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TECTONIC AND VOLCANOLOGICAL STUDIES

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TECTONIC AND VOLCANOLOGICAL STUDIES IN THE ROUYN-NORANDA AREA

Preliminary Report

by

Erich Dimroth
and
Pierre Boivin, Normand Goulet, Marc Larouche

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on

TECTONIC AND VOLCANOLOGICAL STUDIES IN THE ROUYN-NORANDA AREA

Counties of Rouyn-Noranda, Abitibi West and Temiscamingue

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INTRODUCTION

The present open-file report presents preliminary results of structural, stratigraphic and volcanological work in the Rouyn-Noranda area, based on the material obtained during the 1972 field season. The work published here has been done by two independant field parties, led by N. Goulet, and E. Dimroth; N. Goulet studied the geology of the Cadillac break, with special consideration of the tectonics; E. Dimroth and his co-workers (P. Boivin and M. Larouche) covered the area adjoining the Duparquet-Destor-Manneville breaks. The work will be continued until the whole area around Rouyn-Noranda has been covered, probably by 1975 or 1976. The present report has been written by E. Dimroth.

The material obtained during field work will serve as basis of three theses: N. Goulet (Ph.D., Queen's University, Kingston, Ont.); P. Boivin (Dr. III cycle, Université de Clermont-Ferrand, France); M. Larouche (M.Sc., Université Laval, Québec).

Purpose and objectives

This project has been initiated because the evolution of the volcanic zones in Abitibi is still poorly understood. There are good reasons to believe that the evolution of the orogenic structures in the Abitibi belt is not unrelated to pre-existing structures, formed during the period of volcanism. Therefore it is not sufficient to study the orogenic structures alone; rather it is necessary to investigate possible relations between orogenic and volcanic structures.

The present study therefore has two objectives:

(1) It will be attempted to clarify the volcanic stratigraphy to localize the volcanic centers, and to gain a view of their internal construction.

(2) It will be attempted to decipher the course of the orogenic deformation of the area, and to relate the orogenic structures to the pre-existing volcanological situation.

Field Work

Field work comprises the following phases:

(1) Mapping of volcanogenic facies with the aim to distinguish rocks issued from different volcanic centers and to distinguish proximal (close to center) and distal (far from center) volcanogenic facies.

(2) Mapping of key beds within the volcanic units.

(3) Establishment of intrusive relationships, and of the age of the intrusive bodies relative to the volcanic sequence; clarification of the geometry of intrusive bodies.

(4) Determination of tops; measuring of bedding, schistosities, fold axes, lineations, and other tectonic fabric elements.

Principles of Stratigraphy

The Abitibi belt is a volcanic terrain, comparable in many respects to present-day island arcs. Present-day island arcs are built of volcanic complexes, that is of highly complex groups of co-alescing shield volcanoes, whose configuration and spacing change with time. Stratigraphic units are discontinuous. For this reason the principles of layer-cake stratigraphy, used in the Proterozoic (for example in the Labrador trough), cannot be applied to the Archean. Instead we propose to attempt an analysis of the internal construction of the individual volcanic complexes, and of their relations in space and time. This approach owes much to the ideas of Goodwin and Ridler (1970). It is basically a structural approach to the problem of Archean stratigraphy.

Complex tectonic structures and complications of volcanogenic facies impose specific difficulties upon stratigraphic work in the Archean. The most evident features by which volcanic rocks can be distinguished, namely their structures (pillows, flow breccias), depend on local flow mechanisms and therefore have no stratigraphic significance. Individual flows can be differentiated only on the basis of properties intrinsic to the magma, that is by their chemistry, gas content (amygdules) and by telluric phenocrysts. Varioles perhaps are also useful for stratigraphic purposes, although their significance is not certain. It is not possible to determine chemical composition in the field except within wide limits; therefore criteria used by us include phenocrysts, varioles, and amygdules. Variable viscosity of the magma further restricts usefulness of these criteria: viscous magmas (acidic) suffer neither substantial degassing, nor separation of phenocrysts during eruption. Acidic flows therefore are homogeneous in respect to phenocryst and amygdule distribution. Magmas of low viscosity (mafic), on the other hand, suffer rapid degassing, separation of phenocrysts by flow differentiation, and agglomeration of phenocrysts. Therefore phenocrysts and amygdules commonly do not show homogeneous distribution in mafic flows.

Tectonic disruption, which in part developed already during the volcanic activity, introduces further obstacles to stratigraphic analysis. Correlation across tectonic breaks in a complicated task, that demands thorough analysis of the tectonic situation.

GEOLOGICAL OVERVIEW

The southern part of the Superior Province (Goodwin, 1972) consists of east-trending volcanic belts, alternating with metasedimentary belts. The Rouyn-Noranda area has all the characteristics of this association; its northern part belongs to the Abitibi volcanic belt (Goodwin and Riddler, 1970), its southern part to a metasedimentary belt underlain by the Pontiac Group. The volcanic and sedimentary belts have contrasting structural properties.

The volcanic belt is characterized by the following structural properties:

(1) Large-scale folds are isoclinal, with nearly vertical axial plane.

(2) Generally 2, rarely 1 or 3 sub-vertical schistosities are superposed upon the isoclinal folds.

(3) Minor folds and lineations are parallel to the intersection between these schistosities, or to the intersection of one of the schistosities with the sub-vertical bedding planes. Therefore minor folds and lineations are also sub-vertical.

(4) The intensity of the deformation varies greatly; the volcanic belt is brutally segmented by extremely deformed zones, named "breaks". The

intensity of folding and schistosity increases toward the "breaks".

(5) The rocks of the volcanic belts are weakly metamorphosed, except in the vicinity of late-kinematic granite intrusions.

The metasedimentary belt has a completely different structural style.

(1) Schistosity is nearly horizontal; small-scale recumbent folds are present; the horizontal schistosity and the related recumbent folds are refolded, in part under the action of rising granite batholiths.

(2) Rocks of the sedimentary belt have been overprinted by high grade metamorphism, in the amphibolite facies, before intrusion of the granites.

A review of the literature on Archean terrains makes us suspect that the contrast of structural style between the metavolcanic and the meta-sedimentary zones of the Abitibi belt, is characteristic also of other Archean terrains. The predominance in volcanic zones of isoclinal folds with subvertical axial planes, allied with subvertical lineations is characteristic of the whole of the Abitibi belt, and the volcanic zone of Belleterre-Angliers; it has also been described from volcanic belts in South Africa, Rhodesia and Australia. Sub-horizontal schistosities or refolded subhorizontal schistosities and/or the associated recumbent folds (in part refolded) are known from all Archean gneiss terrains where structural studies have so far been presented (Greenland, Kenia) and also are known from parts of Northern Quebec.

Rouyn-Noranda area

The basic tectonic features of the Rouyn-Noranda area are shown in map 1, and cross-sections are presented in figure 1. Basic features are as follows:

(1) The volcanic belt is brutally segmented by two "breaks" (Duparquet-Destor-Manneville break; Cadillac break) limiting two volcanic complexes in the south.

(2) Local eruption of rhyolites and of komatiites took place in a linear zone along the Duparquet-Destor-Manneville break.

(3) The center of the Blake River Group is occupied by a domical structure, intruded by granites. The domical structure is surrounded by a sub-circular stratigraphic depression; isoclinal folds in the Blake River Group warp around the domical "Noranda center". Very likely this center represents a volcanic complex.

(4) Sediments marginal to the south of the Blake River Group are in proximal facies: conglomerates, and thick-bedded, coarse-grained grey wackes. Facies becomes more distal toward the south: thin-bedded, fine-grained grey wackes. This proximal-distal transition of sedimentary facies is accompanied by a transition from isoclinal folds with subvertical axial planes (in the north) to sub-horizontal schistosity and recumbent folds (in the south).

(5) Deeper in the meta-sedimentary belts refolding of the Pontiac by up-rising granite domes results in a pattern of granite domes, separated by relatively tightly pinched synclines underlain by rocks of the Pontiac Group.

It is evident that the tectonic pattern of the volcanic belt is related to the volcanic evolution; the refolding of recumbent folds in the Pontiac Group is related to rising granite batholiths.

GENERAL GEOLOGY

ROCK TYPES

The concepts of submarine volcanism changed very considerably during the last 10 years, mainly due to progress in the investigation of Cenozoic and Recent volcanic rocks. Consequently some of the ideas previously advanced have to be revised. For this reason the writers feel that relatively detailed descriptions of volcanic rock types and of some other rocks are required in this report.

Volcanic rocks

Three types of flows behave basically different as far as their structures are concerned.

1. Ultramafic flows are characterized by spinifex structures described by Pyke, Naldrett and Eckstrand (1972), and by a brecciation that is perhaps due to expansion during hydration. Ultramafic-mafic flows have structures similar to spinifex ("pseudo-spinifex), and have characteristic decussate textures ("chicken track" texture). They suffered brecciation due to expansion during hydration, and have some features (pillows set in hyaloclastic material) in common with mafic flows.
2. Mafic flows are characterized by transitions from massive flows to hyaloclastic rocks (pillows, isolated pillow breccias, broken pillow breccias, hyaloclastites). These rocks have been described by Carlisle (1964), amongst others.

3. Acidic flows are characterized by brecciation due to variable viscosity within the flow.

In addition there exist various types of pyroclastic rocks: ash flow tuffs, ash fall tuffs, antoclastic turbidites, etc.

Ultramafic and ultramafic-mafic lavas

Flows of serpentinized peridotite are up to 10 meters (30 feet) thick, but normally do not exceed 2 meters. Flows typically consist of two main zones (Pyke, Naldrett and Eckstrand, 1973): (1) A lower massive zone, not uncommonly with cumulate layering. (2) An upper spinifex-zone, 0-200 cm. thick. The spinifex zone consists of tabular olivine crystals (now serpentine) that form conical bundles of plates open downward. The crystals are unoriented in the plane parallel to the flow surface; their size increases from the flow top downward. A chilled facies is locally present at the flow top. The massive zone of many flows is brecciated. Fragments are either polygonal or rounded; they fit closely, matrix is virtually absent. Pillows or flow breccias are absent.

A flow of spinifex-textured serpentinite is exposed close to the south shore of Kinojevis River in lots 14-17, range I, Manneville township (locality 1). The flow has been traced westward in drill holes.

Ultramafic basalt (komatiite) with "chicken-track" texture. Extrusive rocks of this composition have first been described by Viljoen and Viljoen (1969a, b). They form flows 3-30 meters thick; most flows are massive, however poorly developed pillows, separated by hyalocalstic material, are exposed north of Lanaudière Lake, lot 41, range west, Chemin de Macamic, Destor township (locality 2). The basalts are now composed of tremolite-actinolite; plagioclase is absent.

Chicken-track textures are produced by decussate skelettal tremolite-actinolite plates. Typically they weather and break as plane surfaces intersecting at high angles; their corners resemble bird tracks. Conical aggregates of platy actinolite, identical to the spinifex structures mentioned above, are present at the top of two flows, at locality 2. We call them "pseudo-spinifex" because their derivation from skelettal olivine is not yet certain[1]. The pseudo-spinifex zones are up to 30 cm. thick, and are at the top of the flows, as are the spinifex.

Breccias identical to the breccias of the serpentinites with spinifex structures are characteristic of the "chicken-track" basalts. This form of brecciation appears to overprint pillow rims, and the hyaloclastic material between pillows, and consequently is younger than the extrusion of the flow. It is overprinted by tectonic structures, and is clearly a non-tectonic type of brecciation. It is likely that the brecciation is related to expansion of the rock during its hydration.

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1) Skelettal olivine has been observed to produce some of the "pseudo-spinifex", and also some of the chicken-track textures. It is fairly certain that these textures are related to spinifex.

Mafic to intermediate lavas: rock types

Mafic to intermediate flows are massive, pillowed, or in part composed of flow breccias (isolated pillow breccia, broken pillow breccia, hyaloclastite) and of aquagene tuffs. Our nomenclature of mafic flow breccias follows Carlisle (1964).

Massive and pillowed flows have been described by many authors, therefore most of their aspects need no special consideration except for their differentiation which has received little attention in previous literature.

Pillow basalts generally show chemical differentiation into monomineralic or oligomineralic patches of widely contrasting composition. Furthermore phenocrysts are not evenly distributed throughout pillows and their matrix.

Phenocrysts are in many cases concentrated in the interior of pillows or in annular zones within the pillows, with fewer phenocrysts in the matrix between pillows and in the pillow skins. Phenocrysts appear to have the same size throughout the pillows, independently of their density. This suggests that phenocrysts did not form during the crystallization of the pillows; rather we think that their inhomogeneous distribution is due to hydrodynamic separation during flowage as described by Bhattajarchi and Smith (1964). Furthermore we have observed cases where one and the same flow contains glomeroporphyritic aggregates at one place, and individual separated phenocrysts at another; this feature suggests that agglomeration of phenocrysts also may occur during flowage.

Many pillowed flows suffered extreme chemical differentiation into monomineralic or oligomineralic patches and zones, composed of chlorite on the one hand, and of albite ± epidote (or pumpellyite) on the other. Generally the chilled border of pillows is composed of chlorite, and pillow margins also are rich in chlorite. Albite and epidote occupy the pillow core, or occupy annular zones about 10-20 cm. from the pillow margin. Albite-epidote patches also are present in the hyaloclastic matrix between pillows. The fact that monomineralic zones occur as fragments within broken-pillow breccias proves that this kind of differentiation occurred rapidly, within minutes, at the time when the fluid lava was chilled.

We suggest that this kind of differentiation is due to energetic reactions between water vapour at supercritical temperatures and the congealing volcanic glass. The intensity of the differentiation depends on the volume of water that came in direct contact with the volcanic magma at the time of the eruption. Therefore the basalts containing considerable hyaloclastic material in the interstices between the pillows show stronger differentiation than basalts with snugly fitting pillows.

Many flows have well formed and closely fitting pillows of loaf, matress, bun or baloon shapes. Tops are easily read from these pillow shapes. Flows with closely fitting pillows grade laterally and vertically into flows that contain considerable volumes of hyaloclastic material in the interstices between pillows. In the latter case pillows commonly are sub-spherical or have irregular outlines; they are poor top indicators.

Isolated-pillow breccias develop from flows with loosely set pillows by further increase of the volume of hyaloclastic material; individual pillows are completely separated by hyaloclastic material. The pillows of isolated-pillow breccias commonly have an irregular ameboid shape. One of the best examples is exposed below the fourth pylon of the hydro-electric power line at lot 7, range east, chemin de Macamic, Dufresnoy township (locality 3).

Broken-pillow breccias are the most variable rock type of the mafic suite. Transitions between broken-pillow breccia and isolated-pillow breccia are beautifully exposed on a small, barren island in the southeastern corner of Hébécourt Lake (locality 4). In this outcrop isolated pillows are slightly brecciated, fragments being separated by 1-4 cm. of hyaloclastic material.

The more common variety of broken-pillow breccia contains fragments up to 10 cm. across, occasionally angular, but more commonly rounded, and often quite irregular in shape, set in hyaloclastic material. The fragments may be sharply set against the matrix, but transitions are more common. Many of the fragments are monomineralic or oligomineralic, composed of feldspar with or without epidote or of chlorite. Irregular patches of feldspar and epidote are also present in the rock. Thus not all fragments have the same composition, and the matrix differs again from the fragments. For this reason the broken-pillow breccias appear to be polymictic; therefore they have been mapped as agglomerates by many geologists. This interpretation is fallaceous, as the fragments of different compositions are derived from differently composed zones of pillows.

Many broken-pillow breccias contain, in addition to pillow fragments, spherical bodies of lava a few cm. across, devoid of a chilled surface. These have been called mini-pillows by some; "globule" may be a better name.

Broken-pillow breccias are beautifully exposed at the shoreline of many of the islands in the center and south of Duparquet Lake, particularly on the south shore of island number 79 (locality 5), but also at many other places.

Hyaloclastites in the strict sense are composed of shards up to 1 cm. large. Globules described above may be present. Weathering produces a characteristic "cellular" surface texture. Hyalocalstites form the interstitial material between isolated-pillow breccias and broken-pillow breccias. Locality 3 shows typical hyaloclastite, whereas the matrix at localities 5 has somewhat different properties.

Aquagene tuffs are composed of finely comminuted glass shards. They form beds several meters thick between basalt flows, or intercalated flow breccias. Grain size varies from a few mm. to submicroscopic; some large fragments of flow breccia are present here and there. Aquagene tuffs generally are laminated on a centimetric scale; graded bedding is present at a few places. Long lenticular zones in aquagene tuffs here and there have been silicified and are now composed of chert. These zones are up to 50 cm. thick and up to 50 meters long. Chert concretions also have been observed.

Aquagene tuffs are not always easily distinguished from ash fall tuffs. No doubt exists about their origin, where lenticular beds of aquagene tuff are interspersed in broken-pillow breccia. Good outcrops of this type are exposed on island No. 134 Duparquet Lake (locality 6).

More difficult to decide is the case of continuous tuff layers separating massive and pillowed flows north of the Duparquet-Reneault road. Good examples are exposed at lots 33-35, range line of ranges 1-2, Duparquet twp. (locality 7). These tuffs are sharply separated from massive flows above and below; thin (less than 5 meters) massive flows also are intercalated between the tuff; these flows grade laterally into flow breccias, which are closely associated with the tuff. It is for this reason that we suspect the tuffs to be aquagene, but thorough study of thin sections will be required before our tentative interpretation can be proved.

Mafic to intermediate lavas: volcanogenic facies

Thickness of mafic flows rarely exceeds 30 meters in the normal facies. Contacts between flows are sharply defined, and are easily located. In many cases massive or pillowed flows are superposed without any intercalated flow breccia aquagene tuff, or sedimentary material. More typically thin (10 cm. - 5 m.) intercalations of flow breccia and/or aquagene tuff are at the top of flows. Flow breccias and aquagene tuffs constitute but a small portion of the volcanic pile, considerably less than five per cent.

Flows of the normal facies show the characteristic stratigraphic sequence recognized by Carlisle (1963). The ideal sequence begins with a massive zone at the base followed by a pillowed zone; both constitute most of the flow, as noted above. The hyaloclastic top shows gradation upward from pillowed lava to isolated pillow breccia, broken-pillow breccia, and finally hyaloclastite and aquagene tuff. Any of these zones may be absent, but those that are present, follow always in the regular sequence. Therefore in addition to (relatively uncommon) complete sequences we have noted many cases in which the sequence is incomplete. Typical examples of this facies are exposed at locality 7, or at lots 35-40, ranges 7 and 8, Duparquet twp. (locality 8).

A second facies is characterized by great thickness of flow breccia, composing perhaps 30 per cent of the sequence. Pillowed flows and flow breccias are very thick, in many cases exceeding 100 meters; flow contacts are difficult to locate and often are poorly defined. We have coined the term "hyaloclastic flooding" for this facies, in order to stress the great thickness of the flows and the prevalence of hyaloclastic material.

The typical sequence of textural zones within the flow is not developed in this facies. Rather we find irregular alternations of thick packets of pillow basalt, and of isolated-pillow breccia on the one hand, and of broken-pillow breccia interspersed with few lenses of aquagene tuffs, on the other. Broken-pillow breccia may follow abruptly upon massive lava. Cross-cutting patches and dykes of hyaloclastic breccias are present, but occur also in the normal facies. Thin dykes, apparently filled with lava of the same composition as the flows, are not uncommon.

Beautiful examples of this facies are exposed at the shore of many islands in the centre and south of Duparquet Lake (for example localities 5 and 6). A cross-cutting patch of isolated-pillow breccia is exposed at locality 3, and a dyke of broken-pillow breccia cutting across pillowed lava is exposed 50 m. west of the road at locality 9 (lot 30, range west, chemin de Macamic, Dufresnoy twp.). Both are in the normal facies. Dykes of lava cut the broken-pillow breccia at lot 4, range 9, Dufresnoy township (locality 10).

Mafic and intermediate rocks: Origin of volcanic facies

Rittmann (1958), McBirney (1963), Tazieff (1968, 1972), Bonatti (1970) and Benett (1972) studied the eruptive mechanisms of submarine basalts. Their results indicate that eruptions are extremely quiet at a depth below 2000 meters. Eruptions close to the surface, on the other hand, are extremely explosive, and give rise to great volumes of aquagene tuff. Aquagene ash-fall tuffs have wide aerial distribution; tuff rings develop at the eruptive vent, and consist of ash fall tuff alternating with tuffs spread by base surges (Waters and Fisher, 1971). Pillows can form only on slopes.

In the present area tuff rings and a really extensives sheets of aquagene tuff are absent. Consequently the writers believe that eruptions occurred at a reasonably great depth, certainly below more than 100 meters. The facies of "hyaloclastic flooding" is restricted to areas containing prominent complexes of gabbro dykes and sheets. These gabbro stockwerks are clearly related to the mafic flows, and likely indicate the location of mafic eruptive centers. Aquagene tuffs are present, particularly in the facies of "hyaloclastic flooding", but their volume is comparatively small. Consequently the writers feel that this facies formed in moderately shallow water (above 2000 meters, below 100 or several hundred meters), and at relatively steep slopes, close to volcanic centers. Dykes and pockets of hyaloclastic material formed where mafic flows overrode pockets of water and/or pockets of water-logged mud, with subsequent phreatic explosion. The normal facies formed in deeper water, in part probably below more than 2000 meters.

Acidic rocks

The Rouyn-Noranda area is classical terrain for the study of structural varieties of acidic rocks. Wilson (1962) in particular promoted the interpretation of breccias and of inhomogeneous acidic rocks as flows. This work has been continued by Lesperance ( ). Recently A. Spence, in what will become a classical volcanological study, has presented a unified theory of acidic flow breccias. In particular Spence has related the development of flow breccias to chemical differentiation by pneumatolytic action during last stages of flowage, and has related the structural facies of acidic rocks to relative distance from the eruptive source. The essence of the work of A. Spence has been published in Goodwin and Ridler (1972, p. 24-26). Our classification of structural types, and their interpretation are largely based on this paper, and on discussions with A. Spence to whom we are deeply indebted. In analogy to Spence we distinguish: (1) Homogeneous rhyolite; (2) Heterogeneous rhyolite; (a) flow laminated rhyolite; (b) rhyolite with ribbon and schlieren structure; (c) rhyolite with linguoid structure; (d) ribbon breccia, homogeneous-fragment breccia and broken-column breccia.

Homogeneous rhyolites require no special description. Columnar jointing has been observed in homogeneous rhyolites at a number of places; it is absent from heterogeneous rhyolites. Columnar joints have diameters between 5 and 30 cm.

Flow laminated rhyolite commonly occupies only small part of a flow. Flow laminae are generally several mm or 1-2 cm thick. They are accentuated by slight differences of material, alternating white, or light grey and slightly darker coloured. Colour variations are due to slight variation of chlorite and sericite content. Flow laminae are grotesquely contorted and folded. Flow laminated rhyolite grades continuously into homogeneous rhyolite on the one hand, and into ribboned rhyolite on the other.

Ribboned rhyolite contains more or less unsharply bounded ribbons or schlieren, of siliceous rhyolite, set in a more chloritic and sericitic matrix. The ribbons and schlieren are 1-30 cm thick, and 50-500 cm long. They are grossly aligned parallel to the stratification, but may be grotesquely distorted in detail. Some ribbons are flow laminated, others are brecciated. Compositional contrast between ribbons and matrix varies within and between flows;

it may be nearly imperceptible at one place and extreme at the other. Ribboned rhyolite grades into homogeneous rhyolite into flow breccias, and into rhyolite with linguoid structure.

Linguoid structures form where ribbon rhyolite and homogeneous rhyolite interpenetrate. The linguoid structures have diameters varying from about 30 cm to 30 meters. They are highly contorted. Spherical or sub-spherical masses of silicified material may be apparently embedded in the chloritized matrix of the ribbon rhyolite. Contacts of the linguoid masses invariably are flow laminated. Compositional contrast of materials varies greatly; differences are barely perceptible at some localities, greatly accentuated at others.

Ribbon breccias forms where the siliceous ribbons of the ribbon rhyolite have been fragmented. The fragments are flow laminated. Sharply angular fragments are embedded in the chloritized and sericitized matrix. Homogeneous fragment breccias contain angular fragments of siliceous rhyolite set in the chloritized and sericitized matrix. Fragments are not flow laminated. However at many places fragments are arranged in trains, proving their derivation from ribbons that lacked flow lamination. Broken column breccias are composed of fragments of hexagonal columns set in a more chloritized and/ or sericitized matrix.

The heterogeneous rhyolites show some chemical differentiation into materials that have been silicified and materials that have been chloritized and/or sericitized. Compositional contrast between both materials varies greatly between and within flows. Observations on fragmentation, and the shape of flow laminations prove that the silicified material was more viscous than the chloritized material during the last stage of flowage. Such observations suggest that the differentiation took place to a large part during the last stages of flowage. There is also no doubt that the inhomogeneities formed in part within the flow, and that the silicified, relatively viscous material, does not only represent crusts that formed at the surface of the flow.

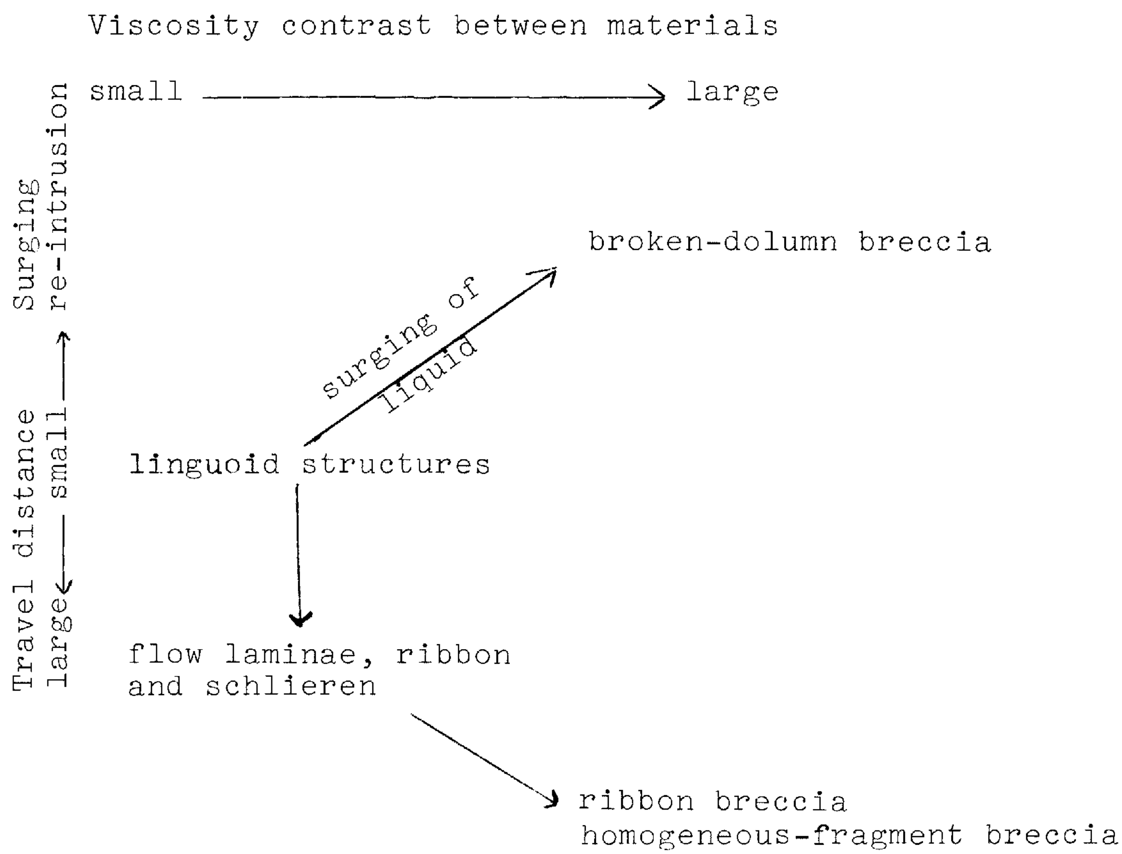
In addition networks of cracks are present in all heterogeneous rhyolites. These cracks are silicified, whereas the patches separated by the cracks contain more sericite and chlorite. This kind of fracturation generally affects the silicified and the chloritized portions of the flow. No movement occurred at the cracks. We therefore believe that the cracks formed during the consolidation of the ryolite, at a time when the flows were completely at rest. Chemical differentiation of flows described above is believed to be due to pneumatolytic action during the last stages of flowage and during cooling.

Spence (in Goodwin, 1972, p.24-25) relates the structural facies described above to proximal or distal position relative to the eruptive center and, of course, to stratigraphic position within the flow. According to Spence the homogeneous facies predominates in the proximal facies, close to the source; it is topped by laminated rhyolite and/or a little flow breccia. Heterogeneous rhyolite - ribboned rhyolite and, according to Spence also rhyolite with linguoid structure, predominate farther from the eruptive center; they are of course again topped, and in places also underlain, by breccia. Finally most or all of the thickness of the flow is composed of breccia at the flow front.

This interpretation is in general agreement with our observations. Linguoid structures, on the other hand, occur where heterogeneous rhyolite abutts abruptly against homogeneous rhyolite. Brecciation and the shapes of the flow laminae leave no doubt that the chloritized material of the heterogeneous rhyolite was less viscous than the homogeneous rhyolite, and that linguoid structures are due to re-intrusion of the still liquid, chloritized material into the homogeneous rhyolite. In this facies therefore the heterogeneous rhyolite has more proximal position (closer to the source) than the homogeneous rhyolite.

For this reason we believe that the facies distribution described by Spence represents the simplest case. In many cases it has been modified by complex re-intrusion processes during the latest stages of flowage, particularly in the more proximal part of the flows. Broken-column breccias also formed by re-intrusion; they developed where increase of hydrostatic pressure in the still liquid interior of a flow led to surging intrusion of the liquid into the consolidated rhyolite that already had developed columnar joints.

Consequently the writers would not classify the flowage structures of rhyolites according to their proximal or distal position within the flows. Rather we would classify them as function of (a) relative viscosity of materials of different composition and (b) travel distance during the interval starting at the time materials of different viscosity and composition formed. Our scheme is presented here as follows:



The various facies of rhyolite are beautifully exposed at the following localities: (1) homogeneous rhyolite with columnar jointing and broken column breccias at locality 11, ½ mile S. of Dalembert River, 2½ miles SE of the mouth of Dalembert River; (2) flow laminated rhyolite and linguoid structures at lot 4, range 4, Destor township (locality 12); (3) linguoid structures at lot 2, range 3, Destor township (locality 13); (4) slightly brecciated ribbon rhyolite at lot 18, range-west, chemin de Macamic, Destor township (locality 14); (5) homogeneous fragment breccia at lot 19, range-west, chemin de Macamic, Destor township (locality 15).

Pyroclastic rocks

Sub-aerial pyroclastic rocks are classified as ash-flow tuffs and as air-fall tuffs, according to the eruptive and transport mechanism. Fiske (1963, 1969) and Fiske and Matsuda (1964) applied the same system of classification to submarine pyroclastic rocks. For the purpose of the present report, however, a purely descriptive classification is preferred. The writers therefore distinguish between (1) local breccia heaps; (2) pyroclastic sheets with great aerial extent: (a) breccias without graded bedding; (b) breccias with graded bedding; (c) ash-tuffs with graded bedding or laminations. Local breccia heaps are not present in the area studied in 1972, and need not be discussed here.

Non graded tuff breccias form beds up to 30 meters thick, alternating with fine grained tuffs, 1-5 meters thick. Coarse grained beds are composed of unsorted fragments up to 1 meter across, angular, or edge rounded set in finer grained debris of rock fragments and crystal fragments. Many of the fragments are amygdaloidal, but very amygdoloidal long-tube pumice is not common. The fragments are set in a matrix of ashes and lapilli. The fine-grained tuffs alternating with the tuff breccia are commonly show tabular lamination. Cross-bedding has been observed. Non graded tuffs breccias are beautifully exposed on the high hills around lots 12-14, range-west, chemin de Macamic, Destor township (locality 16). These rocks are the lateral facies equivalent of the graded tuff breccias. They may have been transported by grain flow or mass flow mechanious.

Graded tuff breccias: Beds up to 30 meters thick of coarse breccia contain blocks of diameters that may reach 1 meter. Larger fragments are sharply angular, and commonly are amygdaloidal. Smaller fragments, up to about 10 cm, are more commonly rounded, and in certain beds contains a high proportion of long-tube pumice. The interstitial matrix is composed of small rock fragments, crystals, and crystal fragments. Somewhat ameboidal fragments of long-tube pumice are abundant, particularly in the finer grained interbeds. Beds of tuff breccia show graded bedding due to decrease of fragment size and increase of pumice content upward as described by Fiske 1963, 1968, and Fiske and Matsuda (1964).

The coarse grained beds alternate rather abruptly with laminated lapilli tuffs and ash tuffs. Coarser varieties of these tuffs contain abundant long-tube pumice. The laminated zone shows multiple repeated graded bedding. Convoluted bedding, load casts, and cross-bedding has been observed. Excellent outcrops of very coarse graded tuff breccias are present at the eastern slope of the mountain 1 mile north of Dalembert River, 2½ miles east-southeast of Duparquet Lake (locality 17). Long-tube pumice is abundant in the eastermost part of this outcrop zone. Fine-grained equivalents of this zone are exposed at island No. 93 of Duparquet Lake (locality 18), where excellent sole marks are exposed, and are also well exposed at the pointe northeast of the island (locality 19).

Fine grained graded tuffs form beds between 10 - several 100 cm thick. They show the usual characteristics of turbidites. Well developed tuff turbidites are exposed on the islands of Lac Rouyn, and at several localities at the south shore of Lac Rouyn. These tuff turbidites alternate with shales.

Interpretation: Graded tuff breccias with long-tube pumice have been interpreted as subaqueous equivalents of ash-flow tuffs by Fiske (1963) and Fiske and Matsuda (1964). The non-graded deposits are so closely associated with the graded deposits that they certainly must have the same origin; perhaps they are their more proximal equivalent, as the pumiceous debris will be carried farther than the rock fragments of higher density. Fiske (1963) suggests that angular fragments may be derived from lava spines and domes that have been shattered by phreatic explosions. The lapilli and ashes of their matrix are perhaps smaller fragments of the same origin.

The fine-grained graded tuffs are either ash-fall deposits, or very distant equivalents of ash-flows, or, the result of reworking of ash flow and ash fall deposits.

Sedimentary rocks

Two classes of sediments are present in this area: (a) pelites (graphitic slate) and chemical sediments (graphitic chert, iron formation), and (b) turbidites (greywackes, conglomerates).

Graphitic slates are exposed on lot 1, range 8; Cléricy township (locality 22); they are too strongly deformed and altered for sedimentological study. Black cherts, generally finely laminated, occur at lot 4, range 4, Destor twp. (locality 23); and at the northern end of lot 24, range 1, Aiguebell twp. (locality 24). The cherts in Aiguebelle townships contain textures that, macroscopically resemble intraclasts (Dimroth, 1968; Dimroth and Chauvel, 1972 a, b) but that could also be derived from volcanic fragments. Both chert occurrences are brecciated, due apparently to post-depositional autobrecciation. Laminated jasper iron formation is exposed at lot 8, range 9, Duparquet township (locality 25), and occurs in drill core from Hunters mine, Duparquet top. Both are thinly laminated on a mm scale. Some silicate iron formation is present at the latter locality. The jasper also is brecciated in places.

The general features of turbidites have been described so many times that no special discussion is required. The reader is referred to Pettijohn, Potter and Siever (1972), Bouma (1962), and Lajoie (1970) for general features of this rock class, to Walker and Pettijohn (1971) for discussion of Archean turbidites, and to Ambrose (1950) and Wilson (1962) for descriptions of turbidites from the present area.

Intrusive rocks

Most of the intrusive rocks of the region have been described in sufficient detail by Ambrose (1950), Wilson (1963), Graham (1954), MacIntosh (1972), and in preliminary reports covering the region. The granites intrusive into the Pontiac Group will be described below in the corresponding paragraphs on the regional geology. We limit our description to two intrusive bodies of greater importance which have not been described previously. They are: (1) a layered gabbro complex east of Duparquet Lake and (2) coronitic pyroxenite in the area north of Reneault.

The layered gabbro complex has the form of a composite laccolith; several sill-like bodies are separated by screens of graded and non-graded tuff breccias. It is very well exposed on top of a mountain southeast of Duparquet Lake (locality 17). The larger part of the body shows rhythmic layering on a scale of 10-30 cm defined by alternating pyroxene cumulate and plagioclase-pyroxene layers. Graded bedding is common. The uppermost part of the complex, at the western margin of the mountain, contains globules of granophyr about 2-4 cm across. The globules of granophyr resemble the ocellae of some nepheline syenites, and we suggest that they also formed by liquid unmixing.

The termination of this complex is exposed at the shore of Duparquet lake (locality 19), where it is easily accessible. The body is only a few hundred feet thick at that locality. The stratigraphically lower part of the outcrop is rhythmically layered, with alternation of pyroxene and pyroxene-plagioclase beds. Layers are 5-20 cm thick; graded bedding has been observed. The thickness of layers increases to about 1 meter toward the top, and layering becomes less well defined through a decrease of pyroxene content in the basal part of the beds. This thickly bedded and more leucocratic zone is approximately 10 meters thick. It contains ellipsoidal bodies, 1-5 cm long, and about 4-12 mm thick. The bodies are composed of pyroxene at the base, crowned by plagioclase. They are perfectly oriented parallel to stratification. The ellipsoidal bodies generally are concentrated in the upper parts of the layers; their size varies greatly from layer to layer, but remains quite constant within layers. The feldspar content of the ellipsoidal bodies increases stratigraphically upwards. They are perfect top indicators. Structures of this kind have not been described in the literature on layered intrusive bodies (for example Wager and Brown, 1968), although they are known to exist elsewhere, for example in the Bell River Complex (R. Béland, personal communication). We suggest that they might be ocellae produced by liquid unmixing of more acidic magma. Apparently a cumulate phase formed within the ocellae during their crystallization.

The upper most layers of the phase with ellipsoidal pyroxene-plagioclase bodies contains schlieren and patches of gabbro pegmatite. An unlayered zone, perhaps 10 meters thick overlies them and contains patches, veins and networks of gabbro pegmatite. The upper contact of the body is not exposed.

Coronitic pyroxenite is exposed at lot 40, range west, chemin de Macamic, Destor township (locality 26), and in the continuation of the pyroxenite zone in Destor township. Part of the pyroxenite contains fine grained ellipsoidal masses, about 2 cm across, surrounded by darker rim. The patches consist of colourless amphibole, the rim of an intergrouth of pyroxene and slightly coloured amphibole in relatively large grains (ca 2-3 mm), the matrix mainly of pyroxene. The origin of this structure is unknown. Porphyry dykes cut the pyroxenite. Reaction rocks containing long prismatic pyroxene oriented perpendicular to the selvage formed at some of the contacts between pyroxenite and porphyry.

Intrusive breccia

An intrusive breccia is exposed in southern Aiguebelle township, between Davangus and Lac Caste. Ambrose (1952) mapped the breccia as agglomerate. However cross cutting contacts of the breccia and gradational brecciation of the country rock are beautifully exposed in outcrops at the township center line, range 1, Aiguebelle twp. and farther west (locality 29).

The breccia contains blocks up to 10 m and more across, of komatiite, gabbro, basalt (pillow basalt, hyaloclastite), rhyolite and porphyry. Most of the visible fragments are 1-50 cm across. Small fragments of chert are present. All thin sections studied so far contain a mylonitic matrix; volcanic material appears to be absent from the breccia. For this reason we suspect that the breccia is of tectonic, not of volcanic origin.

The breccia is little deformed, except for a few outcrops northwest of lac Caste, where it contains a complexly folded schistosity.

RECOGNITION OF ERUPTIVE CENTERS

One of the primary aims of the present survey is to establish a method by which eruptive centers can be recognized. The principles, established during the 1972 field season, are schematically explained in figure 2 ; the most efficient approach appears to be the following procedure:

(1) The volcanogenic facies are described and mapped as recompilation proceeds. Marker beds (in basalts: specific variolitic, porphyritic or glomeroporphyritic beds; all rhyolite flows and tuff flow sheets) are followed.

(2) Proximal facies are established (see fig. 2).

(3) Mapping and petrographic study of intrusive dykes, sheets stockwerks etc. in the proximal facies should establish genetic links between possible feeder dykes and the volcanic rocks of the same composition.

So far the following volcanic centers have been recognized.

(a) A well defined basaltic center extends north of Destor. The Center with a diameter of ca. 5 miles is defined by the association of proximal basalt facies (facies of "hyaloclastic flooding") with a stockwerk of gabbro dykes and sills. Numerous gabbro sills extend into the normal facies of the surrounding basaltic terrain for another 5 miles. This center is very similar to Breiddalur volcano, described by Walker, 1963.

(b) Numerous small centers of rhyolite and komatiite, gave rise to local flows (less than ½ mile long) in a 2 miles zone north of the Duparquet-Destor-Manneville break, in Destor, Aiguebelle and Manneville townships.

(c) The porphyritic andesites or basalts of the lower Blake River Group, between Lakes Duparquet and Hébécourt, are petrographically distinct from aphanitic flows east of Duparquet Lake. Their eruptive center may be located around Hébécourt Lake; however considerable work will have to be done in order to define the geology of this suspected volcanic center.

(d) A layered gabbro complex, may define a mixed center east of Duparquet Lake. However much work will have to be done to relate it to proximal ash flow tuffs east of Duparquet Lake.

(e) Proximal facies of ash flow tuffs at Reneault is intersected by a small dyke of the same composition, and containing the same phenocrysts.

TECTONIC ACTION OF STOCKWORK BATHOLITHS

During work in the south of the present region a new class of batholiths has been recognized, whose intrusion is neither due to stoping or to updoming (gravitative or forceful) of a large body of homogeneous magma but to the gradual, slow opening of a multitude of dykes and sills, and their gradual filling. Large areas of the granitic area within the Pontiac Group are not composed of a uniform granitic massif, but of dyke and sill stockworks which collectively attain batholitic dimensions. The dilation during the gradual, slow, infiltration of magma into the dyke and sill systems, led to swelling and updoming of these stockwerk batholiths. Therefore the tectonic action of stockwerk batholiths upon the country rock is comparable to the upwelling of batholithic masses by gravity, but the mechanism of their intrusion is completely different.

The Pontiac "granites"

Three generations of "granitic" rocks (diorite, quartz diorite, granodiorite, tonalite, rarely granites sensu strictu) are clearly distinguished in the area underlain by the Pontiac Group. Chagnon (1968) recognized their existence; however the present interpretation differs substantially from Chagnon.

The grey tonalite gneiss (= grey granite gneiss and quartzofledspathic gneiss of Chagnon, 1968) underlies a small area south of Montbeillard, and a large dome northeast of Angliers. It is extremely leucocratic (biotite 5% or less), virtually devoid of K-feldspar, and very fine grained. The tonalite is nearly homogeneous in the core of both masses; few screens of the Pontiac schist are parallel to the schistosity. Toward the boundary of the tonalite masses, thin (5-500 cm) sheets of the tonalite alternate with screens of Pontiac metagreywacke. The tonalite is strongly schistose, and shows a well-developed lineation.

A hornblende granodiorite, tonalite and monzodiorite underlies large areas between Angliers and Montbeillard. This rock is medium-grained, and shows poorly developed foliation and an excellent linear structure. Composition is homogeneous on a dekameter or hektometer scale, and in some areas on a larger scale. Three main varieties exist: (a) a porphyritic variety with feldspar phenocrysts up to 2 cm long, (b) a non-porphyritic variety and (c) a monzodioritic variety where quartz is absent. The different varieties ("hornblende granite, pyroxene syenite") have been described in detail by Chagnon (1968).

The hornblende granodiorite is in contact with the country rock at few locations. Generally the heterogeneous granodiorite has invaded the contacts between the hornblende granodiorite and the Pontiac Group. However numerous inclusions of the schist, and of amphibolites prove that the hornblende granite was in contact with the Pontiac before the intrusion of the heterogeneous granodiorite.

At the few contacts dykes of hornblende granodiorite invade the Pontiac. These dykes are devoid of schistosity; linear and planar fabric elements in the hornblende granodiorite are related to the dynamics of intrusion, and are independent of fabric elements in the country rock. Biotite selvages at the contact of dikes prove minor remelting of the metagreywackes during the intrusion of the hornblende granodiorite.

A heterogeneous granodiorite (called "microcline granite" by Chagnon, 1968) is the predominant variety of granite in the area between Montbeillard and Angliers; it underlies immense areas, and is probably the most common rock type in the whole region limited by the Cadillac break in the north and by the Grenville front in the south.

This granodiorite fills complex systems of dykes and sills; it is leucocratic, being composed mainly of feldspar (plagioclase predominating, microcline variable) and quartz. Minor biotite and muscovite are generally present; biotite predominates in the core of the massif, muscovite at the northern border of the massif. Some phases contain garnet, and patches of sillimanite occur locally. The granodiorite extremely heterogeneous. Grain size varies from fine grained (ca 0.1-0.2 mm) to pegmatitic in zones and ribbons parallel to the dyke and sill walls. Ribboning of zones about 1-10 cm thick with different grain sizes and with different compositions is prevalent particularly at the margin of the massif. The phases in the center of the massif are less heterogeneous, although the extreme grain size variation in bands parallel to the dyke walls remains the characteristic of the granodiorite throughout.

The heterogeneous granodiorite furthermore is characterized by the complete absence of flow orientation of minerals. Fine grained phases are unoriented and massive; pegmatitic phases generally show columnar growth textures of quartz and feldspar perpendicular to the dyke walls; biotite rich phases in many cases show analogous growth textures. These textures and the fact that younger ribbons and dykes cut older ribbons and dykes proves that the dykes were not filled at once. Rather they expanded in numerous successive episodes (fig. 3).

Contact relationships of the heterogeneous granite

The density of the dyke system increases gradually over a zone 1 mile or more wide at the contact of the granite "massifs". Some inclusions of the Pontiac are generally present deep within the "massifs" of the heterogeneous granodiorite. These "massifs" as noted do not form a homogeneous mass; they are constitute an extremely complex system of dykes and sills. The density of the dyke system decreases again toward the masses of hornblende granodiorite, however some dykes of the heterogeneous granodiorite are present in virtually all outcrops of the hornblende granodiorite (fig. 3).

Linear and planar fabric elements of the inclusions (Pontiac metagreywacke or hornblende granite) within the heterogeneous granodiorite are parallel within large outcrop areas.

Inclusions have not been rotated even in outcrop areas consisting mainly (50 per cent or more) of the heterogeneous granodiorite. This observation substantiates our conclusion, based on textural observations within the granodiorite, that the intrusion took place by slow and gradual expansion of dykes and sills.

At the other hand the heterogeneous granodiorite exercised remarkable influence upon the tectonics of the Pontiac schist on a large scale. It has been noted above that schistosity of the Pontiac schist is subhorizontal. Dips of schistosity increase gradually within the contact zone (invaded by dykes) of the granite massifs. Within the region of granite massifs the Pontiac underlies narrow synclinal zones with steep schistosity, separating domical anticlinoria underlain by granite (fig. 3). In our view this action is due to swelling of the granite massive during the intrusion of the dyke system which will have a similar bulk effect upon the country rock as the normal process of gravitative updoming of a granite batholith.

AREAL GEOLOGY

NORTHERN AREA

The area studied so far comprises parts of the townships of Hébécourt, Duparquet, Destor, Dufresnoy, Aiguebelle, Cléricy, and Manneville, along the Duparquet-

Destor break. The main purpose of this phase of the work is as follows:

(1) to describe the stratigraphic sequence, and tectonic structure in the areas north and south of the Duparquet-Destor break and

(2) to correlate the sequences north and south of this important structural break.

Previous knowledge on the area is summarized in Ambrose (1950), Graham (1954), Wilson (1962) and MacIntosh (1972).

Compilation maps on a scale of 1000 feet = 1 inch are available for all townships, except Aiguebelle, and Manneville twp. Maps west of the road from Rouyn to Macamic are good, although they require minor revision; the maps available in Destor township are very inaccurate. Maps of Cléricy township are virtually faultless.

Stratigraphy and Correlation

The northern area contains parts of the following stratigraphic units:

A: Kinojevis Group (in the sense of Latulippe, 1968), subdivided in three formations.

B: Lac Caste Group (= lower Kewagama Group of Latulippe, 1968).

C: Malartic Group, subdivided in at least five formations, four of which are present in the area described here.

D: Kewagama Group.

E: Blake River Group with a complex and still largely unknown internal stratigraphy.

Kinojevis Group

The Kinojevis Group comprises the volcanic rocks north of the Duparquet-Destor-Manneville break. It is subdivided in three formations, here introduced: (1) Hunter Mine Rhyolites; (2) Ruisseau Deguisier Basalts; (3) Ruisseau Paré Formation of basalt, komatiite (?), extrusive peridodite and rhyolite.

The Hunter Mine Rhyolite are well exposed in a section from the Palmarolle granite southward through Hunter Mine. Flow rhyolite (much of it flow breccia), minor agglomerate, rhyolite tuff and greywacke are the main constituents. A 20 feet bed of jasper iron formation is intercalated at Hunters Mine. Some conglomerate is present at the presumed top of the unit. The formation is intersected by numerous mafic sills and dykes; mafic flows are perhaps present. Type locality is the section indicated as locality 21, at lot 45, range 9.

The Ruisseau Deguisier Basalts are best exposed in the type section along lot 35, range 8, and lots 37, ranges 6 and 7, between Ruisseau Deguisier and the Duparquet-Reneault road indicated as locality 8. The formation is composed of monotonous mafic flows and lacks key beds. A few flows of komatiite are present close to the top of the formation (locality 2).

The Ruisseau Paré Formation underlies a narrow eastward trending zone at the limits between Aiguebelle and Cléricy townships. The best outcrops are in ranges 1 and 2, Aiguebelle twp. at the township center line. The formation consists of predominating basalt (one variolitic key bed locally present), and small flows of komatiite, rhyolite, and extrusive serpentinite. Interbeds of graphitic chert are present between flows. Some outcrops of thin-bedded greywacke, northwest of lac Mattisard, and at Davangus, may be part of the formation or may be part of the Lake Caste Group, or of the Kewagama Group.

Stratigraphic relations between the Hunters Mine Rhyolite and the Ruisseau Deguisier Basalts are obscured by a narrow schistose zone with complex structure, and by poor exposure. The Hunters Mine Rhyolite likely underlies the Ruisseau Deguisier Basalts. The Ruisseau Paré Formation is also separated from the Ruisseau Deguisier Basalts by a poorly exposed zone. There is little doubt, however that the Ruisseau Paré Formation overlies the Ruisseau Deguisier Basalts.

Lac Caste Malartic and Kewagama Groups

The "Northern Kinojevis Group" of Latulippe is here called Lac Caste Group, after the outcrops east of lac Caste. The unit is composed of greywacke, with minor conglomerate and chert. It is very strongly deformed.

The Malartic Group consists of a basal unit of ultramafic flows, exposed at La Motte (Imreh, in prep.) overlain by at least four formations of alternating mafic and acidic composition (MacIntosh, 1972).

The Kewagama Group is composed of greywacke and subordinate conglomerate.

Lithology and sequence of the three units have been described extensively by MacIntosh (1972) and need not be discussed. Contact relations between the Lac Caste Group, the Ruisseau Paré Formation, and the Malartic Group are unclear. The Kewagama Group appears to overlie the Malartic Group. Contacts between the Kewagama Group and the Blake River Group are also unclear in the present area; interfingering and fault contacts may play a role.

Blake River Group

Only a narrow zone of the Blake River Group has been studied so far. The relations of the base of the Blake River Group to the Kewagama Group are still unclear. However a characteristic marker bed of variolitic basalt extends a few hundred feet above the base of the Group and has been followed across the whole area. The stratigraphy above this marker varies from west to east and will be described in function of two cross-sections, at Duparquet Lake, and at the road from Rouyn to Macamic.

Several thousand feet of andesite and basalt, in large part finely porphyritic or glomero-porphyritic, overlie the variolitic marker at Duparquet Lake. A rhyolite unit comprising at least two flows is intercalated between higher levels of these andesites south of Duparquet Lake, and is continuous with the Waite rhyolite. The rhyolite unit does not re-appear at corresponding stratigraphic levels farther north. An ash flow tuff, intercalated between andesite flows at the center of Duparquet Lake is approximately at the top of the sequence.

The Reneault section is very different. Andesites in this section are not porphyritic. Two markers are intercalated between the basalts: (1) A unit of two rhyolite flows extending from Reneault eastward and (2) A thick sheet of ash-flow tuff (feldspathic andesite or dacite) at the top of the sequence, extending toward Duparquet Lake. A rhyolite flow overlies the ash-flow tuff in a small syncline southeast of Duparquet Lake. Three local rhyolite flows are present between both marker beds.

Duparquet Group

The Duparquet Group underlies Synclinorium extending from Duparquet River to the center of Destor township. It consists in the east of conglomerate, alternating with arkose and greywackes. To the west the grain size decreases abruptly; thin bedded greywacke predominates north of Duparquet Lake; however a prominent basal conglomerate is exposed at the new bridge over Duparquet River, two miles south of Rapide Danseur (locality 27, lot 1, range 7, Duparquet twp.); this conglomerate is characteristic of the Duparquet Group. The Duparquet conglomerate is characterized by a persistent, subordinate component of jasper pebbles. A few rare outcrops close to the Macamic road are devoid of jasper pebbles, but contain abundant quartz and feldspar porphyry of local derivation (locality 28, lot 41, range-east, chemin de Macamic, Destor twp.).

The Duparquet Group overlies the upper part of the Kinojevis Group with unconformity. Graham (1954) has suggested that it is older than the intrusive porphyries. Field evidence has not confirmed this assignment: Nowhere have the writers observed porphyry dykes intersecting the Duparquet Group. Porphyry bodies within the area underlain by the Duparquet Group are domical anticlines that expose the basement of the Duparquet Group. Furthermore the Duparquet conglomerate contains not only blocks and pebbles indistinguishable from the porphyries, but also contains porphyry quartz which obviously is derived from the porphyries of its basement.

Stratigraphic correlations

Presently there exist two alternate hypotheses on the correlation between the stratigraphic units present:

(1) Ambrose (1950), and Wilson (1962) suggested that the Malartic Group occupies an anticline. The Lac Caste Group is considered equivalent to the Kewagama Group, and the Kinojevis Group is considered to correlate with the Blake River Group.

(2) Latulippe (1966) and Graham (1954) suggested that the Kinojevis and Lac Caste Groups underlie the Malartic Group.

Material at hand does not permit a clear choice between both hypotheses. It is certain that the Kinojevis Group has a stratigraphic and volcanological organization which is totally distinct from the organization of the Blake River Group. The total of the evidence appears to favour a solution similar to the hypothesis of Graham and Latulippe, although more complicated hypotheses will be examined. The solution hinges in an analysis of the deformation in the Duparquet-Destor-Manneville break.

Graham (1954) suggested that the Duparquet Group is intruded by the porphyries, and that part of the sediments at Duparquet Lake correlate with the Kewagama Groups. These correlations have been disproved. Compelling evidence proves that the Duparquet Group is younger than the porphyries of the Duparquet-Destor area.

Structural geology

The northern region has the following general structural characteristics:

(1) The large-scale folds are perfectly isoclinal, and have nearly vertical axial planes. Axial planes trend northeast, east, or southeast.

With few exceptions hinge zones are extremely narrow. A schistose zone, with many small-scale faults generally represents the hinge zone. In most cases it is impossible to recognize the stratification in the hinge zone; for this reason most of the large-scale folds can be recognized only by opposite facing of tops. Furthermore it is difficult, and in many cases impossible, to determine the plunge of the large-scale folds. Doubly plunging domical folds are present in the Duparquet Group, but it is not yet known to which degree their shape is determined by more than one period of folding.

(2) Axial plane schistosity related to large-scale folds increases in intensity with decreasing wave length of the folds. Therefore one should suspect that strongly schistose zones also show narrow isoclinal folds. However this is difficult to prove because top criteria are destroyed by the development of schistosity.

The intensity of the first generation schistosity varies very greatly. It is virtually absent in large areas, and its intensity greatly increases toward the Duparquet-

Destor-Manneville break and toward some of the more local "fault" zones. The relations between intensity of folding and intensity of schistosity outlined above led the writers to suspect that the rocks of these "fault" zones suffered intense isoclinal folding; however this is difficult to prove, because top criteria have been destroyed in the schistose "fault" zones. Narrow "fault" zones of local importance often represent the hinges of large-scale folds, as noted above, and as proved by opposite facing of tops.

(3) A second, and rarely third schistosity is superposed on the isoclinal large-scale folds, and are parallel to the axial planes of small-scale folds. The intensity of the second and third cleavages increases with the intensity of the first. The schistosities are sub-vertical, trend NE, east or SE, and deviate ca 30° from the first schistosity.

(4) Measurable small scale folds and lineations, plunge sub-vertically, because they are produced by the intersection of steeply dipping schistosities with a steeply dipping bedding plane (or an older, steeply dipping) schistosity. Pebbles and pillows also are stretched in sub-vertical directions.

(5) The region is subdivided in a number of blocks or segments which are weakly to moderately deformed. These blocks or segments are brutally separated by breaks where deformation is strong to very strong. The following degrees of the intensity of deformation can be recognized.

(a) large scale isoclinal folds; schistosities absent or weak, except in very ductile rocks (slates, hyaloclastites).

(b) large- to medium scale isoclinal folds; one or two schistosities moderately well developed. Weak to moderate stretching of pebbles and pillows.

(c) Medium to small scale isoclinal folds suspected, but difficult to outline because intense schistosity has obliterated most top criteria. Two schistosities(rarely one) very well developed; both are planar. Strong stretching of pebbles and pillows.

(d) intense and narrow isoclinal folds suspected, but difficult to trace because intense schistosity has obliterated most top criteria. Two or three schistosities are very well developed; older schistosities are folded. Strong stretching of pebbles and pillows by oldest schistosity; the stretched pebbles are folded by later schistosities.

Intensity grades (a) and (b) are characteristic of the segments, intensity grades (c) and (d) of the "breaks".

(6) Kink bands are present in many areas that show moderately well developed schistosity, and are present in nearly all areas where the schistosities are very well developed.

Segment north of Duparquet-Destor break

The segment north of the Duparquet-Destor break has the structure of an east-north-east trending synclinorium; the Duparquet-Destor break, trending southeast to east, intersects the synclinorium obliquely.

The northern limb of the synclinorium has a simple monoclinal structure, as far as presently known. No top criteria have so far been found in the Hunters Mine Formation, and monoclinal structure of this units is assumed. Two schistosities trending ENE and ESE are present and intersect in a nearly vertical lineation. Intensity of the schistosity increases southward to the contact with the Ruisseau Deguisier Formation. The Ruisseau Deguisier Formation north of the outcrop area of the Duparquet Group forms a monoclinally south facing unit, as determined by numerous tops. Dips are vertical or sub-vertical. Schistosity is practically absent, except close to the contact with the Duparquet Group.

The center of the synclinorium can be subdivided in four sub-units: (1) The area underlain by the Duparquet Group. (2) The southern fringe area underlain by volcanic rocks, south of the Duparquet Group and north of the Duparquet Destor break. (3) The area between Lepine Lake and the east-center of Destor twp., and the area in Aiguebelle and in easternmost Destor twp.

(1) The Duparquet Group has been folded into a complex, branching synclinorium. Folds are doubly plunging; plunges of domical upfolds of the underlying volcanic rocks may reach 60°. Many folds are slightly asymetric; and the overturned limbs of asymetric folds tend to be thrusted. In the north a number of east-northeast trending faults splay from the Duparquet-Destor break, and carry the volcanics of the Ruisseau Deguisier Formation over the Duparquet Group.

(2) The southern fringe zone shows some east trending isoclinal folds.

(3) Most of the southwestern quarter of Destor twp. is underlain by a stockwerk of gabbro sills and dykes. Tops of basalt inclusions within this gabbroic stockwerk are variable. It is at present impossible to decide where these variations are due to a rotation of inclusions during the intrusion of the gabbros, and where they are caused by folding.

(4) A simple synclinal structure is present in Aiguebelle twp. and in the easternmost part of Destor twp.

Schistosities and small scale folds are absent in most of segments (3) and (4); they are weakly developed in segments (1) and (2), except close to the east-northeast trending fault zones.

The zone underlain by the Ruisseau Paré Formation will be discussed with the Duparquet-Destor break.

Segment south of the Duparquet-Destor-Manneville break

This segment comprises the areas underlain by the Malartic, Kewagama, and Blake River Groups.

The Malartic Group has been folded into a grossly anticlinal structure, the northern limb of which is quite narrow. Schistosities in this group are strongly developed; two schistosities and a generation of kink bands are generally present, except in the southern band of the upper mafic and upper acidic formations. Lack of top criteria did not permit to outline smaller scale folds which doubtlessly are present.

The Kewagama Group has a prominent set of ESE trending synclinal and anticlinal folds. One two or locally three cleavages, and a set of kink bands are superposed on these large-scale folds. Most small-scale folds plunge steeply. Complicated fold-patterns are exposed at number of localities. Schistosities are moderately well to well developed. A fault may separate the Kewagama and Blake River Groups southwest of Mont-Brun.

Only a small part of the Blake River Group has so far been studied. Three segments are described separately: the Duparquet segment, comprising the area around Duparquet Lake, the Reneault segment, comprising the area west of the Macamic road at Reneault, and the area northeast of Dufresnoy Lake.

Two synclines (Cléricy syncline and North Duprat syncline) separated by the Dufresnoy anticline can be outlined in the Duparquet segment. These folds trend east-west and swing southeastward at the east shore of Duparquet Lake. Plunges are to the east. Complex structure, mapped east of Duparquet Lake have been interpreted by interference between the Cléricy syncline (trending southeast) and east-trending folds on existing compilation maps. This interpretation likely is incorrect; it is very likely that these complex structures are caused by intrusion of a saucer-shaped layered gabbro complex into the volcanic sequence.

Rocks in this segment lack schistosity, except close to the Duparquet-Destor break, where one or two schistosities, and a generation of kink bands are well developed.

At Reneault only the segment of the Blake River Group north of the Cléricy syncline has been studied. Numerous top determinations confirm that this section is monoclinal (with one minor fold perhaps present). Schistosity is absent.

Rocks northeast of Dufresnoy Lake are strongly schistose, with one or two schistosities and kink bands present. Top criteria are hard to observe, because of the strong internal deformation of the rocks. For this reason the macro-structures are still poorly known in this area.

Duparquet-Destor-Manneville break

The Duparquet-Destor-Manneville break is a strongly schistose zone trending east-southeast, from the North-shore of Duparquet Lake through Davaugus to Kinojevis River east of Mattisard Lake. The zone branches at Duparquet Lake, where a major splay trending east separates from the main break zone.

The Duparquet-Destor break zone is perhaps $1\frac{1}{2}$ mile wide at Duparquet Lake, where the schistose zone involves rocks of the Kinojevis, Blake River and Duparquet Groups. The schistose zone is either very narrow, or absent, in the segment 3 miles long, immediately west of the Macamic road. Farther east it widens again and a zone, approximately 2-3 miles wide, of intensely schistose rocks represents the zone at Lac Caste. In addition, a slice north of the schistose zone, underlain by the Ruisseau Paré Formation, although in part not schistose, bears evidence of folding and repeated faulting.

Evidence for faulting along this zone is widespread, but many of the larger faults are difficult to locate. Furthermore the writers suspect intense small scale folding in the schistose zone, but fold axes are difficult to locate because top markers have been destroyed.

Numerous dykes of quartz and of feldspar porphyry occur in the zone from Reneault eastward. Dykes of pyroxenite are present east of Davangus. Both are related to small extrusive rhyolite flows and to small flows of komatiite. They are good evidence that intense faulting, probably with a vertical movement, took place in the zone during eruption of the volcanics of the Ruisseau Paré Formation.

A second period of faulting, probably also normal faults occurred after eruption of the Ruisseau Paré Formation.

This period resulted in the development of a wide zone of intrusive breccia between Davangus and Lac Mattisard. The breccia includes completely carbonatized rocks, evidence that some carbonatization must have accompanied the early period of faulting. The breccia had been mapped as agglomerate by Ambrose (1950).

During orogeny the zone has been intensely folded, with continuing faulting, and subsequent development of two cleavages and one or several generations of kink-bands. The presence of narrow folds can be demonstrated in Aiguebelle and Cléricy townships. Two narrow folds are present in the Ruisseau Paré Formation. Farther south, schistosity has generally destroyed top criteria; however remaining graded beds in the Lac Caste Group also indicate changing top direction. Schistosities have two direction: ENE and ESE, with the ENE direction the younger. A NE trending set of kink-bands is superposed on both schistosities.

Faulting must be intense in the Duparquet-Destor-

Manneville break; however individual faults are difficult to locate, in part because outcrop is poor. The relations between cleavages let us suspect that faults had a considerable strike-slip component, with the northern black (Kinojevis Group) moving to the west relative to the southern block.

The Lac Parfouru cross-zone

A north-northeast trending zone, about 3 miles wide is centered between Mont-Brun and Lac Parfouru. This zone is characterized by a large kink in the strike of the Kewagama Group. Schistosities in this zone differ from schistosities elsewhere. A first schistosity trends north-northeast and dips ca 45° west. This schistosity is very well developed, but is difficult to measure, because it is intensely folded. A set of schistosities in this direction is not present outside of the zone; therefore the writers suspect that it is related to the change of strike of formations in this zone. This schistosity has been overprinted by a weak schistosity trending northeast, and a relatively strong schistosity trending southeast. A strong, constant lineation, plunging 45° WNW is intersection of S, and S_3 and is present in all outcrops of this zone. A lineation with this altitude is absent elsewhere in the region.

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