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LA LIEVRE AREA (COMTE DE ROBERVAL)

EXPLORATION GEOLOGIQUE

MINISTÈRE
DES RICHESSES
NATURELLES
DIRECTION GÉNÉRALE
DES MINES

LA LIEVRE

AREA

J.G. Bray

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LA LIEVRE AREA

ELECTORAL DISTRICT OF ROBERVAL

by

J. GUY BRAY

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LA LIEVRE AREA

LAKE ST. JOHN REGION

ELECTORAL DISTRICT OF ROBERVAL

by

J. Guy Bray

INTRODUCTION

General Statement

La Lièvre area was mapped by the writer in the summers of 1958 and 1959. The mapping was part of a project to link the Lake St. John and La Tuque regions. The presence of Roberval Mining Corporation's titaniferous magnetite prospect in the north centre of the area provided an economic incentive. No other substantial magnetite deposits were found, but the outcrop areas of possible host rocks were defined. Indications of other economic mineral deposits were scanty.

The relief is moderate. Continental glaciation left extensive glacial and fluvio-glacial deposits on all but the highest ground. The height-of-land between Lake St. John and the St. Maurice River crosses the northeast and northernmost parts of the area.

The consolidated rocks are Precambrian. High-grade gneisses and amphibolites underlie most of the area. They were intruded first by gabbros, and later by large plutons of a more acidic type. Granite dykes and a few late basic sills are found.

The gneisses trend generally west-northwest to north, with moderate to steep northeasterly dips in most places. The gneiss foliation swings concordantly round the plutons, giving them the appearance of huge "augen" on the map.

Location

The main part of the area, comprising approximately 400 square miles, lies between latitudes 48° 15' and 48° 30' N and longitudes 72° 30' and 73° 00' W . Between longitudes 72° 45' and 73° 00' W , the mapping was continued north to latitude 48° 35' to cover another 55 square miles. The centre of the area is 26 miles west-southwest of the town of Roberval on Lake St. John. The whole area lies in Roberval electoral district. Only the northeastern quarter, including the north western corner of Chabanel township, the western half of Ross, the southern half of Lyonne, and the west half of the southern corner of Drapeau township, has been surveyed.

Access

Float-planes can use the larger lakes throughout the area. It is only a few minutes flying time from Roberval, where Nordair has both a land and a water base, and the Canadian National Railway has a station.

The eastern edge of the area is 21 miles from Roberval, via Ste. Hedwidge on the gravelled La Tuque toll road, maintained by the Consolidated Paper Corporation. This road bisects the area from east to west and then runs south-southeast from the western to the southern margin of the map. Several club and logging roads, best suited to jeeps, extend north and south from the main road. From the Consolidated Paper Corporation's La Lièvre Depot (Plate I-A), in the west centre of the area, a road runs northwest to the Chibougamau highway or La Doré. An International Paper Corporation road branches from the main road, 1½ miles east of the area, and gives access to the southeast corner at Ennuyant lake. A road from St. Felicien via François lake enters the northeast corner. No part of the area is more than 4 miles from a road.

Because of frequent rapids none of the rivers, not even the Grande Trenche, is suitable for extended canoe travel. The Panache lake - Portage lake system forms a convenient waterway, as do the Otter lake - Sauvage lake and Eaux Mortes river - Eaux Mortes lake systems when the dams below them are closed, in the spring.

The cross-country travel is fair, except in some areas of second growth where the bush is very thick and tangled.

Field Work

The writer was in the field for 17 weeks in 1958 and 18 weeks in 1959. In 1958 much time was lost because of rain.

Contoured maps on a scale of two inches to one mile were obtained from the Department of Mines and Technical Surveys, Ottawa. These maps (National Topographic Sheets 32 A/7 and the west half of 32 A/10) are unpublished and were supplied as advance information. They were prepared from vertical aerial photographs, taken by the Royal Canadian Air Force in 1949, on a scale of about 1 inch to 5,000 feet. The maps were used as a base for plotting, and, with the photographs, for planning traverses. The photographs, gave little information about bedrock geology and were on too small a scale for aid in locating rock exposures. Their chief use was in plotting exposures while on traverse.

The area was covered by systematic pace-and-compass traverses at half-mile intervals, arranged at large angles to the strike, and by shore-line traverses of the larger lakes and streams. About 5 per cent of the bedrock is exposed. Valley and flat hill-top areas are commonly drift-covered, but, on the steeper slopes, the soil mantle is generally thin or absent. There are a few exposures in road-cuts, but bedrock was rarely seen along streams or lake shores.

Denis Couillard and Guy Lapointe were able senior assistants; the other party members were Raynald Bell, Donald Colby, Ghislain Dufour, Anders Jepsen, Robert Lamarche, Denis Lalonde, René Robitaille and David Williams, junior assistants; Alfred Lantagne and Herménégilde Lavoie, cooks; and Victor Gagnon, bushman and canoeman.

Acknowledgements

Mr. Armand Veillette, the superintendent, and his staff at the Consolidated Paper Corporation's La Lièvre Depot were always very helpful. Wardens of the St. Maurice Fire Protection Association were also of service.

Guy Lapointe, senior assistant in 1958, is making a study of the Roberval Mining Corporation's magnetite deposit for his M.Sc. thesis (Lapointe, 1960), and information from his work is included in this report.

Mr. René Thibault, of Albanel, a director of the latter corporation, was helpful on several occasions in showing the writer and Lapointe over the prospect he discovered, in giving us access to the drill core, and in allowing Lapointe to use the cabin on the property.

The writer is studying the petrology of the area for a Ph.D. thesis at McGill University under Dr. E. H. Kranck. He was visited in the field by Dr. Kranck and several members of the Department of Mines staff, and is indebted to them for

many valuable suggestions and discussions.

Previous Work

Dresser (1916) seems to have made a cursory examination of parts of the area, although none of it appears on his map. A useful unpublished outline by Osborne (1959) reviews the rock-types observed in neighbouring districts.

DESCRIPTION OF THE AREA

Settlement and Resources

The only permanent inhabitants of the area are the staff of La Lièvre Depôt's offices, workshops and other facilities. With their families they total a few score. Seasonal inhabitants include jobbers, dam-keepers, fire wardens, and Roberval residents who come to hunt and fish. In late summer, several hundred blueberry-pickers camp in the less wooded parts.

The only industry, apart from blueberry picking, is the cutting of pulp-wood. The Consolidated Paper Corporation has the largest holding; others belong to the International Paper and Laurentian Paper corporations. At present, timber is being cut by Consolidated in the west of the area and by International in the southeast. Extensive and repeated fires have affected large tracts in all but the northeast quarter of the area. Some parts are bare of trees, and others are covered by dense second growth vegetation. Spruce, jack pine, white birch and poplar are the common trees; alders grow in the dam ground.

The area is generally unsuitable for agriculture because there are too many trees, hills and boulders.

Fish are not very plentiful, probably because the area is so near a town. Speckled trout and carp were caught; some pike are reported.

Moose, beaver and rabbit are common; bear, otter, fox and numerous smaller animals were occasionally seen.

The average annual precipitation at St. Félicien is 21.35 inches of rain and 90.3 inches of snow, and the average daily mean temperatures are 64° F. in July and 1° F. in January. The Lièvre area is somewhat wetter and colder.

Physiography

Elevation in the area mapped is from 1,050 to 2,000 feet above sea-level. Local relief, which is generally greater in the west than in the east, is up to 500 feet.

The drainage has been glacially disturbed, and lakes and rapids are common. The northeastern sixth of the area and a small portion in the northwest from Rognon lake to Clair lake drain northeast into Lake St. John; the rest of the area drains south into the St. Maurice River system. The only large river is the Grande Trenche, in the southwest corner: the other rivers in the south are its tributaries.

The plutons of younger intrusive rocks generally form steep-sided rounded hills (Plate I-B and C) which are in contrast with the relatively smooth topography developed on the older rocks (Plate I-A). Because of this contrast and the steep intersecting joint-valleys, they are easily recognized in the field, on aerial photographs and on topographic maps.

The gneisses are coarse and massive. Their foliation, though conspicuous on an exposure, affords no easy parting, and, as result, finds little expression in the topography. Where the strike and the direction of ice movement nearly coincide, as in the region south and west of Eaux Mortes lake, low hills may be elongated parallel to this direction, but more commonly the surface is irregular, with some scattered drumlinoid masses of till.

In the northwest, all the major valleys trend to the southeast, crossing the strike. These are believed to be joint-valleys. The largest body of meta-gabbro, northeast of Cariboux lake, is marked by some of the lowest relief in the area.

Apparently the general lines of drainage, including the major streams, are the modified relics of a pre-glacial system. Many of the valleys are narrow and deep, and occupied by eskers. Some valleys lie at large angles to the direction of ice movement, which was between south-southeast and south-southwest. This direction is shown by numerous striae, and by two occurrences of crescentic gouge north of Casques lake, as well as by distribution of erratics and the southerly trend of the numerous eskers.

Bedrock exposures are fairly common, so the superficial deposits, except in valleys, are probably not thick. The pluton areas are well exposed. Post-glacial lake and stream terraces are not uncommon (Plate I-B).

GENERAL GEOLOGY

The area contains rock types that are familiar in other parts of the Grenville orogenic belt. In this report the writer's main object is to describe them.

The consolidated rocks of the area are Precambrian. Most of the area is underlain by high-grade migmatitic plagioclase gneisses (believed to be mostly paragneisses) and amphibolites, along with a few quartzites and pyroxenites formed from limestones. Metamorphosed sub-concordant gabbro intrusions are found throughout the gneisses. The largest of these,in the north-centre of the area, shows compositional layering in several places, and locally contains concentrations of titaniferous magnetite which may prove worth mining.

Large plutons intrude these oldre rocks. The plutons consist mainly of green pyroxene-microperthite quartz-monzonite, with some pink hornblende-microperthite quartz-monzonite and a microcline granite of migmatitic type. Smaller bodies of these rocks are also found. A few narrow granite dykes and basic sills cut the earlier rocks. Rocks of the amphibolite and granulite facies are present.

The unconsolidated rocks are largely glacial in origin, consisting of till and outwash deposits, although there is some later alluvial material.

A notable feature of the area, the gradational nature of most of the geological contacts, is a result of the extreme P-T conditions prevailing during metamorphism, which favoured reaction, diffusion and melting. Thus, continuous changes from paragneiss through migmatite to granite may be seen, and a variety of hybrid rocks accompany the margins of the quartz-monzonite intrusions. Both migmatization and intrusion are products of an ultrametamorphic environment, and are closely related in time. Another product was plastic deformation which is responsible for the broadly concordant structures which characterize the local geology. Few geological contacts transgress the foliation on a large scale except the replacement margins of the upper levels of quartz-monzonite plutons (e.g. around Corne lake in the south centre of the area) and perhaps the northwestern edge of the largest meta-gabbro body which, however, is poorly exposed.

The acidic intrusions in the northwest of the area, north of latitude $48^{\circ}30'$ N , are also poorly exposed. This is unfortunate because they seem to be of a somewhat different kind than those farther south. Their physiographic expression is more subdued. Microperthite, where present, is poorer in plagioclase and pyroxene is less common. The mineralogy suggests somewhat milder conditions of formation.

Table of Formations

Cenozoic	Pleistocene and Recent	Post-glacial	Soil and alluvium
		Glacial	Till, fluvio-glacial sand and gravel
Unconformity			
Precambrian	Granite dykes and basic sills		
	Intrusive contact		
	Pink hornblende-microperthite quartz-monzonite, and hybrids		
	(Gradational contact)		
	Green pyroxene-microperthite quartz-monzonite, and hybrids		
	Intrusive or gradational contact		
	Pink hornblende-biotite-microcline granite ("migmatite granite") including pegmatite and aplite sills		
	Intrusive or gradational contact		
	Meta-gabbro, and hybrids		
	Intrusive contact		
	Mixed gneisses: (not in order of succession)	hornblende gneiss hornblende-biotite gneiss biotite gneiss amphibolite quartzite pyroxenite and marble	

Precambrian

Mixed Gneisses

General

These are the oldest and commonest local rocks. Excellent exposures occur beside of near most of the roads, which, in skirting the higher ground formed by later intrusions, tend to be confined to gneiss outcrop areas. Due to of the isoclinal folding and unresolved structures, their thickness is uncertain but probably it is several tens of thousands of feet.

The mixed gneisses are grey or pinkish, (brown and green where most strongly metamorphosed), generally dark on weathered surfaces, medium or coarse grained, and strongly, and usually coarsely, foliated. Gneisses of several compositions may be present in a single exposure, as might be expected in gneisses formed from a group of sediments. Nearly every exposure shows some concordant pink granitic material. This is commonly coarse grained, and ranges from single feldspar crystals or quartz augen to thick lenses and layers, often pegmatitic. These granitic bands commonly make up 5 to 35 per cent of the rock surfaces, and migmatites with 50 and more per cent are common. Amphibolite bands are also ubiquitous in the gneisses, though quartzite and pyroxenite are rare. Concordant narrow quartz veins or lenses are numerous and, in many places, contain large clusters of magnetite crystals.

Original sedimentary layering has combined with metamorphic processes to produce a strong but irregular compositional banding in the gneisses (Plate II-B and C, Plate III-A). This is a feature of almost every exposure, and is the reason for their being described as "mixed".

Because of their complexity, it is difficult to map separate units on the ½-mile scale, and the map reflects this. Marker formations are few, and even resistant quartzite bands are hard to trace between the scattered exposures. In hand specimen, differences in the proportions of the different minerals are apparent. The irregular layering of the gneisses makes it difficult to determine the tenor of ferromagnesian minerals and attempts to subdivide the gneisses in this way were unsuccessful. Three main types of gneiss were distinguished in mapping: hornblende gneiss (with minor biotite), hornblende-biotite gneiss, and biotite gneiss (with minor hornblende). Pyroxene, where present, is included with hornblende. These three rock-types make up most of the gneiss in the area. The contacts between them are generally gradational.

Biotite gneiss is much less common than the other two types, and is associated with quartzites in many places. Garnetiferous gneisses are uncommon, and generally both quartzitic and biotitic. Some weakly graphitic gneiss was found south of Huard lake. In a few places, notably east of La Lièvre Depot, the hornblende gneiss is rather massive and poorly foliated. In thin section, it shows evidence of deformation, such as bent plagioclase twin lamellae but, in composition, it is no different from the other common gneisses.

Both in hand-specimen and in thin section, the gneisses, like nearly all the rocks in the area, are fresh. Foliation is generally defined by the dark minerals in thin sections but is not conspicuous. The texture is crystalloblastic (Plate VI-A).

Excluding for the present the pegmatite and amphibolite bands, the composition of the local gneisses lies within the following broad limits: quartz 5 to 25 per cent; plagioclase (about An_{30}) 55 to 75 per cent; potash feldspar generally less than 5 per cent; hornblende and/or biotite up to 15 per cent; ortho- or clino-pyroxene 0 to 5 per cent; accessory minerals, mostly magnetite, apatite and zircon, less than 5 per cent. From their composition, the rocks might be described as granodiorite or quartz-diorite gneisses, although, if the important pegmatite and amphibolite content is considered, quartz-monzonite gneiss might be a better name.

Quartz is invariably strained. Feldspar is, in places, weakly microperthitic. Pyroxene, where present, is partly replaced by either hornblende or biotite, or both (Plate VI-B), and commonly shows exsolution of a second pyroxene. Zircon occurs in small, sub-rounded grains. Allanite and sphene were seen in some sections.

Deformation and cataclastic features were seen in a number of sections. In a few exposures the gneiss is finely foliated or mylonitic in appearance; a section of such a rock showed a recrystallized mylonitic structure, with a little kyanite.

Lineation is not uncommon in the gneisses, although it is rarely prominent. Elongation of quartz blebs and of ferromagnesian crystals or clusters is the most common type. Plunging small folds and fluted quartz veins were also measured.

Although some of the gneisses are believed to be derived from sedimentary rocks, few or no structures certainly of sedimentary origin are recognized. It is an inference that the layering is parallel to original bedding.

Metamorphism

This refers to the extreme types of metamorphic alteration, not to the general transformation of the original rocks into gneisses. Two types are distinguished, characterized by a pink and a green colour respectively.

The pink material is the result of migmatization, shown by increasing amounts of concordant granitic material, as described above (p. 12). It consists mainly of quartz and pink microcline, with some sodic plagioclase and a few ferromagnesian minerals. The feldspar is slightly microperthitic. In thin sections (Plate VI-C) the granitic material was seen to grade rather sharply into the gneiss. Microcline in the migmatite bands is generally much better twinned than that in the gneiss.

Most of the migmatitic material appears to have no connection with magmatic igneous bodies and is thought to be the product of metamorphic differentiation or of differential fusion. The not uncommon presence in the granitic bands of rarer minerals such as allanite may, however, indicates an origin in a body of fused rock at depth.

In the highly migmatized rocks, the tenor of dark minerals is low. When granitic material exceeds 50 per cent, the foliation may be indistinct and the banding confused (Plate III-B). The areas of most intense alteration seem to be rather irregularly distributed throughout the district, but they are related to the microcline granites, which are described later.

The green alteration occurs over wide areas (see map) and invariably surrounds the quartz-monzonite bodies. It is generally most intense near their margins, which show a gradation from highly altered gneiss with lenses of quartz-monzonite to impure quartz-monzonite with relics of gneiss. The slightest weathering changes the olive-green colour to brown, with a blue-grey metallic sheen in strongly weathered specimens, but, even where weathering is weak, the colours are distinctive and easily detected. The green colour is closely similar to that of the quartz-monzonites, but only near the contacts do the gneisses contain the green plagioclase-rich microcline-microperthite which characterizes these intrusions.

The green colour of the gneisses, therefore, seems to be a property of their abundant plagioclase which, however, is no different in anorthite content than that in the unaltered gneisses. Except where alteration is weak, the green gneisses contain pyroxene. Thus these gneisses appear to define areas of granulite facies metamorphism.

The more intense manifestations of both types of alteration seem to be mutually exclusive, though all the green gneisses contain some migmatitic bands.

Amphibolite

Conformable layers of amphibolite, from less than an inch to several tens of feet thick, occur throughout the gneisses, and account for 10 to 20 per cent of their area. The thinner layers may be products of metamorphic differentiation, but the thicker ones, no doubt, represent different parent rocks and were mapped separately, where possible.

The rock is dark grey, medium to coarse grained, and well foliated. It is composed of almost equal amounts of hornblende and plagioclase (oligoclase to andesine). The other constituents (magnetite, apatite, zircon and biotite) rarely exceed 10 per cent. A little ortho- or clino-pyroxene may be present. Near their margins the amphibolites are commonly biotitic. This may represent an original gradational change in composition, or metasomatism by potash from the gneisses.

The amphibolites act as the resistant unit in the boudinage structures that are so common in the area (Plate II-A). A lineation of hornblende crystals may be present.

The origin of the amphibolites is uncertain, as the observed mineralogy could have been produced by metamorphism of a limy shale or of a basic igneous rock, or by metasomatism of a marble. Some of the local amphibolites appear to have developed from gabbro (see below: Meta-gabbro). However, since the meta-gabbros generally retain recognizable igneous features and marbles are uncommon in the district, it is likely that most of the amphibolites represent limy shales or thin basaltic to andesitic lavas and tuffs.

Quartzite

Quartzites occur sporadically in the western and southern parts of the area, being most common in the south-west, where thick bands form a conspicuous hill west of Bonhomme lake. The bands may be as much as 50 feet thick, but are generally 15 feet or less. They are commonly associated with quartzitic biotite and garnet gneisses. Quartzite is well exposed at some rapids on the Grande Trenche river, just below the bridge on the La Tuque road.

The rocks are light coloured, medium to coarse grained and rather massive where pure. They consist chiefly of glassy or slightly milky quartz. Impure types, common at their margins, are better foliated. In thin section the quartz is seen to be accompanied by variable amounts of weakly perthitic potash and plagioclase feldspar, and a little biotite. Detrital accessory minerals, such as zircon and magnetite and, in one section, monazite and rutile, follow the foliation and probably indicate bedding planes. Garnet is common in the impure quartzites, and in a few places a sillimanite-garnet gneiss accompanies them.

The quartzites commonly possess a strong lineation, shown by fluted foliation surfaces. These rocks are evidently metamorphosed siliceous sediments. Associated discordant quartz veins may represent mobilized material.

Pyroxenite and Marble

These rocks were found in small exposures scattered throughout the area, near the northeastern and western parts. They are rarely more than 10 feet thick but, owing to their distinctive mineralogy, are conspicuous even if less than a foot across. However, because of their narrowness and low resistance to weathering (particularly if rich in carbonate), they probably fail to crop out in many cases. Typical rocks are conveniently exposed on roadsides at the south end of Corne lake and 1 mile southwest of Casques lake.

The rocks included here are variable in appearance, even on a single exposures, probably reflecting original compositional differences. They are nearly all rather coarse-grained; foliation is crude or absent. Colour ranges from white to dark green depending on mineralogy, which is diverse. However, all types are rich in lime and usually, in magnesia, and poor in potash and soda. In the field the most conspicuous common feature is an abundance of green pyroxene, generally dark. Quartz is scanty or absent in most cases, but siliceous examples were seen, including one thin band composed almost entirely of quartz and diopside in equal amounts. Other common dark minerals are hypersthene, tremolite, biotite, hornblende, sphene and grossularite garnet. Plagioclase (generally calcic, up to An_{75}) and scapolite are the major common, light-coloured minerals, with minor calcite, apatite, magnetite, zircon and vesuvianite. High percentages of free carbonate are rarely seen; the largest body of crystalline limestone found was a boulder in the northwest of the area, near Bruneau lake. In many places pegmatite cuts these rocks and is desilicated.

The mineralogy of the pyroxenites and marbles shows that they represent limestones and dolomites, with variable argillaceous and siliceous contents, which have been metamorphosed and metasomatized.

Abrupt changes in thickness are characteristic, reflecting the mobility of limestones under intense regional metamorphism. Pyroxene-rich bands may form boudins in the softer rock.

Association with quartzite is common. The map also suggests some association with amphibolite, which could have formed from limy shale. Certain other quartz-poor, pyroxene- and/or hornblende-rich gneisses probably represent less pure limy sediments.

Origin of the Gneisses

Valuable clues to the origin of the gneisses are their rhickness, their association with amphibolites and sparse impure quartzites and calcareous rocks, and their occurrence in what is probably the core of an orogenic belt but the most important evidence is their chemical composition. We must decide whether to include the ubiquitous narrow granitic and amphibolitic bands in an estimate of the overall composition. Both are variable in amount; both may be the products of metamorphic differentiation. However, a microscopic comparison of the non-migmatitic material from strongly and weakly migmatized gneisses shows very little difference in composition, except that the former is more potassic. Therefore the migmatitic material is probably not derived from the immediately adjacent gneiss bands, and so we can exclude most of the granitic material. The amphibolite bands are less abundant, and the thicker ones, at least, are probably not differentiation products.

We are thus left with gneisses in which soda considerably exceeds potash. Engel (1956, pp. 81-3) quotes analyses to show that in most typical shales and sandy shales potash is in excess, and that soda-rich types are more often derived from greywacke or tuffaceous greywacke. Such parents would be consistent with a sedimentary environment in which quartzite and limestone are scarce, impure, and generally thin.

Meta-gabbro

This rock occurs sporadically in the gneisses throughout the area mapped; altered xenolithic bodies were found in the younger intrusions in the north near Touladi lake in the south near Panache lake, and in a few other places. A broad arc of separate meta-gabbro exposures swings southeastwards across the eastern part of the area from Rats lake to Panache lake. These bodies may represent the continuation of the large mass northeast of Cariboux lake (see Trend Map). Where best exposed, near Touladi lake, this mass appears to be about 5,000 feet thick. It may be much thicker farther south, but exposures are few and both its continuity and attitude are uncertain. Most of the other meta-gabbros are a few tens or hundreds of feet thick. Thinner bodies tend to resemble amphibolites. Meta-gabbro is well exposed on roads and tracks in the vicinity of the Roberval Mining Corporation's property west of Touladi lake, and on the northeast shore of Cariboux lake.

These rocks are typically medium to coarse grained, dark grey or greenish, and composed of plagioclase, pyroxene, and some magnetite, with hornblende and/or biotite near gneiss contacts. They show little foliation, and clusters of dark minerals commonly give weathered surfaces a spotted appearance. The larger bodies may show some compositional layering (Plates III-C and IV-B). Concentrations of feldspar, pyroxene and titaniferous magnetite were seen. The largest body, at Cariboux lake, shows this best. However, none of these types is really important. Some aplitic gabbro accompanies many of the larger bodies. It generally intrudes the coarser rock (Plate III-C), but the reverse relation is also found. Porphyritic basic dykes are a less common associate. Small gabbro pegmatites occur in a few exposures, notably at the lake 2¼ miles east of aux Rats lake (Plate IV-A). Some of the meta-gabbros are garnetiferous; coronae with garnet were seen in two places. Rocks of a hybrid, intermediate appearance are found in and near the later acid intrusions, especially in the northwest. In some places porphyroblasts of potash feldspar are developed.

In thin section the common meta-gabbros are seen to contain 50 to 60 per cent plagioclase, generally andesine, and much hornblende in place of pyroxene. They might be called diorites, but gabbro is preferred because of their general association with anorthositic rocks in the district. Both ortho- and clino-pyroxene occur, commonly showing schiller. In some cases large hypersthene crystals with schiller are rimmed by smaller, more pleochroic inclusion-free ones. This may indicate that the hypersthene is partly primary. A little biotite may be present, with several per cent magnetite and accessory apatite and zircon.

Rocks rich in titaniferous magnetite (Plate VII-A) are similar in mineralogy to those described above, but apatite is more abundant. Plagioclase content may reach 80 per cent in the anorthositic gabbros, which contain labradorite or calcic andesine.

The aplitic types differ from the ordinary gabbros only in grain-size and in having more hornblende.

Metasomatism apart, the most intense metamorphic effects are seen in the coronites. One is on the bank of Panache Creek in the east of the area, and the other is near Eaux Mortes river, in the northwest centre. They are similar, except that the latter contains olivine, labradorite and spinel. The plagioclase is cloudy with minute inclusions of amphibole or garnet, and the coronae show all or part of the reaction sequence: olivine ($\pm$ magnetite); hypersthene; green amphibole; garnet or green spinel; plagioclase (Plate VII-B).

The acidic intrusions produce a variety of metasomatic effects. About 1 mile southeast of Touladi lake, a track crosses a complete passage from slightly altered gabbro to pure quartz-monzonite. The changes seen in thin section (Plate VII-C) reflect a potash-soda metasomatism: pyroxene and amphibole are replaced by sheafs of biotite, potash feldspar replaces plagioclase, and the plagioclase itself becomes much more sodic, reaching albite in some cases. Quartz may also be present. One section of a gabbro xenolith showed this type of alteration and a partial development of coronae. A few porphyritic dykes, of gabbroic affinity, also show these metasomatic features.

A granite-injected meta-gabbro, 1¼ miles northwest of Touladi lake, contains a small body of massive, fine-grained emery, composed of green spinel, magnetite and corundum. This may be a metamorphosed aluminous sediment or a metasomatic rock.

Near gneiss contacts the meta-gabbro may grade into a biotite amphibolite, and it is believed that a number of amphibolite outcrops represent original meta-gabbro, as indicated on the map, e.g. northeast of Small lake. The thick band west of Traverse lake may also have been a gabbro.

The anorthositic rocks commonly show a lineation of elongated hypersthene crystals.

The meta-gabbros, as the name implies, are believed to represent metamorphosed gabbroic intrusions into the gneiss. The compositional layering is thought to be an original igneous stratification.

Gabbro contacts and banding are generally concordant with the gneisses, and in several places the rock forms recognizable sills. Only in a few exposures, west of Touladi lake, were discordant intrusive relationships seen.

Microcline Granite

This includes a variety of types, from small lenses or bands in gneiss to large bodies of igneous appearance. A genetic sequence probably exists. Rocks of this group occur throughout the area. The supposed sequence is well exposed along the road on the hill west of Sauvage lake. Large bodies crop out west of Touladi lake and of Panache lake.

The migmatitic, granitic material that pervades the gneisses has been described in some detail avobe (p. 15). In thin section (Plate VI-C), this material is seen to be composed of nearly equal amounts of quartz and microcline, with about 5 per cent perthitic plagioclase ; free oligoclase grains, biotite, hornblende and accessory minerals total less than 10 per cent, commonly less than 5. Gradations exist from gneiss with granitic bands or sills through strongly migmatized gneiss to wholly granitic rocks with relic foliation. Thin sections show corresponding changes in mineralogy.

The last-named types may be described as migmatite granites, and were mapped separately where they occur in larger bodies. They are pink, light-weathering, and range in grain-size from aplite to pegmatite. As a rule they are poor in dark minerals. Generally they are strongly gneissic, and, in places, contain gneiss relics. They may grade imperceptibly into the gneisses, or cut them sharply, but their contacts are usually subconcordant.

Bands of a slightly different granite also occur in the gneisses. These may be several feet thick, with sharp concordant contacts, and can be followed for hundreds of feet on large exposures (e.g. along the Petite Lièvre river, west of Rognon lake). They are medium-grained and contain less than 5 per cent dark minerals. Their strong foliation, generally with a pronounced lineation, contrasts with the adjoining gneisses. A thin section shows the same mineralogy as the migmatite granites described above. Quartz-microcline rocks here are probably origin migmatitic injections, rather than of sedimentary.

In thin section the microcline granites appear quartz-rich (up to 50 per cent); microcline, with up to 20 per cent perthitic plagioclase, may reach 70 per cent. Plagioclase (oligoclase) rarely exceeds 15 per cent; biotite and a green pseudo-uniaxial amphibole (also seen in the highly migmatized gneisses) total less than 10 per cent. Magnetite, apatite, zircon and allanite are the common accessory minerals. Weak chloritic alteration is common.

On the Roberval Mining property a large body of microcline granite intrudes meta-gabbro. On the east this granite grades into pink hornblende-microperthite quartz-monzonite, which it resembles. There is some possibility of mis-identification in the field, but their fabric is different: the monzonite is more homogeneous, less gneissic, and does not have relic features; moreover its microperthite is substantially richer in plagioclase.

In view of their lithology, structure, and field associations, it is clear that the microcline granites are migmatitic in origin. Whether this implies that they formed by metamorphic differentiation, metasomatism, differential fusion, or magmatic injection is an open question.
In ultrametamorphism all these processes are at work.
The relationship of these granites to the quartz-monzonites is of greater interest but, because of their gradational or obscured contacts, hard to determine. There are several clues: the largest granite bodies are found around monzonites; both rocks contain microperthite, and amphiboles of low optic angle,

which suggest a similar environment of formation; the granites are richer in quartz, potash feldspar, biotite and volatile content; and in places (for example, the hill west of Sauvage lake), the green alteration invariably associated with the monzonites affects the migmatitic granite.

A possible explanation of the origin of these rocks is presented below. However, this subject is still under debate by many distinguished geologists whose views, which are well summarized by Turner and Verhoogen (1960, ch. 12), have been drawn on freely here.

The strongly granitized gneisses presumably represent the advances of intense heat and emanations from below: a "migmatite front". This front is irregular, as might be expected in an non-homogeneous gneiss series. However, one feature is noticeable: intense migmatization and intense green pyroxenic alteration are mutually exclusive. The large monzonite plutons also must represent loci of extreme heating. If migmatite granite is scarce near their margins, it is likely that such material has migrated away from them under the influence of a temperature-stress gradient.

Such a hypothesis is consistent with the mineralogy of the two rocks: the monzonites appear to be higher-temperature types, and the granites are richer in fugitive components, but their similarities support a related origin.

Thus, in the writer's opinion, both monzonites and granites are products of a single continuous process of ultrametamorphism, under the influence of which the older rocks were transformed, , the more mobile, earliest melting, granitic fraction migrating ahead of the residual, monzonitic material. The energy source responsible for a large monzonite body might also form the large associated granites mentioned above; and the green alteration halo advancing ahead of the monzonites might affect previously migmatized rock.

According to this theory, granite and monzonite are of equal age. However, inasmuch as the granites reached any particular point first, they are older: hence their place in the Table of Formations. It is possible that some granite, for instance the two largest bodies, evolved by later differentiation of monzonite, but their resemblance to the other migmatites is striking.

Microperthite Quartz-monzonite

General

Rocks differing in appearance, but linked by similarities of mineralogy which suggest a genetic relationship, are included here. They are found in all parts of the area, chiefly in the five or six large plutons which underlie about one quarter of the ground, but also in smaller, sill-like bodies. The southwestern pluton, with a mapped area of some 27 square miles, probably is batholitic in its overall dimensions. The other plutons are of comparable size. These rocks are well exposed on and near the main roads in the south and southwest of the area.

Green pyroxene-microperthite quartz-monzonite

This type is the most important of the group, as the map shows. The colour, when fresh, is dark to olive green, but weathering effects may penetrate several feet, and, except in road cuts, the colour seen is brown, with a steely blue-grey lustre where heavily weathered; exposed surfaces are pale buff. The rock is generally coarse grained, except in small bodies and near the margins of larger ones where the crystals are smaller, and in a few places where a light green aplitic phase was seen. A few thin aplite dykes cut the massive rock. Near Merlin lake, in what is probably the uppermost level of a pluton, the rock is locally pegmatitic. A weathered surface shows the typical rock to be a mosaic of granular feldspar crystals, commonly zoned, with interstitial quartz and dark minerals, including pyroxene. Crude foliation may be distinguished in many of the larger exposures (Plate V-A). On a fresh surface quartz is very difficult to recognize and the rock appears structureless.

Quartz-rich types seem to be more common near the margins of large plutons, but the variation is very irregular. Gneiss relics impart a foliated appearance near contacts, which are gradational in detail.

In thin section, the most conspicuous feature is string microperthite, strikingly regular in texture (Plate VIII-A), and generally forming 60 to 70 per cent of the rock. The potash feldspar host in many sections is microcline, though in others it may be anorthoclase. Point counts show over

40 per cent plagioclase in most cases. The texture is typical of exsolution. Plagioclase tends to be concentrated in the margins of crystals (hence their zoned macroscopic appearance, which may simulate rapakivi texture); small twinned grains of free plagioclase (An_5 to An_{30}) commonly rim the perthites, forming up to 20 per cent of the rock. This percentage tends to be highest with plagioclase-poor perthites.

Quartz, showing strain, varies from 2 or 3 to 25 per cent, but commonly exceeds 10; green diopsidic pyroxene occurs in all sections, and may reach 10 per cent. A few per cent of altered orthopyroxene (or olivine?) accompanies the clinopyroxene in some sections. Both pyroxenes generally show metallic and/or pyroxenic exsolution lamellae. A little green-brown amphibole, with a very low optic angle, commonly replaces the pyroxene. Magnetite content may reach 5 per cent; accessory minerals include zircon, apatite, biotite, allanite, rutile and calcite. A mosaic, rather than a granitic fabric, is general.

The mineralogy indicates a high-temperature, hypersolvus rock with a low tenor of water. Plagioclase generally exceeds one third of the total feldspar content, so the rocks are quartz-monzonites. They are far from being text-book examples, however, and the name "microperthite quartz-monzonite" emphasizes this. A few types, if strictly defined, are granites, syenites or monzonites, but the distinction is almost impossible to make in the field, and the use of one name represents a genetic grouping.

Near gneiss contacts the mineralogy is variable. Some rocks with what seems to be relic gneiss banding carry a little brown altered cordierite with the pyroxene.

The fine-grained type found in some marginal zones appears mylonitic in thin section. In one case, which showed mylonitic structure but little strain, recrystallization had caused an almost complete separation of plagioclase, leaving only a few large crystals of perthite. Augen gneisses are found near contacts east of Iron lake and northeast of Casques lake. One section shows evidence of strong deformation, as do sections of three other marginal gneisses. These features may be due more to later movements, when the rocks had become less plastic, than to the original force of intrusion.

Sections of rocks with recognizable gneiss relics show that the amphibolite bands are most resistant to alteration. A sharp boundary was seen in one section (Plate VIII-B). On one side, microperthite, quartz and clinopyroxene; on the other, amphibole (with a low optic angle) and plagioclase. The persistence of a hydrous mineral (amphibole) under such intense metamorphism suggests a very high confining pressure. Potash metasomatism is marked by replacement perthites.

In the field, the metasomatized zone bordering the monzonites appeared to be several hundred feet wide, with a very gradual transition from gneiss to monzonite. This may be so, in places, notably around Corne lake, but some rocks with the most intense apparent alteration showed a normal gneiss composition in thin section. A "relic-filled" monzonite proved to be barely contaminated by gneiss, and a rock virtually indistinguishable from monzonite was found to contain no potash feldspar at all. It thus appears that the transition zone may be quite narrow. The cause of the green colour remains obscure.

The monzonites show both metasomatic and intrusive features. In general, the intrusions are concordant. However, relic gneiss banding may be traced well inside their margins, as in the body south of La Lièvre Depot and in all small ones, and replacement of gneiss may be seen in thin section and on exposures (Plates VIII-B and V-B). Angular xenoliths and disrupted banding are also found (Plate V-C), and the mineralogy includes features such as the perthite, which Tuttle and Bowen (1958, p.129) consider undoubtedly magmatic. These observations are consistent with the formation and emplacement of magma in an ultrametamorphic environment. The magma is thought to have formed by fusion of the older rocks. Migration of migmatitic granitic material may have caused the present rocks to be less hydrous and more basic.

Since these complex intrusions are major features of the local geology, their form is discussed under STRUCTURAL GEOLOGY.

Pink hornblende-microperthite quartz-monzonite

This type was identified in all the large plutons, but only there. It occurs in irregular patches, large and small, with a tendency to occupy marginal parts of the plutons. The largest outcrops are near the northern and southern edges of the map. It is well exposed on the La Tuque road near the observation tower in the southwest.

Exposed surfaces weather very pale pink, or white, and may resemble the green rocks. On a fresh surface the colour is pink to buff, and no pyroxene is seen, but otherwise, in appearance and structure, they are identical with the pyroxene-bearing types. Their mutual contacts are gradational and many feet wide where they are exposed near the observation tower. The pink rock is like the microcline granite, as noted before.

In thin section, its resemblance to the green rock is even stronger. The perthite is the same, and so are the fabric and the accessory minerals. A green amphibole of low optic angle takes the place of pyroxene and there may be more biotite, quartz and microcline, and slightly less plagioclase, but the differences are small. A slight increase of chlorite, sericite and calcite alteration was detected. The rock is a little more acid than the green types, but evidently very closely related.

West of Touladi lake, it intervenes between the microcline granite and pyroxene quartz-monzonite. This contact appears gradational and gneissic. At the contact of the other large microcline granite with monzonite, east of Panache lake, pink monzonite is not seen but this contact is poorly exposed.

The pink monzonite may have originated in several ways. If monzonites and microcline granites are products of a single continuous process, the hornblende monzonite may be an intermediate type. Alternatively, it may be a later differentiate of the pyroxene monzonite, or, thirdly, an altered monzonite. Therefore these rocks may be of more than one age but they are described here for convenience.

Other related rocks

These are of two types: dykes and sills in and near the common quartz-monzonites in the south, and the atypical rocks of the northwestern pluton. Dykes are best seen in the southern part of the area; one was found on the roadside 1 mile south of the observation tower on the La Tuque road. Sills are not uncommon in the gneiss southeast of Corne lake, where much of the bedrock is exposed. The other rocks can be reached via the road northwest of Casques lake.

The monzonites are cut in several places by fine-grained sills and dykes a few inches thick, with sharp contacts. Like the pyroxene quartz-monzonites, they are brownish green in colour, but, in two thin sections, their microperthite is seen to be much poorer in plagioclase. One section is a granite, the other a pyroxene-quartz diorite. Both contain hornblende and a little allanite. They are probably aplites related to the host rock.

The sills in gneiss near the contacts with monzonite are fine to medium grained, greenish or pinkish brown, and several inches thick. Most of them have few dark minerals, and are quartz-rich. Microperthite, like that of the monzonites, is accompanied by a higher proportion of sodic plagioclase than in those rocks, and pyroxene is absent. Some cataclasis was seen. These rocks seem to be quartz-monzonite injections.

In the northwest the plutonic rocks are more basic in field appearance. Those mapped as pyroxene quartz-monzonites show very little quartz, and hornblende quartz-monzonites have more dark minerals and less quartz than elsewhere, and their colour is pinkish grey or brown. In places the rocks are gneissic, and they generally appear variable or hybrid, in contrast to the uniform southern varieties.

In thin section, the chief differences are the lower percentage (less than 20) of plagioclase in microperthite, and the abundance of free plagioclase, maintaining a monzonitic or more basic composition. Quartz is generally less than 10 per cent, and plagioclase is very poorly twinned. Sericite-chlorite alteration is stronger than in the south, and a mosaic texture is absent. Apparently, either the rock has been recrystallized or it formed at a lower temperature and pressure originally.

In the same area the meta-gabbros show strong metasomatic effects and, in several places, incompletely assimilated meta-gabbro xenoliths occur in the monzonites. The area may be along strike from the largest meta-gabbro body (see Trend Map).. Incorporation of large amounts of gabbroic rock into a quartz-monzonite magma would lower its temperature and make it more basic. However this explanation is just a guess. Nevertheless, because of their composition, it is certain that these rocks are closely related to the quartz-monzonites.

Granite dykes and basic sills

Basic sills

These were identified in a number of scattered exposures throughout the area, mostly in the west, in gneiss, meta-gabbro, and monzonite. They are inconspicuous rocks which range from a few inches to a few feet in thickness. The most accessible and conspicuous is probably the one 2¼ miles west of Touladi lake, near an old road.

They are dark or greenish grey rocks, fine to medium grained, commonly foliated and biotitic; some are porphyritic.

Though generally concordant, several of them truncate the gneiss foliation at low angles. They differ in appearance from common basic gneiss bands, either having escaped the full intensity of the prevailing metamorphism, or, like the meta-gabbros, having resisted it.

In thin section, several different kinds of rock were seen. The one intruding gneisses west of Touladi lake is an altered spessartite. Most of the others have an altered igneous, rather than a metamorphic, fabric but appear to have undergone some metamorphism. They are dioritic in composition, with or without pyroxene. Plagioclase of two sizes occurs in several sections; the rocks commonly show chloritic and/or calcitic alteration.

Some are associated in the field with meta-gabbro and, in such cases, there may be a genetic relationship. A few schistose types may represent sheared amphibolites. The majority, however, are thought to be late basic intrusions, injected during the waning phase of metamorphism.

Granite dykes

These are found on almost every gneiss exposure, and on some meta-gabbro ones, but are extremely rare in the monzonites. They are perhaps most common in the north centre of the area.

The dykes are pink, generally coarse-grained or pegmatitic, and rarely more than 18 inches thick. Their mineralogy is little more variable than that of the concordant migmatitic bands which they closely resemble, but, in these discordant rocks, both in 1958 and in 1959, beryl was found. found.

They have steep dips, and sharp contacts which transect and offset the foliation of gneisses and migmatite granites. Evidently they were injected into rocks capable of sharp fracture, probably during the last stages of metamorphism.

Their mineralogy suggests a relation to the migmatite granites, of which they may be a late differentiate.

Cenozoic

Pleistocene and Recent

Large areas, particularly in the northeast and northwest, are covered by irregular ground moraine with numerous large erratic boulders, most of which have not travelled far. Except on higher ground, fluvio-glacial sand and gravel deposits are found scattered on top of the moraine. Numerous eskers, a few over 30 feet high, were found.

Eskers and terraces are not uncommon in the larger stream valleys. Sandy terraces partially border most of the larger lakes. The sand is coarse, and cross-bedded in places. Particularly large terraces occur at Portage lake (Plate I-B), Otter-Sauvage lake and Casques lake. They may represent the filling of broad pre-glacial valleys.

A broad, discontinuous belt of eskers and kames extends south-southwest from the northern edge of the area to La Moelle. South of this are several terraced stream and lake deposits of gravel and sand, perhaps supplied from this source.

Just inside the northeast corner of the area are a few large dunes of fine sand, now partly overgrown. Hyperbolic in type, they indicate a west northwest wind: they are thus only 3 or 4 miles downwind from the esker-kame belt.

The larger present-day rivers are eroding the older sand and gravel terraces.

STRUCTURAL GEOLOGY

Foliation and Folding

Few individual folds can be distinguished, because of the difficulty of tracing the scarce marker bands in scattered exposures. However, the Trend Map shows the areal pattern, and small folds seen on single exposures indicate the prevailent style of folding.

Near large intrusions the gneiss foliation swings to follow their contacts, giving the concordant structure so typical of the area. Such disturbances are local effects. Presumably, the regional trend is shown by the intervening gneisses (Trend Map: domain I) which strike west-northwest in the east and change to north in the northwest part of the area. Plate IX-I is a contoured equal-area (Schmidt net) projection of the poles of all foliations in Domain I (i.e., a π-diagram). It shows that dips are almost everywhere to the northeast and moderately steep. This suggests a general isoclinal folding with overturning to the southwest, a conclusion that is supported by the form and attitude of most small folds (Plate II-C); these also show the characteristic flow structures of the highest grades of metamorphism.

Plutons

The plutons are important structurally because of their considerable size and the way their emplacement has affected gneiss foliation well beyond their margins. As noted noted-in the General Statement, the plutons appear on the map as huge "augen" in many places. Around them the gneisses dip very steeply inwards, indicating a funnel-shaped intrusion. Other relationships were also recorded, and an interpretation of them is now presented.

Regular, concordant, steeply in-dipping margins with few gneiss relics, as in the southwest, are thought to represent the deeper levels of an intrusion, whereas irregular, transgressive margins with lower dips, like those near Corne lake, suggest the roof zone, with pendants and xenoliths. In the Iron lake - Small lake region in the northwest, a domical structure with lenses of monzonite suggests an even higher level, possibly capping a large concealed intrusion.

Conical, carrot-shaped intrusive bodies, resembling salt-domes in form, seem to fit the observed local geology; whether they taper off or enlarge at greater depths cannot be decided here. The Section on the Geological Map shows the type of structure envisaged.

Statistical analysis of foliations measured in and around the plutons shows structural similarities between them, and supports the above interpretation. Plate IX (II to VIII inclusive) consists of π-diagrams from domains II to VIII (see Trend Map). In several of them a small circle was distinguished, indicating that foliation is indeed conically disposed. The centres of these small circles lie close together near the centre of the diagrams, suggesting that the intrusions have subvertical axes. A composite plot of the 5 per cent contours from these diagrams (Plate X-a) brings out the small circle inherent in all of them.

Lineation

Lineations may be detected throughout the gneiss and meta-gabbro outcrop areas, although they are hard to measure on small, smoothed exposures. The lineations plunge at low angles, and therefore tend to swing with the steeply-dipping gneiss foliations. A total of 216 lineations were recorded; of which Plate X-d is a contoured equal-area projection. Separate projections were made for the east and west halves of the map, for the different kinds of lineation, for gneisses with more or less than 50 per cent migmatitic material, for green and unaltered gneisses, and for gneisses in domain I (see Trend Map). All these projections showed substantially the same distribution of points. The area seems quite homogeneous in this respect, although it does appear that lineation is less prominent in the green pyroxene-gneisses.

The Trend Map shows a number of areas (IX to XIX inclusive) within which the structure looks convoluted or confused. Most of these are near plutons. In an attempt to understand the local structure better, β-diagrams were made from the foliations recorded in each area (by plotting on an equal-area projection the intersections of each foliation plane with all the others). Plate X-b is a typical diagram. These diagrams show considerable variation in the positions of their maxima, but a composite plot of the 5 per cent contours from each one (Plate X-c) shows much the same distribution as do the lineations (Plate X-d). Inasmuch as β-diagram maxima are statistical expressions of lineation, this is further evidence of structural homogeneity.

The lineations lie along a great circle. A possible explanation of this uncommon pattern is that a single early lineation throughout the gneisses, perhaps coinciding with the present maximum concentration, was rotated, by later stresses, about an axis plunging west at 60°. This axis (the pole of the girdle in Plate X-d) is inclined to the supposed long axis of the plutons (Plate X-a), so the later rotation may be unconnected with the intrusions. Such a rotation of the folded gneisses might also contribute to the wide variation in dip shown in Plate IX-I.

Shear Zones and Faults

Though small faults were seen on many exposures, the presence of mappable faults was nowhere proved. This may be due in part to the difficulty of tracing marker formations, and to their steep dips. However, in several places, there is evidence of shearing or gaulting which is set out below.

In the southeast, near Coeur lake, a north-striking shear zone is indicated by a rectilinear valley, contorted foliation and abundant, but apparently barren, quartz veins. This may well mark a fault. Another shear zone, east of the La Tuque road at the southern margin of the area, is suggested by a conspicuous linear north-south valley and some epidotization of a nearby exposure. A third is suspected at the northern limit of the area, northwest of Rognon lake, where a little quartz-cemented breccia was found in a linear valley.

Frog brook flows south in a deep straight valley for most of its length. Gneisses crop out on both sides, but those on the east usually contain numerous aplitic granite sills which are not seen on the west. The valley may be the locus of a fault.

In the northwest of the area a set of conspicuous aligned valleys trend south-southeastwards. The most persistent is occupied in part by the Petite Lièvre river (Plate I-A), and can be traced for about 18 miles. Except for accessory epidote in two gneisses near Faux lake and north of the Depot respectively, no evidence of faulting was found anywhere along controlled by joints (see below), although, in some cases, faulting may have followed joints.

North of Huard lake, in the southeast, the gneiss is locally veined with epidote.

Joints

Most joints in the area have steep or vertical dips; exfoliation and release joints, sub-parallel with the ground surface, were also seen. The pattern of jointing in the monzonites, the best-jointed rocks, differs from that of the gneisses. The differences can be seen by comparing the equal-area projections in Plate XI, in which (a) and (b) are of the plutons, (c), (d) and (e) of the surrounding green pyroxene-gneisses, and (f), (g) and (h) are of the remaining gneisses. The green gneisses show a pattern intermediate between those of the unaltered gneisses and the plutons. The unaltered gneisses have a conspicuous maximum at about N. 5^{o} E. (representing a strike of S. 85^{o} E.) that is absent in the altered ones.

The differences in pattern suggest that the stress field associated with the intrusions may have been different from that which deformed the gneisses. This might mean either a local change in conditions or a change with time during orogenesis, or both. Evidently the pluton pattern has been impressed on the surrounding altered gneisses, thus linking their metamorphism more closely with the intrusion of magma.

The south-southeasterly aligned valleys in the northwest were discussed in the preceding section: four projections (Plate XI-(d), (e), (g) and (h)) cover the gneisses from this region. All four show some concentration of joints with strikes of S. 10^{o} to 15^{o} E., which appear to correspond to these valleys. The only other shared maxima are for strikes of S. 40° to 45° E., and these are generally oblique to the foliation, whereas those at S. 10° to 15° E. are sub-parallel to it in most places, especially along the Petite Lelièvre river. Therefore the direction of the valleys may be explained by a combination of jointing and foliation which favoured erosion, particularly by southward-moving ice.

HISTORICAL GEOLOGY

The gneisses probably represent rocks deposited in a Precambrian geosynclinal trough. Apparently they were a thick sequence of either greywackes and/or tuffaceous greywackes, with some basic volcanic intercalations. Temporary or local shallow-water conditions led to the formation of thin limy shales, impure dolomitic limestones, and quartzites. Such a sequence suggests the marginal region of a trough, not far from land.

As orogenesis progressed, semi-concordant gabbroic bodies were intruded and the rocks were folded about axes trending broadly northwest. This deformation was accompanied by regional metamorphism of the amphibolite facies. The metamorphism was associated with, and perhaps caused by, the advance of a migmatite front. Migmatization progressively transformed the gneisses so that, in places, bodies of microcline granite formed, and intruded the older rocks.

The migmatites themselves were driven on by the advance of the other microperthite quartz-monzonites, which represented a more complete fusion of older rock. Ahead of these intrusions, the metamorphism reached the granulite facies.

No genetic relationship was detected between the gabbros and the monzonites.

In the northwest, the monzonites show anomalous features which may have been caused by large-scale incorporation of meta-gabbro into the magma.

The monzonite intrusions were marked by a different stress-field. A later deformation of the folded gneisses about steeply-plunging axes was also detected.

As the ultrametamorphic conditions receded, a few basic sills were injected, granitic dykes cut the cooling rocks at a later stage, and there was some faulting.

Long-continued uplift and erosion removed the overlying rocks and cut deeply into the gneiss complex. The old topography was abraded by Pleistocene continental ice and mantled by glacial deposits.

ECONOMIC GEOLOGY

At present only the titaniferous magnetite deposits appear to be economically promising in La Lièvre area, though several kinds of mineralization have been observed. Sand and gravel are abundant and are used within the area for road construction and maintenance.

Metallic Deposits

Titaniferous Magnetite

This is potentially the most valuable local prospect. Titaniferous magnetite, which is dissiminated throughout the meta-gabbros, is concentrated in layers and lenses in several places. Significant concentrations have been found only in the vicinity of Touladi lake. The Roberval Mining Corporation holds claims to most of the mineralized ground.

Roberval Mining Corporation

References, Claims, Location, History There is no published description of this property. Information used here comes from the following sources: brief reports, in the Department of Mines' files, by Bergmann (1957, 1958, 1959), Grenier (1958, 1959), Osborne (1958), Assad (1958), and Shaw (1959); an unpublished thesis by Lapointe (1960); and the writer's notes.

The Corporation owns the mineral rights in 218 claims, of which 85 were acquired by absorbing Lyndvue Mines Ltd. and Baraca Mines Ltd. in 1959. The numbers are:

claims 1 to 5 of certificates 129434 to 129448 inclusive, 129610 to 129633 inclusive, 146889 to 146891 inclusive, and 146901; and claims 3,4 and 5 of certificate 146900.

This block of claims, over 13 square miles in area, extends from the northwest part of Lyonne township into the unsurveyed ground to the southwest, near Touladi lake.

Concentrations of titaniferous magnetite were discovered in 1956 by Mr. René Thibault, of Albanel. In 1957 Roberval Mining Corporation was formed, and a preliminary ground magnetometer and geological survey was made. This was followed by several thousand feet of diamond drilling.

During 1958 several Department of Mines geologists examined the property and it was also investigated by a crew from Quebec Cartier Mining Company.

In 1959 an option and lease agreement was signed with the Oglebay Norton Company of Cleveland: 10,000 feet of diamond drilling are called for. In April and May, 1959, an airborne magnetometer survey of 45 square miles surrounding the deposit was made by Spartan Air Services Ltd., of Ottawa, and as a result 23 claims were added to the 195 staked before. During the summer Oglebay Norton began work on the property, but no results are available.

Size and Grade At present, it is difficult to make an accurate estimate of the tonnage. There are five "ore zones", but only two of these are known in any detail, and much more drilling is needed on all of them. Grenier (1959) accepts a figure of 55 million tons for proved low-grade beneficiating material in the "A" and "B" zone. If further drilling confirms the present indications, these zones may contain about 124 million tons within a depth of 500 feet, the limit for open-pit mining. Mineralization was present in one drill hole at a depth of 960 feet. New mineralized zones may also be found.

Bergmann (1958) states that the "proved" ore contains about 24 per cent iron and 6.1 per cent titanium oxide. Tests by the Ontario Research Foundation on material with 21.5 per cent iron and 6.1 per cent titanium oxide showed that the magnetic fraction extracted after grinding to -100 mesh contained:

Fe	67.2%
TiO_2	0.3%
SiO_2	2.17%
S	3.36%
P	0.06%

In a similar test carried out by the Department of Mines laboratories on a sample containing 30.04 per cent iron and 8.92 per cent titanium oxide (Certificate of analysis No. Zh-7847), the magnetic fraction represented 25.5 per cent of the weight of the sample, and contained 70.13 per cent iron and 1.18 per cent titanium oxide (Certificate No. Zh-8262).

Such magnetic concentrates are potentially marketable products.

<u>General Geology</u> The deposit is in a large elongated body of meta-gabbro, which is locally anorthositic, and which trends north. The gabbro outcrop is from ¾ to 1 mile in width west of Touladi lake, but magnetite concentrations are found near the eastern margin only. On the east, the gabbro is in contact with coarse, locally pegmatitic, microcline granite. The same granite is found on the west, with strongly migmatized gneisses. The granite has intruded the gabbro and produced a variety of metamorphic and metasomatic effects.

Dykes of granite pegnatite and aplite are also found throughout the gabbro. The country rocks have been described in preceding sections of this report. Foliation in all the local rocks strike generally northwards, and dip east at 70^{o} or more.

The mineralized rock consists of concentrations of medium-grained magnetite and ilmenite, with feldspar and ferromagnesian silicates, forming layers or lenses several inches in width, separated by narrow bands of silicate-rich material (Plate IV-B). This rock is dark grey and weathers to a rust colour. In several places, concentrations of apatite were associated with the magnetite.

Since the gabbro is poorly exposed, the length of the mineralized bands cannot be determined, but continuous widths of up to 15 feet of banded magnetite have been recorded. The scattered exposures of banded magnetite form a zone about 6500 feet long and as much as 1450 feet wide, which is widest in the south, near Silot lake, and tapers north-northeastwards.

On both ground and airborne magnetometer maps a strong positive anomaly follows this zone. At 500 feet an anomaly of about 5500' was recorded over the "A" ore zone, immediately north of Silot lake. This anomaly extends eastwards as far as Touladi lake. Such a continuation into the granite outcrop area suggests the presence of magnetite at shallow depth, either as a xenolith or as an extension of the main body. Weaker anomalies follow the gabbro margins farther south. Their close overall correspondence with the mapped contacts suggests that the anomaly at Touladi lake is not displaced.

Structure The attitude of the magnetite-rich bands corresponds with the foliation of the adjacent gabbro, as do the margins of the anorthositic portions. It is inferred that this compositional layering is a primary feature, probably a magmatic stratification. No evidence of injection was recorded. It follows that the banding can be used to determine the structure.

Generally, foliation follows the contacts, but at Silot lake a lobe of granite projects into the gabbro, cutting off the magnetite bands, which do not reappear on its south side. Just north of the lake the banding swings sharply to strike east, at right angles to the granite contact and about 200 feet from it. The extension of the magnetic anomaly towards Touladi lake, lies along the projection of these east-striking magnetite bands. To the north of them, there are no gabbro exposures for about 1000 feet, and no magnetite bands for a much greater distance, though the anomaly is continuous.

Probably this disruption of the gabbro structure is a result of the granite intrusion. The discordant portion of the "ore" rock may be more or less detached from the main body, forming a large xenolith or pendant in the granite. Some brecciation of gabbro was seen on an exposure in the hinge area (Plate IV-C). A better understanding of this structure is essential to an accurate determination of the ore tonnage. The proposed drilling should solve some of the problems.

<u>Mineralogy and Metamorphism</u> The mineralogy of the unaltered "ore" rock differs from that of the common gabbro in its proportions only (Plate VII-A). However, intrusion of acidic rock has produced a number of changes. As described above (p. 24), this metasomatism tends to produce rocks of intermediate composition, with hybrid type at contacts.

Lapointe reports that polished sections of magnetite show all stages of ilmenite exsolution, from seriate bands and lenses to ilmenite rims about a magnetite core (the textures resemble those seen in the monzonite perthites). The completeness of this exsolution, and the resulting low content of titanium oxide in the magnetite, are the principal factors determining the rock's amenability to concentration: consequently the origin of these features is of great interest.

As Grenier (1958, p. 5) notes, the gross ratio of iron to titanium is about the same as those in the St. Charles, Kenogami, and Alma anorthositic deposits on the other side of Lake St. John. Those deposits have many features in common with this one, but the amount of titanium oxide in the magnetite is much lower here. A figure of 1.18 per cent was given above; Lapointe gives an average of 1.15 per cent, and states that there is little variation within the deposit.

According to Buddington <u>et al</u> (1955), the percentage of titanium oxide in magnetite can be used as a geological thermometer, and from his data a temperature of 400°C is indicated. This is low for a basic igneous rock and even for a granite.

Osborne (1958, p. 2) infers that the exsolution took place as the magnetite was annealed the cooling granite mass. This conclusion is supported by the fact that the granite is part of a considerable pluton, and intimately penetrates the gabbro.

Lapointe also concludes that the anomalous condition of the "ore" rock is due to the granite intrusion, and states that the magnetite from unaltered meta-gabbro indicates a much higher temperature than that from the "granitized" rock. Further confirmation comes from an analysis (Certificate No. (58-F-4958)G) of the magnetic fraction of a sample of meta-gabbro from the xenolith in monzonite described on page 24. It contained 70.02 per cent iron and 1.11 per cent titanium oxide.

Conclusions The banded magnetite resembles other anorthositic and gabbroic deposits in the Lake St. John district (see, for example, Jooste, 1958, p. 22). Osborne (1958, p. 1) noted the similarity to a deposit in Angus township, Ontario, described by Hurst (1931). It is thought that the present deposits are magmatic segregations in a large sill-like body of gabbro intruded into gneiss, and now tilted to a steep angle and intruded, deformed and altered by a sub-concordant mass of granite. If the magnetite originally collected in the lower parts of the gabbro sill, the whole mass may have been inverted, for the magnetite is now nearer the hanging-wall.

The unusual concentrating characteristics of the "ore" rock are believed to be a result of granite intrusion. Magnetite-bearing material found away from a granite outcrop should therefore be tested with this in mind.

The grade, depth, milling features, location (the railway at St. Felicien is only 18 miles away), and potential tonnage make this deposit one of considerable economic interest.

Other parts of the large but poorly-exposed meta-gabbro body should also be investigated more closely for magnetite, as there is little reason at present to believe that valuable concentrations are confined to the vicinity of Touladi lake.

Sulphides

Very few occurrences of sulphides were recorded. Probably these minerals, much more mobile than silicates, tended to migrate away from the hottest zones of metamorphism. Some might have been deposited in the superstructure, but this has been removed by erosion. The most favourable rocks for sulphide deposition in high-grade metamorphic terranes are generally limestones. However these are scarce here, but, in the few there are, flecks of pyrite and chalcopyrite were seen.

A little molybdenite (one of the least mobile sulphides) was found in pegmatite southeast of aux Rats lake.

Traces of pyrite were seen in places in the gneisses and meta-gabbros and in a narrow sheared basic sill at the south end of Otter lake.

Thorite

On the west bank of the East Branch of the Petite Trenche river, about 1½ miles south of Otter lake, a vein cuts meta-gabbro. The vein is 2 to 3 inches wide and contains about 60 per cent of a glassy black prismatic mineral, forming crystals up to ¾ of an inch long. In thin section (Plate VIII-C) this mineral appears to be completely metamict and is accompanied by 25 per cent andesine, 10 per cent quartz, and a few per cent strongly zoned radioactive zircon. X-rays studies of the glassy mineral suggest that it is probably thorite. The vein is weakly radioactive. No others were found.

Non-Metallic Deposits

Beryl

A little pale blue-green beryl was found in two narrow pegmatite dykes, one east of de la Cache lake, and the other south of Eaux Mortes lake. However, examination of this area by two prospectors during 1959 failed to reveal any encouraging concentrations.

Biotite

A weathered pegmatite body in a stream bed north of Philippe lake contains biotite crystals up to 3 inches in diameter.

Ornamental Stone

The coarse, massive portions of the green quartz-monzonites might be worked for ornamental use. In the writer's opinion, the rock is visually more pleasing than the dull black anorthosite so widely used around Lake St. John. Outcrops of this rock are also found nearer Roberval. The well-developed jointing of the quartz-monzonites might be a handicap to their use.

Sand and Gravel

Deposits suitable for construction purposes are abundant throughout the area. Many small pits are in use for road work, and local material has been used for a number of buildings, notably at La Lièvre Depot.

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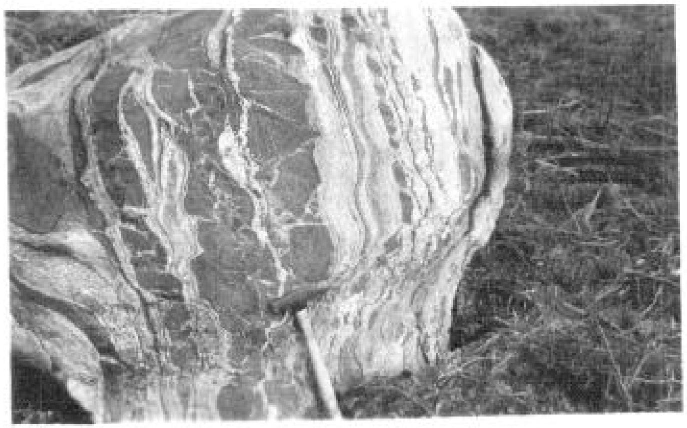
Plate I

A - La Lièvre Depot and the valley of the Petite Lièvre river, backed by subdued gneiss hills.

B - Du Portage lake with sandy terraces, and quartz-monzonite hills beyond; gneiss at far right.

C - Typical bare quartz-monzonite hills south-east of Cygne lake.

Plate II



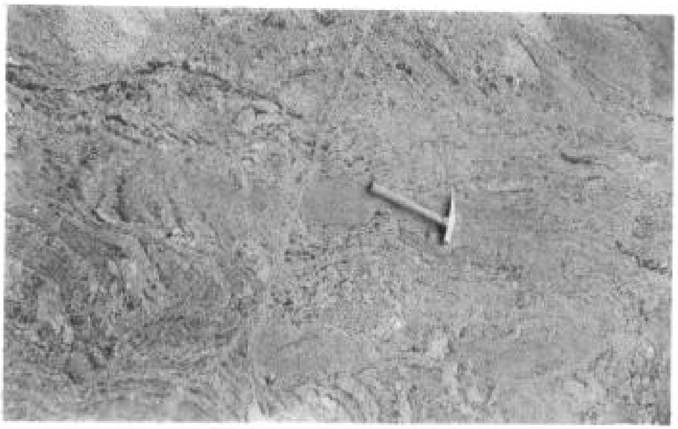
A — Stages in the boudinage of amphibolite bands, seen on a boulder.

B - Typical gneiss with granitic bands (weakly migmatized gneiss), northeast of Merlin lake.

C - Gneiss with thick granitic bands: amphibolite layers show recumbent small folds; southeast of aux Rats lake.

Plate III

A - Typical migmatite gneiss, northeast of Merlin lake.



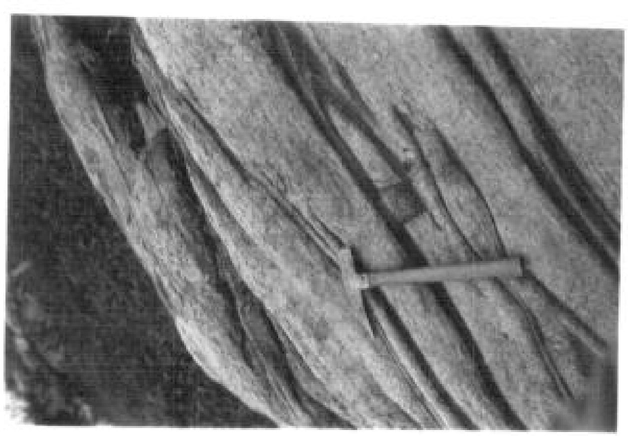
B - "Nebulite": highly migmatized gneiss with confused relict banding, northeast of Merlin lake.

C - Coarse spotted and banded meta-gabbro intruded by aplitic meta-gabbro, southeast of aux Rats lake.

Plate IV

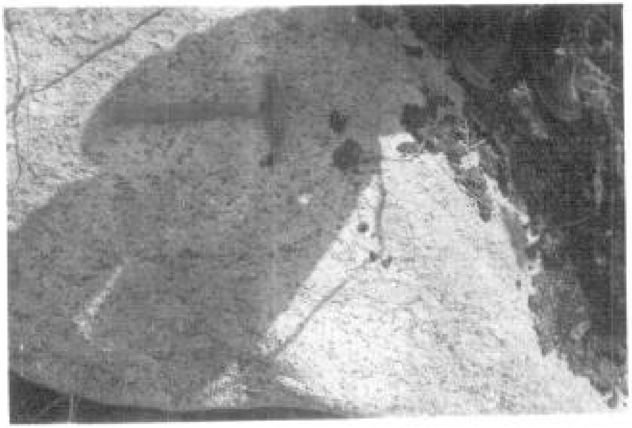
A - Irregular bodies of gabbro pegmatite in meta-gabbro, southeast of Pinson lake.

B - Thick bands of titaniferous magnetite in meta-gabbro, Roberval Mining property. (Photo by G. Lapointe.)

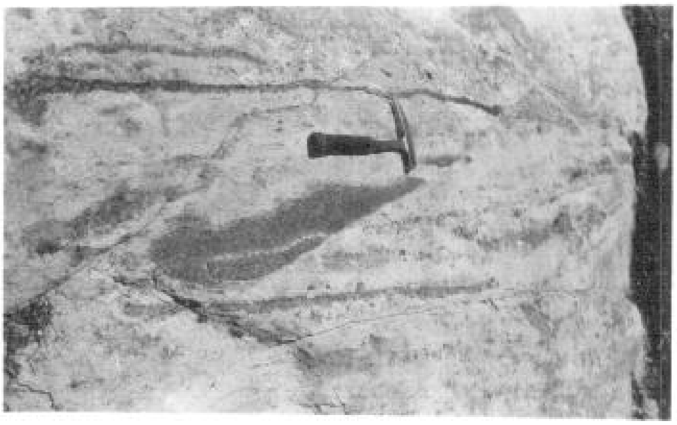


C - Brecciation of fine-grained bands in meta-gabbro, Roberval Mining property. (Photo by G. Lapointe.)

Plate V



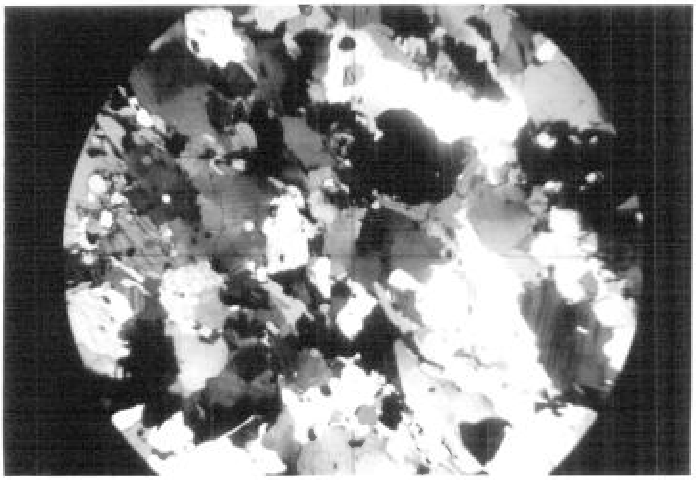
A - Typical weathered surface of quartz- monzonite, showing crude foliation; roadside northeast of Grande Trenche river.



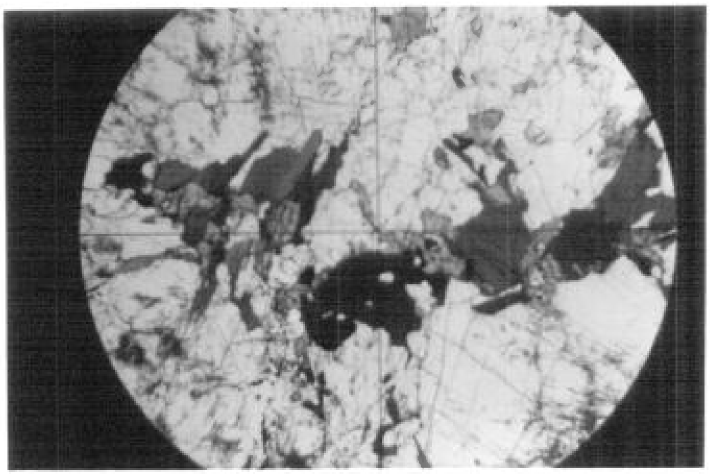
B - Relics of amphibolite (now mica-schist) in gneiss replaced at a quartz-monzonite margin, west of Corne lake.

C - Angular fragments of a disrupted amphibolite band, and a gneiss fragment, in quartz-monzonite, west of Corne lake.

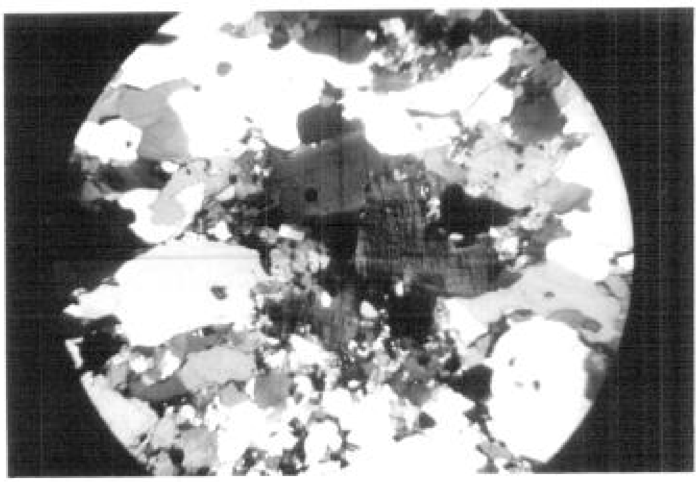
Plate VI



A - Typical hornblende-biotite gneiss, showing crystalloblastic texture; (x-nicols, x13).

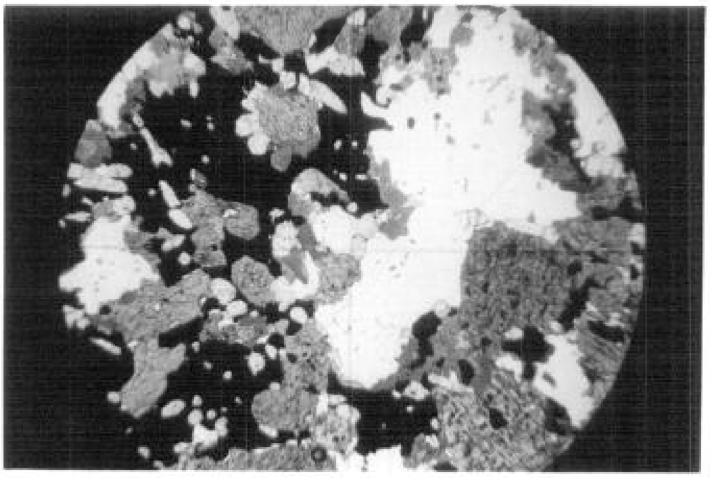


B - Pyroxene-gneiss: diopside altering to biotite (left) and hornblende (right); (plane light, x 13).

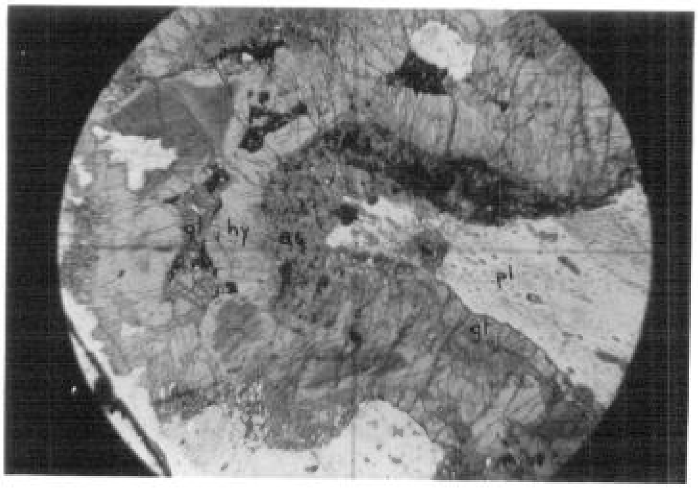


C - Band of migmatitic material (quartz- and microcline-rich) in gneiss: note microcline replacing plagioclase; (x-nicols, x 13)

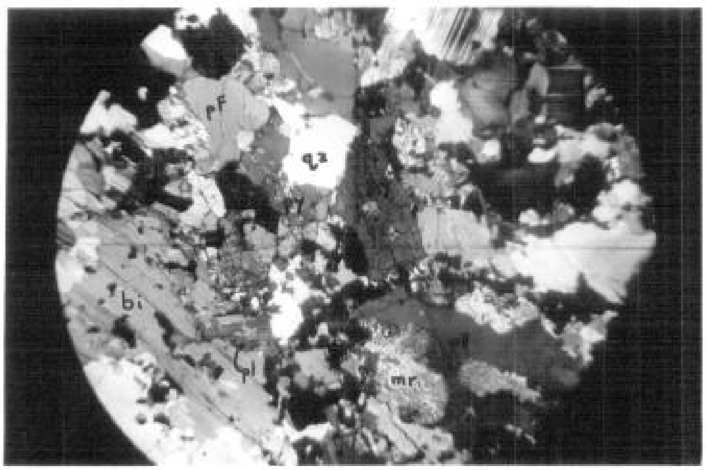
Plate VII



A - Magnetite-rich meta-gabbro: pyroxene with schiller is rimmed by hornblende; apatite is abundant; (plane light, x 13).

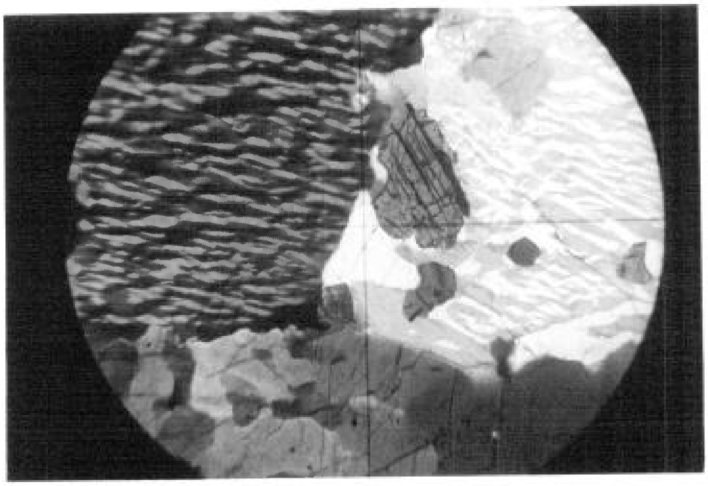


B - Coronite: altered olivine (ol); hypersthene (hy); amphibole with spinel (as); garnet (gt); plagioclase (pl); (plane light, x 13).

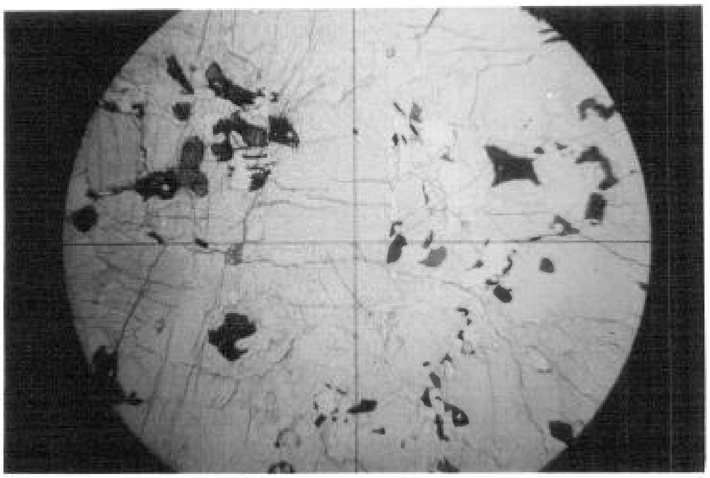


C - Metasomatized meta-gabbro: quartz (qz), biotite (bi) and potash feldspar (pf) replace plagioclase (pl) and pyroxene (py); much myrmekite (mr) is found; (x-nicols, x 13).

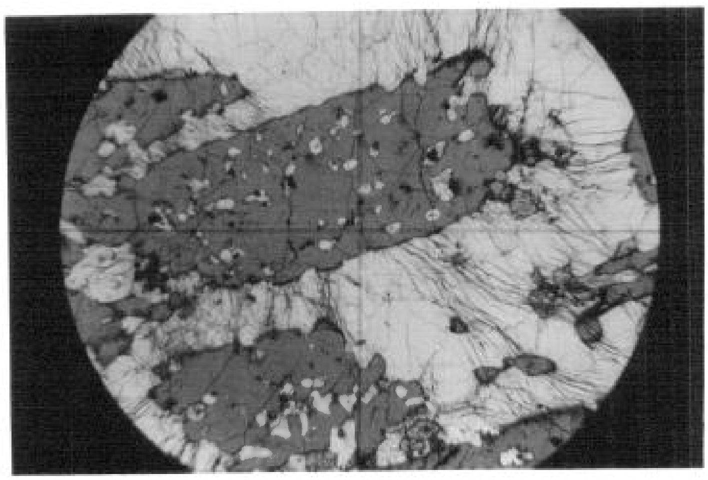
Plate VIII



A - Quartz-monzonite, showing microperthite, pyroxene and plagioclase; (x-nicols, x 51).



B - Gneiss relic in quartz-monzonite: pyroxene at left, amphibole at right, in matrix of microperthite; (plane light, x 13).



C - Metamict thorite, showing radiate expansion cracks; with zircon; (plane light, x 13).

<u>Plate IX</u> (p. 70):

<u>Equal-Area Projections of Foliation Patterns</u>

(For location of domains analysed see <u>Trend Map</u>.)

Domain I 560 poles; II 184 poles; III 109 poles; IV 378 poles; V 92 poles; VI 136 poles; VII 45 poles; VIII 75 poles.

Red lines indicate large and small circles discerned in the foliation patterns; crosses indicate their poles.

<u>Plate X</u> (p. 71):

<u>Equal-Area Projections of Foliation and Lineation Patterns</u>

a) Composite plot of 5 per cent contours from foliation diagrams II to VIII inclusive (see Plate IX). Suggested small circle and pole in red.

b) Representative β-diagram (area XVII, see Trend Map, 26 foliation planes plotted).

c) Composite plot of 5 per cent contours from β-diagrams of areas IX to XIX inclusive (see Trend Map), average 27 foliation planes per diagram.

d) Composite plot of all 216 lineations. Apparent girdle and pole in red.

<u>Plate XI</u> (p. 72):

<u>Equal-Area Projections of Joint Patterns</u>

Younger acidic plutons:

a) All large plutons except that in S.W. corner of area, 73 poles.

b) Large pluton in S.W. corner of area, 99 poles.

Green (pyroxene-) gneisses:

c) East of 72° 45' W., 98 poles.

d) West of 72° 45' W., south of 48° 30' N., 126 poles.

e) North of 48° 30' N., 92 poles.

Other gneisses (pyroxene-free):

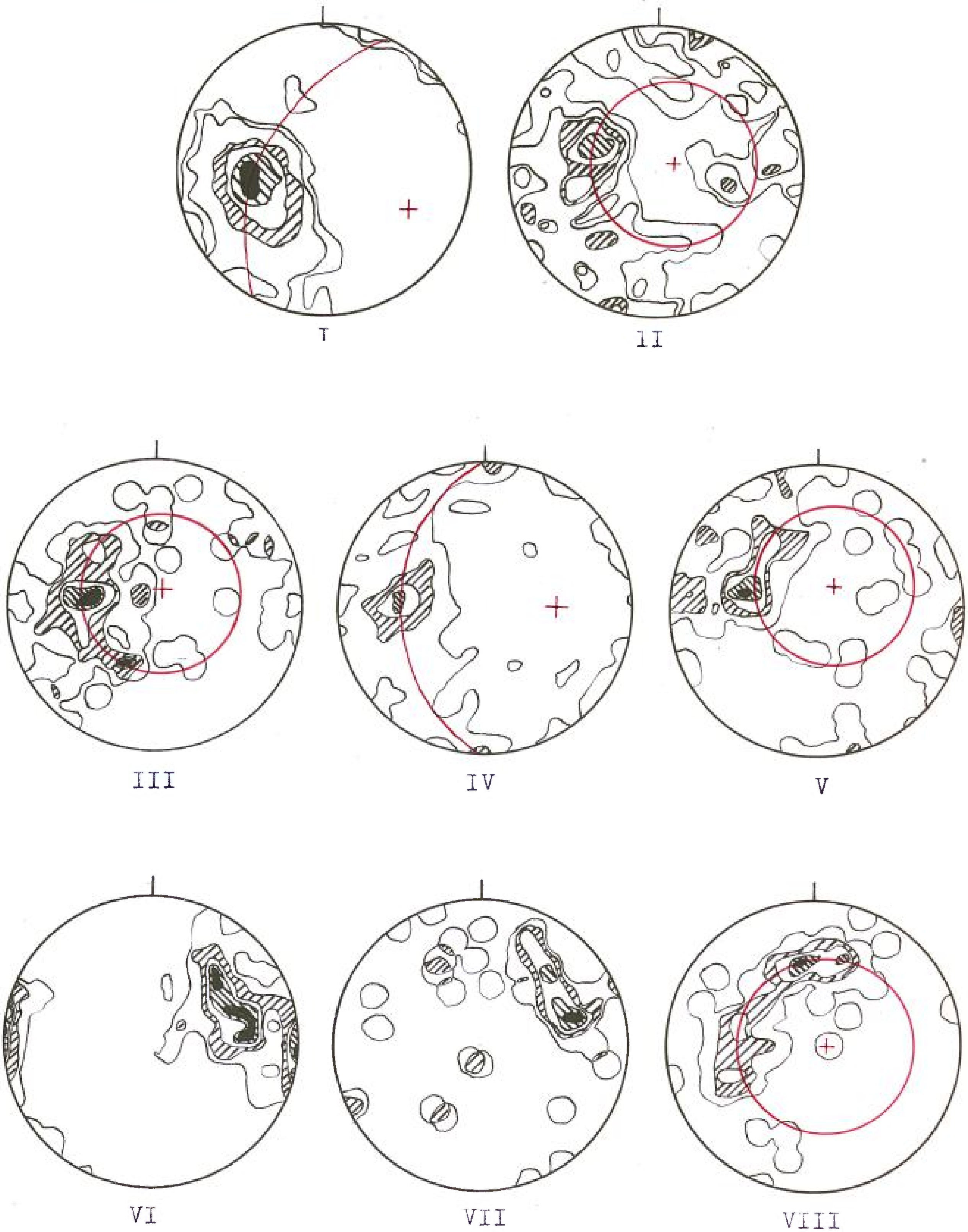
f) East of 72° 45' W., 42 poles.

g) West of 72° 45' W., south of 48° 30' N., 140 poles.

h) North of 48° 30' N., 44 poles.

Plate IX

Equal - Area Projections of Foliation Patterns

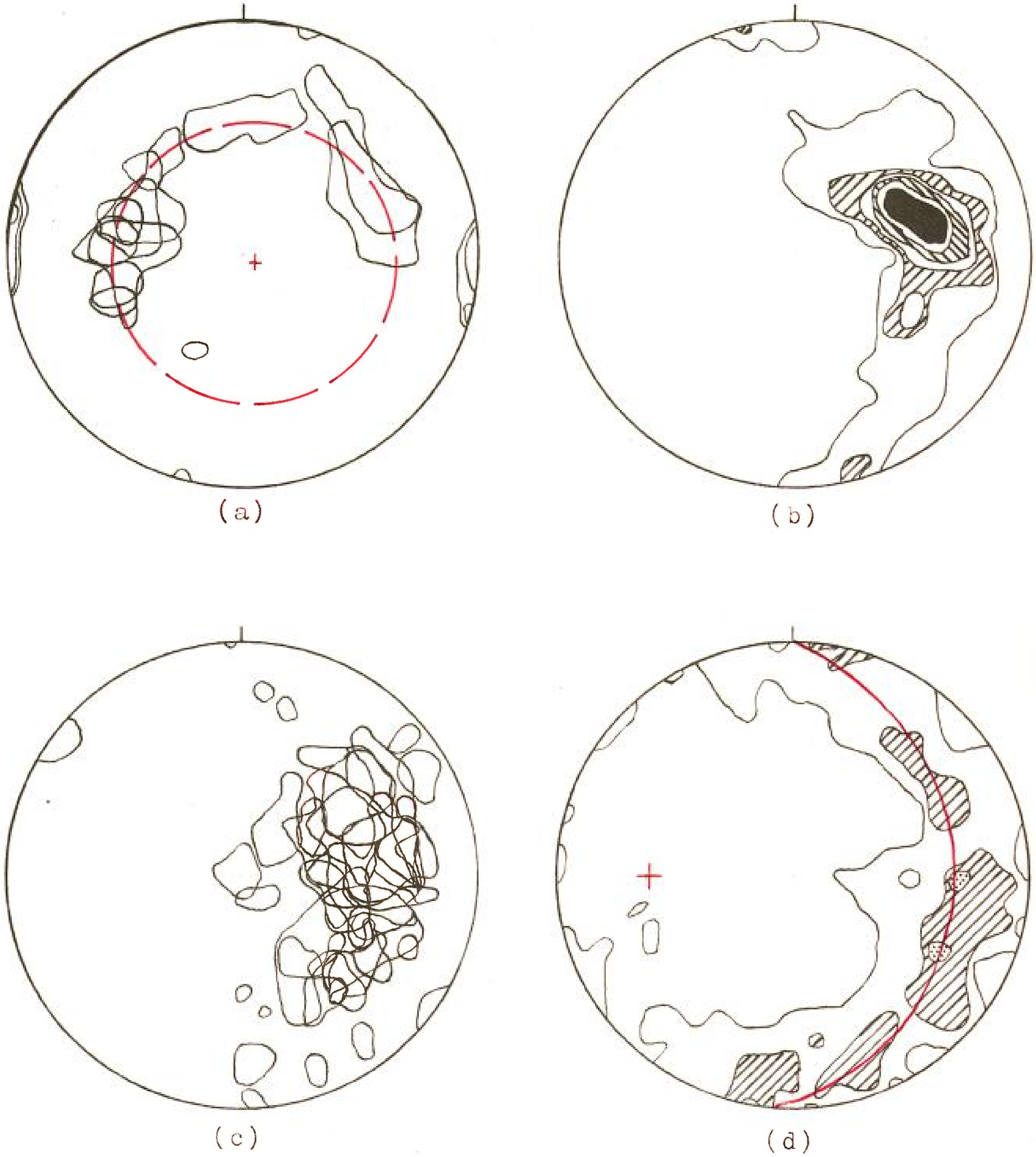


Contours: 1%, 3%, 5%, 7%, 9%; ½% contour added in I & II, no 9% contour in IV.

Explanation on p. 68

Plate X

Equal - Area Projections (Foliation & Lineation)

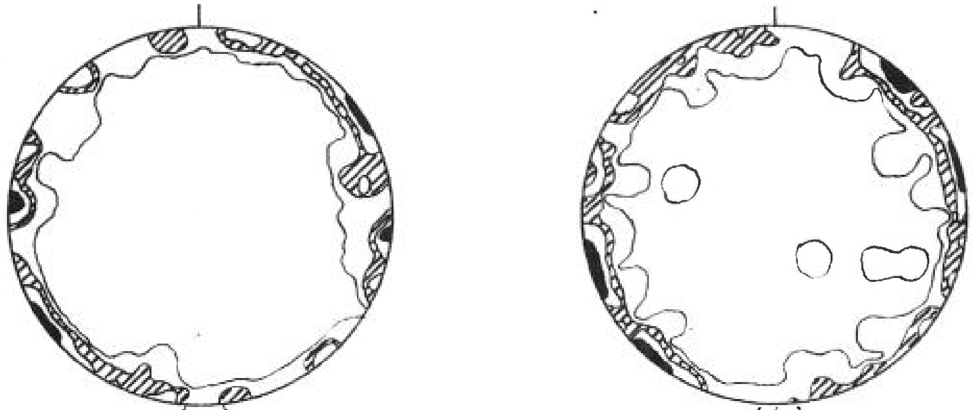


Contours in (b) & (d): 1%, 3%, 5%, etc.

Explanation on p. 68

Plate XI

Equal - Area Projections of Joint Patterns



(a) (b)

Younger acidic plutons

(c) (d) (e)

Green (pyroxene-) gneisses

(f) (g) (h)

Other gneisses (pyroxene-free)

CONTOURS: 1%, 3%, 5%, 7%

Explanation on pp. 68 and 69