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DUPRAT TOWNSHIP AND PART OF SOME ADJACENT AREAS

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TABLES

PART I

DESCRIPTION OF THE MAP-AREA

CHAPTER I

INTRODUCTION

Location and Accessibility.-

The location of the area investigated in relation to the Noranda district is shown on the index map, Fig. 1. The enlarged view, Fig. 2, shows the relation of the inverted L-shaped map-area to the city of Noranda, to the Canadian National Railways Transcontinental Line, and to the various detailed map-sheets which it adjoins or overlaps. For the sake of uniformity, the area on the attached Map A, has been kept rectangular, but the writer wishes to acknowledge that, in the parts that overlap work by Benneman, and Wilson, free use has been made of the geological information recorded on their maps. (See Fig. 2)

The foot of the "L" is a strip extending from the centre-line of Duparquet Township eastward for ten miles to the centre-line of Destor Township, and from the north boundary of Duprat Township, to Range Line III-IV, Duparquet and Destor Townships. The limb of the "L" is the east half of Duprat Township. The whole area comprises about 80 square miles.

The east half of Duprat Township is readily accessible by motor roads leading from Noranda. A branch road to the Elder mine reaches the south border. Truck and mine roads, leading to, and north of, the Waite Mine reach to Range IX.

Similarly all parts of the Destor section are easily reached by ah automobile road along Range Line II-III, the abandoned narrow-guage Beattie tramway, and the Lake Dufresnoy water route in the south.

Fig. 1. The map-area in relation to the main lines of communication.

The east side of the Duparquet section is accessible by a lumber road following Destor Creek for about one mile west of the Macamik Highway, and another leading to the extreme southeast corner and ending at a sawmill on the Dalembert River. This river, flowing westward across the area, is not a practicable water route, due to heavy brush, log jems, and beaver dams. The best approach to the difficult western terrain is offered by the lower reaches of the Dalembert River, near Duparquet Lake. In flood season, motor boats can reach the margin of the area. A second water route, through Lakes Mackay and Destor, and the Dugros river, with portages totalling about 50 chains, crosses the northern part of this section.

Field Work

The area was mapped by pace and compass methods during the summers of 1949, and 1950 on a scale of 1 inch equals 1,000 feet, with the mid of official photographs of the Royal Canadian Airforce scaled approximately 1: 12,000. Original survey and staking lines in Duprat and Destor Townships were cut out where needed. They controlled the location of rock outcrop visible on photographs, to within 50 feet. The Duparquet section was unsurveyed, so that outcrops were necessarily located from chained lines cut for the purpose. The distances from prominent features on the photographs to the east Township boundary were chained along lines running east west approximately a mile apart. Outcrops were tied to the photographic landmarks, and the method is less accurate than that using original survey lines. Traverses were made to record all outcrops suggested by the photographs.

Related Publications

Many regional descriptions in government reports refer to the area. The contiguous areas have been recently mapped in detail, except for the west side, and preliminary or final reports have been published. (See Fig. 2) In addition there are many papers, both published and private, which describe economic deposits and local problams, either within the area, or on the borders. A classified list of relevant literature is contained in Appendix A.

CHAPTER III

GENERAL GEOLOGY

General Statement

With the possible exception of the later diabase dykes, all of the bedrock formations are Precambrian age, and probably belong to the Archaean complex. The surficial rocks consist almost entirely of volcanic rocks, and sediments form only a small percentage of the bulk. The greater part of the volcanic sequence consists of lava and flow breccia. Though pyroclastic horizons are continuous throughout Range II, Duparquet and Destor Townships, they form only a minor fraction of the volcanic assemblage.

The volcanic rocks have been intruded by groups of rocks, which, named in order of decreasing age from relations observed in the map-area, are: (1) dykes and sills of diabase, "andesite", and "rhyolite", older than (2) large sills, and irregular masses of quartz diorite, gabbro ("older gabbro") and related rocks, which are in turn intruded by (3) small dykes of "andesite", splite, and some "rhyolite", (4) granite and satellitic intrusives invaded by (5) "andesite", "diorite" and "rhyolite" dykes, and lastly (6) diabase ("later gabbro") dykes. Small bodies of quartz and feldspar porphyry have obscure age relations and are placed provisionally between (4) the granite and (6) the diabase. Composite intrusives, possibly of more than one age have uncertain status, but may belong to group(3).

The volcanic series and some of the older intrusives are generally tightly folded about horizontal east-west striking axes, so that the trend of the lava belts is parallel to the axes; but in the openly folded southern part of the region they cross the axis in gentle curves. Faulting probably began after deposition of the volcanic sequence, but may have continued recurrently for some time, up to the Proterozoic. The general geology in the south part of the area is quite similar to that described by Wilson (1941) and in the northern part, to that of Graham. (1947, 1948).

Table of Formations

In the stratigraphic table that follows the intrusive rocks are placed in the age groups enumerated, so far as their dates may be fixed by the formations transected. It must be pointed out however, that intensive unpublished investigation of various parts of the map-area by Copeland, (1950, 1951) Schindler (1934), Bray (1940) and Graham (1948) have shown that locally much more detailed tables containing many different age of intrusives of the same, and varies, composition may be constructed. These sequences, however, find no place in a table constructed for the whole area because of the uncertainty of lithological correlation, and the wide tracts of overburden that effectively preclude tracing of cutting relationships except between the major intrusives. Each group in the following table therefore, may contain one or more ages and types of intrusives established by the different workers. On the accompanying reduced-scale map A, many of the minor intrusives do not appear at all.

TABLE IA

TABLE OF FORMATIONS

ERA, period or epoch	Period, Epoch or local name	Formations, and events
	Recent	swamp accumulations and loam
PLEISTOCENE	Glacial	wind blown sand, lacustrine clay, gravel and till.
		GREAT UNCONFORMITY - faulting, mineralization
ARCHAEAN	Algomen(?)	siliceous prophyries
		major faulting, some folding, intrusive contact
		siliceous prophyries, rhyolite, splite, andesite, quartz diorite, lamprophyre, and granite dykes.
		intrusive contact
		granitic intrusives; tonalite, sodic granodiorite, quartz diorite
		intrusive contact
		rhyolite, andesite, diabase, and composite ("sandwich") dykes
		intrusive contact
		"older gabbro" grading to sodic granodiorite; quartz diorite
		rhyolite, andesite, diorite and gabbro dykes.
		major folding, some faulting, probable unconformity
	Abitibi Series	
	Blake River group	andesite, dacite, trachyte and rhyolite lavas, with flow breccia, agglomerate, tuff, some minor chert, derived chlorite, and sericite schists, and related concordant intrusives.
Keewatin	Cléricy Group (Kewagema)	greywacke, a little argillite, and derived schists.

sediments west of the Macamik Highway in the locality described, to the volcanics to the south, are similar in every way to the relations described by Cunning and Ambrose after investigations in Malartic, Bousquet, and Joannès Townships (1940, pp. 15, 16 & 1941, p. 8) and confirm the conclusion that the Cléricy (Kewagema) sediments conformably underlie a volcanic group which these authors have elsewhere called the Blake River group. If no fold axis lies between the top determination in the sediments nearest the contact with the andesite to the south, it must be concluded that the northern part of the volcanic group in Duprat and south Duparquet townships corresponds to the Blake River group, - a point to which reference is made beyond.

Andesite

Andesite lavas form two main belts, each about one mile wide, in Duprat Township, and a narrower belt in south Duparquet and Destor Townships. They are consistantly greyish-green to rusty-brown weathering, fine grained, dense rocks. Massive and pillowed andesite occur in about equal amounts, while flow breccia is very subordinate. Nearly every characteristic structure, texture or composition of the massive lava also occurs in pillowed flows, and only the chief differences need be mentioned here.

The thickness of the massive flows rarely exceeds 75 feet and the majority are no more than 30 feet thick. Grain size within any particular massive section is commonly less than 1 mm., and invariable. It is noticeably coarser only near the bottom of a few flows of unusual thickness.

CHAPTER IV

KEE WATIN-TYPE ROCKS

Cléricy Group

A band of sediments consisting chiefly of greywacke, having an exposed width of about 1,000 feet, outcrops only in the north part of the area. One group of outcrops in Lots 29 to 31, Range III Destor Township, just north of the road to Destor village, has been described by Bannerman (1940, p. 11). The only other exposures, in Lots 26 and 27, West Macamik Road Range, have been described by Graham. (1945, p. 7). In the first locality the sediments are sheared, appear to be partly recrystallized, and cleave easily. They weather a pinkish-white, and in a few places thin dark blue bands of meta-argillite are intercalated with the greywacke. Where there is little schistosity, the strike of the bedding measured on small exposures appears to be N. 63° E., and one doubtful determination of tops suggests the sediments face north. In the second locality, the beds strike between N 50° to 66° E. and grain gradation indicates that they face south. The contact with the south facing andesites to the south is conformable and interbedded.

These rocks were not examined under the microscope.

Stratigraphical Position

The work of Ambrose in Cléricy Township (1941, pp. 7-13); Bannerman (1940, pp. 10 and 11), and Graham (1945, p. 7) in Destor Township, show that the Cléricy sediments are a westward continuation of the Kewagema sediments named by Gunning in hiw report on the Cadillac area. (1937, p. 4) The relations of the Cléricy

Pillowed flows are best developed in ranges IX and X, Duprat Township, but they occur all over. Sections consisting of 100 feet or more of pillow lava are topped by minor amounts of flow breccia. The length and breadth of pillows in individual horizons is consistent, but from one section to another it ranges from 3 to 25 feet. In the cusps between pillows there is generally a little scoriaceous breccia, containing bluish pieces of quartz. The pillow rinds generally weather a darker colour than the interior. Where, however, there has been rusty alteration, the pillow contour is only distinguishable, by the fine hair-like lines on the weathered surface, which follow the rim. Where there has been fracturing, "grid weathering", and development of quartz is concentric laminae inside a vesicular pillow, such as near the Waite and Amulet Mines, the outer contour is frequently obliterated, or at best, is recognizeable only by the structures which vary in a systematic way, with the form of the pillow. The inner margin of thick rinds, as in Range X, Lot 55-60, Duprat Township, weathers a bluish-white and appears to be more siliceous than the interior. Some pillow rims are variolitic, and they bear whitish pin-points up to 1.5 mm. in diameter in a light green matrix. In some pillows the size and number of varioles diminished progressively inward from the rim, but they generally increase. In Lot 53, Range X, varioles range from pin-points at the inner margin of the rim, to large, white-weathering coalesced masses up to 6 inches in diameter in the centre of the pillow.

Thin section examination shows that the variolitic pillow rinds are quite altered to secondary minerals, and even the outline of the varioles is no longer distinct. Their size increases away from the outer margin of the rind, while the number occurring in each successive shell remains about the same, so that crowding results, and they tend to coalesce into blobs about 5 mm. in diameter near the inner side of the rind. Under the microscope the varioles seem to form about 45% of the rim, and consist of grains no larger than 0.1 mm. of clinozoisite, epidote, and zoicite. The matrix consists of relatively clear epidote up to 0.5 mm. grain, actinolite, chlorite, small amounts of sericite, and an unindentified opaque oxide.

Under the microscope the typical andesites fall into three groups that have the different textures; hyalcophitic, pilotaxitic, and intersertal textures. While there is little, if any original glass remaining in the rocks, the textural terms aptly characterize the arrangement of feldspars in matrices which consist of extremely fine alteration products, which, for the most part, may have been derived from minute mineral grains that crystallized from glass.

The most common type of andesite has a hyalcophitic texture, (Johannsen, 1939, p. 47) and consists of relatively clear laths of sodic feldspar ranging from 0.1 to 0.6 mm. long (An_6 - An_{18}), in sub-parallel arrangement, forming incomplete enclosures in the matrix, made up chlorite (+ pennine), secondary quartz, epidote, and other alteration products. Almost all the andesites are invariably porphyritic, and contain scarce phenocrysts of stubby albite or oligoclase twinned on various laws. The hyalcophitic texture occurred in more specimens examined, north of range IX, Duprat Township, then further south. The composition of one relatively unaltered section seemed to be, about 40% albite-oligoclase, 37% epidote, 14% pennine, 6% granular quartz, and small amounts of actinolite, zoisite, and calcite. Most of the feldspar laths of both phenocrysts, and microlites, are dusted with small reddish-brown dots visible under 500 diameters' magnification, which lie on various crystal planes in the feldspar. Under low magnification, the aggregate effect of the dots is to give the crystal an overall brownish cast. In most slides the perfect idiomorphic outline of the feldspar is superseded by ragged re-entrant sides and frotted ends resulting from reaction with the groundmass constituents. The principal minerals in the heavily altered feldspar, are those of a typical saussurite; e.g., chlorite, epidote, sericite, and carbonate. Chlorite occurs in shapeless, of round masses in the matrix. The quartz occurs either as small orbs around the inside margin of a chlorite oval, in poicilitic arrangement with sericite, as granular mossics, or as short veinlets cutting across feldspar laths. The behaviour of the quartz shows it is obviously secondary. The occurrence of quartz in circles or sectors inside the chlorite ovals is a peculiar habit that has been noted in other rocks, and for which an explanation is lacking. Vesicles, or amygdales make up to 5% of some andesites, and contain carbonate, chlorite and epidote. The matrix of some slides is charged with brownish-black material (kaolin?). Hematite patches are common. Minute epidote-chlorite veinlets cut the rock in many places.

There are all gradations from the lavas described to those with diabasic or intersertal texture which are more common in the south part of the map-area. In these rocks, partly idiomorphic laths of dusted plagioclase (An_6 - An_8), from 0.03 mm. to 0.6 mm. long, enclose, and project into, triangular patches of chlorite which certainly represents a former ferromagnesian mineral. The proportion of plagioclase to chlorite varies from 1::1 to 2::1. In a relatively unaltered andesite the following composition was estimated from linear traverses:- plagioclase 60%, chlorite 30%, epidote 5%, minor constituents, 5%. Phenocrysts of plagioclase are rarer in the rocks with this texture. The minor constituents are amphibole, sericite, a little biotite, actinolite, zoisite, and pyrite. A silicified diabasic andesite from the south end of Rusty Ridge, Duprat Township, contained 28% plagioclase, 34% epidote, 21% chlorite, 14% quartz, and 3% others. In places within the area, no boundary could be placed between "older gabbro" and andesite with this texture. A thin section of one of the questionable transition rocks, is very similar to those described, but contains more actinolite.

In all the rocks where the intersertal texture is well developed, the plagioclase, has lost much of its idiomorphic outline; the sides of laths are corroded into cusps, the ends, into forks, or tridents. Brown dusting is common, but there is surprisingly little alteration to saussurite. Quartz occurs in intergrowth with enhedral feldspar mostly altered to sericite in a few places. This intergrowth corrodes feldspar laths. Quartz is also found in vesicles with epidote, plainly showing its secondary origin. Radiating, fibrous, straw-yellow epidote fills some vesicles completely. Veinlets of chlorite cutting all minerals were noted in thin sections.

The third most common texture, which is a variation of the others described, occurs in andesites having phenocrysts of oligoclase (An_{17}) and sodic plagioclase, in a felty or pilotaxitic matrix. Individual feldspar microlites in the felt are no longer than 0.1 mm.

They lie in a matrix, which, where not opaque or dense brown, is seen to consist entirely of secondary minerals in variable proportion, including chlorite, actinolite, epidote, clinozoisite, quartz, pyrite, and cavities. As previously mentioned, the quartz prominently occurs as circles in the chlorite.

Structures in the Andesite

Although all the andesites are much alike in composition, and microscopic textures, they have a wide variety of structures. These are:- porphyritic texture, amygdules, varioles, "mesh fracturing", lamination, and columnar jointing. Good descriptions of many of these features are found in Wilson's report on the Noranda District (1941, pp. 17-19, & plates VB, IXA). In addition the andesites possess a feature called colour banding by the writer, which has not previously been described.

The only macroscopically porphyritic andesite occurs on the north shore of Lake Dufresnoy, in Lot 20, Range II, Destor township, where massive and pillowed andesite contains phenocrysts up to one-half inch in diameter.

Vesicles in the lavas range from flecks to cavities six inches long. Small vesicles are closely spaced, inplaces less than 0.25 inches apart. Many of the amygdales are relatively long or thin and flattened, in the plane of the dip and strike of the flows. This suggests the lavas must have been relatively fluid and fast moving in the flow plane. Had the lava been too viscous, or turbulent the amygdales would probably have had no particular planer orientation. Narrow laminae of quartz alternating with dark coloured minerals are common. In pillows this structure has been termed concentric lamination by Wilson. (1941, p. 19) The laminae are formed by successive fractures up to 1 mm. wide, filled with quartz, which stands out by differential weathering, and they are spaced from one-half to three-quarters of an inch apart. As described by Wilson, the laminae in pillows are parallel to the rim. In places however, the laminae follow only the curved upper surface of pillows. Spacing of laminea varies considerably, and they are closest together near the margins. Locus of developmeht is commonly halfway between the centre and the rim. In several localities the writer has noted relatively stright laminae which after they are traced for 20 feet or more are found to curve over 90°, and rarely in semi-circles, with a radius of a few feet for inapparent reasons. This curved banding resembles the concentric lamination of pillows, but no pillow structure was observed.

Columnar structure, unlike that in the lavas further south, is rarely exposed, and has not been useful in determinations of structure. A section exposed in the Smoky Hills truncates a polygonal system of fractures presumably bounding steeply dipping columns in nearly flat andesite. The rock is whitish weathering near the fractures, and appears to have been silicified, as it is more resistent to weathering than the areas well within the polygone.

A very regular type of banding, which occurs over distances up to 300 yards in massive andesite was observed in Ranges IX and X, Duprat Township. Similar banding occurs in trachytes south of Destor Lake, Duparquet Township. Dark reddish brown weathering bands ranging from six inches to one foot wide are separated by buff coloured bands up to 6 inches wide. The banding is parallel to the strike of steeply dipping flows. The widths of successive bands of the same colour varies but little across the strike of the flows, and the spacing bears no obvious relation to their distance from flow contacts. The broken surface of the hand specimen, shows no difference in texture or colour corresponding to the colour banding on the weathered surface. Similarly examination under the microscope shows that the rocks are too altered to permit determination of any fundamental difference in alternate bands. The regularity and straightness of the feature suggest that it may have been caused by slight differences set up by pulsating laminar flow in very thin sheets. Conceivably different flow layers ih fluid lava, by slight differences in density, gas content, or composition produced by gravitational stratification, formed strata separated from each other by slight changes in physical properties. Were this so, a light and the adjacent dark band might be part of the same differentiated stratum, which, where repeated often enough, produced banding over continuous exposures, 60 or more feet wide.

Flow Breccia

Andesite flow breccia does not make up a large percentage of the volume of the andesitic rocks, but it is a characteristic part of many andesite belts, and because individual bands of breccia of certain types may be traced over distances up to one-hald mile, they supply valuable information regarding the attitude of individual flows.

Three types of breccia, classified by the arrangement, but not the composition of the fragments, have been noted. Of these, the first, called "ribbon breccia" which has been described and illustrated by Wilson (1941, p. 20, & Plate IX B), seems to be rare in the andesites. The ribbons are sinuous, reddish brown weathering, usually finely banded crusts, that may be distinguished on the weathered surface from the andesite immediately adjacent, by a white weathering margin surrounding the fragment.

More common is a breccia consisting of angular to sub-rounded or elongate fragments ranging from lepilli to blocks three to four feet across, which usually weather a lighter colour than the matrix. The fragments are invariably rimmed by a reddish brown zone one quarter of an inch wide. The spaces between larger fragments are filled with smaller, subangular unrimmed fragments heterogeneously mixed with lava. A rough stratification is frequently suggested by the parallelism of the longer axes of the larger masses, but there is no suggestion of sorting, and the texture of the matrix where examined, proves to be igneous. North of Nora Lake, Duprat Township, this second type of breccia is widespread among the lavas. It is impossible to tell at what point fragmentation ceases, for the fragments are not always visible on the weathered surface, and continuous fresh samples taken each foot over twenty feet in one flow showed that the distribution of fragments is quite haphazard.

The third type of flow breccia is illustrated by Figure 10. It is characteristically associated with the tops of pillowed flows, and the best exposures are in Range IX, Duprat Township, where some bands are so wide and continuous, that they have been placed on the map. Loops of ropy, laminated, reddish brown weathering vesicular lava are found intricately mixed with white weathering fragments. Although almost all the fragments weather white, and are harder, and appear more siliceous than the matrix, the differences as observed on the fresh surface, and in thin section, are not everywhere so marked.

Several problems regarding flow breccias may be mentioned here. The considerations apply, except for differences in viscosity, to all the different types of lava. In the ribbon breccia, the reason for the bleaching of the lava around engulfed crusts which seem to have the same composition as the matrix, is not clear.

A second problem arises where the breccias contain diverse, subangular fragments as they frequently do. The diversified appearance of the weathered surface then requires no explanation, but the angularity, close packing of fragments, and the heteroganeous composition of material in the area of a thin section have led some workers to conclude that these breccias are pyroclastic rocks. In discussing brecciated structure in Keewatin rocks, Cooke (1931, p.44) states that "the lava matrix (of a flow breccia) of course, possesses a uniform grain and composition throughout instead of a variable grain and finely fragmental character, as in the case of agglomerate". He distinguishes four possible origins for the fragments, namely: (a) the lava engulfs any loose material it encounters, and the fragments may be of rocks different from the lava itself, (b) the lava may collect ash which fell onto the surface, and the material will be similar to the lava unless two neighbouring volcanoes are simultaneously erupting, (c) the lava breaks off pieces of the rocks through which it passes, and (d), the lava engulfs fragments of its own cooled crusts through kneading, while moving forward. According to Cooke, the first three possibilities produce only a negligible amount of the world's flow breccia, "in fact, instances of flow breccia in which the fragments are unlike the matrix, are so few as to be negligible" (1931, p. 45).

The writer is not prepared to state whether these statements may pass unchallenged so far as the world as a whole is concerned. But within the Duprat area, which is included in the region discussed by Cooke, the nature of the flow breccia indicates that strenuous objection must be raised to the general assumptions underlying Cooke's idscussion.

In the first place, the writer encountered numerous rhyolite flow breccias in which the fragments are commonly indistinguishable except on a polished fresh surface. The fragments are either round, or sub-angular, and small enough to be seen in thin section. Though they have a rhyolitic composition very similar to the matrix, they possess a different texture; some are coarser and other finer grained than the matrix, and many have an entirely different colour than the matrix on both the polished and rough surface. Similar slight, but distinctive differences between some fragments in rhyolite and the matrix, have been noted by Wilson (1941, pp. 12, 13). The differences in some thin sections become evident to the observer only after comparison with a polished surface, and some of the fragments are recognized only by a thin film of sericite around the margin. The igneous nature of the matrix is indicated in the writer's opinion by its finely intergrown character, similar to genuine rhyolites and intrusive acid porphyries, the presence of quartz and feldspar phenocrysts, and rarely, by amygdules. It is remarkable that, if almost all of the flow breccia originated in the manner postulated by Cooke, the rhyolites should contain ubiquitous fragments of other rhyolites which are in some, though not in always obvious fashion, different from the matrix, as shown by the texture and colour. The fragments in the rhyolite flow breccias, as conceived by Cooke, should contain fragments of the identical rhyolite, and should therefore be distinguishable only by a boundary between the particles. The angularity, and fine brecciation in much of the rhyolite is surprising, and should be Cooke's criteria suggest a pyroclastic origin. This reasoning applied to the Duprat rhyolite breccia leads only to the unattractive conclusion that the rhyolite belts are mainly rhyolite agglomerate.

Characteristics of flow breccias at variance with Cooke's hypotheses are also found in the andesites, and dacitic or trachytic flows, as well as in rhyolites. In Lots 50 to 60, Range VIII, in the north east part of Range IX, and the western part of Range VII, Duprat Township, there are abundant examples of flow breccias that contain angular, round, and ribbon-like fragments that are decidely different from the matrix. In some localities, the matrix is andesite, in others rhyolite, and the igneous nature is easily proven by the presence of amygdales or vesicles. The examples cited have not all been examined under the microscope, but the hand specimen shows that many fragments have a much different texture, and different quartz or feldspar content than the matrix. Many weather white, and are more vesicular or harder than examples are toopromientn to constitute the ngligicle fraction of flow breccias in which the fragments differ from the matrix, of which Cooke speaks. It is a curious fact that the actual difference between the fdagments and matrix, where such is the case, or the apparent difference, as seen on the weathered surface, has excited so little comment where flow breccias in this region have been described. That some hard, white weathering fragments resemble the matrix under the microscope has been noted by R. Robinson (1938, p.40) from Beauchastel township. In describing andesite containing flow breccia from the vicinity of the Waite Mine, Wilson states that the brecciated structure and other variations seen on the weathered surface are indiscernible on the freshly broken surface (1941, p.12). Much more work is required to explain how the striking differences apparent on the weathered surface of indubitable flow breccia can be reconciled with the apparent homogeneity of fresh samples.

Wilson, who made a careful study of the brecciated rocks in the Waite and Amulet areas adjacent to Duprat Township, described several examples of breccia in which diverse fragments are found, and in most cases (1941, pp. 20, 21) applied critical criteria to distinguish between flow and pyroclastic breccia, - a distinction which he admits is not always easy to make. He states that where the breccia is intercalated with stratified tuff, it is almost certainly of pyroclastic origin, and where it contains phenocrysts, vesicles, flow lamination, etc., it is obviously flow breccia. He has also, however, used the heterogeneity of the fragments as evidence suggesting a pyroclastic breccia, where the material is not stratified, and has noted that in the pyroclastic breccia the fragments are more closely packed than in flow breccia. With regard to the heterogeneity of fragments, it may be noted that this criterion depends implicitly on the assumption that flow breccias have fragments similar to the matrix. Contradictory evidence has been cited by the writer for both minutely brecciated rhyolites, and coarse flow breccias. With regard to the close packing of fragments, Wilson himself, as well as the writer, has described rhyolites that are minutely brecciated. If these doubtful criteria are rejected, convincing proof for flow breccias requires fluidal characteristics in the matrix, and for pyroclastic breccias, stratification, and the definite absence of igneous characteristics in the matrix. It is in the dubious cases, where reliance must be placed on negative evidence, that the problem is acute. It appears that even in the absence of stratification Wilson has been reluctent to call heterogeneous breccias with a fragmental matrix, flow breccias, although in justice to this investigator it must be stated that he has left the question open, in regard to breccias that occur on the Chadbourne property, the south end of the Tusty Ridge andesite, and around Waite Lake. (1941, p. 13, 14, & 10 resp.) The writer does not mean to imply that Wilson errs regarding the origin of breccias which he has called pyroclastic on the basis of positive criteria, such as those around the city of Rouyn, the southern part of Rouyn area, and the northeast part of the Newbec sheet in Dufresnoy Township, to name but a few examples. It is suggested however that much of the breccia called agglomerate or tuff, on account of its angularity, heterogeneity, and absence of amygdales or phenocrysts, may yet prove to be flow breccia except where it is obviously stratified.

The remarks of Patton concerning flow breccia in Colorado, are interesting in this connection, (1915, p. 399) He states that Iddings misapplied the term flow breccia to coaly, as lava, plastic enough to flow when welded together. In such a breccia the fragments are the same as the matrix. But Whitman Cross, who coined the term flow breccia, after mapping in the Telluride Quadrangle, Colorado, used it in a much different sense to describe : -

> "apparent tuffs of rather indistinct character, many of which were found to be flow breccia, that is, a rhyolite flow holding so many fragments of andesite that the fluidal matrix becomes quite inconspicuous, and cannot be seen with the naked eye..... The fragmental character is most evident near the bottom of the band, and in several sections, a massive flow with many inclusions - a flow breccia follows without any clearly defined line of separation; in fact some specimens collected to represent gravelly tuffs, were found on microscopic examination to be flow breccia" (Cross, 1899)

Other examples of flows holding fragments of dissimilar composition are described by Cross (1905, p.7) and Crawford (1913, p. 176). This description by Cross could apply very well to the dubious andesite and rhyolite flow breccias in many parts of the map-area, especially in Duprat Township. It serves to show that the generalizations of Cooke regarding the heterogeneity, abundance of fragments, and close packing are not sufficient proff of pyroclastic origin, but that the fluidal nature of the matrix must be established or rejected as Wilson did, in some cases. The distinction between pyroclastic and flow breccia is most important when the length and continuity of the period of volcanic extrusion is considered. If the breccia bands is the lava belts from Ranges 1 to x, Duprat Township are correctly interpretated as flow rather than pyroclastic breccia, the succession of extrusives must have formed a continuous series deposited without hiatus or marked change in conditions over a length of time sufficient to build up a thickness of about five miles of lava, of which about one half is brecciated rhyolite.

<u>Summary</u>

Three different types of flow breccia, occurring in lavas ranging from rhyolite to andesite, are described. Their characteristics and those of the pyroclastic rocks in the area described below, are summarized in Table III. Attention is directed to the fact that the use

TABLE III

FLOW AND PYROCLASTIC BRECCIA IN THE DUPRAT AREA

FLOW BRECCIA	Fragments	Matrix	Distinguishing criteria ,remarks
	reddish-brown finely banded crusts with whitish margins	lava	igneous characteristics of the matrix. Fragments the same composition as the lava; more common in rhyolite, dacite than in andesite.
Blocky breccia	angular, sub-rounded or elongate, coarse to fine, rimmed rarely unrimmed	mixed lava and fine fragmental material	no sorting, rude alignment in flow planes, vesicles between fragments; common in rhyolites, also in other lavas; heterogeneously mixed with massive lava
Ropy breccia	white, vesicular, sinuous, elongate	ropy, laminated reddish brown weathering	lamination in the matrix, occasional vesicles; more common in the andesites.
PYROCLASTICS	light weathering, vesicular, coarse to fine, sub-rounded to angular	buff, fine, tuffaceous, resembles matrix of andesite and some porphyry	interbedded stratified tuff, sorting occasional and crude; some resemble porphyritic lavas but contain fine green angular fragments of basic lavas.

of the term "flow breccia" in the Abitibi district, as for example by Cooke, has departed somewhat from its original meaning, and has been used in a restricted sense principally for those breccias in which the fragments are similar to the matrix. A danger inherent in the use of the restricted term is to consider that many flow rocks containing much heterogeneous breccia are pyroclastic though the non-fluidal character of the matrix has not been established. Critical criteria for the distinction between flow and pyroclastic breccia are reviewed, and it is suggested that much more flow breccia occurs among the volcanic rocks than previously realized.

Trachyte

Trachytes form a conspicuous belt extending through Ranges II, and III, Duparquet and Destor Townships. A narrow belt consisting of green dacites and pure grey trachytes has been outlined in the north part of Duprat Township. The total exposed thickness is about 5,000 feet.

The more northerly belt is a strikingly consistent, and therefore valuable horizon of intermediate intrusives. The trachytes are very pale buff to grey westhering rocks. The flows must have been extremely gassy, for in the pillowed sections, abundant vesicles occur inside each pillow, radiating toward the thin brown rims. Alteration of the interior has produced an emerald green core in each pillow, fading to bluish-green and then to white, toward the rim. In most pillows the entire interior is studded with white weathering quartz amygdules about one-quarter inch in diameter. This extraordinary weathered appearance also occurs in some of the massive flows. The characteristics are so marked that it has been possible to compare the pillowed trachytes immediately south of Destor Lake, with similar rocks forming isolated outcrops in

Lot 35, Range X, Duprat Township, about five miles distant. Examination under the microscope shows that the bluish-green alteration occurs where the rock has a felty, more or less opaque groundmass, containing very fine patches of chlorite, and dirty epidote.

Where the massive trachyte is not altered as described above, it is an uniform dense pure grey to greenish-grey rock, occasionally porphyritic. It possesses most of the structures of the andesites, but columnar jointage was not observed.

Of the trachytes examined under the microscope, four-fifths have a trachytic texture, as it is used in a general sense, and many of them are amygdaloidal. Few are porphyritic. They are all fine grained pilotaxitic aggregates of the essential minerals sodic plagioclase, and alteration products of former ferromagnesian minerals, such as epidote, chlorite, clinozoisite, and zoisite. Rarer constituants are opaque oxides, actinolite, sericite, and intergrowths of quartz and plagioclase. The extreme fineness of the matrix between microlites of plagioclase spaced from 0.06 mm. to 0.1 mm. apart, and the anhedral arrangement of all the secondary minerals, suggest that many of the rocks originally had a glassy base. Because the microlites are chiefly altered beyond recognition to an opaque saussurite, or sericite, they are recognizeable as plagioclase only by the idiomorphic outline rather than by optical tests. In less altered sections the maximum extinction measured against elongation indicates that the composition ranges from An_8 to An_{12}. Parallel alignment of microlites is visible in most slides, and a few penetrate intergranular areas of chlorite, suggesting that the latter mineral was formerly a pyroxene. Rarely the felty needles form criss-cross clusters intimately mixed with clusters of pale actinolite microlites in sheafs. Where phenocrysts of plagioclase occur, they form stellate groups cut by chlorite veinlets . They are frequently rhomshaped, well twinned, and make up 5% of the rock. Quartz forms round masses usually composed of several grains that are slightly biaxial, and bear many inclusions. They also occur in oval areas of chlorite up to 0.5 mm. in diameter, whose shape suggests former vesicles. Chlorite also occurs in smaller, irregular or cusp-shaped aggregates 0.06 mm. across which in spite of their abundance and close spacing, also suggests amygdules. The border of each small area of chlorite is a finely crystalline material, with a birefringence no higher than 0.008. It extinguishes in individual patches only 0.003 mm. across. Possibly those areas represent devitrified glass. The discovery by Graham of trachyte glass along the extreme northern border of the band in Duparquet Township, lends support to this view. According to Graham, the refractive indices of the glass, are comparable to those values on curves constructed by George, for glasses having the composition of trachyte. (1948, p. 27)

Many of the alteration minerals occurring in the matrix are also found in composite amygdules. Mention has already been made of the frequent occurrence of amygdules consisting entirely of quartz. Others contain combination such as; epidote and pennine; calcite, thomsonite, fresh albite and quartz in irregular intergrowth; calcite and quartz; prehnite and quartz; calcite, quartz, prehnite and sericite; calcite, clinozoisite and sericite. Of the alteration minerals only zoisite and actinolite have euhedral form. The former occurs as relatively large grains in chlorite.

Because the texture in the matrix is finer than in the andesites, and the secondary minerals more variable and finer grained, estimates of composition are not very accurate. In one fairly clear slide, the composition is: microlites of oligoclase, 59%; interstitial chlorite 19%; clinozoisite 9%; epidote and other minerals 13%.

Dacite

Within the map-area dacite has been grouped with trachyte in a band extending through Ranges VIII, and VII, Duprat Township, and separately in Lots 1 to 3, Range III Destor Township. Undoubtedly dacite also occurs at various points within the andesite belts, and possibly within the rhyolite group but the difficulties of recognition without microscope work, effectively preclude a nice subdivision.

In north Duprat Township the dacite weathers a dull greenish brown. The broken surface is a very light green, and bears amygdules of carbonates up to one-quarter inch in diameter. North of Destor Lake, the rock resembles trachyte on the weathered surface but the fresh surface is a darker, sea-green colour. Like the trachytes and andesites, the dacites possess many of the structures common to intermediate lavas. Under the microscope the dacites examined appear to have an imperfectly developed spherulitic texture in some places. Like the other lavas, the matrix consists entirely of fine grained secondary minerals without external crystal form, but the definite textures in the trachytes and andesites formed by the arrangement of plagioclase microlites are not visible. Subhedral individuals of quartz occur between occasional laths of feldspar. Phenocrysts of plagioclase are uncommon. The outline of some small laths is visible in radiating bunches of quartz and plagioclase, but in most places the texture has been obliterated by alteration. Sericite, chlorite, epidote, carbonate, and opaque oxides have all been noted in the matrix. One very dense felsic, pillowed rock from Lot 53, Range IX, Duprat Township has very small radiating growths of plagioclase microlites in a groundmass of anhedral grains of quartz and orbs of chlorite. No other minerals are present.

A coarse grained dacite north of Destor Lake contains dusted phenocrysts of albite (An_5) up to 0.63 mm. long, in a partly spherulitic, partly felty matrix. The phenocrysts form long laths, and stubby individuals. They are corroded. The composition of the rock is: 11% phenocrysts, 2% primary quartz, 37% feldspar (microlites), 17% chlorite and 33% epidote. That some of the quartz is primary is shown by its interstitial position between uncorroded plagioclase.

Amygdules up to 6 inches in diameter have been noted in the dacites, but the majority are small and well formed. They contain fillings of: granulated quartz and sericite; chlorite and sericite; and chlorite and clinozoisite.

Rhyolite

Rhyolites occur in two broad belts extending southeast through Duprat Township, but also around Dufresnoy Lake in Destor Township. Rhyolite lavas very much more widely in physical characteristics than the other lavas. That the variability of the group is due to the erroneous inclusion of rocks which should not properly be classed as rhyolites is an assumption not justified by the microscopic characteristics of the rocks. In thin section all these rocks prove to have a very simple mineralogical constitution, and the matrix consists simply of a very fine intricate intergrowth of anhedral sodic plagioclase and quartz, or a sperulitic intergrowth of the same minerals. In addition almost all the rocks are porphyritic and contain phenocrysts of albite, quartz or both, but phenocrysts of well twinned albite alone, are more common. They are the only plagioclase with idiomorphic form in these rocks. The intergrown matrix containing a high proportion of quartz, the small amount of ferromagnesian minerals or alteration products, and the occasionally well-developed spherulitic structure, indicate that these extrusives are acidic rocks, a fact confirmed by chemical analyses, as will be mentioned later.

The rhyolites normally have a carious white surface, pitted by the erosion of plagioclase phenocrysts. Brown, and green surfaces however, are not uncommon. The broken surface is hard and flaky, and a dark blue colour, but the colour ranges from white, through grey, to shades of green in different rocks. A comparison of sections from rhyolites of different colours, shows that the various shades may be controlled by what are thought to be slight, yet systematic, differences in the constituents of the matrix. The usual dark blue colour is common in those rhyolites that are altered and contain a small amount of chlorite and an opaque oxide well disseminated through the matrix in very fine grains. In these respects they resemble the "aporhyolites" from Pennsylvania described by F. Bascom. (1893) The grey rhyolites appear to have finely disseminated epidote, coated with iron (?) oxides, subordinate in amount to chlorite.

Where there is a greater properties of epidote, surrounded by little clumps of opaque matter, and less chlorite the rocks are greenish-grey, or pale green, while with an increase in both chlorite and dirty epidote, the rocks are deep green. Whitish to cream coloured rhyolites occur where the ferromagnesian alteration products are subordinate to the sericite developed by alteration of the plagioclase.

Phenocrysts of quartz contain trains of fluid inclusions unrelated to external form. Plagioclase phenocrysts are twinned on albite and Carlsbad laws, and in a few places are corroded by quartz. Though the phenocrysts are generally only visible under the microscope and average from 0.2 to 0.5 mm., exceptionally they are 2 or 3 mm. long and visible in the hand specimen. Except in spherulites the quartz and plagioclase in the matrix are never more than 0.1 mm. in diameter, and commonly not more than 0.022 mm. The accessory minerals pyrite, ilmenite, titaniferous magnetite and ferromagnesian constituents are rare. In one section a single grain of cross-hatched twinned feldspar, possibly microcline was observed. Potassic feldspar is rare or absent. Apatite was noted in only two specimens, and in both of these it is probably a secondary mineral introduced during metasomatism. Apatite occurs in clusters of euhedral grains in a sheared, sericitized rhyolite north of the Dalembert River, near the east boundary of Duparquet Township. Graham has shown by study of alteration up to 350 feet from schist zones connected with the Porcupine-Destor "break" that apatite is one of the minerals introduced during hydrothermal alteration. (1948, p. 121-124). The apatite in the deformed rhyolite is therefore probably derived from later solutions. A thin section of an irregular basified rhyolite from east of Duprat Lake, contains embayed phenocrysts of quartz, attacked by the matrix, and sericitized plagioclase in which the writer has noted frequent, but small crystals of plagioclase, apatite, and strongly coloured chlorite of an unusual type. The rhyolite does not lie far from the faults and ore deposits of the Waite-Ackerman-Montgomery section of Amulet Mines, and it is possible that this rock has undergone abnormal changes due to hydrothermal solutions.

All of the alteration minerals found in the andesites and trachytes are also found in these lavas. Deep green chlorite has been mentioned. Specular hematite is a frequent constituent along joint planes in the rocks, but also within the rock itself. Large amounts of coarse specular hematite occur in pits excavated in rhyolites in north Lots 27, 28, Range X, Destor Township.

In thin section, vesicles were observed in many rhyolites, and they are small. In the field however, cavernous vesicles up to 6 or 8 inches were noted in flow banded rhyolite. Small amygdules under the microscope are seen to consist of quartz, epidote, and chlorite, and veinlets of quartz and epidote are widespread.

The typical dark blue rhyolite consists of about 5% albite (An_7) in phenocrysts 0.5 mm. long. 90% intergrown matrix, containing sodic plagioclase and quartz in equal amounts, and about 5% chlorite, actinolite, and other products of alteration. Plagioclase and carbonate twinning lamellae show signs of post-crystalline deformation. Thin sections are traversed by quartz and sericite filled fractures. Curious

Curious crescentic shaped areas of chlorite contain orbs of an opaque oxide (magnetite?) rimmed with quartz, - a structure analogous to the quartz spheres seen in some andesites. (p. 59) Much rhyolite of this type outcrops in the eastern parts of Ranges V, VII, and VIII, Duprat Township, and south of the Dalembert River, near Lake 1, Duparquet Township.

Spherulitic rhyolite of the type described by Wilson from the Waite area, (1941, pp. 9, 11) occurs as a local variant within other rocks of the group, but forms a continuous and definite belt perhaps 300 feet wide, from Lot 32 to Lot 60, along Range Line, VIII-IX, Duprat Township. The white weathering surface is covered with pin-points resembling sago, or colites. The broken surface is dark-blue green, and translucent. Under the microscope the rock is seen to consist of about 75% closely spaced spherules, up to 0.5 mm. in diameter, 10% phenocrysts of sericitic plagioclase (An_8), a few phenocrysts of quartz, and 15% fine intergrown plagioclase, quartz, accessories and alteration products. Quartz phenocrysts are either mantled with a radiating intergrowth of quartz and feldspar, or they intersect the spherules, some, as far as the centre. Invariably surrounding each spherule is a thin border of chlorite. (- pennine) Where spherulites intersect, the complete rim of one, is preserved by obliteration of the rim of the other. Even when badly altered, they may thus be distinguished from intersecting vesicles.

With the exception of pillow structure and colour banding, all the structural and textural variations in the andesite are found in the rhyolite group. In addition to these features, the rhyolites in central and western parts of the Duprat section, and Lots 21, 22, Range II, Destor Township, are good examples of a feature peculiar to the rhyolites, namely flow banding. The laminae are either continuous over the entire lengths of some outcrops, or highly irregular, contorted, and discontinuous. It occurs in both the porphyritic and non-porphyritic rhyolites, and in the former, suggests the effusive origin of the rocks, in spite of the coarse phenocrysts. The texture in adjacent laminae is identical, but the laminae are discernible by differences in colour. White bands range from 1 mm. to 1 cm. wide, and alternate with pink, green or black bands, of similar widths. In places there is a continuous gradation from fine lamination to coarser discontinuous lamination, similar in every way to ribbon breccia.

Brecciated Rhyolite

The difficulty in distinguishing between flow and pyroclastic breccia, has been mentioned in connection with the andesites. Unlike the more basic lavas, breccia in the rhyolites is rarely confined to a distinct horizon, and is often completely invisible on the fresh or altered surface. Minute brecciation is apparent on polished surfaces, and under the microscope. The majority of the fragments are on inch long, or less, and either angular or round. They consist of all the varieties of rhyolite noted, and like the matrix are occasionally porphyritic. The borders are bounded by flakes of sericite and chlorite which help to outline the fragments in thin section. In places epidote, chlorite and actinolite occur in considerable amounts in the matrix. Euhedral crystals of quartz and relatively unaltered feldspar crystals occur in bunches. Many crystals are fractured and shards occur in the matrix, which however is not made up exclusively of fragments, and seems, where not too altered, to consist of some intergrown quartz and feldspar. Thus in spite of the apparent fragmentary nature of the matrix itself, there is little to suggest that the rocks are pyroclastic. In no way does the matrix resemble those of the indubitably pyroclastic rocks in Destor Township, to be described. Furthermore the brecciation is of such common occurrence, so indefinite in its limits, and irregular in its distribution, so obviously without sorting or bedding, that were the name rhyolite agglomerate applied to brecciated rhyolite, it would probably include most of the rocks mapped as rhyolite. The vixcous flowing rhyolites probably incorporated coarse and fine ejects, at various points in the flow, and the already solidified parts of neighbouring rhyolite flow through which they were forced. In this way the presence of fractures zenocrysts of quartz can be explained.

Some flow breccia is discernible in the hand specimen on the fresh surface. Most of the fragments are "cherty looking" rhyolite, having dark colours. Examples are to be seen at random points in the east end of the Smoky Hills, and in Lots 22, and 23, Range I, Destor Township, on the shore of Lake Dufresnoy.

In a few places, the tops of rhyolite flows contain regularly distributed, and easily recognized breccia. They range from the size of eggs, up to crusts a few inches wide, and 10 feet long. The latter are very hard, white weathering strips, in an amygdaloidal matrix. The best examples of this curious breccia were found in the south part of Lots 40 to 43, Range VIII, Duprat Township.

Figures 11 and 12, show the most well defined rhyolite flow breccia in the map-area. The sheared, yellowish porphyritic rhyolite forms a narrow belt in Lots 18, and 19 West Macamik Road Range. Quartz phenocrysts are visible in both the fragments and matrix, which are very much alike. The distribution of the angular fragments in both photographs shows plainly the lack of stratification and sorting. This rhyolite breccia also occurs around the east end of the prominent rhyolite hill west of Dufresnoy Lake, where it grades into a massive rhyolite, which, were it not for the occasional flow breccia, would appear to be intrusive, for it is uniform over a width of 800 feet across the strike, and devoid of flow structure, although Buffam (1925, p. 89c) reports having seen flow characteristics in this rhyolite.

Pyroclastics

With the exception of some narrow, discontinuous bands in Ranges IX and X, Duprat Township, tuff and agglomerate occur entirely in the Duparquet and Destor sections, mostly along the axis of a syncline outlined in Range II, Duparquet Township. The main band is 2,400 feet thick, and dips vertically. Minor lenses of pyroclastic intercalated with lavas outcrop to the north and south. The great thickness of continuous pyroclastics in the upper part of the syncline therefore represents a culmination in explosive activity, and relative quiescence in extrusion flow activity until one half mile of pyroclastic rocks had been built up.

On the mapping scale used tuff and agglomerate could not be separated with facility on outcrops of considerable widths, due to the number of intercalations. Most of the distinctions on Map A, refer to narrow bands on small outcrops therefore, and the wider outcrops in the pyroclastic horizons are labelled "tuffaceous agglomerate".

All of the pyroclastics have a weathered surface, which when regarded from a distance is a buff, or purplish cream colour, and can thus be distinguished from the darker reddish-brown "older gabbro". In the field the pyroclastics could be divided into mixed tuffs, crystal tuffs, and agglomerate, all of intermediate composition. Under the microscope lithic, crystal and some vitreous tuffs were distinguished. The last term is not strictly applied, for the fragments suspected of being glassy shards are now devitrified. Only the finer grained matrix of tuffaceous agglomerate was examined microscopically, and the composition of the larger fragments was determined in the hand specimen.

Agglomerate

The principal rock type occurring in thicknesses of 500 feet or more is a tuffaceous agglomerate. On the west side of the Duparquet section it is intercalated with pillowed flows and contains chert bands a few inches wide, every few feet. Almost everywhere the agglomerate is bedded, and there is some evidence of size gradation. The gradation is not uniform across the strike of a particular band, but individual rows contain fragments of surprisingly uniform size.. The absence of uniform grading, and the limitation in the size of the largest fragments in a particular row are characteristics confirming the observations of Cooke. (1931, p. 32) Figure 13 illustrates this arrangement, and Figure 14 shows the limited amount of gradation that occurs at the bottom of some bands. Many of the easily visible fragments are white weathering pitted volcanic rocks up to fist size. It is a curious fact that while agglomerate is generally assumed to be angular, and flow breccia fragments are assumed to be rounded, here the agglomerate fragments up to the size of an apple are generally more rounded than flow breccia of corresponding dimensions. The clastic origin of the agglomerate is made obvious however by the bedding, or by the intercalation with bedded tuff.

The bulk of the agglomerate has an intermediate composition corresponding to trachyte or andesite. Although the hard white siliceous fragments appear to be prominent the more easily overlocked intermediate material predominates, and consists largely of andesite or other intermediate intrusives. In general it may be said that the composition is fairly consistent over the entire length of the belt in Duparquet Township. The most common easily visible fragments of megascopic dimensions are a quartz-feldspar porphyry, and a greasy, white to grey weathering felsitic rock containing abundant fine vesicles. Several examples examined in thin section show that it is a very fine grained amygdaloidal intermediate rock which is nearly opaque under ordinary light due to the deep brownish overcast on extremely fine alteration products in the matrix. Some epidote and zoisite in grains about 0.002 mm. across occupy altered feldspar microlites that can be identified only by their form. (See Fig.15) The amygdules are almost entirely quartz though some contain a little chlorite. This felsitic grey amygdaloidal rock resembles some of the gassy underlying trachytes, which possibly are the source of the material. In addition to the two main constituents, there are other fragments consisting of; small blebs of rhyolite, quartz pebbles, porphyritic andesite, andesite, and crystals of feldspar (albite-oligoclase) but the last are more common in the uniformly fine tuffs. Some of the andesite fragments in thin section contained twinned fresh locking plagioclase microlites (An 23 ?) in a translucent groundmass containing the usual chlorite, dirty epidote and other alteration products, with minor opaque oxides and some apatite. The last mineral must be secondary, as it crosses the boundaries between fragments. One vesicular andesite contained cusp-shaped areas of quartz, much chlorite, and amygdules with a chlorite centre, and a coxcomb quartz rim. In general, the alteration in the rock fragments observed in the pyroclastics is of the same degree as in the surrounding lavas.

Rhyolitic rocks are preponderant in the agglomerate only in two places. The first is a point on the north shore of Lake Dufresnoy, Lot 17, Range II, Destor Township. The second, is near the axis of the syncline along the Dalembert River, Duparquet Township. Here, the weathered surface has a striking appearance. Angular, to subrounded, glistening white felsic rhyolite fragments (see Fig. 16) are embedded in a powdery, brown, more basic matrix.

The fresh surface of the rhyolite appears identical to that of the massive rhyolite on top of the agglomerate in this locality All the fragments are fissured by cracks that do not extend into the matrix, and both fragments and matrix are cut by quartz veinlets.

Very coarse agglomerate that may be a vent breccia outcrops in the extreme north part of Lots 1 to 3, Range III, Destor Township. It consists of closely compacted fragments of recrystallized tuffs, older agglomerate, vesicular andesite, blocks consisting of pillowed andesite up to 12 feet in diameter, rhyolite with quartz amygdules, flow banded rhyolite, and trachyte. Coarse grained intrusive rocks were not noted. All structures and textures are well preserved, and there is very little fine matrix. The peculiar absence of recognizeable vent breccias has commanded the attention of Wilson (1941, p. 57) who suggests that most of the volcanic extrusives must have come from fissures rather than cones. The great thicknesses of pyroclastic rocks in some places suggests however that vents should be present in the Abitibi region even though their undisputed presence has not been reported by workers aware of this problem. Wilson has described some doubtful examples. In the vent breccia examined by the writer, the material is unsorted, and the matrix consists of fine pyroclastic material. The breccia is bounded on the bottom or north side, by pillowed lava, and the contact is not exposed. On the south it is intruded by quartz-porphyry, so that the relations are obscured. Flows outcrop east and west of the lenticular mass of breccia. The shape, so far as it can be deduced is neither triangular, or conical, and does not resemble descriptions of vent breccias. The extreme coarseness of the blocks suggests however that this mass of breccia, if not actually in a vent, lies close to the source of the explosion which accumulated it.

Tuff

Though less abundant than agglomerate, fine to coarse grained tuffs have a wide distribution in the pyroclastic belt, and their frequent cross-bedding makes them valuable horizon markers. They extend for 10 miles along the axis of the syncline in the north part of the map-area, and are prominent along the shores of Dufresnoy Lake. A few bands of tuff, none over 10 feet wide, appear interbedded with rhyolite in Range IX, Duprat Township.

All the tuffs weather a pale greenish-brown where the material is fine, and a buff where the lapilli are coarse. The fresh surface of the fine tuffs resembles that of greywackes, and sheared andesites, while that of the coarser tuff is invariably light grey..

Fine tuff was not examined microscopically. It occurs in bands rarely more than 10 feet wide, and has a ribbed appearance on the weathered surface due to the slight differences in resistance of adjacent laminae. In the southeast corner of the Destor section, one band of extremely fine futtaceous, phyllitic greywacke occurs in cross bedded tuffs. The presence of bedded tuffs interspersed throughout the entire section of agglomerate shows that deposition must have proceeded intermittently in bodies of standing water.

Coarse mixed crystal and lithic tuffs occur at various places in the area, but uniform crystal tuffs, - so uniform that they resemble porphyritic rocks - outcrop in a wide band in Range I, Duparquet Township, and along the east shores of Dufresnoy Lake. Crystal tuff fragments in a tuffaceous agglomerate on the large hill west of Lake 1, Duparquet Township resemble the crystal tuff matrix in which they are embedded so closely, that the broken surface of the rock appears almost uniform.

The crystal tuff contains abundant crystals of quite altered greenish-yellow plagioclase in a grey matrix. The feldspars in some slides are zoned. They are poorly bedded rocks, which can be distinguished from the porphyritic andesite by the occasional small angular fragment of dark green rocks. The description by Cunning (1941, p. 18, p. 75) of crystal tuffs from the Blake River group around Rouyn Lake 15 miles to the south, except for the presence of quartz grains, matches the rock just described.

Under the microscope the zoned crystals of plagioclase, which comprise up to 40% of the rock are zoned and cracked in places, and most of them are so altered to calcite, epidote, zoisite, quartz and chlorite, and are so covered with brown stains that determination of the composition is generally impossible. Some are albite, but others may lie in the ranges An_{14-20}, or An_{31-43}. Since calcite feldspars are rare in the volcanic rocks, most of the plagioclase is probably sodic. The feldspars are cut by minute veinlets of chlorite. Between the crystals, very pale chlorite is a common constituent. It forms ovals, irregular crescents, or is shapeless. In places it is intergrown with a quartz mossic, elsewhere it contains secondary albite, and perfect replacement of parts of a tabular crystal of feldspar was noted. The oval areas may be amygdules in fragments whose outline is not now recognizeable. Possibly the crescent shaped areas, in which chlorite is intergrown with some mineral resembling quartz, are devitrified shards. Quartz is a highly variable constituent and forms mossics with non-uniform extinction, strongly suggesting a secondary origin. Epidote in grains up to 0.1 mm. occurs in all slides. Rarer constituents are sericite, carbonate, zoisite, ilmenite, hematite, apatite, and fibrous emphibole. The rocks are cut by criss-crossing veinlets of fibrous tremolite; thomsonite; or albite and quartz.

Alteration of the Pyroclastic Rocks.

Tuff and agglomerate have undergone alteration which is in part, unrelated to regional alteration, and may be described here.

On the dragfolded hill, west of Lake 1, Duparquet Township, the tuff along the border of a gabbro-diorite sill 1,000 feet thick weathers a lighter colour than usual over a distance of 50 feet from the Contact. Veinlets of quartz form a projecting mesh on the weathered surface, and the matrix of the rock seems to be slightly silicified, but this cannot be confirmed for it was not examined in thin section.

Adjacent to the quartz and feldspar porphyries in Range III, Lots 1 to 7, Destor Township, the agglomerate has been considerably altered. The changes may be traced from a normal agglomerate outside the zone of alteration, through areas where the outline of fragments becomes less, and less distinct, where the weathered surface becomes whiter, harder, and more hackly like that of some rhyolites; and where the colour of the fresh surface changes from dirty green to a dark blue with the appearance of fresh-looking feldspars in both fragments and matrix. Unfortunately all the changes could not be studied in detail. One thin section examined at a distance of about 10 feet from what was thought to be true igneous porphyry, may correspond to some of the changes noted by Graham, who studied in detail the alteration along the large masses of feldspar porphyry in Range IV, Duparquet Township. (1948, p. 151).

"Porphyritized" agglomerate as described by Graham, contains porphyroblasts in both fragments and matrix, of one or more of the following minerals: - quartz, chlorite, apatite, sericite, titanite, and carbonate. The thin section examined by the writer, prepared from a specimen which resembles feldspar porphyry, shows that the rock is not homogeneous, for parts of the section must be described separately. There is one area which contains much more chlorite than the rest of the slide. The chlorite is compact, and dense green, and reentrant on all sides, some of which are concave circular arcs. The outer periphery is separated from the centre by a narrow band of quartz. Some of the concave sides of the chlorite nearly enclose spherical masses of secondary quartz choked with inclusions, giving rise to indistinct optic figures. A few feldspars (albite?) crowded with inclusions are similarly enclosed. In the area of predominant chlorite there are also fibrous radiating groups of prehnite. The matrix of this part consists mainly of an intergrowth of plagioclase and quartz, and subhedral, untwinned larger altite crystals, which are surrounded by a clear rim. They contain euhedral apatite, which elsewhere in the slide occurs with clear epidote. Except for the area containing the concentration of chlorite, which seems to be a metamorphosed fragment, the rest of the section has no easily describable texture, and consists mainly of dusted sericitic albite crystals containing apatite, chlorite along cracks, areas of calcite mantling or surrounding new twinned albite, and epidote in small brown grains. All the idioblastic minerals, and those forming relic structures lie in a very fine grained matrix that may consist of feldspar and quartz.

The relic structures, such as the fragment, and the crescentic areas of chlorite show that the rock is not an altered porphyry. The development of apatite, veinlets of carbonate, quartz and albite; and the new quartz and feldspar in the matrix all testify to the hydrothermal nature of the alteration which pervaded the rock. The absence of pyroxene or amphibole shows that no great temperature was reached. All the evidence favours the conclusion that the rock was steeped in solutions emanating from the porphyry.

CHAPTER V

MINOR INTRUSIVES

Under minor intrusives are grouped all the generally narrow, tabular bodies with regular contacts, that intrude the volcanic rocks, the "older gabbro", and the granite complex. Because exposures of cutting relationships are scarce, and because dykes of different ages have similar compositions, the intrusives can be dated positively only with respect to the youngest major rock type intersected. Thus there may be as many as three different ages, namely: - (1) post-volcanic and pre-diorite ("older gabbro"), (2) post-diorite and pre-granite, and (3) post-granite. Correlation using petrographical characteristics over more than a short radius is not considered reliable, because, in addition to having very similar constitution, the minor intrusives of different ages are all fine grained rocks containing similar alteration products, as shown on page .

It has been shown that in the area surrounding the Waite Amulet Mine, that at least two different ages of intrusives are represented, separated by the "older gabbro" [1]. Wilson (1941, pp. 41, 44) has divided the younger group into those which are older and younger than the granitic intrusives, but nowhere has he cited any evidence which shows that some of the dykes described as cutting the "older gabbro" are definitely older than the granite. It is possible therefore that two, and only two age groups of minor

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[1] For cutting relationships, see Geol. Bur. Can. Maps 455 A, 454 A, and 457 A.

intrusives exist in the area, and that all intrusives younger than the "older gabbro" are also younger than the granite. Similarly, among the intrusives mapped as post-volcanic - pre-diorite, there may be some which are much younger. In recent mapping the writer found one dyke which appears to be older than the granite complex, the evidence for which is presented in another part.

Nomenclature

The use of the terms rhyolite, andesite, and basalt to describe many of the minor intrusive rocks is not in strict accord with systematic igneous terminology. The terms were apparently first used in this region, long ago by M.E. Wilson (1913, p. 43) for dykes with the same mineralogical composition and texture as the corresponding extrusives, with which a genetic connection was implied. Later Cooke, James and Mawdsley, in their comprehensive memoir on the Rouyn-Harricana region used "basalt dykes", and "rhyolite" dykes, to refer to intrusives believed to occupy the channels through which the corresponding lava rose to the surface. (1931, p. 27) Though the terms have not come into general use since that time, they have not been abandoned. Within the Noranda district, Wilson has continued to use the names, unfortunatly, not only for old, narrow aphanitic dyke rocks similar in texture and composition to the flows, with which they are presumably connected, but also for later dykes cutting the "older gabbro" and the granite. It is highly unlikely that these later dykes are related to any of the lavas now exposed, and considering their narrow widths, at the level exposed, it is unlikely that they were the channels for later Precambrian extrusives now removed by erosion, which may have once piled up to a great thickness over the present surface. Thus a term such as "andesite dyke" in this district cannot pretend to imply that a genetic connection with an extrusive is recognized, and it refers simply to a fine grained intrusive. The usage is inconsistent even if it is only intended to imply fineness of grain, for some of the corresponding flow rocks have medium grain. Although this lack of precision is regrettable, the writer is impelled to adopt the terminology of Wilson, who mapped adjacent areas, for convenient correlation of the older minor intrusives. For the sake of consistency, the later minor intrusives are also referred to by the name of their extrusive equivalents, since they are similar in most respects to the older "feeder dykes".

Minor Intrusives Cutting Keewatin-Type Rocks

Quartz-Diabase

Throughout all parts of the map-area, there are various lenticular or irregular intrusive bodies of dark brown weathering, fine-grained basic rocks. These rocks are considered to have been originally basic, because the hand specimen shows that the dark minerals are greatly in excess of the light coloured constituents, and while those examined in thin section contain sodic plagioclase, there is an abundance of epidote and chlorite. Ophitic texture is well preserved.

None of the dykes was traced very far, and over short distances it is practically impossible to tell whether these intrusives have been folded with the lavas, especially in the gently deformed section of southeast Duprat Township. Some of the dykes in the north part of the area, have sheared contacts, and they are known to curve in an irregular manner. Others are exposed as rectangular or wedge-shaped areas in the horizontal surface of steeply folded volcanic rocks.

The broken surface of these rocks is very dark, and stained bluish along fractures which commonly are filled with yellow epidote. In thin section, the twinned plagioclase laths, which may range from albite to oligoclase (An 18), are mainly occupied by a saussurite in which there is much carbonate, and possibly sericite, and newly formed albite individuals. Quartz occurs as angular interstitial masses between laths, and as round grains enclosed in the plagioclase. It is difficult to estimate that proportion, if any, of the quartz is primary. Intergrown sericite, the latter representing altered feldspar forms patches in a few places.. The alteration product epidote is well crystallized, and clear of the opacity found in some flows. Carbonate and sericite vary greatly in proportion. Chlorite is the most abundant coloured mineral, and constitutes 50% of one slide. Magnetite and ilmenite are occasional accessories, which in some places occur as dendritic or pseudo-graphic intergrowths with the chlorite.

<u>Diabase</u>

One glistening, black, fine-grained diabase dyke cuts across a diorite dyke intruding rhyolite on an outcrop 500 feet east of the second most southerly bay on the east side of Duprat Lake. It merits separate description because it is the only intermediate to basic rock out of one hundred examined under the microscope, which contains calcic plagioclase. The mineralogical constitution is very simple, and the rock consists of equal amounts of relatively clear labradorite (An 57) laths enveloped in a matrix of hornblende and diopside remnants, and little clumps of pyrite and magnetite surrounded in places by hematite stain. The hornblende is in part derived from the pyroxene, as it grades into uralite in places. It contains nodules of epidote. The hornblende is probably in part derived by a reaction involving the plagioclase as well, since it occurs as very fine green bands along or across cleavage cracks in the labradorite, and it appears to have corroded both sides of plagioclase laths to such a degree that the reentrants on opposite sides meet in some places.

This rock resembles a true, altered diabase from the point of view of composition, more than any other intrusive in the area, and it is probably much younger than the cutting relations suggest.

Andesite

Dykes of andesite, with chilled margins, striking in sets trending east, northwest, and a few other directions, are abundant. They attain widths of 100 feet, but the majority are much narrower. Dips observed in the southern part of the area are steep to vertical. For some unexplained reason these dykes are more numerous in the rhyolite belts than in the andesites. Possibly they are connected with massive flows in some of the andesite belts, and therefore do not transect the andesites. They are all greenish-grey weathering rocks with a green broken surface, and are hypidiomorphic fine grained aggregates comprised of 40% plagioclase (oligoclase ?) quite saussuritized, and pyroxene, or alteration products obviously derived from the pyroxene. The remainder consists of anhedral quartz, altered ilmenite, pyrite, and finely disseminated opaque oxides, and small amounts of sericite or carbonate. The few vestigial remnants of pyroxene (augite) seen are mantled by chlorite (pennine), fibrous actinolite and biotite in places. One dyke in Lot 53, Range IX, Duprat Township exhibits rings of pyrite up to 5 mm. in diameter on the broken surface. The pyrite is probably secondary, and its habit may have been governed by vesicles in the dykes.

Diorite

Quartz diorite may be distinguished from the preceding andesite dykes by its proportionately coarser grain, and darker colour, and from the diabase by the absence of ophitic texture. So far as known these dykes occur only in the vicinity of Duprat Lake, from whence but one specimen was examined microscopically. The rock is a hypidiomorphic, medium grained aggregate of fairly fresh oligoclase; clear crystals of euhedral epidote in subhedral hornblende derived from pyroxene now completely transformed, chlorite, and skeletal ilmenite. A small amount of quartz is interstitial to plagioclase laths, but most of it is entirely surrounded by secondary minerals such as chlorite, and is probably secondary, a surmise supported by the presence of small amounts of myrmekitic-looking intergrowth.

Quartz-Feldspar Porphyry

A porphyritic quartz-feldspar dyke only four feet wide intrudes basic rhyolite a little north of the Duprat Lake shore, in Lot 49, Range IV, Duprat Township. The grain size is surprisingly coarse, and the weathered surface is studded with nodules up to 6 mm. across, that prove to be spherulites under the microscope. The broken surface is bluish grey. In thin section, euhedral quartz phenocrysts, making about 10% of the rock, are fringed by spherulitic intergrowths which penetrate and corrode the quartz crystals. Albite-oligoclase (An 10) phenocrysts up to 3 mm. across comprise 5% of the rock. They have very patchy polysynthetic twinning that resembles perthitic intergrowth, and many are rimmed with spherulitic intergrowth of quartz and plagioclase. The intergrowth constitutes 40% of the rock, and the balance consists of equal amounts of quartz and albite forming a sutured mossic. Chlorite is rare, and ilmenite, occurring in small grains is mainly altered to leucoxene. While the quartz mossic in the matrix may be secondary, at least one third of the total quartz, - that which forms the altered phenocrysts, must be primary. The extreme coarseness of grain in such a narrow dyke, compared with dykes of similar composition suggests that the source may be close at hand, and it is possibly genetically related to the granite complex on the other side of the lake.

Rhyolite

Dykes of rhyolite are not so common as andesite but they have been observed cutting both rhyolite flows and andesite. There seems to be no significant difference between the composition of these dykes, and the flow rhyolite or the younger "rhyolite dykes". Around the Waite and Amulet properties, acidic dykes are very numerous. Some of them resemble the rhyolites described here. Others are slightly more basic porphyritic rocks that form the centres for composite dykes with basic selvedges. Actually, even the most uniformly textured dykes are porphyritic on a microscopic scale, and many of these dykes are property described by the local, and correct names "quartz porphyry" and "feldspar porphyry". The rhyolites are all white weathering rocks with a grey broken surface. They consist of 0 to 15% quartz phenocrysts ranging from 2 to 4 mm. in length; about half this amount of smaller plagioclase phenocrysts (An 10); in a granular groundmass of quartz and sericitized feldspar too small for determination by optical tests. In places micro-pegmatitic intergrowths occur in the matrix, and mantle some of the phenocrysts. Generally no coloured alteration products are present, and only a small amount of carbonate (dolomite ?) and a few scattered grains of opaque are the only other constituents. In a few places however, the rock contains rare epidote and chlorite, and one dyke in Lot 30, Range IX, Duprat Township contains so much chlorite and epidote that it appears to be very basic, though it contains quartz phenocrysts. The rocks are cut by chlorite and sericite veinlets.

Composite Dykes

Composite dykes which occur in profusion around the Waite-Ackerman-Montgomery (now Waite) Mine, and whose numbers diminish in all directions from this locus, have been fully described by Schindler (1934, pp. 20-22, 103, et seq.) and need only be mentioned here. The dykes are multiple layers of acidic porphyries and diabasic aphanites. Locally they have been aptly named "sandwich dykes". The acidic member is invariably younger. The acidic phases weather slightly pink, whereas the basic phases are the colour of the andesites and diabase. Schindler (1934, p. 7) and Wilson (1941, p. 40) state that the composite intrusives are older than the "older gabbro".

Minor Intrusives Younger than the "Older Gabbro"

Andesite

A few bifurcating, narrow dykes of andesite cut the "older gabbro" north of Waite Lake, Duprat Township, and in other places. Many of the dykes have quite irregular strike and dip, but invariably have chilled boundaries against the gabbro. The rocks seem to be similar in most respects to the andesite previously describec, and the minor differences noted here may not be universally characteristic. One slide consists of about 10% quartz phenocrysts, 50% saussuritized feldspar, and the remainder, alteration products including much chlorite. One dyke in Lot 32, Range VIII, Duprat Township contains remnants of pigeonite moulded about the terminations of plagioclase. Cracks in the pyroxene are filled with chlorite. Epidote, large grains of zoisite, a little apatite, and scattered grains of magnetite also occur in the matrix.

Rhyolite

Rhyolite dykes cutting "older gabbro" were noted in Lot 53, Range V, and Lot 38, Range VIII, Duprat Township. The rock is identical with sericitic rhyolite dykes previously described, and suggests that these acidic dykes may have a common age. The feldspar in the groundmass, as well as the phenocrysts, is clouded with brown dots. An acidic porphyry cutting "older gabbro" in the Waite area has been reported by Wilson (1941, p. 40). This rock does not resemble the rhyolite dykes of the writer.

Minor Intrusives Younger than the Flavrian Granite

Among the minor intrusives, known positively by cutting relationships to be younger than the granite complex, are the satellitic dyke rocks, lamprophyre, "aplite", granitoid dykes; and rocks with less obvious kinship, such as rhyolite, andesite, and quartz diorite dykes. Most of these cykes are too narrow to be represented on the accompanying reduced scale map, except schematically. Their mutual age relationships are unknown. The aplites, andesites, and diorites seem to have a preferred orientation, as described in the section on the structure of the Flavrian granite. Data on the other dyke rocks are too few to justify any conclusion about their orientation, and attitude. All of the dykes have relatively straight chilled contacts with the granite.

Lamprophyre - Field Relations

Biotite, pyroxene, and hornblende lamprophyres outcrop in the southern part of the area. None was observed north of Range V, Duprat Township, but Wilson states that a minette occurs in the interior of the peninsula jutting into Dufresnoy Lake. (1913, p. 90) The lamprophyres seem to be distributed both in and around the major acidic intrusives of the area. These cutting the Flavrian granite and the Lac Dufault granodiorite resemble, in every way, other lamprophyres found intruding the volcanic sequence. The rocks occur as dykes ranging from

3 to 50 feet wide. Because they weather easily, their relief is low, their cohtact relationships are only rarely observed, and they are not easily traceable along the strike. One biotite lamprophyre in Lot 41, Rante IV, Duprat Township was traced for 1,000 feet. The dykes strike in all directions. Their dips are generally vertical or steep. A lamprophyre cutting andesite in Lot 50, Range VI, Duprat Township dips 40° west. The few contacts seen were straight and regular, and the dykes had chilled margins.

Due to alignment of biotite plates, some lamprophyres show a slight foliation in the hand specimen. The margin of a hornblende lamprophyre has a linear arrangement of dark minerals parallel to the contact.

"Pebble" Lamprophyres

In this area, as elsewhere within the "Gold Belt", some lamprophyres contain "pebbles" of different rock types. A dyke cutting the granite was observed to carry pebbles of syenite, granitic rocks, and greenstones. In addition, one dyke bears a few rounded fragments of rosy quartz up to three quarters of an inch, in diameter. The pebbles are sparsely distributed, and do not appear everywhere along the dyke. The origin of the inclusions has been discussed by several writers who have found pebbles, but no satisfactory conclusion seems to have been reached.

Robinson, (1941, p. 46) using the St. Helen's Island breccia, near Montreal, as an example to show the diversity of fragments that may be caught in a diatreme, and their possible migration up, and down a pipe, suggests that the diversity of pebbles in the lamprophyre dykes of southwest Duprat Township may be due to similar causes. He proposes that the brecciated fragments were rounded through erosion against the wall rocks during migration.

Cunning and Ambrose have suggested that mechanical abrasion of fragments in the magma seems unlikely, (1940, p. 39)

> "due to the relatively small number of 'pebbles', the slight differences in specific gravity between them and the magma, and the cushioning effect of the viscous liquid."

The density of the writer's lamprophyre is 2.84, that of the surrounding granite 2.73, and the greenstones in the vicinity average about 2.80. Assuming a specific gravity of 2.65 for the quartz pebbles, it does not seem as if any of the pebbles could have sunk in the lamprophyric magma unless it was considerably less dense than the solid of the same composition. On the other hand, it does not seem conceivable that a lamprophyre in a granite massif, bearing greenstone pebbles, could have derived them from below. Cunning and Ambrose assume that the pebbles are breccia fragments torn from the walls of the conduit, and rounded by partial melting or chemical reaction. They fail to find any reaction rims or transfusion phenomens, however. In the writer's examples, fluidal alignment around pebbles, or reaction phenomens are absent.

Mackenzie (1941, p. 16, 17) has described a lamprophyre dyke which can be traced very close to adjecent Cobalt conglomerate. Drift obscures contact relations, but the dyke contains a large angular mass of conglomerate. Little contact alteration is apparent in the photograph accompanying his description. Mackenzie has suggested that the dyke may have derived rounded fragments of diverse rock types from the conglomerate. This hypothesis accounts wall for the shape and diversity of pebbles, but it is difficult to imagine how lamprophyres ever came into contact with disintegrated conglomerate, as no lamprophyric flows have yet been reported. Conceivably the lamprophyric magma might have disrupted Cobalt conglomerate and incorporated round pebbles from that rock. In general, there are serious objections to all the theories presented here. The undeniable presence of 'pebble' dykes, forces however, acceptance of the imperfect and unsatisfactory hypothesis that fragments derived from somewhere along the dyke walls, have been incorporated, and rounded by the magma, without visible alteration either to themselves or to the surrounding magma.

Rock Types

The eleven lamprophyre dykes observed are all soft, dark weathering rocks. Golden brown biotite may be seen in many hand specimens. Microscopic examination shows that all the rocks have penidiomorphic, granitoid texture. They are fine grained aggregates of either dominent amphibole, or dominant biotite, with pyroxene and plagioclase. In the classification of Grout (1932, p. 124) they may be divided into kersantites, spessartites and camptonites.

In the first two types, pyroxene occurs in stout euhedral crystals and varies from augite to a diopsidic pyroxene with Z to c equals 37°, and moderate optic angle. Biotite occurs in well formed plates with fretted ends. It is pleochroic in shades of green and brown, and much of it is altered to chlorite minerals and small grains of epidote. Anhedral feldspar forming the groundmass, occurs in untwinned sheaves. It ranges from calcic oliboclase to albite. A small amount of moiré twinning suggests that some potassic feldspar may be present. Most of the feldspar is quite altered to calcite and sericite. Small needles of a metamorphic, pale green amphibole occur in the matrix. Apatite in euhedral prisms, and small wedges of sphene are occasional accessory minerals. Pyrite and magnetite, both altered to rusty oxides occur in all slides. The rock is cut by fine epidotic seems 0.5 mm. wide. One spessartite comprised 34% pyroxene, 12% biotite, 43% feldspar, and 1% accessory minerals.

The hornblende camptonite is similar in many respects to the rocks described. The plagioclase occurs however in small euhedral tablets in a mesostasis that may have originally been glassy, but which now contains a very pale chlorite mineral, interstitial quartz, and some isotrophic material. That the compact hornblende was formed from pyroxene is shown by the presence of augutic crystals uralitized in varying degree. The amphibole crystals are slightly larger than the feldspars, and give the rock a porphyritic appearance. Many of them contain some biotite. The rock resembles camptonites described by Wilson (1941, p. 43) that cut lavas east of the map area.

A different, more acidic, green weathering lamprophyre outcrops along the southern margin of the area in Lot 45. The rock consists of about one-third chlorite in anhedral shreds, one-half carbonatized feldspar, arranged in sheaf patterns, and one-sixth subhedral quartz, and alteration minerals, such as epidote. The chlorite, which may have been derived from a pyroxene has a particularly vivid 'ultra blue' interference colour. (- penninite ?) Some faces of the quartz are idiomorphic toward chlorite, but it is invariably moulded on to large plates of carbonate, but preceded the formation of chlorite from pyroxene. Hematite, a little sphene, and apatite are rare accessories.

Age

Within the area some lamprophyres are younger than the granite, and they resemble others cutting the older volcanic rocks. They resemble lamprophyres which cut the Lake Dufault granodiorite, whose age relative to the Flavrian granite is not known. (Wilson, 1941, p. 42). Robinson reports that pre-granite lamprophyres occur in the Flavrian Lake area, (1941, p. 46) while others cut the syenite, which has been shown to be younger than the granite (Gussow, 1937, p. 160). It is thus possible that some lamprophyres may be pre-granite, while others may postdate the granite, granodiorite, and syenite, or even the Cobalt sediments, since Mackenzie has shown, as previously mentioned, the existence of Cobalt rocks in the dykes.

Aplite and Granite Dykes

Pink weathering, sugary textures aplite dykes ranging from a few inches up to six feet wide abound in the granite complex. They cut all parts of the mass including the brecciated border facies. One section, under the microscope proved to be a well developed panidiomorphic aggregate of about equal amounts of quartz and albite (An 5) in rounded grains. The albite contains a few quartz grains and is partly altered to sericite. Slightly altered microcline in blocky prisms is a rare constituent. Accessories consist of small needles of biotite in common association with minute amounts of actinolite and epidote. Sphene and magnetite are scarce. Granophyric intergrowth around plagioclase is widespread, but not so abundant as in the albite granite or the dykes described next.

Granite dykes cutting the basic facies of the complex were not examined under the microscope. One dyke cutting the quartz-poor soda-diorite near Lot Post 36-37, Range Line III- IV, is a coarse grained light weathering rock with grains of quartz and feldspar up to 1 cm. in diameter, and some epidote.

White weathering, granular, alaskite dykes are not so common as the "aplite". One section examined consisted of 10% quartz and 90% granophyric intergrowth of quartz and plagioclase (An_{14}). Pseudospherulitic texture suggested by the weathered surface proves, under the microscope, to be due to the extreme development of radiating, graphic intergrowth around plagioclase grains, or former grains which are penetrated and corroded by the growth of central blastetrices of quartz. The common optical orientation of the graphic quartz changes at the outer coronae surrounding old plagioclase crystals, where the graphic texture becomes finer. Original large quartz grains in the rocks have penetrated the small amount of plagioclase not graphically intergrown with quartz. Rare sericite, and an opaque mineral are the only other constituents.

Rhyolite

Pale brown, or white weathering felsitic rocks, that bresk with conchoidal fracture and have a greasy grey fresh surface, intrude the granite as narrow dykes with glassy margins. Thin sections show that these rocks are quite similar to pre-granite rhyolite intrusives and flows. They consist of about 1% phenocrysts of quartz and feldspar in a matrix of intergrown quartz and albite in the proportion 3 ::: 5. Actinolite, a little magnetite, and sphene are present in some sections.

Diorite and Andesite

The andesites are soft, fine-grained green weathering rocks, no different from older andesite dykes. The diorite differs from the andesite in having coarser grain, and from the "later gabbro" (diabase) in that it forms only narrow, non-persistant dykes in the granite. Under the microscope the rock is seen to be an ophitic aggregate of idiomorphic plagioclase, in anhedral pyroxene, or their alteration products. Quartz, some of which is in graphic intergrowth with the plagioclase amounts to 5%. Alteration minerals are chlorite, clinozoisite, and epidote. Apatite and an opaque mineral are rare accessories.

Porphyritic Meta-Diorite

Unusual dioritic rocks occur on then north shore of Dufresnoy Lake, Lot 26, Destor Township, in Lot 18, West Macamik Road Range, and as intrusion in the rhyolite west and east of Dufresnoy Lake, Range II, Destor Township. In the first locality the diorite is an isolated mass; in the second it intrudes sheared rhyolite; in the third it occurs as small dykes up to 10 feet wide, in schistose rhyolite.

The narrow dykes appear to be vertical, and have chilled margins. One mass changes abruptly from a concordant sill in sheared, vertically dipping rhyolite, to a dyke crossing the schistosity nearly at right angles. It is cut off by a west north-west striking fault. The walls of one sinuous dyke are mildly sheared, in contrast to the highly schistose host-rock. The first and second occurrences mentioned appear to be free from deformation. These facts suggest that the porphyritic diorite may be later than the folding of the lavas, and the schistosity developed by the folding, but may antedate or be closely contemporaneous with later faulting.

The rocks all have a soft brown weathered surface, pitted by the erosion of feldspar phenocrysts. Where the phenocrysts are small and scattered the broken surface is a dark blue colour. Where abundant, yellowish, zoned feldspars up to one-quarter inch in diameter are set in a dark green matrix, the rock has a " salt and pepper " appearance.

Two sections of the diorite examined under the microscope were seen to be fine grained granular aggregates of stubby, euhedral albite (An 6) phenocrysts in a matrix consisting mainly of quartz, epidote and chlorite. Phenocrysts of feldspar make up 10% to 50% of the rock, and are quite altered to sericite and a little epidote. The granular matrix has a crushed appearance, and were it not for the intrusive character of the rock it could easily be mistaken for a recrystallized tuff. Granular quartz in slightly biaxial grains up to 0.2 mm. with crenulate borders forms about one quarter of the matrix. Larger quartz grains have interlocking borders with epidote, and chlorite (pennine) and much smaller quartz grains. The chlorite and epidote are abundant, and make up 20% to 35% of the rock. In places the matrix is very fine grained, and appears to contain some slightly altered feldspar as well as the other minerals. The Grains of epidote are clear, and many are rimmed with chlorite. Apatite in good euhedral prisms, cubes of pyrite, and sphene are scarce accessory minerals. Some of the pyrite occurs in the feldspar phenocrysts and must have been one of the first constituents to crystallize.

Because the phenocrysts are undeformed, it is not likely that the rock has been crushed and recrystallized. The slightly corroded boundary on albite phenocrysts, where it is in contact with quartz in the matrix, suggests that the quartz is either a late crystallizing constituent, or that it was introduced while deuteric alteration proceeded during alow cooling.

The rock is termed porphyritic diorite, because although the phenocrysts are albite, and the matrix contains considerable quartz, the high proportion of epidote and chlorite, presumably derived from pyroxene or amphibole, suggest that the rock originally belonged to the diorite clen. So far as known, no identical rocks in the Abitibi region have been described. Thin sections of a porphyritic diorite described by Norman (1947, p. 5) were examined by the writer, and are in no respect similar. The rock resembles however, a dacite porphyry occurring in southeast Duprat Township, which has been described by Wilson (1941, p. 42). The proportion of ferromagnesian minerals in the latter rock is not stated, and the dacite porphyry differs in having euhedral plagioclase in the groundmass. A diorite porphyry described by Cooke (1931, p. 107) from the Opasatika area and the Larder Lake area (1922, pp. 43-44) has well formed albite phenocrysts, but further resemblances are unknown, because the constituents of the matrix are incompletely described.

CHAPTER VI

MAJOR INTRUSIVES

"OLDER GABBRO" GROUP

Quartz Diorite, Diorite, Gabbro, Quartz Gabbro, Quartz-Keratophyre and Amphibolite.

Of the major intrusives, the "older gabbro" probably outcrops over a greater area than the other prominent intrusives of the map-area. In north-east Duprat Township, rocks of this group comprises over one-quarter of the exposures. As mentioned earlier, the name "older gabbro" was used by Cooke, James and Mawdsley to designate those intermediate intrusives that intrude the Keewatin-type rocks, and that are probably younger than the folding. (p. 13) Within the map-area, Wilson has shown that the "older gabbro" is younger than part, if not all, of the folding. The term covers a wide variety of intermediate to siliceous rocks ranging from gabbro to albite-hornblende-quartz rocks, and even albite granite. In places in the Noranda district, the phases grade into one another in such a way as to suggest that they are derived from a common source magma. Elsewhere siliceous diorites and more unusual rock types occur as separate, isolated intrusices, and it is not easy to discern to what age group they belong. Some phases may be of slightly different age, but the possibility that some of the "dioritic" rocks are separated by long periods of time, and have decidely different kinship, cannot be overlooked. The genetic, structural, and time relationships of all the rocks presumably belonging to this group, in much of the Abitibi region, are imperfectly known, and the consenguinous ancestry suggested by the grouping is not everywhere proven. Because the rocks have a relatively simple mineralogical composition, it is possible that several different ages of "gabbro" of the same composition occur throughout the area. This difficulty was recognized long ago by Cooke, et al. who pointed out that there was no alternative to grouping all the so-called dioritic intrusives together until such time as some more positive criterion proved to be a reliable, and distinctive feature, (1931, p. 109) The problem is well exemplified in the map-area, where Cooke and others, (1931, p. 109) recognize four ages of "older gabbro", and Wilson, but one. (1941, p. 27) As it is frequently impossible to tell, from published reports, just what is implied by the terms "gabbro", "diorite", etc., all the characteristics of the various rocks in the Duprat area, belonging to this group are summarized.

Rocks of the "older gabbro" group outcrop as sills, dykes and irregular masses up to one-half mile thick. The wider, or thicker, intrusions are very irregular, but narrow dykes and sills up to 50 feet wide have straight and regular contacts. Due to the common sill-like form of most of the gabbro, and the greenish weathered surface or the finer grained varieties of diorite and gabbro, considerable difficulty attends their separation from older andesites, their "feeder" dykes and sills, minor andesitic dykes, (see p. 102) and the "later gabbro" (diabase) dykes. Numerous observations in the map-area suggest that the following characteristics are useful in separating the "older gabbro" from other intermediate intrusives.

1. Unlike the later diabase dykes, the grain size in the coarse grained gabbro is extremely variable, and changes over distances of a few feet. Clumping of grain is noticeable in many places.

2. Both coarse and fine-grained phases are intruded by numerous pegmatitic segregations, that occur as pods and dyklets with one straight and regular boundary and one irregular boundary.

3. Joints up to 2 inches wide are costed with cellular, rusty, honey-comb quartz, and iron oxides.

4. Unlike the later diabase dykes, the chilled contact weathers a brown or grey, rather than black, colour.

5. The gabbro is cut by younger phases of the same composition, many of which are phorphyritic in places. These younger phases are regular tabular bodies, or more commonly highly irregular multiple intrusives, with successive chill contacts against the preceding intrusive.

6. Except where it is quite altered, the fine grained gabbro can be distinguished from the andesites by the apparent fresh appearance of the broken surface - an illusion produced by the texture rather than absence of alteration.

7. Small, discontinuous granitoid aplitic veinlets containing some pinkish feldspar are seen on the broken surface of some hand specimens.

8. Even in the narrower gabbro dykes the grain size increases relatively rapidly from the salvedge to the middle.

9. So far as known, the "older gabbro" is the only intermediate intrusive which has some gradational contacts with the adjacent rocks.

LITHOLOGY

According to Wilson, (1941, p. 26) the greater proportion of the "older gabbro" in the Noranda District is a diorite containing small amounts of quartz. Plagioclase renging from oligoclase to labradorite, and hornblende are reported. Within the map-area, because of the widespread alteration of the plagioclase in these rocks, they are termed gabbro or diorite if the ferremagnesian mineral is mainly pyroxene or hornblende respectively. According to this division there is more gabbro and quartz gabbro, than diorite.

Diorite

Both the field appearance, and the composition as seen under the microscope indicate that the diorite does not differ appreciably from that to the southeast, which has been amply described by Wilson. (1941, pp. 26-32)

In many places the diorite may be distinguished from the gabbro by the dark grey colour of the weathered surface, the grey fresh surface, and the needle-like form of the ferromagnesian mineral. Arborescent or plumose amphibole is well developed, and north of Waite Lake it ranges up to several feet in length. Even in the more uniform phases along the centraline of Duprat Township it ranges up to three inches long. The weathered surface of the diorites is much smoother than that of the gabbros. Except for an occurrence in Range II, Destor Township, and narrow dykes in Duparquet Township, most of the diorite occurs along the east side of the Duprat section, and north of Nora Lake. In some of the smaller intrusives pinkish feldspar is noticeable.

Under the microscope, the coarse to fine-grained typical diorites are seen to be hypidiomorphic or ophitic aggregates of about equal amounts of saussuritized, twinned, plagioclase in partly corroded laths, and an amphibole which may be either uralite or actinolite. Quartz is occasionally present and makes up 5 to 10% of the rocks. It occurs in both triangular interstitial masses, and in graphic myrmekite intergrowth with plagioclase. The myrmekite in a few places encroaches on the plagioclase, indicating with little doubt that part of the quartz is secondary. Accessory minerals are long, euhedral prisms of apatite, biotite, pyrite, ilmenite, and magnetite. Vestiges of augite, mostly evergrown with uralite, and having slightly bent cleavage cracks occur in some slides.

The plagioclase is altered to a dense saussurite. Where determinations of the composition are possible, the feldspar seems to lie in the range An_{0-18} to judge from the refractive index and () sign of the birefrimgence, although extinction angles suggest a calcicity of about An 39. Biotite forms small reddish-brown rosettes, and is not widely distributed.

Alteration minerals are common. They have no shape. They consist of leucoxene, epidote, chlorite (- pennine), and a little sericite. One specimen from Lot 31, RangeII, Destor Township, contains a large amount of zoisite in clear crystals, and more calcic plagioclase (An_{51}). The chlorite occur along cracks in the pyroxene, and uralite, but is widely developed in separate patches between pyroxene and feldspar.

Gabbro

The gabbroic intrusives differ from the diorites in some respects both in the hand specimen and their microscopic appearance. Unlike the needle-shaped amphibole in the diorites, pyroxene in the gabbro occurs in shorth, stubby, or blocky prisms. This gives the fresh surface a salt-and-pepper appearance, and the weathered surface is dotted with rusty rectangular pits where the pyroxene has weathered. Pegmatite phases are not so prominent, and the grain size is more uniform. Compositional bending is more common in the gabbro, insofar as this area is concerned. Instead of the ophitic texture seen in some of the diorites, the broken surface of the coarse grained specemens has a hypidiomorphic equigranular texture.

Gabbro is more prominent from Range IX, Duprat Township, northward to the limits of the area. In Range IX and X, Duprat Township, and on the drag-folded hill, Range II, Duparquet Township, the gabbro is banded. Dark-green layers half inch wide consisting mainly of coarse-grained pyroxene alternate with white weathering feldspathic bands. Coarser bands up to 6 inches wide in the gabbro contain either light coloured concentrations of feldspar, or dark pyroxene. The bands are generally straight and follow the strike of the contacts. In Lot 43, Range X, Duprat Township, one outcrop of gabbro displays banding, intersecting at an oblique angle to, and truncating, earlier banding.

Yellowish-green epidote stringers one-half inch wide are straight or curved and cut the rocks at all attitudes. Thin joints filled with white "bull" quartz are common. Veinlets of scapolite and antigerite striking N. 70° E. south of the west part of the Dalembert River have been noted. Epidote, chlorite, and amphibole form pods up to several feet long. Open vugs one-quarter to one inch wide, partly filled with epidote, chlorite and quartz occur in many places. Mauve axinite has been found along joint planes and generally disseminated through the rocks, west of the Macemik Highway north of the

Destor Lake lumber road, and also at many points in Duprat Township. The joint coatings, cavity minerals, and veinlets all testify to the late hydrothermal activity associated with the gabbro.

The typical gabbro, under the microscope is seen to consist of a variable proportion of coloured minerals slightly in excess of feldspar, all of which are covered by, or interspersed with a mass of alteration products such as those found in the diorites. Pyroxene is the prominent mineral, and makes up to 45% of the rock. The plagioclase is more or less completely altered to a fairly coarse "saussurite" containing epidote, amphibole, quartz, fresh albite, actinolite, brownish stains, opaque material, and microlites of zoisite. To judge from the amount of dark constituents, which make up to 60% of the rocks, the gabbro must have been at least normally basic, but though calcic plagioclase is to be expected, determinations on some of the relatively unaltered interiors of saussuritized grains shows that it has a composition of about An_3. In some slides, chlorite areas adjacent to feldspar fill corroded embayments in the albite. The pyroxene, which is augite (?), pigeonite, or diopside, varies in its degree of preservation. The pyroxene is variably overlain by a bastitic actinolite, or partly altered to chlorite, with which small amounts of red biotite are associated. In some slides the only alteration undergone by pyroxene, is the filling of the cracks with antigorite and carbonate. Small masses of epidote occur in the uralite growths. Apatite is relatively scarce in the gabbro. It occurs enclosed in all the other minerals. Opaque accessories noted are altered ilmenite, in graphic intergrowth with chloritized amphibole, and some pyrite.

Quartz Gabbro, and Quartz Keratophyre

In Range IX, Duprat Township, at several localities along the Dalembert River Township, and on islands in Dufresnoy Lake, very quartzose, fine to coarse-grained gabbro has been noted. These rocks weather a little lighter than the other phases of the "older gabbro", but have the same generally brown speckled and pitted surface. The fresh surface is a light speckled green colour, fairly hard, and it displays glassy quartz up to 1 mm. across. A medium grained specimen from Lot 44, Range VIII, has the composition; saussuritized plagioclase, 40%; pyroxene 30%, quartz 5 to 10%; and the remainder actinolite, epidote, chlorite, calcite, apatite, biotite, secondary quartz, and opaque oxides. The feldspar which occurs in idiomorphie, tabular crystals ranging from 0.2 mm. to 2 mm. across has an indeterminate composition. The low refringence and (+) birefringence suggests that it lies in the albite-oligoclase range. Augite, though fairly well preserved in plates moulded around the plagioclase laths, is cut by veinlets of antigorite, and in a few places is altered to bastite (?). Tramolite, and actinolite are invariably associated with a little biotite and chlorite, suggesting that all these minerals were derived from the pyroxene. Calcite plates mantle water-clear quartz occurring in rounded and reentrant grains. Quartz also occurs as angular patches interstitial to the altered feldspar, and in a graphic myrmekite growth with the feldspar. The myrmekite has the cuneiform appearance in places common to growths of potassic feldspar and quartz, but optical tests show that it has a (+) birefringence in the altered feldspar sections, which, allied with the saussuritic appearance of the feldspar, suggests that the feldspar is more likely plagioclase.

The quartzose gabbro grades into more siliceous rocks, containing an even larger percentage of quartz, much of which is in myrmekitic intergrowth with plagioclase. The ferromagnesian mineral content is correspondingly reduced. The examples studied occur on the drag-folded hill, and around the Dalembert River, west of Lake 1, Duparquet Township, but it is quite possible that they occur at other localities of important gabbro intrusion. That the rocks are probably silicified equivalents of the "older gabbro" is suggested by the close resemblance to the transitional quartz-gabbros described above, and their occurrence as scattered outcrops within broad belts of gabbor. In thin section they appear to be composed of about 66% altered sodic plagioclase and quartz, mostly intergrown, and about 34% pyroxene, biotite, hornblende, magnetite and alteration products. The pyroxene makes up to 25% of the rocks. Secondary apatite is prominent but constitutes a megligible percentage. It occurs in quartz, chlorite, and within the graphic myrmekitic intergrowth of quartz and plagioclase. The proportion of the quartz and plagioclase involved in intergrowth is variable, and where the feldspar is free of quartz it occurs in stubby euhedral crytals, embedded in slightly smaller ferromagnesian minerals and their alteration products. These rocks have been named quartz-keratophyres, as they approximate these rocks described b Holmes as albite-oligoclase rocks containing some pyroxene, and having an orthophyric groundmass. (1923, pp. 131-132) The hornblende present is obviously derived from the pyroxene. Some actinolite occurs in fibrous blades. Epidote and clinozoisite form euhedral crystals. Biotite forms up to 5% of the rocks. In the myrmekitic varieties it is invariably found with amphibole in the altered plagioclase of the intergrowth. Plates and stringe of carbonate cut across the myrmekite, and penetrate saussuritized plagioclase. Skeletal magnetite encloses some of the myrmekite. The siliceous nature and coarse grain of these rocks aid materially in illustrating the possible sequence of formation of the alteration minerals, and thus provide some clue to the elucidation of the metamorphic puzzle of the map-area.

That the graphic myrmekite is the result of replacement of sodic plagioclase by later quartz is evident from; (1) the way in which the intergrowth penetrates the long side of plagioclase laths; (2) the way contiguous, corroded ends of plagioclase crystals are surrounded by intergrowth, and penetrated by gourd-shaped canals containing the growth; and, (3) the presence of blobs of quartz within the laths. Associated reaction of the original plagioclase is shown by the clear, thin albite rim that surrounds some of the euhedral laths of saussurite. Although there may be no great time interval between the introduction of the different alteration products, the following sequence may be established from the relationships in thin section: -

1) Introduction of quartz in solutions sufficiently volatile for the formation of late apatite, and myrmekite.

2) Reaction and corrosion of the plagioclase.

3) Saussuritization of the plagioclase (excluding the theoretical possibility that the feldspar was first altered, and then intergrown with later quartz without losing its euhedral form).

4) Later introduction of carbonates (calcite) and quartz and albite, forming little veins cutting across all other products.

The significance of the pene-contemporaneous formation of the saussurite-carbonate-albite alteration will be mentioned in connection with the regional alteration. (p. 223)

<u>Variation Within a Gabbro Sill</u>

A section of a vertically dipping gabbro sill in Range XX, Lot 49, Duprat Township, is exposed from wall to wall. The south (lower) side weathers a light buff, which grades to a dark brown on the north side. The colour of the fresh surface does not change so perceptibly, but, ranges correspondingly from light to dark green. Three thin sections of the gabbor taken from the leucocratic (bottom) member, the transition zone and the dark member were examined. The light coloured gabbro consists of quite saussuritized plagioclase and relatively fresh diopside. The latter is out by chlorite veinlets (+ pennine) the alteration products olinozoisite, sericite and leucoxene are rare. The rock is cut by quartz-albite veinlets. In the transition specimen there is no furhter change in the feldspar, but the amount of pyroxene diminiches, and the chlorite channels in it are correspondingly wider. In the dark coloured rock at the top of the sill, the pyroxene content is about the same as in the preceding slide, but it contains reddish brown biotite as well as chlorite, now in broad branching, dendritic cracks. The plagioclase laths are discernible by their cutline only. They contain biotite, much epidote, and fine scaly brown products.

If the differences in alteration reflect differences in the original composition of the upper and lower parts of the sill, brought about by slight gravitative differentiation or rising volatile constituents, our conception of the age of the gabbro must be radically changed for the sill would have had to be emplaced and altered before tilting. Since apophyses of adjacent gabbro sills cut across the strike of the vertically dipping pillow lavas and are not sheared so far as can be seen, this does not seem likely. It must be concluded that the gabbro was intruded and altered after folding took place. The changes could have been brought about by autometamorphism during cooling but it is difficult to account for the preferential development of biotite near one vertical wall of the sill. The phenomenon was not observed in other biotite bearing sills of the area.

Younger Members of the Gabbro Group

Later non-porphyritic members of the gabbro have chilled contacts against the earlier phases, but are similar in composition and degree of alteration. Ophitic and diabasic textures are more pronounced due to the finer grain of these intrusives, many of which are narrower.

Porphyritic dykes containing yellowish phenocrysts of plagioclase up to 6 mm. across have been observed. These dyklets are up to one foot wide, and have a felsitic base. The matrix is so altered that little can be learned from thin section examination.

Coarse-grained pinkish aplitic dyklets less than six inches wide have been observed in north Duprat Township. Because the feldspars are so altered, it is impossible to ascertain whether the pink colour is due to the presence of potassic feldspar. The proportion of the minerals and the type of alteration they have undergone are similar to the main gabbro masses.

Field Relations of the Gabbro Group

The larger dioritic bodies, as seen in plan on the maps[1] show both conformable and cross-cutting relationships, such that there seems tobbe little doubt that the diorite is truly intrusive. On the other hand, the gradational nature of some of the diorite or gabbro contacts is very peculiar, and is open to several interpretations.

Gradational Contacts

Along the west margin of the diorite in Lot 60, Range VII, andesitic lava grades directly into what appears to be dioritized andesite, and thence into diorite. That the adjacent rock was originally andesite is shown by the presence of small amounts of breccia and amygdules up to 6 inches in diameter, filled with chlorite. The rocks are cut by large masses of pink quartz and epidosite masses up to 6 feet in length.

In Lot 61, Range X, Duprat Township, gabbro adjoins pillow lava. There is no chilled contact and the gabbro contains curved bands resembling the concentric lamination seen inside the pillows of some andesites. Further north in the same locality the weathered surface of the diorite is distinctly irregular. Siliceous curved fractures enclose lenticles that are much whiter, finer grained and more siliceous then other parts of the rock. It is thought that these

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1 see for example the Waite Sheet No. 455A, 1939, Geol. Sur. Can.

enclosures are altered breccis, not completely transformed to dioritic rock like the containing matrix.

At the intersection of the Duprat Township centre-line and Range Line VI-VII, no contact can be placed between the diorite and andesite. A thin section of rock from the transition zone resembles the common quartz-diorite. The plagioclase looks fairly fresh, and is dusted with brown dots. Chlorite vesicles are noticeable.

North of the Fourcet Creek road on the south side of the large swamp, there is one outcrop of coarse-grained diorite that grades insensibly into pillow " lava " in which the textures are so well preserved, that top determinations are possible; yet the grain size within the pillows ranges up to one-quarter inch in diameter.

All of the features mentioned above suggest that at certain localities adjacent to intrusive masses of " diorite and gabbro " , intermediate volcanics have been " dioritized ". Alternatively, all the " gabbro " at these localities may be metamorphosed andesite.

Sharp Contacts

The constacts between rhyolite and gabbro are sharp and unambiguous. The gabbro commonly has a chilled margin.

Where the gabbro adjoins brecciated andesite, the contact is nowhere more than a thin yellowish line, and the shill is not noticeable. In places the contact cannot be located by a line, but only by differences in texture and colour of the weathered surface of these rocks. In a few places the contact between diorite and breccia is obscured by deformation, and numerous cracks along the contact are filled with white quartz.

Quartz-Amphibolite

Amphibolitic rocks tentatively included in the " older gabbro " group intrude sheared rhyolite in Lot 27, Range I, Destor Township. Large masses of pyrite occur along the oxidized contact of the two rocks. The intrusive is mainly a medium grained melanocractic quartz-hornblende rock, containing a widely variable proportion of pink feldspar. At one point on an outcrop the feldspar and quartz content increase so greatly that over a distance of ten feet the rock is a white weathering granite with little or no dark mineral, A few apophyses of the granitic material invade the rhyolite. Elsewhere there is very little feldspar in the rock, which consists mainly of gleaming black crystals of amphibole and glassy quartz, with an uneven texture suggesting that the rock is brecciated. It is possible that the composition of the intrusive was consederably altered by the inclusion of basic material. Chlorite and carbonate coatings were observed along a fracture plane in a pit in the intrusive.

This highly variable rock, grading from granite to quartz amplibole is grouped with the " older gabbro " on account of its variability and average intermediate to basic composition. It is quite possible however that the rocks are related to (1) the later Lake Dufault granodiorite described by Wilson (1941,p.32), or (2) to the Lake Dufault intrusive complex or the Cléricy granodiorite described by Cooke et al., (1931, pp. 118-125) or (3) that it is a basic phase of an unexposed major granitic complex such as the Flavrian granite, all of which have a considerable number of highly variable amphibolitic intermediate phases.

Age of the " Older Gabbro "

Cooke has pointed out that there is much more older gabbro in the western Townships of Abitibi, such as Dasserat, Montbray, etc., and that the igneous activity apparently dies out about 25 miles north of Opasatika Lake, and 30 miles east of the Ontario provincial boundary. He also points out that although none of the gabbro has been seen to intrude the Temiskaming (type) conglomerates, the structural relationships (1931, pp. 108-110) show that it cuts actoss the folding involving the Keewatin and Remiskaming rocks. It has been pointed out in the introduction to this thesis that this conclusion may be subject to some revision (p. 12) due to the more recent opinions concerning the age of the folding of the Temiskaming rocks. In Duprat Township, the gabbro has been shown to be later than the folding which deformed the lavas of the Abitibi Series.

However it is possible that some of the gabbro lying in the extreme north east part of the map-area, does not belong to this age group at all. Here the rocks contain more calcic feldspar than has been noted elsewhere. They lie near the boundary of Cooke's areal limitation of the occurrence of the " older gabbro ". According to Bannerman, this gabbro is merely a coarse-grained equivalent of the Keewatin extrusives. (1940, map) He distinguishes this gabbro from a later gabbro on the basis of the latter's association with pyroxene and peridotite (1940, p. 20) Bannerman ststes that the older of the two gabbros is chilled on quartz-porphyry, but its relationship to the Duparquet conglomerate is in considerable doubt. Whereas Bannerman considers the gabbro to be yo nger than the conglomerate, Graham working to the west of the Macamik highway, found that it appears to be older. If it is indeed older than the conglomerate, it possibly belongs to the gabbro group described by the writer from the Duparquet section of the map-area. Granting this assumption, the existence of a gabbro must be recognized that is older than the Temiskaming type conglomerate in Duparquet Township, older than the main faulting associated with the Porcupine-Destor " break," yet younger than the main folding or the sub-Temiskaming rocks. Obviously therefore, if this assumption which appears reasonable, is granted, the Temiskaming rocks have been involved in some folding, however gentle, which is superimposed on the previously folded volcanic rocks; and a period of intrusion separates the two periods of deformation.

It has been noted that in the north of the map-area, the gabbro is more prominent than Wilson's diorite. Although it has sill-like form, the crenulate segregation banding observed in the gabbro on the drag-folded hill clearly shows that the intrusive was drag-folded with the adjacent tuffaceous, agglomerate. Thus if the numerous gabbro sills traced northward, especially up to

Range IX, and X, Duprat Township are of the same age as the ubiquitous diorite and gabbro mapped by Wilson from the north part of Rouyn Township northward, then the age of the whole group may be placed nicely between the earlier folding of the Duprat volcanics and the cross-folding induced by dislocations subsidiary to the Porcupine-Destor " break ".

This conclusion is based entirely on petrographical characteristics of the " older gabbro " rocks throughout Duprat Township and cannot be regarded as firmly supported. Should it prove to be valid throughout this 13 mile section mapped for the first time in detail, the presence of sheared or unsheared gabbro should be of considerable assistance in dating the north-east ore-bearing faults in southeast Duprat Township, and Dufresnoy Township with respect to the major faulting and mineralization along both the northern and southern " breaks " It is significant to note in this connection that Wilson has described both highly sheared, and unaltered gabbro along some faults in the map-area. (1941, p. 30)

<u>Summary</u>

The " older gabbro " within the Duprat area comprises a group of highly variable medium to coarse grained rocks, consisting chiefly of pyroxene gabbro, and hornblende diorite but grading in places to granodiorite and even albite granite. Various phases cut each other. The group is probalby all of the same age, later than the folding of the Abitibi Series, but earlier than the main period of faulting. The conclusions are based on petrographic evidenc

TABLE IV

PRINCIPAL CHARACTERISTICS OF THE "OLDER GABBRO" ROCK TYPES IN THE MAP-AREA

Rock Type	Appearance of the Weathered Surface	Appearance of the Fresh Surface	Mode of Occurrence	Field Characteristics	Microscopical and Other Characteristics
gabbro	brown, pitted	speckled, green	dykes, sills irregular masses	uniform surface	equigranular texture apatite
diorite	dark grey, smooth	grey	dykes, sills	prominent amphibole needles, pegmatitic phases	ephitic to hypidiomorphic texture, such apatite
quartz gabbro	buff, pitted	light green, speckled	?	visible quartz	minor graphic intergrowth
quartz-keratophyre	buff, pitted	greyish-white sugary texture	?		hypidiomorphic texture myrmekitic intergrowth
albite granite	white	pink	irregular small masses		grades to diorite
quartz-amphibolite	dark grey	grey to black	irregular lenses	amphibole up to 1' long and so abundant in places that the rock is black	

Further investigation of the "older gabbro" by spectroscopic analysis is recommended in the hope that some slight difference in the content of trace elements, may be related to the field and petrographic characteristics of any particular member of the group over a wide area. The rpincipal characteristics of the members of the "older gabbro" group are aummarized in Table IV.

Quartz and Feldspar Porphyry

Major intrusions of quartz and feldspar phorphyry occur only in the northern part of the map-area, not far south of branch faults extending from the Porcupine-Destor "break". They are a relatively minor manifestation of greater igneous activity closely associated in space and time with the main fault zone to the north. The characteristics, and the many varieties of these porphyrics have been well described by O'Neill (1933, pp. 89-91). Bannerman (1940, pp. 11, 18) and Graham (1945, pp. 11-12, 1946, pp. 13-15, 1947, pp. 12-13, 1948, pp. 64-68) in other localities, and the description here refers only to the limited extent of porphyry observed in the area.

Both the quartz and feldspar porphyry are white weathering rocks, but where they are sheared or otherwise altered, they weather brown. Purplish to reddish patches in the rocks, especially near cracks, may be due to the oxidation of spangles of hematite. The fresh surface of the rocks is a sub-vitreous sea-green colour, on which phenocrysts of plagioclase or quartz up to 5 mm. long are visible. In the feldspar porphyry, the albite phenocrysts (An_{1-4})

are fairly clear, but they are traversed by cracks containing elongated patches of greenish epidote, and some of them are are dusted with fine brown dots. Rarely, they are clouded by flakes of sericite and carbonate. Quartz phenocrysts in the feldspar porphyry, are generally clear and whole, but some have hazy boundaries. A granular intergrown mixture of two minerals, probably quartz and feldspar fill reentrants and gourshaped corrosion cavities in both quartz and feldspar phenocrysts. The proportion of quartz and feldspar phenocrysts varies widely, even over the range of a small outcrop, so that the petrographic types cannot be easily mapped, but phenocrysts do not make up more than 15% of the rock. The groundmass, is a fine granular intergrowth of quartz and feldspar, with feldspar predominating, but in the feldspar porphyry there are spherulitic intergrowths of quartz and albite. Micrographic growth of these minerals may form a large portion of the matrix. Small tabular laths of albite are arranged in rude flow lines that band round the larger albite. Accessories in the matrix are apatite in stout, yet broken, prisms, and a small amount of an opaque oxide (ilmenite?). Alteration products attain a diameter of no more than 0.002 mm. They consist of brownish-yellow epidote, green amphibole intergrown with sericite, some actinolite, hematite, plates of calcite, very little chlorite, and a greenish mineral with a refractive index greater than quartz, and a variable birefringence, possibly a green (chrome) mica. Veins of calcite have been noted cutting across feldspar crystals, and granular quartz-albite veinlets traverse the slides.

Crescentic pods of granular quartz have been formed in some places. A few pods have a quartz rim and calcite centre, or rarely an albite rim, and calcite centre. One large opaque crystal was noted, in which carbonate occupies cavities. Though much of the carbonate may be calcite, one specimen of brownish weathering porphyry contains such a large amount of ferrous carbonate that the texture is obliterated.

The corrosion of the quartz phenocrysts, the replacement of parts of the rock by carbonate, quartz and sodic plagioclase suggest that the porphyries have been altered by hydrothermal solutions derived from an acidic, late-stage solution of the porphyry magma itself. The activity of such solutions in "porphyritizing" many types of country rock in the vicinity has been described by Graham. (1948)

Age of the Porphyry

Near contacts, and in narrow bodies, the grain size is correspondingly finer, and the characteristics of the rock do not permit easy distinction from intrusive rhyolite dykes, which the writer has found cutting older rocks in the district, especially within the rhyolite belts west of the Macamik Highway, and in Range II, Destor Township. The proximity to the "break" suggests that all the acidic porphyrics are genetically related, and contemporeneous with faulting which may have occurred over a considerable interval of time. The irregular manner of intrusion along fault planes, shear zones, and the shearing present in many of the porphyries all show the close relation with faulting. As there is no essential difference in thin section between the fine-grained quartz and feldspar porphyry, and the rocks described as intrusive rhyolite further south, some of which are most probably connected with volcanic extrusives, it is possible that only one age group of porphyritic intrusives exists in the north part of the area, and that here the rhyolite dykes are actually much later porphyries. Alternatively two or more intrusives of different ages exist, and they have been confused in places. The irregular shape of the intrusive porphyries, and their sheared nature does not positively distinguish them from rhyolite dykes because the latter are known to be both irregular and deformed in places. The only certain criterion is that thick bodies of the porphyry have coarser grain than bodies of rhyolite of corresponding size; and of course certain variants of the porphyry are distinguished by the presence of such unusual minerals as green mica, etc.

East of the Macamik Highway, in the Lépine Lake area, are two types of rhyolite intrusive as well as quartz and feldspar porphyry, that, so far as can be judged from the descriptions by Hannerman (1940, pp. 10-11) are all slike in composition and texture. West of the Macamik Highway, no rhyolite intrusions are reported by Graham, but he describes four types of quartz-feldspar porphyry (1948, p. 66). According to Graham, micrographic feldspar porphyry, of the type occurring in the writer's map-area, is the oldest of the porphyry suite, and it is interesting to note that this porphyry most nearly resembles many of the rhyolite dykes to the south. Graham states that the porphyries are the youngest intrusives (except for the diabase dykes), and he categorically denies the existence of any porphyry older than the Duparuqet conglomerate. This conclusion is consistent with Graham's contention that the so-called, long-discussed "porphyry conglomerate" in Duparquet Township is in reality an angular fault breccia along the contact of older sediments and a younger porphyry, which mixed with breccia produced, (1947, p. 11) but the conclusion cannot be reconciled with the presence of porphyry fragments in the conglomerate east of the Macamik Highway, reported by Hannerman, (1940, p. 12), and feldspar porphyry in the agglomerate of the present map-area. Bannerman held the view therefore that there were two porphyries, and older one, which was the source of the conglomerate pebbles, and a younger feldspar porphyry, which resembled the bostonite porphyry of O'Neill in many respects. (1933, pp. 90-92). O'Neill states that it is practically certain that the local porphyries in the Duparquet area are younger than the conglomerate, but older than the east-west shearing, or the bostonite porphyry.

There seems to be no reason why the conclusions of all three workers just cited are not valid in some respects. Although the Duparquet conglomerate does not occur in the area, the coarse porphyries resemble those described by O'Neill and Graham, which are younger than the sedements. The older porphyry of Bannerman which was the source of the porphyry pebbles in the conglomerate, may have been derived from some distance away. The only question in doubt is that regarding the rhyolite dykes in the area. Since

Graham has shown that there are four ages of porphyry, all post-Duparquet conglomerate, it is possible that some of the rhyolite dykes of the writer and Bannerman, are really a fine-grained phase of the porphyry. In this respect, the remarks of O'Neill concerning the existence of a fine-grained grey rock, which was first thought to be rhyolite, and later known to be an intrusive with rare, small, phenocrysts of quartz, that he classed with the porphyries, are interesting. These statements further support the possibility that there has been some confusion regarding the age and kinship of some of the finer-grained dykes.

THE FLAVRIAN GRANITE COMPLEX

Occurrence and General Field Description

The Flavrian granite complex is an assemblage of highly variable siliceous rocks, outcropping within Duprat Township, over an area of 20 square miles, extending from Nora to Flavrian Lakes in the southwest corner of the map-area, which lies near the middle of the section of the granite exposed in plan. Among the major intrusives of the area, this complex stock is perhaps the most important, for it is the host rock for suriferous quartz veins, exploited at the Elder and Quesabe Mines, within the complex, but slightly outside the map-area.

Where viewed from a distance, the weathered surface of most parts of the stock varies in colour from white to pink with an unifornity that belies its highly variable composition, and it weathers into smoothly rounded forms with crests trending a little east of north. At closer range the white surface appears to be buff coloured, or darker and more variable.

The rocks are cut by many joints which, though apparently striking in all directions, appear on study to have a systematic orientation, as mentioned beyond. (p. 193) Joints are filled with quartz, aplite, and basic to intermediate dykes. Quartz also fills narrow irregular veins, and has been noted in veinlets with feldspar and chlorite. At one locality in Lot 40, Range I, the granite contains reddish-brown weathering soft pods up to one foot in diameter that contain specs of pyrite in a base of chlorite. Epidotic joint fillings or veins are common. Spots of chlorite up to several inches across have been noted, as well as some black hematite in veinlets, specularite joint coatings, and yellowish molybdite stains south east of Lake Lebrun.

Pegmatitic patches seem to be extremely rare, and no pegmatite dykes have been noted. There are however, abundant aplite, lamprophyre and granite dykes cutting the complex, and the border rocks up to one mile away. Quartz diorite dykes were noted in one place, and the stock is crossed by seven diabase dykes.

Lithological Divisions

The granite complex was described by Cooke, James and Mawdsley (1931, p. 127) as being " rather monotonously alike in composition ", throughout. They classed it with the granodiorites on account of its lack of pegmatitic phases, and altered feldspars, but state that it has a highly siliceous composition. In 1937, Gussow, published the results of investigation of several granites in the Abitibi region. He described the Flavrian "granite" as an albite-tonalite, which could be considered a silicified equivalent of the border phases of the Palmarolle and Taschereau massifs, whose centres are potassic. (1937, p. 147). Rôbinson, and Mackenzie, investigated the parts of the Flavrian complex in west Duprat, and Beauchastel Townships respectively. (1940, p. and 1941, p. 12 resp.) They both pointed out that from the mineralogical point of view, the rocks are quartz-bonalites, as classed by Gussow, but they recognized the general usage of the term granodiorite. They report no intrusive contacts within the areas examined. Wilson referred to the eastern edge of the Flavrian mass, along the border of the Amulet map-sheet, as an alaskite (albite-granite) and reported the assimilation of many rhyolite fragments. (1941, p. 34) Kindle, who mapped part of the granite immediately south of the present area, divided the granite into alaskite and granodiorite, the latter containing less quartz, a little hornblende, and albite, as in the alaskite. (1941, pp. 3-4) No intrusive contacts between the two divisions were reported.

This brief résumé serves to show that in spite of the previous attention directed to this relatively small granitic sotck, there is no unanimity of opinion regarding either the nomenclature or the composition of the complex as deduced from the areas examined.

Field Divisions

In field mapping, the "granite" was divided into three parts by the writer. Of the first two divisions, the one contains considerable accounts of ferromagnesian minerals and is correspondingly darker[1] than the other, which weathers pink, and contains

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[1] Throughout the Noranda district, dark-looking siliceous rocks, containing visible amphibole and quartz are frequently termed" granodiorite" or quartz diorite, though they rarely contain calcic feldspar.

large amoun s of visible quartz. The third division included all the "granite" containing recognizeable fragments entrapped in the magma through stoping or other causes. (see Fig. 22, p. 163) This igneous breccia forms a considerable part of the complex in plan, and could not be neglected on the map A, which shows that it occurs in a few places along the eastern border, but also at points well within the border, suggesting that the "granite" has been barely unroofed.

Phases of the "Granite"

To some extent, the field divisions of the granite are related to different petrographic phases. From the selected specimens examined, the lighter, pink-weathering division of the granite includes quartz-tonalite, as suggested by some of the workers mentioned above, and alaskite. The darker, more hornblendic rocks, are mainly various proportions of albite-quartz-diorites. Unfortunately, among the 20 sections examined, there are nearly as many varieties of rock as specimens collected, and the complex is not "monotonously alike". The writer's observation over the greater portion of the complex suggests that the phases are irregularly distributed, though the eastern border appears slightly more basic than the centre, and although the complex is unusually well exposed (35% outcrop), at only one locality was an intrusive contact noted between parts of the mass. These features suggest that the complex is decidely inhomogeneous, and that the symmetrical distribution of phases noted by Gussow in some of the other Abitibian granites is absent.

Quartz-Tonalite

The bulk of the "granite" from the horthern part of Range VI, to the south boundary of the map-area is a white to pink weathering coarse-grained rock in which quartz grains up to 5 mm. in diameter, pink feldspar, and a small amount of dark-green hornblende are visible. Parts of this rock correspond to the tonalite of Gussow, whose analyses are listed in Table V, on the folowing page. (1937, pp. 145-146) The pink colour is due to the tint of the plagioclase, and not to the presence of orthoclase. Hand specimens reveal an irregular grain size and texture on the broken surface. Here and there the grain size varies abruptly from one-quarter inch to one milimetre over a distance of 2 mm. suggesting partial assimilation of parts of the same rock previously consolidated, or extraneous fragments. The finer grained areas are similar in composition to the coarser. The best examples of the characteristic rock type occur in the west part of Ranges I-III.

TABLE V

ANALYSES OF THE FLAVRIAN GRANITE COMPLEX

Component	I	II	III
SiO_2	73.79	72.06	74.89
Al_2O_3	11.83	12.03	13.27
Fe_2O_3	0.72	1.59	0.36
FeO	4.18	4.08	3.65
MgO	0.62	0.73	0.40
CaO	2.21	2.47	1.15
Na_2O	3.94	4.19	4.25
K_2O	0.85	0.58	0.37
[illegible]O	0.90	1.30	1.22
H_2O	0.40	0.20	0.03
CO_2	- - -	- - -	0.78
TiO_2	0.39	0.36	0.22
P_2O_5	0.09	0.13	tr.
MnO	0.07	0.08	tr.
F	0.01[1]	0.01[1]	- - -
S	tr.	tr.	tr.
Total	100.00	99.83	100.59

I. Biotite quartz-tonalite, pit. Lot 37, Range II, Duprat Township. Analyst. W. H. Herdsman.

II. idem. from pit in Lot 28, Range X, Beauchastel Township.

III. Slightly altered Powell granite, Rouyn Township, 1,000 feet east of the Rouyn-Beauchastel Township Line, and 2,000 feet north of the Nipissing Central Railway. Analyst. R.J.C. Fabry (Wilson, 1941, p. 35)

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1 determined be Gussow.

The source pit in Duprat Township was not seen, but samples taken from the general vicinity are characteristic of the description given by Gussow. The normative minerals and the classification according to the C.I.P.W. system are given in Table VI.

TABLE VI

NORMS

Mineral	la		lla	
quartz	39.26%		36.87	
orthoclase	5.03		3.42	
albite	33.30)	An 23	35.45)	An 24
anorthite	10.41)		11.46)	
diopside	0.59		0.27	
hypersthene	8.12		7.53	
magnetite	1.04		2.31	
ilmenite	0.74		0.72	
apatite	0.22		0.31	
Total	98.71		98.34	
Symbol	1.3.2.4		1.3.2.5	
Name	Alsbachose (near Yukonose)		Yukonose	

The quartz-tonalite, as estimated by approximate Rosiwal analytical procedure in thin section, consists of about 63% plagioclase, 20-22% quartz and 14-16% ferromagnesian minerals, mainly hornblende. Epidote occurs in very small amounts. Sphene, magnetite, and apatite are scarce accessories. Small zircons were detected by the fluorscope.

The quartz content is considerably less than that indicated by Gussow's analysis, but as the rock is fairly coarse grained, a considerable error may enter the Rosiwal procedure. Biotite was not observed in this phase of the stock, and among 20 sections taken from various phases, it seems to be an extremely rare constituent. The plagioclase occurs in large, tabular crystals, twinned on various laws, and slightly deformed. The centres are invariably saussuritized to some degree, and contain small grains of epidote, hornblende, and white mica. Many of the crystals are strongly zoned. (Fig. 17) The composition of some inner zones is An_{14}, and that of outer zones, as sodic as An_4, but zoning commonly ranges over only 2mol. % from An_{14-12}. The outer edge of the zoned plagioclase is crenulate, and in places it is penetrated by a quartz full of inclusions. Optical determinations on some plagioclase show that it is (-), and has a composition An_{26-31}, but so far as known, no indices are greater than Canada balsam. No potash feldspar was detected, and fluorescent tests for adularia at low temperatures are negative.

Quartz grains have irregular crenulate edges. Between neighbouring grains of the quartz, narrow gaps are occupied by polysynthetically twinned plagioclase, hornblende, and epidote. Apatite forms euhedral prisms, many of which are partly enclosed in euhedral masses of magnetite in the feldspar crystals - suggesting a normal sequence of crystallization. Some hornblende is also included in the magnetite.

The most striking feature of this rock is the illustration in thin section of the variable grain size observed in the hand specimen. Figure 18, shows a fine-grained part of the tonalite and the rapid change in grain size to adjacent coarse grained tonalite.

The rock name tonalite used here is in accord with the usage of Tyrrell (1929, p. 113), and it agrees fairly well with the description by Harker (1923, pp. 68-69) of tonalites from the type locality, which contain idiomorphic, striated, zoned plagioclase, fairly plentiful quartz, magnetite, and hornblende or biotite.

Alaskite

Pink weathering alaskite is included within the sections delimited on the map A as tonalite, on account of the small scale used, and the difficulty in separating the two phases by field appearance during the survey. Like the tonalite, the rock weathers pink, but the broken surface is a lighter colour grading to white, and has a fresh, sugary appearance. Vugs of epidote; coarse-grained quartz, and pink plagioclase may be seen in the hand specimens, and on particularly smooth surfaces, the graphic intergrowth of quartz and feldspar, which is common in some specimens. An analysis of Wilson's alaskite, from the east margin of the stock is shown in Table V, for comparison with the tonalites.

Most of the alaskite is a myrmekitic rock, in which up to 75% of the quartz and feldspar occur in graphic myrmekitic growths. (Fig. 19) The composition of one medium-grained specimen is 36% quartz, 1% accessory minerals, 1% alteration products, and 62% albite-oligoclase having patchy twins. Coarse quartz grains have undulatory extinction, are slightly biaxial, and are crossed by cracks and bubble trains unrelated to optic directions. The only accessories are rare grains of sphene, and small zircons detected by ultra-violet light. Small flakes of chlorite, and epidote in bladed crystals are widespread, but negligible in bulk.

In places the pink alaskite has variable grain size, and grades into the rocks next described, which more closely resemble the tonalites. No contacts were observed between the alsskite and tonalite, where the two are distinguishable in the field.

Varieties of the Alaskite

North of the Quesabe Fault, in Range LL, Lot 40, the alaskite consists of 36% white, glassy, quartz in rounded grains, and 59% dark, greenish-grey oligoclase (An_{11}) with idiomorphic outline 1% potash feldspar, 2% pale chlorite, and scant accessories. Very little myrmekite growth is present. Much of the feldspar has no external form. Its edges are corroded and penetrated by qyartz to such a degree that in places, twinned, crescent-shaped remnants of the oligoclase are entirely surrounded by quartz. This rock contains the largest proportion of quartz seen in the thin sections of any of the phases.

The extreme northern part of the stock is a pink alaskite consisting of about the same proportions of quartz and feldspar (An_{14}) as the previous example, and a small amount of potassic feldspar. This rock differs from the others in having a small amount of brown biotite associated with magnetite. Hornblende and chlorite are absent. About one-quarter of the quartz and oligoclase from a myrmekitic growth.

In summary, the alaskite and quartz-tonalite are both pink, medium to coarse-grained rocks. The alaskite has a widely variable proportion of myrmekite and more quartz than the tonalite. The tonalite has a hypidiomorphic texture and contains hornblende. Both rocks possess sphene and magnetite as accessories. Apatite is rare. No contact was noted between the two types.

Basic Phases of the Stock

The more basic phases of the stock have veen outlined on Map A, under the names tonalite, granodiorite and sodic hornblende-diorite. These names fit the descriptions very loosely, and are used mainly for their textural implications. Although the textures, grain size, and structures of these tocks vary widely, and the field appearance is most irregular, as a group, they have certain features peculiar to their composition that sets them apart from the quartz-tonalite and alaskite. The medium-grained tocks of this groups are grey weathering. The broken surface displays pink feldspar and dark hornblende in a "crow's-foot" pattern. Good examples are found west of Lake Méritens, and on the eastern margin of the granite in Range IV. The coarse-grained rocks display a more equidimensional feldspar on the fresh surface, and long needle-like hornblende. In places the hornblende forms extremely coarse, jagged crystals on the weathered surface, and makes up to 50% of the rocks, as, for example, in the north part of Lot 40, Range I. Here the rock appears to grade without any contact, into hornblende tonalite. However in Lot 36, Range 111, south of Lake Méritens, the hornblendic rock is chilled against medium-grained pink tonalite. Only at this point, within the whole stock, was an intrusive contact observed. The fine-grained basic phase has a dense black chill 1.5 mm. thick. Near the contact it contains practically no quartz and mineralogically is a syenite. A section ten feet from the contact shows an extremely variable distribution of quartz (Fig. 20)

All of the more basic variants of the complex have about the same amount of quartz as the tonalite (22-24%) and more hornblende (18-32%) with a correspondingly diminished amount of plagioclase (37-50%). They differ in that the idiomorphic character of the plagioclase is largely lost, so that the individuals in hand specimen form the "crow's foot" pattern characteristic of altered diorites in the district. They also differ in that the plagioclase (An_{2-8}, An_{21-35}) is quite latered to a fine grained saussurite containing a host of minerals including epidote, zoisite, clinozoisite, sericite, chlorite, and opaques. These rocks possess much more apatite, which occurs in long euhedral crystals, that the tonalite or alaskite, suggesting a greater concentration of volatiles in the magma. The apatite contains reddish brown inclusions, and is cut across by hornblende in several places. Of the amphiboles, actinolite is much more common than hornblende. It occurs in fretted coigns, and fibrous bunches. Quartz forms interstitial triangular patches adjacent to feldspar, but also occurs within the plagioclase. It encloses apatite. Magnetite is a common accessory mineral that forms pseudo-graphic and dendritic patterns with the hornblende. Sphene rimming titaniferous magnetite has been noted, but it is not so common as in the more siliceous variants. In rocks of this group, only a small amount of graphic myrmekite growth is present.

BORDER ROCKS OF THE FLAVRIAN COMPLEX

Contacts between the stock, and the surrounding rocks were seen only in a few places. In most of these, the border cannot be well defined, for granitoid rocks grande, at least on the surface, into the surrounding rhyolites and andesites. Wilson states[1] that east of Fourcet Creek, the granite seems to show evidence of assimilation, and on this writer's maps the contact is arbitratily drawn across some outcrops which are granitic at one end, and rhyolitic at the other.

In the middle of Range V, the common light pink phase of the stock intrudes altered silicified andesite to the east. Tongues of granitic material have separated some leaves of greenstone from the parent mass, at the level exposed. No petrographical examination was made at this locality.

Altered Rhyolite (?)

North and south of Range Line 11-111 at Lot 54, two small outcrops of a curious, light buff weathering, pitted granitoid rock are separated from a larger outcrop of apparently altered rhyolite by a few hundred feet. On the smaller outcrops, there is no evidence of vestigial flow texture.

The fresh surface breaks with a granular fracture and is plentifully speckled with dark spots of magnetite. In thin section the rock seems to be composed of about 36% altered feldspar, an equal

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1 pers. comm. Sept. 1950

amount of metamorphic amphibole, and about 13% quartz. The remainder is made up of magnetite in skeletal crystals intergrown with the hornblende. The rock is so altered that it is difficult to tell what original texture it may have possessed. All the feldspar is converted to an indeterminate saussurite. The outline of semi-opaque crystals, suggests however that it may have been idiomorphic. The quartz occurs as irregular euhedral grains interstitial to the plagioclase, and in graphic-shaped intergrowth with the plagioclase. The common hornblende excloses the plagioclase laths poicilitically, and is without good euhedral form, showing that it is a late crystallizing mineral. The igneous texture which this rock appears to possess, and its composition suggest that it is a sodic quartz diorite, with abnormal amounts of magnetite. To what extent the rock is contaminated by the nearest rhyolite country rock is not known. The rock does not resemble the " marginal phase " of the granite southeast of Fourcet Lake, described by Wilson. (1941, p. 34) Close to the area just described, Wilson states that the " granite " originally consisted of micropegmetite, apatite, quartz, and plagioclase with small amounts of amphibole. As this description, and the composition of the rock fit some of the latered rhyolites recognizeable by their flow textures, near the stock, it is equally possible that this rock is a contaminated and recrystallized flow.

Gradational Border with Andesite.

West of Duprat Lake, in Range IV, the border between andesite, and a basic phase of the stock lying to the west can be located fairly closely. Within 500 feet of the intrusive, the andesite shows progressive changes in texture and composition as the border is approached. A suite of specimens was collected by the writer, and six sections were examined. The position of the sections is illustrated in the following sketch. (Fig. 20a)

The first specimen and the most distant from the contact (43) is andesite, recognizeable by the smooth brown weathering surface, pillow structure, and some flow breccia. The broken surface shows some visible quartz and minute spots of chlorite. As the locality of slide No. 44, the rock resembles one of the finer-grained diorites on the weathered surface. Quartz is fine, but chlorite forms spots up to 6 mm. long which are easily seen on the altered surface. At locality No. 45, there is no appreciable change in the rock except that the chlorite has a more regular outline. At locality No. 46, the chlorite is strikingly developed in spots up to 1 cm. in diameter, many of which have regular cross-sections suggesting that it is a pseudomorpho of an idioblastic mineral. The broken surface of the rock shows slightly greater quartz contents, sufficient to give the rock a sugary texture. The last specimen of the continuous suite shows the same dark-coloured rectangular areas of chlorite, and the sugary texture, but the over-all hue has considerably darkened. From this point, to the western edge of the outcrop, the rock does not change. Due to rubbish in the trench shown in the sketch, it was not possible to collect furhter continuous specimens. In the middle of the trench, the broken surface of the rock shows it to be a medium-grained " quartz diorite " phase of the stock.

The thin sections exam ned follow the changes in the hand specimen very clearly. No. 44 shows that the original andesite is already altered to an aggregate of saussuritized plagioclase in small laths, surrounded, and partly enclosed by anhedral quartz; some graphic intergrowth of quartz and plagioclase, and a pale green chlorite in small shapeless masses. The changes followed through subsequent slides Nos. 44 to 47, are as follows. Original idiomorphic plagioclase is attacked by qyartz, and is more or less completely altered. New anhedral albite, charged with inclusions, forms irregular masses in the matrix. No large, original feldspars remain. The amount of plagioclase has decreased from approximately 58% to 32%. Quartz, originally occurring in small anhedral grains, has increased slightly in quantity, and greatly in grain size. Much of the clear quartz is poicilitically enclosed in large patches of pale-green fibrous chlorite that corresponds to the rectangular crystals seen in the hand specimen. This chlorite consists of clumps that do not have common optical directions, but the over-all outline suggests the spots in the hand specimen, and shows that it must form pseudomorphs of amphibole. Lastly, the amount of chlorite in <u>small</u> flakes has so increased in the groundmass, that the latter has a greenish tint.

The most altered rock does not have much similarity in texture or mineral composition to the quartz-diorite of the complex across the gap. The latter contains hornblende instead of chlorite, and a more igneous-looking texture. However, at locality " X " a little further south, the quartz-diorite contains visible quartz and feldspar up to deveral mm. in diameter forming a granular matirx, in which large rectangular hornblende aggregate from striking spots, which in the hand specimen have the identical size and appearance of those chlorite spots in the andesite just described.

The changes observed, and the resemblance of the end product to the variable quartz diorite phase of the complex, are highly suggestive that there is no actual contact between the basic border of the stock, and the andesite, and that in the transitional zone, the andesite eas recrystallized without complete melting of the rock. Some silica seems to have been introduced, amd albite formed at the expense of presumably calcic plagioclase. It is highly significant that amphibole exists in the andesite only on the cuter border of the altered zone, and that there is no epidote, or carbonate present. Usually actinolitic amphibole breaks down to give non-aluminous chlorite in solutions carrying sodium carbonate. In the absence of CO_2 this breakdown can only occur where the lime is progressively removed, according to the equation: -

$$\text{Actinolite} + H_2O = \text{Chlorite} \pm \text{Quartz} + CaO$$

(Turner, 1949, p. 53)

Presumably, continued development of the recrystallized rock in the anatectic zone, would give rise to one of the basic phases of the stock. At the zone observed however, the changes were arrested before completion. The existence of amphibole in the " quartz-diorite " and on the outer edge of the altered zone shows the limited amount of lateral migration outward of epidote during the formation of chlorite from amphibole by introduced aqueous solutions.

Nodular Chlorite Rock

Near the intersection of the Duprat Township centre-line, and Range Line III-IV, one outcrop mapped as part of the brecciated phases of the complex, has rather curious features. The brown weathered surface is studded with white weathering nodules up to 0.5 inches across, spaces an inch or less apart. Superficially the appearance is that of dalmatianite found on the east side of the map-area (see p. 257). The broken surface has a glistening dark green colour, and the fresh sections of the spots have forms suggesting rectangular or polyhedral crystals. In the space of 100 feet, this rock grades southward into a very hornblendic " quartz diorite " phase. Patches of pink granite, regular narrow dykes of aplite, and irregular quartz stringers cut the nodular rock, in exactly the same way as in Figure 24, suggesting that it is the border, or preserved remnant of some tongue of volcanics included in the invading stock. The spots are however, best developed along some straight fractures, and are therefore probably related to solutions having access along such channels through the mass. The microscope shows that the spots are oligoclase (An_{10}) and quartz. The feldspar is anhedral, totally saussuritized, and has sutured edges where it adjoins quartz. Chlorite has formed ocellar growths in both minerals. Although the boundary of the spots looks sharply defined in the hand specimen, thin section examination of several shows that they are fairly irregular. Patches of quartz extend from the rim into the ground-mass. The latter consists almost entirely of fibrous, radiating chlorite, with rare quartz, actinolite, an opaque oxide, apatite, and some unidentified material with low birefringence. The relatively clear quartz of the matrix contains very fine " hairs " of green chlorite. (- pennene?) The form of the minerals in the rock indicates that the sequence of mineralization is obviously feldspar first, quartz second, and lastly chlorite; and even were the chlorite replacing some other mineral, the sequence appears so anomalous that the rock may be regarded as composed entirely of secondary minerals. The original character can only be surmised. Possibly, the rock was a porphyritic basic lava, the feldspar phenocrysts of which were silicified by solutions from the adjacent acidic complex, followed by basification during the migration of iron and magnesia. Whatever the origin, this altered rock, cut by quartz stringers, and granitic intrusives; which grades into a quartz-amphibole-feldspar rock, demonstrates that silicification of the country rock has occurred. Its position, well within the boundary of the stock, in plan, shows how close the present surface lies to what must have been a former, undulatory roof.

<u>" Granite " - Rhyolite Dyke Contact</u>

On the same outcrop shown in the sketch, (20a, p. 157), a well banded rhyolite-felsite dyke with parallel walls was traced westward to the " granite " beyond the zone of recrystallized andesite, for about 100 feet into the complex, where it was visible by the ribbing on the surface. A hand specimen cut across the contact showed some remarkable features. The basic phases, at this point a " quartz-diorite " appears to fill in an irregularity in the dyke wall. It has irregular grain size. The dyke has a dark, irregular border about 2 mm. wide, in which the grain size is coarser than in the inferior of the dyke. The border is approximately parallel to the contact with the " quartz-diorite ". In thin section the contact between the two rocks is minutely irregular, and as shown in Figure 21 a micropegmatitic growth from the " quartz-diorite " penetrates the dyke. Figure 22, part of the same slide, shows how the dark border zone of the dyke has coarser grain, which diminishes toward the interior, beyond the inside margin of the border. The myrmekitic diorite shows no effects of contact alteration.

Within the felsite, spots formerly consisting of feldspar phenocrysts, are now composed of much smaller laths of newly crystallized albite, some quartz and chlorite. Spots consisting only of epidote and chlorite also occur in the matrix, and the rock is cut by chlorite veinlets.

The characteristics described suggest that the " host rock ", that is, the quartz diorite, is actually younger than the dyke, a condition, which, in this example, could be brought about only by recrystallization of the old host rock, perhaps with the addition of silica and alkalies from the stock, with little disturbance. The absence of evidences of violent movement, or even slight disturbance at the borders examined, strongly suggest that the " granite complex " arrived at the level at which it is now exposed under quiet conditions, and either melted, assimilated, and otherwise reconstituted some of the encasing rocks. The relations between the dyke at this point, and the " host rock " support this view. It could be argued that the dyke has a slightly coarser grained, rather than chilled, border on account of the escape of volatiles up the walls, and that it was intruded after the host rock, although the latter was still warm enough, and possessed of enough interstitial liquid to penetrate the dyke. If the two rocks were cooled together, it seems that such a reaction is unlikely, for evidences of reaction within the more basic " quartz-diorite " by the more siliceous rhyolite would be expected.

Origin of the Stock

Definite field evidence was found showing that some of the more basic portions of the stock are later than the quartz-tonalite. Limited anatexis has been demonstrated on the east margin of the granite complex. Elsewhere within the basic phases, although there is little evidence of crystalloblastic texture, the uneven distribution of minerals such as quartz as shown in Figure 20, and amphibole, the presence of ghost remnants with dioritic texture and composition, and the variability in grain size over distances of a few inches all suggest that the intermediate magma giving rise to the " diorite " phase owes its present composition in part to syntexis.

The same unevenness of texture has been noted in the quartz tonalite. Additionally, at several points within the tonalite, a few unfoliated inclusions of hornblendic material were noted. The tonalite shows little evidence of syntaxis near the core of the stock, but where the less acidic tonalite obviously forms the matrix of an igneous breccia as shown in Figure 24 on the margin of the mass, it is reasonable to assume that such fragments may have been partly, or wholly digested in other places.

The alaskite phase of the stock contains a variable amount of graphic myrmekitic intergrowth. Evidence has been cited to show that the quartz appears to have corroded the plagioclase crystals forming the " host " of the intergrowth. Drescher-Kaden, who has ably summarized the views on the primary (eutectic) or secondary age of the myrmekite, has pointed out that (1948, p. 34) the greater proportion of authors is agreed that the quartz is secondary in the sense that it has crystallized later than the plagioclase. Drescher-Kaden and Erdsman-dorffer consider that the myrmekite is a metasomatic product resulting from the introduction of quartz shich corrodes the plagioclase (1948, p. 35). As myrmekite is also found in the more basic phases of the stock, where the present composition indicates insufficient quartz to form an eutectic mixture of quartz and plagioclase, it may be concluded with certainty that the graphic quartz in all the phases is later than the plagioclase. The fact that the same myrmekitic intergrowth is observed in some of the later satellic dykes within the stock but not in those far removed from the border, suggests that the quartz was introduced at the end of the period of magnetic activity, and the stock itself functioned as a channel for the accession of silica.

In certain places the tonalite contains no intergrowths of myrmekite, yet it has up to 20% quartz in well formed round grains, showing that tough this phase may have been silicified by later quartz, it was a fairly siliceous rock initially. Because there are no intrusive relationships between the tonalite and alaskite, so far as known, these rocks, were probably derived from a highly variable differentiate of the original " dioritic " magma, prior to silicification. Assimilation of parts of the basic roof has basified these phases in some places, but later silicification has had the opposite effect.

The writer interprets these facts as indicating that the stokc originated primarily by differentiation from a dioritic magma, and subordinately by syntexis. The early intrusions were probably the sodic quartz diorite, which became mafic on contamination with wall rock breccia. Later the more siliceous differentiates may have replaced parts of the earlier intrusions, or forced their way upward among them, or more likely still, they probably stoped their way, assimilating some portions of the older dioritic phase. At this stage, some more basic magma must have left the source by some process not understood for at one point a very mafic quartz diorite intrudes the tonalite. Finally, the stock was permeated from the core outward by a water-rich siliceous rest solution expelled from the magma chamber as it crystallized. The fact that chlorite and carbonate veinlets cut across the myrmekite, both in the " granite " and setallitic rocks, shows that the silica was introduced prior to the retrogressive changes in the stock and its dykes. The final changes, probably brought about after the region was fully heated, and during slow decline in temperature, are retrogressive. They involve the conversion of hornblende to actinolite and chlorite, and what little mica is present, to chlorite.

SUMMARY

The results of this invertigation show that the Flavrian granite complex, previously described as a " granodiorite " monotonously alike in composition, or alaskite, without diorite phases (Cooke, et al. 1931, p. 127) is divided in the present field survey into three groups; myrmekitic alaskite, and quartz tonalite; variable intermediate phases consisting mainly of oligoclase-quartz-hornblende rocks (sodic quartz diorite); and, considerable amounts of igneous breccia. A comparison of the previously published chemical analyses indicate that the rocks have affinities with a sodic magma. Evidence of both igneous and systectic textures is found in all phases except the alaskite. Limited anatexis is shown at one point on the east boundaty, and the general mafic appearance of the intermediate phases near roof and border breccia indicates that assimilation has played a part. Abnormality in the differentiation sequence is shown by the discovery of a basic phase chilled on a tonalite phase. Silicification followed intrusion of intermediate phases, and preceeded later retrogressive changes in the stock. The massif appears to have made its way very quietly to the present level by melting and stoping Effects of intrusion on the country rock are very slight, and are limited to the formation of new quartz. The meramorphic grade, and the hydrothermal minerals in the contact zone are chatacteristic of the rest of the district.

CHAPTER VII

LATER " DIABASE ", DIORITE AND GABBRO

Gabbroic dykes with ophitic borders are the youngest rocks in the area, except for small aplites that cut them. Four large dykes outcrop in the Flavrian granite. Another dyke cutting diorite sills in Range X, Duprat, extends north into Duparquet Township. Widths range from 50 to 400 feet, and the dykes outcrop over distances up to one half mile, or more. The average width of the eleven widest dykes is 220 feet. The dykes from two sets striking in different directions. One set, best developed in the Flavrian granite strikes from nearly north, to N. 20^{o} E. A dyke represented by three isolated outcrops east of Nora Lake strikes at about 70^{o}. This follows a regional trend that is subordinate to north-east, and north striking dykes. All of the dykes have straight walls, uniform widths, chilled margins, consistent strike, and so far as observed, vertical dips. Sinuosity is a large scale feature. Over lengths of less than 100 feet, the contacts do not curve, though they are offset a few feet here and there. A few sub-parallel apophyses invade the country rock. Very little shearing was observed at the dyke walls. It has been shown, from evidence collected from all over the Shield, and summarized elsewhere. (L'Espérance, 1948, pp. 13-15), that the trends, mode of emplacement, and minor variability in the relatively fundamental composition of these dykes support the hypothesis that they occupy tension cracks, filled from the basaltic substratum. The characteristics cited above, and the behaviour of some dykes in the area, to be described below, fit the hypothesis.

In Lot 44, Range X, Duprat Township, a dyke tapers, turns slightly, and disappears at the apex of a wedge shaped fissure in the lavas. The broad dyke in Range V, Deprat Township dies out, and is repeated on échelon twice in two miles along the strike. At the curve in the broad dyke south of Lac Méritens, two narrow branching offshoots lie on the convex side of the curve. Lastly the granite east of Nora Lake is cut by numerous small, dense trap dyklets up to four inches wide, that lie parallel to the trends of the wide dykes. In the absence of a sheeted zone at this point in the granite, it may be concluded that these knife-like tabular bodies, only an inch or so thick, must occupy tension cracks. Had the walls not been pulled apart, it does not seem likely that hydrostatic wedging could have emplaced dykes so narrow before viscosity became insurmountable.

The weathered surface of all dykes is brown due to the oxidation of iron compounds, but from a distance the rock has the appearance of being dark grey. The fresh surface is dark greenish grey and breaks with granular fracture. Grain size and texture vary not only from dyke to dyke, but within individual dykes. " Diabase " is a misnomer, that may be retained to describe only the narrow finer grained dykes or the margins of wider dykes, both of which are usually ophitic. Irregular, phorphyritic phases occur in the wider dykes. Gabbro pegmatites, and aplites are common. Coarse grained dykes have glomeroporphyritic texture to within a few feet of the walls.

The microscope shows that both quartz, and quartz-free phases of the rock are present. Because the composition of the plagioclase is indeterminate due to alteration, the rocks are called gabbro or diorite if the ferromagnesian mineral is mostly either pyroxene, or mostly amphibole respectively. Thin section examination shows that the " fresh " appearance in the hand specimen is deceptive. The rocks are fine to medium grained hypidiomorphic aggregates of altered plagioclase and altered pyroxène, ranging in proportion from 47% ::: 52% to 36% ::: 63%. The varietal mineral quartz amounts to 20% in the quartz-diorite or quartz-gabbro. Seven sections taken from six dykes show that the plagioclase (andesine) is quite altered to " saussurite " but the original euhedral outlines are fairly well preserved, thus showing that the feldspar was originally idiomorphic to the pyroxene. The pyroxene, where fresh, ranges from a member of the clinoenstenite group, (Winchell, 1951, p. 400) to an augitic pyroxene. Where altered, it has been converted either to uralite and even compact hornblende, or directly to antigorite. Patchy individuals consisting mostly of antigorite, and minor amounts of a sensibly isotropic pale green chlorite, are crossed by cracks containing faint green fibrous amphibole. Within the limits of any thin section, all the types of pyroxene alteration described may be seen. In places the uralite contains small grains or clear epidote, and brown mica. Fibrous amphibole borders many antigorite individuals, and grades into hornblende.

Some of the quartz shows undulatory extinction and biaxial properties. It is penetrated by amphibole. Accessory minerals vary in occurrence and abundance. The most common opaque is ilmenite in skeletal crystals. Where the opacity has diminished due to the formation of the white alteration commonly termed leucoxene, three sets of parallel twin lamellae forming triangular grids, are visible. In places ilmenite forms graphic structure with the pyroxene. A little magnetite with red translucent rims is present, and pyrite was observed in the hand specimen. Small grains of opaque mineral have been released in the alteration of the pyroxene. Some sphene borders ilmenite. Apatite occurs as long stout prisms in quartz. In both the quartz bearing, and ordinary " diabase ", there are small pathces of granophyric intergrowth between quartz and twinned plagioclase, probably albite, now altered to sericite. Epidotic quartz veinlets up to 1 mm. wide cut many specimens.

Age of the " Diabase "

Because the dykes are the youngest consolidated rocks, their age cannot be established except within wide limites. Early workers suggested that the dykes were either pre-Cobalt (Cooke, 1922, p. 58), post-Cobalt (but Precambrian), (Wilson, 1918, p. 112) or both (Cooke, 1931, p. 143). The bases for such conclusions were characteristics such as the trends, composition, and degree of alteration, that could be compared with those of other dykes whose age was established by cutting relationships in the areas containing the Cobalt series in Quebec, and Ontario, or the Keweenawan of the north shore of Lake Superior. Since Cooke has shown by critical cutting relationships that both pre- and post-Cobalt dykes exist in western Quebec, (1931, p. 143) later workers have tended to place the dykes in either age group using the criteria previously mentioned. Many pre-Cobalt dykes have large altered phenocrysts of feldspar, and strike north. Many post-Cobalt dykes are fresher, non-porphyritic, and strike northeast or northwest. Four north striking dykes in the map-area have the chatacteristics of both groups. Further, a survey of all recorded detail on " diabase " dykes throughout the Shield shows that no single characteristic belongs exclusively to a particlular set of dykes of definitely established age. (L'Espérance, 1948, pp. 6, 13) Thus, in the absence of Cobalt sediments, it can only be stated that the dykes are later than the granite which they cut. The early reliance on age determination by the helium ratio method, which indicated that the nearby Noranda diabase dyke was Proterozoic age, has since been shown to be premature. (Keevil, 1938) Recent discovery of errors, and corrections in the technique suggest that further determination will probably place the dykes in the late-Precambrian era. (Marble, 1950, pp. 13, 14 & 39)

CHAPTER VIII

PLEISTOCENE

Following the recommendations of Flint, (1947, p. 209) the term Pleistocene is used here to designate all post-Pliocene time. The terms post-glacial or recent, and glacial are used in the informal sense suggested by Flint, and are applicable only within the geographically restricted locality under discussion. The deposits related to ice-retreat occurring in the area north of the Great Lake are generally referred to the last, (north american) or Wisconsin glacial stage.

Glacial

Except for the long ridge in Duprat, previously described, glacial deposits are not conspicuous, for various reasons. They may be buried in part beneath the heavy over-burden of recent swamp accumulation, or post-glacial sand. They may be concealed beneath the clays deposited in Lake Ojibway-Barlow (Wilson, 1918, p. 40; Antevs, 1922, p. 75) which according to Coleman lay across the waterched, in this part of Québec during ice retreat. (1922, p. 40) Scattered boulders found in the Waits and Smoky Hills, may be the only remnants of other glacial deposits, washed and reworked by the waters of Lake Ojibway-Barlow.

North of Duprat Creek, near the east side of the area, a north easterly trending ridge of gravel at 1,190 feet forms a divide within a north west trending valley. It is considered to be an esker by Wilson. (1941, p. 48) The following section was observed in the fresh wall of a gravel pit recently excavated in this ridge: -

6.5 to 12 feet	-	intercalated sandy and gravelly beds, up to 6 inches thick.
6.0 to 6.5 feet	-	sand and gravel
5.0 to 6,0 feet	-	poorly sorted, but crossbedded gravel
4.0 to 5.0 feet	-	water sorted gravels
0.0 to 4.0 feet	-	sandy, bouldery clay.

At lower levels, drift is not visible in Duprat Township, but the log of a drill hole in Lot 48 on Range Line I-II, records 100 feet of drift before striking bedrock. North of the clay-covered Ranges I and II, Duparquet Township scattered mounds of till form a hummocky surface. The divide between Lakes Destor and Mackay is mainly till, rising fifty feet above the lakes. West of the divide, along the outlet valley of Mackay Lake, a drill hole penetrated 130 feet of drift before being abandoned. In Destor Township, a section of sandy drift is exposed in gravel pits in Lots 27, and 18, East Macamik Road Range.

The composition of glacial erratics ranges from lit-par-lit injection gneiss, to conglomerate, which is found as far south as Range VIII, Duprat Township. The latter is probably derived from the Temiskaming sediments about one half mile north of the area. Volcanic boulders from the greater proportion of the erratics, and their similarity to the bedrock volcanics suggests they have been derived from nearby areas. A very large erratic previously mistaken for outcrop occurs in the extreme northwest corner of the area near a trench in drift. When the Lake Dufresnoy section was first examined by the writer a bare island of Temiskaming conglomerate, about eight feet square was found south of Lot 20 in the peninsula, Range I, Destor Township. Subsequent probing with a short perch around the island suggested that it tapered downward, and although bottom was not sounded, the island is probably a large erratic because no Temiskaming conglomerate was found on any of the shore exposures around the Lake.

Glacial striae vary from 340° to 350° strike throughout the area.

Post-Glacial

Clays of Lake Cjibway-Barlow cover much of Range I and II, Duparquet Township. Although they are gullied deeply by streams, stratification was not observed in the cross-sections.

In addition to the sand previously described in connection with the gravel ridge in Duprat Township, hills of coarse sand up to 25 feet high are found in the south part of Lots 29 and 30, Range II, Destor Township. In Lot 44, 1,000 feet north of Range Line VIII-lX, Duprat Township a section of sand is exposed along the valley of a stream. Excavation to a depth of a few feet, shows that the sand is partly consolidated, bedded, and stained a deep brown to purple, by the oxidation of ferrous compounds.

The stratigraphic relations of the sand and clay deposits are not clear. If the dunes were formed during glacial retreat along the advancing shore of Lake Ojibway, they may be contemporeneous with, or slightly younger than the lacustrine clays. In the map-area, dune sand invariably lies above the elevation of the clay, and at one point in northeast Duprat Township it was seen to overlie some clay in which no stratification was observed.

Recent stream deposits are practically absent from the area, due to the small size, and intermittent chatecter of the streams. Deposition in proceeding in swamps margining the lakes in the centre and northwest parts of the area. A drill hole in Range V, Duprat Township, penetrated 30 feet of swamp plant accumulation in a depression in Lot 44, before striking bedrock.

CHAPTER IX

STRUCTURE OF THE MAP AREA

General Statement

The Abitibi Series of volcanic rocks has been involved in folding that decreases in intensity from north to south across the area. Faults of major and minor importance, classified primarily on the basis of strike because of inadequate data regarding the amount of movement, disturb all the bedrock formations of the area.

Bedded tuff and agglomerate in Duparquet and Destor Townships form valuable marker horizons for tracing the general trend of the folded volcanics. In Duprat Township, horizons of spherulitic rhyolite have served the same purpose. Sill-like intermediate intrusive bodies indicate in a general way the broad trends of the folded belts. Pillows, ropy flow tops, flow contacts and in some places, grain gradation have been used to determine the attitude of the flows. Where the pyroclastic rocks are not sheared, cross bedding and graded bedding have aided the alucidation of structure.

FOLDING

Age and Type

The main period of folding involved the rocks of the Abitibi series, and the minor intrusives genetically connected with lavas. The deforming forces threw the lava belts into anticlines and synclines which are closed in the north, and very broad and open in the south parts of the map-area. The fold axes are nearly horizontal and strike generally east-west, suggesting that the stresses which produced them were horizontally directed, and acted in a north-south direction. That the greater part of the folding was completed before the intrusions of the main " quartz diorite ", diorite and gabbro is shown by the cross cutting relationships of these rocks in certain places. (Wilson, 1941, p. 30)

Later, some of the isoclinally folded volcanic rocks in Duparquet Township, and diorite sills were bent into drag folds that have vertically plunging axes.

For convenient reference, the main folded structure, in order of appearance from north to south, have been named as follows: The Dalembert River syncline, the Dufresnoy Lake anticline, the north Duprat syncline, and the Duprat dome.

<u>The Dalembert River Syncline</u>

The axis of this syncline lies in the pyroclastic rocks of Range II, Duparquet and Destor Townships. East of the map-area, it is called the Cléricy syncline by Ambrose (1941, p. 30) who places the axis in Lot 22, Range I, Destor Township, on the peninsula between arms of Dufresnoy Lake. Top determinations observed by the writer indicate that the axis probably lies in the lake a few hundred feet west of the peninsula. It enters the area at this point striking N. 60° W. but it curves westward at about Lot 20, Range I, Destor Township, for an, as yet, undetermined reason. Due to the wide gaps between opposite facing top determinations, the axis cannot be located around Dufresnoy Lake with greater precision than within 500 feet. Dips near the axis are about 90°. On islands in Dufresnoy Lake south of the axis, some dips are as low as 78° N. In Duparquet Township, the axis follows a uniform westward course as far as the hill west of Lake 1, in Range II, Here, a dozen or more reliable attitude determinations in the north limb, observed on the large outcrop west of Lake 1, plainly show that the beds face, and dip steeply, south, and southwest but that the strike gradually changes from north on the east side of the outcrop, to west on the west side so that the beds from an arc concave to the south-west. The most logical interpretation of the structure is that the synclinal axis has been bent into a Z-shaped drag fold whose axis plunges steeply, a little north of east. The relatively few reliable determinations on the scattered outcrop south of the axis support the interpretation. Whether the drag fold has been dislocated by a fault along the Dalembert River cannot be determined from the data at hand, but the possible existence of faulting does not alter the interpretation. The only other possible, (and highly implausible) interpretation is; that the syncline has been cross-folded into a tightly closed anticline, so that the axis of the original syncline has been broken into two parts, plunging steeply both west and east. Because the beds on either limb do not converge toward the synclinal axis, and because both north and south of the drag-folded section the lava belts continue their east-west trends, this interpretation is virtually impossible.

Shearing is not conspicuous in the tuffaceous agglomerate near the axis. Distinct fracture cleavage, and minor faulting are both visible on the large brecciated rhyolite outcrop, through which the axis has been placed south of the river. Steeper dips on the north limb than on the south suggest that the axial plane is inclined steeply north.

Dragging may have been caused by the fault passing along the south edge of Mackay Lake. The Z-shape of the fold indicates that the north side moved east relative to the south side, similar to folds described by Cunning (1940, pp. 45-48) from the west side of Malartic Township. The faulting which produced the fold however, may not necessarily have had a " nearly horizontal " movement, as implied by Cunning (1940, p. 45). An oblique slip fault with a small strike slip component, or a counterclockwise (left hand) rotational fault could conceivably produce similar folds. After a study of the position of faulted synclinal axes and cross faults in Destor and Duparquet Townships, Graham (1948, p. 90) concluded that slip along the Destor " break " was essentially horizontal (transcurrent) and produced right hand separation. The attitude of the drag fold ranks in size with the largest yet reported from the Abitibi region, and is folded more closely than structures of comparable amplitude in the Heva River area, Malartic Township.

The syncline continues northwest beyond the drag fold, and its continuation in west Duparquet Township coincides with a cross-warped syncline that has been outlined by Graham from Hébécourt Township eastward as far as islands in the middle of Lake Duparquet.

The Dufresnoy Lake Anticline

This anticline is roughly parallel to, and about three-quarters of a mile south of the Dalembert River syncline. East of the Macamik highway it appears to plunge gently westward so that a nose is formed in Lot 5 East Macamik Road Range, Destor Township. The axis cannot be traced south of the swamp west of the highway because of the highly sheared condition of the rocks. It does however seem to reappear in its same relative position south of the syncline, near the west margin of the map-area, where the plunge is reversed, and the beds converge eastward.

The North Duprat Syncline

The axis of the north Duprat syncline has been traced from Lot 62, Range IX, Duprat Township, westward and northward into Range X, and thence into Range I, Duparquet Township, where its position becomes uncertain due to lack of outcrop. Abundant pillow determinations locate the axis within 150 feet in Range X, Duprat Township. The lavas dip vertically on the north limb, and are either vertical or overturned on the south limb, dipping as low as 70° S. The strikes of the flows on wither side of the axis converge westward suggesting an eastward plunge. The attitudes of long flow contacts and the changing strike of pillows in the north limb show that the axis has been warped into an arc concave to the north.

The Duprat Dome

South of the north Duprat syncline, the strike of lava flows changes gradually from N. 40° W, near the east side of the map-area, to more nearly north in the west, north of Nora Lake. Dips are as low as 40° E, and tops face in the same direction, so that the flows lie on a broad arch convex to the northeast. From the Nora Lake fault to Range II, attitudes of flow contacts and pillows indicate that the lava belts trend generally north-south. Eastward dips as low as 24° have been noted. In the southeast corner of the area, the strike changes to northeast, tops face southeast, and dips are low. Thus from Range VIII southward, the structure as a whole is a broad eastward facing arch, plunging to the east.

The ideal perfection of the structure is marred by faulting, and three open, subsidiary folds whose axes also plunge to the east. These minor folds have been described by Wilson (1941, p. 49) The most northerly, is the Québec Copper anticline, which plunges south-eastward toward Waite Lake at a low angle. The next anticline to the south, called the Waite Anticline, lacks its north limb, which is cut off by the fault along Duprat Creek. According to Wilson it plunges east and terminates against the Lake Dufault granodiorite east of the map-area. The most southerly minor anticline is seen best on map B, at the end of this paper. Called the Amulet Anticline, it is a very gentle eastward facing flexure in southwest Dufresnoy Township. In the writer's map-area, the intervening minor synclines on the broad arch are more prominent features than the anticlines. Of these, the most conspicuous is the Duprat Creek syncline which plunges eastward across Duprat Lake as shown by the belt of andesite that curves around the west side of the lake. The broad, open, eastward facing arch, spanning the east half of Duprat Township was first inferred by Cooke, James and Mawdsley, (1931, p. 85) who state that the axis strikes S. 76° E, and dips gently toward Lake Dufault. It was accordingly named the Lake Dufault anticline. Later, Robinson predicted that the structure would continue through north east Duprat Township (1941, p. 87). The writer considers that the bisectrix of the broad arch passes close to the south west corner of Duprat Lake, and [illegible] strikes S. 65° E. Information not available to the earlier writers suggests that the arch is the southeast end of an elongated dome rather than a plunging enticline. The trace of the intersection of an anticline with a horizontal surface shows a nose: and dips in any bed on the axis are more gentle than in the corresponding bed on the limbs. Inspection of the maps suggests to the writer that the trsce is circular, and that no distinct nose is visible. The Lake Dufault granodiorite mass partly obscures the attitude of the lavas near the axis however, and either interpretation may be possible.

Faulting

Age and Types

Three types of faults, classified according to their importance and direction, occur in the map-area : (I) prominent east-west chear zones and faults, (2) major east northeast, and west northwest striking faults, and (3) minor faults trending generally north - south.

The first type occurs in the north part of the map-area. The Porcupine-Destor " break " is a prominent example. These faults have both right and left hand separations and appear to dip steeply. (Graham, 1948, pp. 86-99) Faults of the second type are well developed in south Duprat Township. So far as known, those on which some displacement is evident from field mapping all have left separations. Dips are steep. The third type are minor, clean fractures with variable dips. Visible offsets amounting to a few tens of feet or less are frequently seen on outcrops. They have veen shown to be later than type (1), and are probably later than type (2). They will not be described further.

The relative age of the types (1) and (2) is not known. It has been shown that the major east north east faults disturbed the volcanic rocks before the intrusion of the quartz diorite ("older gabbro"), but movement probably recurred at intervals from Archaean to Proterozoic time. (Wilson, 1941, p. 55) If the northeast and north west oblique faults can be correlated with similar faults in the Noranda District, and the area east of the Kinojévis river, movement on some may be related to the main movement on the Cadillac "break", while recurrent movement is probably later that the main period of faulting on the Cadillac " break " (Cunning, 1941, p. 42)

The Destor " break "

In Range III, Destor Township, the Porcupine-Destor " break " was located by Bannerman approximately along the course of the old Beattie Tramway. (1938, p. 2, 1940, pp. 6, 20) It passes out of the map-area in a north west direction, on Lot Line 27-28, Destor Township, at the Macamik Highway. The course of the fault follows a topographic break. A few hundred feet north of the assumed course bare hills rise rapidly to elevations of 200 feet above the flat, swampy country to the south. Several carbonatized shear zones up to 50 feet wide cross the hills of andesite north of the main break on a course about N. 70° E. They are probably offshoots of the main fault zone. No displacement on these shear zones was observed. Other shear zones, subsidiary to the main " break " strike approximately east-west, and have disturbed the rocks in Lots 1 to 7, Range III, Destor Township.

Mackay Lake Fault

A shattered zone has been intersected in drill holes in pillowed trachyte immediately south of Mackay Lake and the ponds west of it, in Duparquet Township[1]. Direct evidence of faulting is

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1 from Qué. Dept. of Mines, Office records
2 Graham, R.B. pers. comm. 1951.

not visible on the outcrops, but the creek draining Mackay Lake tumbles 15 feet into a gorge along which a fault may lie. The fault may strike a little south of east, and continue eastward to Destor Lake, where mildly sheared exposures on the south shore, suggest that it may curve slightly south. Graham states that the fault does not appear to continue west for any great distance.[2] A fault in the assumed location would explain the apparently displaced pyroclastic band which, striking about S. 75° W. enters the area from the north west of Mackay Lake, and reappears about three quarters of a mile ea east of the lake.

Nora Lake Fault

The Nora Lake fault, which may be a major dislocation, has been traced north eastward from the shore of the lake for several miles on direct and indirect evidence. The fault was observed on the larger island in Nora Lake. It is a clean cut, nearly vertical dislocation about an inch wide separating dark green sheared volcanic rocks on the north, from relatively unaffected granite to the south. A mile to the east of the island, the faulted contact of a highly schistose flow rock and granite has been intersected in a diamond drill hole at a depth of a few hundred feet. A mud seam occurs at the contact. Still further east in Lot 47, Range VI, Duprat Township, another drill hole intersected a silicified zone which may correspond to the fault, but there is no evidence of fracturing. From this point eastward, the fault has not been located, but it is believed to cross the map-area, passing a few hundred feet south of the pond in Lot 57, Range VII. The scattered outcrops north of the assumed course of the fault consist mainly of sheared rhyolite and flow breccia broken up by numerous closely spaced fracture zones that strike generally east-west. As shown on the accompanying geological map A, if the Nora Lake fault does continue as imagined, it would account for the apparent left hand displacement of the large dioritic sill striking N. 15° W., in Range VI, north of Waite Lake. It would also explain the general diversity in trend of the lava belts north and south of the fault. The change in the strike of the lavas could be explained by a sharp flexure, but there is little local evidence of intense folding. Thus although the fault may not extend entirely across the map-area as indicated, it is known to continue for at least two miles east of Nora Lake, and probably accounts for the abrupt disappearance of the granite to the north. This fault is possibly the continuation of the Hunter Creek Fault, which follows Hunter Creek northeast, from Dasserat Township into southwest Duprat Township.

The Quesabe Fault

The most prominent dislocation, referred to as the Quesabe Fault by the writer because its trace in west Duprat Township crosses the property of the Quesabe Mine, appears to pass just south of the island in Flavrian Lake, on a course N. 65° E. The large north trending diabase dyke in Lot 39, Range II is offset by the fault about 1, 200 feet west. The eastward continuation to or past Lake Lebrun has not been found in the low ground near the lake. On the east side of the map-area, either of two strong faults located by drilling on the Waite-Amulet Mines property may be the continuation. The one lies along the Fourcet creek road, and the other about 1,800 feet south of Duprat Creek. The latter possibility seems the more likely because the lava belts around the southeast bay of Duprat Lake appear to be offset to the left along the continuation of this fault by the same amount that the diabase dyke is displaced along the Quesabe Fault. The granite on the north side of the fault valley in Lot 41, Range II, is rusty weathering in a few places but does not seem to be disturbed. Careful mapping of the petrographic phases of the granite complex, might in the future give more imformation regarding this fault, or lead to the discovery of similar parallel faults.

Other East Northeast Faults

The diabase dyke north of Méritens Lake appears to have been cut off by another north east fault. The north face of a granite outcrop along the supposed course of the fault, east of the dyke is sheared over a width of one foot, and is coated with chlorite on slip planes. The granite is discoloured dark green, and the microscope shows that it contains considerable chlorite and carbonates.

Evidence for several of the faults comes from outside the map-area. In the andesite in the southeast corner of Duprat Township, several minor faults striking at N. 65^{o} E. have offset dykes about 200 feet left. At the north end of the southerly andesite belt, a strong east-west valley is presumed to mark the westward extension of the Turcot Lake Fault, discovered by drilling on the Amulet Mines property.[1]

Other northeast faults, generally with a steep dip, occur on the property of the Waite Ackerman Mine. They have been described by Wilson, and Gill and Schindler. (1932, pp. 398-416)

Small, discontinuous north east trending fractures have been observed at many points along the east side of the granite and

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1 Noranda Mines Ltd. pers. comm.

the bordering rocks. They seem to be an expression of the same type of movement that has developed along the major faults between which they lie. A small slip of this type is shown in Figure 23, The amount of displacement is unknown, but the curving, quartz filled tension cracks indicate a left hand separation, and most probably left hand slip, in agreement with what is known about the nature of the movement along the other north east faults.

North West Faults

A northwest fault occupies the south west trending part of the Smoky Creek valley as shown on Map B. It does not appear in the Flavrian Lake corner of the map-area, but its presence further to the southeast along Corono Creek in Beauchastel Township has been confirmed by drilling. In the map-area it may follow the low swampy ground to the south of the peninsula on the east shore of Flavrian Lake. Its relations to the Quesabe Fault, which it must intersect, are unknown.

With the exception of the Smoky Creek fault, the west northwest set has few important members. One fault displaces the diabase dyke in the north end of Lot 38, Range II, Duprat Township.

CHAPTER X

Summary of the Metamorphic Processes

The changes undergone by the rocks during metasomatism may be summarized in this way: the metasomatic reactions indicated by the presence of the various mineral assemblages in all the rocks postulate the general prevalence of circulating heated pore solutions, or solutions traversing the rock through distributed fractures. These solutions mobilized sodium carbonate and silica in some places, and calcium carbonate and alumina in other places, depending on the local concentrations at variohs points. Transformations involving the production of epidote, chlorite and zeolite veins may merely involve the redistribution of constituents already present in the rocks, a point, which can only be decided by a suite of chemical analyses. The redistribution is decidely imperfect. From the evidence at hand, changes involving the production of albite from more calcic plagioclase in the map-area postulate the introduction of soda probably in hydrothermal carbonate solutions. The most prominent changes in the intermediate rocks, due to these solutions are; saussuritization, albitization, and the transformation of poryxene to amphibole or chlorite. Only the last change is prominent in the siliceous rocks. Regional silicification has occurred only to a small extent. The assemblage of minerals is characteristic of the greenschist metamorphic facies, and equilibrium is imperfect.

CHAPTER XII

ECONOMIC GEOLOGY OF THE MAP-AREA

General Statement

Like the rest of the Abitibi region, the area included in this thesis is chiefly of interest from the economic standpoint, for the possible concentrations of metallic minerals it may contain. Such deposits in the Noranda district consist of primary copper and zinc sulphide replacement deposits, and gold bearing quartz veins. In the classification of Lindgren, both types of deposit are generally considered to belong to the hypothermal to mesothermal zone (1933, p. 664), but with the application of differential thermal analysis to the study of gold deposits in the Abitibi District considerable difference of opinion has now arisen regarding not only the depth zone to which the deposits belong, but also the age of the mineralization. As the types of mineralization encountered in the map-area have not been studied as yet by new methods, further consideration of this problem is beyond the scope of this thesis.

Considerable gold also occurs with the copper and zinc sulphide deposits, some of which have already been exploited within the map-area, as for example, the Waite Amulet Mine. Because full accounts of this deposit have previously been published[1], and since the writer's attention was confined to later undescribed occurrences, no further reference is made here to the Waite Amulet deposits. Silici-

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1 see Wilson, M.E. (1941, pp. 99, 111) for a summary account of the Waite Amulet Mines Ltd, and bibliography of previous work, and Cooke et. al. (1931, pp. 206, 219) for descriptions of the property, as well as the bibliography of the map-area at the end of this thesis,

fied, and carbonated gold bearing zones along faults in the north part of the area, and auriferous quartz veins in the south part of the area have been prospected, but so far none has been economically developed.

Non-Metallic Deposits

Building Stone

While the Flavrian granite complex is accessible by good secondary roads along the south boundary of the area, the multitude of obliquely intersecting joint sets, heterogeneity of composition, and the large amounts of included breccia, make its local exploitation as a building stone exceedingly unfavourable. On the other hand, the diabase dykes in Range I and II, Duprat Township are cut by a set of flat joints, and a vertically dipping conjugate system, parallel and perpendicular to the walls, so that quarrying could be easily controlled, and they are accessible at present by wagon trails. The quarrying of diabase, or " black granite ", has already proved profitable[1] within the vicinity of the city of Noranda, and although the dykes in the map-area are from 5 to 10 miles from the city by road, the possibility of using these dykes with the advent of greater future demand should be borne in mind.

Road Ballest and Sand

The long north-south trending ridge of sand and gravel mentioned under physiography, (p. 26) extends the entire length of Duprat Township. It is at least 200 feet wide at any point, and ranges up to 30 feet high. The network of roads traversing the ridge in Range VII and VIII, was built by lumber companies from material avail-

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1 W.G. Robinson, Qué. Dept. of Mines resident geologist, (pers. comm)

able in the ridge. Much of it is a fine to medium grained sand consisting of frosted and bright angular quartz, and greenish epidote. The composition is unsuitable for refractory material, but it forms excellent all-weather third class roads in the area. Should economic development proceed in north Duprat Township, this material is readily available, not only in the ridge, but also in the dunes to the e east, further removed from the roads. It is estimated that the ridge contains about 2,000,000 cu. yds. of ballast, but it should be noted that this figure does not express the proportion of sand and gravel available, and it assumes an average depth of 20 feet. The dunes on the other hand, consist mainly of sand, and average about 10,000 cu. yds. each.

GOLD DEPOSITS

Gold is known to occur within the map-area in quartz veins, in carbonated and otherwise altered schist zones related to intrusions of porphyry near faults, and with sulphide replacement deposits. In the first and second instances, the connection of the gold with siliceous, sodic intrusives within the district, has been amply demonstrated, as previously mentioned. (p. 15)

GOLD MINERALIZATION IN ALTERED SHEAR ZONES

So far as known, this type of gold occurrence is confined to the northern part of the map-area. It appears to be related apatially to the major fracture zones, including the Porcupine-Destor " break ", and genetically, to the quartz, and quartz-feldspar porphyry, intruded in the i mediate vicinity of, and in, the intersection of shear zones related to the faulting. (Graham, 1947, p. 19)

Finely dissem:nated gold occurs within the shear zones. No visible gold has been reported. The gangue minerals observed are pyrite, magnetite, hematite, sericite, chlorite and ferruginous carbonate. Graham reports arsenopyrite and molybdenite as well, from the region north of the main " break " but these metals have not been noted further south. This suthor suggests that the gold is related to pyrite in the paragenesis, but the relationship has not yet been demonstrated. (1948, p. 103) According to Graham, who confirms the opinion of previous workers, the gold is believed to have been deposited by hydrothermal solutions representing the final differentiate of the quartz porphyry deposited in breccia zones controlled by faulting. The temperature and pressure conditions during deposition, suggested by the data obtained by the decrepitation of the pyrite gangue, (Graham, 1948, p. 104) are believed to have been 510° C. and 2,900 bars respectively. The localization of the gold bearing solutions seems to have been controlled, not only by the major channels of access, and proximity to the porphyry, but also by the permeability of the host rock. For these reasons, the more interesting occurrences are found chiefly in silicified breccia zones, with finely disseminated pyrite, close to, or lying within the masses of porphyry. Thus they are found where shear zones change strike, providing openings for the intrusion of the porphyries.

So far, those occurrences that have been discovered south of the main " break " are small and bear only low gold values. The favourable exploitation of such zones at the Duquesne Mine, however, lying just outside the map-sheet, to the north of Range III, Destor, suggests that there may be some possibilities within the area. The extensive drift cover may conceal the presence of sheared porphyries, but since the shear zones are straight over short distances, any program of systematic exploration should direct attention to the projected extension of shear zones underneath the overburden. The paucity of quartz and feldspar porphyry within the writer's map-area, and the scarcity of the characteristic alteration associated with these deposits offers little encouragement for this type of prospecting. The Mackay-Destor Lake fault has been particularly disappointing in this connection. Should its course under the overburden be located with more precision, it may prove to be a favourable structure.

PROPERTIES

Destor Valley Gold Mines Limited [1]

This property exemplifies the type of mineralization just described. This company held claims comprising the north halves of Lots 29 to 38 inclusive, Range II, and Lots 29 to 38, Range III, Destor Township. The Desotr road from the Macamik highway cuts across the middle of the property. It is also accessible by the abandoned Beattie tramway, and numerous trails from the road.

The part of the property lying within the limits of the map-area is low and swampy in Range II, and mostly devoid of outcrop. The terrain rises with marked relief north of the Porcupine-Destor Fault, which crosses the property along a line parallel to, and slightly south of the Beattie tramway. Rock exposures consist mainly of pillowed, carbonated, andesite and chlorite schists in the north, and intensely sheared sericitized Cléricy sediments further south; all of

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1 cf. Qué Dept. Mines. Min. Ild. Rept. 1945, p. 66; the Northern Miner, 5 July, 1945, and Preliminary Report on the Dufresnoy Lake-Dalembert River area, Abitibi County, Qué. Dept. Mines R. l'Espérance, 1951. (in press)

which are intruded by diorite dykes, and small masses of quartz-feldspar porphyry.

Up to autumn, 1945, the property had been explored by 29 drill holes, totalling 14, 274 feet. Four of these holes are within the map-area. Chlorite, talc and sericite schists near the main fault, and sheared pyroclastics and porphyry were intersected. Fine pyrite mineralization carried only low gold values. According to company reports, 27 inches of solid sulphides and quartz were inte sected in two holes 2,000 feet apart. No assays were available to the writer.

2,800 feet north of the Destor Road, on Lot Line 28-29, a trench 4 feet by 2 feet, and 2 feet deep was excavated in rusty porphyry cutting andesite. No mineralization is visible in the trench. Another trench 20 feet by 4 feet, and 3 feet deep, across the contact of the porphyry and andesite, is mostly filled with débris. The porphyry in the trench is highly carbonated and contains specular hematite in small strings and pods. A third trench, along the contact of a foot-wide quartz vein cutting chloritic andesite 1,200 feet south of Range Line III-IV, on Lot Line 26-27, contains brown carbonates and quartz. Assays from this trench taken by the writer yielded less than 0.01 oz. gold.

The property has been inactive since 1947.

Gold Associated with Quartz Veins

White quartz veins up to 10 feet wide cut sheared rhyolite, andesite and trachyte around Dufresnoy Lake in the northeast part of the area. They are parallel to the schistosity for the most part, and except for small amounts of metallic oxides, do not appear to contain any minerals of value. Gold assays by the writer indicate that these veins are barren.

Gold bearing quartz veins and silicified zones connected with the veins, appear to be confined to the Flavrian granite complex, and its immediate vicinity in the south part of the map-area. Many of the veins have been investigated by mining companies in the past decade, but none so far has either been developed, or proved to be of commercial grade.

Within the veins, gold occurs principally in bluish quartz, in the native state, and also in tellurides. During a visit to the Elder mine, just south of the map-area, the writer observed rather spectacular coarse free gold, and large masses of tellurides in the quartz of some hand specimens. The occurrence of gold within the map-area is known mainly from drill-hole intersections, as few outcrops of the veins have been observed. Most of the gold is confined to the veins and very little is found in the wall-rock altered zone, which is unimportant, but one specimen shown the writer at the Elder Mine, consisted of native gold in coarse grained " granite " from the wall-rock itself. The gangue minerals occurring in the veins are; a little rusty pyrite, carbonate, hematite, and of course, quartz. In the silicified brecciated zones discovered by drilling, fine gold occurs with pyrite, a little chalcopyrite, and some carbonates. Assays from the veins are variable and erratic, and range up to 0.2 oz. per ton, over a width of 4.5 feet. In the silicified zones, they range from 0.01 per ton over one foot, to 0.34 oz. per ton over 4.5 feet.

The writer compiled data furnished by considerable exploration in Ranges I to III, Duprat Township, which shows that gold bearing veins and breccia zones strike from N. 45° to 60° E. and dip at low angles both southeast and northwest. Vertical veins striking north, and east trending veins dipping about 30° south also contain gold. Though production at the Elder Mine, has shown the importance of the gently dipping east-to-northeast striking veins, the north-south vein has also produced gold. Exploration by other companies proceeded in the east part of Range I and II, in the hope of intersecting the favourable structures of the Elder Mine, and although spectacular intersections of visible gold in quartz were located by drilling, the northeast extension of the Elder system is by no means proven. It is possibly succeeded in this direction by other parallel veins.

The relation of the gold veins to the faulting, or to the joint sets analysed in the granite area, is not entirely cleat. The north-south veins are roughly parallel to a prominent joint set in the granite, and may have been opened by tensional stresses acting at right angles to this direction after consolidation of the granite, or they may be north striking joints opened at some much later time by other stresses. It may be significant that north striking joints filled with about one inch of apparently barren quartz in Lot 46 Range I, assayed by the writer, contain traces of gold up to 0.006 oz. per ton. It is possible that this slight gold mineralization occurred at the same time as the jointing in the granite, and it may be contemporaneous with the formation of the quartz veins. On the other hand, if the veins are joints opened by stresses acting in a restricted direction, the presence of gold in the quartz of joints striking parallel to the quartz veins is of no particular significance, for the filling of both joint plane and vein may have occurred at a much later time than the general jointing in the granite. The lack of data on the gently dipping joints precludes a comparison with the gently dipping quartz veins, but conceivably, these veins as well, could be joints opened at some later time.

A more evident relation appears to exist between the quartz veins and the recognized faulting. There is a rough parallelism between the gently dipping veins, and the east north-east striking faults in the area. Small slips striking in this direction, have left hand separations, as indicated by quartz filled tension cracks, and some of these little faults contain quartz. From the drill-hole data on the property of Phelps Gold Mines Ltd., the writer attempted to match the fracture zones appearing in various holes. The results suggest that some faulting strikes about N. 53° E. and dips 75° S. Development at the Elder Mine reveals that the south dipping veins widen where the dip flattens[1] suggesting that they occupy planes opened by high angle reverse faulting. Until more data point to some contrary interpretation, these facts suggest that the gently-dipping gold bearing fissures may have been opened by movements along high angle, east north-east striking faults having a dip-slip component.

If this interpretation is correct, the veins are approximately the same age as the east north-east faulting in the area, which, probably through recurrent movement, displaces the north-south diabase dykes. This inference is supported by the presence of a diabase dyke which cuts the veins in the Elder Mine.

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1 Robinson, W. G. pers comm. (1950)

The prospect of gold occurrences within or near the granite complex is favoured by the presence of the Elder and Quesabe Mines, the former within the granite itself, and the latter not far from the western boundary. The eastward continuation of the Quesabe Fault toward Lake Lebrun; its possible connection with one of the Amulet Faults (p. 187); and, the other east northeast striking faults, revealed by the present mapping, are all encouraging indications that other gold bearing quartz veins may yet be discovered in this area. Most of the faults are devoid of surface expression, and are indicated only by the obvious offsetting of major pre-fault structures. Attention to the minor indications of faulting is therefore recommended, and to the possible existence of narrow veins at such localities. The unimpressive width (2 feet) of the discovery vein of the Elder property which outcrops within the map-area, serves to show that such narrow veins should not be disregarded.

Properties

The geology and mineralization of all the gold properties within this part of Duprat Township, are very similar. As they have already been individually described (L'Espérance, 1951) repetition is avoided here. The following property is selected as a typical example.

Phelps Gold Mines Limited[1]

This company holds the south halves of Lots 46 to 49 inclusive, Range II, bearing claim number C-8582 ; and parts of Lots 45 to 48 inclusive, Range II, bearing claim numbers C-8580, and 8581.

Most of the property is accessible by vehicle through a track extending morth from the Elder Mine road, which connects with Evain, on the Kirkland Lake - Noranda highway.

1 Robinson, W.G. The Flavrian Lake Area. Qué. Dept. of Mines Geol. Rept. No. 13, 1943. The Northern Miner, 9 August, 1945, and 20 September, 1945.

The claims lie in an area of low relief about one mile from the east margin of the Flavrian stock, and are underlain chiefly by " granite " cut by aplite, lamprophyre, andesite, and diabase dykes. Numerous quartz veinlets ranging from stringers an inch or more in width, up to one foot, trend somewhat east of north, and dip either steeply or very gently. They carry small amounts of rusty carbonates. Small faults trending north of east occur on a few outcrops.

From July 1945, to June, 1946, the property was explored by a geophysical survey, and 12,006 feet of drilling in 37 holes, laid out along two rows running northeast through Range Line I-II, at Lot Post 48-49, to intersect possible veins parallel to the Elder Mines' No. 1. vein. In view of the destruction of the core record by fire in the spring of 1950, the following data is derived from company records.

Following the discovery of a nearly flat, gold-bearing quartz vein, mineralized with pyrite, about 400 feet north of Lot Post 48-49, Range II, eight holes were drilled to intersect the vein within a few feet of the surface. Assays from a silicified section of granite ranged from \$5.00 over five feet to \$3.85 over one foot.[1] The vein was found to dip at about 15° southeast, and it did not continue to carry gold values in that direction. Further drilling from September 1945, completed a 2,000 foot cross-section in the southeast corner of Lot 47, Range II. Here two rows of northwest dipping holes intersected two low grade mineralized zones consisting of quartz stringers, carbonates, a little pyrite, and chalcopyrite bearing gold averaging about 0.1 oz. over variable widths. Low grade

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1 gold assays calculated at \$38.50 per oz. - the prevailing price of gold (1946)

gold mineralization was obtained in holes drilled on the southeast part of the property.

Mr. H.A. Honsberger, consulting engineer, was in charge of operations at the property.

SULPHIDE REPLACEMENT DEPOSITS

Sulphide Mineralization

Interesting occurrences of sulphides with rather unusual associated alteration, have been found in several parts of the area, especially in Duprat Township. The rpincipal minerals of interest are chalcopyrite and sphalerite. Pyrite and pyrrhotite are associated with these minerals, and pyrite also occurs separately. The mineralization discovered so far is characteristic of the sulphide replacement deposits of the Noranda district. The Waite Amulet copper-zinc deposits on the east margin of the map-area are a prominent example. As comprehensive reports on this occurrence have already been published (see Appendix A, and Wilson, 1941, Cooke, et al. 1931) attention is directed here to the types of mineralization, ore controls, the alteration, and the possibilities of those prospects not previously described. So far, none of these occurrences has proved to be of economic interest.

Metallic sulphides, consisting chiefly of pyrite disseminated in small grains, or localized in stringers, are found at points within the various intermediate intrusives; along flow contacts; at the junctions of dykes and flows; in brecciated rocks, such as the tuffaceous agglomerate in Range II, Duparquet Township; and in fractured volcanics, such as the rhyolite and andesite south of Fourcet Lake, Duprat Township. Masses of solid pyrite also occur between intrusives and volcanics, as for example, in Lot 27, Range II, Destor Township. Many of the intrusive rhyolites and porphyries are speckled with fine points of rust resulting from oxidation of metallic sulphides, such as the body in Lot 37, Range VII, Duprat Township. A few of the siliceous intrusives contain stringers of chalcopyrite up to one-half inch wide. In the past, particular attention seems to have been paid to those occurrences of sulphides along contacts, and the disseminated sulphides in siliceous intrusives. Many of the prospect pits noted during traverses occur in massive lava flows where there has been little fracturing or shearing, and where the mineralization is sparse and disseminated. Grab samples taken by the writer from such occurrences fail to indicate any interesting values in copper or gold. While dykes, and intrusive contacts may be important structural elements in the localization of ore-bearing emanations, the possible sterility of these loci, for anything but pyrite should be borne in mind, in any programme of systematic prospecting.

The presence of minor amounts of the sulphides along the intrusive, and extrusive contacts, along faults and other structures throughout the area, suggests the general prevalence of ore-bearing emanations, which had access to the host rocks, due to the inherent weakness of the structures mentioned. Only however, where the host rock is sufficiently amenable to replacement is an attractive concentration likely to occur.

Past experience in this area (Wilson, 1941, p. 59) shows that although rhyolites are particularly favourable for replacement deposits, the character of the rock replaced is not so important as its brecciated state. The occurrences of sulphides in pyroclastic, or rhyolite flow breccia show that these rocks are more pervious to ore solutions than the massive unfractured lavas. It has thus been found that replacement proceeds more easily through brecciated sections of rocks, along fault zones, and where massive rocks are broken up by a large number of criss-cross fractures along which resistant silica weathers out in a " grid " or mesh pattern. " Grid " fracture patterns, allied of course with indications of rock alteration such as dalmatianite, have been useful indicators of the occurrence of ore deposits on the Waite Amulet property. The significance of the " grid " pattern, where there is otherwise no indication of rock alteration, is unknown. In summary, it may be said that, to judge from previously discovered occurrences, replacement deposits in this area are governed primarily by a favourable, unobstructed channel of access, and a permeable brecciated host rock, and subordinately, by the composition of the rock.

The prospect of sulphide occurrences governed by the conditions just mentioned, within the map-area, is good. The presence of the Waite Mine on the east side of the area indicates the proximity of ore solutions at least in the south part of the area. East northeast faults, some of which have been brought to light by the present mapping, provide source channels and more may exist beneath the drift cover. The rhyolite breccia, and the rhyolite-andesite contacts on the east margin of the granitic sotck may be favourable hosts for the deposition of ore-bearing solutions. The drag folding along the great pyroclastic band in Duparquet Township almost certainly indicates the presence of faults obscured by the thick overburden. The pyroclastic breccia is a favourable host rock, and the presence of some mineralizing solutions is shown by an occurrence of chalcopyrite found in a trench in tuff 3,000 feet north of the Dalembert River, and 2,700 feet east of the centre-line.

In neither of these localities, or others, is the proportion of chalcopyrite or sphalerite in the deposit as exposed, sufficient to be of value, but the thick drift may effectively conceal faults of importance, which so far have not been fully explored by drilling or geophysical methods. Careful explorations by these methods along the east-northeast fault in Duprat Township is recommended. The possible connection of the Quesabe fault, with the fault along the Fourcet Creek road, makes the area between Duprat and Fourcet Lake potentially attractive. It is interesting to note that a decade ago Wilson suggested that

> " the most favourable locality for further exploration is probably the depression north of Lake Fourcet especially if breccia is present in the rhyolite beneath the Rsuty Ridge andesite at this point. " (1941, p. 139)

- a suggestion supported by the recent interpretation of the faulting, and with which the writer is in complete agreement.

Alteraiion Connected with Sulphide Mineralization

In addition to the usual oxidized appearance of the sulphide zones, there are several rather unusual types of rock alteration associated with weak mineralization. These merit attention as their occurrence may eventually prove to be connected with much more important mineralization at some distance from the alteration.

This has already been demonstrated in the case of dalmatianite.

Dalmatianite

The most prominent type of alteration is that producing the abundant white nodules in the rocks adjacent to certain of the Waite Amulet ore bodies. The altered rock, locally known as " spotted dog " or dalmatianite, has been of signal assistance in the search for ore in the area. As the type locality for this alteration, which according to Lindgren (1933, pp. 688, 743-744), is associated with magnesian metasomatism of the Orijarvi type, has been fully described, (Wilson, 1941, pp. 67-69) no further reference is necessary, Thus far, no occurrences of dalmatianite north of those appearing on Wilson's maps, have been observed by the writer.

Spotted Alteration

Up to the present, this type of alteration has been found only south of Range VIII, Duprat Township, in rhyolite and dark intermediate lavas, where it resembles, but is not identical with the dalmatianite of the Waite Amulet area. Essential differences between the dalmatianite and the spotted alteration are the nodules of cordierite, rosettes of gedrite and crystals of brown mica in the former, whereas the latte consists mainly of ovoids of quartz and chlorite. It is by no means certain that the structures described as ovoids are filled vesicles. The ovoids range from specks up to 1 inch in diameter, and they are spaced from 0.1 inches to several inches apart. Mineralization associated with this type of alteration consists of spots, clusters, vesicles, and veinlets of chalcopyrite, pyrite, sphalerite and occasionally pyrrhotite.

The sulphides occurring in spots appear to replace quartz and chlorite in varying degree. An occurrence of this type was noted in andesite, in the north part of Lot 35, Range VII, in faulted contact with rhyolite flow breccia. Thin section examination of a spotted sample, shows that a small amount of chalcopyrite surrounds some of the quartz orbs. Very indefinite circular areas of a chloritic material are bounded by pyrite and pyrrhotite. The andesite is very fine grained and more or less opidotized.

Another occurrence of the spotted alteration was found in rhyolite, outcropping in a swamp about 4,000 feet north of Range Line V-VI, on Lot Line 40-41, Duprat Township. No spots are visible on the weathered surface at this locality, but the fresh surface bears orbs of sulphide, chlorite and quartz in various combinations. Chlorite spots have vague shapes and a few are cut by minute veinlets of pyrrhotite. Some amygdules consist entirely of sulphides.[1] None is over hald an inch in diameter. The relations suggest that the sulphides have replaced the areas of chlotite alteration, but the sequence of replacement has not been established.

The most prominent occurrence of spotted alteration occurs in massive andesite, near Lot Line 50-51, south of the Township centre-line. An account of this deposit is given under the description of properties.

In all the occurrences of spotted alteration, the amount of contained sulphides is not of economic importance, but the alteration is an indication of the presence of available ore- solutions, and strongly suggests the presence of a nearby fault, from

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[1] A similar occurrence of sulphides occurring however in larger orbs, was reported by Wilson from the Beaver Mountain Copper Mines Ltd., property, Dufresnoy Township. (1941, p. 136)

which sulphides emanated into the porous parts of lavas.

MINERALIZATION ASSOCIATED WITH SILICIFIED RHYOLITE

Field Occurrence

A very local occurrence of intense silicification, and weak sulphide replacement, of a type so far as known never previously described, occurs in an unusual flow rock outcrop in Lot 45, Range IX, Duprat Township. The locality of the discovery lies just north of the lumber road where it crosses this outcrop; subsequently similar rocks were noted in a swamp in Lot 43, Range IX.

In both field and microscopical appearance, the rocks are more easily illustrated than described. They are provisionally included within the rhyolite belt which passes through this part of Range IX, as shown on map A. The rocks weather grey to white, and have an extremely irregular weathered surface in which a certain amount of heterogeneously distributed siliceous breccia is visible in places. The breccia is indistinct, and resembles flow breccia seen elsewhere in the rhyolites. The broken surface is extremely variegated, and no two hand specimens are exactly alike. One specimen from Lot 45, has scattered pyrite, pyrrhotite, chalcopyrite, and possibly sphalerite visible in scattered grains on the broken surface, blebs of opalescent blue quartz up to 0.3 inches in diameter, irregularly distributed, buff coloured phenocrysts of altered slightly zoned plagioclase, and small amounts of glassy looking quartz speckled with dark green grains of unidentifiable material. Except for the apparent phenocrysts of feldspar, the texture hardly resembles that of an igneous rock. In a few places, the broken surface appears more homogeneous, and it contains stubby looking phenocrysts of plagioclase in a rhyolitic-looking matrix. A few zones were noted in Lot 45, where the rock contains abundant white orbs up to one-quarter inch in diameter, closely packed in rows about one half inch apart. These spots are presumably spherulites occurring in bands, as they have been observed in other rhyolites. The broken surface of the rock in Lot 43, is quite different and consists of scattered phenocrysts of feldspar, in a smooth, pearly grey opalescent siliceous matrix, which is reticulated by fine dark-green wavy lines about 2 mm. apart so that they form an irregular polygonal mosaic. In short the mosaic resembles a miniature " chickenwire ". The " chickenwire " appearance is probably due to the coalescence of globular structures, such as spherulites in the flow, for it has been noted in other, more normal rhyolites north of Duprat Lake.

Microscopical Characteristics

In spite of the extremely variable appearance of the broken surface, all the thin sections examined are so similar, that they must belong to the same flow, or intrusive member. Under the microscope, the slides consist of about 5% albite, or oligoclase phenocrysts in a micro-allipsoidal matrix containing about 5 to 10% quartz in grains of various shapes, but chiefly parallelopipedons. The matrix consists of a number of fine granular alteration products forming such a confused aggregate, that determination of minerals is practically impossible.

The plagioclase phenocrysts, which range up to 8 mm. in diameter, are relatively unaltered except for flecks of sericite that dot much of their surface. A typical phenocrysts is shown in

Figure 10. They lie within, or across the boundaries of the micro-ellipsoids described beyond.

The quartz laths, the matrix, and their mutual relations are better illustrated by photomicrographs than by description. Under oridnary light, the laths, or parallelopipedons of quartz are relatively clear (see Figs. 30a and 31a). They have euhedral forms suggesting the habit of feldspar. The resemblance is so great, that on first examination, they were thought to be feldspar. Lines of inclusions cross the crystals, commonly perpendicular to the long sides. Under crossed nicols the laths are resolved into separate patches of quartz with variable extinction. Wherever determination of the patches is possible optical tests show that they have the (+) sign of birefringence, interference colours, and and uniaxial interference figure of quartz. Some patches are slightly biaxial, with 2E apparently about 20°. Refractive index tests on shards of the crystals obtained by fine grinding show that the greater and lesser indices are similar to those of quartz in the third decimal place. The laths in some slides are regularly segmented across the length by patches of quartz having no common optical orientation, but possessing rectangular shape, as shown on the right side of Figure 31b. In others, relatively clear individual laths (Figs. 31a, and b) consists of very complicated patches of quartz. Some of the smaller laths extinguish uniformly, showing that the quartz has perfectly replaced the pre-existing mineral. (Fig. 32b) The quartz lathes range up to 0.8 mm. long, and many are curved, or broken into several parts, separated by the matrix. (Figs. 35, 36a and 37). The laths are terminated by rectangular, slightly rounded, wedge-shaped, or notched ends, as shown in Figures 33a, 34 and 36a. Some of the quartz is broad and tabular. (Figs. 35 and 36a) A large porportion are long, thin, and show an imperfect fluidal alignment, suggesting that the quartz has replaced an original phenocryst mineral, as shown in Figure 35. Length to breadth ratios vary from 1::4 to 1::4. Laths mutually cross (Figs. 32a, 33a, 34, 36a and 39), others occur in parallel bunches (Fig. 35), and a few form rectangular frameworks enclosing part of the matrix. (Fig. 32a). Invariably the longer sides of the laths are parallel. Figures 34 and 36a show the relationship of the quartz laths to the curious looped arrangement of the matrix resembling a tile floor, or " chickenwire ", for which the name micro-ellipsoidal has been adopted from Benson. (1915, p. 144) Many of the laths occur within the loops, but others interrupt the continuity of the boundaries.

The micro-ellipsoidal nature of the matrix is no less remarkable than the habit of the quartz. The igneous nature of the matrix is clearly shown by the phenocrysts, and more so by the occasional vesicle as shown in Figure 33a. In ordinary light, the matrix of most slides is composed of brownish to greenish cells averaging 1 mm. in diameter, which are seen to be bounded either partly, or completely, by one or more black lines. The clearest examples illustrated are in the left central part of Figure 34, and the top central part of Figure 36a. In places the black boundaries are margined by a thin line of colourless material. In other places the lines bounding cells are not at all visible, but the presence of cellular structure is detected by the pattern formed by dark nuclei at the centre of each cell surrounded by lighter coloured edges. The darkening of the centre of the cell is caused by a concentration of black lines, and is best illustrated by the areas on each side of the bottom part of Figure 31a. Some cells have nuclei of dirty brown epidote group minerals, green chlorite, mixtures of the two, or they are composed of clouded material having little or no birefringence - suggesting partly devitrified glass. The majority of cells consist principally of an opalescent quartz forming the base for many flecks of other minerals, and for the black dots, and lines. This quartz gives very hazy, " sick-looking " uniaxial figures, probably due to the peculiarity of its crystalline state, and it is the opalescent orbs seen in hand specimens. The quartz forming these cells extinguishes in patches heterogeneously oriented, as shown in Figure 38. Fine, dark lines forming an imperfect radiating structure in most cells (Fig. 38) are resolved under a magnification of 1,200 diameters into chains made up of grains about 0.001 mm. across that have high relief, and the variable interference colours of epidote.

The cellular structure observable in most thin sections strongly resembles the perlitic partings frequently described from devitrified rhyolitic glasses of mero-crystalline rhyolites. (Tyrrell, 1929, pp. 60, 100 and Fig. 41) The fine radiating lines, emphasized by the rows of dark (epidote ?) beads along them may represent either shrinkage cracks, or they may be related to spherulitic structure within the cells. In this respect, the structures, except for their altered state, have a striking resemblance to spherulites and perlitic cracks in rhyolites from the western United States, described by Zirkel. He describes sub-rounded and drawn-out spherulites (as in Figs. 5 and 11) which are bounded by brownish lines that he interprets as perlitic cracks. (1876, pp. 168 et seq. and Plates VI, VIII, Fig. 1)

Even closer resemblance is found with a description by Benson of the rim of a pillow in lava from the Hundle district, south Australia. (1915, p. 144) He states:

> "the extreme outer margin of one pillow in Swamp Creek exhibits a structure of which no parallel is known to the writer ...... It so clearly resembles the plan of a pliiow-lava that it may be termed micro-ellipsoidal structure. It is probably the first stage in the formation of variolitic structures, preserved, owing to sudden quenching"

The ellipsoids are reported to measure up to 0.2 mm across. They have radiating fibres, a dark brownish green colour (due to chlorite or sugite?) and they are surrounded by a ring of clear epidote.

> "This epidote is separated from the epidote in the adjacent micro-ellipsoid by a thin band of grey, dirty material which widens out into tricuspate areas at the point of contact of three microallipsoids just as does the material between the large ellipsoidal masses in pillow-lava" (1915, p. 145)

The close resemblance of the Duprat example to the descriptions of cooling and devitrification structures (spherulites, varioles, etc) cited above, suggests that the cellular structure is beyond all doubt, primary, and related to the cooling of a viscous lava. It is not likely however that the cell boundaries in the writer's example are original perlitic cracks, for these delicate structures are commonly obliterated by devitrification, and also because many of the boundaries are closely spaced double lines. They do however appear to be identical to the micro-ellipsoids of Benson, and the radiating, lines which Zirkel found in spherulites are suggestive of some type of radially exerted stress. The fact that some of the lines pass from one micro-pillow to another without descontinuity however, makes this interpretation questionable. They could possibly be original flow lines formed in a viscous rhyolite glass, and marked by chains of crystallites.

The possible origin of the cells is suggested by a recent description by Osborn (1949, pp. 73-78) of structures in artificial glass. He noted that large cells, bounded by cooling cracks, formed in a glass consisting of 33% SiO_2 by weight, when poured from a mould onto a porcelain slab. The large cells, contained small cells averaging 0.12 mm. in diameter, of about one-eighth the size of those shown in Figure 34. Orborn attributes the formation of the cells, to convection currents developed in the upper part of the cooling glass. He considers that ellipsoidal lava, except for the difference in scale, is composed of similar convection cells, and that extrusion over a wet surface would increase convection by lowering the viscosity in the bottom layers of the lava. It seems to the writer, that, in the absence of conflicting data, this explanation is adequate to account for the cellular appearance of the porphyritic rhyolite. With this interpretation, the laths, which have mutual cutting relationships with the micro-pillows, must have been original, and cannot be porphyroblasts, a conclusion supported by their euhedral shape, and the fact that they are replaced by quartz. The preservation of the original structure indicates that merasomatic changes in the rock, and devitrification proceeded with delicate replacement.

Figures 32a, 33a, and 37, illustrate a dark halo around some of the crystals in the matrix. The disposition of the halo suggests that it is causally related to the crystals now pseudomorphed by quartz. However, the halo does not occur around all crystals, and some haloes occur where there are no crystals. If the development of the haloes is connected with the laths, this distribution suggests that the haloes formed after the laths, but that they persist where laths disappear. Under high magnification, the only difference between the halo area, and the rest of the matrix is the relative abundance of the fine black to semi-opaque grains thought to be epidote.

In several slides, such as Figures 34 and 40, blebs of sulphides, mainly pyrite and pyrrhotite, cross ellipsoidal boundaries, and they replace quartz laths in such a way that they must be secondary.

Similar Occurrences

During the second field season of this survey the writer's attention was drawn to structures in the rhyolite belt surrounding the south end of the Rusty Ridge andesite, which are so similar, that one cannot resist the suggestion that the phenomena are related. In several slides of sericitic rhyolite, not far from the Waite Amulet Mines, curious wedges, or imperfect lath-shaped structures of quartz were noted, (Fig. 42) which are analgous to the quartz laths of the occurrence in Range IX. Some of the semi-rounded structures are more perfectly symmetrical than others, as shown in Figure 43a. Opaque sulphides are found in all the slides. The igneous nature of the matrix is clearly shown by the presence of vesicles, so that the angular-looking pieces of quartz are not likely to be shards unless the flow contains considerable amounts of incorporated crystal tuffs. Surrounding each clear piece of quartz, is a quartz border of about the same width, so charged with inclusions that it cannot be easily distinguished from the matrix in plain light (see Fig. 42a) though it is distinct under crossed nicols. (Fig. 42b) Such aureoles of quartz also surround the vesicles. Unlike the northerly examples, micro-ellipsoidal structure is not easily visible. (Fig. 44). Fairly well-formed laths of quartz are, as before, replaced by sulphides in exactly the same fashion (Fig. 44) as previously noted in Lot 45, Range X. In some of the sections the matrix appears pale yellowish-brown in ordinary light, and under crossed nicols appears to consist of granular alteration products too fine for identification. More sericite occurs here than in the northern examples, and the matrix contains some altered feldspar. These rocks differ in having no feldspar phenocrysts. They seem to be entirely replaced by quartz (Fig. 41a) illustrates a large rectangular quartz bleb which has replaced a former feldspar phenocryst..From the same area, a very fine example of the type of replacement, shown in Figures 41a, and b in which the idiomorphic outline of feldspar is occupied by a quartz mosaic, is illustrated by Schindler (1933, Plate IX).

Origin of the Structures

Due to the fine-grained nature of the matrix, which effectively precludes optical work, and in the absence of X-Ray determination of the minute minerals, no very satisfactory explanation may be given for all the curious features of these rocks. Consideration may be given to however, to the following question :

1) what primary lath-shaped mineral has been replaced by quartz?
2) from whence was the silica replacing parts of the matrix and crystals, derived?
3) what is the relation between the sulphides and the quartz?

Origin of the Laths

Evidence has been cited to show that the original rock was probably a glassy siliceous lava, and that the laths are original crystals. Therefore the quartz has replaced some mineral which may occur as phenocrysts in a rhyolitic lava. The only likely possibilities are that the quartz has replaced (a) feldspar or (b) tridymite.

Evidence supporting the hypothesis that the quartz pseudomorphs are after plagioclase, is the habit of many of the laths, and the undisputed replacement of feldspar by quartz in the more southerly examples. (Fig. 41a, & b) On the other hand, some of the shapes of the laths are so unlike the habit of tabular or lath-shaped feldspar that the possibility does not seem likely. Furthermore, it is unlikely that the plagioclase would occur in the bunches shown in Fig. 36a, & b, or that plagioclase phenocrysts would remain unreplaced by quartz as shown in Fig 39, whereas less than 1 mm. away small laths are replaced by quartz. In one section not illustrated, the laths of quartz lie in parallel arrangement partly within the boundary of a plagioclase phenocryst.

The probability of the second alternative is not enhanced by the parallelopiped habit of most of the quartz. Though tridymite is orthorhombic pseudo-hexagonal at its usual temperature of crystallization, the writer is not aware of any occurrence in which it is described as other than wedge-shaped individuals or twins. In addition, the occurrence of phenocrysts of tridymite is a contentious issue. In the lavas of the Creede District, Colorado, Emmons and Larsen (1923, p. 47) state that tridymite occurs as minute drusy crystals in spherulitic growth or in the groundmass. However, they also state that the tridymite commonly occurs in vesicles, and only phenocrysts of quartz were observed. The habit of the tridymite in the groundmass is not described. Rodgers, in reference to Emmons' and Larsen's description, (1928, pp. 80, 81) categorically denies the existence of tridymite as a megmatic mineral, and ascribes its origin to pneumatolytic metamorphism. The orthorhombic form of tridymite, stable below 117° C. has axial ratios close to that of the hexagonal form, with c 1.653 (Dana, 1892, p. 192) or C::A 1.653 (Winchell, 1931, p. 192). The common appearance of the lath form of quartz in the thin sections would thus demand a common parallel orientation of hexagonal (or orthorhombic) tridymite plates, with their broad planes transverse to all the thin sections - a coincidence so fortuitous that it seems precluded.

In spite of the objections to the feldspar hypothesis, one is forced to conclude that it is the more likely of the two possibilities. Replacement of feldspar by quartz may have proceeded under such selective conditions that only plagioclase of a certain calcicity was affected. Alternatively, the lava may have contained crystals of sanidine or orthoclase, which conceivably could be replaced by selective mobilization of potash. Because there are no reported occurrences of potash feldspar in the acidic lavas in this area, the former hypothesis, however undatisfactory, seems to be the only possibility.

Source of the Silica

The presence of some sulphide mineralization in the rhyolite, and the opalescent nature of the silica in the groundmass both suggest that the silica has been provided by hydrothermal solutions of the type accompanying sulphide mineralization. The examples of quartz mosaics replacing feldspar near the Waite Amulet Mine, described by Schindler, and the present examples from the same locality in which quartz clearly replaces some previous mineral, are both close to replacement deposits of considerable magnitude.

In his review of silicification at the Horne Mine, Price has pointed out that the ore solutions are a potential source of silica, but that many other reactions are involved, (1933, p. 132) such as the release of silica during sericitization, or during the replacement of silica minerals by sulphides. That the solution replacing the feldspars in the present example consisted mainly of SiO_2 and water is shown by the fact that all the constituents of the feldspar have been removed, and their place is taken only by quartz. In the absence of sericite, and other alteration minerals, there is no doubt that this example is an intense type of silicification, requiring additional silica from an external source. As such solutions are known to be associated with ore deposits in this area, it is concluded that the rock has been altered by hydrothermal ore solutions. Several examples of silica metasomatism are known from this district, at the Robb-Montbray, Newbec, Coniagas, Aldernac, and Waite-Askerman properties, according to Cooke et. al. (1931, p. 161) who concluded that although part of the silica may have been derived from sericitization, some parts are so siliceous that it seems probable that quartz has been introduced. Other examples have been noted by Ambrose (1941, p. 80) in the Cléricy-La Pause area in connection with sulphides in diabase dykes, and by Cunnin and Ambrose (1940, p. 57) in the Malartic area.

Relation to the Sulphide Mineralization

So far as known, the complete replacement of feldspar by quartz mosaics has occurred only near sulphide mineralization, from which the solutions were presumably derived. The occurrence, therefore, of similar alteration in Lots 45, and 43, Range IX, Duprat Township, suggests the proximity of a sulphide body. The intense, localized nature of the lateration shows that the channel by which such solutions were accessible is close at hand. The fact that grab samples of the rock indicate 0.05% Cu, and 0.10% Zn, content shows the presence of at least some sulphides. The nearest known ore deposit is five miles to the southeast. Since lateral migration could hardly have been effective over this distance, the ore solutions probably travelled vertically from some source directly below the altered locality. If an ore deposit exists here, it may perhaps be too deep for mining. On the other hand, if there is more than one channel of access, so far not discovered due to the overburden, other evidences of ore may be found nearby. In either case, the favourable indications in this area certainly warrant a search for tangible evidence of sulphide mineralization. The rusty discoloration of sand lying northwest of this locality may be of some significance, though assays of the sand are negative.

Summary

Complete pseudomorphic replacement of plagioclase, so far as known without parallel, occurs in connection with sulphide mineralization in Lots 43 to 45, Range IX, Duprat Township, in rhyolite. The similarity of the changes to phenomena observed near ore deposits of the Waite-Amulet mine, and the demonstration elsewhere within the destrict, of the prevalence of silica accompanying sulphide replacement, both suggest that a concentration of sulphides may be present in this vicinity.