# THE OLGA-GOELAND LAKE AREA

## ABITIBI-EAST COUNTY

by

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The basic intrusive rocks constitute a well-differentiated series that ranges from amphibolite to diorite to syenite.

The northern and the southern granite are characterized by oligoclase feldspar and interlocking texture. These two masses are believed to be magmatically related and their differences are explained as resulting from depth of consolidation.

The Goéland batholith differs from the other two granitic bodies by its equigranular texture and the more basic composition of its plagioclase.

The petrographic descriptions of the intrusive rocks are followed by considerations on their age and mode of intrusion.

No mineral deposits of economic importance have been found though conditions for their occurrence are not unfavourable.

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Note: All the photomicrographs were taken with natural light.

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## INTRODUCTION

### Location and means of access

The Olga-Goéland Lake area comprises approximately 460 square miles and it is bounded by longitudes 76°40' and 77°15' west, and by latitudes 49°45' and 50°00' north. It lies at about 100 miles north of Senneterre, a town on the Quebec-Cochrane line of the Canadian National Railway.

The most direct canoe route is by way of Bell river from Senneterre to Mattagami lake, the eastern end of which is included in the map-area. There are two other routes each of which uses part of Bell river. One starts from the town of Rochebaucourt and descends the Laflamme river to Kanikwanika island where it joins the Bell river, and then follows the Bell to Mattagami lake. The other follows Bell river from Senneterre to the mouth of Wedding river, 56 miles to the north; ascends Wedding river to its source, Wedding lake; crosses over to Ruisseau Duplessis through a three-mile portage; follows this creek to O'Sullivan river, and the river to Waswanipi lake. Waswanipi lake drains into Goéland lake through a branch of Waswanipi river. There are numerous portages along all these routes.

Facilities for land transportation are now being provided. About twelve years ago, a wagon road was constructed from Senneterre to Rose lake Mine on Madeleine lake, 20 miles south of the southeast corner of the map-area. This road is now being repaired and extended to Bachelor lake, 30 miles southeast of Goéland lake. It will cross the O'Sullivan river and thus provide a fast and cheap means of reaching the area.

The Canadian National Railway has just completed a branch line from Barraute to Kiask Falls, on the Bell river, 47 miles north of Senneterre. The line, at that point, meets the Senneterre-Bachelor Lake road.

Hydroplanes have been used extensively to penetrate into the extensive region lying north of the main railway line. Any of the large lakes in the map-area can be reached from bases at Senneterre in about one hour's flying time.

## Travel facilities in the area

The greater part of the region can be reached rather easily from the shores of the lakes and the banks of the main rivers. The two segments of the Waswanipi river, although interrupted by a few rapids, are navigable by canoe. The rapids can all be run with a large canoe, but cannot be ascended. Red Chute, at the outlet of Olga lake, is avoided by a well-beaten trail, about 1200 feet long.

The north-central part of the area is the most difficult of access. Its western section can be reached through Canet river which, in the spring, may be ascended with fully-loaded canoes, up to its main fork, two and half miles south of the northern boundary of the area. To cover the eastern section, the party ascended Frederic creek which empties into Maicasagi lake two miles north of latitude 50°00'. The creek is rather shallow, but, early in the season, it is navigable, with only two portages, to its fork, eight miles west of the eastern boundary and one mile south of the northern limit of the area. From that point a four-mile base line was cut in a southwest and west direction.

Travel in the woods is quite difficult in the swampy areas because of extensive growth of alders and a dense second-growth of coniferous trees. Elsewhere, the region is easily traversed, except for a few local patches of wind-falls.

## Field Work

Traverses were run across the area by pace-and-compass at approximately half mile intervals. As far as possible, these traverses were made across the general structure of the rocks.

Vertical air photographs, on a scale of about one-quarter of a mile to the inch, were used continuously in the field, and permitted the location of many low exposures. All the exposures along the lakes and rivers were examined in more detail than required by the scale of regional mapping.

## Previous Work

The region was visited for the first time by Robert Bell of the Geological Survey of Canada, in 1895 and 1896. During these two summers, Bell (1895, 1896, 1900)[1] investigated a large tract of land bounded by Rupert river on the north, the upper part of the Ottawa river on the south, Mistassini lake on the east, and the Quebec-Ontario boundary on the west. The main rock groups are shown on his map published in 1900, and they are briefly described in the G.S.C. Summary reports for 1895 and 1896.

In 1912, Bancroft (1912) examined and described a region including Olga and Goéland lakes. Later, Cooke (1927) collected and plotted all the known information on a map published by the G.S.C.. Other workers who contributed to the knowledge of the area include Lang (1932), Norman (1937),

1. The bibliography is given at the end of this thesis. References to bibliography are given by the author's name and year of publication, but if the author's name appears in the text, the year only is given.

Freeman (1938, 1940), and finally Auger (1942) who, in 1938, studied that part of the region lying west of Olga lake.

## Acknowledgements

The field work on which this thesis is based was carried out, for the Quebec Department of Mines, during the summers 1947 and 1948. The writer is grateful to Mr. A.-O. Dufresne, Deputy Minister of the Department, and to Dr. I.W. Jones, Chief of the Geological Surveys Branch, for permission to use the information collected during these seven months of field work for thesis material. Further, during the winter 1948-49, the writer, while on the staff of the Department of Mines, was given all the time and the facilities required to complete this thesis.

During the season 1947, Dr. Claveau, of the same Department, spent about six weeks with the writer in the field, in the capacity of Technical Supervisor. His tactful guidance, his encouragements and criticisms not only in the field, but also throughout the preparation of this thesis have proved invaluable.

Dr. F.F. Osborne, of Université Laval, spent three days with the writer in the field and, in addition, checked numerous thin-sections. Many references were also supplied by him, which were otherwise unobtainable.

Much information used in this thesis was collected by Mr. Malcolm Ritchie, senior assistant in 1947, and Mrss. Walter Coombes and Bruce Lyall, senior assistants in 1948. Their unfailing help is gladly acknowledged.

The maps used for the field-work were prepared by the staff of the Quebec Department of Mines from vertical air photographs taken, in 1946, by the Canadian Pacific Airlines. The final map accompanying this thesis was drawn by the personnel of the Drafting Division of the Department of Mines. Sincere thanks are due to Mr. L. Valois, Chief of the Division, for this courtesy.

The writer is also pleased to acknowledge having received much benefit from many consultations with Dr. J.E. Gilbert, of the Department of Mines.

This thesis was written under the direction of Dr. J.E. Gill of McGill University. Dr. Gill has offered many valuable suggestions while the work was in progress and he has kindly read the manuscript critically.

## PHYSIOGRAPHY

### General considerations

The Olga-Goéland lake area is located in the southern part of the Canadian Precambrian Shield. It lies north of the east-trending Continental Divide which crosses the Ontario-Quebec boundary just a few miles north of latitude 48°00'N. . From there, the Height-of-land zigzags around this latitude for about 200 miles eastward to turn quite abruptly north and northeast, passing about 20 miles east of Chibougamau lake. It thus forms a rough arc of a circle with a radius approximately 130-140 miles long, and its centre is the present area.

The slope of the land, both northward and westward from the Continental Divide, is gentle. The elevation of the Height-of-land 20 miles east of Chibougamau lake, is a little over 1500 feet. To the south, where the C.N.R. line crosses it east of Monet station, its elevation is 1493 feet. Senneterre, which is 100 miles south of the present area, stands at 1023 feet above sea-level. The highest elevation in the Olga-Goéland lake area is less than 1000 feet above sea-level (probably around 950 feet). Generally then, on the Hudson Bay side of the Canadian Shield, the slope of the land, in a westerly direction from the Chibougamau region to the map-area is 4 feet per mile, whereas from Senneterre northward, it is only about 2 feet per mile, over a distance of 100 miles. Such slopes are within the limits of the gradients found on old erosion surfaces throughout the world.

In order to acquire a proper understanding of the local topography, it is necessary to review, if only briefly, the general physiographic history of the Canadian Shield, as it has been traced by numerous workers (in particular: Wilson, 1918; Coleman, 1909; Cooke, James and Mawdsley, 1931; Cooke, 1929, 1930, 1931). Studies carried out in those regions where post-Archean rocks are still found, have established beyond doubt that the surface of Canadian Shield is an ancient, somewhat dissected peneplain. Further, unconformities exposed through erosion, show that the Shield has undergone not one but many cycles of erosion, some of which produced peneplains.

One such buried peneplain, or palaeoplain, is found beneath the Palaeozoic fossiliferous sedimentary rocks that fringe the Shield and occur locally within it.

The even skyline, marking the summit levels in most areas is generally regarded as marking the position in the present topography of the last fairly complete peneplain. This stood in its normal relation to sea-level until about mid-Tertiary time when uplift in relation to the sea resulted in renewed down-cutting and rapid reduction of the weak-rock areas. Extensive straths were developed and subsequently incised before the onset of glaciation. A marked uplift and westward tilting of the eastern part of the Shield, bordering the Gulf of St. Lawrence, was a feature of the Late Tertiary changes.

This rising of the Shield was accomplished slowly because some major streams were able to cut across the rising mountains, carving deep gorges: Hamilton and lower Saguenay rivers. At the same time, dissection of the plain-like surface proceeded rapidly, rivers carving a mountain system out of the rather flat peneplain, e.g. the Laurentides and the Torngats. The cycle was abruptly interrupted in its early stages by the Pleistocene glaciation which forms one of the most fascinating chapters in the history of North America.

## Local topography

The whole area, as already indicated, lies less than 1000 feet above the level of James Bay. Topographic features which could be used as land marks are conspicuously lacking. Seen from the air, the region presents the aspect of a monotonous plain dotted irregularly with low hills that seldom exceed 50 feet in height.

A particularly extensive low tract, characterized by swamps and muskegs, covers a great deal of the northwestern quarter of the map-area. It forms the southern part of a swampy area which extends for great distances to the north and to the west, and which is locally called the "Mattagami Swamp". The basic pattern of this low ground consists of alternating patches of open muskegs, swamps densely covered with alders, and small isolated stands of black spruce. This pattern is interrupted by a few shallow lakes, and low morainic hills. The southern limit of this tract is shown on the general geological map (Map No. 1, in pocket). The borders of the individual swamps and muskegs are very intricate in detail. Small lakes are present within most of them and these indicate that, at one time, the area was covered by much larger lakes, possibly only one extensive lake, in which knobs of sand and gravel, and low rocky hills stood out as islands.

The highest hills are found near the southern border of the region. Their height ranges from about 75 to 150 feet. From west to east along these hills, one successively meets most of the rock types found in the region: oligoclase granite south of Olga lake; volcanic and sedimentary rocks west and south of Laurent Bay; hornblende granite east of that bay; volcanic rocks and biotite granite, east of Goéland lake. The kind of underlying rock thus seems to have little bearing upon the relief.

## Drainage

The area is located near the junction point of two important drainage systems which, together with their tributaries, bring to Mattagami lake the run-off from an area exceeding 16000 square miles: the Bell river and the Chibougamau-Waswanipi systems.

The first one, Bell river, flows northward into the western part of Mattagami lake. Its source is Villebon lake, in Villebon township, about 32 miles south of Senneterre. This lake is on the north side of the Height-of-land which at this point runs east-west, and separates the lake from the head-waters of the Ottawa river on the south.

The second, and by far the greater, drainage system originates from the Height-of-land, a few miles east of Chibougamau lake. This lake drains into Waswanipi river which collects the discharge from Opawika river and the chain of lakes along it before flowing into Waswanipi lake. Thence the water flows to Goéland, Olga, and Mattagami lake through short westward-flowing segments of Waswanipi river.

An important addition to the drainage comes from Maicasagi lake, the southern end of which is included in the map-area. This lake receives the discharge of Chensagi lake on the north, and Maicasagi river on the east. It is connected with Goéland lake by a shallow arm: Max Narrows.

The levels of the different lakes give a good idea of the general westward slope of the region:

| | |
|---|---|
| Height-of-land east of Chibougamau lake..... | 1500' |
| Chibougamau lake............................ | 1253' |
| Waswanipi lake.............................. | 830' |
| Goéland and Maicasagi lakes................. | 810' |
| Olga lake................................... | 785' |
| Mattagami lake.............................. | 765' |

The reference datum plane is the level of James Bay.

The local drainage is collected by three main basins: Mattagami, Olga, and Goéland (with Maicasagi) lakes. The northwest quadrant drains into Mattagami lake mostly through Canet river which flows south and then west from its source in the granitic areas north of the northern limit of the region. The southwest quadrant drains into Olga lake through east-west flowing streams, whereas Goéland and Maicasagi lakes collect the run-off from the east half of the area.

Except for a few sections along the two segments of Waswanipi river, the streams are all flowing in valleys that have been excavated in glacial deposits. No streams has yet attained 'grade' and the irregular courses are not due to meandering, but to original irregularities in the sloping surfaces on which the streams developed. The courses of most streams are here and there interrupted by rapids. Such rapids are generally caused by accumulations of large glacial boulders that the streams have not yet had time to dispose of.

Red Chute, at the outlet of Olga lake is a notable exception. On leaving the lake, the waters cascade turbulently over a ten-foot ledge, to drop again another eight feet in the next few hundred yards. (Plate I).

The Waswanipi river, at this place, flows across a sedimentary belt which, about 400 feet downstream from the ledge, displays strong evidence of shearing. This shear zone is 15 feet wide, and is parallel to the northeast bedding of the rocks. It appears to have been responsible for the initiation of the fall. The scarp has, up to the present, migrated 400 feet upstream. This scarp cannot be traced outside the river valley. If it existed before glaciation, it has been obliterated. The channel itself, at the outlet of the lake, follows a pre-glacial, northwest fault which offsets the shear zone.

Because of the narrowness of the valleys, the level of the streams is very variable. In the spring, just after break-up, the level is commonly about ten feet higher than in midsummer. (The mouth of Canet river was sixteen feet above normal in the middle of June 1947). Heavy summer rains often raise the level of the streams, near their heads, by many feet. The abnormal level generally persists for a few days, often facilitating access by canoe into an area otherwise accessible only on foot.

The drainage pattern is a modified dendritic one. East of Olga lake, the east-west streams debouching into the east-trending bays may follow lines of weakness parallel to the strike of the volcanic rocks. There is, in fact, abundant evidence of strike shears in these rocks. Since, however, most of the streams flow in narrow valleys, cut so far only in glacial deposits, it is difficult to arrive at definite conclusions as to local controls without spending in the study of these features much more time than can be devoted in the course of geological mapping on a regional scale.

## Pre-glacial Valleys

Evidence of pre-glacial valleys was noted only in a few places:

1) A stream flowing northeastward into Maicasagi lake at a point about one quarter of a mile south of the northern boundary of the map. This stream flows in a valley which, two miles east of its source, is at least 1000 feet wide and is bordered on both sides by granitic hills about 50 feet high. The floor of the valley as well as most of the hills are covered with glacial debris consisting mostly of sand with a few boulders and clay. The lower course of the river, from a point about three and a half miles in a straight line from its source, may have been in an easterly direction before glaciation instead of northeasterly. This is shown by the occurrence of a valley, marked by a series of small swamps, in direct eastward continuation of the upper reaches of the river. The valley is bordered both north and south by low granitic hills similar to the ones farther west, and could represent the pre-glacial location of the stream.

Westward from the source of the river, the valley disappears under the glacial drift cover.

2) A stream flowing eastward from a point just south of mile post 19, on the survey line running through the centre of the map. This small creek flows in a valley which, at its head water, is about 1500 feet wide, being limited on both sides by low hills of volcanic rocks. This valley is also almost completely filled with glacial deposits.

3) At the south end of Maicasagi lake, a wide sinuous depression, marked by swamps and muskegs, extends from the south end of the lake to a wide bay on the northeast shore of Goéland lake. The valley, now enclosed by scattered hills, crosses the present channel of a large river which flows west and north into Maicasagi lake. The sinuousity of the depression is believed to reflect the meandering course of an old river which has disappeared as a result of glaciation. A similar, though wider, swampy area lies on the point east of Laurent bay on the west shore of Goéland lake.

These data are unfortunately too few and too widely spaced to permit reconstruction of the pre-glacial drainage. However, the trends of the old valleys, none of which follow the direction of glaciation, are in general accordance with the schistosity of the underlying rocks, indicating that the drainage was adjusted to the bedrock structure. Such a control is also suggested by the east-trending bays on the east shore of Olga lake.

## Physiographic history of the region

The physiographic history of the region may be briefly summarized as follows:

1) Erosion of the Archean rocks and development of a peneplain at least by early Palaeozoic time.

2) Submergence of this peneplain and deposition of Palaeozoic (Ordovician?) limestones. This submergence is inferred from the presence, within the map-area, of fossiliferous boulders, the importance of which is discussed under "Pleistocene Deposits".

3) Summit peneplain. It is probable that several cycles of erosion affected the area between the Ordovician and the end of the Mesozoic. No details can be supplied from this area, but it is clear, from other parts of the Shield, that the summit peneplain had been formed and partially dissected before the onset of glaciation (Cooke, 1931). The age of the summit peneplain is not definitely known, but it is probably to be correlated with the summit peneplain of the Appalachian system, which is variously dated as late Cretaceous to middle tertiary or even later. D.W. Johnson, after extensive studies, advocated a Tertiary age for it (Johnson, 1931).

4) Rejuvenation, through differential uplift. A new erosion cycle was started during which straths were developed in valleys adjusted to structure. These straths were excavated in the exhumed early-Palaeozoic surface.

5) Late-Tertiary uplift. There is no record of this uplift in the map-area. It is probable that the youthful valleys excavated by the rejuvenated streams were obliterated during the next chapter in the history of the region.

6) Pleistocene glaciation, during which the topography was modified and the drainage completely disturbed.

7) Modern cycle. Following the retreat of the glaciers, a modern cycle developed over the gently-undulating surface of the glacial deposits. This cycle is now in the stage of youth.

## GENERAL GEOLOGY

Any geological cross-section drawn northward from the boundary between the Temiskaming and the Grenville sub-provinces, in northern Quebec would show an alternating succession of intrusives (mostly granitic) on one hand, and older (volcanic and sedimentary) rocks on the other. In spite of large unmapped areas, it is possible to divide the volcanic-sedimentary complex into three main belts, more or less parallel and trending generally east-west. From south to north, the belts are: Ville Marie-Guillet lake, Rouyn-Bell river, and Waswanipi-Chibougamau, each of which is separated by more or less continuous bodies of intrusive rocks.

The Waswanipi-Chibougamau area, in turn, branches out, eastward from the Quebec-Ontario border, into three zones partly separated by granitic rocks. To use the terms given in the Geology of Quebec (Dresser and Denis, 1944, Fig. 12, p. 124), the zones from south to north are: Quevillon-Panache, Pusticamica-Opawica-Obatagamau, and finally Mattagami-Waconichi.

The volcanic and sedimentary rocks of the Olga-Goéland lake area, are a part of the northern zone. The area is located at about 20 miles east of the region where this zone loses its identity through combining with the centre one to form a wide area of old rocks trending westward toward the Quebec-Ontario boundary. (Fig. 1).

The present map-area thus straddles the east-trending contact between volcanic-sedimentary rocks on the south, and an extensive series of granitic gneisses on the north. Most of the rock exposures are low and generally covered with thick moss. They commonly measure only a few hundred square feet (or less) except around the shore of the larger lakes and along the banks of Waswanipi river where removal of the 'clay' cover has exposed large sections of the bedrock.

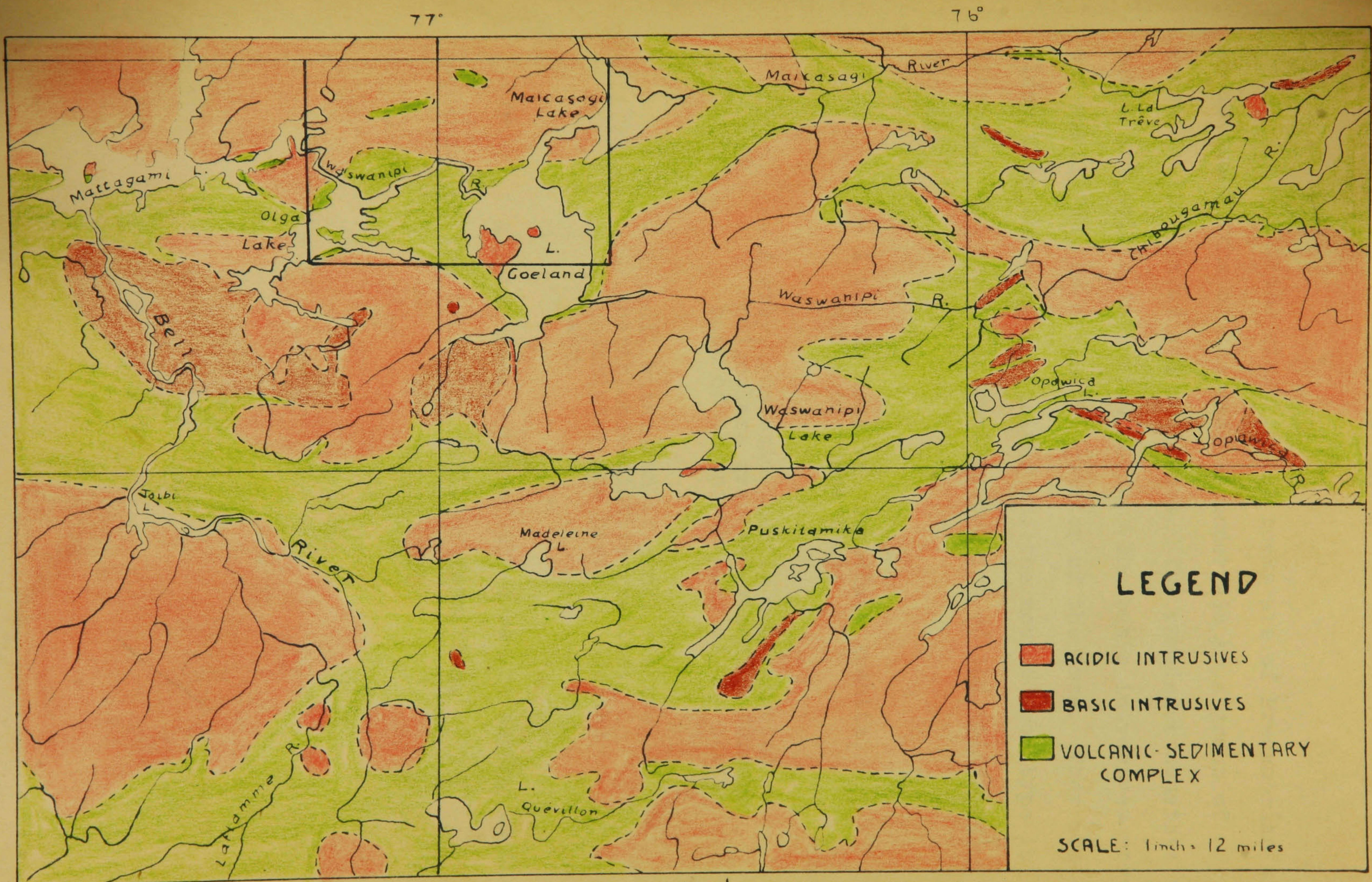



FIG. I

MAP SHOWING PART OF THE WASWANIPI-CHIBOUGAMAU AREA

AFTER MAP No. 703A, SOUTHERN QUEBEC (WEST SHEET) 1942.

All the consolidated rocks are of Precambrian age. About two-fifths of the area is underlain by a group of Keewatin-like lavas and sediments. The remainder consists of basic and acidic intrusive rocks. The basic intrusives crop out mostly in the northwest quarter of the area. They are older than the acid intrusives and the most common type is diorite. The acidic intrusives consist of the following bodies:

- A rather massive oligoclase granite, south of Olga lake;

- A grey, gneissic, partly contaminated oligoclase granite extending through most of the north half of the area;

- A small batholith of pink, massive hornblende-biotite granite, underlying the basin of Goéland lake.

All the rock types of the area are shown, in their sequence, in the following table of formation.

## TABLE OF FORMATIONS

| | | | |
|---|---|---|---|
| Cenozoic | Quaternary | | Clay, clayey-sand, varved-clay, till, pure sand. |
| | | GREAT UNCONFORMITY | |
| PRECAMBRIAN | | | Diabase (Keweenawan?) |
| | Archean | | Pink, microcline granite and pegmatite. |
| | | | Lamprophyre, diorite, and amphibolite dykes. |
| | | | Coarse-grained, pink, massive, hornblende-biotite granite (Goéland batholith). |
| | | | Grey, generally massive, oligoclase granite (Olga quartz-diorite), probably related to the "northern granite". |
| | | | Grey, gneissic oligoclase granite, often referred to as the "northern granite". |
| | | | Diorite-Syenite sequence (basic series) |
| | | FOLDING | |
| | Archean | | Concordant bodies of fine-grained gabbro, and of granite porphyry. |
| | | Volcanic-sedimentary series | Meta-trachytes, generally porphyritic, often fragmental. Some beds of tuffs. |
| | | | Fine-grained greywackes recrystallized into biotite and/or hornblende schists. Few beds of chert. |
| | | | Meta- andesites (and possibly minor basalt flows) commonly ellipsoidal. Some beds of tuffs. |

## VOLCANIC-SEDIMENTARY SERIES

Excepting the area occupied by Goéland lake, which is underlain by a small granite batholith, the rocks of the volcanic-sedimentary series occupy roughly the southern half of the map-area. They form part of a long belt of these rocks which extends for more than 200 miles from the Quebec-Ontario boundary, through Mattagami lake to and beyond Chibougamau lake. In the region studied, the belt varies in width from four miles, west of Olga lake to about ten miles, just east of Goéland lake. The best exposures are on the west and south shores of Laurent Bay, around Olga lake, and on the numerous islands in this lake.

This belt of Keewatin-like rocks may be pictured, west of Goéland lake, as consisting of a core of predominantly trachytic flows surrounded by strips of andesitic and sedimentary rocks. Northward from the area of trachytes, there outcrops first a band of sedimentary rocks, then a belt of andesitic lavas. On the south side, the succession is reversed: the andesites occur next to the trachytes and separate them from the remains of a sedimentary band cropping out on the south shore of Olga lake. The general trend of both the bedding and the schistosity in that area is east-west.

On approaching the Goéland batholith, the trachytes give place to a north-south crescent-shaped band which consists of andesites containing long narrow sedimentary layers. These lavas wrap themselves around the west nose of a granite mass which underlies Goéland lake. East of Goéland lake, the lavas are represented by an east-trending belt which, at the eastern border of the map-area, is nine miles wide.

Many inclusions of older rocks were found in the intrusives, both basic and granitic, exposed in the northern half of the map-area. The inclusions are usually small, either angular or ellipsoidal, and their greatest dimensions seldom exceed a few feet. Occasional larger units do occur, however, and they are indicated on the map. The two largest of these, in the north centre of the area, have been joined on the map by dashed lines which correspond to the contact drawn by the Geologists of the Dominion Gulf Exploration Co. as a result of Geophysical surveys (personal communication).

## Andesitic Rocks

These rocks are meta-volcanics, mostly meta-andesites, with a few meta-basalts. Their structural characters are generally so well-preserved that their volcanic origin can be recognized readily in the field and under the microscope. This group is exposed as three main belts:

a) North of Olga lake. The andesites form a zone trending east to northeast and up to three and a half miles in width. It is bounded on the north by granitic intrusives and on the south by a sedimentary band. The belt is exposed for a length of only three miles. At its western end, north of Red Chute, it is truncated by intrusive basic and acid rocks. Its eastward extension could not be ascertained because of heavy drift cover.

b) Near the southern margin of the area. This belt trends west to northwest and extends from the south shore of Laurent Bay to the western border of the map-area. It follows the north shore of the southernmost east-trending bay on the east side of Olga lake and includes the largest island of this lake. The average width of this zone is approximately one mile and a half.

c) Around and west of Goéland lake. If it were not for the Goéland batholith, this belt would presumably cover the greater part of the southeastern quadrant of the map-area. On its eastern end, where it leaves the present area, it is about nine miles wide. Its western limit is an arcuate line roughly following the western shore of Goéland lake at a distance varying from one-eight of a mile, south of Laurent bay to about one mile northwest of that bay. At the north end of Goéland lake, the zone is in contact with the northern granites thus effectively masking the trachytes on the south, west, and north.

In addition to these three main belts, a few small bodies of andesitic rocks have been found within the area of trachytes. The more important of such intercalations are seen along the east shore of Olga lake, both north of Waswanipi river and on the point south of the northern bay. Other occurrences are on the north and south side of the Waswanipi river almost exactly at the centre of the map-area.

The presence of inclusions of volcanic rocks in the northern intrusives has already been mentioned. These rocks resemble the lavas of the main belts, but they possess, as could be expected, peculiar characters and it seems best to treat them separately.

## Main belts of andesites

### Description

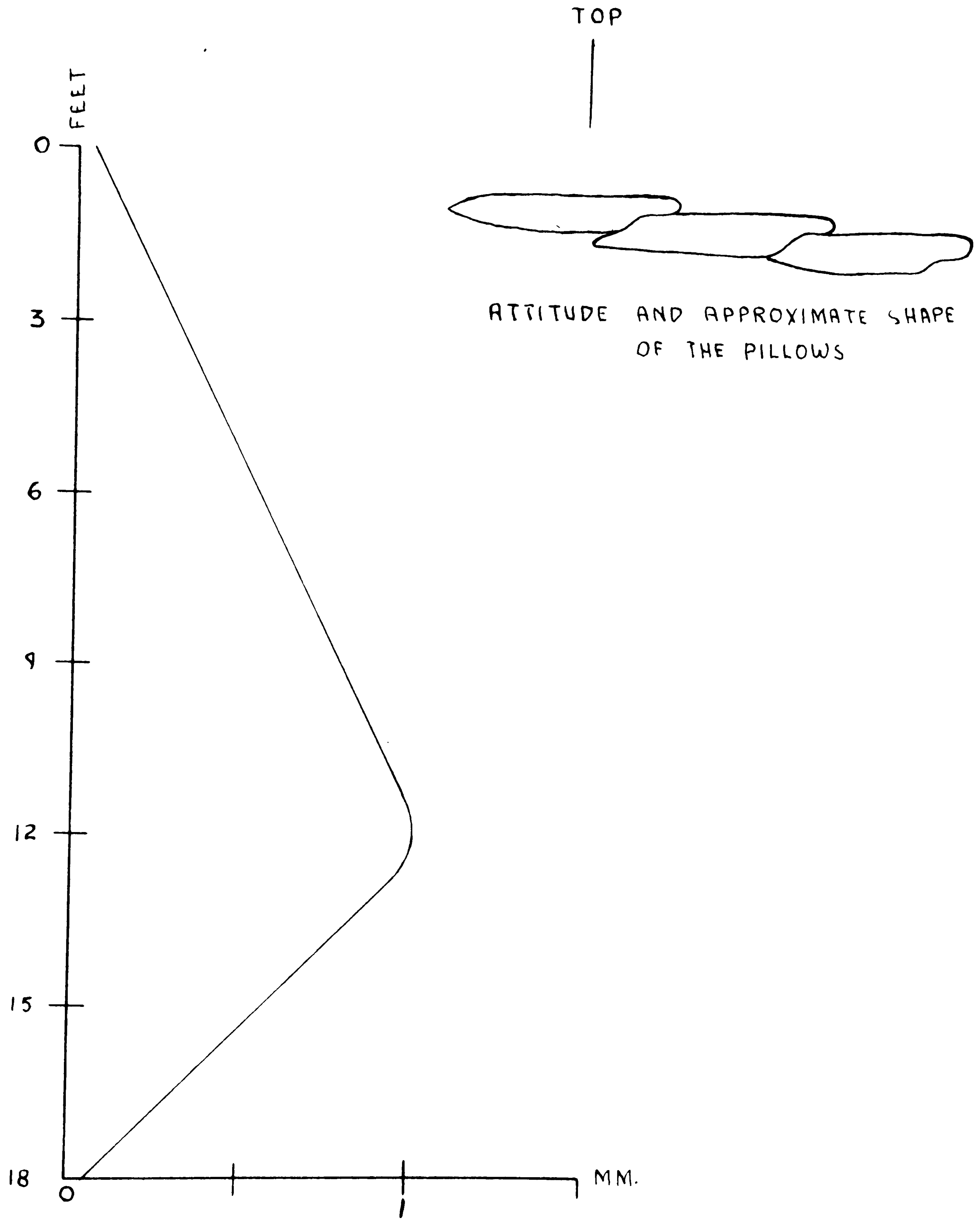
The intermediate lavas, in the main belts, are fine-grained, sometimes almost aphanitic, and dark grey, often with a greenish tinge. They commonly have a porphyritic appearance, although the largest crystals are of porphyroblastic development. Amygdaloidal flows, in which the amygdules are very flattened, have been noted in a few places. The structure of these lavas shows all gradations from almost massive to highly schistose.

Many pillows were seen, specially on the clean rock surfaces surrounding Olga lake. All the pillows are very much deformed: the ratio length/width is commonly of the order of 20/1, so that the pillows appear as thin lenses from which little information can be obtained as to the attitude of the flows. Only in one locality could a determination be made of the top of a flow. This locality is on the south shore of the middle bay, east side of Olga lake, at about one-half mile east of the mouth of the bay.

The pillows are located in the upper part of an 18-foot flow. They still have a faint bun shape and their arrangement indicates that the top of the flows is facing south. As a corroborative, a systematic series of specimens, taken all across the flow, shows that, near both borders, the grain is aphanitic, and that the coarsest part of the bed is at 12 feet from the top as indicated by the pillows. The curve shown on Fig. 2 differs from the one prepared by Cooke (1925) as to the position of maximum grain size, but they both show the same tendency.

## Petrography

The andesites consist generally of amphibole and feldspar, with some quartz, epidote, chlorite, calcite, and magnetite. The proportion of these minerals is highly variable:




VARIATIONS IN GRAIN SIZE IN AN ANDESITIC PILLOWED FLOW.

FIG. 2

| | |
|---|---|
| Amphibole.......... | 40-80% |
| Feldspar........... | 10-50% |
| Quartz............. | 5-15% |
| Epidote............ | 5-20% |
| Chlorite........... | Acc.-10% |
| Calcite............ | 0-15% |
| Magnetite.......... | 0- 2% |

The common amphibole is ordinary hornblende and has the following optical properties:

Absorption formula: Z= blue green to deep blue
Y= olive green
X= greenish yellow to straw yellow

$Z \wedge C = 16\text{-}24^{\circ}$ ; (-) 2V= 75-80% ; Absorption: $Z > Y > X$.

One section contains a much paler, less pleochroic amphibole, identified as actinolite:

Absorption formula: Z= light green
Y= olive green (pale)
X= straw yellow

$Z \wedge C = 18^{\circ}$ ; (-) 2V= $85^{\circ}$.

The feldspar of these rocks can seldom be accurately determined. It is usually clouded by kaolin, white mica, and carries ragged masses of epidote, and possibly clinozoisite in the core. Some of the fresher specimens contain original broken phenocrysts of a plagioclase near andesine (An28-30) in composition. Faint traces of albite twins can be seen occasionally although, because of the alteration, twinning is generally inconspicuous. No prominent zoning has been observed.

Albite is present in most of the rocks. It occurs in places as small, clear anhedral grains along the borders of the altered feldspar. More commonly, it is found as fat lenses measuring, as a rule, up to 5 mm. in their longest dimension (exceptionally up to 3 centimeters). In these, the albite is still clouded with kaolin and especially epidote. The lenses are aligned parallel to the schistosity and they have grown by pushing aside the smaller minerals of the rock. They are truly porphyroblastic. (Plate II-B).

Some quartz is found in all the rocks. It occurs as small lenses parallel to the schistosity or as veinlets cutting across it. Often also, it is interstitial to the altered feldspars and to the hornblende, and contains minute inclusions of those two minerals. In the amygdaloidal flows, the amygdules mostly consist of quartz which is often shattered and carries shreds of chlorite. Altogether, probably little of the quartz is original.

The most abundant chlorite is penninite. It is light green, has a low birefringence, and is positive. Clinochlore was found in one slide. The chlorite is always derived from hornblende, and its greatest development is found in and near the numerous well-defined shear zones which traverse the andesites of the area.

Calcite may be found either as small specks distributed through the rock or as veinlets, as much as one inch thick. These follow the schistosity. It is often associated with quartz and pyrite. The small, disseminated grains may be the result of alteration of the calcium-bearing minerals of the rock, mostly plagioclase, but there is no doubt that there has been considerable migration of material to form the veinlets.

Texture

The texture is essentially crystalloblastic. It is dominated by two minerals, namely hornblende and albite, which are the products of recrystallization. The lenticular habit of the albite porphyroblasts and their relation to other minerals has already been mentioned.

Throughout the main bands, hornblende occurs as tabular grains, up to 2 mm. (commonly less than 1 mm.), or as shreds, depending upon the stage of metamorphic development. Prismatic faces are generally much more abundant than terminal faces. The flakes of the mineral, in those rocks where re-crystallization is more advanced, have a length up to 2 mm. . Their orientation is erratic: some follow the borders of the albite porphyroblasts, while other abut against them. Even in the more massive types, however, there is always at least a general subparallel orientation of the grains imparting to the rock a faint schistosity. This schistosity is more apparent in those specimens in which the hornblende has only recrystallized in the form of long, thin shreds.

It has not been possible to define consistant bands in which most of the hornblende would appear either as well-developed prisms or as shreds. The paucity of exposures and the impossibility of separating the two types in the field may be offered as a possible explanations. Another reason which seems probable may lie in slight local differences either in original composition or in intensity of metamorphism. Rocks of different composition behave differently during metamorphism. It is also possible that, in a homogeneous series undergoing metamorphism, small changes in otherwise constant conditions of temperature and pressure (specially stress) may cause local differences in the appearance of the end product.

The grains of original feldspar are, as a rule, less than 1 mm. long and lie in any direction within the rock. The crystals boundaries are in some places well-preserved, in spite of rather extensive fracturing. Generally, however, and especially in those specimens where the albite porphyroblasts are better developed, the shapes of the original feldspars are irregular. They either form indistinct masses, clouded with epidote, or sinuous streaks between trains of hornblende flakes. Many of the larger grains are surrounded and partly replaced by hornblende.

## Changes in composition due to metamorphism

These rocks are now characterized, as to composition, by 1) the presence of hornblende; 2) the sodic nature of the plagioclase; 3) the low percentage of original quartz (if any). What changes have these lavas undergone since the time of their extrusion? This question can only be answered partially.

The changes in the feldspar are not easily traced. As mentioned above, the composition of the few original grains of plagioclase that are not too altered to prevent determination is close to the oligoclase-andesine boundary in the isomorphous series. Since these grains, however, are clouded to some extent, by epidote, their original composition was probably more calcic. The visible effect of metamorphism on the feldspar has been the transformation to albite and epidote. From the arrangement of the grains, it seems that the porphyroblasts of albite were formed before the prisms and shreds of amphibole were developed.

Poikilitic inclusions are common in the hornblende. The minerals thus found are clouded feldspars and small grains of amphibole diversely oriented. The latter have the same pleochroic formula and thus are probably a hornblende of similar composition as that of the enclosing prisms.

As a whole, it may be said that there has been little change in the bulk composition of these rocks. Metamorphism has caused recrystallization of hornblende and partial development of albite. This latter process was not carried out to completion as is evidenced by the remnants of clouded original plagioclase.

Some beds which are now characterized by the hornblende-albite association, were probably originally more basic and have acquired their present compositions as a result of metamorphism. In this connection, it is appropriate to discuss the presence of magnetite, reference to which has been purposely delayed until now.

As indicated in the composition table, magnetite varies from zero through accessory to a maximum of two per cent of the rock. It occurs commonly as small grains along and within the flakes of hornblende, rarely as dust or large clots. One specimen contains well-developed octahedra of magnetite around which the schistosity is seen to curve.

In some places, magnetite accompanies secondary chlorite and it is then quite likely a released product from the transformation of hornblende into chlorite. One however must seek another explanation for the presence of magnetite (up to two per cent) in those rocks where chlorite is either absent or present only in accessory quantity.

In these cases, magnetite may have been an original mineral. Harker (1935, p. 175 and 185) states that iron oxide in the form of magnetite is common both in andesites and in basalts. This is very likely the explanation of the presence of some of the magnetite present in the rocks now under study. However, its constant association with hornblende in rocks devoid of chlorite is believed to be significant. If the magnetite were all original, it would presumably be distributed erratically in the rocks. When these rocks undergo metamorphism, magnetite may segregate to form clots or bands, but there is no reason why it should become associated with hornblende in preference to the other minerals e.g. feldspar.

The hypothesis is advanced that part of the magnetite, specially in those rocks devoid of chlorite, represents a released product resulting from the transformation of pyroxene into hornblende. No other indication has been seen of the former presence of pyroxene in any of the thin-sections studied. The pyroxene, if it was ever present, has been entirely transformed into hornblende as a result of the metamorphic conditions imposed upon it. The action of shearing stress may in particular be invoked: "Shearing stress has the effect of promoting the amphibolization of any original augite, and postponing the reverse change, which in fact is attained only rather exceptionally" (Harker, 1932, p. 284).

## Type and grade of metamorphism

The critical mineral association in these andesitic belts is hornblende-albite-epidote. They thus fall quite naturally in the albite-epidote-amphibolite facies described by Turner (1948, p. 88). As far as can be ascertained from microscopic studies, most of the original rocks consisted generally of hornblende and plagioclase so that the mineralogical changes were likely effected quite easily. A few beds, however, probably had a basaltic composition and these too have now the hornblende-albite-epidote association.

That such extensive and widely separated belts of rocks should present similar characteristics must be due to regional metamorphism. The rocks have many of the characteristics described by Harker (1932) for the lower grade of such metamorphism: Albite porphyroblasts are numerous; hornblende is well developed; some epidote is still left which is not yet assimilated. The changes were not high enough to obliterate all primary structures, although such features as amygdules and pillows are highly deformed.

## Andesitic rocks found as inclusions

A fresh surface of these rocks, because of the fineness of grain appears dark-grey, almost black. Weathered surfaces reveal the presence of a rather high percentage of feldspar that gives the rock a characteristic granular appearance.

The exact nature of all these inclusions could seldom be determined with certainty because recrystallization has obliterated all primary structures. From their field appearance, especially their composition, more basic than any of the sedimentary rocks in the area, they were classified as andesites. Microscopic examination has revealed their composition to be essentially the same as the lavas just described.

This composition is:

| | |
|---|---|
| Plagioclase (An32)..... | 40-45% |
| Hornblende............. | 30-40% |
| Quartz................. | -15% |
| Chlorite............... | Acc.- 2% |
| Magnetite.............. | Acc.- 1% |
| Epidote................ | Acc. |
| Biotite................ | Acc. |

The plagioclase, although generally cloudy, still shows much twinning after the albite law. It is rather calcic (An32) and the grains seldom possess any boundaries reminiscent of crystal faces. Since, in addition, the larger grains (about 2 mm.) contain numerous small flakes of hornblende, this plagioclase is interpreted as being entirely recrystallized. In contrast with the andesitic rocks of the main belts, the inclusions do not contain any albite.

The amphibole has a much lighter color than in the main bands:

Absorption formula: Z= light bluish green
Y= pale olive green
X= greenish yellow

Z C= 14-24° ; (-)2V= 80°

It is more distinctly green that the hornblende of the main belts, and according to Turner (1948, p. 90) this indicates a higher metamorphism.

Besides feldspar, hornblende, and possibly magnetite, the remainder of the minerals are probably hydrothermal. Among them, quartz is the only one occurring in important quantity, and, as usual in these recrystallized rocks, it is found as disseminated grains and as veinlets. Biotite, chlorite, and epidote are mostly found in association with these veinlets, less commonly in association with hornblende. These also are likely of hydrothermal origin.

Notable differences in composition with the other andesites are, in these inclusions, the lack of albite and the negligible quantity of epidote. These two features could well be the result of a single cause, viz. the development of andesine from albite under more rigorous metamorphism. If epidote is formed from released lime during the decomposition of a basic feldspar into a more sodic type, it is to be expected that during the reverse process, albite may assimilate the lime from epidote in order to readjust itself to the new conditions imposed upon it. Another explanation for the lack of epidote may lie in the fact that this mineral is essentially a stress-mineral (Harker, 1932, p. 149), and the textural evidence indicates crystallization without great stresses acting on the rocks.

The texture of those andesites which are found as inclusions is typically granoblastic; it results from the fine mosaic arrangement shown by hornblende and feldspar. (Plate III-A). Grains of both minerals are about the same size (1 mm. or less) and their boundaries are generally interlocking, although hornblende has a tendency to be more idioblastic.

The significant minerals in these rocks, hornblende and andesine, indicate higher metamorphic conditions than were operative in the rocks of the main belts. Since the decussate granoblastic texture implies low intensity of directional forces, it is concluded that temperature was the main factor in the production of the observed effects. The mineral association places the rocks within the amphibolite facies of Turner and Eskola, a grade somewhat higher than the andesites forming the main belts. These inclusions belong to the medium grade of thermal metamorphism.

This same granoblastic texture is again seen in two specimens taken within the main belt, but close to the contacts with intrusive granites: one was collected north of Red Chute and the other, from the extreme southeast corner of the map-area. The similarity, in hand specimen and in thin-section, of these rocks which undoubtedly belong to a volcanic series has greatly facilitated the recognition of the nature of the northern isolated volcanic inclusions.

On the east shore of Goéland lake, south of Maicasagi lake, exposures are very few. However, the volcanic rocks cropping out in that area are characterized by a composition and texture similar to that of the andesites of the main belts. Hornblende occurs either as well-developed prisms or as thin shreds. On approaching the granite contact toward the south, one first notices the appearance of numerous narrow lit-par-lit injections of granitic and feldspathic material along the planes of schistosity. These injections, one mile from the contact, are about one quarter of an inch thick, and they occur sporadically. They gradually increase in number and size until, about one hundred paces from the contact, one concordant body is found which is seventy-five feet wide.

The lavas always keep their schistose appearance, but the texture changes. The grain size does not increase, yet the individual grains gradually assume their boundaries. They thus become more and more visible until, near the contact, the rock is perfectly granular. Microscopic examination shows the rocks to have a similar compostion and the same granoblastic texture as the lavas in the roof-pendants. A similar phenomenon was observed north of Red Chute, although in this case, the rock is slightly more basic and, in consequence, the textural changes are less apparent in the field.

Because of the lack of exposures and the impossibility of examining every minor change under the microscope, information on the actual transition stages in these rocks is necessarily sketchy. Enough observations have been made, however, to indicate that, along the contact with intrusives, the lavas have undergone a thermal metamorphism which succeeded the period of regional metamorphism and which obliterated the effects of the latter.

It is a noteworthy fact that in all these rocks characterized by a granoblastic texture, the grain size is smaller than in the other lavas. Since the main factor (possibly the only one) was either high temperature or at least (moderately high) temperature acting for a long time, coarse grain should be expected. This phenomenon, however, is not an isolated case, and it has been very clearly explained by Turner (1948):

> "Though the grain size of a rock on theoretical grounds should increase without limit during prolonged metamorphism, growth of very large crystals is actually rare. Even in purely termal metamorphism in the absence of deforming movements, recrystallization not infrequently results in diminution of grain size, as when a phenocryst of feldspar, while retaining its original external form, is converted to an aggregate of smaller grains." (p. 157).

The action of deforming movements would greatly facilitate the production of such a texture. A forceful intrusion of a large mass could cause the crushing of the rocks near the intrusive or within it. This effect could then be followed by recrystallization under static conditions attendant upon the loss of heat evolved by the cooling magma.

Retrograde metamorphism in the andesites

To resume the above discussion, it appears that the andesitic rocks, and some basalts, have undergone two different types of metamorphism depending upon their position with respect to the main intrusives. The rocks of the main belts, excepting those near the contacts with granitic intrusives, have been changed by regional metamorphism, to hornblende albite rocks corresponding to the albite-epidote-amphibolite facies. The inclusions in the intrusives, as well as the rocks near the contacts, have recrystallized to a granular assemblage of hornblende and andesine, corresponding to the second grade of thermal metamorphism.

All the intermediate lavas, however, have undergone extensive shearing along restricted zones, especially in the main belts. The amount of chlorite developed as a result is rather small as determined in the thin-sections examined. This is explained by the fact that, for purposes of microscope studies, only the fresher specimens were considered. In the field, on approaching a shear zone, the amount of chlorite increases gradually until the rock becomes a highly chloritic schist, glistening with waxy flakes of chlorite. This schist crumbles so easily that it is usually impossible to detach a specimen of suitable size. The width of such transition zones ranges from a few inches to many feet.

Hydrothermal development of chlorite, in the more massive rocks is exceptional. Generally the formation of chlorite has been favored only along definite shear zones at a time following the first period of regional and thermal metamorphism. Other hydrothermal effects, consisting mostly in the introduction of quartz, calcite and pyrite, are as a rule intense along such zones.

Slight bending of the hornblende prisms and occasional fracturing of albite porphyroblasts has been observed in some of the rocks away from the main shear zones. These may probably be regarded as mild or remote effects of the stresses whose greatest intensity was localized along those zones which are now heavily sheared and chloritized.

## Sedimentary rocks

The sedimentary rocks, as already mentioned, form three main bands in the area. The first and larger one, later referred to as the Red Chute band, occurs on the north side of the core of acid lavas and lies south of an andesitic belt. This band is from one to two miles wide and crosses the northern part of Olga lake. Like the northern andesites, it is truncated at its western end, just west of Olga lake, by later intrusive rocks. East of the north end of the lake, the band undoubtedly persists for some distance, as suggested by the exposures present along the northeast shore. The extent of its eastward continuation is however, a matter of conjecture because of uninterrupted mantle cover. It is possible that this band extends far enough east to be truncated by the gneissic granite, the contact of which appears to run in a southeasterly direction under the swampy area.

The second belt of sedimentary rocks is exposed near the southwest corner of the map-area, along the south shore of Olga lake and on nearby islands. As shown on the map, it varies in width from one to three-quarters of a mile, it trends approximately northeast and is a little over three miles long. This belt probably continues eastward for a greater distance. The granitic exposures all along the south shore of the deep east-trending bay, at the southern extremity of Olga lake, are for a large part composed of mixed rocks or migmatite, in which most of the inclusions are of sedimentary rocks.

The third principal occurrence of sedimentary rocks forms a crescent-shaped band which extends from the south shore of Laurent bay (Goéland lake) to the Waswanipi river, a distance of about six miles. Its convex side is toward the west. This band is up to one-quarter of a mile wide and its eastern border follows approximately the western shore of Goéland lake. The north end of this band gradually tails out into andesitic rocks, as indicated by interstratification of both types of rocks on south shore of the Waswanipi river, one-quarter of a mile west of Goéland lake. The belt appears to be much thicker on the south shore of Laurent bay, near where it is truncated by the Goéland batholith. This increase in thickness is believed to be due to drag-folding, evidence of which will be discussed later.

In addition, numerous narrow strips of sedimentary rocks are found intercalated with the andesites, north and east of Goéland lake. The most extensive are shown on the map, but there are many more, especially on the southeast shore of Goéland lake, which are too small to be separated from the lavas. In this locality indeed, Claveau (1948) has found the southern extension of the volcanic rocks to consist predominantly of typical sedimentary rocks. That such an extensive horizon is not found northward cannot be explained only by lack of continuous exposures. It appears probably that Claveau's sedimentary rocks form a lenticular body (similar to the one on the west shore of Goéland lake) which is interlayed with the lavas and whose northern tip fingers out near the southern border of the present area.

Red Chute Sedimentary rocks

These rocks are everywhere schistose and fine-grained. Porphyroblasts of feldspar are often the only grains that can be identified in the hand specimen. The beds are generally thin, seldom more than one inch in width, although on some exposures, no bedding was observed across widths of many feet. Such thicknesses appear to result only from the fact that the different beds are close in composition and color. On the cleanest surfaces bedding lines only appear very faint and the slightest film of dirt is sufficient to mask them.

Away from the intrusives, the sedimentary rocks are very homogeneous, but, as one approaches the plutonic rocks, veins and igneous seams, lenses of various composition are noticed. At Red Chute, about 500 feet east of the north-south contact with the syenites, the injections consist of quartz which forms bead-like veins or follows the sinuous courses of drag-folds. Westward, small stringers of aplite, pegmatite, and syenite are found in increasing number. The syenite is older than both the aplite and the pegmatite, but the age relations between the aplite and pegmatite could not be determined. About 200 feet east of the contact, a ten-foot concordant body of syenite contains inclusions of coarse garnet-hornblende rock. Continuing westward, the sedimentary rocks are highly contorted and contain a multitude of igneous stringers.

Similar phenomena have been observed on the west side of the small plug of oligoclase granite, on the west shore of Olga lake. In this case, however, dislocation effects are very minor and the igneous material consists almost exclusively of oligoclase granite, similar in composition to the main intrusive.

The color of the sedimentary rocks is variable in the different shades of grey, rarely purple or black. The rocks are completely metamorphosed and most of them are devoid of any clastic texture. In spite of the universal development of schistosity, the original bedding planes of the rocks have been remarkably preserved. This feature was of great help in recognizing the true sedimentary nature of the rocks.

According to their mineral compositions, the rocks may be classified into three groups: 1) biotite - 2) biotite/hornblende - 3) hornblende-schists. Groups 1 and 2 are exposed mostly on the north shore of Olga lake, whereas group 3 predominates on the west shore. In addition, chert layers are numerous throughout the belt and a two-inch magnetite bed was seen on the south end of the point immediately south of Red Chute.

The mineral composition of the schists, as determined with the microscope, is as follows:

Biotite schist:

| | |
|---|---|
| Quartz............. | 40-45% |
| Plagioclase........ | 20-25% |
| Biotite............ | 20-30% |
| Sericite........... | 0-10% |

Accessory: magnetite, potassic feldspar, epidote, calcite.

Biotite/hornblende schist:

| | |
|---|---|
| Quartz............. | 40-45% |
| Plagioclase........ | 20-25% |
| Biotite............ | 10-20% |
| Hornblende......... | 10-15% |

Accessory: as above.

Hornblende schist:

| | |
|---|---|
| Quartz and Feldspar | 45-65% |
| Hornblende......... | 25-50% |

Accessory: chlorite, magnetite, calcite, epidote, biotite.

Everywhere in the schists, the feldspar is probably plagioclase. It is always clouded to some extent and cannot be identified with certainty, especially where it occurs as grains 0.02 to 0.03 mm. in diameter. Many rocks, however, contain plagioclase porphyroblasts showing a degree of cloudiness and relief similar to the smaller grains. The composition of the porphyroblasts ranges from An28 to An33 and it is assumed that the small grains have a similar composition.

Biotite is of the brown-pleochroic variety. Its absorption formula is: dark brown to greenish yellow. In the biotite schists, on a section perpendicular to the schistosity, biotite occurs as delicate needles, about 0.5 mm. long, almost perfectly aligned in one direction which is also that of the bedding. (Plate III-B). The needles are uniformly distributed through a mass of quartz and feldspar whose grain size is from 0.02 to 0.03 mm. . In one section cut parallel to the plane of schistosity, biotite appears as more or less rounded flakes, partly altered sericite. The latter mineral occurs as clots of minute flakes, very irregular in outline and some of them contain remnants of biotite, dust or iron oxide, and less frequently epidote.

The hornblende of these rocks is much lighter in color than the hornblende found in the recrystallized lavas. Its grain size, and also that of the associated biotite, is larger than the biotite in the biotite-schists: the grains measure up to two mm. in length. The optical properties of this hornblende are:

Pleochroic formula: Z- light bluish green
Y- light olive green
X- straw yellow

Absorption formula: Z>Y>X ; $Z \wedge C = 17^{\circ}-19^{\circ}$ ; (-) $2V = 75^{\circ}$

Poikilitic inclusions of quartz and feldspar are common in the prisms of hornblende and they testify to their secondary origin. Of still greater significance is the preservation of numerous rounded grains of hornblende which are believed to be original constituents of the rock. (Plate IV-A). Such detrital grains are found within lozenge-shaped basal sections or in more or less rectangular prisms. The secondary hornblende has always grown in optical continuity with the nucleus although the physical boundary of the latter has in all cases been preserved.

The relations between the different groups of schists are unknown. As already noted, close to the intrusive at Red Chute and along the north shore of the lake, the biotite-schists are interbedded with the biotite-hornblende-schists. The alternating beds are often very narrow: one thin-section contains a central layer, 7 mm. wide, of hornblende flanked on both sides, by biotite schists. Southward, along the west shore of the lake, these schists are superceded by the hornblende-rich rocks which, because of their darkness and uniformity in composition, could easily be mistaken for altered lavas. No gradations between the different schists has been observed either in the field or under the microscope.

On the west shore of the lake, numerous low isolated exposures of sedimentary rocks are found over a distance of about one-half a mile west of the small plug of oligoclase granite. The rocks, away from the intrusive, appear to correspond to the biotite/hornblende schists which are found at Red Chute, although the amphibole may be slightly more abundant. It is difficult to establish their true composition, however, because of extensive hydrothermal alteration. Chlorite, epidote, and leucoxene are the conspicuous new minerals and form about 30 per cent of the rock. These minerals do not possess any directional element, but from clots typical of development under conditions of uniform pressure.

Closer to, and within the granite, these rocks are very brittle hornfels which ring quite clearly under the blow of a hammer, and break readily into sharp angular fragments. Their color is dark grey, with sometimes a green or purple tinge. In spite of the evidently more intense metamorphism, to which they have been subjected, their bedding is well-preserved in numerous places.

These rocks are so altered and so fine-grained that, under the microscope, sericite, which occurs as small non-oriented flakes, is the only mineral that may be identified with certainty. The remainder of the rock forms a maze of minute grains which appear to consist of quartz, epidote, and magnetite.

Throughout this belt, numerous narrow layers of chert were observed. Recrystallization through metamorphism, has changed them into fine-grained impure quartzites and weathering gives them a light-grey color, which makes them stand out prominently among the darker schists.

On the west shore of Olga lake, the schistosity is locally transgressive to the bedding. If, in such cases, cherty layers are present, a remarkable feature has been produced. During folding, the sediments were locally highly crumpled and, when the schistosity happened to cross the bedding, the cherty layers, more brittle than the encasing schists, broke in numerous places. These small fragments, probably through flowage and slippage effects, assumed lenticular forms and migrated short distances along the planes of schistosity of the schists. Layers thus completely fragmented, have the appearance of a conglomerate. Transitional stages, often preserved, permit the proper explanation of their origin. (Plate IV-B).

The highest grade of metamorphism in this belt was attained in a few inclusions found inside a concordant body of syenite, injected into the sedimentary rocks about 200 feet east of the syenite contact at Red Chute. These inclusions are seen over a length of 100 feet, from the tree-line to the river. They are well-rounded and the largest chunk has a diameter of three feet. They are medium- to coarse-grained rocks, dark in color, and they contain numerous red garnets. Their composition is:

| | |
|---|---|
| Hornblende........ | 55% |
| Red Garnet........ | 20% |
| Quartz............ | 15% |
| Plagioclase....... | 5% |
| Accessory: chlorite, biotite, hematite, clinozoisite. | |

Much of the hornblende is in well-formed, slightly bent prisms which contain poikilitic inclusions of quartz. It is more similar to the hornblende of the intermediate lavas than to that of the nearby sedimentary rocks:

Pleochroic formula: Z- deep blue green
Y- olive green
X- pale green

Absorption formula: $Z>Y>X$ ; $Z\wedge C=20^{\circ}$ ; (-) $2V=75^{\circ}$

Garnet has a glassy lustre and a deep-red color; in thin-section, it appears creamy, and is completely isotropic. The grains are subidioblastic and enclose small crystals of hornblende and quartz. Because of the ubiquitous presence of such poikilitic inclusions which would have rendered the results inaccurate, the determination of its specific gravity was not attempted. From its color and its presence in a rock which contain aluminum, calcium, and iron, the garnet is believed to be either almandite or andradite, or possible a mixture of the two molecules.

The feldspar is completely saussuritized. It forms irregular masses, none of which even remotely resembles the shape of a crystal. It is insterstitial to hornblende and contains ragged grains of it. Magnetite, as small specks and lenticular grains, is also a common inclusion. The feldspar is, in many places, partly eaten up by garnet so that its formation dates between the recrystallization of hornblende and the development of garnet.

Quartz has two modes of occurrence. What appears to be old quartz is found as lenticular masses that have no common direction of elongation. This quartz has been shattered to very small pieces. More than half the quartz, however, occurs as large grains which show strong undulose extinction and are slightly broken, but have not been subjected to the same crushing stresses as the lenses. Many grains are disposed along parallel lines forming discontinuous veinlets.

This hornblende-garnet rock is quite unlike any of the sedimentary rocks of the belt in which it occurs. It does not display any indication concerning its origin, but it certainly developed from a rock that was more basic than the nearby biotite- and biotite/hornblende-schists. Even if all the quartz be considered as original, the proportion of this mineral would still be considerably lower than in the sedimentary rocks. Another significant point is the absence of garnet in those sedimentary rocks which are immediately in contact with the syenite intrusive. The possibility of extensive transfer of material to and from the magma is ruled out because the dyke has essentially the same composition as the main syenitic body.

These observations indicate the presence, within the sedimentary beds, of a conformable layer of different, more basic composition. This layer was more easily ruptured than the surrounding rocks so that the intrusive syenite could infiltrate itself along it, thoroughly brecciate it, and subject it to sufficient temperature and stress to induce the development of garnet. This bed, which is not believed to be sedimentary, could then be either a volcanic flow or a basic intrusive.

The difficulty in separating true lavas from associated intrusives of similar composition has been commented upon by most students of Precambrian rocks. Through metamorphism, especially as it affects the texture, a fine-grained lava may recrystallize to a coarser grained rock which is indistinguishable from an intrusive. This difficulty is further enhanced when, as in the present case, the formation is represented only by a few chunks in the middle of an intrusive body. The dimension of the fragments, their shape, their grain size, and composition offer no decisive evidence in favor of either hypothesis.

Sedimentary rocks south of Olga lake

The sedimentary rocks in this belt are similar in color and composition to the rocks exposed in the band just discussed. They are dark-grey rocks in which closely-spaced bedding planes are still occasionally visible. They differ from the north belt in having a slightly coarser grain and in the presence of garnet which, though not universally present, is of widespread occurrence. A typical section studied under the microscope shows the following composition:

| | |
|---|---|
| Quartz........... | 40% |
| Feldspar......... | 15% |
| Biotite.......... | 5% |
| Hornblende....... | 15% |
| Calcite.......... | 5% |
| Garnet........... | 20% |

Accessory: epidote,magnetite.

The rock is finely banded as a result of alternations of biotite- and hornblende-rich beds. In the latter, biotite is present in small amounts and appears to be the product of recrystallization of hornblende. Garnet, which is mostly concentrated in the lighter (biotite) beds, forms masses up to 4 mm. in width. Such masses do not constitute uniform crystals, however. The characteristic form of the mineral has not been developed. Garnet occurs as small, partly-isolated grains constituting no more than 60% of the mass. The remainder consists of quartz, carbonate, some feldspar and biotite. (Plate V-A).

No exposure in this southern belt is free from injected material. The sedimentary rocks are traversed by stringers, dykes, concordant bodies of granite, pegmatite, and aplite. (Plate V-B). The proportion of these intrusions is greatest along both the south and north contacts with the oligoclase granite, where a true zone of migmatite has been formed.

This phenomenon is even more conspicuous eastward from the belt, along the south shore of the deep bay. Along that shore, there is a zone, about one-half a mile wide which constitutes a gradational contact between a quartz-hornblende schist and the southern intrusive. The granite is always predominant, but some remnants of intruded rocks are seen on almost every exposure. The remnants assume different shapes so that the resulting complex is much varied. In some exposures, the old rocks persist only as ragged, more or less crushed masses; in others, they occur as sharp-cornered inclusions; more generally the two rock types form an assemblage consisting of long thin lenses of schists alternating with concordant bodies of intrusive material. The width of each band varies from many feet to mere stringers less than one-eight of an inch, and their lengths commonly attain scores of feet. Weathered surfaces of this complex often have the appearance of a well-bedded sedimentary series. (Plate VI-A). Features resembling pillows have even been produced as a result of pegmatitic injections along two sets of joints in the inclusion. (Plate VI-B).

The nature of the injected rock in this zone is not positively known. As it is impossible to study all the minor variations of such a complex, one must to a great extent rely on megascopic field observations in order to obtain a broad picture of it. Since these exposures were mapped after the northern sedimentary rocks and most of the volcanic rocks in the west half of the area had been studied, it was possible to proceed, in exploring the complex, by a method of comparison,not only of hand specimens, but also of the general surface appearance of the rock exposures.

The greatest proportion of the inclusions could thus be classified as representing recrystallized sedimentary rocks. They are similar to the schists found on the west shore of Olga lake. Although no actual bedding was seen, there are nevertheless some transverse variations in composition of the injected rocks. The darker schists are generally predominant over the biotite rocks such as found at Red Chute.

Another argument in favor of the sedimentary nature of these rocks is provided by the abundance of closely-spaced intrusions parallel to the schistosity and probably also the original bedding, since, as discussed below, the two directions generally coincide. The rocks are schistose, but still dense and there is a strong suggestion that the bedding planes provided the channels (planes of weakness) along which the granitic material was introduced.

A few fragments of hornblende schist included in the migmatite are of less certain origin. Their composition is:

| | |
|---|---|
| Quartz............ | 20% |
| Plagioclase (An23) | 30% |
| Hornblende........ | 40% |
| Biotite........... | 10% |
| Accessory: | epidote, apatite, potash-feldspar, magnetite. |

Their grain size is much larger than in any of the sedimentary rocks, and all their principal minerals are recrystallized. The plagioclase is fresh and occurs as porphyroblasts containing inclusions of quartz, biotite, and hornblende. Hornblende is subidioblastic and many grains are full of non-oriented inclusions of quartz, apatite, and magnetite.

Biotite, pleochroic from dark- to light-brown, forms flakes or long narrow stringers attached to, and crossing through, the hornblende in a way which suggests clearly its secondary origin from the amphibole mineral.

The optical properties of hornblende are:

Pleochroic formula: Z= deep greenish-blue
Y= dark olivine green
X= light yellow green

$Z \wedge C = 25^{\circ}$ ; $(-)2V = 75^{\circ}$

These schists are quite similar to the hornblende-garnet rock found in the syenite body at Red Chute. Their hornblendes, in particular, have about the same properties and composition. The main differences between the two rocks are the presence of garnet at Red Chute, and of biotite in the south. Both minerals are, however, derived from hornblende. Without necessarily implying that the two rocks have the same origin, it may be pointed out that the appearance of one or other mineral may simply reflect differences in metamorphic grade.

<u>Sedimentary rocks in the eastern half of the map-area</u>

These rocks are more thinly bedded than those around Olga lake. The thickest bed observed measures eight inches and such a width is exceptional. Commonly, the thickness is less than one inch, and many exposures consist of alternating layers as thin as one-eight of an inch. The color of the beds ranges from almost white to black through different shades of grey. Reddish colors, due to a coating of iron hydroxydes are also common. The alternations of such narrow layers (Plate VII-A) creates a striking effect and is reminiscent of the varved schists described by Eskola in Finland. (Eskola 1932, Plate II).

The grain-size is still small: the largest grains are about 1.5 mm. in diameter. Many beds, however, show a definite variation of size, and on many exposures, enough determinations of the variations could be made to obtain the correct attitude of the series.

The composition of these rocks varies so widely that a detailed description of all the types is not possible. The following table shows the composition, as determined with the microscope, of the most common types:

I

| | |
|---|---|
| Albite............. | 40% |
| Quartz............. | 30% |
| Chlorite........... | 12% |
| Epidote............ | 5% |
| Muscovite.......... | 10% |
| Leucoxene.......... | 3% |

Accessory: pyrite, hematite.

II

| | |
|---|---|
| Plagioclase (An24). | 60% |
| Quartz............. | 20% |
| Biotite............ | 15% |
| Hornblende......... | 5% |

Accessory: hematite, albite or potash-feldspar.

III

| | |
|---|---|
| Plagioclase (An17). | 30% |
| Quartz............. | 40% |
| Biotite............ | 25% |
| Magnetite.......... | 2% |
| Garnet............. | 3% |
| Accessory: sericite, epidote. | |

The rocks belonging to these types are of lighter color and are much more abundant than the intervening dark-grey beds which are similar to the hornblende schists cropping out on the west shore of Olga lake. Their feldspar, quartz, and biotite clearly show evidence of metamorphic development. The hornblende has the same composition as that of the schists just referred to, and it occurs as sub-rounded grains about 1 mm. in diameter. Most of the grains are partly gone over to biotite.

Cream-weathering chert was seen on almost every exposure. The beds have a thickness comparable to that of the detrital rocks, but they are not continuous. Chert most commonly occurs as narrow ribbons, only a few feet long, which pinch out at both ends. The chert is completely recrystallized to a grey, fine-grained quartzite.

An exposure on the southwest shore of Laurent bay contains a great concentration of cherty fragments in a matrix of well-layered biotite-hornblende schists. The fragments show a great variety of shapes, although lenticular forms predominate. They range in length from less than one inch to fifteen inches.

This rock has a striking resemblance to a conglomerate, but careful examination failed to reveal, in the fragments, the presence of any rock type other than chert and probably some micaceous quartzite. Furthermore, the fragments show a much wider range of shapes and sizes than the boulders found in the truly conglomeratic beds of the region. (Plate VII-B). For comparison, a photograph of the conglomerate of the Mattagami series, on the north shore of Mattagami lake is inserted on plate VIII-A.

Because of these observations, it is believed that the "conglomerate" exposed on the southwest shore of Laurent bay is not a true conglomerate. It seems that during folding, the schists behaved more or less like plastic layers, while more rigid beds of chert and quartzite could not yield sufficiently to avoid being broken into a great number of fragments. The explanation is strengthened by the presence of curved fragments (not shown on the photograph) which are believed to represent the remains of drag-folded layers. This process is essentially similar to the phenomenon already described on the west shore of Olga lake, the differences resulting only from the attitude of the schistosity with respect to the bedding of the rocks.

## General considerations about the sedimentary rocks

In spite of the well-preserved state of the bedding and occasional cross-bedding, the use of genetic names has been purposely avoided in the discussion of the schistose rocks of sedimentary origin. This method of treatment, which contrasts with the procedure followed in the study of the volcanic rocks, has been adopted for two reasons.

Because of the fineness of grains in these recrystallized rocks, it is not at all known in which category the original sediments would fit in the usual classification based on the size of detrital grains. The limit between sands and finer-grained materials, either silt or clay, has been fixed at 0.0625 mm. (Twenhofel, 1932, p. 218). Many of the present schists, especially those that are rich in biotite, consist predominantly of particles smaller than one-sixteen of an inch in diameter, whereas the few detrital hornblende grains observed range from 0.5 to 1 mm. . It seems that the detrital sediments belonged partly to the sand, and partly to the silt class, but, as it had been mentioned already, the alternations are so numerous that the rocks can be described only as units, disregarding the finer details.

The composition of the rocks, before recrystallization, is also a matter of some conjecture. The sediments contained originally layers of colloidal silica and of impure sandstone; the general predominance of quartz in the schists indicates a derivation from rather acid rocks. Feldspar and dark minerals, however, are too abundant for the coarser rocks to be called sandstones. On the other hand, the term "greywacke", although admittedly best suited, is strictly not applicable. All modern definitions of this term (in particular: Shrock, 1948-a; Pirsson and Knoff, 1926) insist on the presence in a greywacke of rock particles, besides a greater diversity of minerals than in a sandstone. It could, of course, be argued that metamorphism may have obliterated the fragments, but this is not very likely, considering that, at least in some of the beds, original grains have been entirely preserved.

The schists developed from sediments which, with respect to their grain size, lay on the silt-sand boundary. These sediments could, with much detailed work on their composition, be separated into siltstone, impure sandstone, greywacke and chert. For simplicity, however, it seemed best to designate them collectively as "sedimentary rocks".

The presence of detrital grains of hornblende may serve as a basis for further speculations on the composition and mode of origin of the sedimentary rocks.

According to Harker the normal course of metamorphism (either thermal or regional) does not lead to the formation of hornblende in arenaceous and argillaceous sediments. Apparently such sediments are too poor in lime to favor the development of this mineral. Further, hornblende-rich sediments are rare. In fact, hornblende is listed as an accessory mineral (forming less than one per cent of the rock) in the "Table of the Common Minerals of Sediments" prepared by Krynine (1948, Table I, p. 133).

Hornblende schists of sedimentary origin are, however, common in the Archean rocks of the Canadian Shield (Dresser and Denis, 1944, p. 60). In general, the origin of the hornblende is not discussed. Probably the writers considered this mineral to have been present as detrital grains, as it is the case in the area now under study.

The hypothesis of the introduction, in the sediments considered here, of the lime necessary to allow the formation of hornblende was soon discarded, not only because of the detrital grains, but also because of the relations between the biotite- and the hornblende/biotite-schists at Red Chute. In that locality, both types of schists are interbedded and no gradation between them has been observed. Since both types appear equally permeable, if lime was added to some beds to enable the development of hornblende, why should the other beds, interstratified with them, show no evidence whatsoever of similar additions?.

The presence of hornblende in quantities far exceeding its usual amount in the sedimentary rocks throws some light on the conditions of erosion at the time of the formation of the sediments.

When rocks are subjected to chemical weathering, their constituents become separated in accordance with their respective solubility. Lime and soda are mostly removed in solution, whereas alumina, being less soluble, tends to concentrate and form the main element of the clastic deposits (quartz, being resistant both physically and chemically needs not enter the present discussion). Potash, while being as soluble as soda, commonly stays with alumina, because it is adsorbed more firmly than soda by the colloidal particles of clay (Grim, 1942). When the rocks undergo metamorphism, the resulting minerals will be dependent on the kind and stage of the metamorphic process. But they cannot fail to reflect to some extent the influence of that previous chapter in the history of the rock. The minerals so produced, in rocks whose constituents originated through chemical weathering, will be predominantly alumina- and potash-rich: such as biotite, cordierite, andalusite, cyanite, garnet sillimanite, etc. .

The restricted development of such minerals in the present area is noteworthy. If along with this fact, one considers the testimony of the detrital hornblende, of the fine grain of the rock, and finally of the general composition of the sediments, the following hypothesis seems plausible:

The sediments were derived from an acidic terrane which stood rather low above the basin of deposition, the gradients of the streams being such that they could not carry particles greater than possibly 1 mm. . Transportation was effected over a distance sufficient to permit the almost perfect rounding of the hornblende, although, because of recrystallization, the original shape of the grains of the other materials is unknown. The rocks from which the sediments were derived had been degraded under conditions which favored mechanical desintegration rather than chemical weathering. Therefore, the sediments were produced under conditions considerably cooler than those of the tropical zones of the modern time.

Similar conditions have been advocated by Eskola (1932, p. 33) for some varved schists in the Archean of Finland.

## Trachytes

The trachytes underlie a roughly-triangular area, the apex of which is an imaginary point lying in Olga lake somewhere north of the largest island. They are bounded on the south and on the east by andesitic belts. Most of their north boundary is hidden by glacial deposits. It would appear to follow the general trend of the Waswanipi river at a distance of one to one half a mile north of it for eight miles eastward from Olga lake. Along this distance, the trachytes are probably bounded on the north by the extension of the sedimentary band cropping out on the north shore of Olga lake. Further east, however, they are in contact with gneissic granite, probably as far as Max Narrow, where they are superceded by the north end of the belt of andesitic rocks which surrounds Goéland lake.

As exposed on the east shore of Olga lake, the belt is four miles wide. It broadens gradually eastward to become eight miles wide at a point about two miles west of Goéland lake. From there, the belt is divided into a south and a north segment which curve around a body of andesitic rocks to finally disappear under them.

Description

The trachytes are light-green to greenish-brown, commonly slightly schistose rocks. As revealed through microscopic examination, they are all porphyritic to some extent. In many specimens, the phenocrysts cannot be observed with a hand lens, and such rocks have a uniform glassy appearance.

Faint remnants of pillows were seen on the point south of the mouth of Waswanipi river. On a horizontal surface, these now appear as flat elliptical forms, about one foot long and three inches wide. The ellipses are distributed over a width of eight feet and their long directions are parallel to the schistosity. The presence of amygdules, although useless for determination of the attitude of the flows, was most helpful in establishing the true volcanic character of certain doubtful exposures.

Many of the trachytic flows are fragmental. Because of their interesting character, these flows will be described separately.

Microscopically, the trachytes consist of a fine groundmass composed predominantly of feldspar, and in which are embedded a variable amount of feldspar phenocrysts. Numerous other minerals are found in the groundmass. Their proportions are variable, as shown in the following table:

| | |
|---|---|
| Feldspar, as phenocrysts.... | 10-40% |
| Feldspar, as groundmass..... | 20-70% |
| Quartz...................... | 1-10% |
| Epidote..................... | 1-20% |
| Calcite..................... | Acc.- 5% |
| Chlorite.................... | Acc.-15% |
| Biotite..................... | 0- 4% |
| Sericite.................... | Acc.-20% |
| Magnetite................... | Acc. |
| Hematite.................... | Acc. |
| Leucoxene................... | Acc. |

The phenocrysts are generally 1 mm. (sometimes up to 3 mm.) in length. They commonly show Carlsbad and Albite twinning. Saussuritization is widespread, but phenocrysts fresh enough for identification are found in all slides. Their composition is remarkably uniform: Albite near An7. The feldspar of the groundmass occurs in grains so small that accurate determination is not possible. Potassic feldspar may be present, although a comparison of refractive indices seems to indicate that the feldspar of the groundmass has a composition essentially similar to that of the phenocrysts.

A certain quantity of quartz may be original in those rocks, but most of it appears to be later than the consolidation of the lavas. The introduced quartz is found as small veinlets cutting the rock, or as amygdules filling the vesicles. The amygdules are very oblong and their shattered quartz contains, in places, remnants of clouded plagioclase. In many specimens, quartz is also found as large rounded clots of minute grains. These are distributed erratically and are believed to represent crushed quartz eyes. Finally some quartz is found, in the ground mass, as individual grains which generally are a little larger than the feldspar.

Of all the thin sections examined only two show biotite. It is pleochroic from dark-green (almost black) to light-green. The flakes are ragged and small, and are in part altered to chlorite. There is thus a suggestion that biotite may have occurred in all the rocks, and that chlorite, which is present in all the sections (it is commonly the only dark mineral) may be an alteration product of biotite. The usual chlorite is greenish, and has a low birefringence. It belongs to the pennin-ite group.

## Texture

The trachytes are characterized by a well-preserved porphyritic texture: most of the plagioclase phenocrysts are still intact. (Plate VIII-B). In the rare broken phenocrysts, the fragments are still close enough to one another to allow the reconstitution of the original crystal. The cracks are commonly filled with calcite, sometimes epidote, and-or quartz. In a few cases, the fragments have been rotated and now lie transverse to the bulk of the phenocryst.

As seen in thin sections, the rock exhibits a pronounced fluidal (trachytic) texture. This results partly from a sub-orientation of the phenocrysts themselves, and partly from the alignment of the original minerals (mostly biotite and feldspar) of the groundmass. In the schistose rocks, the texture is further accentuated by an alignment of the shreds of chlorite and the flakes of sericite in a direction parallel to the lines of flowage.

The behavior of these platy minerals, when they meet a phenocrysts, is in typical contrast with the arrangement observed in the porphyroblastic andesites. In the latter, the porphyroblasts have more or less pointed ends, on either side of which the platy minerals diverge. They show evidence of having grown by pushing aside the smaller minerals. In the trachytes, only the minerals around the side edges of a phenocryst are wrapped around it. The ones opposite the centre of the phenocryst are not disturbed, and abut straight against it (Fig. 3).

## Fragmental trachytes

Several of the acidic flows are characterized by the presence of a large number of fragments in them. Two kinds of inclusions are found, each producing a different type of breccia.

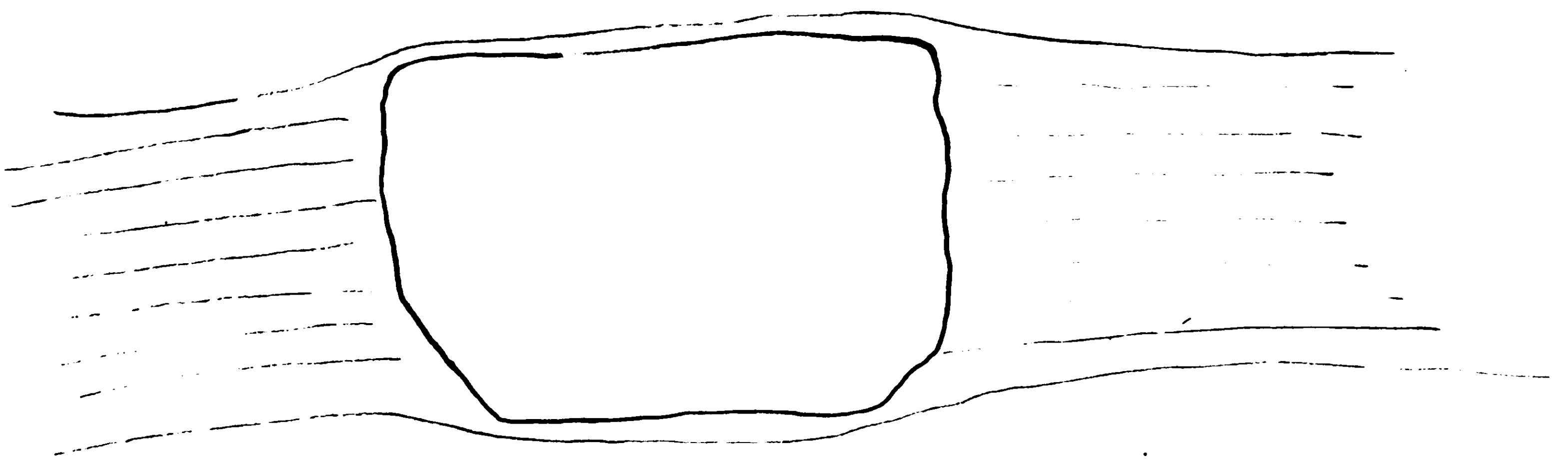
### First type of flow breccia

On the north shore of the point opposite the east end of the large island in Olga lake, a fragmental zone of particular interest was seen at about 3000 feet east of the tip of the point. The main rock consists of fine-grained, slightly porphyritic trachyte. It contains fragments of a rock having about the same composition as the matrix, but in which

FIG. 3


PORPHYROBLAST OF ALBITE IN ANDESITIC LAVA

P = PRESSURE SHADOWS, OFTEN FILLED WITH QUARTZ AND/OR CALCITE



PHENOCRYST OF ALBITE IN TRACHYTIC LAVA

the feldspar phenocrysts are more numerous and larger (up to one-quarter of an inch).

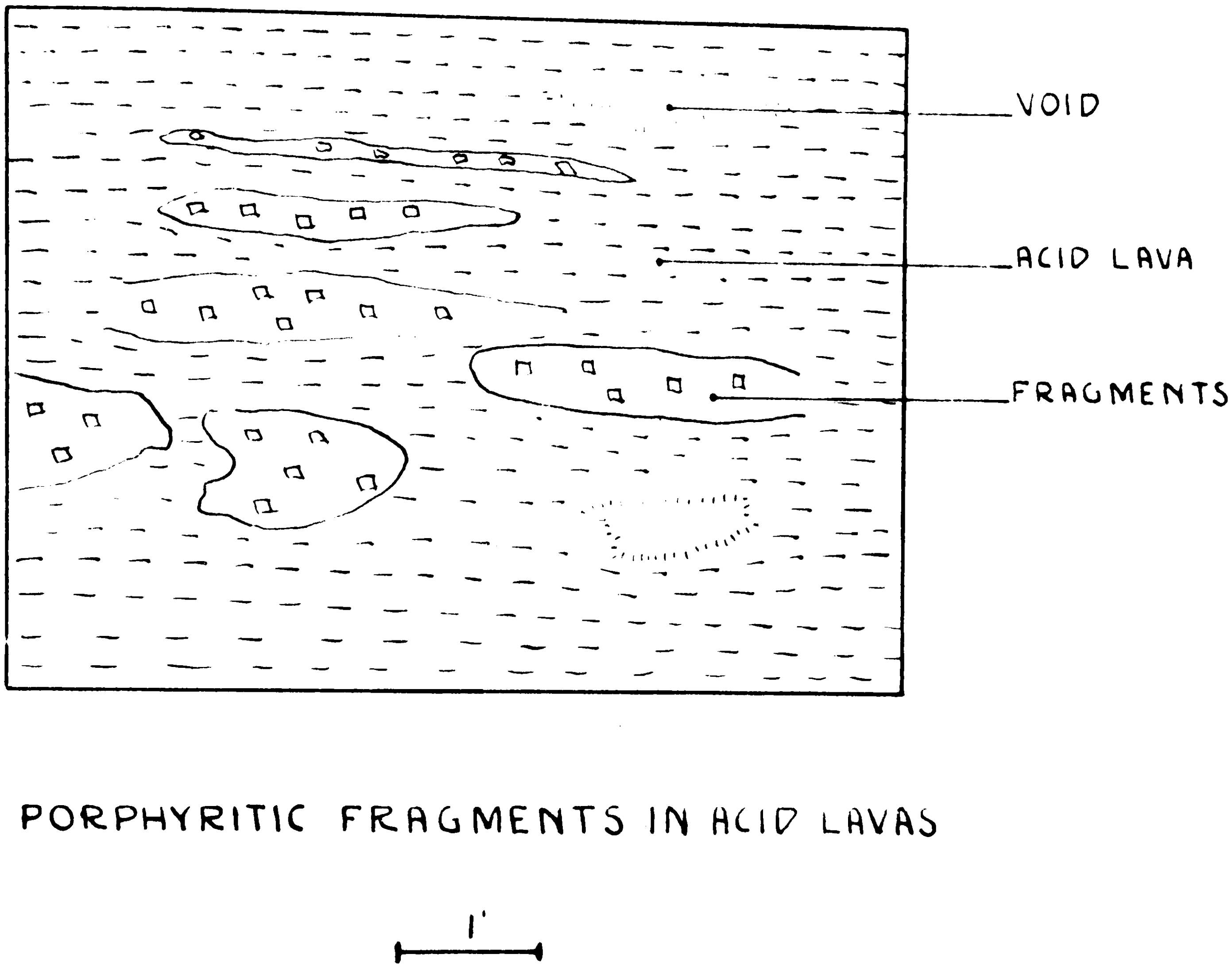
The fragments are of all sizes from a fraction of an inch to almost three feet in length. Their width is variable so that some fragments are ellipsoidal whereas others have a ribbon-like appearance. In a few places, there is evidence that some fragments have been broken, and the pieces have drifted away from one another (Fig. 4). In other instances, quartz replaces selectively the porphyritic fragments (Fig. 5).

This type of fragmental lava is easily comparable with the structure observed by Wilson (1941) in the Noranda district and described by him as a flow breccia. The fragments, which became enclosed in the lava during the spreading of the latter, may represent loose materials in the path of an advancing flood of lava. These would be picked up and engulfed in the consolidating lava. On the other hand, the breccia might have resulted from the consolidation of the surfaces of the lava flows, and subsequent breaking of the crusts, while movement was going on. The presence of large phenocrysts only in the encasing rock favors the first mentioned method of formation.

Second type of flow breccia

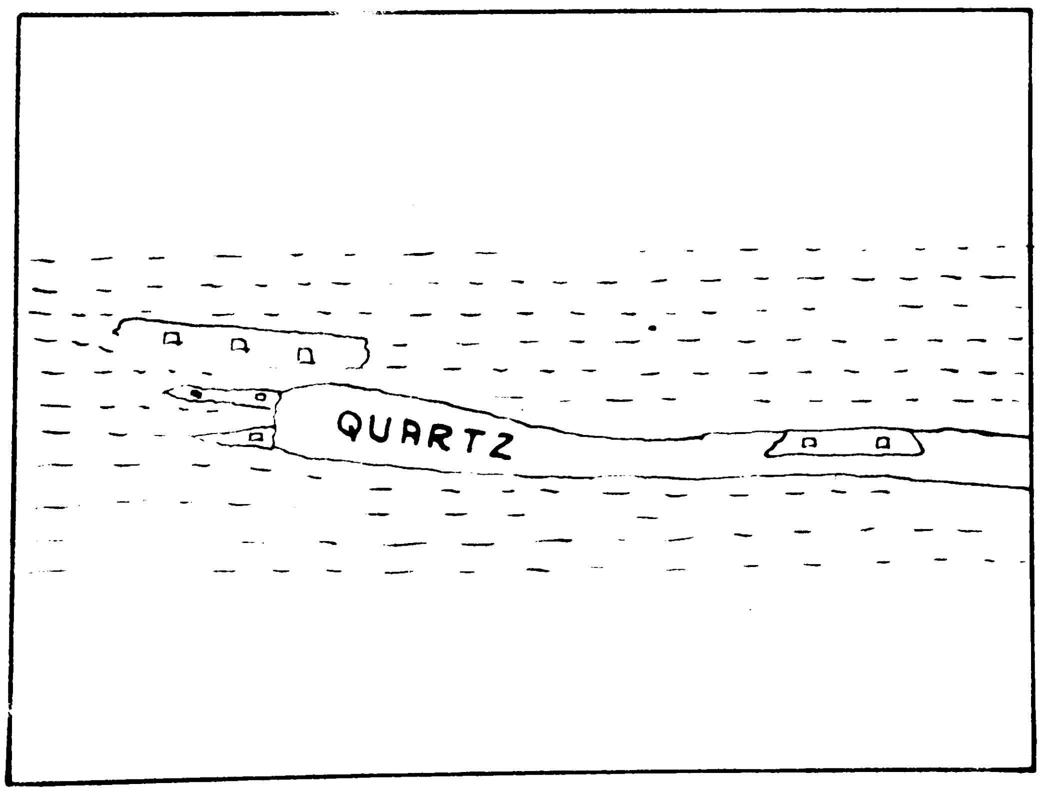
The most typical fragmental flows of this type are on the east shore of Olga lake, south of the Waswanipi river,

FIG. 4




PORPHYRITIC FRAGMENTS IN ACID LAVAS

FIG. 5




QUARTZ REPLACING FRAGMENTS

and also on the south shore of the northern bay. In the first locality the flow is 25 feet thick and is exposed for over 100 feet. In the second locality, fragmental flows are exposed for a length of about one quarter of a mile, around the west end of the point in the middle of the south shore. Since the shoreline bevels the east-west schistosity, the flows appear to be at least 500 feet thick. Similar fragments were also found, north of Goéland lake, two miles northeast from the bend where the Waswanipi river changes from a north to a west course. In all the exposures, the fragments are distributed rather uniformly across the whole width of the flows.

The inclusions in these flows are of two categories: a) small fragments, angular to sub-angular, whose greatest dimension seldom exceeds a few inches; b) flat ellipsoids which attain a length of fifteen inches and whose intermediate axis does not exceed four inches. Both types of fragments are seen in the same exposures, although the smaller pieces are more numerous south of the Waswanipi river, and the oblong fragments predominate in the other localities.

The composition of both types is the same. They all weather to a cream-buff color and their fresh surface is a lighter green than the enclosing lavas. Their very fine grain, finer than the matrix, gives them a glassy, sometimes cherty, appearance.

As a rule, they do not contain any conspicuous phenocrysts. The orientation of the elongated fragments is very regular: they all lie with their long axis in horizontal position and parallel to the schistosity of the enclosing lava.

One oblong fragment, believed to be quite representative, was studied in thin-section and its composition was found to be very similar to the matrix: Completely saussuritized feldspar phenocrysts form about ten per cent of the rock and they are set in a groundmass consisting of epidote, clouded feldspar, calcite, chlorite, sericite, and some quartz. The composition of the feldspar could not be determined. It has, however, the same appearance as the albite of the matrix and it is thus presumed to be a sodic plagioclase. The fragments also contain shattered amygdules of quartz.

The striking feature of this fragment is its well-preserved physical condition. The outlines of the phenocrysts are well defined. They are smaller than in the matrix but none of them has suffered any granulation. Their orientation along parallel lines produces a fluidal texture that is better developed than in the matrix. Again this texture is rendered more conspicuous by the shreds of chlorite and flakes of sericite which are parallel to it.

These oblong fragments are interpreted as volcanic bombs. The small angular ones, mixed up with them, may represent pieces torn away from the inside wall of the volcanic chamber; more probably they could have originated through the breaking of the bombs.

## Tuffs

Bands of tuffaceous sediments were observed only in ten different places in the area. They occur within both types of lavas, although predominantly in the trachytes. One narrow band, six inches in width, was found interlayered with the sedimentary rocks on the north shore of Olga lake.

The thickness of these fragmental volcanics is usually measured in inches, with the exception of the 30-foot bed already mentioned in the description of the andesitic rocks. They are all schistose, but most of the beds, because of their grain size could be more accurately designated as slates. In one locality, it was possible to break thin resistant slabs, one-sixteenth of an inch thick and measuring up to six inches square.

In all the occurrences, the tuffs are acid, very fine-grained and are delicately banded. This feature results from interlayering of two types of rocks in beds that may be as thin as one-eight of an inch.

One type has a glassy appearance and a generally cream color. The composition of this type cannot be resolved under the microscope. The rock appears to be thoroughly silicified. Some of these beds show variations in color, and thus in basicity, from light grey to almost white in a direction perpendicular to their bedding planes. At the place where the top of a flow was determined with the use of pillow and grain gradation, these small bands were found to vary in color from dark greenish-grey, at the bottom, to almost pure white at the top. Shrock has seen similar variations in beds of recently fallen ash surrounding the vocano El Paricutin (Shrock, 1948-b, p. 331, Footnote 1).

The order of variations in color in the tuffs are opposite to those found in varved clays (Flint, 1947), and Precambrian varved sediments (Shrock, 1948-b, p. 86, Fig. 45) although admittedly the deposits did not originate under similar conditions. With sufficient observations, this variation in color may become a useful means of determining the attitude of the flows in which the tuffs occur, and thus become an important help in solving the structure.

The layers interbedded with the glassy beds are dark grey and coarser-grained (about 1 mm.). They are uniform in texture and color. They consist of angular fragments of clouded albite, and clear quartz embedded in a fine mass of quartz and feldspar. The schistosity is marked by long thin flakes of sericite which curve around the larger fragments. Some of the rocks contain iron oxides, in amounts varying from accessory to 30 per cent. The predominant oxide is a deep orange-brown hematite. Magnetite is rare, and its occurrence as small specks surrounded by hematite suggests that probably all the latter mineral is an alteration product of the magnetite. Most of the tuffs show evidence of introduction of quartz, as veinlets along the planes of schistosity.

Metamorphism of the trachytes

The trachytes are surprisingly different in appearance from the andesites. Their albite phenocrysts do not display any evidence of granulation or recrystallization. They are still present in their original form, and the trachytic texture, which had developed during the consolidation of the lava, has not been altered. It has simply been rendered more conspicuous by the development of chlorite and sericite in shreds and flakes parallel to the schistosity.

This different behavior of the trachytes must, in the writer's opinion, be related only to the difference in composition between the two types of lavas, and to the absence of igneous intrusions in the neighbourhood of the trachyte. It is intended to discuss the structure of these rocks in a separate chapter, but it may be said here that the trachytes are believed to lie in a synclinal area, and that their extrusion occurred between two periods of andesitic volcanic activity. Since the andesites, both underlying and overlying the trachytes, have similar metamorphic characters, it is concluded that differences in factors such as temperature, pressure, and stress are not responsible for the difference in the appearance of the two types of volcanic rocks. Furthermore, the absence in the trachyte, of the granoblastic texture so well-developed in the andesites found either as inclusions in, or along the contacts with, the intrusive rocks, implies that the trachytes have not been subjected to the later thermal metamorphism that affected these andesites.

It has been seen, however, that the andesitic belts have undergone regional metamorphism under conditions such as to favor the development of hornblende and of albite porphyroblasts. These minerals constituted the stable association under the newly created environment. The trachytes, consisting as they did predominantly of albite, were already in equilibrium with these new conditions and therefore could not undergo much mineralogical change.

During their long history, however, the trachytes have not been immune to a certain amount of transformation.

Some of these are believed to be due to metasomatism (probably hydrothermal), while others may be classed as retrograde metamorphism.

### Hydrothermal alteration

Quartz, calcite, and epidote are believed to result from this type of metamorphic process. Quartz never exceeds ten per cent of the rock, and, as already indicated, most of it (if not all) has been introduced after the consolidation of the rock. It fills vesicles, or occurs as eyes or small veinlets. Calcite most commonly fills the cracks of the broken phenocrysts.

Epidote is also a hydrothermal mineral. The possibility that it is entirely of local origin, through the alteration of the original minerals of the rock, has been considered. In such a case, one would have to postulate that the composition of the trachytes was originally more basic. Not only would the plagioclase be more calcic, but the rock would have contained as well a calcium-rich ferromagnesian mineral. During the degradation of these minerals, epidote would be produced along with a host of other reaction products and residual sodic plagioclase. Chlorite, calcite, iron oxides, white mica are minerals likely to result from such metamorphic processes, and they are all present in the rocks.

Several observations, however, militate against this hypothesis, at least for most of the epidote. The first argument is provided by the size and distribution of the mineral. Saussuritization has taken place to a mild degree in the trachytes. The products thus formed cloud up the feldspars, but they occur as minute specks which can be identified only with the highest magnification available on the microscope. Many of the specks consist of epidote, but, since their proportion cannot be easily evaluated, they are not included in the percentage of epidote shown in the composition table.

The quantities shown refer to epidote occurring as definite grains always larger than the feldspar of the ground mass. As such, epidote is distributed erratically through the rock, or forms veinlets generally parallel to the schistosity. When associated with the albite phenocrysts, it is commonly more abundant along the edges, where it forms salients, than in the centre of the crystal. In a few cases, some phenocrysts are almost completely replaced by epidote. There again, it does not seem to be the result of alteration of a more calcic plagioclase, since neighbouring phenocrysts of albite are seen which have hardly been affected at all.

Another argument is provided by a comparison between the relative amounts of epidote and chlorite in each of the thin-sections. If both minerals were alteration products, there should be a consistant relationship between their relative quantities, assuming that the original minerals were homogenously distributed throughout the whole mass of the trachyte. No such relationships are found, as indicated by the following figures which are representative of the sections studied:

| Chlorite % | Epidote % |
|---|---|
| Acc. | 5 |
| 1 | 12 |
| 7 | 3 |
| 5 | 1 |
| 15 | 15 |
| 5 | 20 |

For these reasons, epidote is considered as having been introduced in the trachytes, along with the hydrothermal quartz and calcite.

## Retrograde metamorphism

The trachytes, like the andesites, are cut by numerous shear zones which follow the schistosity. Along these, the acid lavas become fine-grained sericite-chlorite schists. Unfortunately it was not possible to collect a suite of specimens that would show the complete changes from a massive trachyte to a well-developed schist in the centre of a shear zone. The presence of epidote and of iron hydroxydes, the latter resulting from the weathering of pyrite, was taken as an indication that microscopic study would be too hampered by alteration.

Three specimens collected on the point just south of the outlet of Waswanipi river, into Olga lake, may be easily arranged into a series showing the early stages of the progressive development of the schistose structure. Study of their thin-sections reveal that, as the schistosity becomes more conspicuous in the hand specimens, chlorite and sericite[1] assume a greater importance, while biotite disappears, and albite diminishes:

| Spec.No. | Chlorite | Sericite | Biotite | Albite | Structure |
|---|---|---|---|---|---|
| P-222/47 | Acc. | Acc. | 4 | 85 | Almost massive. |
| P-224/47 | 1 | 8 | 3 | 70 | Slightly schistose. |
| P-229/47 | 7 | 20 | 0 | 60 | Moderately schistose. |

In the centre of the shear zones, sericite is so abundant that the rock has a silky appearance. Sometimes many albite phenocrysts are present, thus producing a good augen structure.

## Adequacy of the term "trachyte"

The rocks described under this name are characterized by the predominance of albite occurring both as phenocrysts and in the groundmass. Quartz is subordinate, and biotite, the only

1. It is possible that, in many instances throughout this thesis, the name "paragonite" would be more appropriate than "sericite". However, since there is no conclusive evidence that such a mineral exists (Winchell, 1946, p. 270) and since the writer had no facilities to determine the composition of the mica, it has seemed best to use sericite in a purely descriptive sense to designate all the white mica of secondary origin.

dark mineral that is probably original, never exceeds four per cent. Because of their light color these rocks were classified as "dacites" in the field. Their appearance and, as was found later, their composition are very similar to the lavas described as dacites by Cooke, James and Mawdsley in the Harricanaw region (C.J. & M., 1931, p. 30).

These authors have extended the meaning of the term well beyond the limits of its original definition. In order to gain a complete understanding of its meaning, it would be necessary to repeat the clear discussion of Johannsen (1932, Vol. II, pp. 390-398) on this subject. Mostly, a dacite is understood as the equivalent of a Tonalite: it is a quartz-andesite. Shand (1943) gives many modes which are averaged in the following table:

| | |
|---|---|
| Quartz.......... | 18% |
| Orthoclase...... | 11% |
| Albite.......... | 31% |
| Anorthite....... | 24% |
| Melanites....... | 12% |

The rocks under study clearly do not belong to this class of rocks. They do not properly fall in the trachyte group either, according to Johannsen's definition of this group:

| | | |
|---|---|---|
| Orthoclase...... | 75% | |
| Oligoclase...... | 11% | |
| Augite.......... | 10% | |
| Magnetite....... | 4% | (also includes titanite and apatite) |

On the form of occurrence of the feldspars, the same author writes (p.70):

> "In some cases, the phenocrysts of a trachyte are entirely plagioclase, and the potash-feldspar is confined to the groundmass or to the groundmass and narrow mantles around the plagioclase phenocrysts".

The present rocks contain albite both as phenocrysts and in the groundmass. They do not carry any determinable amount of potash-feldspar. Shand (1943) recognizes a "soda-trachyte" in which albite predominates over orthoclase. If albite becomes so abundant that orthoclase is excluded, the resulting rock may, in the writer's opinion, still be called a trachyte: it would occupy the extreme southwest corner of Shand's feldspar field (Shand, 1943, p. 201).

## PRE-FOLDING INTRUSIVES

Under this heading, are discussed two types of intrusives, Gabbro and Granite Porphyry, which are found as sills within the Volcanic-Sedimentary series. These intrusives are believed to be pre-folding and, therefore, much older than the main intrusive masses described below. The age relations between the two types are unknown.

## Gabbro Intrusives

Occurrences of gabbro are very restricted in the present area. The intrusives dealt with here are believed to have been emplaced before the folding of the volcanic-sedimentary rocks, and they are not related to the large intrusive masses which will be described below. As in other regions of intermediate volcanic complexes, the problem of separating the true lavas from concordant intrusives of similar composition is a difficult one. Often recrystallization has produced a rock which in texture is very similar to the intrusive.

Unmistakable sills, however, have been seen throughout the area. The largest ones are near the southern border, between Olga and Goéland lakes. A similar rocks is exposed on the point south of the north bay on the east shore of Olga lake. Smaller, unmappable, units are found in numerous places in the area, especially in the west-half, and one such body is even found intruding the sedimentary rocks at Red Chute.

These rocks are fine- to low medium-grained, that is, slightly coarser than the average lava. As a rule they are more massive than the volcanic rocks, although occasional small bodies were seen which had suffered the same shearing as the enclosing lavas. This shearing and concordant habit are taken as an indication that the rocks were injected as sills before the complex was folded.

The dark minerals constitute 35% to 50% of the rocks. The most prominent is amphibole in the form of actinolite. In some specimens, the needles are quite long (up to 6 mm.) and they lie without any linear orientation. Most commonly actinolite forms lenses or irregular masses with horsetails, typical of metamorphic development. The origin of the amphibole is revealed in a few sections, where ragged remnants of a pyroxene (probably of the diopside-hedenbergite series) are found partly changed into actinolite.

Besides the pyroxene, the only original mineral appears to be plagioclase now strongly altered and cannot be identified. This plagioclase was probably calcic because a large percentage of clinozoisite, up to 35%, is present in the rock and seems to have been derived from it. Minor quantities of albite and late quartz, frequently associated with calcite, are also found in the rock.

These minerals form a groundmass in which the actinolite needles are set. Even the feldspar occurs as exceedingly small grains. Masses of such fine feldspar grains have in places sharp, almost square angles indicating that the original plagioclase has been thoughroughly shattered. Contrary to the behavior of the andesites, there was no development of porphyroblasts in the rocks previous to the formation of the amphibole.

## Granite Porphyry Intrusives

Numerous small masses of light-colored granite porphyry are found in the area. They generally form narrow sills and occur in the three main rock groups, andesites, sediments, trachytes, although they are more common in the latter group. The largest sill occurs on the north shore of the Waswanipi river, just east of Olga lake. Discontinuous exposures suggest that the sill is about two and a half miles long. Similar rocks found on the southern part of the island north of the mouth of the river may belong to the same mass. If this is true, the sill would have a possible length of three miles and a width of several hundred feet.

The rock is fine grained, conspicuously porphyritic, and varies in color from creamy-white, when fairly fresh, to various shades of brown or even green, when strongly affected by hydrothermal alteration. In fairly fresh specimens, seen in a few places on the north shore of the Waswanipi river, the rock is only moderately deformed. Under the microscope, it is seen to contain numerous phenocrysts of quartz and of partially altered feldspar, set in a strongly sericitized groundmass, in which the schistosity is marked by sericite flakes curving around the phenocrysts. The feldspar phenocrysts that are fresh enough to be identified have the composition of Oligoclase (An13-24).

In general, and probably because they were less competent than the enclosing trachytes, the porphyries have been highly deformed. They are strongly crushed and, under the microscope, the phenocrysts of quartz and feldspar are intensively broken. The groundmass is fractured and the cracks are filled with secondary quartz and calcite.

The porphyritic texture is conspicuous on the weathered surface of the rock. On fresh fractures, the texture is masked by the crushing of the phenocrysts and the advanced alteration of the rock. For the same reasons the porphyritic texture is generally indistinct in the thin-sections.

## GENERAL CONSIDERATIONS ON THE VOLCANIC-SEDIMENTARY SERIES

To complete the study of the Keewatin-like rocks, a few general problems remain to be considered. Foremost among them, are their structure, their history and their correlation with other similar volcanic-sedimentary belts exposed in the southern part of the Canadian Shield. As a necessary introduction, one must first examine those criteria upon which the structural interpretation is based.

## Structural criteria

The complete study of a rock formation entails not only the recognition of its nature, but also the determination of its place in the local stratigraphical column to which it belongs.

In the present area, little difficulty was ever experienced in establishing, in the field, the nature of the different rocks encountered. The sedimentary rocks are generally recognized because of their good bedding. Also it was soon discovered that the sedimentary rocks contained a much higher percentage of quartz than the surrounding lavas. The volcanic rocks show all or some of the following features: flow lines, pillows, amygdules, uniformity of composition over widths far exceeding those of individual sedimentary beds, low percentage of quartz and general composition more basic than in the clastic rocks.

Criteria establishing age sequences are, however, exceedingly rare. As already mentioned in a previous chapter, only one top determination was possible in all of the volcanic belts. This locality is on the south shore of the middle bay, east side of Olga lake, at about one-half mile east of the mouth of the bay. The attitude of the flow is as follows: it strikes at 100°, dips 85°-S, and faces south. It thus lies south of an east-west trending anticlinal axis.

There is no doubt that, in spite of recrystallization, many of the lava flows still exhibit variations in grain size, but the contacts between individual flows have been very rarely observed. Similarity in composition between successive lava flows or layers, paucity of tuffaceous material, general dirty state of the exposure, metamorphism both progressive and retrograde, played their part in so effectively masking the contacts. Furthermore, if the complex interfingering noted in modern volcanoes, (Krauskopf, 1948; Shrock, 1948-b, p. 342-345 Fig.301-304) were the rule in Precambrian time, it is no wonder that, after all the changes undergone by these rocks, their assemblage cannot be easily deciphered.

Top determinations in the sedimentary series were made on numerous occasions, but with one exception, they were all made in the band of sediments which borders the west side of Goéland lake. The criteria generally used in these thinly-bedded series was grain gradation. Cross-bedding was seen once in this belt, and once in the sedimentary rocks exposed on the west shore of Olga lake.

This latter locality is about one mile southwest of Red Chute. On this exposure, the bedding is southeast and dips

$85^{o}$-S, whereas the schistosity strikes northeast. Fairly well-preserved cross-bedding indicates that the bed faces north and is thus overturned. The value of this information, however, is greatly diminished by the fact that, in this particular area, there is evidence of cross-folding, the nature of which could not be determined.

The several top determinations made in the sedimentary rocks on the west and north side of Goéland lake, indicate that the top of the series faces toward the Goéland batholith. Since the sedimentary rocks are interbedded with the andesitic lavas, the attitude of the eastern andesitic belt may, at this locality, be inferred from the structural observations made in the clastic rocks. The west and north side of the belt therefore faces toward the batholith and, since the dips are in direction of the tops of the beds, a synclinal structure is indicated.

In addition to these top determinations, the following general observations were made in the field:

1) As far as could be ascertained, the schistosity is everywhere parallel to the bedding of both the sedimentary and volcanic rocks, except for a stretch of about one mile on the west shore of Olga lake, where the two structures intersect one another, in places at a high angle;

2) The schistosity, which is everywhere developed, trends approximately east-west, from the western border of the area, for a distance of twelve miles eastward. On approaching the Goéland batholith, the strike of both the bedding and the schistosity abruptly changes to follow the contours of this intrusive body.

## Structure

The above data are too meagre to allow a positive interpretation of the structure, and thereby of the history of these isoclinally-folded rocks. The sequence of the rock groups in the western part of the area is particularly puzzling. As already mentioned, the trachytes are succeeded on their north side by a sedimentary belt, followed by an andesitic belt, whereas, on their south side, the succession is reversed. Another problem to be explained is the disappearance of the trachytes under the belt of andesitic lavas, on the west shore of Goéland lake.

In order to explain the peculiar succession of the rock groups, the following hypothesis is offered: The regional structure is believed to consist of an eastward-plunging syncline, followed to the south by an anticline. Both folds are isoclinal and the north limb of the anticline has been dislocated by faulting.

Synclinal structure

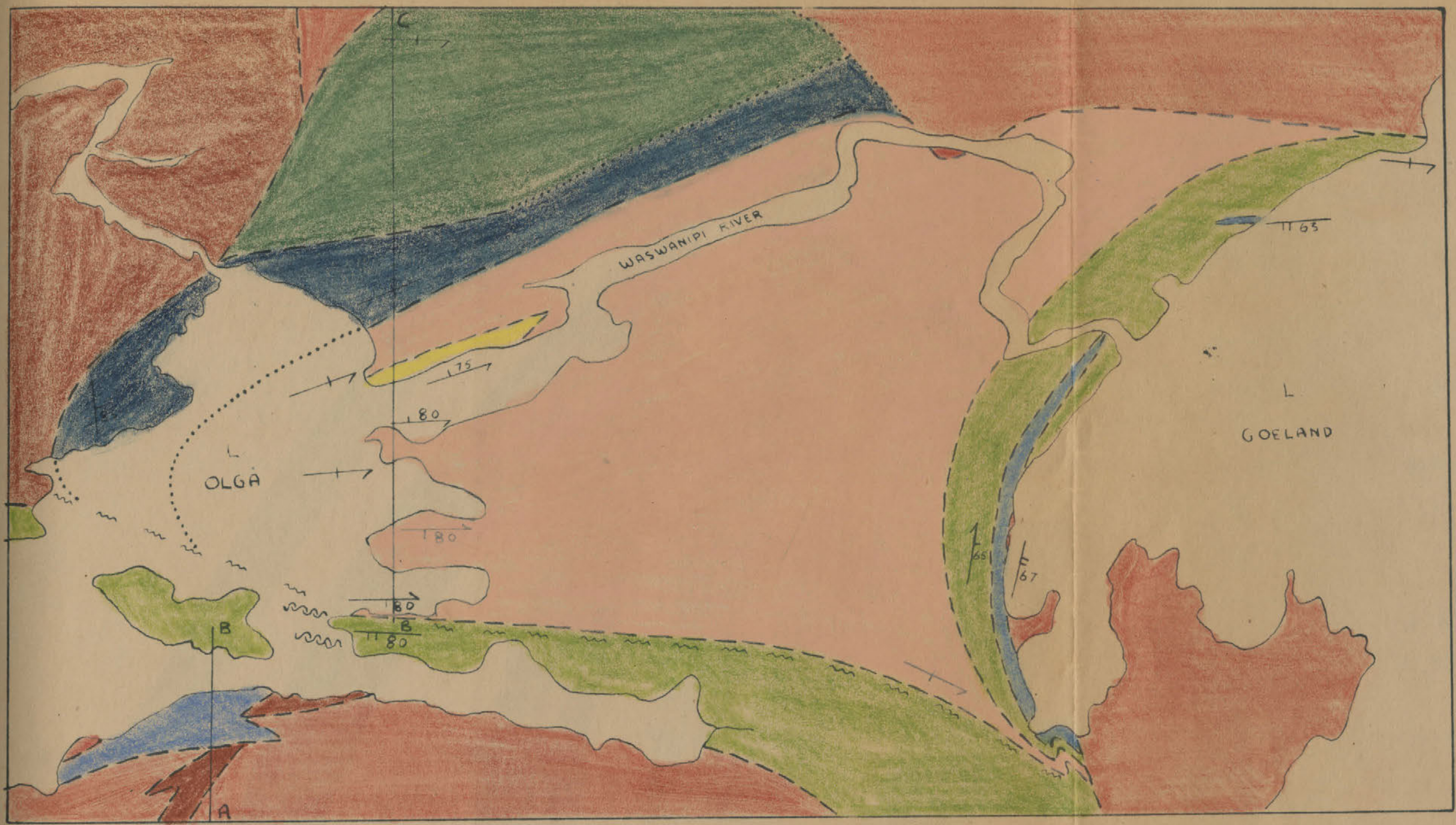
The andesitic belt surrounding Goéland lake is folded into an east-west syncline plunging eastward. Its axis appears to cross the lake at a mile or so south of its outlet into the Waswanipi river. If this axis were prolonged westward, it would bisect the triangular body of trachyte into more or less symmetrical halves, and would meet the western border of the map-area close to the apex of that sedimentary belt exposed on the northwest shore of Olga lake (Red Chute belt).

The westward convexity of the eastern andesitic band is thus repeated both in the trachytes and in the sedimentary rocks. The belts would thus be folded into an eastward-plunging syncline and their stratigraphic succession would be, from oldest to youngest:

Northern andesites,
Red Chute sedimentary rocks,
Trachytes,
Eastern andesites.

This interpretation may be questioned on the basis of the observed dips in the trachytic flow exposed on the east shore of Olga lake, in the vicinity of the postulated synclinal axis (Fig.6). Indeed, the dips that are not vertical, in that locality, would seem to favor an anticlinal structure. However, such dips may be due to overturning, and it is believed that

FIG 6




GRANITIC INTRUSIVES

BASIC SERIES

GRANITE PORPHYRY

SEDIMENTARY ROCKS, SOUTH SHORE OF OLGA LAKE AND WEST SHORE OF GOELAND LAKE

ANDESITES, EASTERN AND SOUTHERN BELTS

TRACHYTES

SEDIMENTARY ROCKS, RED CHUTE BELT

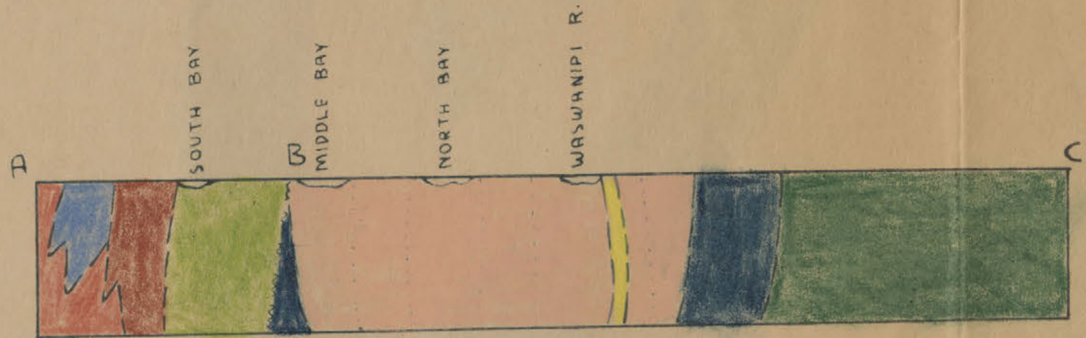
ANDESITES, NORTHERN BELT

SHEAR ZONE

POSTULATED FAULT

HORIZONTAL SCALE: 1 inch : 2 miles

SYMBOLS AS ON MAP No. 1




INTERPRETATION OF THE STRUCTURE OF THE VOLCANIC-SEDIMENTARY ROCKS.

more significance must be attached to the outcrop pattern of the belts: The westward convexity of the eastern andesites where they supersede the trachytes; the blunt termination of the trachytic band on its west side; the arcuate shape of the sedimentary rocks (Red Chute belt) which seem to curve around the nose of the trachytes; all this pattern strongly suggests that the different rock groups belong to the same fold system.

## Anticlinal structure

The reversal of succession south of the trachytes is easily explained if the andesites and the sedimentary rocks in this locality are considered to be younger than the trachyte. According to this hypothesis, the complete stratigraphic column of the Keewatin-like rocks in this region would be, from oldest to youngest:

Northern andesites,
Red Chute sedimentary belt,
Trachytes,
Andesites (eastern and southern belts),
Sedimentary rocks south of Olga lake.

The latter two belts would represent the south flank of an anticline brought into contact with the trachytes through a steep fault striking parallel to the axial plane of the folds. The postulated attitude of the strata before faulting and the location of the fault are shown diagramatically on Fig.7. As

FIG 7

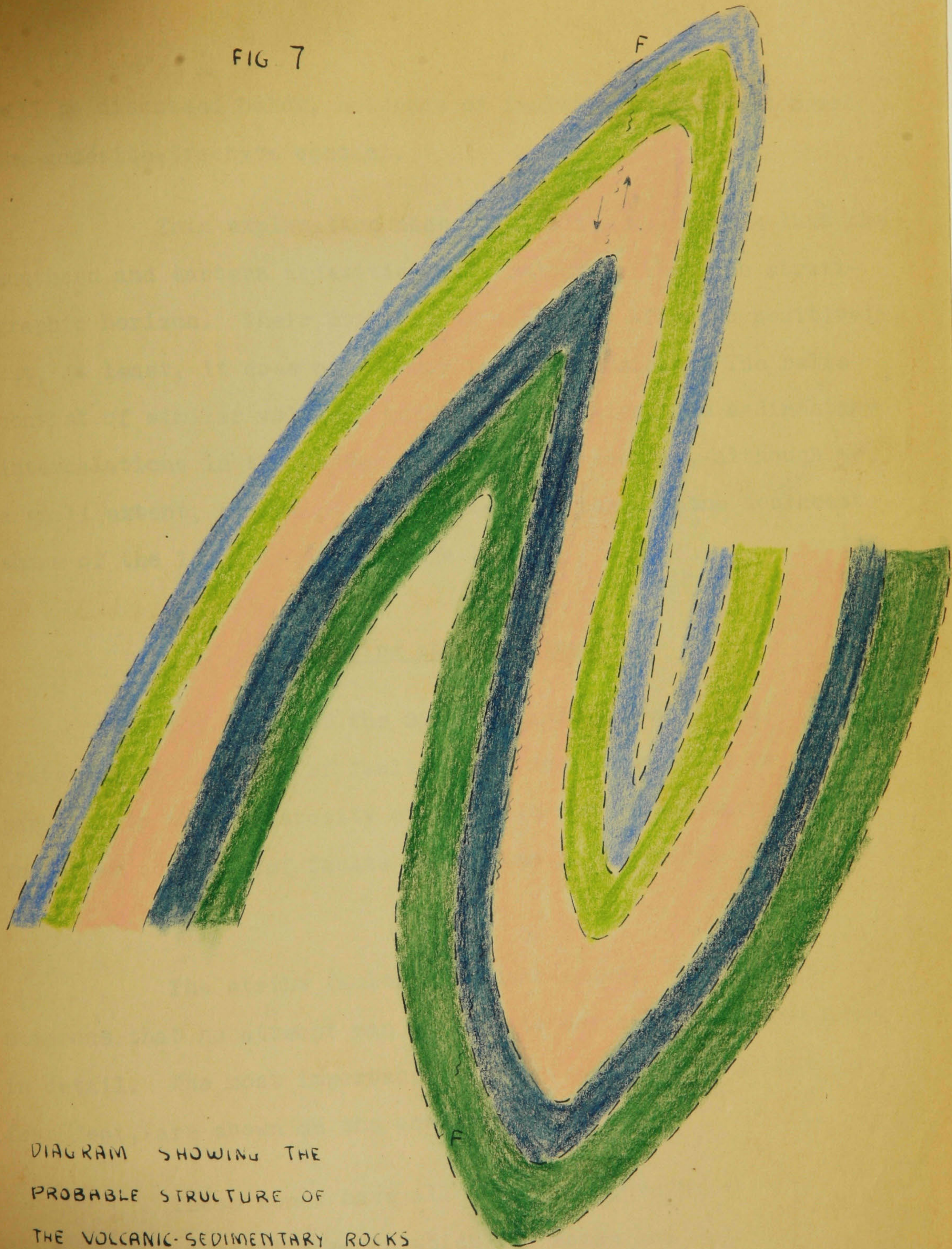



DIAGRAM SHOWING THE PROBABLE STRUCTURE OF THE VOLCANIC-SEDIMENTARY ROCKS PRIOR TO THEIR DISPLACEMENT ALONG THE POSTULATED FAULT F-F.

will be discussed below, evidence of faulting is abundant near the andesite-trachyte contact.

This explanation necessitates the assumption that the southern and eastern andesitic belts belong to the same stratigraphic horizon. Their correlation cannot be effected positively, but, at least, it does not appear to be impossible. The belts consist of similar volcanic rocks. In addition, the sedimentary intercalations in the eastern belt are represented, although to a small extent, by the narrow sedimentary band on the southeast shore of the large island in Olga lake.

## Shearing and Faulting

The rocks of the Olga-Goéland lake area are traversed by two sets of faults: the most common set is parallel to the schistosity of the volcanic-sedimentary series; the other consists of faults that trend in a general southeast direction.

The strike faults are shear-zones. They are so numerous that no attempt can be made to describe their locations in detail. The most important ones, those exceeding a width of four feet, are shown on the accompanying map.

These zones have all the same appearance: they consist of a central area in which the rocks are intensely crushed, and which, as a consequence, is often marked by a slight depression in the surface of an exposure. On either side of this central area, there is a transition zone of varying width (up to 100 feet, total width) in which the intensity of shearing decreases away from the centre. It has not been possible to ascertain the amount or direction of movement in any of the shear zones.

Hydrothermal activity has been widespread in these shear zones. The rocks, as mentioned above, are intensely chloritized, especially in those bands that withstood most of the shearing. Veins, lenses, clots, and stringers of quartz and ankerite are common.

The fault postulated above (Fig. 7) may coincide with one of the two shear-zones exposed respectively on the north and on the south side of the point opposite the east end of the large island in Olga lake. The north one is the larger. Its total width is about 100 feet, although the movement was mostly concentrated across a width of one foot, where the lavas are very thoroughly crushed.

The abundance of east-west shearing in the west-half of the map-area, the three east-trending bays in the east shore of Olga lake, the general westerly course of the Waswanipi river may indicate the presence of a regional "break" comparable to the Cadillac Break. Most of the movement in this break would have been localized along zones that could be reflected, in the present topography, by the east-trending depressions.

Three main oblique faults and a few smaller ones have been observed in the map-area. They all strike between $105^{\circ}$ and $160^{\circ}$, except one minor fault on the west shore of the large island in Olga lake. This fault strikes at $80^{\circ}$.

Offsetting of formations was observed in two instances only. At Red Chute, the shear zone and the contact between the sedimentary rocks and the syenitic intrusive are offset along a fault. The strike separation is about 100 feet right (east side south). Along a small fault on the north shore of the Waswanipi river, two miles east of Olga lake, the relative displacement of the blocks is only two feet with the east one also displaced southward.

The other two outstanding faults are located respectively on the west side of the large island in Olga lake, and on the east shore of Maicasagi lake, two and a half miles northeast of the south end of the lake. The displacement at these faults could not be determined, but strong movement is indicated by the presence of fault breccias (respectively eight and two feet wide) containing angular fragments that measure up to several inches.

As far as could be observed, all the oblique faults are later than the strike shears. Their relations to the main intrusive bodies are known in two places only: The Red Chute fault is definitely younger than the syenitic member of the basic series; the Maicasagi fault breccia contains fragments of a granitic dyke presumably related to the northern gneiss. It seems probable that the strike faults (shear zones) are pre-intrusive, while the oblique faults are post-intrusive.

## History

If the above structural interpretation is correct, it is possible to vizualize an admittedly hypothetical, but logical sequence of events in the history of the rocks. Assuming that the trachytes lie in a syncline, the sequence of deposition of these Keewatin-like rocks would be as follows:

1) On a floor, of which no trace has been seen in the area, a series of andesitic lavas were poured out. This series is now represented by the northern east-trending belt exposed in the western half of the area.

2) Following this period of volcanic activity, the surface of the lavas was brought down below sea-level and, in the basin thus formed, sedimentation permitted the building of a clastic series, about one mile in thickness. This horizon is now

represented by the arcuate band exposed north of Olga lake. Some considerations about the conditions under which these rocks were deposited have been given in the chapter dealing with sedimentary rocks.

3) The next period was one of volcanic activity. The lavas extruded were of more acidic, generally feldspathic, composition.

4) The building of the stratigraphical sequence was continued by a recurrence of andesitic volcanic activity. Their deposition was interrupted, now and then, by short periods of sedimentation, to which belongs the narrow belt of sediments bordering the west shore of Goéland lake.

5) The last important period was one of sedimentation. The clastic rocks deposited during this time are represented by the small sedimentary belt exposed on the south shore of Olga lake.

6) At many stages, the rocks already formed were invaded, in concordant fashion, by small bodies of gabbro and granite porphyry.

It may be fitting to point out here that volcanic activity, in any particular period, was never confined to the extrusion of a homogeneous kind of lava. The andesitic belts contain a few acidic flows and probably some basalt. The trachyte band in turn, should be visualized only as consisting predominantly of acidic rocks, but they contain numerous small andesitic flows. The boundaries between the two types of lavas were not sharp: a regular sequence was at times broken by the ejection of different volcanic material. Studies of more recent volcanoes have shown that the interfingering of different types of lavas is quite a common occurrence. To cite only one example, Lassen Peak, which is considered as a dying volcano, has erupted lavas of four types: rhyolite, dacite, andesite and basalt. (Day and Allen, 1925).

The contacts between the main sedimentary and volcanic belts have not been observed anywhere. Numerous observations, however, in the east half of the area, have shown that there is no unconformity between the smaller sedimentary units interbedded with the volcanic rocks. The crescentic belt itself, on the west shore of Goéland lake, terminates northward by a series of concordant intercalations in the lavas. Since the andesites exposed on either side of this belt have similar attitudes, it seems logical to conclude that the crescentic belt is simply an intercalation, larger than the numerous other ones found in the region, and that the passage from one type to the other was effected through a gradual transition.

Less information is known concerning the contacts between the western belts. The fine-grained texture of the clastic rocks, the presence of chert, the absence of conglomerate certainly indicate that no pronounced orogenic movement took place previous to the deposition of the sediments. The general parallelism of the primary and secondary structures, within the belts, is interpreted as a suggestion that all the rock sequences were deposited in a conformable fashion.

A similar conclusion has been reached in many surrounding areas (Freeman, 1943; Milner, 1943; Longley, 1943).

## Applicability of metamorphic name

When dealing with rocks, whose composition has been changed by metamorphism, the problem arises as to what name should be given to these rocks. Should they be designated by a genetic name, or by one which describes the present, new mineral assemblage?

The difficulty in recognizing the original nature of a rock has led to the use of blanket expressions in the geologic literature.

In Canada, one such term is "greenstone", which is still extensively used in mining circles, but which has almost lost all significance: "The term is used frequently when no accurate determination is possible" (Rice, 1948).

To define a complex series of mixed rocks, the Scandinavian petrologists have coined the term "leptite". "This term is used to signify those aphanitic or fine-grained metamorphic Archean rocks which are composed mostly of quartz and feldspars with subordinate amounts of colored minerals". (Eskola, 1914, p. 131). Under this term, are included rocks of satellitic, volcanic, as well as of sedimentary origin. "The inclusion of so many essentially different rocks under this collective term is justified only by the difficulty of recognizing the differences without detailed chemical or microscope examination" (Eskola, 1914).

There are, in the region under study, rocks which present certain problems as to their origin. Among them, may be listed especially the dark inclusions in the migmatite zone, south of Olga lake; the hornblende-garnet inclusions in the syenite concordant body, at Red Chute; a few exposures which, because they lack definitive internal characteristics, cannot positively be identified as either lavas or sills. These cases, however, are relatively restricted, and, on the whole, the rocks are too easily identified to be designated by such blanket expressions.

A modern, more precise, way of describing metamorphic rocks is based on the consideration, or principle, that "in rocks that have reached internal equilibrium under a given set of pressure-temperature conditions, the mineralogical composition is determined purely by the bulk composition of the rocks and varies regularly with changes in the latter" (Turner, 1948, p. 54).

This principle, first applied by Goldschmidt (1911, pp. 121-146), was expanded by Eskola (1921) into the principle of "metamorphic facies". A metamorphic facies includes rocks of any chemical composition, and hence of widely different mineralogical compositions, which have reached equilibrium during metamorphism under a particular set of physical conditions. According to this concept, rocks, whatever may be their origin, are described by the assemblage of their critical minerals.

References to metamorphic facies have been made during the discussion of the rock types studied in the previous chapters. Nevertheless, it has been thought preferable to designate the rocks by their genetic names, instead of a metamorphic expression. The reason for this procedure is a consequence of the nature of the field work.

The area was studied in as much detail as was permitted by the scale of mapping, but this survey is still of a preliminary type. The nature, the boundaries, and the stratigraphic relationships of the different belts of rocks encountered, thus assume an importance which necessarily supersedes that of metamorphism. Enough information, however, has been given on the general metamorphic changes to serve as a basis for more detailed investigations.

The metamorphic characters, as far as they are now known, may be conveniently reviewed here: The andesites consist essentially of secondary hornblende and feldspar. In the main belts hornblende occurs as shreds or prisms, and the feldspar is albite which in many samples has the shape of large lenses of porphyroblastic development. Through thermal metamorphism, some andesites have been converted into a granoblastic rock consisting of hornblende and andesine. The original sedimentary rocks have been changed into schists in which the dark mineral is either hornblende or biotite or both, and which also contain feldspar (andesine) porphyroblasts. Garnet is practically restricted to the sedimentary rocks of the south shore of Olga lake. Its occurrence in this belt may be a reflection of the postulated increase of stress in the southern rocks. The main mineral of the trachytes (albite) shows no metamorphic development.

Generally, the metamorphism of these rocks cannot, and should not, be described as "high" or "intense". None of the rocks has reached a grade higher than the second grade of metamorphism, as defined by Harker (1932). Their place is, depending on the type, either a little above or below the upper limit of Turner's (1948) Greenschist facies. Commenting on the Abitibi "greenstones", Osborne (1948) writes:

> "The greenstones are actually no more altered than the corresponding rocks in part of the Appalachian region of the Eastern Townships".

## Regional Correlation

In 1885, Lawson coined the term "Keewatin" to describe a series of highly folded volcanic schists in the Lake of the Woods region. The Special Committee on Nomenclature for the Lake Superior Region, recommended, in 1904, that the name Keewatin be extended to the volcanic schists of the basal complex of the Southern Sub-province (Bell, 1904). From the type-locality, this term spread rapidly eastward into northern Ontario and Quebec.

In 1911, another term was defined which was to become very popular in the Canadian geologic literature. Miller and Knight (1914) found a conglomerate within the pre-Cobalt basal complex, near Cross and Kirk lakes, in the Cobalt district and named it the Timiskaming series. They proposed that this name be given to all the belts of conglomerate and associated sediments in the basal complex of the Timiskaming region.

The relations between Lawson's volcanic series and Miller's sedimentary series, described as they were in localities which lay so far apart, have been the subject of a long controversy, the history of which is beyond the scope of this work. Much confusion has arisen from the indiscriminate use of these terms to describe sequences, respectively volcanic and sedimentary, that are encountered away from the original localities.

Wilson (1918) was one of the first Canadian Geologists to throw a note of caution on the use of these terms. In his memoir, he critically studied the criteria by which correlation could be made between the sequences exposed in the different subprovinces. In the general statement preceeding the discussion of the criteria, Wilson writes (p. 65):

> "With the possible exception of the south shore of lake Superior and the lake Huron-lake Timiskaming sub-provinces, the available data upon which the rocks of these separated regions can be correlated, are exceedingly meagre; and, for the present, at least, the only logical course would seem to be to build up a separate nomenclature for each sub-province by using the name originally defined in each sub-province, supplemented by such new local means as geological investigation requires".

These words, although written more than 30 years ago, have not lost any of their significance. As recently as 1940, after three years of mapping in the Cadillac-Malartic region, Gunning and Ambrose (1937, 1940) adopted local names in preference to the terms Keewatin and Timiskaming, which had been used by Cooke, James, and Mawdsley (1931) to describe the same volcanic-sedimentary complex.

Presently, in northern Quebec at least, these terms are still quite extensively used, but not in their original meaning. It is now recognized that there are many layers of sediment in the Keewatin and many volcanic flows and fragmental deposits, in places, in the Timiskaming (Moore, 1929). The current opinion of most Canadian Geologists is aptly exposed in the following quotation:

> "It has now been shown, as a result of more extended and detailed mapping, that the greywacke-conglomerate type of sediments occurs above, interlayered with, and below volcanic series in different parts of the Shield, and that very careful detailed studies and good exposures are necessary to permit correlation in any detail even over moderate distances." (Gill, 1948, p. 25).

The terms Keewatin and Temiskaming should not be, and generally are not, used except to indicate lithological similarity to the original series described under these names. They are often followed by a suffix, such as (-type, or -like), and this usage has been followed in this thesis. As they are interpreted here, Keewatin-like rocks mean a predominantly volcanic series with interbedded sediments, and the expression implies that the series is the oldest found in the region.

It has not seemed advisable to give the complex a local name, because it extends for too great distances both east and west outside the boundaries of the present area. When the belt is known in its entirety, the problem of placing it in its proper place in the geological sequence will undoubtedly constitute the subject of interesting studies.

For the time being, it is of great interest to note that the rocks of the Olga-Goéland lake area confirm the now-accepted fact of intercalations of sedimentary rocks within a series composed mainly of volcanics.

## POST-KEEWATIN-LIKE INTRUSIVES

Intrusive rocks form a large percentage of the bedrock of the map-area. They are grouped into a basic series and an acid series. The intrusive bodies described in a previous chapter are not included here as they appear to be genetically affiliated to volcanic rocks rather than to the two intrusive series mentioned. Dyke rocks, including lamprophyre and possibly late diabase, are younger than these two series and are discussed later.

The basic series (commonly called the "Diorite-Syenite Sequence") is older than the acid series. It is definitely the more complex of the two and consists of several types of rocks, or facies, which appear to represent differentiates from a common igneous mass. The various differentiates, in their present state of alteration, range in composition from amphibolite to diorite to syenite.

The acid series includes mostly plagioclase-rich granites. They form three main bodies:

1) Southern, generally massive granite (Olga quartz-diorite);
2) Northern, generally gneissic granite;
3) Goéland batholith.

The first two possibly belong to a single intrusive stage. In addition, a few small bodies of massive pink granite are found which are distinctly later than the northern granite.

## Diorite-Syenite Sequence

The rocks of this group underlie a large region whose southeastern boundary is marked by a wavy line that crosses the map-area in a northeasterly direction, from the west shore of Olga lake. This boundary passes through Red Chute and it possibly extends beyond the north border of the region, if the small body of similar rocks along this border, just west of longitude 77°00', belongs to the main mass. Because of the lack of exposures, in the intervening area, this question must be left open. For the same reason, similar doubts arise about the location of the northern boundary of this intrusive mass. This boundary, east and north of Mattagami lake, may follow approximately the border of the swampy area, because generally the intrusive rocks of this series have, in that region, a greater tendency to form hills than the other rock types. The rocks are best exposed around Mattagami lake and along the section of Waswanipi river connecting Olga and Mattagami lakes.

A few, small lenticular bodies presumably belonging to the same series occur elsewhere throughout the area. They are in places found, as on the southeast shore of Maicasagi lake, intruding the sedimentary-volcanic complex in an apparently concordant manner. More commonly, the rock is found as inclusions in the members of the acidic intrusive suite. The largest of these occupies a long triangular-shaped area of two square miles, with its base along the east shore of Max Narrows. Its apex is less than one-half a mile south of the northern limit of the map-area. Two other fairly large bodies are found on the south shore of Olga lake, south of the largest island.

## Amphibolite

Dark, coarse, amphibole-rocks were noted at numerous places in the area. They commonly occur as angular fragments within the dioritic members of the series, and, as such, their typical locality is on the east end of Mattagami lake. Larger, mappable units are found in two places: 1) on the west shore of Olga lake, where they are exposed for about one quarter of a mile around a small point lying between exposures of sedimentary rocks on the north, and of andesitic lavas, on the south; 2) on the southeast shore of the southernmost, east-trending bay, of Olga lake, where the exposure measures a few hundred square feet.

The amphibolites consist predominantly of hornblende whose large crystals constitute from 80 to 95 per cent of the rock. Other minerals include: a completely clouded feldspar, and small amounts of quartz, albite, biotite, chlorite, clinozoisite, apatite, and magnetite. With the exception of the saussuritized feldspar, apatite, and possibly magnetite, all the other minerals appear to be secondary. Augite could be identified in one thin-section. In other specimens, however, some of the hornblende grains contain ill-defined cores that could not be identified, but that are probably uralite after pyroxene. It is thus possible that part, if not all, of the hornblende is an alteration product of pyroxenes.

<u>Diorite</u>

The most common members of the basic series have the average composition of a diorite. They form the bulk of the rocks of the series and are also found in predominance in the smaller masses. Although the rocks of this group are called dioritic as a whole, they nevertheless vary appreciably from place to place, both in the proportion of their dark mineral content and the nature of their plagioclase. They, furthermore, constitute a number of sub-facies, some of which show, locally, cutting relationships to the others. This is especially the case around the east end of Mattagami lake where the complexities of the basic series are best displayed.

The diorites are from fine- to coarse-grained, and in places, they are coarse enough to be called pegmatites. The feldspars crystals are almost always euhedral and as a result, the rock often has a porphyritic appearance. Schistosity is generally absent, and when present, it is rather faint. The finer-grained types are generally dark-grey, whereas the coarser-grained, because of their larger feldspars have the appearance of a mosaic of pink or white grains in a dark-green mass.

The average composition of the dioritic member of this series is:

Plagioclase........ 40-60%
Microcline......... 0-30%
Quartz............. 0-25%
Hornblende......... 10-50%
Biotite............ 10-20%
Accessory and secondary minerals: epidote, chlorite, magnetite, zoisite, clinozoisite, and titanite.

Following is a description of the various facies of the diorite which becomes less basic toward the south of the mass.

Around the north shore of the east end of Mattagami lake, and in the few inland exposures in the north half of the map-area, the diorite carries a fairly calcic plagioclase, with an average anorthite content of 30 per cent. Microcline is rare and wherever present it is in accessory quantity. Quartz is occasionally found in small amounts, and often appears to be of late origin. One specimen is cut by a veinlet of potassic feldspar associated with quartz. Hornblende is of the common green-pleochroic variety, sometimes with a bluish tinge parallel to Z.

Around the south shore of Mattagami lake and the group of three islands nearby, the basic series commonly consists of a complex assemblage of many dioritic sub-facies. The transition from one to the other is generally so indistinct that it is doubtful whether the areas underlain by each type could be delimited even through detailed work. Exceptionally, however, along the south shore of lake, especially close to, and outside the west boundary of the map-area, it has been possible, through cutting relationships, to distinguish three different sub-facies of the dioritic group.

The composition of the sub-facies, as revealed through microscopic study of thin-sections, does not vary sufficiently from one to the other to warrant special discussion. The rock underlying the middle of the three islands may be taken as representing the average diorite in this vicinity. It carries a fairly sodic plagioclase (An7-16) and hornblende is still the predominant mineral although it is more altered than in the more basic rock to the north. Biotite occurs only sporadically and never exceeds 15 per cent. Quartz is still in minor amount, but it is much more regularly distributed: each thin-section contains about 5 per cent of this mineral.

Farther south, a fairly consistant dioritic facies is exposed along the Waswanipi river, from Mattagami lake to a point about one mile west of Red Chute. The same facies underlies the group of low hills, south of the river.

The striking mineralogical change in the localities just mentioned results from the appearance of microcline in percentages that vary from 10 to 30. Biotite also becomes a persistently and uniformly distributed mineral. It constitutes 15 to 20 per cent of the rock. Secondary alteration is common in this facies and consist of some epidotization and slight sericitization.

The preceding discussion is summarized in the following composition tables:

- I -

## Amphibolites

| | |
|---|---|
| Hornblende......... | 80-95% |
| Feldspar........... | 5-10% |
| Late Quartz........ | 0-10% |

Acc.: biotite, chlorite, apatite, magnetite, clinozoisite.

- II -

## Diorite, north Mattagami lake

| | |
|---|---|
| Plagioclase (An28-34).. | 40-65% |
| Hornblende............. | 25-60% |
| Quartz................. | 0- 5% |
| Biotite................ | 0-15% |

Acc.: microcline, epidote, apatite, magnetite, zoisite, clinozoisite.

- III -

## Diorite,south Mattagami lake

| | |
|---|---|
| Plagioclase (An7-16)... | 40-80% |
| Hornblende............. | 10-50% |
| Biotite................ | 0-15% |
| Quartz................. | 4- 5% |

Acc.: microcline, epidote, apatite, clinozoisite.

- IV -

## Diorite, Waswanipi river

| | |
|---|---|
| Plagioclase (An16-19).. | 40-70% |
| Microcline............. | 10-30% |
| Hornblende............. | 15-40% |
| Biotite................ | 15-20% |

Acc.: apatite, epidote, zoisite, sericite.

The inclusions occurring in the granite along the south shore of Olga lake, in the southern part of the map-area, generally belong to the dioritic facies. They are found as two apparently disconnected bodies, oriented parallel to the structure of the sedimentary rock and now found as remnants within the younger oligoclase granite.

The rocks have the same appearance as those of the main mass to the north. They are grey, fine- to coarse-grained. The feldspars are either white or pink and generally idiomorphic: porphyritic texture is very common. The main constituents of the rock are highly variable:

| | |
|---|---|
| Plagioclase (An14-28)... | 35-80% |
| Hornblende.............. | 25-60% |
| Biotite.............. | Acc.-15% |
| Quartz................. | - 5% |

Acc.: epidote, sericite, chlorite. Magnetite (sometimes with a leucoxene border).

The range of compositions confirm the field observations as to the existence of many facies. The many types examined might be arranged into a sequence corresponding to, and as complex as, that of the northern rocks. Such a sequence, however, could not be established, because of the lack of cutting relationships.

## Syenite

The syenitic facies of the series, though found occasionally around the east end of Mattagami lake, is typically developed near Red Chute and in the areas both to the north and to the south. It thus forms a band which appears to vary in width from half a mile to one mile along the southeast border of the main dioritic mass. Syenitic rocks also occur, but to a restricted degree, in associations with the diorite along the Waswanipi river.

The transition from the dioritic to the syenitic facies is well exposed on a small rounded point, on the south shore of Waswanipi river, about one mile west of Red Chute. Travelling from west to east on that point, over an area of diorite, one first comes across what appears to be a gradational contact, which is ten feet wide, between the two facies. After a few feet of overburden, however, diorite reappears and it is cut by a six-inch dyke which, by color and composition, is related to the syenitic facies. Ten feet further, both facies are separated by a distinct contact line which runs north-south. Thence, syenite continues eastward, with local variations, until it gives place to the sedimentary rocks at Red Chute.

In hand specimens, the syenite is not much different from the more basic facies, except for a lighter color due to the reduced quantity of ferromagnesian minerals. It has the same texture and it is commonly massive. Close to the contact with the sedimentary belt, it possesses a distinct lineation resulting from the alignment of the hornblende prisms. The mineral composition of the syenite is:

| | |
|---|---|
| Plagioclase (An12)... | 35% |
| Microcline........... | 30% |
| Quartz............... | 5% |
| Biotite.............. | 20% |
| Hornblende........... | 10% |
| Acc.: sericite, epidote, apatite, and magnetite. | |

Texture of the diorite-syenite rocks

The euhedral development of the plagioclase is widespread in the rocks on the basic series. Whether the rock has a porphyritic or an equigranular appearance, the plagioclase is almost always bounded by crystal faces. It is rare to see plagioclase which has interlocking boundaries with either hornblende or biotite.

These last two minerals form either large flakes with irregular terminal faces or clots of small grains that seem to fill the spaces between the plagioclase crystals. Microcline and quartz are interstitial to all the above minerals. In a few places, there has been partial replacement of plagioclase by a myrmekitic intergrowth of quartz and microcline at the contact between the two feldspars.

Deformation effects are not very conspicuous in the massive rocks of the main extent of the series. The feldspars show no granulation along their edges, and their cleavages and twins are not bent. Slight bending of the biotite flakes has been observed only in a few specimens. Quartz grains show undulose extinction and some of the larger crystals are broken into a few pieces, none of which appears to have been rotated from its original position.

The rocks of the smaller bodies generally show greater strain. In most of them, the feldspar is slightly granulated and the quartz crystals are extensively shattered. All these strains are the result of deformation which the rocks have undergone after the consolidation of all the minerals.

Correlation and age of the basic series

The main extent of the series and the several small bodies found throughout the map-area, may belong to more than one stage of intrusion, but because of their petrographic similarity, it has been thought preferable to include them under the same group. As mentioned above, cutting relationships between the different facies have been observed in very few places. Even on the best exposures, "it cannot be said to what extent the several associated rock types are the result of successive injections during the same intrusive cycle or, on the other hand, represent injections of various ages". (Dresser and Denis, 1944, p. 63).

The basic series is intrusive into the Keewatin-like volcanic and sedimentary rocks, and it is in turn intruded by the masses of oligoclase granite. The series is similar in composition to the northern and western facies of the massive Dunlop intrusive described by Longley (1943) in the Kitchigama Lake Area. This intrusive is considered by Longley to be related in age to the Bell River Anorthosite Complex exposed in the Opaoka River Area and which is considered by Black (1942) to be pre-folding.

The arrangement of the different facies, as previously described, would seem to indicate that the main extent of the series is vertically folded and that its more acid, youngest, member lies along the southeast border of the mass. The stratigraphical sequence of the series, with its top toward the south, is thus in accord with the synclinal structure which in this area has been postulated for the rocks of the Volcanic-Sedimentary complex. Accordingly, because of its field relations, the basic series might be considered as pre-folding.

Important objections against this hypothesis are the massive state of the rocks and their apparent lack of metamorphic recrystallization. If they had been interbedded with the lavas and clastic rocks before folding, their minerals should show, at least to a certain degree, effects similar to the ones noted in the finer-grained rocks: these effects are recrystallization, schistosity, shearing, crushing. It is true that in a few specimens, traces of a cataclastic texture were seen, but this texture is generally so inconspicuous that it may be more correctly related to slight post-consolidation stresses than to enormous forces which must have been active during the folding of the Keewatin-like rocks. These observations favor the hypothesis that the basic series is late or post folding.

As mentioned above, some lineation has been observed in the syenite at Red Chute. The lineation results from the alignment of hornblende prisms in a direction parallel to the schistosity of the nearby sedimentary rocks. It plunges westward at about $25^{\circ}$. This linear element is repeated as a "rodding" in the nearby meta-sediments, but the plunge is steeper ($50^{\circ}$ west).

The syenite is traversed by numerous sets of joints. Near Red Chute one set is dipping steeply east and lies almost at right angle to the lineation. The surface of these joints is rough and displays no trace of polishing. These steep joints are interpreted as tension fractures.

This linear structure introduces some difficulty in the structural interpretation given above. Indeed, if the lineation is parallel to the axis of the main fold (Sander's b-axis), the fold would plunge west instead of east as postulated. However, because of small number of observations and the restricted aerial distribution, the writer prefers to interpret this lineation as a local phenomenon possibly associated with either the shear zone or the fault which are found in this locality.

## Classification of the basic series

It is rather difficult to give a proper specific name to this intrusive sequence. In the diorite, the dark minerals are sometimes present in sufficient quantity to give the rock the appearance of a gabbro. The plagioclase, however, in all the types, is always too sodic even for a diorite. For many facies, Idding's term "laugenite" (oligoclase diorite) would seem appropriate. Since this term is not in general use and further, since it does not convey the idea of the great complexity found in this series, the expressions "diorite-syenite sequence" or "basic series" are preferred by the writer.

## Massive Oligoclase Granite

## (Olga Quartz-Diorite)

The granitic rocks exposed on the south shore of Olga lake are the northern part of a large batholith which Freeman (1938) has named the "Olga Quartz-Diorite". Their contacts with the sedimentary rocks on their north side has already been described. Although the contact zone is intricate and is generally less then one half mile across, almost every exposure in those hills that border the southern limit of the map-area, contains a few inclusions of dark biotite-hornblende schist.

In order to find the pure facies of this rock, it is necessary to go outside the confines of the present area. As described by Freeman, the Olga Quartz-Diorite is a variable grey and red rock of medium grain which normally consists essentially of oligoclase (An20), quartz, and biotite with small amounts of microcline, albite, hornblende, epidote, apatite, and titanite. Its average mode is:

| | |
|---|---|
| Oligoclase..... | 65% |
| Quartz......... | 25% |
| Biotite<br>Hornblende<br>Epidote | .... 10% |

Microcline is commonly in small amounts except near the contacts with older rocks, where it may be as much as 30 per cent of the rock.

Two years ago, the writer (Imbault, 1947) had the opportunity to study the part of this batholith that is exposed in the Iserhoff River Area, and the mineral composition of the rock in this locality is essentially the same as that given by Freeman:

| | |
|---|---|
| Plagioclase........ | 35-40% |
| Quartz............. | 20-35% |
| Biotite............ | 20-30% |
| Epidote............ | 5-10% |
| Microcline..(less than | 5%) |

Much of the plagioclase in this locality is zoned: it is from An24-34 in the core to An12-15 in the rim. The homogeneous crystals have the composition An18-20. This rock, as well as the one described by Freeman, has a faint cataclastic texture.

Within the Olga-Goéland lake area, this granite has its characteristic grey color, and, as seen on the hand specimen, an interlocking (granitic) texture. Even those tongues which intrude the sedimentary rocks in a lit-par-lit fashion have a massive structure that only rarely gives place to a faint gneissic structure. The mineral composition, however, differs from the modes given above. The less altered representatives of the mass contain generally more microcline:

| | |
|---|---|
| Plagioclase (An14-24).. | 50% |
| Microcline............. | 20-25% |
| Quartz................. | 10-20% |
| Biotite................ | 5-10% |

The more contaminated facies, usually found close to the inclusions are also characterized by microcline and, in addition, by the appearance of amphibole with corresponding decrease in biotite. The following table shows the approximate composition of those true border facies along the south shore of Olga lake:

| | |
|---|---|
| Plagioclase............ | 50-70% |
| Microcline............. | 10-30% |
| Quartz................. | 10-20% |
| Biotite................ | 0- 2% |
| Hornblende............. | 5-10% |
| Epidote.............. | Acc.- 3% |

Acc.: Sericite, hematite, magnetite, apatite, pyrite.

The plagioclase, except in one specimen, is from An20 to An33 and the grains are so granulated that it is impossible to ascertain the shapes of the crystals. In one rock, however, the plagioclase is An14 and the grains are porphyroblastic.

The amphibole is ordinary hornblende and it occurs as ragged individuals or clusters of grains. Ferro-hastingsite (Billings, 1928) has been seen in one thin-section. Its optical properties are:

Pleochroic formula: Z= deep bluish green,
Y= deep olive green,
X= pale greenish yellow.

Z C = 23° ; Uniaxial (-)

The amphiboles are believed to be partly magmatic and partly the result of assimilation of older rocks into the granite.

The origin of secondary amphibole is well shown on the west shore of Olga lake where a small triangular plug is exposed that has a composition similar to the rocks of the main mass of Olga quartz-diorite. The exposures on the east side of the plug, along the shore of the lake, contain numerous inclusions of fine-grained hornblende schist. The inclusions are generally elliptical and their long axes are aligned in a general northerly direction, that is, parallel to the assumed borders of the intrusive.

A few inches away from the inclusions, the granite has a green-tinted pink color and the feldspars are euhedral. Its composition is:

| | |
|---|---|
| Plagioclase (An20).. | 50% |
| Microcline.......... | 25% |
| Quartz.............. | 15% |
| Hornblende.......... | 15% |

Hornblende occurs as individual grains, slightly altered to chlorite with a release of magnetite.

Immediately at the contact with the inclusion, the granite is grey, from a higher content of ferromagnesian minerals:

| | |
|---|---|
| Plagioclase (An15).. | 35% |
| Microcline.......... | 20% |
| Quartz.............. | 10% |
| Hornblende.......... | 35% |
| Acc.: sericite, epidote, magnetite. | |

Hornblende occurs predominantly in lenticular masses. These consist almost exclusively of small non-oriented hornblende crystals separated from one another by a network of completely clouded feldspars. In addition, hornblende is also found as porphyroblasts peppered with poikilitic inclusions of quartz, feldspar, and magnetite.

These dark, hornblende-rich spots clearly represent small pieces of older rock, probably a volcanic, detached from their parent body by the magma. In some cases there is evidence that the slightly-zoned, euhedral crystals of plagioclase flowed around these masses since the long axis of the crystals are parallel to the outlines of the lenses.

The increase in the proportion of hornblende is thus due, in this granitic plug, to contributions from the invaded rocks. This contamination is similar to the process described by Collins in the Pre-Huronian Batholithic rocks of the Onaping Map-Area (Collins, 1917).

Microcline also seems to owe its origin to contributions from the invaded rocks. Its constant appearance in those portions of the granite which are close to remnants of older rocks cannot indeed be purely coincidental. The potash was likely derived from some mineral present in the invaded rocks, probably biotite.

## Gneissic Oligoclase Granite

## (Northern granite)

### DISTRIBUTION

The northern granite underlies an area greater than any other single rock type of the region studied. It belongs to a great expanse of intrusive rocks which extends for large distances east, west, and north of the map-area. The local boundaries of this mass are rather indefinite. The topography is of no help in their determination, since granitic rocks form hills that are generally no more conspicuous than the low mounds underlain by volcanic rocks.

The southern boundary appears to follow a sinuous line which runs from the southwest shore of Maicasagi lake, westward to a point about one half a mile north of Post 7 on the east-west survey line. This point represents the southern tip of a narrow granitic tongue which is in contact with andesitic lavas on the southeast, while, on the northwest, it is limited by the rocks of the basic series.

It has not been possible to establish the relationships between the main mass of granite and the smaller bodies of similar rocks cropping out on the edge of the swampy area in the northwest quadrant of the region. From their physical characters and composition, these rocks belong to the same body and they are here interpreted as such. The absence of exposures, however, in the intervening areas throws too much uncertainty concerning the actual position of the contact line, and it seems preferable to leave the question open.

## INCLUSIONS

The main characteristics of the northern granite is the almost universal presence of inclusions. Distinct bodies of older rocks forming roof-pendants in the granite mass have already been described. Besides, practically every exposure of granite, in this northern area, contains small inclusions. Most of these consist of fine-grained hornblende and/or biotite schists that, both in hand specimen and in thin-section, resemble the volcanic-sedimentary series. Rocks belonging to the basic series are also found, but in minor amounts.

Inclusions of schist and of basic intrusive rocks were seen, only twice on the same exposure. One locality is on the northwest-facing escarpment that bounds the low granitic hill in the south tip of the tongue mentioned above. The other locality is on the northwest shore of Maicasagi lake, slightly less than one mile south of the northern boundary of the map-area. In both places, the two types of older rocks are found in relative abundance and they are quite uniformly mixed.

The small inclusions generally measure a few square feet or less and they are commonly angular. In places, they form ribbons, a few inches wide and scores of feet long, lying parallel to the fluidal structure of the granite. Sometimes, because they are not clearly cut by offshoots of the intrusive, these ribbons cannot be distinguished from basic dykes, except by comparison with specimens of undoubted inclusions.

The contact between the inclusions and the granite is always sharp. Significant transitions from granite to older rocks have been observed in a few localities. These zones, which will be described below, show an intimate interlacing of the two types of rocks, tending toward the production of a gneiss. However, except where the alternating bands approach in thickness the size of individual minerals, the physical boundary between the two rock types is well preserved in these transition zones.

PETROGRAPHY

Because of the wide distribution of inclusions, the granitic rocks in this northern body show numerous variations in their field appearance. These variations are conspicuous not only from one locality to another, but they are also commonly observed in a single exposure. Consequently, it is almost impossible to describe a rock that could be considered as the pure, non-contaminated representative of the mass.

Generally, the northern granites are light-colored rocks, either grey or pink. They are fine- to medium-grained, and possess a well-developed interlocking texture. In some of the exposures, the granite is massive, but the gneissic structure is sufficiently common throughout the mass, to justify the use of the term "gneiss".

As much as possible, the specimens selected for microscopic studies were taken away from the inclusions. It was found that all the gneissic types have, on the whole, a fairly consistant mineralogical composition:

| | | |
|---|---|---|
| Plagioclase............... | 40-70% | Av. 52% |
| Microcline................ | 5-30% | 10-15% |
| Quartz.................... | 5-45% | 24% |
| Biotite................. | Acc.-30% | 15% |
| Amphibole (2 cases only).. | - 5% | |
| Acc.: epidote, chlorite, zoisite, magnetite, apatite. | | |

The plagioclase is always quite fresh and subhedral: straight crystal faces are rounded at the edges and the growth of individual crystals has been arrested as they came in contact with other grains of plagioclase of the same composition. Albite and Carlsbad twins are common. The composition of the plagioclase, in 18 of the 21 thin-sections studied, is from An14 to An21, and the grains are slightly zoned. The three remaining sections, although generally similar to the others, contain a more calcic, strongly zoned plagioclase: An24 in the core, and An17 along their outer border. Since these last three specimens were collected near the northern boundary of the east-half of the map-area, they may indicate north-south variations in the granite.

The oligoclase is clearly the oldest of the light-colored minerals of the rock. Microcline, on the other hand commonly has polygonal shapes, but none of them resemble the crystal form of the mineral. Quartz, as is usual in granitic rocks, is entirely interstitial. The grains pinch, swell, and curve as they fill the voids between the earlier minerals, with the result that, in hand specimens, the subhedral form of the plagioclase is masked and the rock has an interlocking texture. Microcline and quartz are probably of the same age, since, in places, they form a myrmekitic intergrowth which, in a few instances, has replaced part of a plagioclase grain at the contact between the two feldspars.

Of the essential ferromagnesian minerals, biotite is much more abundant than amphibole. It is pleochroic from dark-brown to brownish-yellow. It occurs as more or less parallel flakes, a few millimeters long (exceptionally 1 cm.). Many of the oligoclase grains contain small flakes of biotite. This is interpreted as evidence that the formation of biotite at least began before that of oligoclase.

Noteworthy quantities of amphibole have been found in two thin-sections only. This amphibole is in both cases a soda-rich type, and probably belongs to the Hastingsite group. Its physical properties are:

Pleochroic formula: Z= dark blue
Y= almost violet
X= greenish yellow

$Z \wedge C = 30^{\circ}$ ; (-)2V = very small.

This amphibole occurs as irregular prisms or as trains of small grains. The prisms have many inclusions of quartz and clouded feldspar, and many of them terminate by an interfingering of amphibole and biotite. The trains form discontinuous streaks which often intersect one another as they curve around the larger grains of light-colored minerals.

Among the accessory minerals, apatite and possibly magnetite appear to be original. The other three, namely epidote, chlorite, and zoisite are alteration products.

## ORIGIN OF THE GNEISS

### Hypotheses advanced by previous workers

The first hypothesis concerning the origin of this granitic gneiss was advanced by Lang, following a rapid survey of the Waswanipi lake area in 1932. In his report, Lang (1932) writes:

> "A complex of generally grey granites, banded gneissic rocks that are lit-par-lit injections, or migmatites, and granitized inclusions of what were once probably volcanics and interbedded sediments occupies practically all the area north of Mattagami lake and extends north of lake Olga and lake Goéland.... The grey granite appears to be distinct from the types described in a previous paragraph (mostly Olga Quartz-Diorite) and is believed to be older." p. 42D.

A few years later, Freeman (1938) gave these granitic rocks the name "Mattagami Gneiss". After comparing the many variations found in this gneiss with specimens from the contact zone of the Olga quartz-diorite-sedimentary belt, on the south shore of Olga lake, Freeman concluded that both the gneiss and the contact zone consisted of migmatite. The gneiss, in particular, was considered as having formed "by recrystallization and metasomatic replacement of a shell above a crystallizing quartz-diorite magma". The process, Freeman believed, was of hydrothermal nature.

These two hypotheses, while differing in the postulated physical state of the intruding material, are similar in that both recognize the existence of two kinds of material in the gneiss: an older rock (sedimentary or volcanic) has been invaded either by a granitic magma (Lang) or by hydrothermal solutions derived from a magma (Freeman), thus making the Mattagami gneiss a composite rock.

Scope of the problem

The origin of granitic rocks, and particularly of the gneissic facies of the granites, has long been the subject of controversy. From the early days of Geology, the notion that sedimentary rocks can be converted to granitic rocks has been attractive.

Leaving aside the history of this controversy, the present diverging opinions may be briefly summarized as follows: On the one hand, the view is held that granites were formed through the consolidation of a magma. On the other hand, a school of geologists holds the opinion that granite is formed by replacement of preexisting rocks through some agency (not connected with magma). Discussing this theory, Read says:

> "Granitization means the process by which solid rocks are converted to rocks of granitic character without passing through a magmatic stage." (Read, 1948, p. 9).

In view of the commonness of granites in the crust, the problem of their origin is a very important one. The problem indeed is twofold. As a first step, one must consider whether a granite results from injection of a magma or by granitization. In addition, the origin of the granitic magma, if such is found to exist, must be explained. Failure to distinguish between these two aspects of the question, namely the origin of granites and the origin of granitic magma, has often led to confusion.

A thorough discussion of both phases of the problem is clearly beyond the scope of this thesis. It is felt, however, that a few remarks on the granite- versus- granitization controversy will constitute an appropriate introduction to the discussion of the origin of the Mattagami gneiss, as visualized from the writer's observations.

## Origin of granites

The great Uniformitarian, Hutton, was the first proponent of the magmatic theory (Bradley, 1928, pp. 362-364). Since Hutton's days, a great many geologists, especially in

Germany and North America, have been able to find more evidence of the intrusive nature of the granites. Numerous pertinent observations have been recorded, among which the following are the more important: chilled edges, cross-cutting relations, contact metamorphism without gradation, angular non-oriented fragments of older rocks found as inclusions in the granite, consistent pattern of internal structures such as lineation, foliation, diagonal, and cross joints.

If indeed all the granitic rocks possessed all the above characteristics, it is doubtful whether the magmatic hypothesis would have ever been questioned. However, many masses throughout the world display some features which, a priori at least, seem difficult to explain with this hypothesis. The features are mainly:

1) General presence of gradational boundaries between granite and schists or sediments.

2) Strike and dip of foliation in exact continuity and identical directions with the foliation in the surrounding metamorphic area, for instance, the batholith of the French River Area (Quirke, 1929).

3) Metacrysts in a schist wall and phenocrysts of the same composition in the granite bordering it, for instance, along the border of the Rapakivi granite.

Obviously, hypotheses of granitization have originated from the need of explaining in a satisfactory manner the existence of granitic gneisses. The several theories that have been advanced up to the present time will now be discussed briefly. Ortho-gneisses need not be considered here since there is little difference of opinion about them, if the idea of a granitic magma be accepted.

The various origins of secondary granite may be classified as follows:-

- Infiltration of granite along the folia of pre-existing rocks;
- Metasomatic changes caused by ichors derived from magma;
- Selective refusion;
- Emanations not related to magma.

## Hypothesis of granite infiltration

According to this hypothesis, a granitic magma can penetrate along closely-spaced channels in the invaded rocks. In order to produce a gneiss, the laminae must be exceedingly thin. This hypothesis is thus dependent on the fluidity of the invading magma. The writer is not aware of any experimental data on this problem, although field observations seem to indicate that a granitic magma, at least in some cases, possesses a high degree of fluidity.

Fenner's observation in the Highlands of New Jersey are particularly instructive (Fenner, 1914). In this region, Fenner has observed numerous gradual transitions from granite to inclusions that lie parallel to regional schistosity. Most of the strata show some effects of crumpling and twisting. In addition, vertical exposures show that support was given by the magma to thin tabular sheets standing upright. From these data, Fenner concludes 1) that the intrusion was effected among the layers of a previously schistose or foliated rock without causing great disturbances in position; 2) that the magma was thin, but not as fluid as water.

Hypothesis of metasomatic changes

Over a century ago, French geologists, impressed by the many transitional features along granite contacts, developed the idea of granitization. While still maintaining that a granitic magma was involved in granitization, they believed that its intrusion was preceded by a cortège of emanations that transformed the wall-rocks into granite and so made possible their assimilation by the advancing magma. The hypothesis has later been considerably extended by Sederholm in Finland, who coined the term migmatite to describe all the gneisses of mixed origin. (Sederholm, 1923, 1926, 1934).

Following the lead of these geologists, numerous other workers have recently adopted and developed in widely-separated regions, the concept of mobile fluids accompanying the main intrusion: Barth (1936), Billings (1938), Goranson (1925), McGregor (1938), Stark (1935). Except Goranson, who believes that the metasomatizing solutions follow the intrusion, all the proponents of the theory hold the opinion that granitization is effected mainly through the action of highly mobile alkali-fluids associated with an intruding granite, but preceding the actual intrusion of the mass.

Whether or not all the followers of this French "classic" school are prejudiced by relics of the Huttonian magmatic theory remains to be proved. Indeed some of Sederholm's conclusions have already been seriously questioned (Wegman and Kranck, 1931). Nevertheless, it cannot be forgotten that the recognition of granitization processes is a result of their studies, and that their theory, although based on hypothetical premises, has been elaborated in a very logical manner.

Hypothesis of selective refusion

To Sederholm is due the theory of regional re-solution. As a result of his extensive studies of the Finnish Precambrian rocks, he developed the hypothesis that there could be regions where erosion has proceeded for a long enough time to attain the depth at which the granitic magma was made by the re-solution of the already solidified deeper parts of the earth's crust. This process of sub-crustal melting, Sederholm calls "anatexis", and if it followed by movement of the newly-formed magma, the resurrection is called "palingenesis".

The product of anatexis should not, according to Buddington, be called a primary magma. This author (Buddington, 1943) would restrict the definition of a primary granite more closely:

> "The granite magma, derived from melting of the sial, may, by definition, be called primary only if part of the sial were primordial." (p. 139).

However, without necessarily adopting Van Hise's idea of the "metamorphic cycle" most geologists would certainly concede that the product of the consolidation of fused sediments is a granite, if the composition is appropriate. As such, anatexis does not properly belong to the processes of granitization as this term is commonly understood.

## Hypothesis of granitization without magma

The supporters of this hypothesis - the transformists - reject the necessity of a magma in the production of granitic rocks. Changes in the older rocks are effected by "emanations" without defining any source. The process consists in addition of certain substances, mostly lime and soda, to the rocks becoming granitized, with concomittant expulsion from the rocks of the constituents not needed for the forming granite. The excess material, consisting mostly of basic elements, (Fe, Mg, etc.) becomes fixed in the "basic fronts of granitization". (Reynolds, 1947).

The transformation of a sediment or of a lava series into a granitic rock thus requires a great transfer of material. In order to become a granite, a sediment must lose at least half of its content of magnesium and iron oxides in addition to some alumina. These are replaced by lighter material, mostly lime and soda. These quantities become more considerable if the rocks being granitized have a more basic composition, for instance, that of an intermediate lava. The difficulty attached to this transfer lies in the necessary movement that must be postulated. A visualized by Reynolds, the heavier and less mobile constituents (Fe, Mg) are displaced outward and upward by the lighter ones.

Another difficulty of this hypothesis lies in finding the mode of the migration of the emanations. If they travel as compounds, what has become of the other ion? In order to avoid this difficulty, transformists (Perrin and Roubault, 1939, Reynolds, 1947) have proposed a theory of ionic movement. Both the material brought in and the material expelled travel through the rock by means of diffusion of ions. The diffusion takes place mostly through defective crystal lattices, and along the boundaries of closely-packed grains.

Diffusion from magma to solid rock has been quite conclusively proved by Jones (1930) in his studies of quartzitic inclusions in gabbro near Sudbury. However, could ions diffuse from a solid to a solid, for great distances at a temperature much below the melting point of the silicates? This question has not yet been finally answered.

Solid diffusion may be an important factor in granitization, but, before its role is universally accepted, certain features found in granites require explanation. In particular, there is need to explain the presence of normally-zoned plagioclase crystals in granites of all ages. How could solid diffusion be responsible for the huge masses of Precambrian granites, while being, at the same time, incapable of bringing small crystals to a uniform composition?

## Classification of gneisses

It seems probable that, as is often the case in controversies, the teachings of each school are applicable in different cases. As remarked by Read, "there may be granites and granites". The position of each school is aptly exposed in the following quotation from Buddington (1948, p. 21):-

> "I have been unable to find any criteria which both "Magmatists" on the one hand and "Transformists" on the other hand would agree to as decisive tests to descriminate between the validity of application of the rival hypotheses to a given case. Each would, however, agree that both the hypothesis of granite from magma, and granite by granitization are valid concepts. The problem then is the actual relative quantitative significance of each process in the development of granite in general or in particular".

Buddington himself believes that less than 15 per cent of the granites of the Northwest Adirondacks are the product of granitization and migmatization. Most American geologists would probably accept a figure close to this estimate.

Raguin's subdivisions of granites is believed to be quite to the point (Raguin, 1939). He separates the granitic rocks into two groups: 1) GRANITES DIFFUS, heterogeneous, schistose granites in large masses within the para-schists that appear to have limited their spreading; 2) GRANITES EN MASSIFS CIRCONSCRITS, homogeneous masses. The granites of the first group result from anatexis and they represent the ultimate limit of metamorphism in a rock series. The granites of the second group are the product of consolidation of a granitic magma.

The above discussion is summarized in the following classification. This table is drawn on the assumption that the different hypotheses are applicable in different bodies, an assumption that the writer does not feel qualified to either prove or disprove.

1 - Granites, orthogneisses
  a) protoclastic
  b) cataclastic
2 - Granites, composite gneisses
  a) lit-par-lit injections
  b) migmatites
  c) agmatites
3 - Granites, not from magma.

## Origin of the northern granite gneiss

The northern granite of the Olga-Goéland Lake area is believed to be, following this classification, partly protoclastic and partly lit-par-lit injection gneiss. This opinion is based on the following facts:

1) As noted above, the general composition of the Mattagami gneiss, away from inclusions, is very regular. It possesses the same mineral association, in approximately the same proportions, as the southern granite which appears to be without doubt an intrusive body. The variations in the gneiss are no greater than in the other granite and certainly do not exceed the limits of heterogeneity that may be expected within such a large mass.

2) Well-preserved inclusions of rocks belonging to the volcanic-sedimentary series and to the basic series are found in the same exposure. Their presence is not easily explained by any granitization hypothesis.

3) The gneiss is cut by dykes and apophyses that have a composition and a texture similar to it.

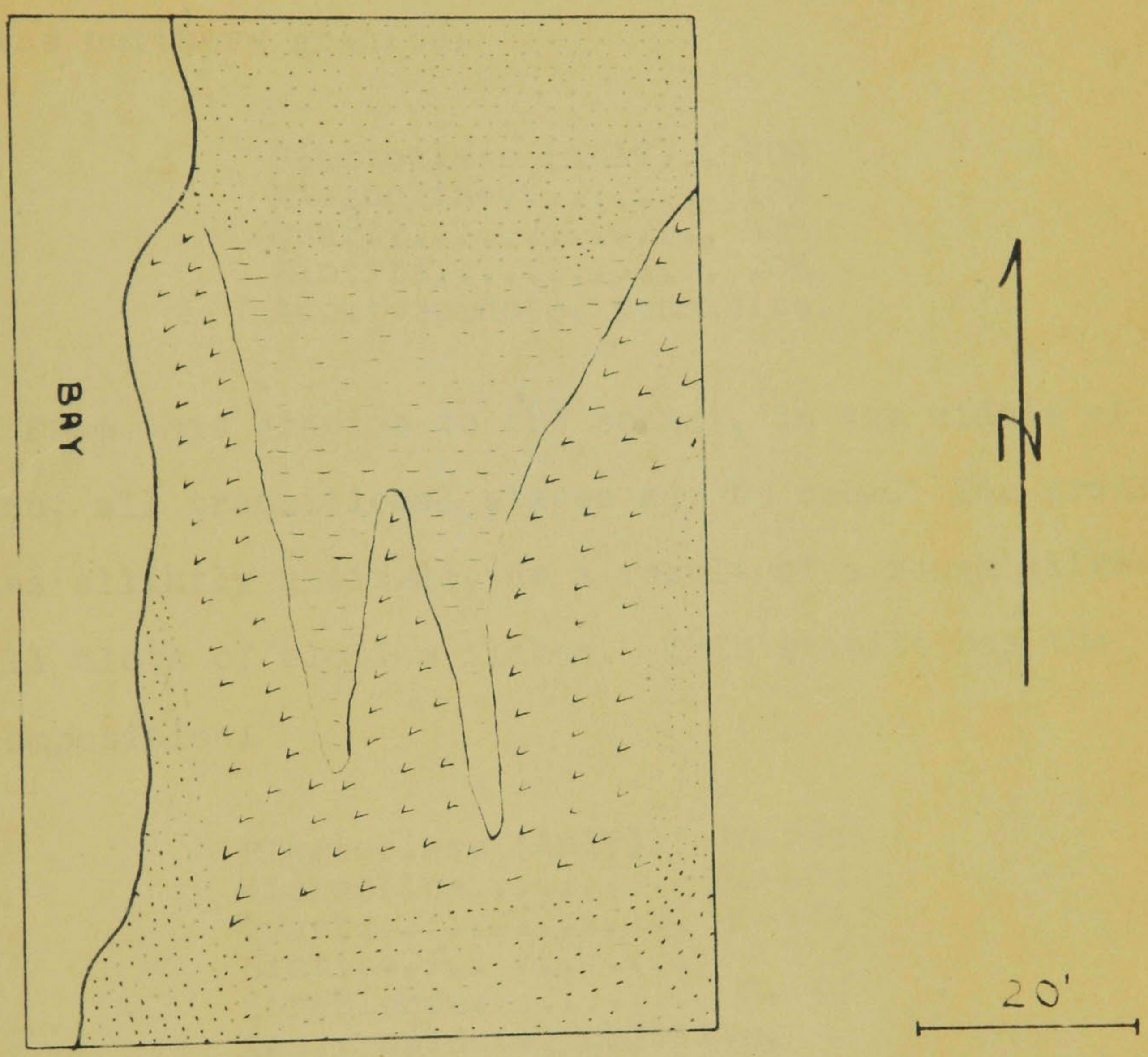
4) The common presence of normally-zoned plagioclase crystals is difficult to explain unless they were formed through the solidification of a liquid mass.

5) The angular inclusions, with sharp contacts, are not consistant with any hypothesis postulating hydrothermal or solid transformation processes.

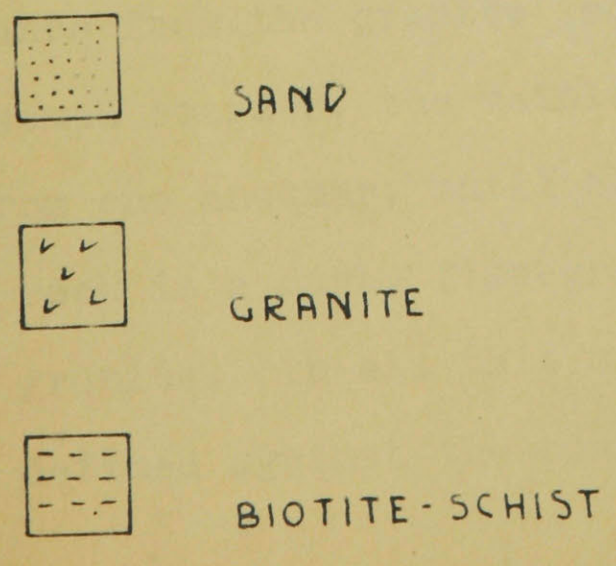
6) No evidence of anything that even remotedly resembles a basic front has been seen in the map-area.

7) Several gradational contacts between granite and schists have been observed throughout the map-area. The best one will now be described. It is exposed on the south shore of Canet river where it enters Mattagami lake. At this locality, a triangular band of biotite schist, partly surrounded by granite, is exposed over a length of about 75 feet, with a maximum width of 25 feet along the base of the triangle. (Fig. 8). Specimens were taken systematically across the band following two lines, 30 feet apart, transverse to the schistosity of the inclusion.

FIG. 8




INCLUSION OF BIOTITE - SCHIST IN GRANITE



On both sides of the schist, and opposite the tip of the triangle, the intrusive has a mineral assemblage similar to that of the northern granite:

| | |
|---|---|
| Plagioclase (An17).. | 40% |
| Microcline.......... | 10% |
| Quartz.............. | 40% |
| Biotite............. | 10% |
| Acc.: epidote, penninite. | |

From this granite to the schist, in the middle of the inclusion, all transitional stages may be seen. The granite first becomes slightly gneissic, as a result of a rough alignment of small clots of biotite flakes. This granite has the following composition:

| | |
|---|---|
| Plagioclase (An19).. | 10-25% |
| Microcline.......... | 20-40% |
| Quartz.............. | 30-40% |
| Biotite............. | 15% |
| Hornblende.......... | 0- 5% |
| Acc.: epidote, chlorite, apatite, hematite. | |

Farther in, narrow bands of schist, 1/8 to 1/32 of an inch thick, give the granite a coarser gneissic appearance. As the distance from the granite increases, the intruding material becomes scarcer, the veinlets become more widely separated from one another, until about ten feet inside the schist, the rock is a dark, fine-grained schist that shows no evidence of granite. In all this zone, the layers of schist are sharply defined against the coarser intrusive material.

Composition of the alternating bands:

Light-colored

| | |
|---|---|
| Plagioclase (albite)..... | 10-15% |
| Microcline.............. | 30% |
| Quartz.................. | 45-50% |

Acc.: biotite, epidote.

Dark bands

| | |
|---|---|
| Quartz......... | 40% |
| Biotite........ | 20% |
| Epidote........ | 30% |

Composition of the schist in the centre of inclusion:

| | |
|---|---|
| Hornblende......... | 40% |
| Biotite............ | 20% |
| Microcline......... | 15% |
| Plagioclase (An35). | 10% |
| Quartz............. | 15% |

Acc.: epidote, apatite.

This schist is characterized by alternating layers of hornblende- and biotite- rich material.

A significant phenomenon in this zone is the increase of microcline nearer to the intruded schist. A similar increase in the contact zone of the Olga quartz-diorite has already been discussed. There is, however, south of Canet river, definite evidence that the gneiss has been intruded by dykes of a younger granite rich in microcline. It may be that part of the noted additions of potash are to be related to this intrusive.

Testimony of the hydrothermal changes that affected both the granite and schist is abundant. Epidote is found in all the thin-sections studied. In one case, it clouds all the minerals. Quartz veins are numerous. Some traverse without a break the contact between the two rock types.

It is quite clear that the exposure just described contains two types of rocks: an older schist and some granitic material. This fluid, through consolidation, gave a rock which: 1) contains zoned crystals of plagioclase; 2) maintains its identity even in narrow stringers; 3) becomes strongly gneissic only in those places where the intruded schist was more thoroughly split up, namely on the sides and away from the tip of the inclusion.

From these facts, it is concluded that the fluid that injected the schist at that locality was not of hydrotermal, but of magmatic nature. This conclusion is evidently applicable to the whole of the northern granite. The physical properties of the intruded rocks are believed to have been the main factor in determining the character of the resulting composite gneiss: Massive, jointed rocks were partly preserved as more or less angular inclusions; more fissile rocks were intruded along closely-spaced bedding planes, thus producing a fine- to medium-grained gneiss.

## RELATIONS BETWEEN THE SOUTHERN AND THE NORTHERN GRANITES

The above discussion shows not only that the northern granitic gneiss is a true granite, but also that it is very similar in composition and texture to the southern (Olga) granitic body. The main difference between the two masses results from the commonly gneissic structure and the more contaminated state of the northern granite.

This difference loses much of its significance if these two bodies are compared with the other batholiths that have been described in the Waswanipi-Chibougamau belt. Indeed, all the granites from Madeleine to Chibougamau lakes, are characterized by the absence of potash, or at least the predominance of soda (Shaw 1939, MacKenzie 1936, Mawdsley and Norman 1935, Norman 1937, Tolman 1931).

The universal presence of acidic plagioclase in the granitic rocks may be diagnostic of magmatic relationships. It is to be wondered whether these isolated masses do not represent cupolas of a single extensive batholith in which the volcanic belts would form huge roof-pendants.

If this hypothesis be true, then the difference between the northern granite of the region under study and the southern granite would simply reflect a difference in the original elevations of the "cupolas". Difference of erosion cannot be considered as a possible factor since both masses have been planed down to about the same level.

The features observed in the northern "cupola" would be those found near the top of the intrusive where the magma is still in contact with, and is contaminated by, the invaded rocks. The general absence of inclusions within the southern granite would mean that this "cupola" has reached a higher level than the northern one. Its present eroded surface represents a deeper level of the magma chamber where, except along the sides, remnants of invaded rocks are not present.

## Goéland Granite

### Description

Numerous exposures of a pink granite are found along the shores of Goéland lake and on some of the islands in the lake. This granite thus appears to form a batholith about 10 miles in diameter which would underlie most of the lake. In addition, two small bodies of similar rock crop out east of the lake, within the wide area of andesitic lavas. The granitic rocks exposed in the extreme southeast corner of the map-area probably belong to the same intrusive.

The Goéland granite is quite different from the other types described above. Besides its pink color, it is characterized by an equigranular texture, a massive appearance, and regular composition: pink feldspar, quartz, hornblende, and minor biotite. Its grain size is medium to coarse. In many places, weathered surfaces have a porphyritic appearance, as a result of large quartz grains standing out against the leached feldspars.

Petrography

The mineral composition of this granite, as determined in thin-sections, is:

| | |
|---|---|
| Plagioclase......... | 65-80% |
| Microcline.......... | 5-10% |
| Quartz.............. | 10-15% |
| Hornblende.......... | 5- 8% |
| Biotite.......... | Acc. - 2% |

Acc.: calcite, sphene,
apatite, epidote,
chlorite, hematite,
magnetite, sericite.

Apatite is probably the earliest mineral in the granite. It occurs as small, euhedral grains which are found as inclusions in both plagioclase and hornblende.

Generally the plagioclase grains are almost perfectly euhedral. Zoning of the grains is universally present. In the fresher specimens, this zoning is manifested by shells that show different extinction angles, whereas, in the more altered rock, zoning is manifested by the presence of concentric lines of alteration. The composition of the core is about An24-28, while that of the rim is An19-20.

Hornblende also appears to be an early mineral of the rock. Its long flakes lie without common orientation, and would be well-defined if they were not partly eaten up by alteration products such as epidote and biotite.

A few occurrences of myrmekitic intergrowths of quartz and microcline were observed, and they are taken as evidence that both minerals belong to the same stage of crystallization. Microcline occurs as grains less than one mm. and it is always interstitial. Some quartz shows similar characteristics, but in many places, the rock contains large clots of clear quartz. These clots measure up to one centimeter in diameter, and their quartz is only slightly broken.

Secondary alteration is manifested by the partial saussuritization of the plagioclase and local transformation of hornblende into biotite and epidote. The magnetite may be a released product of the latter process.

Titanite is found in every specimen. The grains are generally too small to be identified even with a hand lens, although occasionally perfectly euhedral (prismatic) crystals were observed that measure up to 3 mm. in length.

Cavities are common in this granite. They are from less than one-quarter of one inch to over one foot in diameter. Their walls are rough and most of them are partly filled with substance such as quartz, calcite, epidote, hematite. The largest one observed (about 13 inches) was lined almost all around by a coating of hematite, about one mm. thick, overlain by a layer, 5 mm. thick, consisting of glassy quartz crystals, that terminate outward from the wall with good crystal faces. Clots of massive, brownish calcite, the size of a fist, are attached to this surface, in a few places. More than half of this cavity is empty.

Besides occurring in the cavities, epidote, and jasper often form veins, several inches thick. The walls of the epidote veins are commonly sharp. Some hematite veins have sharp walls, although in many places, hematite has penetrated a short distance into the granite and has given it a deep-red color.

The Goéland granite gets its most distinctive character from its texture. Its euhedral crystals of plagioclase and its large rounded clots of quartz may be seen on all the exposed parts of this body. Except in the rocks exposed in the southeast corner, gneissic structure resulting from alignment of dark minerals is entirely absent. On a few shore exposures, however, a faint planar structure is revealed from the disposition of the quartz grains. Granulation is rare and it is restricted to the borders of a few quartz grains. The coarse grain size is believed to result from slow consolidation aided by the presence of abundant volatiles.

## Mode of intrusion

A glance at the map accompanying this thesis, reveals that the invaded volcanic and sedimentary rocks dip into the batholith along its western, northern, and northeastern border.

If the structural interpretation given above is correct, the belt of andesitic lavas with their sedimentary intercalations belong to an eastward-plunging synclinal structure. The present dips in this belt around the Goéland batholith would thus result from the folding of the pre-intrusive rocks.

The batholith, with its planar structure parallel to the bedding and the schistosity of the older rocks, appears to have come up in the trough of the syncline without materially affecting the existing structure. It has been emplaced after the folding of the lavas or at least at a time when these rocks had acquired their broad structural character.

The doubling of thickness observed in the sedimentary belt south of Laurent bay may be a result of this intrusion. As indicated on the map, a drag-fold has been postulated to explain the greater thickness of the belt in this locality. This assumption is based on the presence on the west shore of the bay, of small drag-folds that plunge steeply northward and have an orientation similar to the larger postulated one. Since the planar structure observed in the nearby exposures of granite trends in a northwesterly direction, it is considered probable that a push in that direction by the granite, could cause the drag-folding in the sedimentary rocks.

Age of the Goéland granite

Offshoots of this batholith are found in the volcanic-sedimentary belt on the west shore of Goéland lake and two small plugs of similar rocks pierce the lavas on the east side of the lake. These satellitic bodies prove conclusively that the granite is younger than the lavas and the clastic rocks.

This is the only definite age relationship known concerning the Goéland granite. Petrographically, however, the rock is quite similar to the hornblende granite mapped by Claveau (1948) in the Waswanipi River Area (West sheet). This hornblende granite, according to Claveau, grades westward into a quartz syenite that he studied during the summer 1946, in the Iserhoff River Area, and which is younger than the "Olga quartz-diorite".

Geological mapping yet to be done, is expected to throw some light on this relationship. If the above assumptions are correct, they would indicate that the Goéland batholith was injected after the consolidation of the other large granitic bodies of the region under study.

## DYKES

Numerous dykes of various composition and different ages have been recorded throughout the map-area. Most of them, because of their areal distribution, mineral composition, and texture, may be readily correlated with one of the main intrusive masses described above, namely: the diorite-syenite sequence, the southern granite, and the northern granite. The remainder of these satellitic bodies, believed to be younger in age, consist mostly of the following types:

Lamprophyre,
Pink granite,
Diabase,
Amphibolite and diorite.

Lamprophyre dykes

The term lamprophyre is used to designate a group of fine-grained, dark rocks that are found in many localities. These rocks consist essentially of hornblende and plagioclase, although the proportions of each mineral are somewhat variable: hornblende is from 50% to 80%, while a plagioclase that is believed to be original, forms 5% to 25% of the rock. Minor constituents are: fresh albite, quartz, biotite, chlorite, magnetite, apatite, leucoxene, hematite.

Hornblende is of the ordinary green-pleochroic variety. It forms a felted mass of small flakes that have no orientation at all. In some of the thin-sections, this mass appears to have partly recrystallized. The rock contains ragged masses of hornblende, up to 2 mm. in diameter, full of small flakes that have preserved their own crystal boundaries. The development of the hornblende "envelopes" may have occurred in the magmatic stage, since none of them contain any inclusions of feldspar.

The plagioclase is always anhedral. It occurs as brownish masses partly surrounded by a rim of fresh albite. In one thin-section, a plagioclase, believed to be original, was identified as An20. Albite is undoubtedly a late mineral since in addition to surrounding the plagioclase grains, it forms veinlets associated with quartz.

The lamprophyres cut the dioritic and granitic intrusive masses. Around Mattagami lake, they intrude a grey granite dyke related to the northern granite, and they are in turn cut by stringers of pink granite.

Pink granite dykes

Occurrences of pink granite are mostly concentrated around the east end of Mattagami lake. Generally the granite forms well-defined dykes and stringers which cut the northern granite and, as mentioned above, also intrude dykes of the lamprophyre group. In a few cases the borders of the granite could not be observed, but similarity in composition was used to classify the intrusives.

Besides their pink color, these rocks are characterized by a low percentage of dark minerals, and by a high proportion of potassic-feldspar. Their composition is:

| | |
|---|---|
| Microcline............. | 30-50% |
| Plagioclase (An13-15).. | 13-30% |
| Quartz................. | 30-40% |
| Biotite................ | 0- 5% |
| Acc.: epidote, magnetite, sericite, chlorite. | |

The plagioclase crystals, as in the main granitic masses, are generally subhedral. The microcline grains also possess partial crystal boundaries. Both feldspar, however, are in places, extensively crushed in contrast with the quartz whose large grains show only a slight undulose extinction.

These dykes are comparable in composition, to the large body of pink granite exposed in the centre of the Iserhoff River Area (Claveau, 1946). Accurate correlation between these granites is evidently impossible in the present state of knowledge. Nevertheless, it is considered likely that they all belong to the same intrusive cycle and that they represent the end stage in the consolidation of the huge batholith postulated at the end of the discussion on the northern granite.

Diabase dyke

A small exposure of a grey, brown-weathering diabase was seen on the top of the dioritic hill located one mile north of Mattagami lake, and 3000 feet east of the western border of the map-area. This exposure only measures a few square feet and it is completely isolated from the diorite. It was thus impossible to ascertain the dimensions and shape of the mass, or its relations to the diorite.

The rock has medium grain and a well-developed ophitic texture. It consists essentially of diopside (65%) and plagioclase, An40 (30%). The diopside is partly altered to tremolite, and some of the plagioclase is replaced by late quartz.

Because the field relationships are too scanty, this small exposure has not been shown on the accompanying map. However, from its composition and texture, the rock might be interpreted as a Keweenawan dyke.

Amphibolite and diorite dykes

The Goéland batholith is in many places cut by basic dykes, most of which strike in the northeast quadrant. The dykes are black, medium-grained rocks of equigranular texture. As a typical representative, a thin-section was studied from a 15-foot dyke exposed on the small island immediately west of the largest island in Goéland lake.

This rock consists of remnants of green hornblende crystals within a mass of greenish-white tremolite. This latter mineral occurs as long thin prisms or as irregular clots that correspond in shape to the altered portions of the hornblende grains. Accessory minerals are: magnetite and calcite. Magnetite is found either as dust or as trains of small grains distributed in the tremolite. Calcite commonly forms ragged masses between the amphibole crystals. It is also found within the tremolite, where it forms intergrowths along the cleavage planes, and radiating structures.

Hornblende, because of its well-shaped grains, is believed to be the oldest mineral. The basic composition of the rock suggests that it contained pyroxene, but no evidence of the former presence of pyroxene has been observed. Hornblende has altered to tremolite. Such a transformation is suggested not only by the contact relationships between the two amphiboles, but also by the distribution of magnetite. Indeed magnetite always occurs within the tremolite and may well represent the iron released during the postulated alteration of hornblende into tremolite.

A similar dyke on the same island has been brecciated after its consolidation and injected by less basic material (Plate IX). This "composite" dyke has a width of 30 feet and its walls are sharp against the granite. The younger intrusive has a dioritic composition: it consists essentially of plagioclase and hornblende in equal quantities, with small amounts of calcite, magnetite, chlorite, biotite, and apatite.

The plagioclase is An15 and slightly clouded. The grains are generally subhedral and a few of them are partly replaced by calcite. Hornblende of the green-pleochroic variety is also subhedral. It is very fresh, except for minor alteration to biotite and chlorite.

## PLEISTOCENE DEPOSITS

As far as could be observed the Pleistocene glaciers removed all the soils and subsoils, in the region under study. Erosion of fresh rock, however, appears to have been slight. Glacial striae and polished surfaces are the only visible results of the rock denudation accomplished by the glaciers. On exposures of every rock type in the area, smooth surfaces may be seen in which narrow and shallow striae are indented. Many granitic exposures have a highly polished, mirror-like surface which post-glacial weathering has left practically intact. Glacial fluting and roches-moutonnées are very rare. (Plate II-A).

The most conspicuous effect of glaciation was the deposition of an extensive blanket of both glacial till and outwash deposits. These, by filling the depressions, have not only disturbed the drainage but have given the area its plain-like appearance. The deposits fall into two main categories: glacially-transported sand and boulders, and lacustrine muds and silts. Of these, the muds are by far the most important.

The muds are generally massive and sandy, although well-varved 'clays' are seen occasionally. In the varved sediments, the summer layers are generally about half and inch, the winter ones, one quarter of and inch, thick. The 'clays' seldom exceed 30 feet in thickness, and the elevation of their top stands at approximately 800 feet above sea-level as determined with an aneroid barometer from the level of Olga and Mattagami lakes as reference points. They rest on sands and gravels and, in a few restricted places, they are overlain by a coating of glacial till. The thickness of the till varies from about two feet, on the east shore of Olga lake, to at least 30 feet on the Waswanipi river, nine miles to the east.

These lacustrine deposits are part of the 'Clay Belt', an area of 68000 square miles in northern Ontario and Quebec. The 'clay' accumulated, during the retreat of the glaciers, in a large lake impounded between the Height-of-land on the south, and the front of the waning Labrador ice-sheet, on the north. The eastern boundary of the lake, as now established, passes, in a northeasterly direction, at about 80 miles east of Goéland lake (Dresser and Denis, 1944, Fig. 2, p. 26).

No stratification has been observed in the sands and boulders. These deposits are consequently believed to consist exclusively of glacially-transported debris. Field observations supplemented by careful studies of aerial photographs failed to disclose the presence of any of the features attributable to fluvo-glacial deposition, such as eskers, crevasse fillings, outwash plains, etc. . The characteristic appearance of the deposits is as small hills of no particular shape, erratically distributed mostly through the northern half of the map. Northeast of Goéland lake, many such hills are grouped in a way which suggests that they possibly represent a recessional moraine. Many morainic hills are believed to have a solid rock core because of the fact that all the rocky hills of the region are partly covered by such deposits.

Trains of more or less rounded boulders have been noted on the flanks of many hills. They consist generally of only one type of rock and, from the writer's observations, they may be taken, in this region, as an indication that rock of this type is exposed not very far northward. In fact, the presence of a sedimentary belt on the northeast shore of Olga lake, was revealed by numerous boulders, the largest of which was three feet in diameter. These boulders lie at less than 1000 feet south of the southernmost exposure of the sedimentary rocks.

Numerous boulders of fossiliferous rocks were observed over a distance of one-half a mile along the northeast shore of the middle bay, on the east side of Olga lake. The boulders are of dolomitic limestone and are generally sub-rounded, except for a slab, devoid of fossils, which measures 4'x3'x3". From a rapid inspection of the specimens collected, Professor T.H. Clark, of McGill University, believes (oral communication) the rocks to be Ordovician or Silurian in age.

The local distribution of the boulders and the preservation of the thin slab of such a dimension, created the impression that the Palaeozoic rocks from which the boulders were derived should occur in place not far northward, probably less than two miles from the beach. Unfortunately the region to the north, in the direction of the glacial striae, is completely masked by overburden.

Fossiliferous boulders have been described by other writers at the same latitude and even farther south. The region described in the reports listed below extends from longitude 76°50' to 77°45'; from latitude 49°25' to 50°00'N. and measures over 2500 square miles (Auger 1942, Bancroft 1912, Béland 1945, Longley 1943).

During the summer 1948, two prospectors, on a reconnaissance trip for the Dominion Gulf Exploration Company, discovered an exposure of fossiliferous limestone, on the south shore of Waswanipi lake. The following details have been kindly supplied by Dr. Knowland, chief geologist of the Company.

The exposure is about 75' x 50' in areal extent, and is nine feet high. The limestone is brownish grey weathering and buff grey on a fresh surface. It is fairly pure-looking with individual beds up to 5 inches thick. The strata are practically horizontal. No time was taken to secure a representative collection, but from the specimens brought back, Dr. Fritz, of the Royal Ontario Museum, was able to identify positively one genus: Bryozoan Heterotrypa, which suggests middle Ordovician age. From a boulder collected by the same party, six miles northwest of this exposure, Dr. Fritz identified the Gastropod Maclurites which also suggests a similar age.

This discovery is of great importance, revealing as it does, the presence of Palaeozoic rocks almost exactly at the centre of an area, having a diameter of nearly 400 miles, in which no rocks younger than Precambrian had heretofore been found. It strenghtens the possibility that the fossiliferous boulders seen in the surrounding regions may be of local origin. It now looks more probable than ever before that Ordovician seas extended continuously across the area between the St-Lawrence river and James Bay.

## ECONOMIC GEOLOGY

Most of the northern half of the map-area, because of extensive overburden, offers little economic attraction to ordinary methods of prospecting. Furthermore, the underlying rocks consist generally of intrusive masses in which no trace of mineralization has been found.

The large tract underlain by the rocks of the volcanic-sedimentary series has been repeatedly visited, without success, in the last few years. Nevertheless, all the shear zones are somewhat mineralized and the following localities deserve at least a brief mention.

1) The sedimentary rocks at Red Chute.

2) The andesitic rocks on the north and south side of the point opposite the east end of the largest island in Olga lake.

3) The trachytic flows on a small island in the Waswanipi river, just below the bend where the river changes from a north to a south course.

4) A complex of sedimentary and volcanic rocks, with numerous sills of porphyry, exposed west of Goéland lake, half a mile north of Laurent bay, and 1500 feet inland. A strong magnetic anomaly was noted in this locality.

5) A sheared porphyry sill within sedimentary rocks north of Goéland lake, two and half miles north of Waswanipi river.

In all these localities, the rocks are intensely crumpled along wide shear zones. In addition to hydrothermal veins of quartz and calcite, pyrite is abundant in these zones and chalcopyrite was noted in a few places. A total of ten grab-samples taken from these localities have been analyzed in the Laboratories of the Quebec Department of Mines. No gold has been found, but most of the specimens contain some silver (up to 0.040 oz/ton) and traces of copper.

Generally, however, the region possesses many of the conditions that are found in other areas of Western Quebec where valuable ore deposits have been found. These favorable conditions are:

1) Extensive shearing of the volcanic-sedimentary belt;

2) Granitic intrusives on either side of the belt;

3) Evidence of hydrothermal activity within each of the shear zones;

4) Abundance of pyrite mineralization;

5) Presence of small silver and copper values.

To these facts must be added the possibility of finding other metals like zinc, lead, nickel, etc., whose determination was not sought for in the analyses. In any case, a comparison between the intrusive masses exposed in the different areas of Western Quebec especially with respect to their minor elements, might prove of value in judging the economic potentialities of each area.

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# P L A T E S

**Plate I** - A - Upper part of Red Chute, outlet of Olga lake.
B - Lower part of Red Chute.

**Plate II** - A - Glacial fluting, east shore of Olga lake.
B - Photomicrograph of albite porphyroblast in andesitic lava, west shore of Olga lake. (x30).

**Plate III** - A - Photomicrograph of granoblastic texture in andesitic lava found as inclusion in granite, north-centre of the map-area. (x30).
B - Photomicrograph of biotite-schist, Red Chute. (x60).

**Plate IV** - A - Photomicrograph of recrystallized hornblende grain of clastic origin, west shore of Olga lake. (x60).
B - Narrow cherty layer, drag-folded and broken into fragments by a cross-schistosity, west shore of Olga lake.

**Plate V** - A - Photomicrograph of garnet in light-colored biotite-schist of sedimentary origin, south shore of Olga lake (x60).
B - Crumpled sedimentary rocks, closely injected by stringers of granitic material, south shore of Olga lake.

**Plate VI** - A - Injection-complex having a sedimentary appearance, south shore of Olga lake.
B - Pillow-like structures formed by granitic material injected along intersecting joints.

**Plate VII** - A - Thinly-bedded sedimentary rocks, southwest shore of Laurent bay, Goéland lake.
B - "Pseudo-conglomerate", broken lenses of chert and micaceous quartzite, southwest shore of Laurent bay.

**Plate VIII** - A - Conglomerate of the Mattagami Series, north shore of Mattagami lake.
B - Photomicrograph of porphyritic trachyte, south shore of Waswanipi river where it enters Olga lake. (x30).

Plate IX - "Composite dyke" (diorite with fragments of amphibolite) cutting the Goéland batholith, small island immediately west of the largest one in Goéland lake.

The wrtier is indebted to Dr. J. Claveau, of the Quebec Department of Mines, for the following photographs:

Plates II-A; IV-B; V-B; VI-B; VII-A.

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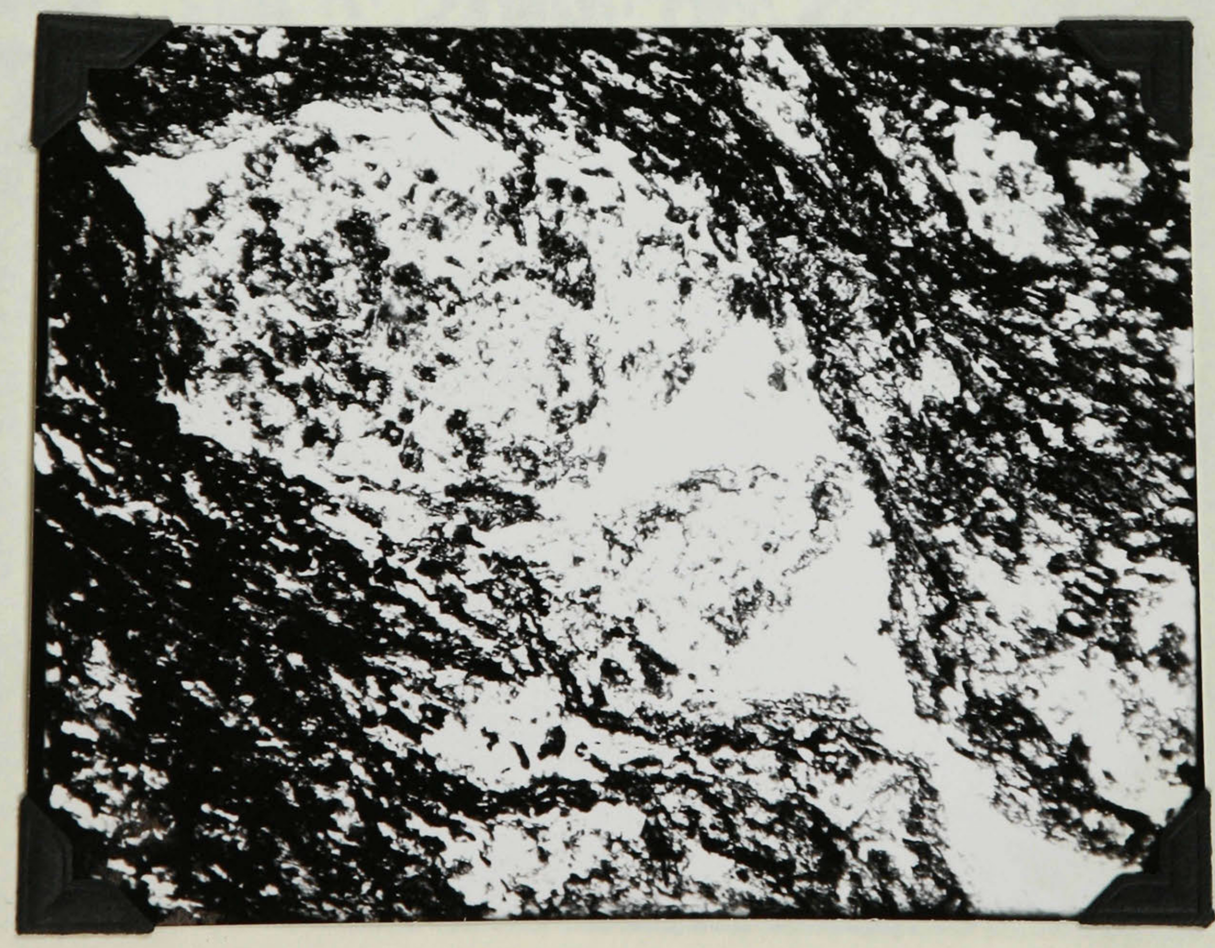
Plate I

A. - Upper part of Red Chute, outlet of Olga lake.

B. - Lower part of Red Chute.

Plate II

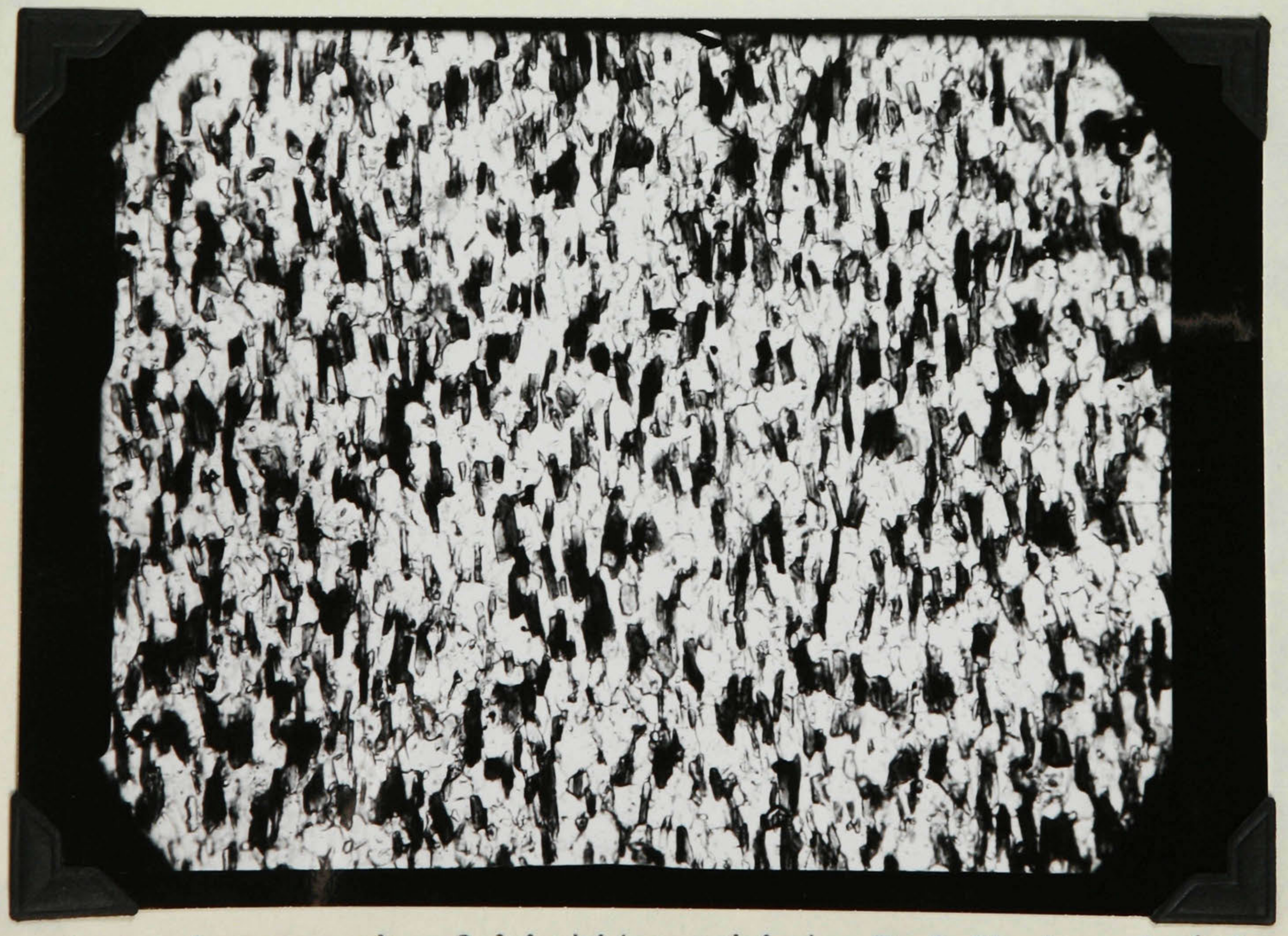
A. - Glacial fluting, east shore of Olga lake.



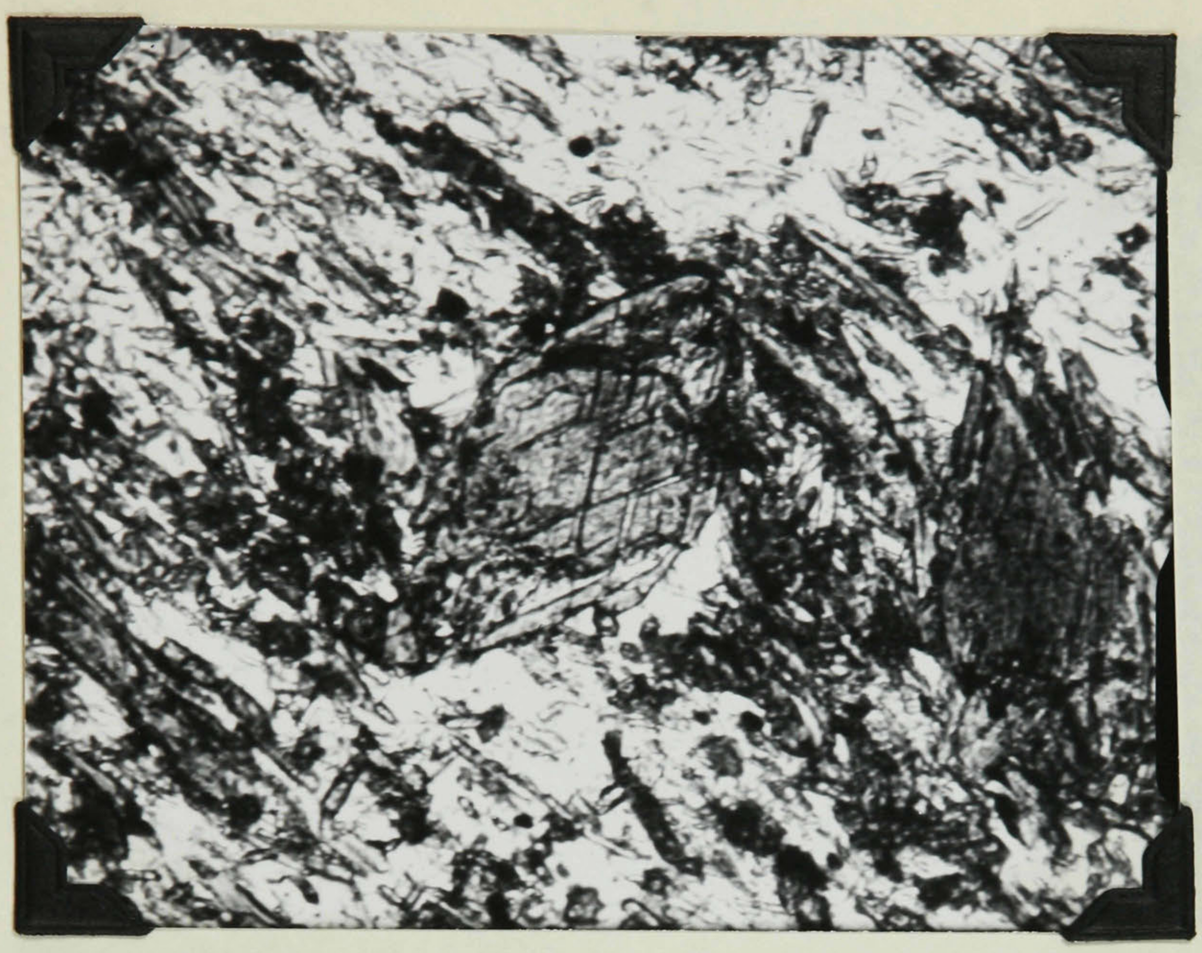
B. - Photomicrograph of albite porphyroblast in andesitic lava, west shore of Olga lake. (x30).

Plate III

A. - Photomicrograph of granoblastic texture in andesitic lava found as inclusion in granite, north-centre of the map-area. (x30).



B. - Photomicrograph of biotite-schist, Red Chute. (x60).



A. - Photomicrograph of recrystallized hornblende grain of clastic origin, west shore of Olga lake. (x60).


B. - Narrow cherty layer, drag-folded and broken into fragments by a cross-schistosity, west shore of Olga lake.

Plate V

A. - Photomicrograph of garnet in light-colored biotite-schist of sedimentary origin, south shore of Olga lake. (x30)

B. - Crumpled sedimentary rocks, closely injected by stringers of granitic material, south shore of Olga lake.

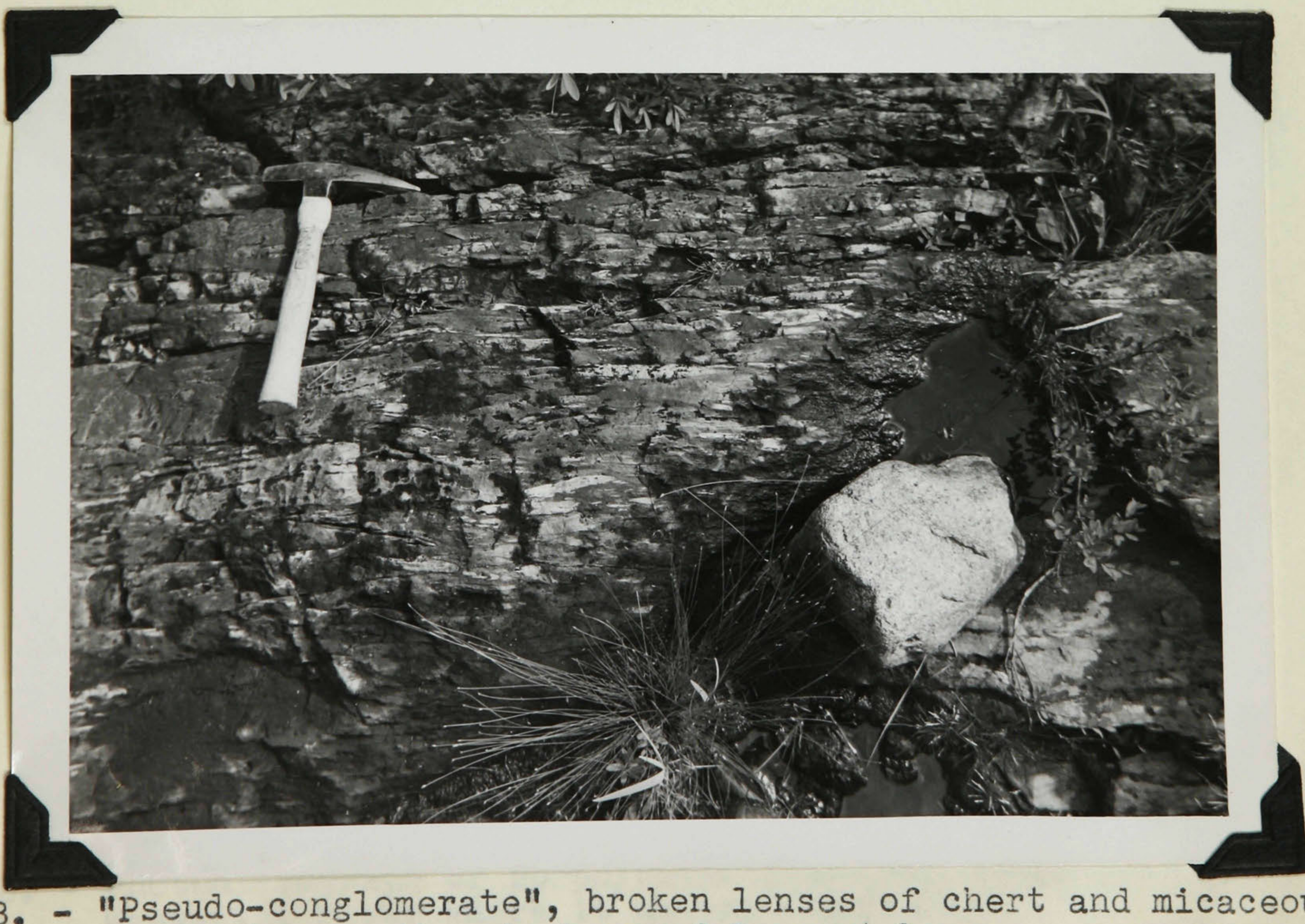
Plate VI

A. - Injection-complex having a sedimentary appearance, south shore of Olga lake.

B. - Pillow-like structures formed by granitic material injected along intersecting joints.

Plate VII

A. - Thinly-bedded sedimentary rocks, southwest shore of Laurent bay, Goéland lake.



B. - "Pseudo-conglomerate", broken lenses of chert and micaceous quartzite, southwest shore of Laurent bay.

Plate VIII

A. - Conglomerate of the Mattagami Series, north shore of Mattagami lake.

B. - Photomicrograph of porphyritic trachyte, south shore of Waswanipi river where it enters Olga lake. (x30)

Plate IX

"Composite dyke" (Diorite with fragments of amphibolite) cutting the Goéland batholith, small island immediately west of the largest one in Goéland lake.

# MAP No. I

CENOZOIC
QUATERNARY
Clayey sand, gravel, some pure sand
PRECAMBRIAN
POST-KEEWATIN-TYPE INTRUSIVES
4 Pink, massive microcline granite
3 Hornblende-biotite granite
2 Oligoclase-biotite granite (2a) generally gneissic, partly contaminated (2b) generally massive (Olga quartz-diorite)
1 Diorite-syenite sequence
KEEWATIN-TYPE ROCKS
K5 Schistose granite porphyry
K4 Fine-to medium-grained gabbro
K3 Fine-grained schistose trachytes often porphyritic and fragmental, few beds of tuff
K2 Recrystallized greywacke, impure quartzite, chert (Probably more than one age)
K1 Schistose hornblende andesites, commonly pillowed, few beds of tuff (probably more than one age)
Strike and dip of bedding: (a) inclined, attitude not determined (b) inclined, normal position (c) overturned
Strike and dip of schistosity and gneissic structure: (a) vertical (b) inclined (c) not determined
Direction and plunge of lineation
Joint
Glacial striae
Shear zone
Fault
Individual outcrop observed
Outline of main ridges
Geological boundaries: (a) approximate (b) inferred from geophysical data
Prominent scarp
Limit of upper navigability at low water (b) rapid (c) portage
SCALE IN MILES
OLGA-GOÉLAND
LAKE AREA
ABITIBI-EAST
Geology by
P.E. IMBAULT 1947-1948
L. MATAGAMI
Opawica River
MORAINIC HILLS
FREDERIC CREEK
L. MAICASAGI
MAX NARROWS
R. WASWANIPI
L. OLGA
LAC AU GOÉLAND
LAURENT BAY
711
712
713
611
612
613