist. The sediments show very little indication of granitization. On the other hand, the uniform composition of the granodiorite suggests a magmatic origin. The increase in mafic content near the sediments is slight and evidently due to assimilation. Derivation by replacement of a different sediment is possible but not too probable because no trace of such a sediment was found. Thus, it is believed that the Carpenter granodiorite was intruded as a magma.

The structure of the intrusion appears to bear a relationship to its emplacement. The conformability of gneissosity with the folds in the sediments suggests that intrusion and uparching were contemporaneous. The textural character of the rock indicates crystallization under stress. It is therefore, proposed that the magma was emplaced forcefully in a partially crystalline state. Thus, stresses or shear couples set up by differential movement of the "crystalline mush" with respect to the limbs of the fold has resulted in the observed pattern of the foliation. The accompanying squeezing action has probably caused concentration of later crystallizing liquids at the margins of the intrusive thus, giving rise to the prevalent lit-par-lit injections.

SHENSTON-MATHER INTRUSION

A complex band of granitic rocks extending in an east north-east direction across Shenston township, part of Dobie township, Mather and Kingsford townships has been called the "Shenston-Mather intrusion". It has an average width of approximately 7,000 feet, but its outline is irregular. In the western part of Shenston township the width is only several hundred feet whereas in the north-west part of Dobie township it bulges out to 14,000 feet.

Composition

The intrusion shows a large and almost random variation in composition. It ranges from diorite to quartz monzonite and true granites probably exist in some of the related dikes. In figure 5, the results of modal analyses have been plotted on a Q-Pl-Or diagram similar to that used by Chayes (1950). The plots fall on both sides of the low temperature valley (Bowen, 1937) and a grouping of points is virtually non-existant. Undoubtedly the analyses are considerably in error because of the coarse-grained nature of many of the specimens. However, these errors are not believed to be sufficiently

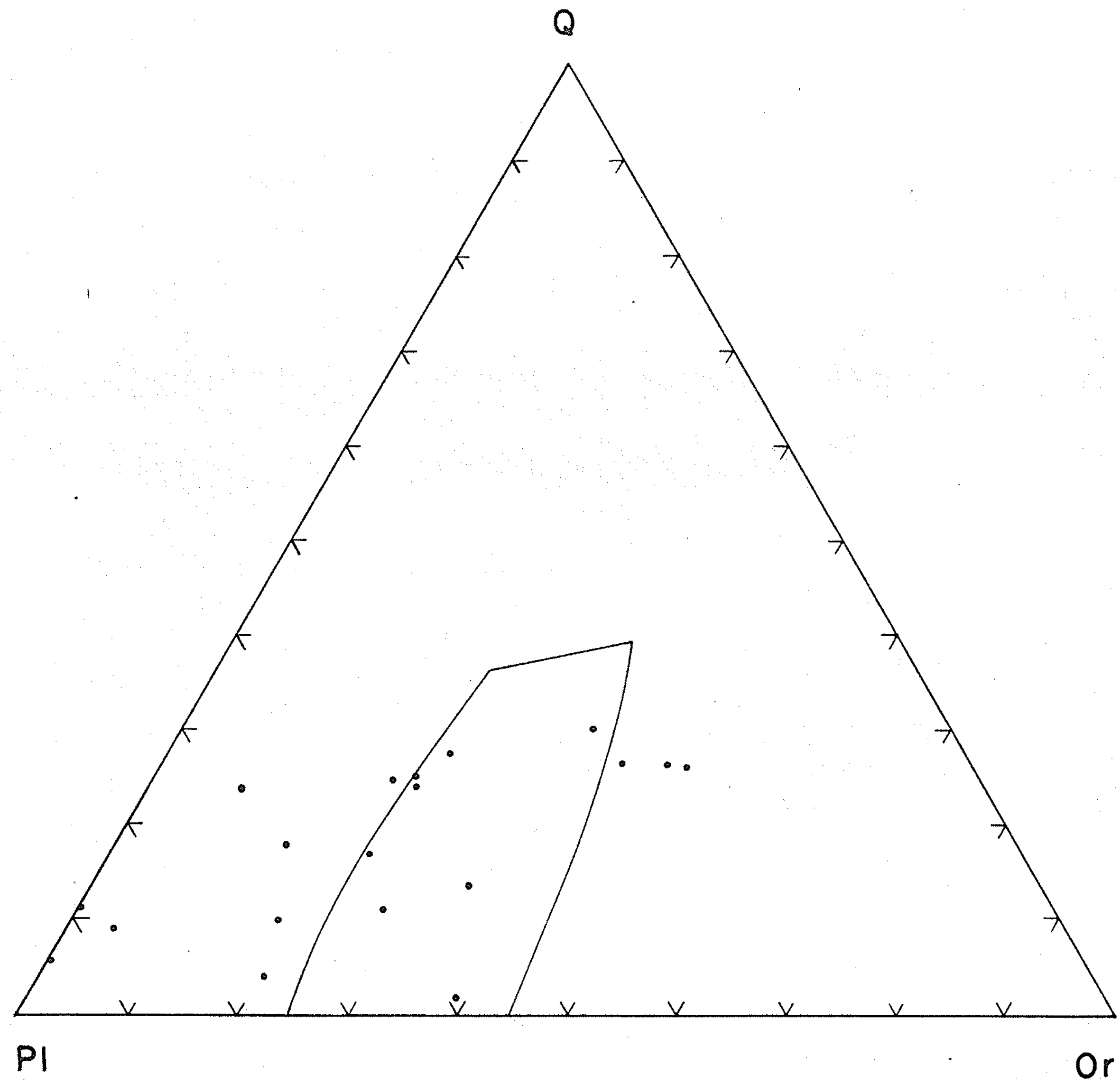


FIGURE 5. Volume percent recalculated to 100 of quartz (Q), plagioclase (Pl), and potash feldspar (Or) in thin sections of the Shenston-Mather granitic intrusive.

large to detract from the true picture at its present stage of development. On the other hand, a visual examination of all the specimens collected from the intrusive suggest that two more or less distinct phases predominate and that these are concentrated in definite parts of the intrusion. An indication of these two phases is given by the distribution of plots on the Q-M-F diagram in figure 6. The phase with the most mafics is characterized by the presence of hornblende. It ranges in composition from diorite to quartz monzonite, consisting mainly of granodiorite. The other phase is largely quartz monzonite and its principle mafic mineral is biotite. On the basis of both the modal analyses and field observations the phases are believed to be gradational into one another.

Character

The two groups are considered distinctive enough to warrant separate descriptions.

Basic Phase

The hornblende-bearing material is mottled in appearance with white to pinkish feldspar surrounded by dark greenish-grey to black mafics. Most commonly it is porphyritic but medium-grained equigranular material is present. Phenocrysts are of feldspar and range from 1/4 to one inch in length. Gneissosity is generally well developed and in the porphyritic material alignment of crushed phenocrysts gives a typical augen-gneiss

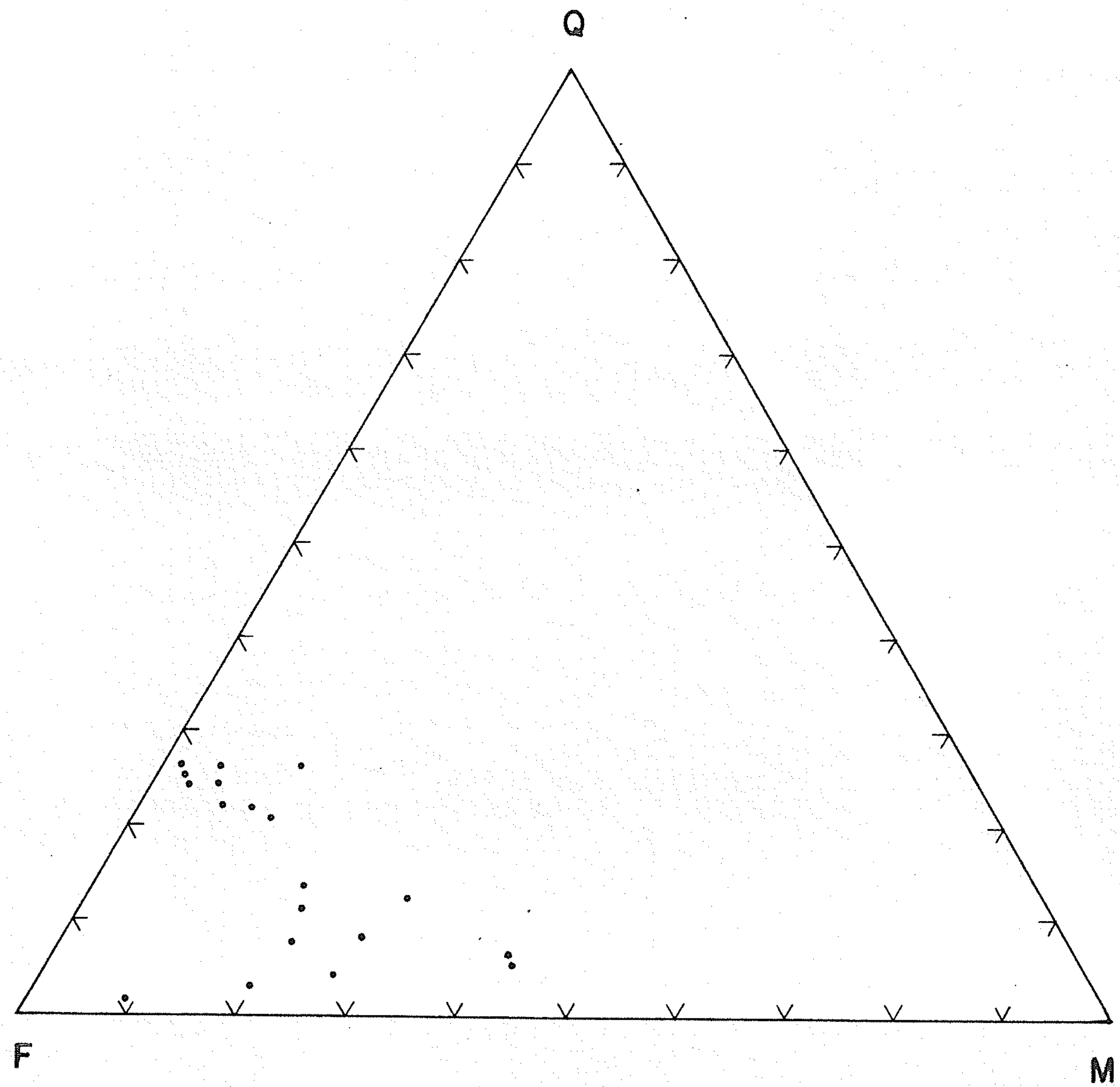


FIGURE 6. Volume percent of quartz (Q), total feldspar (F), and dark minerals (M) in thin sections of the Shenston-Mather granitic intrusive.

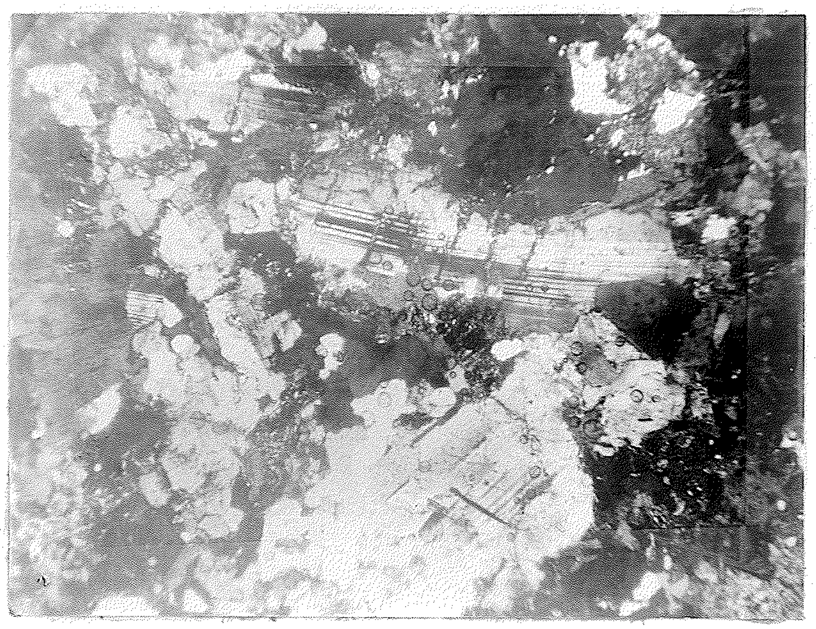
appearance (Plate 17A).

The majority of the phenocrysts are oligoclase or andesine. They are well twinned and infrequently are weakly zoned. Sericitization is moderate to intense. Microcline forms phenocrysts but more commonly it is confined to the ground mass.

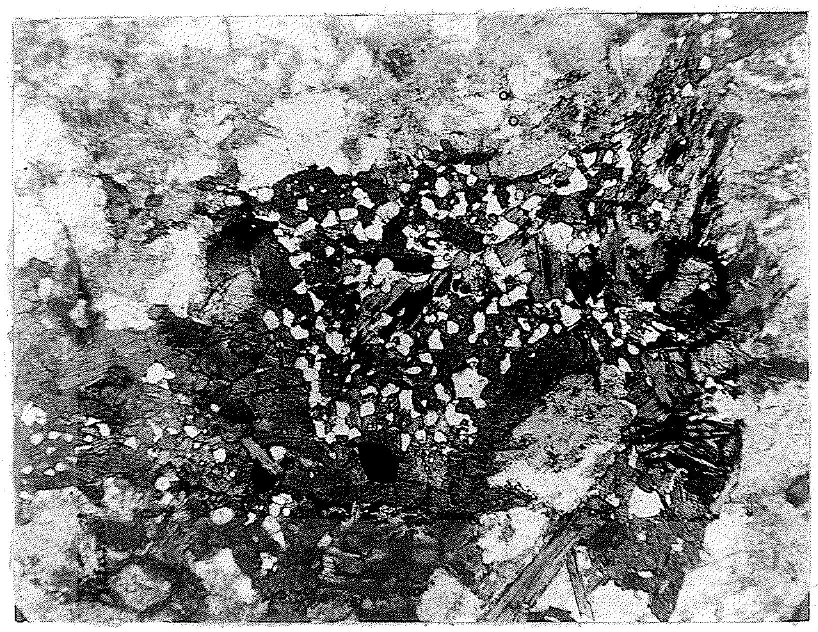
Hornblende makes up from one to two thirds of the total mafics. It is a dark green strongly pleochroic variety and occurs in crystalline masses one to 10 millimeters in length. Characteristically it shows poikilitic habit, having abundant inclusions of quartz (Plate 17B). Biotite is brown and together with minor amounts of epidote is found closely associated with hornblende. Quartz is distributed throughout the matrix in anhedral strained crystals. Accessories are apatite, sphene and iron sulphides.

Acid Phase

The biotite-bearing group where found in Kingsford township is pink, becoming pinkish-grey in Mather and Shenston townships. It forms the granitic material in the lit-par-lit and here is grey in color with a more streaky appearance. The rock is finer grained than the basic phase, grain-size ranging from one to 5 millimeters. However, it is similar to the basic phase in that it shows moderate to strong gneissosity and a characteristic crushed appearance (Plate 18A). The main constituents are quartz, oligoclase, microcline and biotite. Gran-



A. Coarse-grained basic phase of the Shenston-Mather intrusion showing the effects of crushing and granulation. Crossed nicols. X25 (Specimen N-28-7)



B. Basic phase of the Shenston-Mather intrusion showing the poikilitic habit of the hornblende. Ordinary light. X25 (Specimen F-7-6)

A. Acid phase of the Shenston-Mather intrusion showing strain and crusting. Crossed nicols. X25 (Specimen N-57-1) ular epidote, less than 0.1 mm in size, is the only minor constituent. Hornblende is rare. Where prevalent, microcline is confined to bands and layers which parallel the gneissosity and surround the other minerals suggesting that it is introduced late in the formation of the rock.

Structure

The intrusion is bounded by "Mather sediments" in Shenston and Mather townships and by granitic intrusions in Kingsford township. A pronounced straight gully near the east boundary of the map-area suggests that the north contact of the body is a fault. This fault is shown on the map extending across Kingsford township. It may form the granite-sedimentary contact across Mather township because of (1) a lineament formed by the limit of outcrops of the granitic material and (2) the absence of lit-par-lit or migmatite comparable to the previously described 1500 foot zone occuring on the corresponding south boundary.

Sharp contacts of the Shenston-Mather intrusion with the adjacent rocks are seldom exposed and then only for short distances. One of the better examples is in the NE 1/4, section 31, Shenston township where a sharp conformable contact between the gneissic granitic rock and the Mather sediments is exposed. Most sedimentary inclusions have well defined outlines and, although they almost invariably show some evidence of replacement, they are still markedly different in composition from the enclosing granitic material.

The gneissosity of the intrusive has a persistant trend of approximately N70°E along the entire length of the body. It is noted that this trend does not conform with the strike of the sediments which the granitic rocks surround in eastern Kingsford township. Here, only local concordance exists with the sediment-granite contact.

The distribution of the phases within the intrusive is irregular. The hornblendic phase is concentrated in a lens-shaped pod, approximately 15,000 feet by 4,000 feet, in central Mather township and it forms the bulk of the intrusive in Shenston and Dobie townships. The acid phase occurs mainly in Kingsford township and in the marginal parts of the body in Mather township. It must be emphasized that the main masses of these two compositional groups are not sharply divided. Rather, they are intimately associated with all gradations between them.

Dikes

Granitic dikes are probably more common to this intrusion than to any other part of the Emo area. The majority are of quartz monzonite composition and they are most prevalent within the hornblende-rich phase. To a large extent they cut across the regional gneissosity of the main intrusion and many have gneissosity developed parallel their own walls.

Pegmatite dikes are equally common in both phases. Some of these have sharp well-defined contacts. Others, however, have indistinct borders, and feldspar "phenocrysts" closely resembling the coarse crystals of the pegmatite are locally abundant within the transected granitic rock.

Genesis

The extremely variable composition and texture of the Shenston-Mather intrusion immediately suggests that it has originated by processes of granitization. On the other hand, evidences of igneous origin are as follows:

(1) Sharp sedimentary-granite contacts.

(2) Relatively unaltered sedimentary xenoliths.

(3) Discordance between the gneissosity of the granitic rock and bedding or schistosity in adjacent sediments.

(4) In the eastern part of the area where the sediments are rich in hornblende, the granitic material has only biotite and, conversely, in the western part where the granite has hornblende the sediments do not.

(5) The presence of prevalent and evidently related dikes, many of which show gneissosity transverse to that of the main body.

On this basis it is believed that the bulk of the mass has crystallized from a magma.

The compositional and textural differences of the two dominant phases points to two stages of crystallization. The coarse-grained porphyritic phase probably began to crystallize slowly and at considerable depth. From textural relationships, andesine was probably the first mineral to begin to separate out, followed shortly by hornblende. At a somewhat later stage potash feldspar and quartz began to form. About this same time biotite appears to have taken the place of hornblende as the crystallizing ferromagnesian mineral and, undoubtedly, some of the hornblende was transformed. Meanwhile, the plagioclase was evidently becoming more sodic.

The finer grain size and xenomorphic texture of the more acid phase seem to indicate that all its minerals, i.e. feldspars, quartz, biotite and possibly epidote, have crystallized simultaneously and comparatively rapidly.

It is suggested that the magma may have risen to shallower depths at about the time that biotite took the place of hornblende. Possibly factors arising from intrusion caused this change. A certain amount of differentiation may have occurred in early stages of crystallization. As a result of subsequent intrusion, the coarser, more basic phase became concentrated in irregular masses surrounded by and grading into the more acid one. The sequence in which the minerals in the basic phase began to form and their replacements in the acid phase may be represented as follows:

Basic Phase	Acid Phase
Andesine	
Aligoclase	Oligoclase
Hornblende	
Biotite-epidote	Biotite-epidote
Potash feldspar-quartz	Potash feldspar-quartz

Stresses in a NW-SE direction, particularly during intrusion, are probably the cause of the persistant gneissosity and of the crushed character of the early formed phenocrysts.

The wide variation in composition shown on the Q-Or-Pl diagram in figure 5 must still be explained. Much of the variation on the plagioclase side of the thermal valley is undoubtedly due to effects of differentiation, assimilation, and redistribution of material by differential pressure. Furthermore, the original magma itself may have been non-uniform.

The plots of analyses on the orthoclase side of the thermal valley present a more difficult problem. The composition of the magma and, hence, of the rocks crystallized from it should never cross the thermal valley as a result of straightforward differentiation processes. Nor should such a transition be brought about by assimilation. Part of the difficulty may lie in the fact that the thermal valley was outlined by Bowen for the system quartz-orthoclase-albite whereas the plagioclase in the rocks analysed has an appreciable content of anorthite. Chayes (1950, p. 243) however, calculated that the difference should be relatively insignificant and his own work certainly bears this out. Unlike Chayes' rocks, the more basic phase of the Shenston-Mather intrusion contains hornblende and has a much higher color index. However, the effects of the mafic constituents may also be negligible because physico-chemical evidence suggests that "the dark minerals . . follow separate paths of crystallization without interfering with the light constituents" (Barth, 1952, p. 103).

Two possibilities remain:

(1) Two different magmas were involved in formation of the Shenston-Mather intrusion.

(2) The intrusion, though derived from a magma, has been modified by metasomatism.

The first possibility is not born out by field observations. Contacts between the phases appeared to be almost imperceptibly gradational. Petrographic comparisons suggest that, although grainsize varies considerably, more or less the same textural characteristics are common to all phases. Furthermore, specimens which come from closely neighboring localities which are virtually identical otherwise, when analysed, plot on opposite sides of the thermal valley.

Evidences of metasomatism, though inconclusive, are more abundant. The apparent randomness in the distribution of the potash-rich material is suggestive. Some probable granitization effects have been described in the nearby sediments and in some of the granitic rocks associated with pegmatite. As mentioned previously the potash feldspar is to some extent confined to bands parallel to the gneissosity, possibly because it has been introduced late in the formation of the intrusion. Thus, apparently the best explanation for the origin of the Shenston-Mather granitic intrusion is that it has been derived from a magma and that late in, or subsequent to, its crystallization metasomatic addition of potassium has occurred. The mechanism of this addition is unknown.

CHAPTER VII   SUMMARY OF CONCLUSIONS

The geology of the Emo area is typical of the Archean geology of large parts of the Canadian Precambrian Shield. It consists of a metamorphic terraine of highly folded sedimentary and volcanic rocks invaded by multiple granitic intrusions and a number of less extensive basic intrusions. For the rocks examined, the following generalizations can be made:

(1) The sedimentary rocks fall into two major divisions. These have distinctly different compositions and are apparently separated in age by an appreciable amount of time.

What is believed to be the older division now exists as hornblende-plagioclase-quartz schists which are locally garnetiferous or diopsidic. Originally, they were evidently silty deposits in which calcite and chlorite formed a large part of the matrix. Tuffaceous material was probably a major component.

The other sedimentary division is comprised of three units. The predominant one consists of plagioclase-biotite-quartz schists apparently derived from feldspathic greywackes and interbedded shale. Small amounts of conglomerate bearing dacite clasts make up the second unit. The third unit is low grade magnetite iron formation which occurs in narrow bands in the schists.

(2) The volcanic rocks are classified as (a) intermediate and acid volcanics and, (b) basic volcanics. Both subdivisions consist of an assortment of lavas, agglomerate and tuffaceous sediments. The intermediate to acid lavas are predominantly dacite with minor amounts of quartz latite and rhyolite. The basic lavas are typical "greenstones" and evidently are predominantly basaltic in composition. Pillows or ellipsoids are a common structural feature.

(3) The Emo complex of interbedded clastic sediments, iron formation and volcanic rocks is characteristic of the assemblage attributed to eugeosynclinal sedimentation.

(4) The metamorphism in the sediments and volcanics studied is largely a medium to high grade regional type. It is believed to be related to the granitic intrusions in the area because, on approaching these masses, the grade appears to increase from the upper biotite zone to the sillimanite zone. Local thermal or contact metamorphism is suspected in the vicinity of the Dobie basic intrusion but conclusive evidence is lacking.

(5) The basic stock outcropping in Lash and Carpenter township, consists essentially of a slightly uralitized hypersthene gabbro. This is evidently a normal igneous rock in which local primary alignment of crystals suggest that intrusion took place subsequent to at least partial crystallization.

The intrusion is cut by and, hence, is older than two (and perhaps more) of the granitic intrusions. It can probably be looked upon as an ophiolitic type of intrusion.

(6) A heterogeneous group of small basic dikes and sills are common in the area. They range in composition from hornblende diorite to hornblende gabbro and in part can be classed as lamprophyre. Probably several age groups are represented but the majority are indicated to be older than the granitic intrusions.

(7) The "Carpenter granitic intrusion" is indicated to be a normal igneous body of relatively uniform composition. The pattern of its gneissosity has evidently been produced during intrusion and in conjunction with folding of the invaded sediments.

(8) The Shenston-Mather band of granitic rocks has a considerable range of composition although two phases, hornblende, granodiorite and quartz monzonite, appear to predominate. Derivation of this body from a magma is favored on the basis of field evidence. However, results of modal analysis plotted on a Q-Pl-Or diagram point to at least local metasomatic enrichment in potash within the body.

(9) The effects of granitization in the sediments are appreciable but are believed to be surpassed in magnitude by assimilation in granitic magmas.

(10) Dikes of diabase and quartz diabase represent the youngest

known intrusions in the area. They are typical both in lithology and persistant trend of the so-called Keweenawan dikes found elsewhere in the Canadian Shield. Intrusion of these dikes has undoubtedly been related to tensional conditions in the earth's crust.

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APPENDIX

RESULTS OF MODAL ANALYSES

Carpenter-Lash Intrusion

Specimen	Mineral	Counts	Volume	Percentages
N-14-8:	Quartz	526	30.9	34.5
	Plagioclase	818	48.1	53.6
	K-feldspar	183	10.7	11.9
	Biotite	173	10.2	
	Total	1700	99.9	100.0
F-43-3:	Quartz	368	24.1	26.5
	Plagioclase	865	56.7	62.2
	K-feldspar	157	10.3	11.3
	Mafics	135	8.9	
		1525	99.9	100.0
F-46-4:	Quartz	466	31.0	36.7
	Plagioclase	776	51.6	61.0
	K-feldspar	29	1.9	2.3
	Biotite	233	15.5	
		1504	100.0	100.0
F-47-1:	Quartz	274	26.3	31.9
	Plagioclase	494	47.4	57.4
	K-feldspar	92	8.8	10.7
	Biotite	183	17.5	
		1043	100.0	100.0
F-47-4:	Quartz	578	33.9	40.4
	Plagioclase	771	45.3	53.9
	K-feldspar	81	4.8	15.7
	Biotite	273	16.0	
		1703	100.0	100.0

Shenston-Mather Intrusion

Specimen	Mineral	Counts	Volume	Percentages
N-18-4:	Quartz	360	21.0	24.0
	Plagioclase	1017	59.3	67.6
	K-feldspar	127	7.4	8.4
	Biotite	165	9.6	
	Epidote	47	2.7	
		1716	100.0	100.0

RESULTS OF MODAL ANALYSES Con't

Specimen	Mineral	Counts	Volume	Percentages
N-18-5:	Quartz	360	24.7	25.5
	Plagioclase	717	49.2	50.8
	K-feldspar	334	22.9	23.7
	Biotite	28	1.9	
	Epidote	18	1.2	
		1457	99.9	100.0
N-18-6:	Quartz	319	26.8	27.2
	Plagioclase	374	31.4	31.9
	K-feldspar	481	40.3	41.9
	Biotite	6	.5	
	Epidote	12	1.0	
		1192	100.0	100.0
N-27-2:	Quartz	295	22.3	25.0
	Plagioclase	632	47.7	53.3
	K-feldspar	258	19.5	21.7
	Biotite	112	8.5	
	Epidote	27	2.0	
		1324	100.0	100.0
N-27-3:	Quartz	313	22.5	24.3
	Plagioclase	661	47.6	51.5
	K-feldspar	311	22.4	24.2
	Biotite	69	5.0	
	Epidote	35	2.5	
		1389	100.0	100.0
N-28-5:	Quartz	199	11.4	14.3
	Plagioclase	721	41.3	51.8
	K-feldspar	473	27.1	34.0
	Biotite	220	12.6	
	Hornblende	62	3.6	
	Epidote	70	4.0	
		1745	100.0	100.1
N-31-3:	Quartz	37	4.4	6.0
	Plagioclase	578	69.0	94.0
	K-feldspar	- -	- -	
	Biotite	27	3.2	
	Hornblende	195	23.3	
		837	99.9	100.0

RESULTS OF MODAL ANALYSES Con't

Specimen	Mineral	Counts	Volume	Percentages
N-33-4:	Quartz	15	1.5	1.7
	Plagioclase	540	53.5	59.0
	K-feldspar	360	35.7	39.3
	Hornblende	94	9.3	
		1009	100.0	100.0
N-36-1:	Quartz	214	14.0	17.3
	Plagioclase	735	47.9	59.3
	K-feldspar	291	19.0	23.4
	Biotite	243	15.8	
	Epidote	50	3.3	
		1533	100.0	100.0
N-50-1:	Quartz	545	25.2	26.1
	Plagioclase	538	24.9	25.8
	K-feldspar	1006	46.5	48.1
	Biotite	73	3.4	
		2162	100.0	100.0
N-51-1:	Quartz	328	26.4	27.9
	Plagioclase	549	44.2	46.6
	K-feldspar	300	24.1	25.5
	Biotite	66	5.3	
		1243	100.0	100.0
N-57-1:	Quartz	501	24.8	26.4
	Plagioclase	527	26.1	27.7
	K-feldspar	871	43.1	45.9
	Biotite	123	6.1	
		2022	100.1	100.0
FN-2-5:	Quartz	231	26.4	30.2
	Plagioclase	246	28.1	32.2
	K-feldspar	287	32.8	37.6
	Biotite	74	8.4	
	Epidote	38	4.3	
		876	100.0	100.0
F-5-3:	Quartz	199	13.0	18.4
	Plagioclase	719	47.1	66.5
	K-feldspar	164	10.7	15.1
	Biotite	194	12.7	
	Hornblende	201	13.2	
	Epidote	50	3.3	
		1527	100.0	100.0

RESULTS OF MODAL ANALYSES Con't

Specimen	Mineral	Counts	Volume	Percentages
F-5-6:	Quartz	63	3.6	4.5
	Plagioclase	1044	60.2	75.1
	Orthoclase	284	16.4	20.4
	Biotite	142	8.2	
	Hornblende	120	6.9	
	Epidote	82	4.7	
		1735	100.0	100.0
F-6-4:	Quartz	70	8.0	10.2
	Plagioclase	489	56.1	71.1
	K-feldspar	129	14.8	18.7
	Biotite	65	7.5	
	Hornblende	82	9.4	
	Epidote	36	4.1	
		871	99.9	100.0
F-28-6:	Quartz	120	6.5	11.1
	Plagioclase	957	52.0	88.9
	K-feldspar	-	-	
	Biotite	216	11.7	
	Hornblende	547	29.7	
		1840	99.9	100.0
F-28-7:	Quartz	66	5.3	9.1
	Plagioclase	624	49.6	86.4
	K-feldspar	32	2.5	4.4
	Biotite	266	21.2	
	Hornblende	269	21.4	
		1257	100.0	99.9
F-28-8:	Quartz	176	8.4	11.5
	Plagioclase	930	44.5	61.0
	K-feldspar	419	20.0	27.5
	Biotite	250	11.9	
	Hornblende	317	15.2	
		2092	100.0	100.0

Lash-Carpenter Basic Intrusion

Specimen	Mineral	Counts	Volume	Percentages
N-38-1:	Plagioclase	821	62.4	
	Augite	271	20.6	
	Uralite	224	17.0	
		1316	100.0	

RESULTS OF MODAL ANALYSES   Con't

Specimen	Mineral	Counts	Volume	Percentages
N-40-1:	Plagioclase	341	57.2	
	Augite	146	24.5	
	Hypersthene	101	16.9	
	Uralite	8	1.3	
		596	99.9	
N-46-2:	Plagioclase	505	51.2	
	Augite (Hypersthene)	395	40.0	
	Uralite	87	8.8	
		987	100.0	
F-34-7:	Plagioclase	415	55.4	
	Augite	174	17.5	
	Hypersthene	131	23.2	
	Uralite	29	3.9	
		749	100.0	
Upper Sedimentary Division				
N-5-9:	Quartz	334	34.3	
	Plagioclase	378	38.8	
	Biotite	261	26.8	
		973	99.9	
N-12-5:	Quartz	282	16.6	
	Plagioclase	597	35.3	
	K-feldspar	550	32.5	
	Biotite	264	15.7	
		1693	100.1	
N-14-1:	Quartz	481	32.6	
	Plagioclase	637	43.2	
	Biotite	358	24.2	
		1476	100.0	
N-14-5:	Quartz	363	30.4	
	Plagiocalse	602	50.4	
	Biotite	218	18.2	
	Garnet	10	.9	
		1193	99.9	
N-28-3:	Quartz	417	28.9	
	Plagioclase	657	45.7	
	Biotite	364	25.3	
		1438	99.9	

RESULTS OF MODAL ANALYSES Con't

Specimen	Mineral	Counts	Volume Percentages
N-28-4:	Quartz	243	24.1
	Plagioclase	561	55.7
	K-feldspar	51	5.1
	Biotite	151	15.0
		1006	99.9
N-30-1:	Quartz	325	29.5
	Plagioclase	489	44.5
	Biotite	286	26.0
		1101	100.0
FN-2-1:	Quartz	517	26.6
	Plagioclase	889	45.7
	Biotite	539	27.7
		1945	100.0

REPRESENTATIVE SUITE OF SPECIMENS AND SPECIMENS EXAMINED IN THIN SECTIONS

Lower Sedimentary Division

N-14-7	F-10-2
N-50-5	F-10-3
N-53-2	F-33-5
N-56-2	F-46-2
F-8-6	F-47-3
F-9-10	F-52-7
F-9-12	

Upper Sedimentary Division

N-5-9	N-31-2
N-5-11	N-31-6
N-12-5	N-33-2
N-12-6	N-33-3
N-12-7	FN-2-1
N-14-1	F-9-2
N-14-3	F-9-9
N-14-5	F-12-3
N-28-3	F-28-5
N-28-4	F-C-11
N-30-1	

Intermediate and Acid Volcanics

N-9-2
N-9-3
N-9-4
N-9-6
N-10-2
N-10-10
N-13-3
N-13-5
N-16-6
N-17-1
N-17-7
N-17-8
N-17-10
N-63-7
N-63-8
N-65-3
N-65-5
F-3-6
F-3-7
F-3-9
F-3-10
F-4-4
F-4-6
F-4-7
F-9-4
F-9-5
F-10-7
F-13-1
F-13-3
F-28-3
F-28-4
F-33-1
F-33-2
F-33-3
ND-9-1
FN-1-4

Dobie Basic Volcanics

N-5-2
N-10-5
N-10-7
N-12-3
N-33-1
N-66-1
N-66-3
N-66-6
N-66-10
F-4-1
F-13-4
F-13-5
FN-1-5
FN-1-6
FN-3-1
FN-3-2
ND-1-1
ND-1-2
ND-2-2
ND-9-2
F-C-8

Carpenter Basic Volcanics

N-56-8
N-56-9
N-57-5
N-57-7
N-65-6
N-65-7
F-52-7

Carpenter-Lash Basic Intrusion

N-38-1
N-38-2
N-38-4
N-40-1
N-46-2
N-48-1
N-58-5
F-34-2
F-34-3
F-34-6
F-34-7
F-41-3

Hornblende Diorite and Gabbro

N-10-12	N-56-6
N-13-6	F-9-7
N-13-10	F-10-9
N-17-2	F-12-8
N-56-3	F-15-4

Diabase Dikes

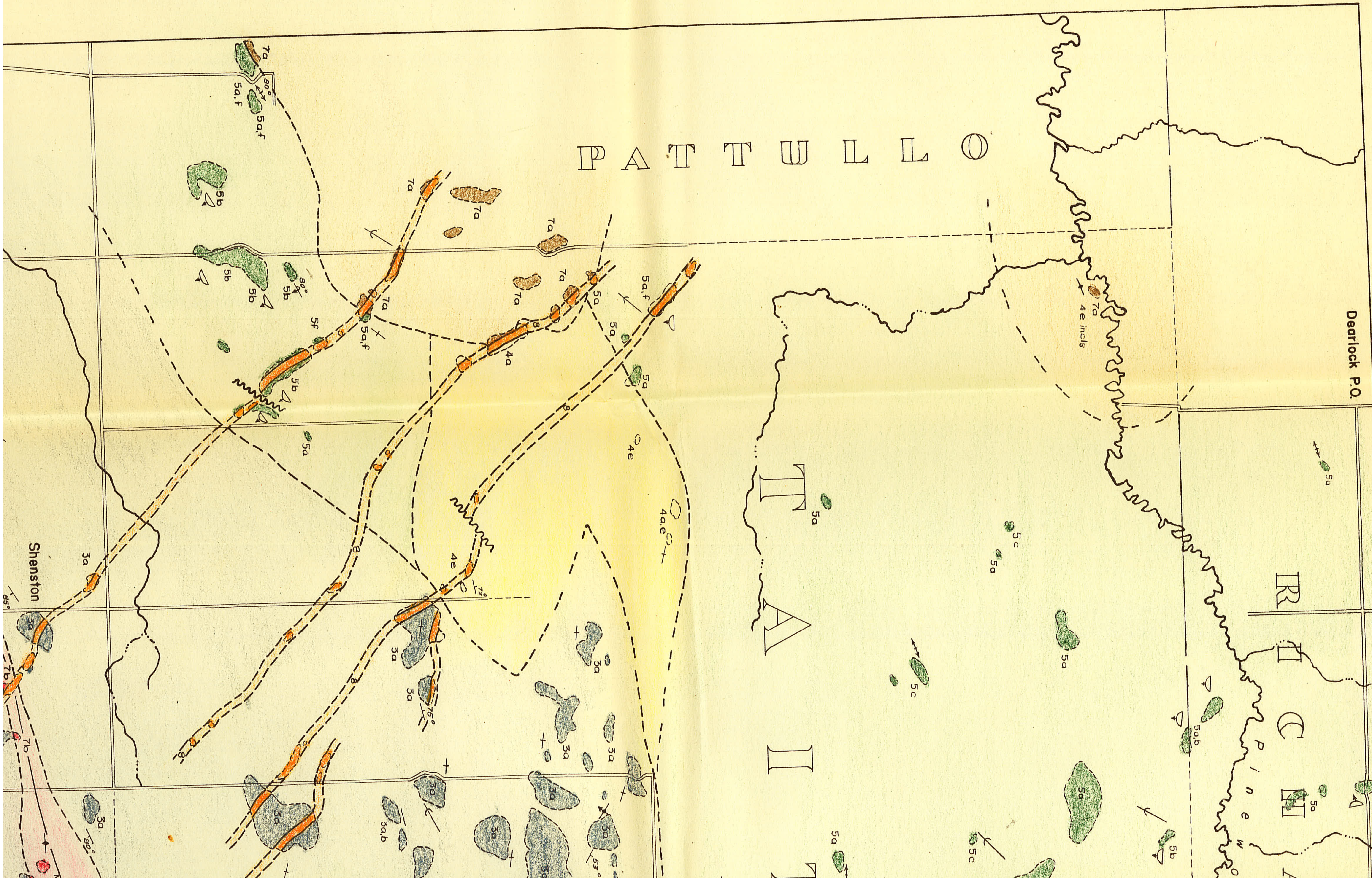
N-4-2	F-12-6
F-4-3	F-12-7
F-12-5	FN-1-1

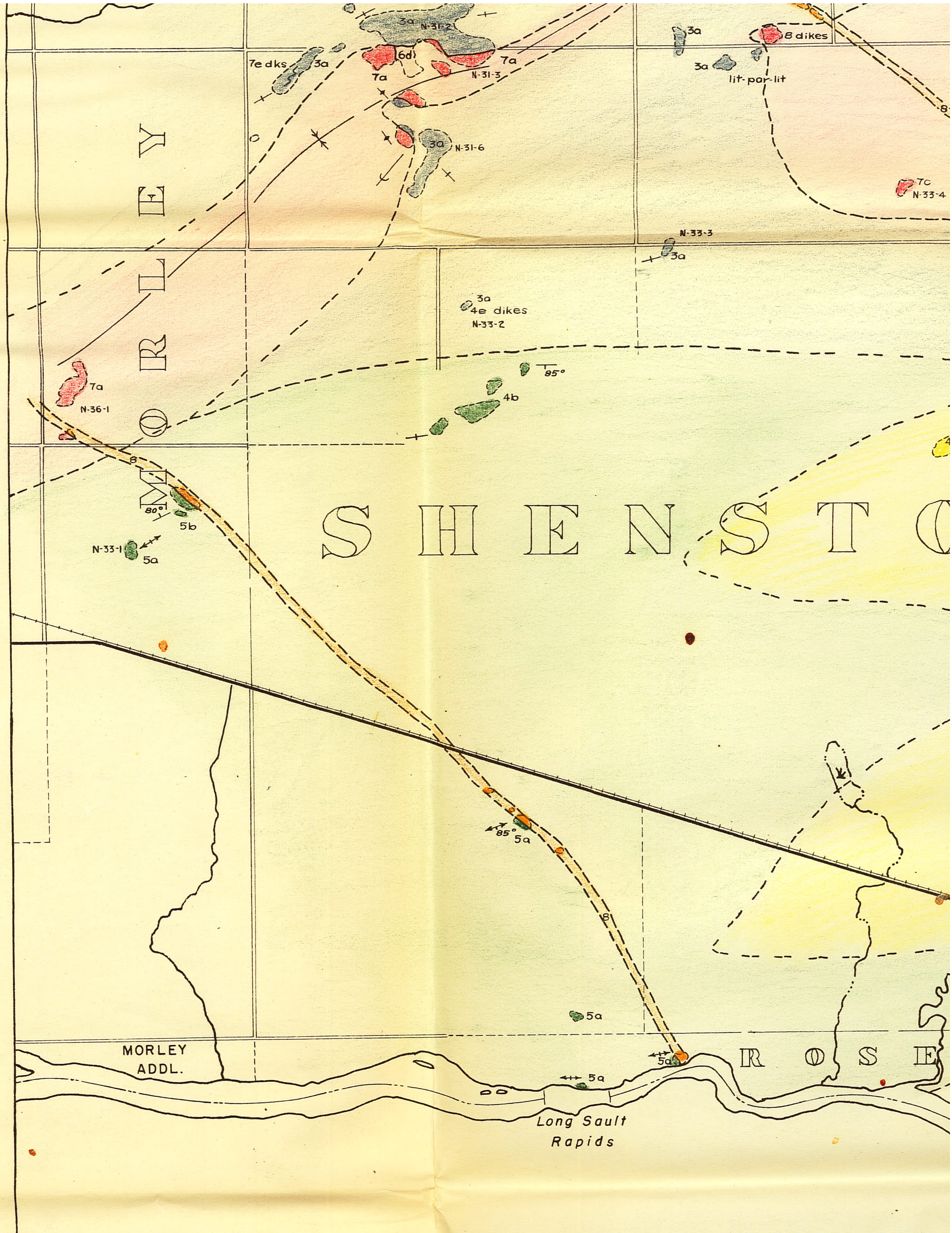
Carpenter-Kingsford Intrusion

N-49-1	N-53-5
N-53-3	F-46-4
N-53-4	F-46-5

Shenston-Mather Intrusion

N-18-4	F-5-8
N-18-5	F-6-3
N-18-6	F-6-4
N-21-1	F-7-6
N-27-2	F-8-1
N-27-3	F-15-1
N-28-5	F-15-2
N-31-3	F-15-5
N-33-4	F-15-6
N-36-1	F-15-7
N-50-1	F-28-6
N-51-1	F-28-7
N-57-2	F-28-8
F-5-3	FN-2-3
F-5-6	FN-2-5


PATTULLO
Dearlock P.O.
Shenston



UNITED STATES OF AME

LEGEND

QUATERNARY

RECENT

Peat, alluvial sands, silt, clay-loams.

LEGEND

QUATERNARY

RECENT

Peat, alluvial sands, silt, clay-loams.

PLEISTOCENE

Bedded clay-loams, glacial clay, silt, sand, gravel, boulders.

PRECAMBRIAN

POST–KEEWATIN

KEWEENAWAN

Quartz diabase dikes 8

GRANITIC INTRUSIVES

Chronological Sequence Indefinite

Tait Intrusive.
Potts Intrusive.
Lash Intrusive.
Devlin Intrusive.
Kingsford Intrusive.
Shenston-Mather Intrusive.
Carpenter Intrusive.

Pegmatite dikes 7f; granitic and aplitic dikes 7e; quartz monzonite 7d; monzonite 7c; hornblende granodiorite 7b; granodiorite 7a.

BASIC INTRUSIVES

Dobie Intrusive.
Carpenter - Lash Intrusive.

Norite 6a; hypersthene diabasic gabbro 6c; h

KEEWATIN

Carpenter Volcanics.

Mather Sediments.

I.F.

Dobie - Tait Volcanics.

Carpenter Sediments.

VOLCANIC DIVISIONS of
BASIC VOLCANICS

Basalt 5a; p
basalt porph
basic tuff a

INTERMEDIATE and A

Dacite 4a;
rhyolite 4c;

SEDIMENTARY DIVISIONS
UPPER DIVISION

Greywacke

I.F.

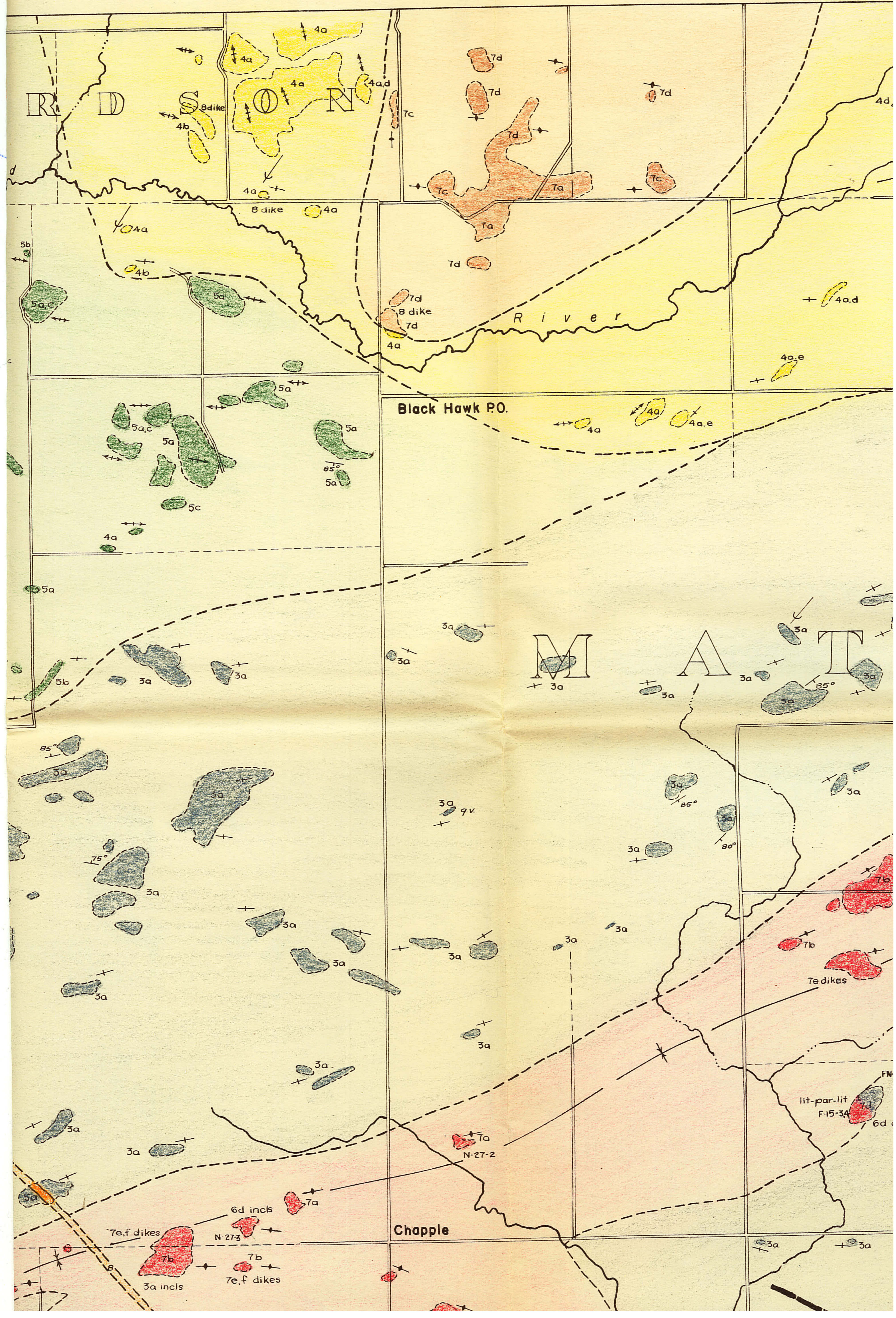
Iron format

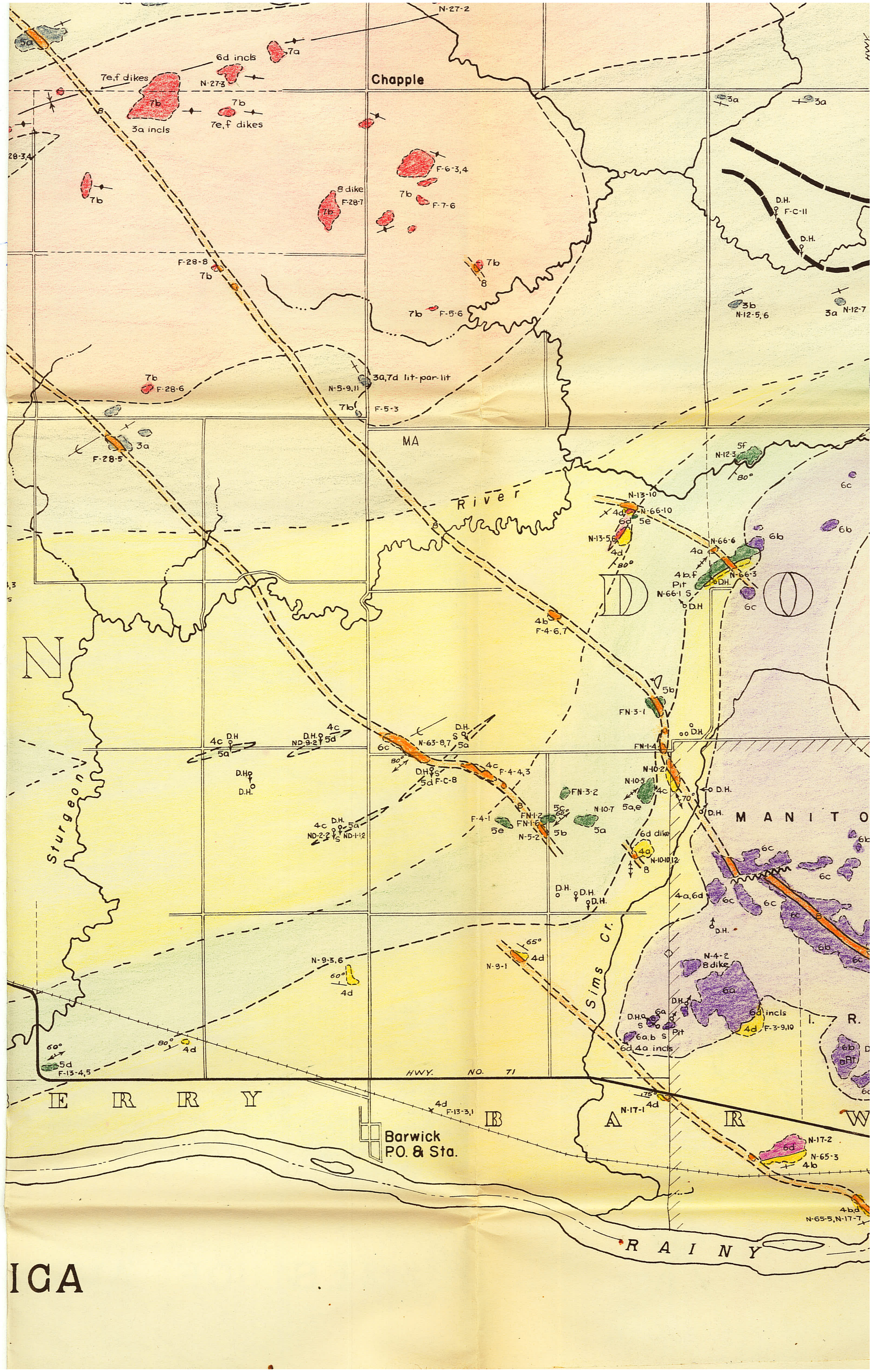
LOWER DIVISION

Hornblende

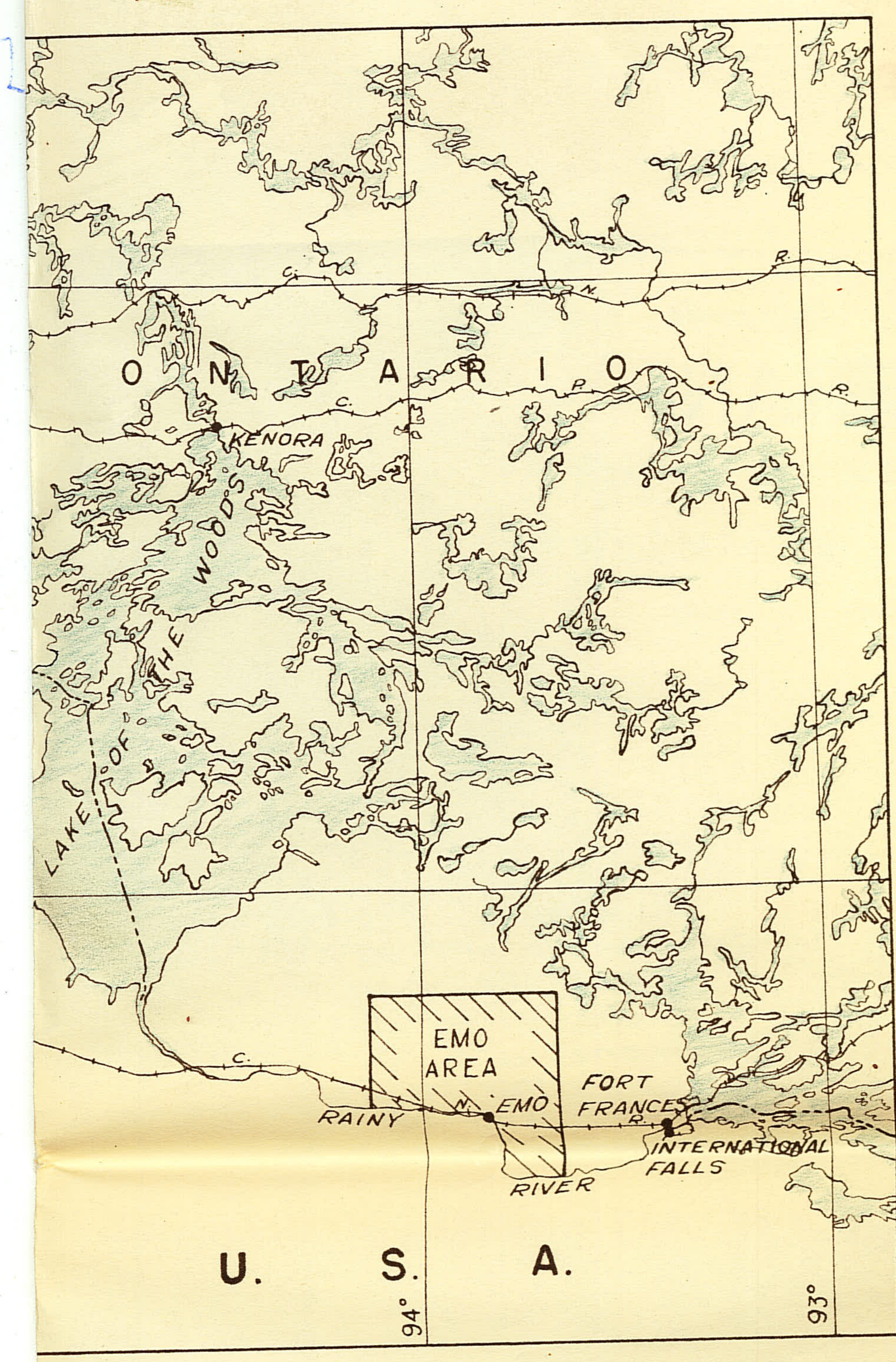
COUTCHICHING or KEEWATIN

Siliceous tuff 1a; biotite and hornblende schist


R D S O N
M A T
Black Hawk P.O.
River
Chapple
8 dike
7e dikes
7e,f dikes
3a incls
6d incls
N-27-3
N-27-2
lit-par-lit
F-15-34


Chapple
River
Sturgeon
Sims Cr.
MANITO
RAINY
HWY. NO. 71
Barwick P.O. & Sta.
E R R Y
B A R W
D O
IGA

ICA



Scale, 1 inch to 20 miles

bro 6b;
ende diorite 6d.

KEEWATIN

basalt 5b; coarse basalt 5c;
5d; amygdaloidal and vesicular basalt 5e;
ediment 5f; basic agglomerate 5g

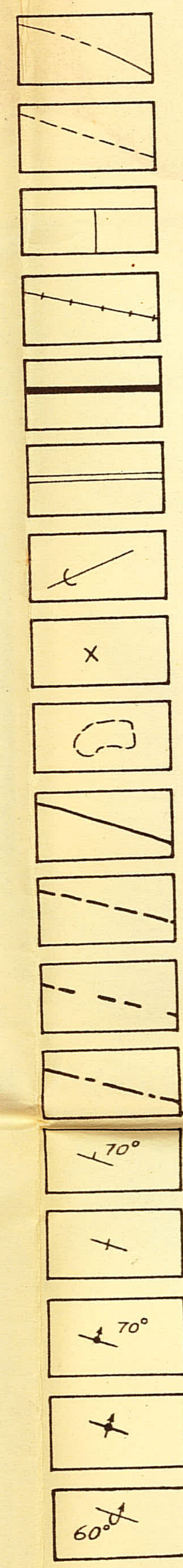
OLCANICS
te porphyry 4b; quartz latite and
rmediate agglomerate 4d; tuff 4e.
he KEEWATIN

derived biotite schist 3a; conglomerate 3b.

st 2a; garnetiferous hornblende schist 2b.

R A I N Y

SYMBOLS



International boundary.

Survey lines, including townsh
boundaries.

Township boundaries, unsurv

Railway.

Paved highway.

Motor road, graveled.

Glacial striae.

Small rock outcrop.

Boundary of rock outcrop.

Geological boundary, definec

Geological boundary, approxi

Geological boundary, assume

Geological boundary as in
geophysical data.

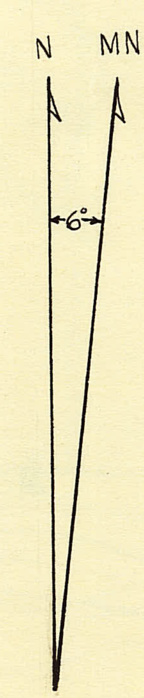
Strike and dip of bedding
of top unknown.

Strike and vertical dip of
direction of top unknown.

Direction (arrow) in which incl
face from gradation of gr

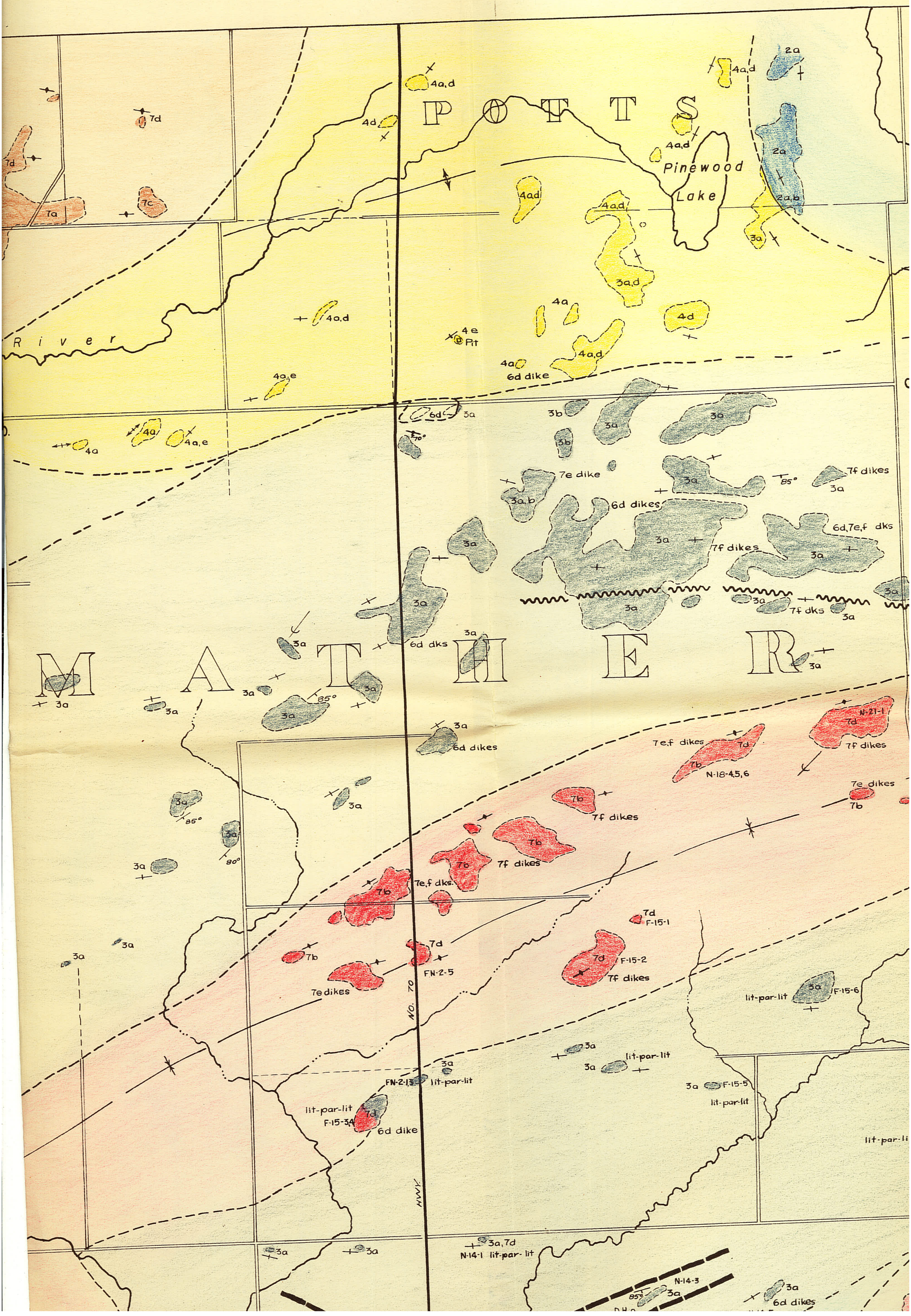
Direction (arrow) in which ve
face from gradation of g

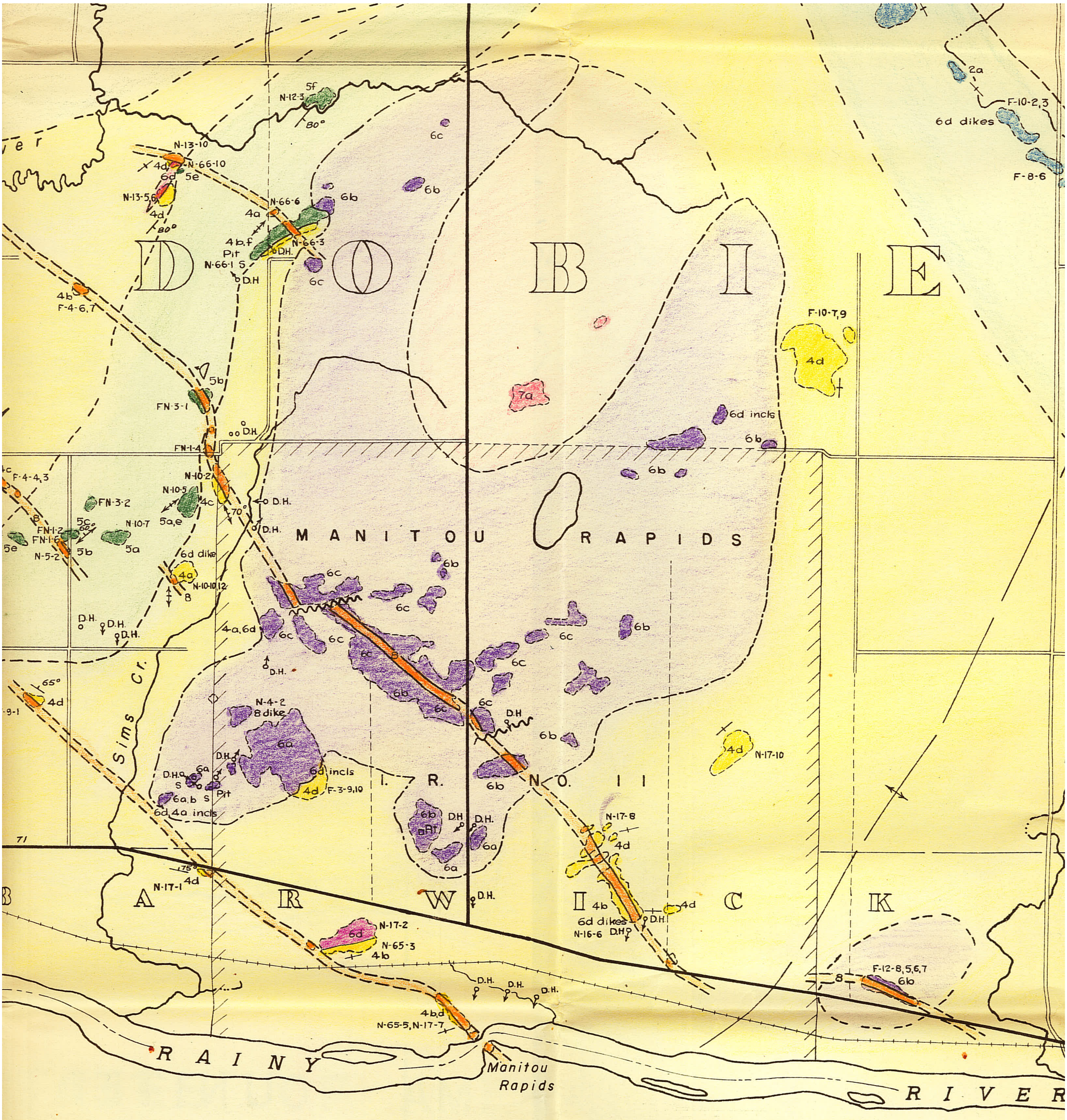
Direction (arrow) in which ov
flows face. Dip in direction



DISTRI

Geology


POTTS
MATHER
Pinewood Lake
River
HWY. NO. 70
4a,d
4d
4ad
4a,e
4a
4e Pit
4d
3a,d
6d dike
3a
3b
3a,b
2a
2a,b
7a
7c
7d
7b
7e dike
7e dikes
7f dikes
7e,f dikes
7e,f dks.
6d dikes
6d dks
6d,7e,f dks
7f dks
lit-par-lit
F-15-34
FN-2-13
FN-2-5
F-15-1
F-15-2
F-15-5
F-15-6
N-18-4,5,6
N-21-1
N-14-1
N-14-3
3a,7d
85°
80°
70°



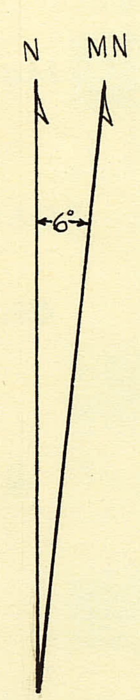
SYMBOLS

	International boundary.
	Survey lines, including township boundaries.
	Township boundaries, unsurveyed.
	Railway.
	Paved highway.
	Motor road, graveled.
	Glacial striae.

	Direction in which lava flow[s] indicated by shape of pillo[ws]
	Synclinal axis.
	Anticlinal axis.
40°	Direction of plunge of fol[d]
50°	Strike and dip of schistosit[y]
	Strike of vertical schistosi[ty]
60°	Strike and dip of gneiss[osity]

SYMBOLS

	International boundary.
	Survey lines, including township boundaries.
	Township boundaries, unsurveyed.
	Railway.
	Paved highway.
	Motor road, graveled.
	Glacial striae.
x	Small rock outcrop.
	Boundary of rock outcrop.
	Geological boundary, defined.
	Geological boundary, approximate.
	Geological boundary, assumed.
	Geological boundary as indicated by geophysical data.
70°	Strike and dip of bedding; direction of top unknown.
	Strike and vertical dip of bedding; direction of top unknown.
70°	Direction (arrow) in which inclined beds face from gradation of grain size.
	Direction (arrow) in which vertical beds face from gradation of grainsize.
60°	Direction (arrow) in which overturned lava flows face. Dip in direction of loop.
	Direction in which lava flo… indicated by shape of pil…
	Synclinal axis.
	Anticlinal axis.
40°	Direction of plunge of f…
50°	Strike and dip of schistos…
	Strike of vertical schisto…
60°	Strike and dip of gneis…
	Strike of vertical gneiss…
	Drag-folds.
	Fault, indicated or assu…
Pit	Test pit.
o D.H.	Drill hole, vertical.
D.H.	Drill hole, inclined.
S	Sulphide mineralization.
MA	Magnetic attraction.
N-5-3	Hand specimen, number …
	Boundary of Indian Res…
q.v.	Quartz vein.

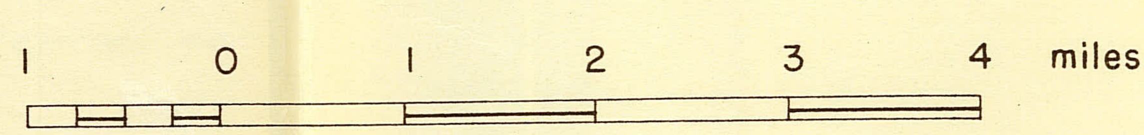


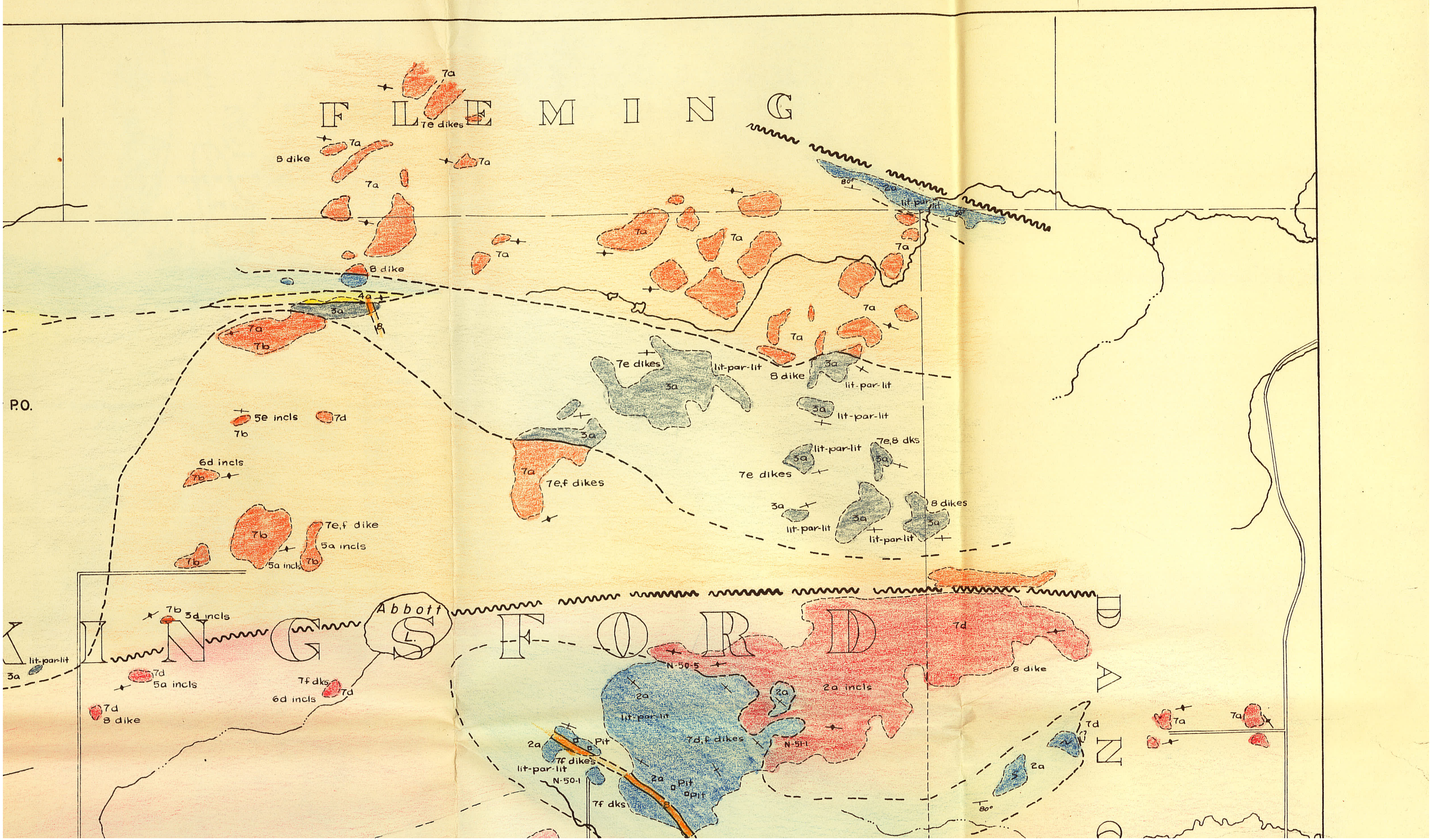
EMO AREA

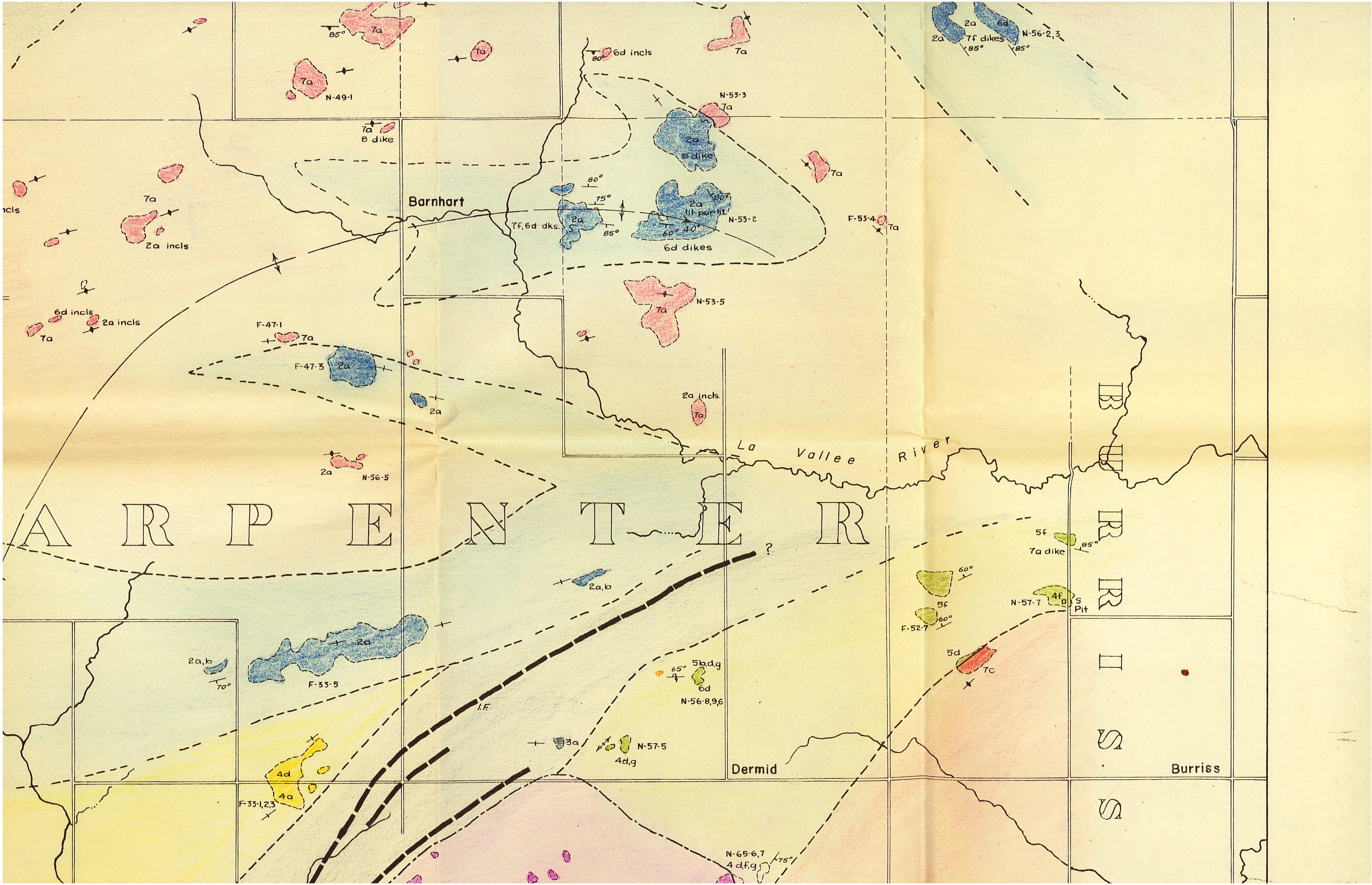
DISTRICT OF RAINY RIVER, ONTARIO

Geology by G.L. FLETCHER and T.N. IRVINE

Scale, 1 inch to $\frac{1}{2}$ mile

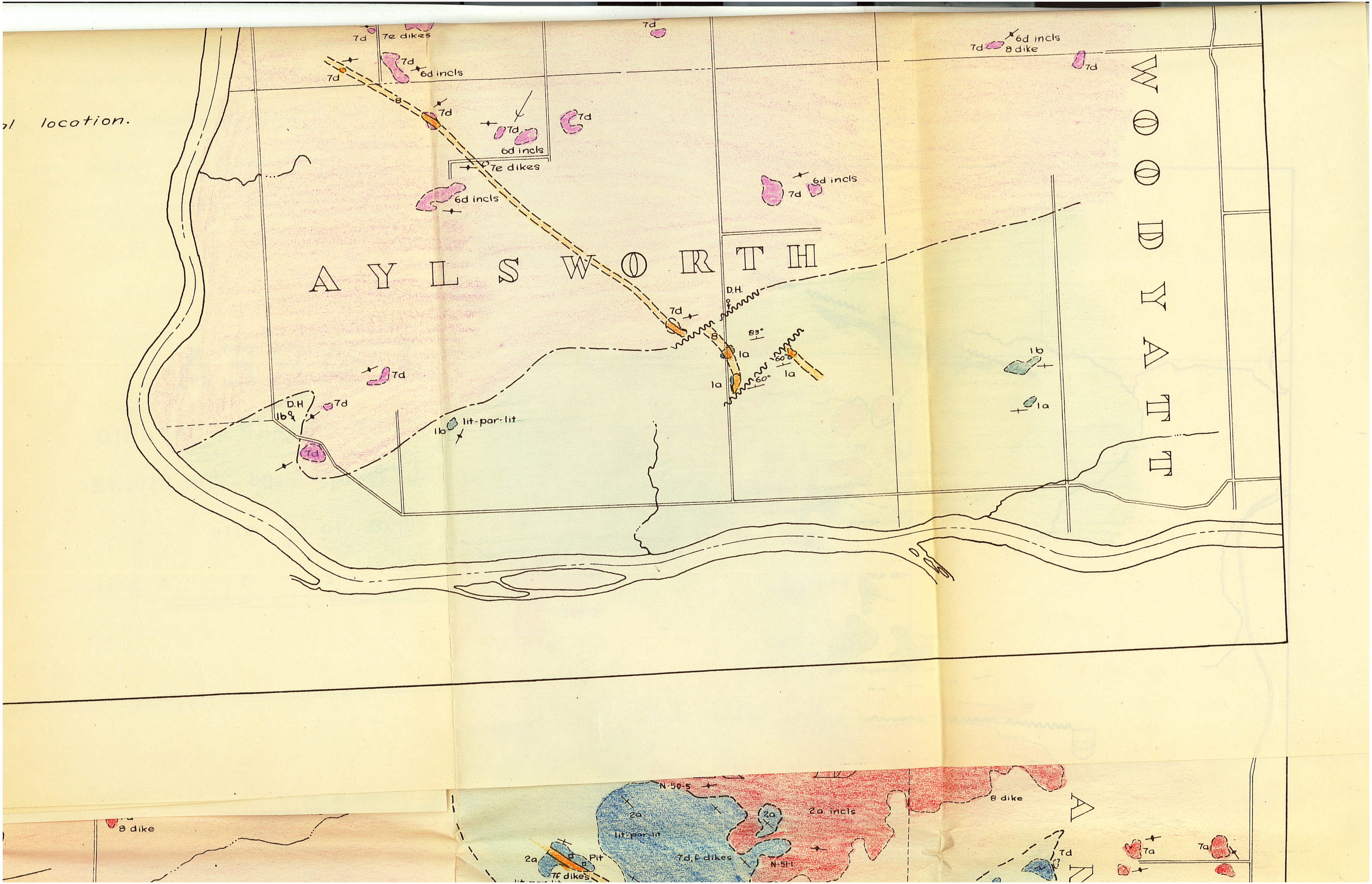



F L E M I N G
K I N G S F O R D
D A N
Abbott L.
P.O.
7a
7e dikes
8 dike
lit-par-lit
3a
4a
8
7b
5e incls
7d
6d incls
7e,f dikes
7e,f dike
5a incls
3d incls
7f dks
2a
2a incls
N-50-5
N-51-1
N-50-1
7d,f dikes
7f dikes
Pit
7e,8 dks
8 dikes
80°



7a
N-49-1
6d incls
N-53-3
7a
2a
6d
7f dikes
N-56-2,3
7a
8 dike
2a
8 dike
Barnhart
2a incls
6d incls
2a incls
7f, 6d dks.
2a
2a
lit-par-lit
N-53-2
6d dikes
F-53-4
N-53-5
F-47-1
F-47-3
2a
2a incls.
N-56-5
La Vallee River
CARPENTER
BURRISS
2a,b
5f
7a dike
N-57-7
4f
S Pit
F-52-7
5d
7c
2a,b
2a
F-33-5
5b,d,g
6d
N-56-8,9,6
I.F.
3a
N-57-5
4d,g
4d
4a
F-33-1,2,3
Dermid
Burriss
N-65-6,7
4 d,f,g

L A S H
D E V L I N
W
Devlin
P.O.
Sta.
location.
I.F.
6b
7c
7d
7e dikes
6d incls
6d
7d dikes
8 dike
6d incl
70°
5a,g
7e,f dikes


location.
AYLSWORTH
WOODYATT
7d
7e dikes
6d incls
8 dike
8
D.H.
1a
1b
lit-par-lit
83°
60°
2a
2a incls
N-50-5
N-51-1
7d, f dikes
Pit
7f dikes
7a