THE GEOLOGY OF THE CAPISISIT-INCONNU LAKE AREA

ABITIBI-EAST, QUEBEC

By

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MAP of the Capisisit-Inconnu Lake area. Scale: 1"- 1 mile.

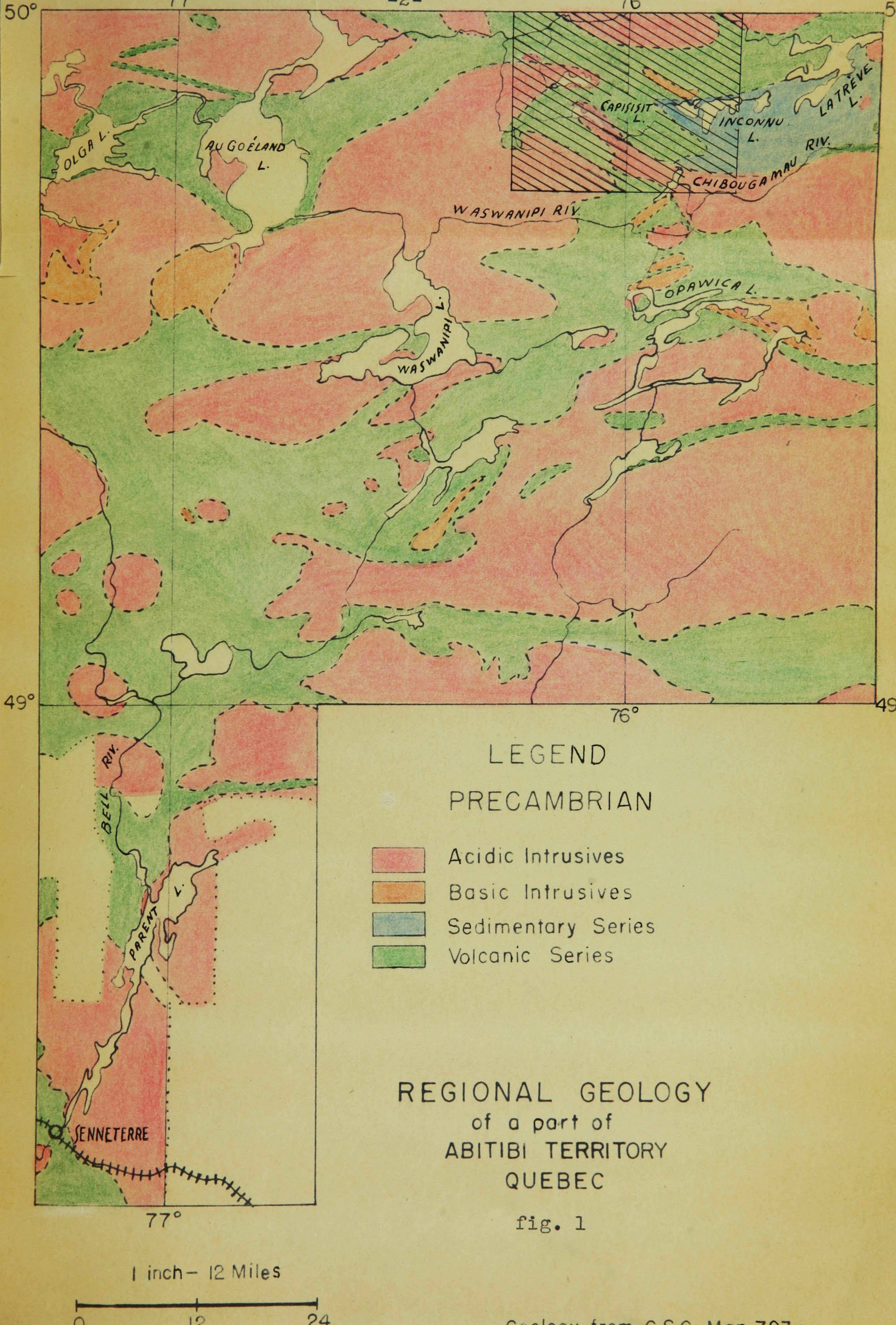
Chapter 1

INTRODUCTION

Location and Means of Access

The Capisisit-Inconnu Lake map-area (fig. 1, p. 2), described and studied in this thesis, is located about one hundred and ten miles north-northeast of the town of Senneterre, Abitibi County, a divisional point on the Canadian National Railways line from Quebec City to Cochrane, Ontario. It lies between the meridians of 75°45'W. and 76°15'W. and the parallels of 49°45'N. and 50°00'N. It covers about four hundred square miles and includes most of the townships of Branssat and Kreighoff and of the projected townships Nos. 616 and 716, with narrow strips of projected townships Nos. 615 and 715, to the west, and of the townships of Daine and La Ribourde, to the east.

The area is most readily accessible by air from hydroplane bases at Senneterre and Amos, in Abitibi County, or at Rouyn, in Temiscamingue County. Capisisit or Inconnu lake can be reached from Senneterre in slightly more than one hour, under normal flying conditions. Landing can be easily made on either of these two lakes, as well as on



REGIONAL GEOLOGY
of a part of
ABITIBI TERRITORY
QUEBEC

fig. 1

Geology from G.S.C. Map 703a

McDonald lake, slightly north of Capisisit lake, on Renault lake, about four and a half miles south of Inconnu lake, and on some of the larger and deeper stretches of Maicasagi river, especially near the western limits of the map-area (see plate 1, A and B). The air route is, by far, the simplest and, probably, the cheapest way of reaching the area.

The principal canoe route to the area is from Senneterre northward down Bell river to Mattagami lake and up Waswanipi river through Olga lake to Goéland lake. From Goéland lake, the major portion of the Capisisit-Inconnu Lake map-area can be reached by going northeastward through Max Narrows and Maicasagi lake and up Maicasagi river to the mouth of Inconnu river about one mile west of the western boundary of the present area.

From the junction of Inconnu and Maicasagi rivers, the northernmost section of the map-area is accessible by going up Maicasagi river which flows close to westward near the northern boundary and its tributary, La Trève river, which crosses the northeast corner of the map-area in a general northwestward direction. McDonald creek, a tributary of Maicasagi river, and Branssat creek, a tributary of La Trève river, are two fairly small streams which can be used at high waters for travelling with lightly-loaded canoes, and these two streams provide good means of access to the section of the area south of Maicasagi river and north of Inconnu and McDonald lakes.

The central part of the area is best reached by going up Inconnu river from its junction with Maicasagi river and across Capisisit lake to Inconnu lake which extends to the eastern boundary of the map-area. Inconnu river is a good waterway with only two major rapids along the lower part of its course, that is for about ten miles upstream from Maicasagi river. Farther eastward, however, and especially along the stretch included between Capisisit lake and the western boundary of the map-area and along that portion of its course just downstream from the outlet of Inconnu lake, the river is cut by numerous and frequent rapids, and travelling is difficult.

The southwestern part of the area is best reached by canoe by ascending the long stream draining the section between the southwestern part of the map-area and a point on Inconnu river a short distance outside the western boundary. This is a muddy, meandering, and shallow stream that can be ascended at low water to about its third main fork, about four miles northeast of the southwest corner of the map-area (see map in pocket).

The southeastern section of the area can be reached from Goéland lake by going up Waswanipi and Chibougamau rivers which flows nearly westward about two miles south of the present map-area, and, from Chibougamau river, up Renault creek to Renault lake, on the southern boundary of the eastern half of the map-area.

Two east-west and one north-south survey lines have been cut in the present map-area. The principal east-west township line goes right across the central part of the area and passes just north of Capisisit and Inconnu lakes. It is in a rather poor shape and difficult to follow. The north-south surveyed township line starts at post No. 60 of the above mentioned east-west line and continues southward to south of the present area. The other surveyed line, the central line of projected township No. 616, starts from post No. 5 of the north-south township line and goes westward across the southern section of the western half of the map-area. These latter two lines were cut recently and, consequently, are very easy to follow.

All the portages of the area already in use before the writer's visit were cleaned out during the field work done for this thesis, new ones were cut where thought necessary, and a number of lines were cut and blazed to facilitate the access to certain parts of the area. Those portages, trails, and lines are shown on the accompanying map.

Land traversing across the country is, in general, fairly easy, except through occasional patches where the underbrush is thick, and windfalls abundant.

Field Work and Acknowledgments

The writer is obligated to the Quebec Department of Mines who gave him the opportunity of studying the present thesis area, and Dr. I. W. Jones, Chief of the Quebec Geological Surveys Branch, was at all times most helpful in this project. The writer wishes also to express his indebtness to Dr. Jacques Claveau of the permanent staff of the Quebec Geological Surveys Branch who spent six weeks with him in the field and whose assistance and suggestions were at all times most helpful.

The field work connected with this thesis was carried out during the summer months of 1947 and 1948. All the rock exposures along the navigable streams were visited, and pace-and-compass traverses, spaced about half a mile apart, were run systematically, mostly in a north-south direction, so as to cross the structural trend of the rock formations which is predominantly east-west. An extensive use was made of vertical air photographs taken by the Royal Canadian Air Force and supplied by the Quebec Department of Mines. A thorough stereoscopic study of these photographs permitted the writer to modify land traverses so as to avoid low swampy regions and concentrate on the higher sections of the area where the chances of finding rock exposures were better. The rock exposures visited during the summer of 1947 were immediately platted on the air photographs and they were transferred directly on the base map at the same time as the latter was compiled by the Quebec Department of Lands and Forests in the fall of 1947. The writer believes that the accuracy of the mapping was greatly improved by that method and wishes to convey his appreciation to Mr. G. Barrette of the Quebec Department of Lands and Forests, who made this arrangement possible. The work done during the summer of 1948 was compiled on a base-map furnished by the Topographic Survey of Ottawa and modified by the writer during his field work.

Ian Bain of University of Toronto and Malcom Ritchie of McGill University proved to be most helpful senior assistants, whereas Walter Faesler and René Lavertu of

Laval University and Bruce Lyall and W. G. Gillespie of McGill University were very able junior students. Carl Faesler Jr. and J. Lépine, as cooks, R. Bordeleau, A. Imbeault, and U. Therrien, as canoemen, perfomed their duty in a very satisfactory manner.

This thesis was written under the guidance of Professor J. J. O'Neill, Vice-Principal of McGill University, whose suggestions were of a great help to the writer. Most of the petrographical work was done under the direction of Dr. F. F. Osborne of Laval University, and much assistance was also received from discussions with Dr. J. E. Gill of McGill University, Dr. Jacques Claveau of the Quebec Geological Surveys Branch, and Mr. P. E. Imbault, a graduate student of McGill University.

Previous Geological Work

Although broad reconnaissance surveys by several investigators have included the area studied in this thesis, no real detailed systematic geological examination of it had been made before 1947. Dr. Robert Bell of the Geological Survey of Canada did broad reconnaissance work along the main water routes of the Waswanipi area in 1895 and 1896, and widespread geological observations are mentioned in his preliminary reports published in 1896 and

1897 (21 and 22). Mr. Brock, Dr. Bell's assistant, on his way up Waswanipi river to Mistassini lake in 1896, made a few geological observations on the rock exposures along the course of Waswanipi and Chibougamau rivers, thus including the southeast corner of the Capisisit-Inconnu Lake area. Dr. Bell writes in his preliminary report of 1896 (22):

> "In ascending the Waswanipi River (from Waswanipi lake) on his journey to Lake Mistassini, Mr. Brock observed only granite, like that of Waswanipi Lake, for the first fourteen miles by the general course of the stream. Then for the next seven miles, there are greenstones and green schists, with whitish quartzite in the central part of this distance and granite near its eastern extremity. At one mile further on, syenite containing epidote, occurs, and gneiss and granite occupy the next eight miles". (p. 71A).

On Dr. Bell's map, published in 1900 (23), 90 per cent of the present area is mapped as underlain by "Laurentian gneisses" intruded by granites in about equal proportions. Between Pijuwyan (Renault) lake and Burnt Wood (Capisisit or McDonald) lake, the "Laurentian gneiss" is a "white quartzite" and is outlined as a wedge pointing towards the southwest and included in an arrow head-shaped zone of "Huronian schists", the extreme point of which extends to about ten miles due west of Opawica lake with the two barbs terminating against Burnt Wood and Pijuwyan lakes, respectively.

J. A. Bancroft in 1912 (10) explored some portions of the drainage basin of Nottaway river but did not travel as far east as the present Capisisit-Inconnu Lake area. All the geological information gathered prior to 1927 in the Nottaway River basin was collected by H. C. Cooke and shown on his map published in that year (52). A. H. Lang (83) visited the Waswanipi Lake area in the summer of 1931 during which "the shores of all lakes and streams navigable by canoe were examined in so far as time permitted" (p. 36D) and land traverses made "in strategic places" in the 5.500 square-mile area between latitudes 49° and 50° north and longitudes 76° and 78° west. However, no information on the geology of the Capisisit-Inconnu Lake area is given in his report.

The maps published by G. W. H. Norman in 1936 (109, 110, and 111) and G. W. H. Norman and J. A. Retty in 1938 (121) were the first ones to give a fairly exact broad aspect of the geology of the present area. J. C. Sproule, in 1936 (136 and 138), examined in some details the area lying between latitudes 49°00' to 50°00' north and longitudes 76°00' to 77°00' west, completing "the mapping of the area by examining the parts not covered by earlier workers and reviewing previously studied parts with a view to co-ordinating the results obtained with previous work" (136, p. 2). His report, however, is devoted almost exclusively to the mineral occurrences of the area above outlined, and little information is found in it concerning the geological formations of the present map-area.

The geology of the region adjacent to the Capisisit-Inconnu Lake map-area is known by the reconnaissance surveys mentioned above together with the work done in the Opawica, Lewis, Assinica, and Mishagomish Lake map-areas by G. Shaw of the Geological Survey of Canada in 1939 and 1940 (128, 129, 130, 131, 132, 133, and 134) and in the Bachelor Lake area which was mapped in 1946 for the Quebec Department of Mines by Dr. W. W. Longley (91 and 92) with the present writer as senior assistant.

Two preliminary reports and maps giving the main results of the investigations made by the writer in the present area were published in the falls of 1947 and 1948 by the Quebec Department of Mines (63 and 64).

Chapter 11

PHYSIOGRAPHY

The general topographical features of the Capisisit-Inconnu Lake area resemble those of many other parts of the Canadian Shield. It had undoubtedly, like the rest of the Shield, a very eventful physiographic history, but its mountains were eroded, and the area was partly peneplaned during the great lapse of time between the close of the last Precambrian orogeny (Algoman ?) and the onset of the Pleistocene glaciation. Nowhere is there evidence that a considerable amount of bedrock was removed by glaciation and, at the end of the Pliocene period, the area had a relief probably very similar to the present one. Since the final retreat of the Pleistocene ice sheet, the effects of erosion by streams and of weathering by atmospheric agents have been almost negligible. Ice-polished surfaces and well-preserved parallel glacial striae are of common occurrence on the massive and hard rocks of the area. The superficial desintegration and decomposition of the bedrock and of the larger components of the glacial till does not generally exceed fractions of and inch.

The topography of the present map-area is essentially characterized by relatively low, rocky hills, few in number and surrounded by lower and flatter lands containing detrital accumulations of different kinds left by retreating glaciers, lake-and-swamp-filled depressions resulting from the disturbance of the drainage by the relatively recent glaciation of the area, and clay and sand plains which are the result of deposition of material in large glacial lakes.

The whole of the area under study is well north of the height of lands between the St. Lawrence and Hudson Bay drainage basins. The lowest elevation is about 850 feet above mean sea level, where Maicasagi river crosses the western boundary of the map-area. The water level of Inconnu river is at about 875 feet at the western boundary of the map-area. Capisisit lake stands at an elevation of approximately 950 feet, and the eastern extremity of Inconnu lake, on the east boundary of the map-area, is close to 1,000 feet above mean sea level. The average water levels of McDonald lake, Renault lake, and La Trève river, in the northeast corner of the map-area, are about 935 feet, 950 feet, and 990 feet respectively.

Physiographical Districts

Broadly speaking, the Capisisit-Inconnu Lake area can be divided into three physiographical units, each showing characteristic relief and drainage pattern and underlain by rocks of different character.

Those sections of the map-area underlain by sedimentary and massive acidic to intermediate intrusive rocks have the smallest relief of all. This district of small relief includes the southwestern part of the map-area, underlain by a massive border facies of the Waswanipi granite, the southern section of the eastern half of the map-area, from Renault lake eastward, underlain by a medium-grained granite, the elongated area underlain by the Capisisit Lake granite, and a belt averaging six miles in width and extending right across the map-area in a general southeasterly direction and including the whole of the sedimentary rocks of the present area and the diorite-syenite complex around and west of McDonald lake.

The monotonous flatness of those sections of the map-area (see plate 11, A and B) is broken only by a few subdued rocky hills, not more than 100 feet high, and by low and broad accumulations of glacial drift. The lakes in this district of small relief are shallow, and their shores are generally low and flat (see plate 11, A and B). Renault lake, in the southeastern part of the map-area, is an outstanding exception, but its relatively considerable depth (over 200 feet) in relation to its size, and its high, rocky shores mostly made of jointed granitic rock and schistose volcanics, are considered to be the effect of faulting.

Most of the streams of this district of small relief are insequent, and they flow over unconsolidated glacial or aqueo-glacial deposits. A few are subsequent, resequent, or obsequent, and the resulting drainage pattern is mainly dendritic with a tendency towards a rectangular form over jointed granitic rocks.

A medium relief characterizes those portions of the map-area in which the surficial rocks are lavas or gneissic acidic intrusive rocks. This district of relief somewhat more accentuated than the first one discussed above, includes the whole northern section of the map-area north of the main belt of sedimentary formations, the area located on both sides of Inconnu river west of Capisisit lake, in the western half of the map-area, and the narrow band of volcanic rocks, in the vicinity of Renault lake and eastward.

The maximum relief of this district is of the order of 400 feet, and hills and ridges are more abundant than in the regions underlain by sedimentary or granitic rocks. A sharp knoll, composed of volcanic flows, on the north shore of Maicasagi river opposite the mouth of McDonald creek, rises to an elevation of over 300 feet, and a very prominent conical hill which can be seen from a distance of at least ten miles rises to a height of 400 feet above the lower surrounding ground in the section underlain by gneissic granitic rocks, one mile south of the northern boundary of the map-area and one mile and a quarter east of the seventy-sixth meridian. Other relatively prominent elevations in this district are the two hills, about half a mile north of Inconnu river and one to two miles west of Capisisit lake, and a "plateau", about two miles long and three miles wide, underlain by highly folded volcanic rocks, near the northeast corner of the map-area.

The structurally-controlled streams of this district of medium relief tend to form treillis to rectangular drainage patterns.

The sections underlain by basic to ultrabasic intrusive rocks form the highest and most rugged district of the map-area. Furthermore, small basic intrusive bodies form the backbones of many small ridges in sections underlain mainly by volcanic or sedimentary rocks. The two series of ridges north and south of Capisisit lake consist mainly of gabbroic rocks, and one hill, near the lake, in the southern series of ridges, rises to close to 700 feet above the level of the lake (see plate 111, A and B and plate 1V, A). This is the highest elevation of the whole area, and the average height of the ridges on the two shores of Capisisit lake is about 300 feet (see plate 1V, B). Another series of sharp ridges, made of intrusive rocks of basic composition, extends from the northwest side of Inconnu lake to close to the seventy-sixth meridian, and conical knolls and elongated ridges are also present in the area underlain by gabbroic rocks, from the west shore of Renault lake northwestward to Inconnu river.

In this district of relatively considerable relief, the drainage pattern is radial, annular, or rectangular, depending upon the stage of dissecation of the hills and ridges and the presence or absence of structural features such as local schistosity or joints in the basic intrusive rocks.

Drainage

The western half of the map-area is, in general, better drained than the eastern part, and moderately extensive swamps and muskegs are found only in the southwestern corner and close to the western boundary of the map-area, west of McDonald lake. In the eastern section, swamps and muskegs are abundant around Inconnu lake, in the low area underlain by volcanic rocks, north and northeast of Branssat lake, and between the two masses of gneissic intrusive rocks, in the north central section, immediately west of Branssat creek.

The great majority of the streams empty into Maicasagi river which flows into Maicasagi and Goéland lakes. Renault lake is drained through Renault creek into Chibougamau and Waswanipi rivers which empty into Waswanipi lake. All are components of the Waswanipi-Bell-Nottaway system which discharges into James Bay.

The structure of the bedrock has controlled the direction of the principal streams and the elongation of the largest lake basins. The minor streams are either partly influenced by the structure of the surficial rock or completely consequent on the glacial depositional surface.

Maicasagi river is the largest stream of the map-area and is, for most of its length in the present area, together with its tributary La Trève river, a subsequent stream flowing approximately westward in a wide, pre-glacial valley, about 150 feet deep close to the western boundary of the map-area. The passage of glaciers left abundant drift accumulations at about right angle to its channel, and those unconsolidated deposits are responsible for the series of meanders in the river near the center of the western half of the map-area. There, the river has not yet completely cut through a north-northeasterly-trending sand and gravel ridge, about 50 feet high and half a mile wide (see plate V, A). At that point, the usually deep, slow-running waters become very shallow and strewn with boulders rolled downstream by the current so that a flat rapid about one mile long has been produced.

Inconnu river flows generally in the direction of the principal structures of the bedrock in the western half of the area, and its abrupt changes in direction are where weak zones inclined to the general structure are encountered. The river appears generally to follow a pre-glacial channel and, although there are nine major rapids along that stretch of the river, it is to be noticed that all but three of them are the result of accumulations of boulders across the river channel by glacial ice.

Those accumulations of morainic material were considerable enough at a certain number of localities along the old river channel to block it completely, and the river was diverted for short stretches from its previous channel. Where the bedrock was encountered along those stretches, rapids and falls were produced, and the river has not yet started to cut appreciably through the bedrock in Post-Pleistocene times.

In the eastern half of the map-area, eastward from about one and a half miles east of the seventy-sixth meridian, Inconnu river flows in general direction approximately at right angle to the local structure of the underlying gabbroic and sedimentary rocks. Numerous rapids are also present along this stretch of the river which is obviously at a very early stage of its life.

On the other hand, that small tributary stream that joins Inconnu river from the east, close to two and a half miles east of the seventy-sixth meridian, and which extends eastward to less than one mile west of Gilles bay, on Inconnu lake, has a much wider valley apparently out of proportion with the actual magnitude of the stream.

It is considered probable that this tributary stream flows along the pre-glacial channel of Inconnu river which was blocked by extensive accumulation of drift material close to the present west shore of Gilles bay. Such an accumulation of detrital material caused a raise of the level of the water in that section of the area and produced most of the shallow water basin now occupied by Inconnu lake which found the easier outlet which it now occupies, about two miles to the north.

McDonald lake empties into Maicasagi river through a small creek which flows approximately at right angle to the general structure of the underlying bedrock, and at least part of its course is determined by a zone of weakness which is shown in exposures of sheared rock along it. This outlet of McDonald lake lies almost level with the adjoining land and is obviously a very young stream. On the other hand, a tributary joining Inconnu river, about one mile east of the western boundary of the map-area, flows along a strong depression extending all the way from Inconnu river to McDonald lake and even visible for a short distance on the north shore of McDonald lake. This depression is, in places, close to half a mile wide, and cliffs of bedrock, at one point 50 feet high, are exposed on each side of it. It very probable that McDonald lake was previously drained into Inconnu river through this now misfit stream, and that the jamming of its channel by glacial deposits, close to the present south shore of McDonald lake, was the factor which produced the emptying of the McDonald lake water basin into Maicasagi river.

The smaller streams of the map-area are partly subsequent and partly insequent. The southwestern section of the map-area, underlain by massive or jointed granitic rocks covered by a thick mantle of clays, shows a post-glacial drainage system generally made of insequent components. The shallow streams of this section are muddy, and their waters are greyish to chocolate brown, owing to the great abundance of very fine material over which they flow.

Chapter 111

NATURAL RESOURCES

Timber and Water Power

Relatively recent forest fires have swept the western part of the Capisisit-Inconnu Lake map-area aparing only small patches of medium-sized trees generally located in the lowest ground. The eastern half of the area has been pretty well spared by those fires, but the abundance of sand and gravel hills and the presence of extensive muskegs have prevented the growth of commercial types of trees in the section of the area north of Inconnu lake. The southern section of the eastern half of the area is pretty heavily wooded (see fig. 2. p. 24).

Black spruce is the commonest type of tree in the wooded sections, and birch and banksian pine occur in lesser abundance. In the better stands, the spruce trees have butt diameters of ten to twelve inches, but most of them are slightly smaller and would be suitable for pulp and, some extent, for small timber. The re-growth in the burned areas is not yet large enough to be of any value (see plate V, B and plate Vl, A).

Maicasagi river would be the only river within

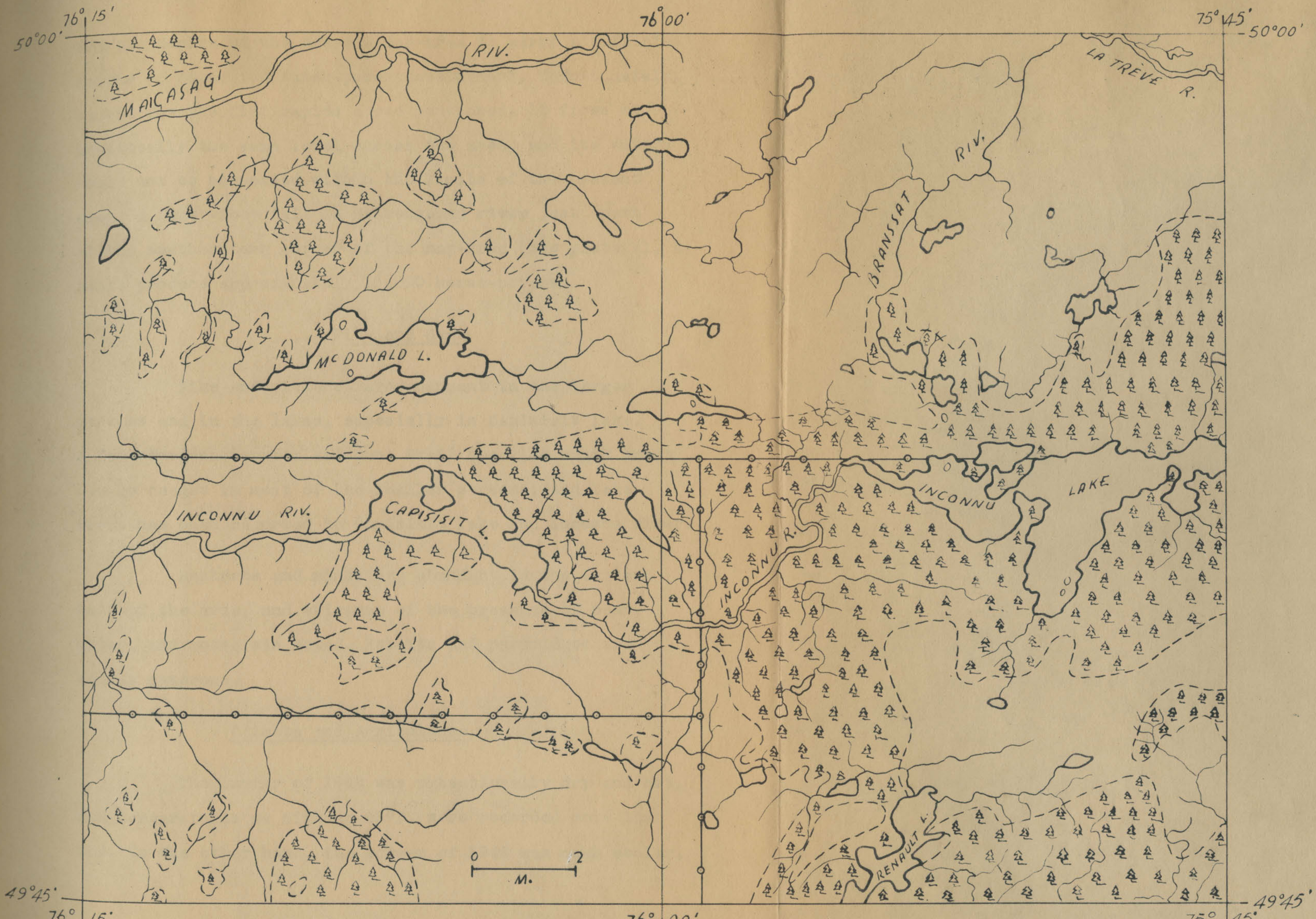


fig. 2 AREAS COVERED WITH TREES OF ECONOMIC SIZE

the boundaries of the present map-area to carry a sufficient volume of water for water-power development. Unfortunately, except for the flat rapids above mentioned, it flows at practically the same level across the area, and its waters could not be harnessed within the limits of the present area. A forty-foot fall in Chibougamau river just south of the southeastern corner of the map-area (see plate Vl, B) could produce approximately 15,000 horse-powers.

Fish and Game

Pike and pickerel are abundant in the larger streams and in the lakes, especially in Capisisit lake. A few sturgeons were also seen. Small speckled brook trout can be caught in most of the smaller streams, and lake trout has been reported in Capisisit lake and Inconnu river.

Muskrats and minks are abundant in the eastern half of the area, and evicence of the presence of bear, otter, and moose was noted. Rabbits and partridges are fairly numerous.

Climate and Agriculture

The summer of 1947 was exceptionally dry and hot, and temperatures as high as 95°F. were recorded more than one. On the other hand, the summer of 1948 was much cooler, and rains were very frequent (see fig. 3, p. 27). The average summer precipitation appears to be of the order of ten to twelve inches.

The low, clay-rich sections of the area, and especially the large low tract in the southwest quadrangle of the map-area appear suitable for farming. In general, however, the soil cover is either too thin or the coarse detrital material too abundant for the possibility of more than very small scale farming.

Mining

No mining or diamond drilling has yet ever been done within the boundaries of the present map-area, although considerable development work has been accomplished in the Opémisca-Chibougamau district some 40 miles to the east and in the Opawica-Bachelor Lake district immediately to the south. Prospectors were very active in the western half of the area in 1948.

The possibilities of the presence of economic mineral deposits within the limits of the map-area will be dealt with in chapter XIII.

Observations of temperature made during the Summer of 1948 between latitudes 49°45' N. and 50°00'N. and longitudes 75°45' and 76°00' W.

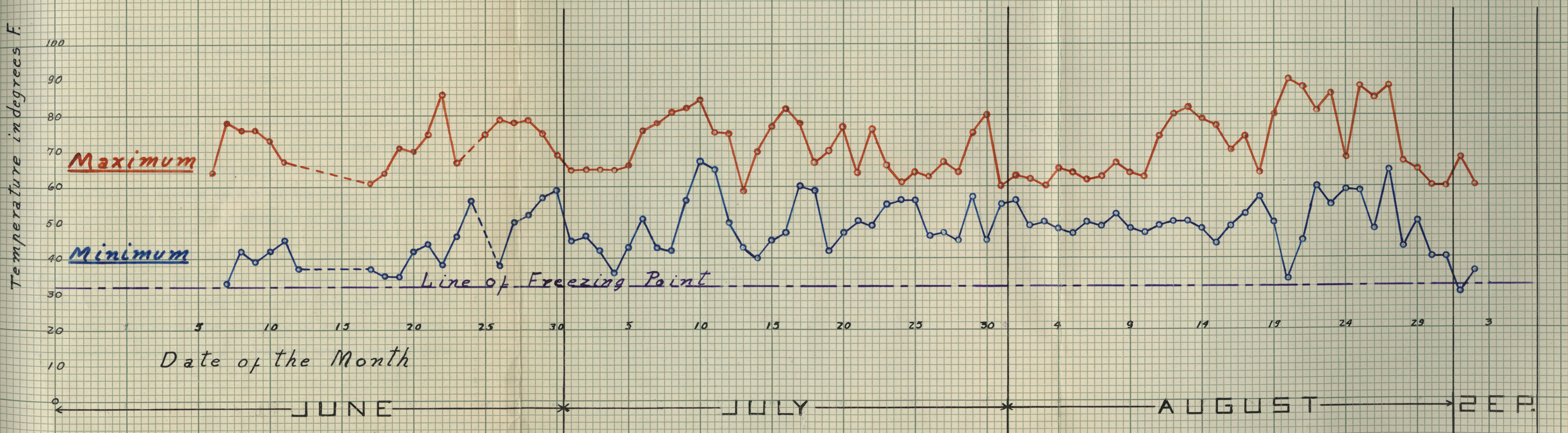


fig. 3

Chapter lV

GENERAL GEOLOGY

The low and heavily-covered southwestern and eastern parts of the Capisisit-Inconnu Lake area offer few rock exposures. In the remainder of the map-area, although abundant morainic accumulations are encountered, the bedrock is more extensively exposed than is generally the case in this part of the Canadian Shield.

Rock exposures are particularly abundant in the sections of the area where the dominant underlying rock is of the gabbroic type, i.e., in the two parallel series of ridges north and south of Capisisit lake and extending southeastward to Renault lake, and in the high ground south and west of Branssat lake. The gneissic intrusive and volcanic rocks of the northern part of the map-area and the eastern section of the Waswanipi granite body also exhibit good concentrations of exposures.

All the consolidated rocks of the area are of Precambrian age. Approximately 65 per cent of them consist of volcanic and sedimentary rocks, with associated basic to ultrabasic intrusives. The remaining 35 per cent are made of intrusive granitic rocks of various types, most of which constitute marginal zones or lobes of more extensive masses lying outside of the map-area. Granitic, syenitic, dioritic, and porphyritic dykes are scattered throughout the whole of the area underlain by volcanic, sedimentary, and gabbroic rocks, and relatively fresh olivine diabase, quartz diabase, and d iabasic gabbro of probable Keweenawan age, occur in a few scattered localities, more abundantly in the eastern half of the map-area.

TABLE OF FORMATIONS

Cenozoic	Unconsolidated Deposits	Sand, gravel, till, clay, peat.
Great Unconformity		
Precambrian	Unaltered Basic Intrusives	Diabasic gabbro, quartz diabase, olivine diabase, related aplites (Keweenawan ?).
	Intrusive Contact	
	Acidic Intrusives	Lamprophyre, pegmatite, syenite porphyry, diorite porphyry, quartz porphyry, granodiorite, and granite dykes. Coarse-grained hornblende syenite. Renault Lake Intrusive: albite granite, oligoclase granite, quartz diorite, diorite. Waswanipi Granite: biotite granite. Capisisit Lake Granite: hornblende-biotite granite. Diorite-Syenite Complex. Maicasagi River Gneiss: gneissic oligoclase granite, gneissic quartz diorite, fine-grained granite.
	Intrusive Contact	
	Altered Basic Intrusives	Gabbro, metagabbro, hypersthene gabbro, norite, olivine norite, hyperite, anorthositic and dioritic gabbro, associated anorthosite, pyroxenite,serpentine.
	Intrusive Contact	
	Sedimentary Series	Feldspathic sedimentary rocks, greywacke, basic arkose, slate, argillite, some chert and iron-rich beds. Conglomerate. Some interbeds of volcanics.
	Volcanic Series	Massive, ellipsoidal, porphyritic, and fragmental basaltic to andesitic flows. Some interbeds of volcanic tuffs and basic sediments.

Chapter V

VOLCANIC SERIES

General Statement

The oldest rocks of the Capisisit-Inconnu Lake area include lava flows, breccias, tuffs, and a few interbeds of basic sediments similar to those which underlie a large part of the Temiscamian sub-province of the Canadian Shield. The variable degree of regional metamorphism to which those rocks have been subjected, combined with the presence of numerous altered small intrusive bodies of related composition and of thin interbeds of basic clastics have always been a stumbling block to the Precambrian geologists. As a result, their age, nomenclature, and correlation has long been a matter of conjecture.

The earlier workers in the Temiscamian sub-province simply described the rocks without attempting to classify them, and their contribution to our knowledge of those rocks was probably much larger than that of many subsequent workers who put too much stress on classification and correlation between somewhat similar-looking types of rocks occurring in widely scattered areas. McOuat in 1871 (95) referred to the rocks of Dasserat lake, Kawasuta river, and Duparquet lake as diorites, Robert Bell, of the Geological Survey of Canada (21, 22, and 23) associated them with the Huronian rocks of Lake Temiscaming (21).

W. J. Wilson (160) and J. E. Johnson (80) also described as Huronian the "greenstones" and schists of the eastern and the western parts of the Abitibi region respectively. A. E. Barlow (12), in 1903, simply refers to them as greenstones and schists but, in 1906 (13), he classified the schistose greenstones of the east side of lake Timiskaming as Keewatin, presumably on account of their lithological similarity to the series of folded and metamorphosed hornblende schists, diabases, diorites, chlorite schists, and volcanic agglomerates described from the Lake of the Woods region and named Keewatin by A. C. Lawson in 1885 (84 and 85).

M. E. Wilson, in his reports of 1908 and 1909 (153 and 154), referred to both the sedimentary and volcanic rocks as Keewatin but, in 1912 (155), he gave the local name of Pontiac to the greenstones of sedimentary origin of the Larder Lake District and Pontiac County, and, in 1913, (156) he dropped the name of Keewatin altogether in favor of the term of "Abitibi Volcanic Complex" which he adopted for the greenstones of volcanic origin of the same area.

Nowadays, the term Keewatin is generally used to indicate that the rocks are pre-Huronian and lithogically similar to a series of rocks in the Lake of the Woods area. As the term has a little stratigraphic value, the writer believes that it is preferable to use "Keewatin-type" or "Keewatin-like" rocks, which describes better their similarity of appearance to rocks mapped elsewhere in the Canadian Shield as Keewatin. Some workers prefer to use local names for the different meta-volcanic and meta-sedimentary series, but those may become very cumbersome later on when more work is done, and a correlation based on stratigraphical relations, always desirable, becomes possible.

On account of their alteration, the Keewatin-type volcanics of the Canadian Shield are generally very difficult to name and classify with accuracy. The nomenclature of the different types of lava flows should be based on the composition of their feldspar, but as most of the original minerals of the rocks can seldom be determined, one has to rely mainly on the field appearance of the rock. James, Cooke, and Mawdsley in their description of the "Keewatin series" of the Rouyn-Harricanaw Region (54), present a good discussion of the general characteristics of the different types of altered volcanics of the

Temiscamian sub-province. They state:

> "The composition of the lava seems to have determined, to some extent at least, the degree of its alteration. The basalts and andesites have commonly, though not invariably, been changed to aggregates of chlorite and carbonates, and have consequently acquired the dark greenish colour that suggested the field name "greenstones" (p. 26).
>
> "it is impossible, in practice,however, to a attempt a precise classification, as the number of varieties is immense, and each variety would require the protracted study of numerous thin sections to arrive with certainty at the original composition. The geologist who must extend his examination over a large area is forced to rely to a large extent on the general appearance of the rock as shown by the weathered surfaces, supplemented by a microscopic examination of a number of selected specimens which, in many instances, prove to be of little value on account of alteration. The names in common use, accordingly, have about the following meanings:
>
> "Basalt". Dark, basic-looking, much altered quartz-free lavas.
>
> "Dacite". Commonly lighter in colour and more feldspathic but not necessarily so, with a small amount of quartz.
>
> "Trachyte". Light-coloured, fine-grained lavas without quartz.
>
> "Rhyolite". Light-coloured, fine-grained lavas with much free quartz, commonly porphyritic.
>
> "Greenstones". This field term properly applies to the altered basic types, "basalt and andesite", but in many cases applies in practice to any altered lava of basic appearance" (p. 26 and 27).

Thus a lava the original composition of which "as inferred from examination of clean weathered surfaces" or from microscopical analysis, "varied from about 25 per cent feldspar and the remainder mainly pyroxene to about 50 per cent feldspar and 50 per cent pyroxene" (p. 27) should be classified as a basalt and, when the content of feldspar is between "possibly 50 and 60 per cent" (p. 28), the rock becomes an andesite. It should be always borne in mind, however, that such an inference of the original composition is sometimes very difficult to make on account of the extent of the alteration of the constituents, the silification of the more basic types, or the chloritization of the more acidic varieties.

When a determination of the calcity of the plagioclase feldspar of the rock is possible, it is naturally a much more reliable criterion for classification of the volcanic rocks and it should be used in preference to the basis offered above by Cooke, James, and Mawdsley. Unfortunately, the plagioclase is generally recrystallized, and, in many cases, its original composition has been changed by the introduction of soda or silica at a later stage.

Distribution

Keewatin-type rocks underlie between 25 and 30 per cent of the Capisisit-Inconnu Lake area. They naturally fall into two broad generally southeasterly-trending belts separated one from the other, across the central part of the area, by a large belt of sedimentary formations, and two minor zones south and east of Renault lake in the southeastern section of the map-area.

The southern belt of volcanic rocks is, in general, well exposed and has a width of about one and a half miles at the western limit of the map-area. There, it is bounded on both the north and south sides by large bodies of acidic to intermediate plutonic rocks. Eastward, the northern limit of the belt becomes in contact with the southern edge of the belt of sedimentary formations mentioned above. The belt of volcanics also widens and, at the west end of Capisisit lake, it crops out for four miles across. East of that point, it is split into two minor belts by an elongated body of granitic rocks which is about two miles wide and extends in a southeasterly and southerly direction to about one and a half miles east of the seventy-sixth meridian.

These two minor belts and, to a smaller extent, the main belt as well, are intruded by numerous masses of basic intrusive rocks of various size and composition. These intrusive bodies are particularly abundant in the south central section of the map-area and, at many points, considerable difficulty has been encountered in drawing their boundaries. Some aid in attempting to do so is given by the fact that, in general, the masses of basic intrusive rock form the hills and ridges while the volcanics underlie the lowlands. Minor amounts of volcanic rocks may underlie scattered small sections of the area mapped as made of basic intrusive rocks, and this is believed to be especially probable in the section of the area west and northwest of Renault lake. It is also possible that the small zone of volcanic rocks on the west shore of Renault lake, at the southern boundary of the map-area, and the one extending eastward from approximately one mile north of the northern end of Renault lake constitute a single and same zone connected westward with the main southern belt of volcanics but, as no exposure of volcanic rocks could be found in the intervening areas, they were mapped as separate one from the other by gabbroic intrusive rocks.

The northern belt of volcanics is continuous right across the area and, in general, less well exposed than the southern one. Its southern edge is in contact with the belt of sedimentary rocks mentioned above along its whole length across the map-area, except at a few points near the center of the map-area, where small intrusive bodies of basic to intermediate composition occur at the contact between the two main types of rocks. To the north, it extends to the northern boundary of the area along a three and a half miles long stretch at the northwest corner and along another four mile stretch near the northeast corner of the map-area. The remainder of the belt is bounded to the north by a gneissic intrusive of acidic composition, and the contact between the two is generally characterized by a relatively narrow zone of hybrid rocks.

At the western boundary of the map-area, over two and a half miles of volcanic rocks are included within the boundaries of the area under study. Eastward, the width of the belt of volcanic material decreases gradually to the seventy-sixth meridian where it is less than two thousand feet wide. Immediately east of the seventy-sixth meridian, it widens abruptly, and its maximaum width of over seven and a half miles is soon reached. At the eastern boundary of the map-area, it is about six miles across.

Southern Belt of Volcanic Rocks

Under this heading are grouped all the extrusive rocks south of the main belt of sedimentary formations near the center of the map-area. It includes the main belt of lavas and associated rocks around and west of Capisisit lake and eastward, as well as the two small zones of lavas west and northeast of Renault lake.

The lavas of the southern belt occur as an extensive series of flows of various thicknesses including massive, ellipsoidal, fragmental, amygdaloidal, vesicular, and porphyritic types. Several of the flows have retained a massive character, but, more commonly, they have a determinable and, locally, a strong schistosity. The primary structures are usually pretty well preserved, except in the highly schistose flows, though the pillows have generally been strongly flattened and are seldom reliable for determinations of tops and bottoms of flows. The pillowed lavas are the most abundant types of flows in the southern belt of volcanic rocks, and this structure proved very useful in places to separate schistose basic lavas from fine-grained schistose, basic to ultrabasic intrusive types of rocks.

Fragmental lavas and flow breccias are relatively abundant and vary in thickness from one foot to a few scores of feet. Interbeds of tuffs, a few inches to about fifteen feet thick, were found in the lavas at various places.

Vesicular and amygdaloidal lava is not common and, in most occurrences, the vesicules and amygdules are flattened. Most of the amygdules consist of agglomerations of feldspar and quartz, but some have a low content of carbonates.

Fine-grained, basic sedimentary rocks were also frequently found interbedded with the volcanic flows especially in the area south of Inconnu river between the western boundary of the map-area and the central part of Capisisit lake. On small rock exposures, the basic clastic beds are difficult to distinguish from the lavas with which they are associated. Some beds of basic sedimentary rocks are, however, well exposed at a few localities, such as on a low ridge some two miles southwest of the west end of Capisisit lake. There, lavas, tuffs, and basic sedimentary beds are exposed together. The volcanic rocks consist essentially of slightly schistose basic flows with thin interbeds of tuffs. A width of ten feet of the exposure consists of well-bedded and banded, fine-grained sedimentary material in layers varying in thickness from four inches to one foot. Some good exposures of basic sedimentary rocks are also to be seen on the northern slope of the high ridge south of Capisisit lake, on the shore of the western extension of the same lake, and at scattered points near and along Inconnu river from Capisisit lake westward.

Petrography

In general, the massive, ellipsoidal, vesicular, and amygdaloidal flows of the southern belt of volcanics correspond to lavas of basaltic composition. In very few localities, the rock is fresh enough to show saussuritized but still identifiable plagioclase-feldspars of the composition of labradorite, and the relative amounts of dark-and light-colored minerals in the more altered facies also correspond to flows of basaltic composition as defined by Cooke, James, and Mawdsley (54). The porphyritic flows appear more andesitic, and dacite and rhyolite are totally absent, with the possible exception of fragments and inclusions in the basaltic flows.

Several thin sections of the lavas from the southern belt were examined under the microscope, and it was found that, with the exception of the porphyritic flows, the variation in composition is very small within the whole belt. In the relatively massive lavas, such as those found about two and a half miles southwest of the western extension of Capisisit lake, the felted pattern of plagioclase laths typical of basalts is plainly visible, and the plagioclase itself is fairly fresh. It has the composition of a labradorite (An_{52} to An_{65}) and makes between 20 and 30 per cent of the rock. Amphibole constitutes from 60 to 80 per cent of the rock. In the more altered and schistose facies of the lavas, the microscope shows a felted mass of secondary amphiboles and of highly saussuritized or secondary feldspar. The usual accessory minerals are magnetite, ilmenite, epidote, clinozoisite, leucoxene, titanite, and occasional chlorite, quartz, and carbonate. Magnetite and ilmenite are intimately associated with the amphiboles, and disseminated pyrite is common.

The porphyritic flows show phenocrysts of white plagioclase up to one and a half inches long, enclosed in a very fine-grained matrix composed mainly of amphiboles and epidote, with about five per cent of secondary quartz. The phenocrysts are, in general, rounded, although some exhibit euhedral to subhedral outlines, and all are altered and finely fractured. Their composition cannot be determined with accuracy under the microscope because of their alteration, but their indices of refraction indicate that they are probably andesine or labradorite. About two per cent of the rock is made of fresh, secondary, sodic oligoclase, in fine grains, mostly grouped around the altered more calcic primary phenocrysts.

Although these porphyritic greenstones are considered as being mostly of extrusive origin, it is realized that the size of their phenocrysts is somewhat larger than in ordinary porphyritic lavas. Recent work on volcanoes and lava extrusion has indicated that a high proportion of the material produced during a period of eruptive activity is of intrusive origin although comagmatic with the lavas and exceedingly difficult to distinguish from them. It is possible that these unusually large phenocrysts belong to such an intrusive facies comagmatic with the adjacent ordinary fine-grained lavas.

Most of the fragmental flows are made of sharp angular fragments set in a fine-grained basaltic matrix. Some of the fragments are up to one foot across, but most of them are from two to four inches. The fragmental flows are generally two to 15 feet thick, but one flow, south of Capisisit lake, is approximately 30 feet across. A high proportion of the fragments are somewhat lighter-colored than the matrix which encloses them. Those examined under the microscope appear very altered and are seen to be composed of an aggregate of products of alteration and secondary minerals. One fragment taken from a basaltic flow, the composition of which was 80 per cent hornblende and 15 per cent calcic plagioclase, was found to contain 60 per cent epidote and about 15 per cent actinolite, with quartz, carbonates, chlorite, magnetite, ilmenite, and pyrite.

The banded tuffs associated with the lavas are generally fine grained, highly acidic, and greenish grey in color, with very narrow dark bands of more basic material. Thin fragmental volcanic beds are commonly present interstratified with the tuffs. In general, the tuffs have been extensively altered and, in many places, much sheared. In thin sections, the acidic tuffs appear as composed almost exclusively of quartz and epidote, with very minor iron oxides and leucoxene. The basic ones are made up mostly of chlorite, sericite, and iron oxides, with a little quartz.

All the interbedded sediments of the southern volcanic belt are essentially quartz-hornblende schists, and all original features other than the pronounced banding have been obliterated by dynamic metamorphism. Individual bands in the schist maintain remarkable uniformity in width and composition, and the difference in composition of the various bands is quite apparent on large weathered surfaces. Some layers contain as much as 75 per cent hornblende with a little quartz and feldspar, whereas others may contain 90 per cent quartz. Garnet-rich, very thin bands are present at a few localities. In general, however, hornblende and its products of alteration make about 45 per cent of the rock, with altered feldspar and varying amounts of quartz as the other principal constituents.

One particularly good cross-section of the various types of Keewatin-like rocks of the area is afforded in the well-exposed part of the southern belt of volcanics, south of Capisisit lake. There, as one travels southward from the middle southern shore of the lake and across the main hill, thin interbeds of basic sediments and basaltic lava flows are first found at a locality about three thousand feet from the shore of the lake and they extend from there for about a quarter of a mile.

Slightly schistose and somewhat pillowed basaltic flows dominate for the following thousand feet, and then fine-grained basic intrusives are encountered, first in narrow, schistose, concordant, sheet-like bands, and increasing in amount farther south to the top of the ridge where massive, fine-to medium-grained gabbro with inclusions of basaltic lava is the dominant rock. The contact between the gabbro and the volcanics is, in places, very sharp; elsewhere, it is hard to find. Basaltic to andesitic lavas are found again on the southern slope of the ridge, and close to their contact with the gabbro, the volcanic flows have been metamorphosed into a very hard and uniform material having the appearance of a hornfel. The rock is somewhat slaty, very fine grained, and appears under the microscope as a felty aggregate of secondary hornblende, altered calcic plagioclase feldspar, and a small amount of iron oxides. The hornblende makes about 80 per cent of the rock, and the plagioclase about 15 per cent. This baked basaltic lava grades slowly southward into more and more schistose flows with a decreasing number of gabbroic intrusions, and, at about eight thousand feet from the shore of the lake, highly-pillowed lavas interbedded with flow breccias, minor volcanic tuffs, and fine-grained greywacke become predominant. Porphyritic basaltic flows, about five hundred feet thick and bounded to the north and south by ellipsoidal lavas, occur half a mile north of the contact of the Keewatin-type rocks with the granitic intrusive to the south.

Rounded Inclusions in Lava Flows

Lighter-colored, somewhat rounded inclusions are present in some of the lava flows throughout the area, but they are so much more abundant in the volcanics of the southern belt that they are studied here along with them. These inclusions are there subangular to rounded and the largest tend to have the shape of spheroids or ellipsoids (see plate V11, B and plate V111, A). The smallest are round or cigar-shaped and are fraction of an inch across. The largest seen was three feet long and one foot across. The great majority of themhave their long axis oriented parallel to the schistosity of the enclosing lava, but where the schistosity is at an angle with the strike of the flows, their long dimension may occur parallel to either the flow structures or the schistosity.

In composition, they are fine-grained rocks, invariably lighter in color than the enclosing matrix. The contact of the larger nodules with the matrix is, in general, marked by what appears to be a narrow chilled margin in the lava and a "reaction rim" inside the nodule, about a quarter of an inch thick. Although most of the nodules are highly cross-fractured, they usually do not weather as readily as even relatively massive basalt (see plate V11, B and plate V111, A). Quartz is commonly present in the fractures.

Under the microscope, they appear as composed of aggregates of secondary minerals: epidote, 60 per cent, secondary amphiboles (mostly actinolite), 15 per cent, leucoxene, titanite, sericite[x], saussurite, and iron oxides, with varying amounts of quartz and carbonates. The primary constituents of the nodules have been completely obliterated, except in one specimen which shows relics of phenocrysts of very altered feldspar.

Many hypotheses have been put forward to explain the occurrence of nodules of this type all through the volcanic flows of the Temiscamian sub-province. Gunning and Ambrose (72), in their description of nodular flows of the Malartic area, refer to the small nodules as squeezed amygdules. M. E. Wilson (159) describes an andesitic flow breccia of the Noranda district "consisting of well-rounded masses up to 2 feet or more in diameter enclosed in a fine

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xSericite is, in this thesis, used for fine to very fine secondary white mica and includes the potash-lacking variety, paragonite, if this mineral exists.

or less brecciated andesitic matrix" and refers to it as "probably formed by the breaking up and engulfing of a thick crust and sufficient re-fusion of the margins of the fragments to give them a rounded outline". Longley (90) classifies them as volcanic "bombs" probably produced by "fire fountains in the lava streams" (p. 10).

The striking similarity of composition between the angular fragments of the flow breccias described above and of the rounded inclusions found in the area is believed by the writer to be one of the best clues as to the origin of at least some of the nodules. It seems conceivable that some of the very small types represent more or less squeezed amygdules, but this explanation does not hold good for the occurrence of rounded inclusions up to three feet long. In at least two cases, light-colored, rounded inclusions were found in small basic intrusive bodies close to their contact with the nodular lava flows. A certain proportion of them were also found in the core of the pillows of some of the ellipsoidal flows, and these might be considered as the result of differential metasomatism of the pillowed lava flows.

On the other hand, most of the larger nodules were found in relatively massive and only slightly-altered basaltic flows, and, if they are solely the product of metasomatism, it seems to the writer that the basaltic matrix should have become also somewhat more altered in the vicinity of the nodules, and it is not the case.

Although their shape is commonly that of bombs, if they are considered as such, their highly different composition implies that they could not have been produced by "fire-fountains" in the lava flows or by the same magmatic extrusion which produced the basaltic matrix. It is not probable either that the bombs only would have been replaced by more acidic material, after their inclusion in the basaltic matrix, so as to produce the present occurrence of acidic nodules in a basic matrix.

The writer is of the opinion that both the angular and rounded inclusions are closely related in origin. It seems, as a rule, that the rounded inclusions are present in thick, relatively massive lava flows, whereas the angular types occur commonly in thin, more schistose, and altered flows. The fragments were engulfed in the lava flows and, where the latter were thin, they were simply incorporated without being re-worked, but in the case of thick flows, the re-fusion of the margins of the fragments was sufficient to give them a rounded outline.

The origin of the fragments themselves is rather obscure. On account of their very different composition, they are not believed to have been derived from the already-consolidated part of the flows which later produced the enclosing matrix, but they probably represent the break up of an already-altered possibly more acidic lava. It is conceivable also that both the angular fragments and the nodules were constituents of loose material incorporated from the surface over which the basaltic lava flowed after its extrusion.

Northern Belt of Keewatin-type Volcanic Rocks

In contrast with the southern belt of volcanics which is broad in the western and very narrow and interrupted in the eastern half of the map-area, the northern belt of volcanic rocks is generally narrow west of the seventy-sixth meridian and quite wide in the eastern half of the map-area. It is generally also much less well exposed. An outstanding exception is the large "plateau" of folded volcanics exposed near the northeast corner of the map-area.

Some difficulty has been encountered in the classification of the rocks underlying the central northern section of the east half of the map-area. The ground is there low and swampy, and the rock exposures very few. Furthermore, the observed exposures of "greenstones" in that section of the area located between the crescent-shaped gneissic intrusive body, three to four miles west of the eastern boundary of the map-area, and the main mass of the gneissic intrusive to the west, are generally highly altered and injected and some could be considered as belonging to a hybrid facies of the gneissic intrusive. However exposures of somewhat fresher and less injected volcanic rocks on the shore of Branssat creek, about two and a half miles south of the northern boundary of the map-area, and of altered but definitely volcanic rocks, at a locality about a quarter of a mile south of the northern boundary of the map-area, seem to justify the present interpretation of the relations between the gneissic intrusive rocks and the intruded and altered volcanic formations.

The rocks of the northern series of volcanics are structurally essentially similar to the ones of the southern belt. They also consist of massive, ellipsoidal, amygdaloidal, and fragmental flows, with thin interbeds of tuffs and basic sediments. The massive types of flows seem to predominate in the western half of the map-area, whereas the exposures close to the eastern limit of the area generally shows well-preserved to highly-deformed pillow structures. Flow breccias and agglomerates are somewhat less abundant than in the southern belt, and so are amygdaloidal and vesicular flows. Tuffs and basic sediments were occasionally found in the eastern section of the area but, farther west, interbeds of basic sediments occur more and more abundantly as one gets closer to the contact between the volcanic and sedimentary rocks.

In composition and texture, the volcanic rocks of the northern belt are also essentially similar to the ones of the southern section of the area. They are essentially amphibolite schists containing between 60 to 80 per cent ferromagnesian minerals and 20 to 40 per cent generally altered plagioclase-feldspar. Accessory and secondary minerals usually include magnetite, ilmenite, epidote, clinozoisite, sericite, and chlorite. However, they are, in general, more metamorphosed than the flows of the southern belt, and this will be dealt with later in this thesis, in the chapter on the metamorphism of the pre-granitic rocks.

Chapter Vl

SEDIMENTARY SERIES

Distribution

Sedimentary rocks make about 30 per cent of the surficial rocks of the Capisisit-Inconnu Lake area. The distribution of their exposures indicates that they underlie a broad southeasterly-trending belt across the whole of the map-area. This belt is slightly over four and a half miles wide at the western boundary of the map-area and, from about two miles west of the same boundary, it is split for a distance of about six miles into two minor bands by a large body of acidic to intermediate intrusive rocks extending from the west into the present area and surrounding McDonald lake.

At the seventy-sixth meridian, the belt of clastic rocks is still close to four miles wide, but it decreases in size to about two and a half miles at the outlet of Inconnu lake. From that point eastward, its width increases, with a westward projection about two miles across, north of Renault lake. At the eastern boundary of the map-area, the belt is over eight and a half miles wide and it extends eastward through La Trève, Mechamego, and Michwacho

Lake areas into the Opémisca Lake area (121, 17, 18, 19, 20, and 112).

A small group of exposures of altered rocks, apparently related in origin with the ones found within the main belt of sedimentary formations, occurs near the eastern boundary of the map-area, about three miles north of Inconnu lake. These may represent a small zone of sedimentary rocks independant from the main belt. They might, on the other hand, constitute part of a narrow secondary belt connected, farther east, with the major belt.

Within the boundaries of the present map-area, the main belt of sediments is generally bounded to the north and south by volcanic rocks. At many places, however, such as along its northern edge, near the center of the map-area, and along its southern boundary, southwest of Gilles bay, on Inconnu lake, the belt of sedimentary beds is in contact with masses of altered basic intrusive rocks which have come up between the two main series of "greenstones" rocks of the area.

Characters of the Rocks

To the naked eye, the typical sedimentary rock of the area appears as a medium-to very fine-grained, highly feldspathic rock. The banding is, in general, well pronounced although, in some cases, the rock is massive and poorly bedded. The medium-to fine-grained types tend to occur in thicker beds, from six inches to over twenty feet across, whereas the very fine-grained types are commonly finely banded and show very distinct bedding, fractions of an inch to a few inches thick.

The medium-to fine-grained types are the most common of the group, and their high content of feldspar gives them an arkosic appearance on weathered surfaces. They are represented by two different groups of rocks which are generally distinguishable in the field but more easily identified under the microscope. The rock of the first group is made up of altered crystals of plagioclase with a few grains of quartz, embedded in a very fine-grained, feldspathic groundmass containing a little quartz, biotite, white mica, calcite, epidote, clinozoisite, and iron ores. The larger plagioclase grains are, as a rule, subangular to rounded and range in size from fractions of a millimeter to about two millimeters. The subhedral to anhedral outlines of the altered plagioclase grains constitute one criterion which permits to distinguish the clastic rocks from porphyritic dykes and sills of very similar composition which are commonly found associated with them. The other is the presence and shape of the quartz grains in the two types of rocks. In the feldspathic sediments, some of the quartz appears disseminated in the rock in close association with the plagioclase, and part of it appears as large opalescent eyes and in fractures. In the porphyritic dykes, only the latter two types are present, and no primary quartz can be recognized in association with the plagioclase.

The fact that the larger primary plagioclase grains of this type of feldspathic sediment are commonly subangular indicates that the constituents of the rock have not undergone much trituration by transportation and that they were probably derived from a nearby source. They may represent tuffaceous sediments.

The fine, equigranular types of feldspathic sedimentary rocks are the more common of the series. They are usually well layered, with beds normally a few inches thick. Their composition varies within fairly wide limits, but acidic plagioclase (generally oligoclase or andesine) is always the dominant constituent. Quartz may or may not be present, but it generally makes around 15 to 20 per cent of the rock. Biotite is the main ferromagnesian mineral, but hornblende is not altogether absent. Garnet is occasionally present. The accessory minerals are iron oxides, epidote, clinozoisite, sericite, apatite, leucoxene, titanite, and kaolin. Some varieties contain up to 70 per cent red garnet, probably almandite.

The fine-to very fine-grained types of sedimentary rocks include argillite, impure chert, ferruginous chert, slate, and probably sedimentary tuffs. They are dark grey to white, as a rule, finely banded, and the alternation of dark and light-colored beds is very conspicuous on weathered surfaces (see plate V111, B and plate 1X, A). In hand specimens, they appear as composed of particules of silt grade, and the identification of the components is very difficult, except in the case of the slates in which amphiboles needles may be distinguished with the naked eye.

Argillites are the most common of the very fine-grained types, and slates, cherts, and siliceous magnetites occur in smaller quantity. Beds of chert and siliceous magnetite commonly occur interstratified, and good exposures of them can be found about two miles north-northeast of the east end of McDonald lake, along McDonald creek, about one mile south of Maicasagi river, on the south shore of McDonald lake, and at a few other scattered points in the whole of the sedimentary belt. Good exposures of slates occur along the south shore of McDonald lake, close to the end of the portage from Capisisit lake, and on the east shore of Gilles bay, about two miles north of the extreme southern extension of the bay.

The main characteristic of the fine-to very fine-grained types of sedimentary rocks is, with the exception of chert and siliceous magnetite, their high content of very fine plagioclase feldspar. Quartz makes about fifteen per cent of the rock, along with white mica, biotite, chlorite, epidote, clinozoisite, iron oxides, garnet, and other very fine-grained products of alteration. The cherty types of sediments contain usually about 50 per cent very fine quartz, with iron oxides and hornblende or biotite. The proportion of iron oxides and quartz is reversed in the case of siliceous iron-rich beds, and on one exposure of them, along McDonald creek, iron oxides make over 80 per cent of the rock.

Exposures of conglomeratic material occur at two localities within the limits of the map-area, and abundant boulders of similar rock are present on the shores of the two lakes just east of Inconnu lake and of the eastern boundary of the map-area.

The first locality of exposures of conglomeratic rock is about four hundred feet south of the southern shore and three thousand feet west of the east end of McDonald lake. The main exposure of conglomerate is about 20 feet long and 10 feet across. It contains numerous pebbles of basic and ultrabasic material set in a matrix of fine-grained basic greywacke similar to the rock found north and south of the exposures of conglomerate. The pebbles are from a fraction of an inch to about six inches in diamater, and all have been so flattened and altered that it is impossible to speculate on their original outlines prior to their deformation by dynamic metamorphism and before their alteration by the intrusive body around McDonald lake.

Most of the pebbles appear as made of a medium-grained amphibolite with a variable, but always rather low, content of light-colored minerals, probably mostly feldspar. Under the microscope, they are seen as schistose and fractured aggregates of hornblende (60 per cent) and altered plagioclase-feldspar (30 per cent). The plagioclase belongs to a calcic species, and it is believed that these dark-colored pebbles represent recrystallized and flattened angular or rounded fragments of basaltic lava which were incorporated in a fine-grained basic matrix.

The contact between the intrusive mass around and west of McDonald lake and the intruded sedimentary and conglomeratic rock is exposed on the south shore of McDonald lake, a few hundred feet west of the exposures of conglomerate mentioned above. All along the exposed length of the contact, the intruded rock has been strongly brecciated, and angular as well as flattened fragments are present in a granitic matrix.

In the other exposures of conglomeratic material, on the north shore of the eastern half of Inconnu lake, and in the boulders of similar rock on the shore of Daine and La Ribourde lakes, just east of Inconnu lake, the pebbles, cobbles, and boulders are very fresh and vary in size from a fraction of an inch to about 18 inches. The large majority of them are well rounded with only a few subrounded (see plate lX, B and plate X, A).

The conglomerate, as might be expected, exhibits considerable variation in characteristics from place to place, but the matrix varies only as to the texture and the size of the grains. Its composition is strikingly consistent, and plagioclase feldspar is, by far, the dominant constituent.

Along the north shore of Inconnu lake, the pebbles make about 15 per cent of the rock, and they are cemented together by a fine-to medium-grained feldspath-rich rock containing angular to subangular grains of plagioclase up to one millemeter across. The greatest proportion of the pebbles are made of fine-to medium-grained grey and pink granite, with about 35 per cent of them consisting of a feldspathic greywacke very similar in composition to the matrix itself.

Eastward, the pebbles become generally larger, more abundant, and, in places, they make over 70 per cent of the rock. The matrix is generally a fine, even-grained, feldspathic aggregate and, in some cases, rounded pebbles of very similar, highly feldspathic material make up to 50 per cent of the rock. In other occurrences, granite, syenite, diorite, pegmatite, and quartz constitute the main constituents of the pebbles. Pebbles of amphibolite or volcanic material were not recognized in these exposures of conglomeratic rock.

The stratigraphical significance of these occurrences of conglomeratic rocks, and the mode of origin of the conglomerates of the area will be treated in the chapter on the structural geology of the pre-granitic rocks of the area.

The diverse types of waterlaid clastic rocks of the area have been variously altered by dynamic metamorphism which accompanied the intense folding of the rocks and, locally, by the effects of the intrusions of plutonic rocks, especially those of acidic composition. The structural, textural, and mineralogical changes which took place in them under the influence of those new conditions will be discussed in a subsequent chapter along with the ones which occurred in the volcanic and altered basic intrusive rocks.

Chapter Vll

BASIC INTRUSIVE ROCKS

An outstanding feature of the Capisisit-Inconnu Lake map-area is the presence, in the volcanic and, to a lesser extent, in the sedimentary rocks, of a great number of large and small bodies of intrusive rocks mostly of basic or gabbroic composition. The scale on which the map is constructed does not permit one to show at a glance the ubiquity and thus the full importance of the intrusive rocks of this composition. Only the larger, outstanding masses and a few minor ones are shown on the accompanying map. Although they are found intruding both the volcanic and sedimentary series, they are much more commonly associated with the volcanics.

A notable feature of the basic intrusive rocks of the area is their differentiation and, although they are all classified here under the heading of "basic intrusives", they really constitute an intrusive complex ranging in composition from ultrabasic to intermediate. The great mass of the rock is, however, of close to gabbro in composition, and, therefore, the ultrabasic and intermediate facies can be treated as subordinate to the basic or gabbroic type of intrusive.

The largest and best-exposed mass of basic intrusive rock occurs in the southern section of the map-area, on both sides of the seventy-sixth meridian. There, two series of ridges, composed mainly of gabbro extend southeastward from both the north and south shores of Capisisit lake to about two miles south of Gilles bay on Inconnu lake and west of Renault lake. The southern section of this gabbroic intrusive mass extends southward into the Opawica Lake map-area (128 and 130) and the Bachelor Lake area where the rock was mapped by Longley as made of "highly recrystallized basic sediments" (92).

Numerous exposures of gabbroic rocks, just south of Inconnu river and about one and a half miles west of Capisisit lake, form the backbones of a number of closely-spaced east-west trending ridges flanked by small exposures of volcanic rock and have been joined together, on the accompanying map, into two lenticular bodies of basic intrusive. Just south of Branssat lake and northwestward, there occurs a series of northwesterly-trending ridges underlain by gabbroic or somewhat dioritic and anorthositic rocks. A series of good exposures also indicates the presence of a lenticular body of gabbroic rock, about two miles long and three thousand feet wide, close to two and a half miles north of the eastern extension of

McDonald lake. Other smaller masses of basic to ultrabasic intrusive rock can be seen just north of the western part of Colette lake, west and southwest of Huguette lake, and at the eastern boundary of the map-area, around the little lake two miles north of Inconnu lake.

Besides the larger masses of gabbro mentioned above, a number of smaller bodies of basic to ultrabasic intrusive rocks indicated by a restricted number of exposures are found scattered through the sections of the area underlain by volcanic or sedimentary formations. Those masses which seem large enough to be shown on the map separately from the intruded volcanic or sedimentary series have been outlined with their long dimension parallel to the regional trend, in accordance with the shape and trend of the better-exposed, larger masses of the area.

As just stated, the outlines of the bodies of gabbroic intrusive rock suggest imperfect tabular masses, generally trending close to parallel to the bedding or schistosity of the intruded volcanic and sedimentary series. The large gabbroic bodies of the southern central part of the map-area may appear to constitute exceptions to this rule. It is believed that their apparent local discordance with the intruded volcanic rocks is due to the lack of critical exposures which would allow a better and more exact delineation of the intrusives together with the local complexity of the folding and the disturbances created by the emplacement of the granitic intrusive bodies to the southwest, northwest, and southeast. Faulting may have also played an important part in this apparent discordance of structure.

The intrusives of gabbroic composition are considered as having been introduced as sheets or sills, prior to the main period of dynamic metamorphism which folded them along with the intruded volcanic or sedimentary formations. In general, the contacts between the intruded series and the intrusive bodies are quite sharp although, in some cases, there is a zone of transition between the two types of rocks, and the boundaries of each are difficult to draw. This "transitional" type of contact is well exhibited on a large exposure about one and a half miles north of the eastern extension of Capisisit lake. There, the intruded rock is a fine-grained, somewhat schistose, basaltic lava and, as one approaches the gabbroic intrusive from the south, the amphibolite schist of the altered basaltic lava is seen to become gradually coarser grained, less and less schistose, and grading slowly into massive, medium-grained, amphibole-rich gabbro.

In general, the large bodies of gabbroic rocks are quite massive away from their contact with the intruded flows or beds, whereas they are schistose at the periphery. The small masses display a good schistosity concordant with that of the adjoining volcanic or sedimentary rocks. It is obvious that the gabbro bodies were more resistant to dynamic metamorphism than the associated volcanic flows and sedimentary beds. The various grades of metamorphism reached by the gabbros of the area during the main period of stresses will be treated along with the metamorphism of the volcanic and sedimentary rocks in the following chapter.

The "gabbroic" rocks of the area are fine to coarse grained and vary in color from almost black to almost pure white, passing through the various shades of green, depending upon the relative abundance of ferromagnesian and feldspathic minerals. The following types of rock are found: serpentine, more or less altered pyroxenite, basic gabbro, olivine norite, norite, hyperite, gabbro, dioritic and anorthositic gabbro, diorite and anorthosite.

Buddington (35), in his description of the gabbro-anorthosite rocks of the Adirondacks writes:

> "The division lines for different rock facies of the gabbro-anorthosite group have for purposes of description in this report been set as follows:
> Anorthosite, 0 to 10 per cent mafic minerals; gabbroic, noritic or dioritic anorthosite, 10 to $22\frac{1}{2}$ per cent mafic minerals; anorthositic or feldspathic gabbro or norite, $22\frac{1}{2}$ to 35 per cent mafic minerals; gabbro or norite, 35 to 65 per cent mafic minerals, and mafic gabbro or mafic norite, 65 to $77\frac{1}{2}$ per cent mafic minerals" (p. 19).

The present writer has set his divisional lines approximately as follows: anorthosite, 0 to 10 per cent mafic minerals; diorite, 10 to 25 per cent mafic minerals; dioritic or anorthositic gabbro, 30 to 40 per cent mafic minerals; gabbro, norite, or hyperite, 40 to 75 per cent mafic minerals; basic gabbro or norite, 75 to 90 per cent mafic minerals, and ultrabasic facies, 90 to 100 per cent dark-colored minerals.

A look at the map will show that these different types of intrusive rocks were not mapped separately. An sttempt to do so was made in the field, but the difficulty of identifying them with the only help of a portable lens, and especially their more or less advanced alteration and the somewhat irregular distribution of their exposures due to their closely related origin, together with the small size of some of the intrusive masses, made the task impossible. Specimens of each of the numerous types of "gabbroic" rocks above-named were collected, and a good number of them studied under the microscope. They are described below.

Serpentine

Only very few exposures of serpentine rock were located throughout the area underlain by the basic and ultrabasic types of intrusives. They were, in all cases, closely associated with exposures of altered pyroxenite, and the two were very difficultly separated in the field. They are fine-to medium-grained, very dark green, almost black rocks which weather rusty green. One specimen collected from a small exposure at a locality about half a mile west of the western shore of Renault lake and half a mile north of the southern boundary of the map-area, was studied under the microscope with very unsatisfactory results.

The rock is essentially composed of pale green to almost colorless flakes of antigorite and fibrous green chrysotile. Some of the serpentine appears faintly pseudomorphous after a pyroxene and is probably bastite, but most of it occurs in somewhat rounded accumulations of flakes of antigorite surrounded by rims of fibrous, darker green chrysotile. Dust-like particles of iron oxide (probably magnetite) are scattered through the rock, but their distinctly oriented concentration in some of the rounded grains suggests the irregular cracks ordinarily found in olivine. Grains of ilmenite, partly gone to leucoxene, are also seen in association with the magnetite. A little chlorite is present in the interstices between the serpentine crystals and is a highly pleochroic, dark green penninite. Secondary amphibole, probably uralite, also occurs in small amount. It is believed that most of the serpentine was derived from an olivine-rich rock containing a subordinate amount of pyroxene, probably enstatite or hypersthene.

Pyroxenite

Relatively fresh to completely altered pyroxenitic facies of the "gabbroic" rocks are found throughout most of the area underlain by the basic to ultrabasic intrusives, but more abundantly in the southern half and especially in the large gabbroic body in the south central section of the area. There, exposures of a highly pyroxenic facies of the intrusive occur close to the southern edge of the belt of gabbro north of Capisisit lake, and along the northern contact of the tabular mass south of the same lake. Farther towards the southwest, pyroxenic intrusive rocks outcrop abundantly on the ridges south of Inconnu river, along and slightly east of the north-south survey line, on each side of the seventy-sixth meridian, slightly north of the southern boundary of the map-area, and on the two ridges immediately west of Renault lake. Other much smaller occurrences of pyroxenite are to be seen scattered throughout the map-area, such as in the tabular gabbroic masses just north and west of Colette lake, south and west of Branssat lake, etc. The best exposures of this type of ultrabasic rock are, however, concentrated in the main mass of gabbro of the south central section of the area.

To the naked eye, the fresh pyroxenites appear as medium-to coarse-grained rocks which weather rusty brown. On freshly broken surfaces, they are dark green, and the shiny surfaces of the pyroxene grains are very conspicuous. They are generally massive and have a high specific gravity. They readily alter to amphibolite, probably uralite, and this process of uralitization is much more advanced in the larger masses than in the small ones.

The fresh pyroxenites examined under the microscope consist of an aggregate of rhomboids or prismatic grains of diopside up to 10 mm. long, with secondary amphibole, and a low amount of serpentine and iron ores. The diopside makes about 75 per cent of the rock, and its products of alteration, secondary amphibole and serpentine, about 20 per cent. Iron ores and their products of alteration make about five per cent of the constituents. The diopside is pale greenish brown, very slightly pleochroic, and it commonly exhibits well-developed parting or striations parallel to the orthopinacoid or (100) cleavage characteristic of diallage. Other grains have prismatic outlines. The plane of the optic axis is parallel to (010), and the extinction angle $C \wedge Z$ around 42°. The mean index of refraction, as determined by oil immersion, is close to 1.695. The maximum interference color is blue of the first order, and the maximum birefringence is 0.024-0.027. It is biaxial positive, with an angle very close to 60°.

The texture of the pyroxenites is generally granular, although, in some specimens, it is slightly schistose, and the diopside grains occur as an interlocking mosaic. Some occur as well-formed, fresh crystals, but the majority are surrounded by a rim of slender parallel prisms of green to pale green uralite having the optical properties of actinolite. This rim is generally less than 0.5 mm. thick in the least altered pyroxenite rock, but it becomes gradually thicker as the rock becomes more altered and more schistose. The final product is an amphibolite in which relics of pyroxene crystals may or may not be visible in the amphibole grains, and the rock has then generally a schistose texture.

Serpentine makes about five per cent of the fresh pyroxenite rock, and some of it is associated with uralite and is probably a product of alteration of the diopside. Fibrous antigorite also occurs in rounded agglomerations containing abundant very fine grains of iron ores, and this is believed to be the result of alteration of grains of olivine which were probably present in the very fresh pyroxenite. The olivine did not make more than five per cent of the rock in any of the specimens studied.

Iron ores form an interesting constituent of the pyroxenites. Magnetite and ilmenite are the two main species, and a low tenor of pyrite is present in the most altered specimens. As stated above, abundant very fine dissemination of magnetite occurs with the antigorite apparently secondary after olivine. Very fine dust of iron oxide, probably magnetite, occurs also commonly in dense concentrations in the individual grains of pyroxene and gives them a characteristic schiller appearance.

Ilmenite occurs in fairly large grains up to 3.0 mm. across. Those grains are rounded and commonly surrounded by a rim of whitish opaque leucoxene which, in the more altered facies of the pyroxenites, may, in turn, be surrounded by a rim of titanite. Small cubes of pyrite are disseminated in some of the pyroxenites.

Basic Gabbro or Norite, Olivine Norite, Norite, Hyperite, Gabbro

Intimately associated with the serpentines and pyroxenites and undoubtedly derived from the same magma, is a series of pyribole-rich rocks containing variable amounts of plagioclase-feldspar. These rocks of the gabbroic type constitute the main portion of the basic intrusive masses outlined above and shown on the accompanying map. Several different facies can be distinguished in this gabbroic suite but, for the reasons stated above, they were not mapped separately.

In the most basic varieties, plagioclase feldspar and its products of alteration make about 10 per cent of the rocks, and gradations can be followed in the field from ultrabasic pyroxenites or amphibolites in which plagioclase feldspar is totally absent to dioritic or anorthositic gabbro in which there is only ten per cent ferromagnesian minerals and, in a few cases, to an almost pure plagioclase rock or anorthosite.

A specimen of plagioclase-poor gabbro was selected from the southern edge of the gabbro hill located slightly over one mile north of the east end of Capisisit lake. The rock is a massive, medium-to coarse-grained, mafic-rich gabbro. Light-colored constituents are very low, about 15 per cent, and a faint ophitic texture is recognizable. The rock weathers dark brownish green and has a soapy appearance on fracture.

Under the microscope, this gabbro appears as made essentially of over 80 per cent ferromagnesian minerals and about 15 per cent altered plagioclase-feldspar. The rock is holocrystalline, subhedral, medium grained, and has a faint poikilitic texture with small, diversely oriented, altered grains of plagioclase included in the large pyroxene or amphibole crystals. Hypersthene and its product of alteration, uralite, make over 75 per cent of the rock, and olivine and serpentine about two per cent.

The calcity of the plagioclase is difficult to determine accurately, on account of the intense saussuritization of the grains, but it is certainly as high as An_{60}. Biotite is a product of alteration of the pyroxenes and amphiboles, and apatite is present in small amount. Fine dust of magnetite is scattered through the pyroxene and concentrated along cracks in the partly-serpentinized olivine grains. Ilmenite, surrounded by leucoxene, also occurs in medium-sized grains. The rock is an olivine norite, and its low content of plagioclase, together with the presence of olivine, makes it an intermediate type between the ultrabasic facies and the main mass of slightly more acidic gabbro.

The typical gabbro of the area is a medium-to coarse-grained rock varying in color from dark green to pale green, depending upon the relative abundance of ferromagnesian and plagioclase minerals. The massive varieties ordinarily exhibit in the field a mottled appearance due to the differential weathering of the light-colored plagioclase and the dark green ferromagnesian minerals. On fresh surfaces of the least-altered varieties, a diabasic texture is commonly visible, and the dark-colored minerals appear to blend one into the other. In the more altered and schistose types, the original constituents are not recognizable, and the finer-grained facies of the intrusive is, in places, difficult to identify with the intruded altered basaltic lavas which may possess almost identical textural and mineralogical characteristics.

Under the microscope, the typical gabbro is medium-to coarse-grained rock showing a faint ophitic or poikilitic texture and composed mainly of altered pyroxenes and labradorite, with subordinate amounts of iron ores, leucoxene, titanite, apatite, and alteration products. The rock is generally even grained, and the grains average 2.0-4.0 mm. in size. Very fine or very coarse-grained facies are locally found.

The calcity of the plagioclase does not vary very much and averages about An_{60}. The amount of plagioclase in the rock, however, varies widely, and all the transitional types of rocks between the basic and the anorthositic facies are found. The most abundant pyroxene is diopside. Locally, however, diopside is partly or completely replaced by hypersthene or enstatite, and the rock becomes a hyperite or a norite. In the majority of the sections observed, the pyroxenes are much uralitized, and only small remnants or relics of them are to be seen in large secondary hornblende grains. Epidote and clinozoisite are the commonest products of alteration of the plagioclase.

Dioritic and Anorthositic Gabbro, Diorite, Anorthosite

Mafic-poor facies of the gabbroic suite of intrusives are found in many of the larger masses of the area. In the small and very small bodies, they are characteristically absent. The best exposures of the plagioclase-rich facies of basic intrusives are found in the large mass located in the south central part of the area and in the series of ridges south and west of Branssat lake.

In the southern section of the area, exposures of the dioritic or anorthositic facies of the gabbro occur near the northern edge of the belt north of Capisisit lake and close to the southern boundary of the southern belt. Good exposures of slightly-banded gabbro are present about one mile north of the southern limit of the map-area and about three quarters of a mile east of the contact between the basic intrusive and the Waswanipi granite. Lenses and layers of dioritic to anorthositic material also occur at localities a short distance east and west of the portage between Capisisit and McDonald lakes, and lenticular segregations and narrow dykelets of creamy white anorthosite cut the dioritic facies of the gabbro, on the ridges south and west of Branssat lake.

The best exposures of plagioclase-rich representatives of the gabbro clan are, however, along the northeast margin of the mass north-northwest of Renault lake and along the northern border of the elongated body south of Gilles bay and Inconnu lake. At a locality about one and a half miles northwest of the north end of Renault lake, the gabbro complex is highly dioritic and exhibits well-defined banding and anorthositic segregations and dykelets. The layers are generally thin, not exceeding two inches, and vary in composition from close to 100 per cent ferromagnesian minerals to 100 per cent plagioclase. The anorthositic layers are creamy white, and the plagioclase appears highly crushed. The bands strike about S.35°E. and dip about 45° towards the east. The small size and paucity of the exposures did not permit to follow the layers for more than a few feet along their strike, but their width appears to be quite constant along the observed length. The contact between the different layers, although generally well defined, is not an intrusive contact, and the crystals of one layer frequently interlock with those of the adjoining layer. In the layered gabbro observed at the above-mentioned locality, there is a gradual increase in the proportion of plagioclase in going towards the southeast to a maximum in which the rock is made of less than ten per cent hornblende and more than 90 per cent light-colored constituents. Beyond the point, the composition abruptly changes, and the rock is a basic gabbro containing not more than 20 per cent plagioclase. The layers do not seem to have a marked symmetry. Anorthositic dykelets cut across the bands at any angle and are composed of an almost pure plagioclase rock.

Slightly north of the above locality, the rock is a medium-to fine-grained dioritic gabbro containing about 50 per cent plagioclase feldspar and 50 per cent hornblende. The hornblende is idiomorphic, and the plagioclase fills the interstices between the amphibole prisms. This medium-to fine-grained dioritic gabbro is cut by numerous lenses and dykelets of a coarse-grained intrusive of similar composition. The texture of the rock is pegmatitic, and the prisms of hornblende are up to one and a half inches long. The plagioclase is interstitial to the hornblende which is apparently secondary after pyroxene. The plagioclase is greenish white and much saussuritized, especially where it is associated with secondary quartz which occurs in well-developed opalescent eyes. Small grains of magnetite are disseminated through the rock and especially as inclusions in the hornblende crystals.

Other occurrences of pegmatitic gabbro were noticed throughout the basic intrusive masses, but more commonly in association with the more acidic facies of of the gabbro clan.

The typical dioritic facies of the gabbro is a medium-grained rock containing mainly plagioclase feldspar and hornblende and their products of alteration. To the naked eye, it generally appears as a light green rock, and the distribution of the light and dark-colored constituents is quite apparent on weathered polished surfaces. The feldspar is creamy white and appears highly altered, and very fine shiny sericite flakes are visible on some surfaces of fracture.

In thin sections, the diorite appears as a holocrystalline, subhedral, and much altered rock containing between 20 and 35 per cent secondary bleached hornblende, between 60 and 75 per cent andesine or its products of alteration, and a low content of iron ores. The texture is generally granular, and the plagioclase grains tend to fill the interstices between the better-developed hornblende crystals. The hornblende is light colored, only slightly pleochroic from pale green to almost straw brown, and it contains abundant very fine dust of iron ores, probably magnetite. The maximum extinction angle $C \wedge Z$ is 21°, and the mineral is biaxial negative with a axial angle of about 55°. It is probably a bleached pargasite.

The plagioclase feldspar of the diorite is intensely crushed and altered, and it seems that the more anorthositic the rock gets, the more intense are the cataclasis and the alteration. A few fairly reliable determinations of the calcity of the plagioclase of the diorite were made and they indicate that it is an andesine of the approximate composition An_{40}-An_{45}. The plagioclase is, however, generally thickly saussuritized and replaced by epidote, clinozoisite, sericite, and secondary albite or sodic oligoclase. Carbonates and quartz may or may not be present. The presence of titaniferous magnetite is marked by some relatively large opaque black grains surrounded by rims of white leucoxene and titanite.

A few specimens were secured from the anorthositic layers and dykelets. The purer anorthosite is a creamy white rock having a highly feldspathic appearance. It contains small and numerous irregular patches of a pale green substance, apparently saussurite. The rock appears generally highly crushed and, if faint outlines of crystals suggest that the rock was coarse grained before its shattering, no definite evidence confirming this suggestion was found.

Under the microscope, the rock appears as composed of a very fine aggregate of secondary minerals with only faint remnants of primary constituents. Only few poor determinations of the calcity of the primary plagioclase were possible on account of the intense saussuritization and fracturing. The plagioclase appears to have been a calcic andesine varying in composition from An_{42} to An_{46}. Some sections consist of about 90 per cent zoisite and clinozoisite with only a little sericite and carbonates; other specimens are made almost entirely of sericite, but the average anorthosite now consists of about 70 per cent saussurite and 25 per cent sericite. Secondary amphibole and chlorite make about three per cent of the rock. Some specimens show fracturing and introduction of quartz, andesine, and epidote in very thin veinlets. This injected andesine appears to be slightly more sodic than the original primary plagioclase.

Genesis of the Gabbro Complex

Large masses of gabbro very seldom have a homogeneous composition, and variations like the ones observed in the present area have been described and discussed by numerous writers. The gabbro and associated pyroxenites, diorites, and anorthosites of the Chibougamau (14 and 97), Opémisca (112 and 115), and Opawica (128 and 130) regions are very similar to the ones of the present area and are probably related to them. The Bell River Complex, about 65 miles to the west of the present area, has been studied by Freeman (61 and 62) and especially by Black (27). The Duluth gabbro has, like the one of the present area, an ultrabasic (pyroxenite) and a plagioclase-rich (anorthositic) facies, and the Bushveldt Complex also ranges in composition from an anorthosite to a pyroxenite. Banded basic rocks were described by Harker in 1908 (167), Ussing in 1912 (148), Junner in 1929 (168), Buddington in 1939 (35), and by many others.

So it is obvious that the features observed in the gabbro complex of the present area are not unusual in basic masses of a certain size, and most of the geologists who have described them have also discussed their probable mode of origin.

They generally agree that the different facies of the complex are the product of differentiation in situ of a gabbroic magma. Cooke presents good evidence of that along with his description of a large Tertiary intrusion of gabbro in the East Sooke Peninsula, Vancouver Island (165). Bowen (29) considers the anorthosite of the sills of Thunder Bay, Ontario, as a gravitation differentiate in place from a diabasic magma. Grout (69), for the anorthosite of the Minnesota sills, the Winchells (after

Van Hise and Leith) (149), for the anorthosite of part of the Duluth lopolith, Wagner (171), for the banding of the Bushveldt lopolith, Norman (115), for the gabbro-diorite sills of the Opémisca area, Black (27), for the Bell River Complex, etc., came to a similar conclusion.

In fact, the problem of the origin of the banded basic rocks is the problem of the origin of the anorthosites found in much larger masses in different parts of the world. The masses of gabbro of the present area are too small, and the exposures of the different facies too few and scattered to permit a lengthly discussion on their origin, but a table taken from Buddington's memoir on the Adirondack igneous rocks (35, p. 209) gives a good summary of the hypotheses put forward by the most distinguished workers on the problem of the origin of the anorthosite in general, hypotheses which can be applied to the genesis of the gabbro complex of the present area.

Major phases in development of anorthosite, gabbro, syenite, and granite as visualized by certain geologists

Bowen (1917)	Miller (1918 and 1929)	Grout (1928)	Balk (1931)	Buddington (1936)
1. Intrusion of gabbroid magma in form of laccolith.	1. Intrusion of a gabbroid magma in form of a laccolith.	1. Intrusion of a basaltic magma in form of a sill.	1. Intrusion of a magma of intermediate composition resembling a diorite, in form of a lens tilted to the northeast.	1. Intrusion of a gabbroic anorthosite magma; multiple domical roof, shape otherwise unknown. Local outlying sheets.
2. Development of an upper chilled, gabbroid border facies.	2. Development of an upper and outer chilled gabbroid border facies.	2. Development of a chilled gabbroic border at the top and bottom.	2. Border facies is not a chill zone but a more strongly deformed portion.	2. Development of a composite gabbroic anorthosite border facies, as a chilled zone.
3. Settling of mafic crystals to form gabbro and peridotite at the bottom.	3. Probable settling of mafic crystals to form gabbro and peridotite at the bottom, leaving residual anorthositic magma.	3. Rise of plagioclase phenocrysts in magma to form a zone of gabbro below, grading up into anorthosite beneath chilled roff facies.	3. Aggregation in the magma of crystallized minerals with local concentration of a mafic ones to form spherical bodies of gabbro.	3. Partial settling of mafic minerals during consolidation resulting in a true anorthositic body above.
4. Settling of plagioclase crystals to form anorthosite above gabbro, and leaving a syenitic magma above.	4. Solidification of residual plagioclase-rich magma to form a large body of anorthosite between gabbro and chilled border.	4. Development of a basic zone near the base through settling of mafic crystals, and solidification of lower half of chamber, leaving a more alkalic and siliceous magma beneath anorthosite. Some disturbance.	4. Aggregation of labradorite crystals and clusters in the magma to form anorthosite masses.	4. (a) Segregation of local bodies of gabbro and mafic gabbro formed in connection with differentiation of gabbroic anorthosite. (b) Widespread intrusion of olivine gabbroic magma as sheets and local dikes.
5. Solidification of residual syenite magma between upper chilled border and anorthosite. "Transitional rocks" are facies of the differentiation.	5. Distinctly later intrusion of a batholithic mass of syenite-granite magma. The "transitional rocks" are the result of magmatic assimilation of still hot anorthosite by syenite or granite magma.	5. Final differentiation leaves a granitic residual magma which may intrude anorthositic facies to yield "transitional rocks."	5. Squeezing out of residual syenite-granite magma to leave anorthosite as a crystal residue. "Transitional rocks" are those in which the syenitic or granitic magma is not entirely cleared of labradorite crystals during differentiation by squeezing.	5. Distinctly later widespread intrusion of quartz syenitic magma as sheets and local stock-like masses. Extensive gravity stratification of thickest sheets yields mafic syenite to granite. Local "transitional rocks" formed by injection and disintegration of anorthosite.
				6. Period of orogenic deformation and dynamic metamorphism accompanied in later stages by granitic intrusions of batholithic character on a large scale and as sheets and phacoliths on a small scale. Local "transitional rocks" formed with syenite and anorthosite. Local deformation continues after emplacement of granite.

In short, a gabbroic magma was emplaced in numerous thin, medium, and thick, relatively extensive sills between the nearly or flat-lying volcanic flows and sedimentary beds. There was uplift of the roof rocks or depression of the floor or both of these in at least certain cases as shown by some of the lenticular blunt masses, but there is nowhere definite evidance that the magma was transgressive. Cooling and crystallization was much faster in the small and thin sill-like intrusions, and no extensive differentiation of the constituents could take place, and thus the generally homogeneous gabbroic composition of the minor masses of the area.

In the larger masses, cooling was much slower, and early-formed olivine and pyroxene crystals sank to the floor giving the peridotite and pyroxenite. With further cooling, more mafic crystallized together with calcic plagioclase to form gabbro above the peridotite and pyroxenite, and then, dioritic gabbro, gabbroic anorthosite, and anorthosite were deposited in sequence one above the other.

Filter-pressing and external stress were probably the effective agents in the squeezing out of the probably plastic or partly crystallized plagioclase-rich material to produce the dykelets and lenticular injections now cutting through the main mass of the rock.

The layers may have resulted from a number of processes, such as successive additions of magma, subsidence of the floor, convection currents, difference in specific gravity of the crystals, movement within the crystal mesh just before consolidation, etc. That there ~~was~~ were at least two different intrusions of magma is indicated by a few cross-cutting relationships observed in the field. Small dykes of pegmatitic gabbro cut across the banded intrusive at the locality defined above, and a few occurrences of small, fine-grained, discordant gabbro dykes cutting through the larger mass were noticed at scattered points.

Several syenitic, granitic, and aplitic dykes and quartz veins were observed cutting through the gabbroic rocks of the area, but they are thought to be related to the later granitic intrusions of the region. The injections of gabbroic magma were probably on too small a scale to have produced a significant residual syenitic-granitic magma such as is usually found with the large masses of anorthosites and gabbros.

The fact that gravity differentiation and gravity stratification are considered to be the most plausible explanation for the presence of facies of different composition in basic igneous rocks, especially where layers are present, has an important bearing on the working out of a complex structure.

As Buddington puts it in 1939 (35):

> "In all cases where there is transitional gradation from the mafic to the felsic layer, on a moderate scale, the gradational transition is slowly upward in the direction of the more felsic layer" (p. 91).
>
> "Such gradational units may therefore, if proper precautions and judgment are exercised, and particularly if statistical treatment is possible, be used to determine the direction in which the top lies in complex structures in a fashion similar to that by which graded bedding is used to determine the tops of sedimentary beds where the question is that of overturning" (p. 91).

Applications of that principle in helping to work out the structural features of the area will be made in the chapter on the structural geology of the area.

Chapter V111

METAMORPHISM OF THE PRE-GRANITIC ROCKS

General Considerations

The pre-granitic rocks of the area, *i.e.*, the volcanics, sediments, and "old" gabbros have after and, to a smaller extent, during the final stage of their emplacement found themselves under external conditions which were different from the ones prevailing at the time of their making and with which they were in equilibrium. In response to those changes in external conditions, *i.e.*, temperature and stress, the rocks have tended to reestablish the disturbed equilibrium and to readjust themselves to the new environments. As a result, profound changes have been induced in their structure, texture, and constituent minerals.

Although some of the pre-granitic rocks of the area have been both locally and regionally altered and transformed, the effects of regional metamorphism are much more apparent and they are responsible for the main structural, textural, and mineralogical transformations which occurred in them. The structural changes are the development of linear characters such as a schistosity, the elongation and flattening of pillows in amygdaloidal lavas, the elongation of pebbles and fragments in conglomerates and volcanic breccias, drag folding, etc. Mineralogical changes include mainly the chemical destruction of the primary constituents of the rocks and the formations of new minerals more nearly in equilibrium with the new environments at the time of the maximum intensity of stress and of the corresponding elevation of temperature.

Barrow, in 1893 (15), in a study of an area of metamorphosed sedimentary rocks of the southwestern Highlands, showed that zones of different intensity of metamorphism could be distinguished by mapping the distribution of certain characteristic or critical minerals of the rocks. Tilley, in 1925 (141), extended Barrow's concept, added precision to the term "zone" as defined by Barrow, and has since been an active student of metamorphic rocks, continuing his work along the same line.

A metamorphic "zone" is, after Tilley (141), an area bounded by lines or isograds drawn between points of first entry of the distinctive new minerals into the assemblage. Such a line, joining, for example, the points at which garnet appears in the suite, must be, if the rock possesses constant textural and structural characteristics, a line of equal pressure and temperature.

According to Tilley, an isograd may be defined as "a line joining points of similar P. T. values under which the rock as now constituted originated". More precisely, an isograd is the intersection of an inclined or vertical isogradic surface with the earth's surface.

Theoretically, a separate isograd may be drawn on the earth's surface for each newly-produced mineral in a progressively metamorphosed series of rocks. However, as it is in rocks having the composition of ordinary argillaceous sediments that the successive stages of advancing metamorphism are most clearly indicated by corresponding mineralogical changes, and since six really characteristical minerals appear one after the other during the process of their progressive metamorphism, six metamorphic zones are recognized as a matter of common practice (74). These and their bounding isograds are as follows:

Chlorite zone
   Biotite isograd
Biotite zone
   Garnet isograd
Garnet zone
   Staurolite isograd
Staurolite zone
   Cyanite isograd
Cyanite zone
   Sillimanite isograd
Sillimanite zone

This sequence of zones of characteristic minerals for argillaceous sediments and other types of rock which have been worked out by different authors are generally of difficult application in Precambrian rocks, owing to the generally considerable variations in composition, texture, thickness, and competency of the rock formations which have been subjected to metamorphism and to the general paucity of rock exposures. However, some workers have succeeded in mapping them fairly accurately. Ambrose has successfully used this method in discussing the regional metamorphism of the Missi Series near Flin Flon, Manitoba (4), in which the original rock was "a greywacke astonishingly uniform in grain size and composition" (p. 260). The occurrence of small patches of volcanic rocks throughout the different metamorphic zones of the Missi Series also allowed Ambrose to study their progressive metamorphism along with the one of the sedimentary beds and to make the correlation between the two.

Since, as stated above, regional metamorphism has been by far the more important and active factor in promoting changes in the pre-granitic rocks of the area under study, it is permissible to postulate that, in general, both the structural and mineralogical changes will be closely related in intensity. The pre-granitic rocks of the area are, broadly speaking, composed of: a) relatively thick flows of basalts and andesites; b) thin flows of fragmental lavas, flow breccias, and tuffs; c) conglomerates; d) waterlaid sediments varying in composition from highly basic through argillaceous to highly feldspathic and, occasionally, highly siliceous and in thickness from fractions of an inch to scores of feet; e) basic intrusive masses varying in composition from ultrabasic to anorthositic and in size from a few square feet to square miles.

It is obvious that the ideal conditions of the South-Eastern Highlands of Scotland and of the Flin Flon district are not realized here, and that the different zones of same intensity of metamorphism will be difficult to distinguish and map with a reasonable degree of accuracy. The differences in composition, texture, structure, and competency between the various types of rocks were such that they did not respond with the same readiness to the stresses which were applied to them during the regional metamorphism. The massive, resistant, and large gabbroic masses of the area were less changed structurally and mineralogically than the volcanic and sedimentary rocks, and the thick lava flows and sedimentary beds were also less metamorphosed than the thin beds of tuffs, breccias, etc.

Furthermore, retrogressive metamorphism, thermal metamorphism in the vicinity of inrusive masses, circulation of magmatic waters, etc., have also contributed to local changes in the composition and appearance of the rocks and, consequently, to increase the difficulty of tracing the different isograds and of mapping the zones of different intensity of regional metamorphism.

Broadly speaking, rocks of the chlorite, biotite, and garnet zones of Barrow's sequence (15) are found in the argillaceous, feldspathic, and siliceous sedimentary beds of the area, and the corresponding grades of metamorphism occur in the volcanic, gabbroic, and basic sedimentary rocks. An outstanding feature of the basic intrusive, extrusive, or clastic rocks of the area is the abundance and variety of minerals of the amphibole group. It is thought that a study of the characters of those amphiboles and of their association with other minerals may help in a better understanding of the process of metamorphism of the basic rocks in general.

Amphiboles

The different varieties of amphiboles can be best studied in the gabbroic intrusive masses of the area on account of their abundance in this type of rock and especially because of the various grades of metamorphism beautifully shown by some gabbroic bodies which go from very fresh and massive at their center to as schistose and metamorphosed as the surrounding volcanic or sedimentary rocks at or near their periphery.

Three different types of amphiboles can be distinguished in the basic intrusives, two of which also occur in the metamorphosed volcanic and sedimentary rocks and are by far more abundant than the first one.

Primary, dark blue-green hornblende was identified in low amount in a certain number of specimens of the gabbros, and one of the latter, taken from a coarse-grained, basic gabbro dyke located in the south central part of the area, is made of 65 per cent of primary hornblende, 20 per cent of acid labradorite, 10 per cent actinolite, together with large agglomerations of magnetite and ilmenite. The labradorite is slightly saussuritized but it is well twinned and easily identifiable. The gabbro has a faint ophitic texture.

The primary hornblende is dark blue-green, highly pleochroic, and it occurs generally in stout prisms somewhat altered at their contact with the plagioclase grains into pale green, acicular actinolite. Pleochroism parallel to Z is dark blue, parallel to Y, olive green, and parallel to X, light brown. The absorption is Z>Y>X. The indices of refraction are slightly higher than the surrounding actinolite, and n_β is close to 1.68. The maximum interference color is bluish green of the second order, and the birefringence is close to 0.026. The maximum extinction angle $Z \wedge C$ is 27°, and the mineral is biaxial negative with an axial angle of about 75°. The larger hornblende grains contains fresh magnetite and titaniferous magnetite in fine to very fine dissemination, also in agglomerations and in fairly large skeleton crystals. Little definitely primary hornblende was recognized in the basic intrusive rocks, and none in the volcanic and sedimentary series.

The most common type of amphibole in the basic intrusives and in the slightly metamorphosed volcanic rocks of the area is a pale green to green, slightly pleochroic actinolite. It occurs in small amount in association with antigorite as a product of alteration of olivine which it commonly surrounds in minute needles at the contact with plagioclase grains. Its most widespread occurrence is, however, in association with the different members of the pyroxene group which it replaces in all stages, from narrow rims around the margins of grains or grain agglomerations to large poikilitic grains enclosing tiny relics of pyroxene. In the case of the orthorhombic pyroxenes and diallage, the replacement proceeds from the margins and the planes of cleavage, and several remnants of the same large pyroxene grain may be left isolated in a single poikilitic amphibole grain. In the case of ordinary augite and diopside, there is also the marginal replacement, and, in addition, small irregular patches of amphibole develop throughout the grains, in advance of the main front of complete replacement.

This type of amphibole is generally acicular and fibrous, green to pale green in color, and slightly pleochroic with X, straw Y, greenish yellow, and Z, pale green to green. The absorption is Z>Y>X, and the refractive indices are slightly lower than those of the primary hornblende, that is, $n_\beta \simeq 1.66$. The maximum interference color is purple-red of the first order, and its optical orientation $Z \wedge C = 17^{\circ}-21^{\circ}$. Its dispersion is generally very low with r>v, and the mineral is negative with an axial angle of about 82°.

It was observed that, in some of the specimens of massive gabbro studied under the microscope, large pyroxene grains were almost completely intact except for a narrow border of pale green, acicular amphibole surrounding them. In other cases, the pyroxenes were completely or partly altered to green fibrous amphibole surrounded by a pale green phase which was definitely identified as later than the green phase in to which it seemed to grade slowly. It was noticed also that the green type of fibrous amphibole appeared more abundant in the specimens selected from the largest masses of gabbroic intrusives.

From the above considerations, it may be concluded that the fibrous green and the pale green amphiboles of the gabbros represent two different types of alteration of the pyroxenes. The green phase is probably the result of magmatic uralitization of the early-formed pyroxene crystals, i.e., there appears to have been a late magmatic reaction in the closed system between the interstitial liquid and the earlier-formed pyroxenes in the larger basic to ultrabasic masses of the area. In the smaller masses, cooling was too rapid, and no such magmatic reaction had time to take place. Abundant very fine iron oxide dissemination is present in both the green and the pale green amphiboles. The pale green amphibole associated with the olivine is also of the magmatic type and is, in all observed cases, in close association with the green uralite of the large masses. In some specimens, it also grades into a green-brown hornblende, very rich in iron and, in places, pseudomorphous after olivine.

The pale green phase of the actinolite is the dominant mineral of the lava flows and basic sediments which have been subjected to the lowest intensity of regional metamorphism (see plate X11, A). As in the cases of the gabbros, the mineral contains generally fairly dense dissemination of fine iron oxides and is commonly associated with a little chlorite. It is possible that most of this actinolite is the product of alteration of pyroxene minerals in the lava flows, but no relics of pyroxene could be found in the specimens studied, and, if the abundance of disseminated iron ores suggests such an origin, no other criteria are at hand to confirm such a suggestion.

The green and pale green actinolite is generally found in gabbros and lavas the feldspars of which have been partly or completely chemically disintegrated by regional metamorphism and, in a few cases, an identifiable primary feldspar is found in association with them. They represent a low grade of metamorphism which is rather the stage of breaking down of the plagioclase feldspar the calcic components of which give rise to a very fine aggregate of new aluminosilicates of lime of the epidote group, whereas the sodic components separate out as granules of albite too small and too intimately associated with the new aluminosilicates to be identifiable as individual grains under the microscope.

This green and pale green amphibole grades into and is associated with a blue-green hornblende of a different type. All stages of gradation from the pale green, fibrous actinolite to the stout prisms of the highly pleochroic, blue-green hornblende can be seen in the volcanics and, to a smaller extent, in the gabbroic and sedimentary rocks. As stated above, the fibrous actinolite is pale green, very slightly pleochroic,and is clouded by fine grains of iron oxides. At the first stage of the gradation into the blue-green hornblende, stage which corresponds to the appearance of identifiable small grains of clearer, newly-formed albite, the actinolite becomes slightly greener and clearer but is still generally fibrous. At later stages, the amphibole looses its acicular forms and becomes more deeply colored, and the final product is a granular, clear, strongly pleochroic, blue-green hornblende characteristic of the higher grade of metamorphism of the gabbroic, volcanic,and basic sedimentary rocks of the area (see plate Xll, B). It is closely similar to the one described by Rice, 1935 (122), except that it does not tend to have its "plume-like" habit, but is generally found in stout prisms and granules.

The most characteristic features of the hornblende are a strong bluish green to greenish blue pleochroism, parallel to Z, deep olive green, parallel to Y, and pale yellow or straw brown, parallel to X, and its absorption Y>Z>X. Its refractive indices, as determined by oil immersion, are closely similar to the ones given by Rice (p. 308), the maximum interference color is purple blue, and its birefringence is close to 0.022. The orientation $Z \wedge C$ is 15°-20°, the axial angle about 60°, and the mineral is negative with dispersion r>v (distinct). The analyses given by Rice show, as he pointed out, the unusual relationship $Fe_2O_3 > FeO > Al_2O_3$ in type A, and $Fe_2O_3 > Al_2O_3 > FeO$ in type B.

The intensity of color, pleochroism, and clearness of the grains of hornblende increases along with the intensity of regional metamorphism and reaches its maximum in the garnet or andesine zone, the highest grade of metamorphism reached in the area.

In the following page, a table is presented giving the physical and optical properties of the diverse amphiboles of the pre-granitic rocks of the area together with the composition of the associated plagioclase feldspar, the type of rock in which the amphibole is present, and the mode of origin of the mineral.

Table of the Properties of the Amphiboles of the Pre-Granitic Rocks

	Primary Hornblende	Green Actinolite	Pale green Actinolite	Blue-green Hornblende
Shape	Stout prisms	Fibrous	Fibrous	Granular, prismatic
Color	Dark blue-green	Green	Pale green	Blue-green
Pleochroism X	Light brown	Straw	Straw	Pale yellow or straw
Y	Oline green	Pale greenish brown	Greenish yellow	Deep olive green
Z	Dark blue-green	Green	Pale green	Greenish blue to bluish green
Absorption	Z>Y>X	Z>Y>X	Z>Y>X	Y>Z>X
n_β	1.68	1.66	1.66	1.68
Birefringence	0.026	0.023	0.023	0.022
Sign	Negative	Negative	Negative	Negative
Optic Angle	75°	82°	80°	60°
Dispersion	r>v (distinct)	r>v (low)	r>v (low)	r>v (distinct)
Optical Orientation	$Z \wedge C = 24^\circ - 27^\circ$	$Z \wedge C = 17^\circ - 21^\circ$	$Z \wedge C = 17^\circ - 21^\circ$	$Z \wedge C = 15^\circ - 20^\circ$
Character and Calcity of Associated Plagioclase	An_{60}	Altered, An_{60}	Altered, An_{60}; Neocrystallized, An_{0-10}	Neocrystallized, An_{10-45}
Nature of the Rock	Basic intrusives	Basic intrusives and lavas	Basic intrusives, lavas, and basic sediments	Lavas and basic sediments
Mode of Origin	Early magmatic	Late magmatic, uralitic	Early regional metamorphism	Higher grades of metamorphism

Zone of Early Metamorphic Changes

As stated above, the pre-granitic rocks of the present area have not been affected to the same extent by the forces which acted upon them after their emplacement. The more resistant and structureless types have withstood the stresses more than the weak and thin formations and, consequently, have been less metamorphosed.

The most resistant and massive rocks of the area are undoubtedly those belonging to the basic intrusive group, and it is to be expected that some of the larger masses of gabbroic rocks may have been but slightly changed, especially in the central part of the thick sills. Such is the case, and specimens of gabbro collected from the larger bodies show that the rock has, in certain cases, pretty well preserved its original characters. Those relatively fresh gabbro rocks are particularly well-exposed in the large masses in the south central part of the area and south and north of Capisisit lake.

The primary ophitic, poikilitic, or granular texture of the least altered gabbros is still easily recognizable in a number of specimens, and the only changes which have affected the rocks are the uralitization of the pyroxene, the saussuritization of the plagioclase, the serpentinization or amphibolitization of the olivine, and the alteration of the large grains of titaniferous magnetite. The least altered specimens are still quite massive and, as the metamorphism progresses, the elongated constituents become more and more aligned, and, later, a schistosity develops.

All the mineralogical changes referred to above may be considered as partly late magmatic and partly of an early regional metamorphism origin, and it is difficult to distinguish one type from the other, as the final results are the same. In this zone of early metamorphic changes, the primary plagioclase are either present in slender laths or fairly stout prisms still retaining their euhedral to subhedral outlines and fresh enough to permit accurate determinations of their calcity. In the more altered facies, the plagioclase grains are much clouded with very fine zoisite, epidote, kaolin, iron ores, and, probably, very small submicroscopic grains of a much more sodic plagioclase. The boundaries of the individual plagioclase grains become at the same time subhedral to anhedral and, at the last stage, they are very diffuse.

Alterations of the ferromagnesian minerals goes along with the disintegration of the plagioclase, and antigorite and a pale fibrous hornblende are produced from olivine, and pale green to light green fibrous actinolite from hypersthene, enstatite, and diopside. These newly-formed minerals replace the old ones more and more until only relics of the primary minerals are present in the rock which becomes very rich in pale green and green fibrous actinolite and uralite. Abundant, very fine iron oxide grains are produced in the change of olivine and pyroxenes into serpentine and actinolite, and those grains occur thickly disseminated in the secondary ferromagnesian minerals and, to a smaller extent, in the altered plagioclase. In some of the most altered specimens, small acicular grains of pale green actinolite and chlorite occur within the saussuritized plagioclase grains, and, obviously there was transfer of material from the pyroxenes into the saussuritic aggregate.

Grains of titaniferous magnetite up to 2.0 mm. across are scattered throughout some specimens of the relatively fresh gabbro. Along with the saussuritization of the plagioclase, the uralitization of the pyroxenes, and the serpentinization of the olivine, the titaniferous magnetite becomes surrounded with a rim of white opaque leucoxene which becomes thicker in the advanced stages of the alteration and, in some sections, only rhombhedral networks of residual magnetite remain in a mass of thick leucoxene.

A few specimens collected from exposures of massive and apparently unaltered basaltic flows of the area can be classified as belonging to the latest stages of this zone of early metamorphic changes. The plagioclases of the basalts are, like the ones of the gabbros, highly saussuritized, but fairly good determinations of their calcity were obtained in at least three specimens. Pale green to green actinolite is the only ferromagnesian mineral, and its physical and optical properties are strikingly similar to the ones of the amphibole of the gabbro just described. Very fine iron oxide inclusions are also present, and the close similarity between the two amphiboles suggests a common uralitic origin.

Albite-Chlorite-Sericite-Actinolite Zone

With increasing intensity of metamorphism, new minerals start to form from the products of disintegration of the primary constituents, and the original texture of the rock begins to be destroyed. This zone of low grade metamorphism is again well represented in the basic intrusive masses of the area and, to a smaller extent, in the volcanic and sedimentary rocks.

The gabbroic rocks of this zone of low grade of metamorphism look somewhat similar, macroscopically, to the ones just discussed, but the alignment of the elongated constituents is more apparent, and, in some specimens, the rock tends to be very slightly schistose. The microscope reveals that the original ophitic, poikilitic, or granular gabbro has been almost completely replaced by a somewhat felty aggregate of secondary minerals. The texture is usually nematoblastic, and the fibrous actinolite and chlorite are generally well aligned.

Relics of pyroxenes are still visible in some of the specimens studied, and a small amount of chlorite is present in a few of them. Granules of fresh clear albite appear in association with the saussuritized primary plagioclase, and the fine grains of epidote and zoisite present in the types described above tend to grow bigger and aggregate. The amphibole is still the fibrous pale green to green actinolite, but all traces of pseudomorphism after pyroxenes or olivine have disappeared, and the iron oxides which was very finely disseminated in the uralite and actinolite tend to occur in slightly bigger grains, up to 0.2 mm. across. A very little of the primary titaniferous magnetite remains as relics in large nodules of leucoxene, and small granules of titanite begin to appear disseminated in the latter mineral. Carbonate and sericite occur in small amount in a few of the studied sections.

The changes occurring in the volcanic flows and basic sedimentary rocks at this stage of metamorphism are very similar to the ones which take place in the gabbro and which have just been described. The dominant minerals are fibrous actinolite, epidote, and zoisite, small relatively fresh albite, iron oxides, leucoxene, titanite, accidental carbonates, sericite, and introduced pyrite and quartz.

The chief constituents of the more feldspathic sedimentary rocks belonging to this zone of metamorphism are saussuritized feldspar, sericitic white mica, quartz, chlorite, epidote and zoisite, albite, actinolite, carbonates, iron ores, leucoxene, titanite and a few grains of apatite.

The rock is very slightly schistose and, under the microscope, has a slight cataclastic texture. Quartz makes generally 10 to 15 per cent of the rock, although it constitutes 50 per cent of the constituents in one section and is totally absent in others. It occurs generally in rounded, unbroken, small grains showing undulatory extinction. Clouded and saussuritized feldspar grains are the dominant constituent and secondary, clearer, and poorly-twinned albite (An_{5-8}) makes from 10 to 40 per cent of the rock. White mica and chlorite vary widely in relative proportions but generally constitute together about 25 per cent of the average sedimentary rock of this type. In some specimens, white mica greatly predominates over chlorite, in others, the reverse is true. In the lowest grade of metamorphism, the mica occurs in very small flakes concentrated together with fine epidote and zoisite, and to a smaller extent, chlorite, in highly-altered, primary feldspar grains. In higher grades, such concentrations give way to widespread dissemination through the rock, but the individual grains or flakes grow in size with increasing intensity of metamorphism. Fibrous, pale green actinolite occurs in association with chlorite in some of the more basic varieties of sediments. Apatite is present as a few small euhedral grains.

Some of the minerals such as the chlorite and actinolite seem to have crystallized at least partially before the main period of stress, and their fibres are bent and rotated. The other minerals have apparently crystallized after the maximum intensity of the regional metamorphism even if some quartz grains show undulatory extinction. Those grains would surely have been shattered if the rock had been affected by appreciable movements after they were formed. The relatively clear, untwinned, uncleaved character of the albite as well as the undeformed euhedral crystals of apatite and the white mica flakes suggest that those minerals are the result of post-kinematic neocrystallization.

Oligoclase-Biotite-Hornblende Zone

Most of the rocks of the two main zones of volcanics of the area and of the eastern half of the sedimentary belt belong to the biotite metamorphic zone as defined by Harker (75, p. 209). A few specimens of gabbro were also found to belong to this group, but at this stage, the gabbros have become somewhat similar to the basaltic lavas with which they are in common association, and only a restricted number of specimens of this type of gabbro were selected in the field. Both rocks will be treated here together under the more general name of basic igneous rocks.

To the naked eye, the basic igneous rocks belonging to the oligoclase-biotite-hornblende zone of metamorphism appear as moderately schistose, dark green rocks in which hornblende is by far the predominant mineral. The major primary structural characters of the rocks, such as flow, pillowed, or amygdaloidal structures are slightly deformed but still plainly visible. Small grains of feldspar appear as filling the interstices between euhedral amphibole prisms and acicular grains. The rock is a hornblende schist.

The microscope reveals that it is essentially composed of amphiboles, oligoclase, biotite, epidote, quartz, chlorite, iron ores, leucoxene, titanite, and accidental sericite and carbonates. The texture of the rock is generally schistose, felty, homeoblastic to porphyroblastic, and, in some specimens, poeciloblastic. The average composition of of the rock is the following:

Amphiboles	65%
Oligoclase (An_{10-28})	30%
Quartz	2%
Epidote	1%
Iron ores, leucoxene, and titanite	1%

The tenor in quartz varies from total absence to 30 per cent, but most of it has been introduced at some stage during the metamorphism, and little of it is found in the specimens which have not been affected by late magmatic solutions. Epidote is also frequently associated with hydrothermal quartz and constitutes only a low percentage of the constituents of the rock unchanged by hydrothermal metasomatism.

The association of the amphiboles of the rock with other ferromagnesian minerals, biotite and chlorite, and the character of the amphiboles themselves are very interesting. At and slightly above the biotite isograd, chlorite is still more abundant than biotite, and so is the pale green or green fibrous actinolite of the chlorite zone. As the metamorphism progresses, biotite grows at the expense of chlorite, and bluish green hornblende replaces the fibrous actinolite. The first stage of replacement of actinolite by hornblende is a change in color from pale green or green to bluish green and the elimination of most of the very fine iron ore inclusions in the actinolitic amphiboles. In the following stages, the fibrous amphibole recrystallizes into short and stubby prisms or rhombs, the blue color becomes more apparent, and the fine iron ores are absorbed by the recrystallized hornblende or collect together in a sort of <u>sammel-kristallization</u> to form much larger euhedral to subhedral crystals of magnetite. This bluish green hornblende is is the one discussed above and described by Rice (122). It is present either as small, slightly-elongated grains having their C axis parallel to the schistosity of the rocks or, less commonly, as porphyroblasts interrupting the planes of schistosity. It is apparently formed by addition of iron from the disseminated very fine iron oxide grains and of alumina from minerals of the epidote group to the pre-existing fibrous actinolite. As the change from actinolite to hornblende takes place, most of the iron oxides disappear, and the minerals of the epidote group decrease in importance.

The appearance of biotite, together with that of the greenish blue amphibole, is the phenomenon which marks the lower limit of this zone. The change chlorite to biotite takes place generally slightly before the transformation of the actinolite into the greenish blue hornblende, and fibrous actinolite is commonly present as poikilitic inclusions in biotite flakes. White mica soon disappears, and some of the chlorite persists to the upper boundary of this zone. It is probable that all the white mica is used to combine with some of the chlorite to produce biotite in the lowest grades of this zone, and the excess of chlorite persists even above the garnet isograd.

The newly-crystallized oligoclase of this zone occurs, in general, in small-to medium-sized grains, generally clearer than the albite of the preceeding zone. It is also present as porphyroblasts up to 2.0 mm. across which partly interrupt the planes of schistosity.

The sedimentary rocks of the oligoclase-biotite-hornblende zone have gone through transformations somewhat similar to the ones described above and which have affected the basic igneous rocks. The basic sediments have taken a composition closely similar to that of the altered volcanics of the same zone since their original composition was very similar to that of the lavas. The only differences are the greater amount of quartz and biotite and the lesser abundance of tremolite or hornblende.

At the biotite isograd of the more feldspathic types, the rock has a slightly better developed cleavage than in the lower stage of the chlorite zone. Otherwise, both rocks are very similar. They are made up of the same minerals except for the presence of a more calcic plagioclase and, especially, of brown mica in the biotite zone. This mineral ranges in amount from negligible at the biotite isograd to a maximum of 15 per cent of the constituent minerals.

The colored mica occurs generally in small elongated prisms, well aligned parallel to the schistosity and, at the same time, generally parallel also to the bedding. Less commonly, it is flaky and in larger grains. It is clear, highly pleochroic, very pale yellow to colorless, parellel to X and reddish brown, parallel to Y and Z. Its absorption formula is Y and Z very closely similar and much larger than X. It is probably an iron-rich variety.

Along with the appearance and increase in the amount of biotite, white mica and chlorite decrease in quantity. Close to the garnet isograd, one of the two minerals is practically missing. In the more acidic types of rock, the chlorite disappears early, and much white mica is left unused and it has a tendency to "sammel-crystallize" and form relatively large flakes. In the more basic varieties, a small amount of chlorite remains after the white mica has gone over to biotite and at least some of it seems to combine with epidote to form the greenish blue hornblende.

A few, medium-sized clastic grains of quartz remain at the biotite isograd, but they soon become granulated and broken down into lenticular aggregates parellel to the schistosity. In many specimens, small rounded grains of quartz occur as inclusions in newly-crystallized oligoclase grains.

Andesine-Garnet-Hornblende Zone

The rocks in which minerals of the andesine-garnet-hornblende zone occur are generally concentrated in the northern section of the eastern half of the map-area, around and south of McDonald lake, and in the volcanics of the south central section of the map-area. Exposures of them are also found widespread here and there in the biotite zone where they represent probably accidental less resistant and more easily changed series of rocks. The rocks of this zone of the highest intensity of regional metamorphism in the area include mostly volcanics and sediments, but some of the anorthositic facies of the gabbroic intrusives also belongs to it.

The igneous rocks of the andesine-garnet-hornblende zone are generally highly schistose, and porphyroblasts of dark green hornblende, light-colored plagioclase, and red garnet are commonly visible on slightly weathered surfaces. Hornblende is the commonest mineral, and garnet is usually limited to a few grains. All the minerals appear fresh to the naked eye.

The microscope shows that the average basaltic lava of this zone is a holocrystalline, subhedral rock with a well-defined crystalloblastic texture. The fabric may be granoblastic or porphyroblastic. The colored minerals are generally idioblastic, and inclusions are commonly found in the plagioclase, hornblende, or garnet porphyroblasts and are usually arranged in a poeciloblastic manner.

The constituent minerals are generally very fresh, except where retrogressive or hydrothermal metamorphism was effective. The andesine is generally very poorly-twinned and cleaved and varies in composition from An_{30} to An_{45}. However, in about 70 per cent of the specimens studied, the calcity of the plagioclase was between An_{30} and An_{35}. Porphyroblasts of andesine have grown to be up to 2.0 mm. across and they commonly contain inclusions of pale green to green acicular tremolite or greenish blue hornblende, more rarely, of biotite.

Hornblende makes generally between 60 and 80 per cent of the rock. It is very fresh, usually slightly more pleochroic than in the preceeding zone, and it occurs in fine granules or, less commonly, in well-formed porphyroblasts. In very few specimens, a small proportion of the amphibole is present as a felt of very small needles sweeping around the porphyroblasts of andesine or garnet in perfect flow lines. On the whole, it is evident that most of the amphibole crystallized after the cessation of the main movement and at about the same time as the plagioclase since inclusions of hornblende occur in numerous porphyroblasts of plagioclase and small grains of clear andesine are also present in some of the large crystals of hornblende.

Biotite and chlorite were noticed in a few specimens but always in small amount. A few small grains of quartz occur in association with the fresh andesine in three of the specimens studied, and magnetite, leucoxene and titanite generally make about one per cent of the average rock. Small idioblastic grains of apatite are widely disseminated in most of the specimens.

The typical sedimentary rock of the andesine-garnet zone is a pale grey, finely crystalline, commonly garnetiferous, quartz-andesine schist. Except for the presence of garnet, the rock of this zone does not look very different from the one of the biotite zone, and the two are not easily distinguished without the use of the microscope.

The garnets are generally very few in numbers although, in some thin beds, they may make up to 70 per cent of the mineral constituents of the rock. Generally, their proportion is less than two per cent. They occur as anhedral, generally rounded grains, seldom more than 1.0mm. in diameter, although one grain was found which had a diameter about ten times as large as that. They commonly contain inclusions of all the other minerals of the rock and are obviously of late crystallization. The planes of schistosity sweep around the grains which are commonly broken and only in one case was there seen evidence that a large grain had rotated (see plate XIII, A). The garnet is reddish brown and apparently rich in the almandine molecule.

The plagioclase which makes between 20 and 60 per cent of the rock is a clear, poorly-twinned, and uncleaved andesine, similar in composition and characters to the one just described in the study of the volcanics of this zone. Quartz varies in amount from 10 to 40 per cent. It is completely recrystallized and occurs either in narrow bands parallel to the foliation or in lenticular eyes disturbing the planes of schistosity.

Biotite and muscovite are abundant in the acidic types of sediments and occur in small flakes or prisms generally oriented parallel to the schistosity. In the intermediate facies, greenish blue hornblende and biotite are approximately in similar proportions, and biotite-rich beds often alternate with thin hornblendic layers. In the basic sedimentary rock of this zone, hornblende is the dominant ferromagnesian mineral, and a little chlorite may also be present.

Magnetite, ilmenite, leucoxene, titanite, and apatite are commonly present in small amounts, and tourmaline and sericite occur in some of the hydrothermally altered specimens.

Paragenesis of the Minerals of the Regionally Metamorphosed Pre-Granitic Rocks

A study of the paragenesis of the minerals of regionally metamorphosed rocks implies that the system is isochemical throughout, so that there is no introduction or loss of material and that the new minerals are formed only at the expense of those already present in the rock. The composition and structure of the original rock should also be at least fairly uniform over a certain distance, otherwise there might be transfer of material from one type of rock to the other, and the system may become chemically heterogeneous.

These conditions are well realized in the volcanic and in most of the basic intrusive rocks of the area in which the types and relative porportions of mineral constituents do not appreciably vary from one place to another. The great diversity of structure and composition found in the sedimentary rocks, and their commonly abrupt changes in composition and structure from one bed to the other may seem to make a general study of the changes induced in them by regional metamorphism a much more complicated problem. However, it is found that there was very little transfer of material from one type of rock to the other, and this fact was frequently noticed under the microscope. Each type of sediment was generally metamorphosed according to its original composition. Progressive changes in the most basic sediments were closely similar to the ones which took place in the volcanics, and each of the argillaceous, siliceous, and feldspathic types was changed by metamorphism in accordance to its original composition.

The primary feldspar of the lavas and of the gabbros was a calcic andesine or a labradorite, and poor but reliable enough determinations of the calcity of original plagioclase feldspar of waterlaid clastics also indicated that it generally belonged to the andesine group.

Thus, at the onset of regional metamorphism, andesine and labradorite were the two dominant types of primary plagioclase in both the basic igneous and in the sedimentary rocks. The other main constituents were pyroxene and uralite or actinolite, in the lavas and gabbros, and quartz, clayey material, and a variable amount of ferromagnesian minerals, in the clastics. Iron ores were also common to both types of rock.

During the final magmatic stage of the igneous activity and the very beginning of the regional metamorphism, the intermediate plagioclase of the igneous and sedimentary rocks began to break down with the production of a mixture of very fine zoisite and new sodic plagioclase feldspar, and silica was released. As iron was abundantly present in both the igneous and sedimentary rocks, a certain amount of it was absorbed by zoisite and some epidote was formed together with it.

With slightly increasing intensity of metamorphism, the granules of albite became large enough to be visible under the microscope, and the new plagioclase is seen to occur generally in fairly clear, untwinned, and poorly-cleaved grains, commonly agglomerated towards the periphery of the altered primary plagioclase. Slightly fractured quartz, and scales of chlorite and white mica are the other main minerals of the greywacke or argillite, and pale green to green actinolite, with a small content of chlorite, are the principal other constituents of the basic igneous rocks at this stage. Free iron oxide is abundant in very fine grains in the lavas and gabbros and in some of the ferruginous sedimentary rocks. Relatively large magnetite and ilmenite grains are also present, more abundantly in the igneous rocks.

Oligoclase generally appeared in the suite at about the same time as biotite. It occurs usually in fine, clear granules, but porphyroblasts of oligoclase are not uncommon. With the appearance of oligoclase, a marked decrease is seen in the amount of the fine zoisite, and concomittant with the appearance of biotite, white mica and chlorite decrease in amount. In the volcanics and gabbro, very little white mica was available to combine with the chlorite and, as a result, little biotite was produced, and chlorite persists into the garnet zone. In the sedimentary rocks, their relative amounts vary widely. In some of the rocks, they were of approximately equal abundance, and no chlorite or white mica is left over at the garnet isograd. In others, one mineral is prevailing over the other, and the amount of the chlorite or white mica which was not absorbed by the other to form biotite remained as such into higher zones of metamorphism.

The appearance of biotite and oligoclase in the rocks was also accompanied by the recrystallization of the actinolite into the greenish blue hornblende mentioned above. This recrystallization is seen as accompanied by a decrease in the amount of very fine iron oxide and possibly of epidote, and it is probable that some of the chlorite left over after the crystallization of biotite combines with some of the epidote and contributes to the formation of some of the blue amphibole.

Quartz is mechanically broken and crushed early in the biotite zone and, at the garnet isograd, it is generally drawn into lenses, and no recognizable detrital grains are left. Ilmenite alters to leucoxene which, in turn, tends to go over to titanite in the more advanced stages of the biotite zone.

In the highest grade of metamorphism, that is, in the garnet zone, the plagioclase becomes still richer in the molecule anorthite and has the composition of a sodic to intermediate andesine. Zoisite disappears, epidote greatly diminishes, and it is assumed that the necessary anorthite is produced by the reverse of the reaction which took place when the primary labradorite or andesine was broken down. Silica needs to be supplied, but there is, at his stage, even in the most basic rocks of the area, enough quartz to take care of the silica needed in the reaction. The necessary alumina is supplied by the zoisite and epidote, and any excess of iron may go in the hornblende, biotite, or be rejected as free iron oxide.

The appearance of the garnet is considered by Harker (75) to take place "mainly at the expense of the remaining chlorite in the rock, but (it) must also draw much of its iron from magnetite" (p. 219). Tilley (141) and Phillips (119) are of the same opinion, but Ambrose (4) points out in his paper on the metamorphism of the Missi Series that "white mica is abundant at the garnet isograd evidently greatly in excess of the amount necessary to produce biotite from all the chlorite" (p. 268). Occurrences of garnet in rock containing abundant white mica were also noted in numerous specimens of the sedimentary rocks of this area. Furthermore, garnet is very rare in the altered basic lavas or sedimentary rocks of the area whereas abundant chlorite persists in some specimens up into the andesine-garnet zone. Finally, as noted by Ambrose (4), chlorite is seen to react with epidote to contribute to the formation of some of the hornblende of the rock. As he puts it:

> "There is a distinct possibility that epidote, biotite, and magnetite play a part in the formation of the garnet, but until more determination is obtained, the precise mode of origin of this mineral must remain unexplained" (p. 268).

The quartz of the garnet zone is generally in elongated aggregates or in narrow bands parallel to the schistosity. It seems that it has played very little active part in the chemical reactions during the process of metamorphism, except, possibly, for the supplying of a small amount of silica necessary to the recrystallization of andesine in the garnet zone.

Local Metamorphism

In restricted parts of the area, the effects of regional metamorphism are more or less masked by some other changes due to the nearby presence of intrusive masses of various types, but mainly of acidic or intermediate composition. These thermally metamorphosed rocks do not occupy any extensive section of the area, and their presence is revealed by only a limited number of exposures.

Thermally metamorphosed volcanic rocks can be seen in the vicinity of basic intrusive rocks at a locality about one mile south of Capisisit lake (see p. 46) and north of Inconnu river, about one mile west of Capisisit lake. A series of outcrops of highly metamorphosed basaltic lavas occur close to the northern boundary of the Waswanipi granite, slightly over two miles southwest of the western extremity of Capisisit lake. The lavas are massive or very slightly schistose and are composed of 15 to 45 per cent fresh labradorite (An_{60}) occurring in clear, slender laths in a granoblastic or felty mass of secondary greenish blue hornblende, similar to the one found in the garnet zone of regional metamorphism. A similar exposure of basalt occur at a locality two miles north of Inconnu lake and one mile west of the eastern boundary of the map-area in which the main constituent minerals are blue-green hornblende and fresh labradorite. The lavas of the northern belt of volcanics are also intensely altered and injected close to their contact with the gneissic intrusive to the north and between the two intrusive masses in the northern section of the eastern half of the map-area.

Retrogressive Metamorphism

Some specimens of sedimentary rocks belonging to the biotite or garnet zones contain much chlorite and white mica in close association with the biotite or the garnet. In certain metamorphosed lavas, gabbros, or sedimentary rocks, the secondary oligoclase or andesine is also partly clouded with saussurite. The garnet porphyroblasts of the highest zone of metamorphism are in places fractured, broken, and surrounded by a narrow rim of dark green highly pleochroic chlorite. Inclusions of a similar type of chlorite in garnet are also commonly present in some of the specimens of garnetiferous sediments.

Biotite is frequently seen to break down to chlorite and sericite. This type of chlorite does not occur in clean-cut flakes as in the albite zone of metamorphism but in long fibers or in rosettes containing tiny grains of magnetite or sagenitic networks of rutile needles.

The retrogressive metamorphism appears generally related to action by intrusive bodies of acidic composition, and distinctive hydrothermal epidote and quartz are commonly found in rocks which have been affected by it. Carbonates and pyrite also occur in them. Good examples of retrogressive metamorphism can be seen in the lavas and sediments in the vicinity of the intrusive body around and west of McDonald lake and just south of the gneissic intrusive, of the northern section of the map-area.

Chapter lX

GRANITIC INTRUSIVES

General Statement

Granitic rocks underlie close to 35 per cent of the Capisisit-Inconnu Lake map-area and they include various types belonging to at least two and probably several different ages. Most of the small porphyritic dykes or sills which are found widespread throughout the area underlain by volcanic, sedimentary, and gabbroic rocks were evidently emplaced before the main period of folding and dynamic metamorphism of the rocks which they intrude. A small number of them, however, are post-folding and some are intrusive into the different types of granitic bodies of the area. They will be treated together later in this chapter after the study of the main granitic intrusive masses of the area.

All the larger bodies of acidic to intermediate intrusive rocks of the area are believed to be post-kinematic or syn-kinematic, and the localization of some of them has undoubtedly been determined by the pre-existing regional structure of the volcanic, sedimentary, or gabbroic formations. Others have also very probably been active agents in the folding and deformation of the intruded "greenstones" rocks, and this will be discussed in a subsequent chapter.

Only one single mass of granitic intrusive rock, the Capisisit Lake granitic body, is fully included within the boundaries of the present map-area. The other granitic masses which appear on the accompanying map constitute marginal zones or lobes of more extensive bodies lying mainly outside of the map-area. All the different acidic intrusives will be treated individually in this thesis.

Maicasagi River Gneiss

Distribution

About 45 square miles of the northern section of the map-area are underlain by a fine-to medium-grained, generally gneissic, border facies of a very extensive acidic intrusive mass lying north of the present area. Although the areal extent of the part of the intrusive which is included within the present map-area is almost infinitesimal as compared with the extent of the mass further north[x] , the writer has for the sake of conciseness and clarity in

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[x] Geol. Surv. Can., Map 307A.

this thesis given to the very small gneissic marginal facies of the intrusive the name of Maicasagi River gneiss after the large river flowing over it, close to the northern boundary of the map-area.

Within the limits of the present map-area, the Maicasagi River gneiss outcrops in the north central section where it forms a half pear-shaped mass having a maximum width of three and a half miles at the seventy-sixth meridian and extending northwestward to the northern limit of the map-area, three miles east of the western boundary. The extreme northeast corner of the map-area is also underlain by another lobe of the same type of intrusive, and between this section and the main mass, gneissic rock underlies a narrow crescent-shaped area, about four miles long and one and a half miles across at its maximum width. This lenticular concordant body is probably connected farther north (131, 132, 133, and 134) with the main mass of the intrusive and is interpreted as a long and narrow, concordant offshot of the granitic body. This crescent-shaped body is well exposed near its center in the map-area, and its contact with the volcanic rocks to the east is pretty well established. Westward, however, the ground is very low and covered with a thick mantle of clay, and only very few exposures of altered lavas occur here and there between the crescent and the main mass of gneissic intrusive rock to the west. The presence of these exposures together with the fact that the ground underlain by the intrusive is there generally higher and slightly hilly, whereas the surficial rocks of the low areas to the southeast are lavas, seems to justify the assumption that volcanic rocks are also present between the main mass of gneissic intrusive and the exposures of similar rock to the east, and, consequently, the two bodies were outlined as seen on the accompanying map.

Character of the Rock

The Maicasagi River gneiss is a fine-to medium-grained biotite gneiss. Its color varies from very light grey to dark grey, depending upon the relative abundance of biotite and light-colored constituents. In a few cases, the rock is almost massive, but, generally, it has a distinct to well-developed foliation caused by the alignment of the biotite flakes and, to a smaller extent, by the linear arrangement of the agglomerations of quartz and feldspar grains. The gneiss weathers generally light grey, although the biotite-rich facies may turn rusty brown under the influence of the meteoric alteration.

In the field, the rock is seen to vary widely in composition, texture, and appearance. It is cut by numerous younger bodies of intrusives and it contains abundant more or less digested inclusions of "greenstones" disseminated all through the sections exposed within the limits of the map-area, but more abundantly near their contacts with the intruded volcanic rocks.

The rock of the main part of the gneissic intrusive mass contains about 25 per cent quartz, 15 per cent black glistening biotite, and 60 per cent greyish white feldspar. Some specimens contain close to 50 per cent glassy quartz disposed in lenses well aligned parallel to the foliation as marked by the biotite grains. Close to the contact with the intruded greenstones, the rock is much richer in ferromagnesian minerals, and hornblende is abundantly present with biotite. In the smaller crescent-shaped body, the rock is, in general, much less foliated than in the main mass, especially towards the contact with the volcanics to the east. In the exposures at the extreme southern point of the same body and in the two very small lenticular bodies just south of the main mass and slightly east of seventy-sixth meridian, the rock is a medium-grained massive or very faintly-foliated, mafic-rich intrusive and it has the composition of a hornblende-biotite diorite.

Under the microscope, the main type of grey biotite gneiss is a hypidiomorphic to panallotriomorphic granular rock composed of abundant fresh to highly-clouded plagioclase feldspar (An_{26}-An_{36}), with variable amounts of quartz, biotite, and secondary minerals. A protoclastic texture is present in a good number of the sections studied, but recrystallization has healed the fractures in a few of the specimens examined. Quartz generally makes 20 to 40 per cent of the mineral constituents and may occur in unstressed, stressed, or fractured, large to very small grains. Oligoclase-andesine varies in amount between 40 and 60 per cent of the rock, and biotite makes up about 10 per cent of the constituents. Chlorite, sericite, apatite, titanite, epidote, iron oxides, and leucoxene are the accessory and secondary minerals. Some of the quartz appears as rounded inclusions in the plagioclase, and the biotite occurs generally in small, well-aligned flakes or prisms and commonly forms clots with epidote, chlorite, iron oxides, leucoxene, and apatite. Chlorite is the main product of alteration of biotite, and some of the epidote occurs as rims around small allanite cores which are probably of magmatic origin.

Microcline is also present in most of the sections examined and it invariably occurs as a very late constituent corroding the oligoclase-andesine or, in association with quartz, as a fracture-filling mineral. It was noticed that in the specimens studied, microcline is totally absent or in very small amount where the plagioclase of the rock is clouded and fractured and where the protoclastic texture is still well recognizable. In the sections in which microcline is more abundant (up to ten per cent), the plagioclase is generally recrystallized, very clear, untwinned, and poorly cleaved, and the texture has become granular. This coincidence and the occurrence of deuteric microcline and quartz will be more fully discussed below.

Greenstone inclusions are found disseminated in the whole of the area underlain by the gneissic intrusive and, as stated above, they are more abundant closer to the contact between the intrusive and the volcanic rocks to the south and east. They also appear to be more concentrated in the main mass of the intrusive than in the crescent-shaped and the other smaller bodies in which they are only very widely scattered.

The size of the greenstone inclusions vary from fractions of an inch to some feet across, and they are generally subangular and elongated, although angular fragments are not by any means absent. Their long dimension is generally parallel to the foliation of the immediately adjacent intrusive grains. Most have a lenticular shape, some are sheet-like, and this character was evidently determined by the strong schistosity of the volcanic rocks through which the gneiss is here intrusive. One such inclusion, at a locality a few hundred feet south of Maicasagi river and about one and a half miles west of the seventy-sixth meridian, is five feet wide and is exposed over a length of about one hundred feet. Its long dimension is parellel to the foliation of the enclosing gneissic intrusive and to the schistosity of the enclave itself. It is obvious that the intrusive acidic material came up first along the planes of schistosity of the volcanics which represented zones of easy intrusion, and, eventually, the large sheet-like band of schistose volcanics became separated from the main mass and was carried away by the slowly-moving, plastic intrusive material.

The degree of alteration and assimilation of the inclusions by the intrusive varies somewhat but is generally low. The central part of the large sheet-like enclave mentioned above is made of relatively fresh, schistose basic lava in which remnants of pillows are still recognizable. It has the composition of the average amphibole-rich lava of the area, and although it is cut by abundant pegmatite dykelets, the alteration by the intrusive is limited to a narrow zone, one inch or two in thickness, at the immediate contact. This narrow zone is first marked in the lava by the appearance of porphyroblasts of pinkish grey feldspar up to 8.0 mm. across and growing between the planes of schistosity. The rock is there composed of about 50 per cent feldspar and 50 per cent amphiboles. Closer to the enclosing gneiss, the proportion of feldspar becomes larger, the porphyroblasts seem to be partly resorbed, and the rock becomes more granular in texture. Hornblende is still the only recognizable ferromagnesian mineral but, farther out, biotite makes abruptly its appearance, and a thin rim around the inclusion appears to be composed solely of biotite and feldspar and it grades slowly into the normal biotite gneiss.

The majority of the observed inclusions were however much smaller and, generally, they have lost their angular contours and have oval or more or less attenuated lenticular shapes. In many instances, a portion of the enclave has been drawn into a long tail parallel to the foliation of the rock and to the long dimension of the main mass of the inclusion itself.

Schlieren-like structures are commonly seen in the gneiss. They generally constitute relatively long, narrow, and streaky bands, slightly coarser grained than the enclosing rock and composed of a large proportion of biotite and, frequently, hornblende which is totally lacking in the average foliated granitic intrusive. Like the fresher inclusions, the schlieren are always elongated parallel to the foliation of the intrusive and, although some may be primary and due to movement in the partly differentiated magma, it is believed that most of them represent small inclusions of volcanic rocks which were partly fused and the constituent minerals of which were partly or completely reworked and made over to new minerals more closely in equilibrium with the new environments.

A good number of specimens of the various types of inclusions were examined under the microscope in order to obtain all the possible information concerning their alteration and digestion by the enclosing gneissic acidic magma. The average composition of the gneiss in which xenoliths of lavas are found is that of a quartz-diorite or an oligoclase granite in which the main constituents are quartz, oligoclase-andesine, and biotite. No hornblende occurs in the intrusive which has not been contaminated by the intruded volcanics or by inclusions of foreign material.

A specimen taken from the central part of the large xenolith of ellipsoidal lava mentioned above did not reveal any peculiar characteristics different from those of the normal type of volcanic rocks of the area. The texture is schistose, and the predominant minerals are greenish blue hornblende and saussuritized plagioclase, apparently oligoclase or andesine. Epidote, zoisite, very little biotite, chlorite, titanite, and leucoxene are the secondary minerals. No specimen of the transitional facies between the biotite-rich zone at the periphery of the inclusion and the hornblende adjacent zone was studied under the microscope, but the line of demarcation between the two seemed, to the naked eye, to be quite sharp, and very little interpenetration of the hornblende and biotite crystals seems to have taken place.

The microscopical examination of some of the smaller drawn out and more digested inclusions shows that the rock is of a midway character between the unaltered xenolith and the gneissic matrix. Hornblende and biotite are closely associated, and the alteration of hornblende into biotite is very well seen. This alteration generally begins at the periphery and along the planes of cleavage of the hornblende, and, at later stages, only small relics of pale green hornblende remain as inclusions in the growing biotite crystal until the amphibole has completely disappeared. At the early stages, the biotite has a tendency to be pseudomorphous after hornblende, but this character disappears very soon after. Epidote and chlorite are also present in association with the amphibole and biotite, and titanite occurs sometimes in large idioblastic grains.

It is obvious that a certain amount of digestion of hornblende-rich greenstone inclusions has taken place in the gneissic intrusive. Biotite and oligoclase or andesine were crystallizing in the magma at the time of the incorporation of the fragments of volcanic rocks, which were made of hornblende and probably oligoclase. The magma was already saturated with the mineral hornblende which is higher in the reaction series than biotite and so, according to Bowen's theories (32), it could not dissolve the hornblende. It could however modify it or make it over to biotite with which the intrusive was in equilibrium. Petrographical analyses show that such a transformation took place although apparently on a small scale since only a thin rim of biotite-rich material surrounds the larger inclusions of amphibolite schist.

The condition of the magma, as indicated by the physical and chemical transformations of the inclusions, must have been, at least in the cases of the larger xenoliths, of thick viscosity which did not permit more than a slight surficial mingling of the material of the inclusion with that of the matrix or gneiss. The foliation of the gneiss flowing around the inclusions and the presence of a "tail" attached to one or both extremities of the long dimension of some of the inclusions also point to a partial fusion and transformation of the hornblendic material while the matrix was in plastic condition or in process of solidification. A further study of the already-crystallized constituents of the granitic rocks at the time of intrusion into the volcanics will be made in the discussion on the origin of the gneissic structure of the intrusive .

An outstanding feature of the area underlain by the gneissic quartz diorite and oligoclase granite is the diversity and abundance of dykes and small masses which cut through the intrusive and so are, for the most part, posterior to its emplacement and crystallization. The oldest types of later intrusive are represented by a few fine-grained pink to grey, generally massive dykes and small bosses of oligoclase granite. One such small mass of fine-grained oligoclase granite is present on the south shore of La Trève river about five hundred feet east of the eastern boundary and so just off the present map-area, and dykes of similar rock occur widespread through the larger bodies of the gneiss. The rock of those younger masses and dykes is more acidic than the material which constitutes the gneissic intrusive and is generally made up of about 45 per cent acid oligoclase (An_{12-15}), 20 per cent fresh, well-twinned microcline, 20 to 40 per cent, quartz, and close to 10 per cent biotite. The accessory and secondary minerals are titanite, apatite, zircon, chlorite, epidote, allanite, leucoxene, and a little iron oxide. The contact between the dykes and the intruded gneiss is generally sharp although, in some cases, it is very obscure and, in these last occurrences, the dyke rock itself is faintly gneissic with a foliation parallel to that of the gneiss. It seems clear, in the case of these dykes, that the gneiss was not yet completely solidified when it was invaded by the more acidic magma, and the faint lineation of the dyke rock is due to the same cause which had given rise to the foliation of the main mass of intrusive and which was still faintly effective at the time of the intrusion of the dyke. In one observed fine-grained dyke, a faint foliation was developed parallel to the walls of the dyke and not along planes parallel to that of the gneiss itself.

At least on one exposure, a slightly gneissic oligoclase granite dyke was observed cut by one of the fine-grained massive albite granite dykes which are also abundantly disseminated throughout the area underlain by the foliated intrusive. The albite granite dykes are generally fine-to very fine-grained, massive, pink rocks whose main constituent are albite (An_{6-8}), 35 per cent, microcline, 40 per cent, quartz, 15 per cent, and dark green biotite, 5 per cent. At a locality about one mile west of the southern extremity of Veto lake, in the north central part of the area, and on the big hill about half a mile farther west, the fine-grained granitic rock occur in somewhat larger masses in which fragments of the gneissic oligoclase granite or quartz diorite occur as angular, haphazardly-oriented inclusions. It is therefore evident that at least some of the magma of the large gneissic intrusive mass had completely solidified before the fine-grained albite granite dykes, lenses, and small bosses were introduced.

The fine-grained albite granite is seen in a few places to cut but, more commonly, it is intruded by fairly numerous leucocratic granite and aplite dykes and by an outstanding number of medium-grained pegmatites occurring in the form of lenses, dykes, dykelets, and stringers. Pegmatite makes over 75 per cent of some exposures in the area underlain by the gneissic intrusive, and if some pegmatitic dykes appear concordant with the foliation of the gneiss, the great majority of them cut across it at any angle. Those dykes and stringers are also very common in the volcanic rocks adjacent to the gneissic intrusive and, in both types of rocks, they commonly grade into white quartz veins and stringers.

Most of the pegmatites look fresh, unstressed, and massive, but a few of them show oriented lenticular agglomeration of fractured and partly recrystallized quartz grains, and these were obviously subjected to stress after their emplacement and solidification.

Origin of the Gneiss

Gneisses, i.e., rocks possessing a gneissic structure, may have originated in more than one way. They are mainly:

i) gneisses in which the foliated structure of the rock is directly connected with a differential movement in the nature of flowing.

ii) gneisses in which the banding is directly due to the effect of composite magmatic injection or gravitational differentiation in situ.

iii) gneisses which represent the extreme phase of metamorphism of bedded sedimentary or schistose igneous rocks in which the gneissic structure is the result of primary lithological differences or metamorphic segregations in the rock.

iv) gneisses in which the foliated or banded structure is due to differential injection and replacement of schistose or bedded sedimentary or igneous rocks by intrusive material.

v) gneisses which result from the bodily deformation of plutonic rocks under the operation of powerful mechanical forces, the banding in this case standing in relation to the manner in which those forces were applied.

vi) gneisses which result from two or more of the causes cited above.

The Maicasagi River gneiss is obviously of intrusive origin as clearly seen in the field where cutting relationships are abundantly present in the adjacent volcanic rocks. It is associated with only slightly metamorphosed greenstones, and even if intrusive relationships and greenstone inclusions did not occur, it would be still difficult to consider it a paragneiss on account of the difficulty of conceiving such an extremely metamorphosed rock adjacent to only slightly altered volcanics from which it is obviously not separated by a fault.

The orthogneiss cannot either be considered as the result of a composite magmatic injection or of gravitation differentiation in situ. It is admitted that exposures of rock representing more than one period of intrusion are found in the area underlain by the gneiss, but the other intrusive bodies are only very small and represent later, more acidic differentiates of the same magma which produced the main mass of the gneiss and are in no way related to the gneissic character of the rock. The absence of definite banding, lack of definite magmatic segregations, the attitude and character of the foliation, the shape of the intrusive masses themselves, and the large granitic facies to the north as well as the character of the contact with the intruded volcanics, eliminate the possibility that the gneiss would be the result of differentiation in situ.

The hypothesis that the gneissic character of the intrusive may result from intense mechanical stresses applied to an already consolidated granite body does not hold good owing to of the lack of sign of any extensive shearing and fracturing in the rock as seen either macroscopically or microscopically and because of the occurrences of massive granitic bodies disseminated through it.

It remains that the gneissic character of the intrusive may be due to flowage movement or injection of a bedded or schistose series of rock producing migmatites and an injection gneiss. Both processes probably contributed their share to the production of the foliated character of the rock, but differential movements of the plastic material constituted by far the more effective process in the present area. It was seen above that only very little assimilation of the intruded rock took place in the granitic matrix as shown by the characters of the inclusions of greenstones which are abundantly present in the gneiss. Furthermore, the zone of contact between the intrusive and the intruded rock, although containing abundant pegmatite dykes, does not show any appreciable amount of injection or migmatization by the intrusive magma. Lit par lit injections especially are completely lacking, and it is very probable that if the gneiss was of an injection type, a zone of injected and partly transformed rock would be present near the contact between the intrusive and the intruded rocks.

The process of development of the foliated structure can be seen on some of the weathered exposures of the rock but much more clearly in thin sections under the microscope. The rock has generally a protoclastic texture, and the primary minerals, plagioclase, biotite, and some of the quartz show granulated peripheries, fragmentation of the larger grains, and arrangement of the fragments into thin leaves elongated parallel to the foliation of the rock.

The plagioclase feldspar was crystallized before the cessation of the movement for the larger grains show bent lamellae, and they have commonly been crushed to fine granular aggregates disposed in lenticular agglomeration parallel to the foliation. The biotite had also separated since many flakes are bent, and the mica does not occur along definite lines of flow, but in poorly-defined agglomeration here and there in the rocks. However, as mentioned above, some of the "schlieren" are considered to be remnants of small fragments of greenstone caught up and partly digested by the intrusive. A first generation of quartz had also crystallized before the final disappearance of the stresses, since many quartz grains have been either granulated at the periphery or shattered and collected in lenses or ribbons parallel to the foliation of the rock.

The characters of the numerous dykes and small bosses which intrude the gneissic intrusive also give some information concerning the time of the cessation of movement in the magma. At the time of the injections of the small bodies of acid oligoclase granite, the movement was very weak or had completely stopped since some of the dykes are very slightly foliated whereas some are completely massive. The albitic dykes studied are all massive, and so the stresses were not appreciably active at the time of their intrusion.

Some of the pegmatite dykes and lenses show a striking alignment of fractured quartz and feldspar crystals on weathered surfaces and are taken to represent pegmatites which crystallized while the movement was still in progress. The great majority of the pegmatites and aplites, however, appear to have solidified after the complete cessation of movements since they are not granulated or foliated and they cut at all angles across the gneissic character of the rock. Similarly, the quartz veins and lenses were in no way affected by stresses and they occur at any orientation and appear quite fresh.

Microcline is abundant in the oligoclase-albite, aplite, and pegmatite dykes and is disseminated in many specimens of the gneiss. It is frequently in association with fresh and unstressed quartz and it was never found to be stressed or fractured. As it commonly corrodes the primary plagioclase grains and fills the interstices between them, it is believed that microcline and some of the quartz are of a deuteric or hydrothermal generation and that they are of post-tectonic crystallization.

It is thus believed that a flowage movement which was effective during the consolidation of the quartz diorite-oligoclase granite magma but ended during the sodic oligoclase-albite stage was responsible for the greatest part of the foliated character of the gneissic intrusive. The partial or complete digestion and assimilation of small greenstone inclusions contributed to emphasize that foliated character of the intrusive, but only on a small scale.

The fact that the adjacent smaller masses of quartz diorite or oligoclase granite are only very slightly foliated or completely massive is another factor in favor of the foliated structure produced by differential flowage. In the small masses, the rock cooled too quickly and crystallized too fast for the production of a flowage movement as pronounced as in the main intrusive mass, and, consequently, the rock is more massive.

The gnessic Maicasagi River border facies of the large granitic mass north of the present area suggests in appearance and composition, the contact facies of the Olga quartz diorite found extensively around Olga lake, some 40 miles to the west,and which Freeman (60) has interpreted as being of hydrothermal origin. However, the distance between the two gneissic bodies is much too great, and the rock too complex to justify any tentative correlation between them.

Diorite-Syenite Complex

The rocks mapped as "diorite-syenite complex" cover approximately 50 square miles and occur in a triangular area having its apex one and a half miles east of the eastern end of McDonald lake and its base, some six miles wide, extending along the western boundary of the map-area from Inconnu river northward.

In general, the rocks are massive and show a well-defined granular texture. Primary flow structures are visible in a few exposures, however, and a gneissic facies occurs along a shear zone that follows the contact with the volcanic-sedimentary rocks west and southwest of McDonald lake.

The main portion of the intrusive complex is a coarse-grained rock containing 35 to 50 per cent of dark minerals and having, except for a subordinate part occupied by a gabbroic type of rock, the appearance of a diorite or of a mesocratic syenite. The coarse-grained facies underlies that part of the triangular area mentioned above lying west of a north-south line passing at one mile east of the outlet of McDonald lake. Eastward from this line, and with no gradation or contact exposed, the intrusive rock is finer grained, and its content of dark minerals appears somewhat lower than that of the coarse-grained facies. This medium-to fine-grained facies of the intrusive complex has more the appearance of a normal syenite.

Two occurrences of fine-grained granite were found in the coarse-grained facies of the complex. Pegmatite dykes and small masses are to be found in the whole intrusive mass, but they are less abundant in the finer-grained facies. Two altered and mineralized lamprophyre dykes, about 12 inches wide, cut both the coarse-grained complex and the younger pegmatite dykes intruding it, about five hundred feet east of the western boundary of the map-area and one mile south of the east-west surveyed township line.

Gabbroic Facies

The gabbroic facies is found with the dioritic facies in the southwestern part of the triangular area underlain by the rocks of the intrusive complex. The best exposures of gabbro (3a on the accompanying map) are at a locality about half a mile east of the western boundary of the area and a few hundred feet north of the surveyed township line. The rock has a fresh appearance and is a medium-to coarse-grained aggregate of dark minerals and purplish grey plagioclase in about equal amounts.

Under the microscope, this facies is seen to be composed of 50 per cent calcic plagioclase, 35 per cent pyroxene, two per cent biotite, with some chlorite, uralite, actinolite, apatite, hematite, and a little pyrite and quartz. The plagioclase is fresh, markedly twinned and has been identified as a labradorite (An_{55}).

Two types of pyroxenes are present, a monoclinic and an orthorhombic type. The monoclinic pyroxene is pale greenish with very faint pleochroism and exhibits, in general, good cleavages. It has a positive elongation, an extinction angle $C \wedge Z$ of 39°-42°, and a birefringence of 0.025-0.028. Its optic axial plane is parallel to (010), and it is positive, with an axial angle of about 60°. It is identified as diopside and makes about 20 per cent of the rock. The orthorhombic pyroxene, hypersthene, is intimately associated with diopside and makes about 15 per cent of the rock. It is pleochroic from pale reddish to very pale green, shows good cleavages in many grains, and has a somewhat lower birefringence than diopside (0.010-0.014), but higher refractive indices, (around 1.72). It is biaxial negative with an axial angle of about 75°, and the optic plane is parallel to (010). The dispersion is rather low, with r greater than v.

A Rosiwal analysis of the gabbroic facies of the diorite-syenite complex gave the following results.

Labradorite (An_{55})	43.3%
Diopside	25.0%
Hypersthene	19.0%
Amphiboles	6.5%
Biotite	1.6%
Chlorite	0.4%
Apatite	0.3%
Iron ores	3.9%
Sericite	traces
Saussurite	-

Both types of pyroxenes are surrounded by a narrow rim of products of alteration. Around the hypersthene, this rim is mostly iron oxide, probably hematite, whereas the diopside is surrounded by a pale bluish green to almost colorless amphibole, which is mostly is small needles. Small grains of iron oxides are also present as inclusions, especially in the orthorhombic pyroxene and, to a lesser extent, in the diopside. Most of the biotite appears to be a product of alteration of the diopside, whereas chlorite is seen more commonly associated with hypersthene. A small amount of apatite is present, and pyrite is also widespread throughout the rock.

The fabric of the rock is generally granitic but, in places it is micropoikilitic with small, rounded, and diversely-oriented grains of pyroxene in the labradorite.

Dioritic Facies

The gabbroic facies of the complex grades in the field into and is surrounded by a slightly more acidic facies, generally dioritic in appearance (3b on the accompanying map). Scattered exposures of this dioritic facies are found north of the exposure of gabbro mentioned above for a distance of about two miles, and for twelve hundred feet to the south. Towards the east, the diorite extends right to the contact with the volcanic and sedimentary rocks and, to the west, to the western limit of the map-area.

In the field, the diorite appears to have slightly less dark minerals than the gabbroic facies, and the plagioclase in the unaltered diorite is light grey with only a very slight tint of purple color. The diorite is slightly coarser grained, and the granular texture is more apparent than in the gabbro.

Four thin sections of specimens of the dioritic facies of the intrusive were examined under the microscope, the freshest of which was collected half a mile due west of the gabbro exposure mentioned previously. The fresh rock is a holocrystalline medium-to coarse-grained aggregate of fresh andesine (An_{34-38}), with pyroxene, biotite, secondary amphiboles, apatite, epidote, magnetite, quartz, and microcline (see plate XlV, A).

The composition of the fresh diorite, as determined by the Rosiwal method, is the following.

Andesine (An_{34-38})	53.9%
Diopside-augite	22.9%
Hypersthene	2.1%
Amphibole (uralite)	6.3%
Biotite	10.4%
Chlorite	0.4%
Epidote	1.1%
Titanite, leucoxene	0.3%
Iron ores	1.3%
Quartz and microcline	1.3%

The two types of pyroxenes are surrounded, as in the case of the gabbro, by rims of uralite, and biotite is also intimately associated with them. Iron oxide is fairly abundant in and around the pyroxene crystals in association with small grains of apatite. Quartz and microcline are in fine grains and crystallized late. The potassic feldspar corrodes the andesine, and quartz is common along cleavages and fracture planes in the biotite and pyroxenes. Epidote is mostly a product of alteration of the pyroxenes.

In all the other exposures of the dioritic facies examined, the feldspar is, to the naked eye, somewhat lighter in color and is andesine (An_{32}-An_{42}). Under the microscope, the andesine is clouded, saussuritized, and surrounded by rims of a more albitic plagioclase and microcline. The pyroxenes are also much more altered and have largely changed to amphiboles. An orthorhombic pyroxene is identifiable in only one section, but the cores of all the larger crystals of amphiboles are either lighter in color and less pleochroic than the periphery or still contain relics of monoclinic pyroxene and abundant iron oxide. Quartz and microcline are, in general, more abundant in this altered facies than in the fresh type, and chlorite, with titanite and leucoxene, occurs in small amount in association with the ferromagnesian minerals.

Syenitic Facies

The remainder of the intrusive complex is essentially a coarse-to medium-grained rock of syenitic composition. The coarse-grained syenite facies contains generally between 30 and 40 per cent dark minerals, whereas hornblende and biotite form ordinarily around 25 per cent of the medium-grained type.

Several thin sections of the syenitic facies of the complex were examined under the microscope, and all the specimens were found to possess essentially similar textural characteristics and mineral association, the latter with the exception of the greater abundance of dark minerals in the coarse-grained facies, and the presence of identifiable andesine in a few specimens.

Two specimens secured from the coarse-grained facies, at a locality about three thousand feet east of the western boundary of the map-area and fifteen hundred feet south of the east-west township line were found by Rosiwal analysis to have the following approximate compositions.

	A	B
Andesine (An_{34-38})	25.1%	18.2%
Albite (An_9)	24.8%	28.8%
Amphiboles (mostly uralite)	29.7%	25.4%
Biotite	10.3%	10.5%
Microcline	7.2%	8.3%
Quartz	2.3%	4.3%
Chlorite	0.2%	0.6%
Epidote minerals	1.4%	1.8%
Titanite, leucoxene	0.6%	0.2%
Iron ores	0.3%	0.3%
Tourmaline	0.1%	0.5%
Sericite	traces	0.1%
Saussurite	-	-

The andesine is, in general, highly clouded but good determinations of its calcicity were obtained. The albite, which is fresh, surrounds and corrodes the andesine and was obviously introduced after the crystallization of the more calcic plagioclase. The microcline is younger than both the andesine and the albite and apparently of the same age as the quartz. Vermicular microcline occurs frequently in the albite.

The hornblende is generally highly pleochroic from dark bluish green to pale brown, but the cores of many of the larger grains are lighter colored, less pleochroic, and contain abundant iron oxide inclusions. The amphibole appears, in a few cases, pseudomorphous after pyroxene, and it is believed that most if not all of it is a product of alteration of the pyroxene. The biotite appears largely secondary after hornblende.

In all the other specimens of the syenitic facies of the complex, the rock is a granular aggregate of albite-oligoclase, microcline, hornblende, biotite, and a little quartz. The sodic plagioclase (An_8 to An_{13}) makes between 25 and 65 per cent of the rock, with an average of 40 per cent. It is generally fresh and, in the coarse-grained facies, it occurs either in small grains or as rims around highly saussuritized cores the indices of which are distinctly higher than albite or oligoclase (see plate XlV, B). No positive determination of the calcicity of this saussuritized plagioclase could be made in these specimens, but the writer has little doubt that they are remnants of a plagioclase similar to the one identified as andesine in other specimens of the diorite-syenite complex. In one section of the coarse-grained syenitic facies, a slightly broken euhedral crystal of feldspar shows a highly clouded core surrounded by an albitic zone which is in turn rimmed by microcline. The albite corrodes and projects into the saussuritized core and is itself corroded by microcline that rims it. This is obviously not primary zoning but rather a secondary phenomenon. These phenomena are easier to observe in the coarse-grained facies because of the larger grains of feldspar; they undoubtedly occur in the fine-grained type of syenite, but, because of the finer texture of the rock, the alteration of the primary plagioclase to albite and oligoclase has been more complete.

Microcline makes between 20 and 25 per cent of the average syenite and was one of the last light-colored minerals to crystallize.

Hornblende makes up between 15 and 30 per cent of the syenite and, in most of the sections examined, it evidently formed from pyroxene. Augite was recognized in the center of large hornblende crystals in two specimens of the coarse-grained facies of the syenite, and in all, of them, the cores of the larger hornblende grains is lighter in color, less pleochroic, and richer in iron oxide inclusions than the periphery.

Biotite varies from one to fifteen per cent and most of it appears to be secondary after hornblende. The content of quartz is of the order of five per cent, except near the contact of the syenite with the adjacent sedimentary rocks where quartz is, in one section, 25 per cent of the rock. Epidote, allanite, titanite, sericite, iron oxides, apatite, and chlorite are the common secondary and accessory minerals, and tourmaline was observed in two specimens.

Granite is exposed at two points in the area underlain by the intrusive complex under consideration. Those two outcrops of granite are shown on the accompanying map (3e). One is located about 1 1/5 miles east of the western boundary of the area and one mile north of the east-west surveyed line; the other occurs slightly over half a mile east of the western limit of the area and some two thousand feet south of the surveyed line mentioned above. The northern exposure of granite is very low, partly covered, and does not permit the study of the relationships between the syenite and the granite, but the southern one is along a small ridge and occurs as a plug-like mass, about three hundred feet in diameter, of a fine-grained grey granite intruding the coarse-grained syenitic facies of the complex. The granite consists essentially of a granular aggregate of microcline, albite, and quartz. The albite (An_8), which makes about 25 per cent of the rock, is slightly saussuritized and was apparently the first mineral to crystallize since small inclusions of it are present in the quartz which, in general, fills the interstices between the plagioclase grain and makes about 12 per cent of the granite. The microcline is the latest constituent of the three, and large grains of the potassic feldspar contain numerous diversely-oriented inclusions of quartz and albite. It also corrodes the albite in a myrmekitic fashion.

Biotite is the only ferromagnesian of the granite; it occurs in small flakes and makes about five per cent of the rock. Apatite is associated with the biotite which is seen in places going to sericite. Magnetite is present in relatively large euhedral crystals.

Origin of the Diorite-Syenite Complex

The border facies of the intrusive mass tends to be slightly gneissic and to contain partly-digested inclusions of greenstone. The intruded formations themselves have been altered near their contact with the intrusive, and *lit par lit* injections are common in the sedimentary rocks along the northern border of the intrusive, from McDonald creek westward to the western boundary of the map-area and along the south shore of McDonald lake and southwestward. Highly altered and *lit par lit* injected volcanic rocks are also found along Inconnu river from the western boundary of the area eastward for a distance of at least two miles and north of the same river close to the southeastern limits of the complex.

On the other hand, the tenor in quartz in the intrusive is usually much greater near its contact with the sedimentary rocks than it is close to the volcanics, and this suggests that some of the intruded rocks has been incorporated in the intrusive. It can be seen on the accompanying map that the outcrops of the gabbroic and of most of the dioritic facies of the complex are somewhat in line with the east-west gabbro bodies north of Capisisit lake. This suggests that the gabbroic and the dioritic facies may have been formed from a similar gabbro body which has been left largely intact at its center, but, outwards, it has been reworked to yeld a diorite. On this hypothesis, it is, however, difficult to explain the remarkable freshness of the constituents of the gabbroic and of some of the dioritic facies. Furthermore, the calcity of the plagioclase in the gabbro bodies north of Capisisit lake is An_{60}-An_{65}. It is hardly conceivable that the content of anorthite of the plagioclase could be reduced from An_{65} to An_{55}, and even An_{35} in the fresh diorite, without any traces of the old plagioclase being left and especially without any extensive alteration of the pyroxenes, which are quite fresh in the gabbroic and in part of the dioritic facies. In the gabbro bodies north of Capisisit lake, the pyroxenes are much altered and have been converted to hornblende and tremolite. The same is true for the much larger gabbro masses of the southeast corner of the area.

Some exposures of the dioritic facies are north of the line of the above mentioned gabbro bodies north of Capisisit lake, and furthermore, traces of a calcic plagioclase are still visible in almost all the exposures of the intrusive complex, even those very close to the contact with sedimentary rocks.

The hypothesis that the fresh gabbro could be part of a younger basic intrusive cutting through the dioritic-syenitic complex is incompatible with field relationships. The gabbro was observed grading into fresh diorite, and small pegmatite dykes were seen intruding both of them.

It is suggested that most of the complex intrusive mass under study, if not the whole of it, was at the origin, a dioritic rock with a gabbroic facies in at least one locality. Field relationships and microscopical studies indicate that at least the coarse-grained syenitic facies of the intrusive is the altered equivalent of the original diorite or gabbro.

Six characteristic specimens of the different types of the diorite-syenite complex were selected from those collected in the field and submitted to the Quebec Department of Mines Laboratories for chemical analyses. Unfortunately, owing to circumstances beyond the writer's control, complete chemical analyses could not be obtained, and the alumina was not given separately from the iron, titanium, zirconium, chromium, and phosphorus oxides so that it becomes impossible to calculate the norms of the different facies of the complex. The analyses were, however, very useful as illustrations of the intimate genetic relations of the different facies, relations which were determined from field relationships and microscopical studies.

The approximate mineral percentages of the six specimens submitted for chemical analyses as determined by Rosiwal analyses are the following.

	1 %	11 %	111 %	1V %	V %	V1 %
Quartz	-	1.3	2.3	5.0	2.0	10.2
Potash feldspar	-	1.5	7.2	10.4	-	19.7
Albite (An_9)	-	-	24.8	-	62.6	49.4
Oligoclase (An_{11}) .	-	-	-	59.3	-	-
Andesine (An_{35})	-	53.8	25.1	-	-	-
Labradorite (An_{55}) .	43.3	-	-	-	-	-
Hypersthene	19.0	1.0	-	-	-	Tr.
Diopside-augite ...	25.0	21.2	-	-	2.5	Tr.
Amphiboles	6.5	6.3	29.7	13.5	18.2	11.3
Biotite	1.6	10.4	10.3	5.1	10.1	5.0
Chlorite	0.4	0.4	0.2	-	-	0.5
Epidote, zoisite, allanite	-	3.1	1.4	1.1	0.6	1.0
Titanite, leucoxene	-	0.3	0.6	0.8	0.3	1.5
Apatite	0.3	2.0	1.0	0.8	1.3	0.8
Tourmaline	-	-	0.1	0.1	-	-
Sericite	Tr.	Tr.	Tr.	0.6	0.4	1.2
Iron ores	3.9	1.3	0.3	0.3	0.6	0.3
Carbonates	-	-	-	-	0.3	-

1 - Coarse-grained, fresh gabbro, from a small exposure, about three quarters of a mile east of the western boundary of the map-area and a few hundred feet north of the east-west surveyed line.

11 - Fresh looking, coarse-grained diorite, from a locality about three quarters of a mile north of No. 1.

111 - Somewhat altered, coarse-grained diorite with large plagioclase grains having a greyish core surrounded by a pinkish white rim. Selected from a small exposure about one and a half miles north of No. 11.

1V - Coarse-grained, altered diorite or mafic-rich syenite or monzonite, from about one mile east of No. 11

V - Coarse-grained, mafic-rich syenite with large grains of white feldspar, from half a mile east of No. 111.

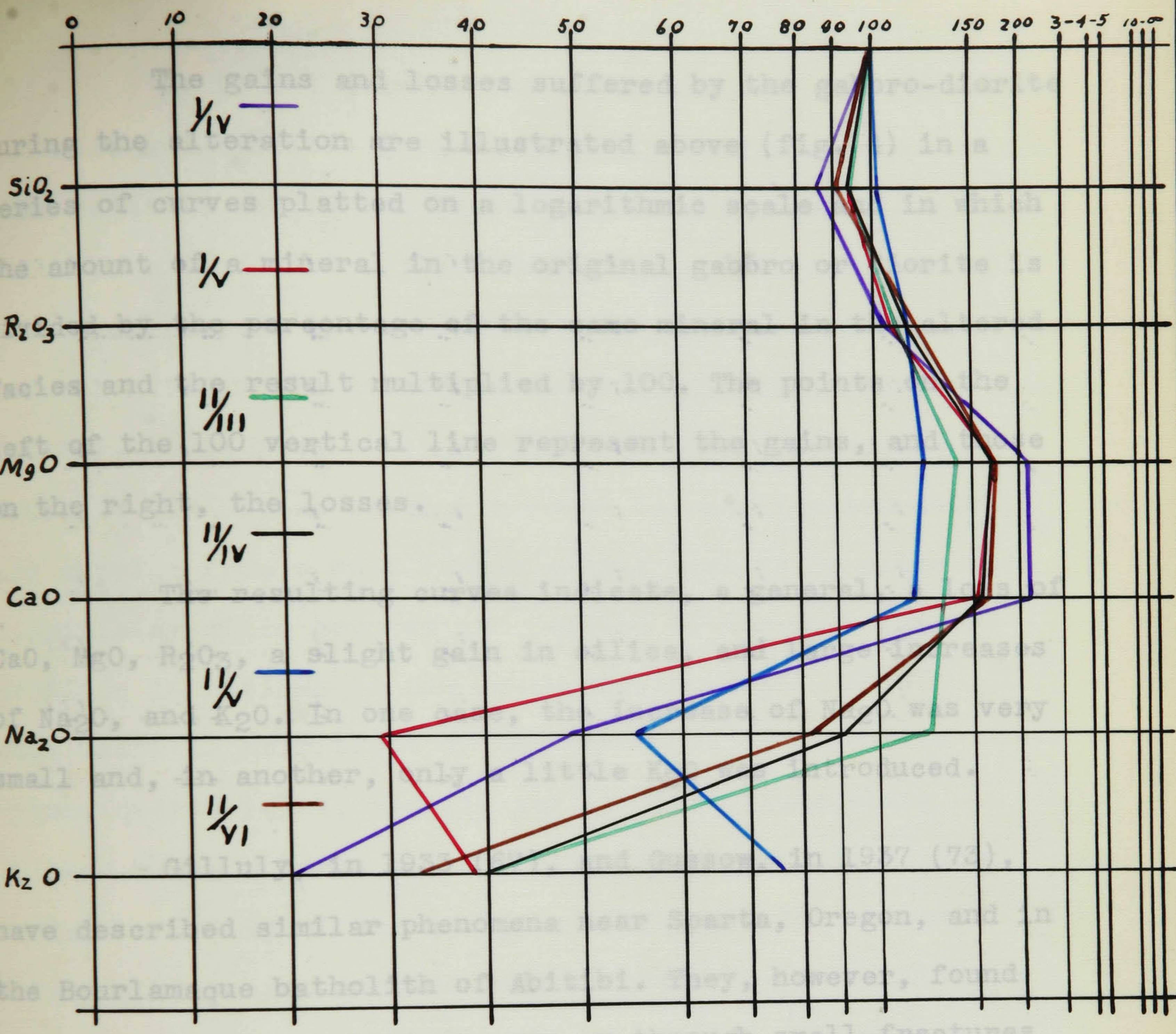
Vl - Gnessic, quartz-rich, boarder facies containing white and pink feldspar, from a locality a few hundred feet of the western boundary of the area and three quarters of a mile north of Inconnu river.

The results of the chemical analyses of the six specimens are given below.

	1 %	11 %	111 %	1V %	V %	V1 %
SiO_2	50.2	54.2	57.0	58.?	53.4	60.0
R_2O_3	23.7	25.0	23.7	23.1	22.7	21.4
CaO	11.6	8.5	5.9	5.4	7.6	5.1
MgO	9.7	7.0	5.3	4.4	5.8	4.8
P_2O_5.........	0.09	0.29	0.4	0.28	0.3	0.3
Na_2O	2.2	4.2	3.3	4.6	7.6	5.1
K_2O	0.5	1.0	2.5	2.5	1.3	3.0
Volatiles ...	2.1	0.1	2.3	2.0	1.6	0.6

R_2O_3 = | Al_2O_3
| Fe, total in Fe_2O_3
| TiO_2
| P_2O_5
| ZrO_2
| Cr_2O_3

Comparison of the analyses of the diorite-gabbro with those of the altered diorite-syenite facies shows that while there w~~a~~s only minor changes in the major oxides in the course of the alteration, there is a decrease of CaO and MgO and an increase of Na_2O and K_2O.



Curves illustrating the gains and losses of material during the albitization of the Gabbro-Diorite Complex.

fig. 4

The gains and losses suffered by the gabbro-diorite during the alteration are illustrated above (fig. 4) in a series of curves platted on a logarithmic scale and in which the amount of a mineral in the original gabbro or diorite is divided by the percentage of the same mineral in the altered facies and the result multiplied by 100. The points on the left of the 100 vertical line represent the gains, and those on the right, the losses.

The resulting curves indicate, a general, a loss of CaO, MgO, R_2O_3, a slight gain in silica, and large increases of Na_2O, and K_2O. In one case, the increase of Na_2O was very small and, in another, only a little K_2O was introduced.

Gilluly, in 1933 (67), and Gussow, in 1937 (73), have described similar phenomena near Sparta, Oregon, and in the Bourlamaque batholith of Abitibi. They, however, found evidence that the solutions came up through small fractures and shears, and that the alteration proceeded outward from those zones. No such channelways for solutions were identified in the field, but the paucity of exposures and the scale at which the geological mapping was done may well account for the lack of such evidence.

It is not possible to state whether the original gabbroic and dioritic facies are early differentiates of the same magmatic mass which later generated the solutions which have tended to replace the original plagioclases by more sodic types, the pyroxenes by amphiboles, biotite, and chlorite and to introduce deuteric quartz and microcline. However, it is possible that the small granitic bodies, actually visible as cutting through the earlier intrusive, are cupolas from a much larger acidic mass lying below the dioritic-syenitic complex and related to the much larger granitic intrusions to the south and southeast. This conclusion is reinforced by the abundance of pegmatite dykes, quartz veins, and _lit par lit_ injections along Inconnu river between the Capisisit Lake granite and the western boundary of the area, as well as in the volcanics between the coarse-grained granitic mass in the southwestern section of the area and the altered dioritic intrusive under consideration.

Capisisit Lake Granite

A fine-to medium-grained, pink, generally massive granite occurs in the form of an elongated southeasterly-trending mass completely surrounding Capisisit lake and extending to slightly east of the seventy-sixth meridian, in the south central section of the area. Good exposures of it can be seen along the northern shore of Capisisit lake, especially on the large peninsula slightly west of its center, and south of Inconnu river in the southeastern extension of the mass.

In the exposures around Capisisit lake, the granite is a relatively fresh and massive aggregate of quartz, pink feldspar, and hornblende. The microscope shows that the rocks is actually made of about 50 per cent albite (An_8), between 15 and 35 per cent microcline, 10 to 25 per cent quartz, about 15 per cent hornblende and biotite, and small amounts of chlorite, epidote, allanite, titanite, apatite, sericite, and iron ores. South of Inconnu river, the granite appears to the naked eye as a much altered pink rock composed mainly of feldspar, quartz, and very fine-grained biotite. The microscope reveals the absence of hornblende, and the dark minerals are biotite and its products of alteration. The accessory minerals are the same as in the fresher facies around Capisisit lake.

The albite is fresh in the specimens from the shores of the lake, but, southeastward, it becomes very altered and difficult to identify accurately. Dark green, highly-pleochroic hornblende makes about 15 per cent of the fresh granite, but, where the albite is saussuritized, the horblende is altered to biotite. In most of the specimens of the granite collected south of Inconnu river and in which the albite is much altered, no hornblende is left, and biotite and chlorite are the only dark minerals. In others, the hornblende is surrounded by a rim of biotite, numerous inclusions of which are also present in the amphibole. In the most altered facies, biotite flakes are themselves surrounded by rims of chlorite which also penetrates along the cleavage planes of the biotite. Sericite occurs as a product of alteration of both biotite and albite.

The potassic feldspar, microcline, is invariably fresh and well twinned. It commonly occurs in large grains containing rounded and angular inclusions of albite and quartz, and, in a few specimens, of hornblende, biotite, and sericite. The quartz is, in general, intimately associated with microcline.

The southeastern section of the Capisisit Lake granite mass has, in general, lost its massive character and has taken in places a very faint foliated texture. A well-developed protoclastic microtexture is almost everywhere present in the rock, and the albite, biotite, and, to a smaller extent, the quartz, show the effects of stress. The microcline is, in general, remarkably free from granulation or crushing, and it very frequently occurs in large unstrained grains containing fragments of all other minerals of the granite (see plate XV, A). Some of the quartz also exhibits similar characteristics, but, in general, it has been stressed and fractured. Most of the microcline and some of the quartz undoubtedly crystallized after the culmination of the stress which produced the shattering and granulation of the granite.

Waswanipi Granite

Some 60 square miles of the southwestern section of the map-area are underlain by a large granitic mass, which is a marginal facies of a more extensively-exposed body to the west and south of the present area. This granite was described by W. W. Longley in his reports on the Bachelor Lake (91) area to the south of the western half of the present map-area, and the name of Waswanipi granite was given to it (92).

Exposures of the Waswanipi granite occur abundantly in the southern central section of the western half of the map-area, and its contact with the intruded gabbroic and volcanic rocks can be traced fairly accurately along the eastern limit of the mass. Towards the west, however, the boundaries of the intrusive body are covered with thick glacial deposits, exposures are very scanty, and, consequently, the contact can be defined only approximately.

Considerable variations in appearance, composition, amd texture were observed in the Waswanipi granite within the limits of the present area. It may be stated, however, that the normal granite is a medium-to coarse-grained, quartz-rich, leucocratic rock containing abundant pale pink feldspar and a low tenor of dark minerals, mostly biotite and its products of alteration. The rock is, in general, massive, but a distinct foliation is visible in the contaminated contact facies along the eastern boundary of the mass. In some other places, farther away from the intruded rocks, the biotite may show some degree of alignment, but, generally, the granite is quite massive. Pegmatitic dykes and lenses are abundant in the whole area underlain by the granite.

Under the microscope, the rock appears as a granular aggregate of albite (An_{8-10}), microcline, quartz, and biotite as the main constituents, with chlorite, sericite, epidote, allanite, zoisite, titanite, zircon, and iron ores as secondary and accessory minerals. Albite makes between 35 to 70 per cent of the rock and is usually fairly fresh. In many of the plagioclase grains, zoning is present, and the somewhat clouded cores have refractive indices slightly higher than those of the surrounding albite and presumably they are of a slightly more calcic composition. The content of potassic feldspar, mostly microcline with a small amount of orthoclase, varies widely even within the limits of a single exposure. In some specimens, it is practically absent, whereas, in others, it makes over 50 per cent of the rock. The microcline is always fresh, well-twinned, and sometimes in large grains containing in a poikilitic fashion scattered unoriented grains of albite. In practically all the specimens examined, the potassic feldspar corrodes the albite, and it appears that most of the microcline crystallized after the precipitation of most of the triclinic feldspar.

Quartz makes between 15 and 35 per cent of the rock and is also of late crystallization. It iflls the interstices between albite grains and contains inclusions of plagioclase and mica. Biotite is the only primary dark mineral of the granite and makes up two to fifteen per cent of the rock.

It is brown, highly pleochroic, and alters readily to chlorite, with the appearance of sagenitic networks of rutile or magnetite. Sericite, allanite, epidote, and zoisite are in places fairly abundant. Primary muscovite was found in a specimen of the pegmattitic facies of the granite, and large cubes of pyrite occurs in the gneissic contaminated contact facies.

A protoclastic texture is a conspicuous feature of this facies of the Waswanipi granite, and most of the larger grains of primary quartz and albite have been granulated at the periphery and some completely shattered. The albite seems, however, to have resisted the stress much better than the quartz, and, in the gneissic contact facies, it frequently occurs as large well-aligned "augen" whereas the quartz has been completely granulated. The biotite often shows bent lamellae, and, in places, quartz and potassic feldspar grains have grown between the planes of cleavage of the biotite and have pushed them apart. Some of the quartz and most of the microcline is obviously of post-kinematic crystallization since grains of these two minerals are unstressed and contain fragments of all the other constituents of the granite.

Renault Lake Intrusive

The granitic rock mapped as the Renault Lake intrusive constitutes a small marginal facies of a very large intrusive mass of granite which has been recognized and studied farther south and east by many workers including Shaw (128, 129, and 130), Beach (17, 18, 19, and 20), Retty and Norman (121), Norman (111), etc. Shaw describes the main mass of the rock as an oligoclase granite or tonalite, whereas the border facies in the Mechamego Lake and Michmago Lake map-areas is, according to Beach, a hornblende granodiorite.

The northern border facies of this granitic intrusive underlies about ten square miles of the southernmost part of the eastern half of the map-area. Renault lake is located almost along the western contact of the intrusive with volcanic and gabbroic rocks to the west and north. Farther east, the contact swings to the east-southeast and is close to parallel to the strike of the adjacent volcanic and gabbroic series.

To the naked eye, the Renault Lake facies of the granitic intrusive is a medium-grained, generally massive rock whose proportions of light-colored and dark minerals may vary widely from one locality to the other. This variation of constituents is due mainly to contamination of the intrusive by the ferromagnesian-rich intruded gabbroic or volcanic rocks and the numerous partly-digested inclusions which are present in the immediate border facies. However, the average content of biotite which is the normal constituent of the rock and of its products of alteration very seldom seems to be over 20 per cent. Quartz also makes generally about 20 per cent of the rock and it occurs in fractured glassy grains. The feldspar is pink or greyish white, and the rock generally weathers pinkish grey.

Studied under the microscope, the rock is seen to vary in composition between an albite granite and a diorite. The normal facies appears to be that of an albite granite having essentially the following composition.

Quartz	15-20%
Albite (An_{6-9})	50-60%
Microcline	10%
Biotite and Chlorite	10-15%
Apatite and Titanite	1%

On the small island near the east shore of Renault lake, the plagioclase is slightly more calcic (An_{14}), and a low content of actinolite is associated with the chlorite which is secondary after biotite. The rock is therefore an oligoclase granite. Near the eastern boundary of the map-area and close to the contact with the zone of volcanics to the north, the intrusive is a quartz diorite with quartz as high as 20 per cent, andesine (An_{31-33}), 50 to 60 per cent, biotite and its products of alterations, 20 to 25 per cent, and a low content of actinolite. At other localities near the boundaries of the intrusive mass, quartz is absent, the plagioclase is a sodic andesine, and the intrusive is a diorite.

Although, as it was stated above, the rock appears generally massive with only an occasional slightly foliated facies, its texture, as seen under the microscope, is, with very few exceptions, essentially protoclastic. All the larger grains of plagioclase are surrounded by numerous small fragments, and the quartz, less resistant to stresses than the plagioclase, has generally been highly smashed and has partly recrystallized in elongated leaves parallel to the foliation where the latter is present in the rock.

The microcline is always very fresh, well-twinned after the albite and pericline laws and it appears to be essentially a mineral of the final stage of consolidation of the rock. It is unstressed, frequently in large grains poikilitically including unoriented fragments of plagioclase and quartz, flakes of biotite and chlorite, and grains of epidote. It also corrodes the albite and oligoclase and frequently makes myrmekitic intergrowths with them. Microcline is totally absent in the quartz diorite and dioritic facies of the rock.

The intrusive is, as a whole, somewhat altered, and the constituent minerals, except microcline and quartz, are generally partly gone over to secondary products. The plagioclase grains are clouded with saussurite, sericite, and very fine iron ores. Some of them, especially those belonging to the albite group, have retained faint relics of zoning with cores slightly more calcic than the peripheries.

The biotite is generally wholly or partly gone over to pale green, slightly pleochroic chlorite commonly occurring in bent or twisted lamellae. The chlorite contains abundant iron oxide grains, and epidote and white mica are also associated with it. These are all considered to be products of alteration of the biotite.

Dykes of pink aplitic leucocratic granite are found cutting the main mass of granitic rock, and medium-to coarse-grained pegmatites are very abundant on the shores of Renault lake and eastward. These dykes do not seem to follow any structural pattern but cross-cut the granite in any direction regardless of the foliation where the latter occurs in the rock. The pegmatites frequently grade into white, milky, barren quartz veins.

Coarse-Grained Syenite

A very coarse-grained, mafic-rich syenite or shonkinite is exposed at two localities about eight hundred feet apart on a low elliptical hill about twenty-five hundred feet long and fifteen hundred feet wide, located close to one and a half miles slightly north of west of Huguette lake. The southern of the two exposures is very small, but the northern one is about a hundred and twenty-five feet in diameter and it consists of a coarse-grained hornblende-feldspar rock. The feldspar crystals are euhedral and occur in specimens up to three inches long (see plate X, B). They are greyish, weather pinkish, and are generally stained on altered surfaces by abundant iron oxide from the neighbouring amphibole crystals. The amphibole grains are anhedral and interstitial to the feldspar crystals. Epidote, chlorite, and some cubes of pyrite are also visible to the naked eye. The rock was found to weather very readily in the field owing probably to the coarseness of it constituent minerals.

Fragments of the feldspar were examined under the microscope, and the refractive indices of the mineral were checked by oil immersion. They were found to be close to 1.527, and the characteristic cross-hatched twinning of the microcline was plainly visible in most of the fragments studied. In some of them, the feldspar is a microperthite with very acidic albite as the sodic constituent.

The amphibole is a dark green-blue, highly-pleochroic variety apparently belonging to the alkaline group. Only poor determinations of the optical properties of the amphibole could be made on account of the alteration, the deep coloring, and the presence of a thick dissemination of iron oxides in the fragments. Those determinations seemed to indicate that the amphibole is of the arfvedsonite variety. In appearance and texture, the coarse-grained syenite is related to late facies of intrusive masses described in some areas of the Grenville sub-province by Osborne (170), De La Rue (166), etc. The paucity and the deep weathering of the exposures of the rock in the present area together with the absence of observed contacts and field relationships make a serious detailed study of the rock an impossible task. It may represent a late and contaminated facies of the large granitic intrusive mass to the north.

Dyke Rocks

As stated above, pegmatite and, to a smaller extent, aplite dykes occur abundantly in association with the major acidic intrusive masses of the area, with the possible exception of the Capisisit Lake granite in which they are not as conspicuous. In the volcanic, sedimentary, and gabbroic rocks, their presence is generally limited to and near the contact between the intruded rocks and the plutonic bodies. Farther away from the acidic intrusives, few occurrences of pegmatite and aplite are to be seen. A small exposure of coarse-grained pegmatite makes a very low island in Inconnu river, at the bottom of the second rapid, about one mile down the river from the outlet of Capisisit lake. Some two miles farther downstream, small pegmatite dykes cut through a highly hybrid rock of granitic appearance, and small pegmatitic dykelets occur in the lit par lit injected volcanic rocks near the middle of the one mile-long rapid in the river, about two miles east of the western limit of the area.

Granite dykes occur in wide dissemination throughout most of the area underlain by the pre-granitic rocks, but most of them are small and not worthy of an extensive study in the course of gelogical exploration on a regional scale.

A pink granite dyke, about fifteen feet wide, was seen cutting through the gabbroic rocks on the north-south township line near their contact with the Capisisit Lake granite, about one eight of a mile north of post No. 5, and a similar one, probably the prolongation of the one above, occurs along the blazed line about one and a half miles to the southeast. The rock of those relatively large dykes is a fine-grained, pink, leucocratic granite the main constituent of which is pink feldspar. Quartz makes about 15 per cent of the rock, and chlorite, probably secondary after biotite, about five per cent.

Other granite dykes which may be worth mentioning also occur along the course of Inconnu river, about three miles east of the western boundary of the map-area, in sedimentary rocks, about two and a half miles north of Colette lake, and along the north shore of Inconnu lake half a mile southeast of post No. 64 and a quarter of a mile east of post No. 65 of the east-west surveyed line. In these last two occurrences, the rock is a fine-grained, granular aggregate of andesine (An_{34-37}), 60 per cent, quartz, 20 per cent, biotite, 10 per cent, hornblende, 5 per cent, and titanite, epidote, apatite, chlorite, and iron ores. The dykes intrude conformably fine-grained, grey sedimentary rocks, and the contact between the two types of rock is very faint and both rocks look somewhat similar except for their texture.

Buff to dark grey porphyritic dykes are to be seen in all sections of the Capisisit-Inconnu Lake area, but more abundantly in the areas underlain by volcanic, sedimentary, and gabbroic rocks. The largest seen during the field seasons are those outcropping on Inconnu river slightly west of the outlet of Inconnu lake, those at the southern tip of Gilles bay, and the ones intruding sedimentary rocks at a locality about two miles slightly east of south of the ones on the shore of Gilles bay.

The porphyritic dykes vary in width between a few inches and over ten feet, but most of them are of the order of two feet across. The great majority of them have been introduced as concordant bodies prior to the main period of folding of the volcanic, sedimentary, and gabbroic rocks, probably as thin sheets, and they have been rendered schistose to a degree comparable to that of the rocks they intrude. Other are massive, unsheared, and are probably post-tectonic.

In most of the porphyritic dykes, the phenocrysts are euhedral to subhedral plagioclase feldspar grains enclosed in a darker-colored, finer-grained, feldspathic matrix. The calcity of the plagioclase phenocrysts varies from one dyke to another from An_8 to An_{25} in the specimens examined. Those containing albite or sodic oligoclase are usually lighter colored than those containing the more calcic oligoclase phenocrysts. Small quartz porphyry dykes were seen at only scattered places. One larger dyke of this type occurs at the contact between the coarse-grained facies of the diorite-syenite complex and the intruded sedimentary rocks, about three thousand feet south of the outlet of McDonald lake. The great majority of those porphyritic dykes, and especially the schistose and sheared types, are altered and contain secondary quartz and carbonate with scattered pyrite.

A few very dark, commonly porphyritic trap dykes were seen at widely scattered localities throughout the area. The trap dykes do not generally exceed six inches across their strike and they intrude both the pre-granitic rocks and the granites. The largest of them were found in the diorite-syenite complex where they are represented by two altered and mineralized lamprophyre dykes, about 12 inches wide, cutting across the complex and its related pegmatites, at a locality about five hundred feet east of the western boundary of the map-area and one mile south of the east-west surveyed township line (p. 157).

Two specimens of the trap dykes were examined under the microscope, and the rock appears as a much altered aggregate of iron ores and secondary minerals. Faint relics of phenocrysts are still visible in the two specimens, and, in the dyke cutting the diorite-syenite complex, the phenocrysts were apparently biotite. Iron ores make over 60 per cent of the rock of the dykes, and the other constituent minerals are chlorite, carbonate, epidote, zoisite, and serpentine.

Chapter X

POST-GRANITIC BASIC INTRUSIVES

General Considerations

Relatively unaltered intrusive rocks of basic composition including olivine diabase, diabasic gabbro, and quartz diabase outcrop at a few localities throughout the map-area, more abundantly in the eastern half. They intrude the volcanic, the "old" gabbroic, the sedimentary, and some of the granitic rocks and they appear to constitute the youngest consolidated rocks of the area.

Dykes of similar types of rock are widely distributed in the Temiscamian sub-province and, to a smaller extent, in the whole of the Precambrian terranes, the world over. At least two ages of similar diabase or diabasic gabbro dykes and sills have been recognized around the Great Lakes (43, 44, and 149) and in the Rouyn-Harricanaw district where they are represented by one pre- and one post-Cobalt series (54). In the Chibougamau district, only one series is recognizable, and the dykes belonging to it are inferred by Mawdsley and Norman to be younger than the Chibougamau sediments (97). As they state it:

> "This inference is based on the following: (1) the freshness of the diabase in contact with the highly indurated and more altered state of the sediments; (2) the absence of any known shearing and schistosity in the diabase, whereas the sediments are intensely sheared and altered in a wide belt along the McKenzie Narrows fault; (3) the inferred parellelism of the dykes to the southwesterly extension of the McKenzie Narrows fault across the north side of Portage island. Such parallelism suggests that southeasterly faulting, which is later than the sediments, contributed to the formation of fractures along which the diabase was able to ascend" (p. 49).

No age distinction between the different post-granitic diabasic bodies is possible in the present area owing to the total absence of Huronian sediments and of cutting relationships between the different diabase dykes. They are however all considered as post-granitic on account of their intruding of the Waswanipi granite and the Maicasagi River intrusive.

The trend of the late basic dykes of the area varies from N.25°E. to S.80°E., and their size appears generally quite limited. Their maximum width is about 150 feet, and their length, as suggested by the distribution of their exposures, does not appear to exceed one mile.

Distribution

Four relatively large exposures of fine-grained diabase and quartz-diabase occur at a locality about one mile east of Veto lake, in the northern part of the east half of the area. They constitute elongated masses about 60 feet wide, from 100 to 200 feet long, and rising about 20 feet above the surrounding gneissic granite. A glance at the map will show that the four exposures naturally fall into two series, one of which trends N.25°E., and the other N.35°E. The intervening ground between the two southern and the parallel northern exposures is covered with a thick accumulation of morraininc material, and it is probable that the four outcrops make only two uninterrupted dykes, even possibly only one farther south. The trend of the dykes is generally parallel to the strike of the main set of joints and, to a smaller extent, to the foliation of the acidic intrusive.

Medium-grained olivine diabasic gabbro is present along the north shore of Inconnu lake, slightly less than two miles west of the eastern boundary of the map-area. Two exposures of quartz diabase also occur on the east shore of Gilles bay, about one and a half miles south-southwest of the olivine gabbro of the north shore of Inconnu lake just mentioned. One exposure of very fresh, olivine-bearing gabbro found in the south central section of the area underlain by the "old" gabbro complex, at a locality about three and a half miles northwest of Renault lake, is interpreted as belonging to a younger diabasic intrusive related to the other late Precambrian basic rocks of the area. No contact were seen on the small exposure, but the rock weathers highly rusty and looks very fresh under the microscope, two features not generally encountered in the "old" gabbros of the area.

An fine-grained olivine diabase dyke trending N.35°E. is also exposed in the Waswanipi granite, slightly over one mile north of the southern boundary, near the center of the western half of the map-area. This dyke is well visible for nearly a quarter of mile along its length, and its width is quite constant at about 50 feet. It intrudes the coarse-grained Waswanipi granite, and a black, very fine-grained, chilled border selvage, about five inches thick, is presentat the immediate contact between the two. Both the main mass of the diabase and the chilled contact weather rusty brown.

Description of the Rocks

The olivine diabases, the quartz diabases, and the diabasic gabbros of the area have so many features in common that it not believed necessary to describe them separately. They all look somewhat similar in the field except for the possible recognition of some olivine grains in the coarser-grained types of olivine-bearing diabase.

The late Precambrian basic intrusives of the area outcrop as narrow elongated bodies having very uniform width and a sharp contact with the intruded rocks, were these be granitic or pre-granitic rocks. The narrow chilled border and the sharp contact are taken to indicate that the temperature of the magma was only a little above that of freezing when the diabase magma came to rest. The quickly chilled border acted as insulator between the wall rock and the still liquid magma towards the center of the dyke, and crystallization took place slowly without any extensive amount of heat being given off to the adjacent rock, and no appreciable fusion, metamorphism, or stoping of the intruded formations took place.

The average type of diabase is a medium-to fine-grained, dark grey to almost black rock in which a diabasic or ophitic texture may or may not be recognized in the field. The rock always weathers rusty brown on account mostly of its abundance of magnetite and ilmenite, grains of which are generally visible to the naked eye. Olivine and quartz are sometimes in large enough grains to be identifiable with a pocket lens, and the plagioclase appears very well formed and in pale to dark grey, generally fresh crystals.

Under the microscope, all the diabasic intrusive rocks of the area show a more or less well-developed ophitic or poikilitic texture, and the minerals are generally fresh to very fresh (see plate XV, B).

The average compositions of the different types of late diabases of the area are the following:

Olivine diabases

Labradorite (An_{60-63})	55%
Olivine	15%
Augite	20%
Hypersthene	2%
Biotite	5%
Iron ores	3%

Quartz diabases

Labradorite (An_{60-63})	55%
Augite-Diopside	33%
Biotite	2%
Micrographic quartz and acidic plagioclase	7%
Iron ores	3%

Diabases or diabasic gabbros

Similar to quartz-diabase but without the micrographic intergrowths of quartz and sodic plagioclase.

All the constituents of the diabasic rocks enumerated above are the primary and the most important minerals of the rock. The accessory and secondary minerals for the whole group are serpentine, chlorite, actinolite, epidote, zoisite, saussurite, sericite, leucoxene, titanite, and apatite.

Most of the labradorite is fresh and in slender lathy crystals possessing euhedral outlines. Occasionally, somewhat more altered, larger subhedral grains have the wavy extinction characteristic of ill-defined zoning. These larger crystals of plagioclase appear to have crystallized later than the lathy types since the latter commonly occur as inclusions in the large crystals, and the laths protrude into them. Their outlines are more irregular than those of the lathy plagioclase, and their refractive indices are slightly lower than those of the older type. They were found in all of the olivine diabase dykes with the exception of the one in the western half of the map-area. Both plagioclases have euhedral outlines against olivine in some cases, and, in others, some of the lathy crystals are younger than olivine or of the same age. In one specimen studied, olivine grains enclose well-twinned small lathy plagioclase grains and, just besides, small grains of olivine are included in a relatively large plagioclase lath.

The micrographic intergrowths of quartz and acidic plagioclase (apparently sodic plagioclase) are of a much later origin. They occur generally in anhedral grains distributed irregularly throughout the mass and, in some cases, they corrode and surround the lathy plagioclase (see plate XVl, A).

Large to small grains of iron ores occur in all the collected specimens of diabase and are especially abundant in the olivine-bearing type. Magnetite and titaniferous magnetite, in euhedral to subhedral grains up to 2.0 mm. across, make close to ten per cent of the olivine diabase exposed along the north shore of Inconnu lake, (see plate XVl, B). These grains are generally closely associated with olivine and, to a smaller extent, with pyroxene. Euhedral crystals of ilmenite and magnetite are common as inclusions in olivine, plagioclase, and pyroxene grains, and, consequently, the iron oxides should normally belong to the very early stage of crystallization.

Apatite occurs in long slender laths cutting across all the other minerals or, less commonly, in small euhedral grains occasionally included in magnetite, olivine, plagioclase, pyroxenes, and biotite. According to the generally accepted concept that the included and euhedral minerals were the first to crystallize, the order of classification of Rosenbusch for igneous rocks is here realized, with apatite having been the first mineral to form, followed by magnetite and ilmenite, olivine, and pyroxene. This order of crystallization has, however, been subjected to numerous criticisms in recent years, and arguments against it are very strong. The apatite and iron ores are accessory minerals, and their proportional amount is very small, fractions of one per cent in the case of apatite. Their very early crystallization implies that the magma has become saturated with them very early, a fact which, on account of their small amount, is hard to believe. Both these two minerals are also found abundantly in pegmatites, and so are definitely, in certain cases, residual products of the crystallization of igneous rocks. Furthermore, it can be observed in two of the specimens of the olivine diabase of the north shore of Inconnu lake that grains of apatite have grown between the planes of cleavage of the biotite grains, pushing them apart. Some of the apatite was, therefore, formed after at least part of the biotite. The latter mineral, as it is seen below, was formed mostly later than olivine, labradorite, pyroxenes, and iron ores. The aggressiveness of the apatite is probably the reason of its idiomorphic outlines, and its growth may have occurred during the late stage of crystallization of the rock from residual solutions which may also have taken material from already solidified constituents in their environment.

The case of the iron ores is more complex. Iron-rich, reddish brown, and highly pleochroic biotite is generally associated with the iron oxide grains. It is apparently the product of reaction of the iron ores with hydrothermal solutions, and the change over occurs only in the grains which were easily reachable by those solutions. A few of the magnetite grains which are completely surrounded by olivine, pyroxene, and plagioclase are not altered. In other cases, a rim of biotite occurs on only the one side of the grains which is outside of the partly enclosing larger grains of olivine or pyroxene, and the solutions did not alter the other section of it (see plate XV1, B). Some of the biotite also occurs as alteration product of the pyroxenes and most of it is probably a very late mineral formed after the iron ores and probably at about the same time as apatite.

Hypersthene was definitely identified in only one specimen of the olivine diabase occurring in the southern section of the western half of the area. It is present in somewhat altered, medium size, euhedral prisms, commonly wrapped in augite. It is a colorless mineral having refractive indices slightly lower (1.660) than those of augite and a much weaker birefringence (0.012). It has a negative elongation, a parallel extinction, and is biaxial negative with an axial angle of about 80°. Its axial plane is parallel to (010).

Both augite and diopside occur in the diabases, but it was noticed that augite is generally the monoclinic pyroxene of the olivine diabases, whereas diopside is the main pyroxenic constituent of the quartz diabases and of the diabasic gabbros. Augite is almost colorless, diopside is pale green, and both are younger than plagioclase, olivine, and iron ores(?).They generally enclose and wrap around laths of labradorite and olivine grains (see plate XV, B). In two specimens, few grains of pyroxene were tentatively identified as pigeonite, but the axial angle of the pyroxene (about 60°) is too large for a normal pigeonite. The mineral is intimately associated with diopside.

Although the Late-Precambrian diabasic rocks of the area are relatively fresh, they have not altogether escaped alteration. The olivine and orthorhombic pyroxene were especially susceptible to post-crystallization transformations.

The first stage of alteration of the olivine is the appearance of cracks, generally filled with very fine iron oxides. These cracks are the result of an increase in volume of the olivine and they commonly extend into the neighbouring plagioclase or the enclosing pyroxene grains. Later, the cracks become the loci of formation of an almost colorless serpentine which becomes pale green at a later stage and forms agglomerations or rosettes. Chlorite is commonly associated with serpentine, and both seem, in places, to go over to pale green tremolite. Small needles of serpentine, chlorite, and tremolite are present throughout the plagioclase grains in some specimens and they probably represent a transfer of material during late magmatic or early metamorphic stages.

The contact between the pyroxene and labradorite is generally marked by resorption of the feldspar by the pyroxene the birefringence of which is much lower along the edges. The alteration of the pyroxenes is diverse.

1) Hypersthene alters

a) to a fine aggregate of very small needles parallel to the cleavages of the orthorhombic pyroxene and probably belonging to the bastite variety of amphibole.

b) to a fine aggregate of slightly pleochroic green needles having a higher birefringence than bastite and probably of the uralitic type.

The orthorhombic pyroxene is corroded and attacked from the margin inwards and from cracks and cleavage planes. All gradations can be seen in the rock from incipient alteration to an almost complete transformation in which relics of hypersthene are left as islands in the mass of fibrous parallel needles. The orthorhombic pyroxene rarely alters to biotite.

2) Diopside and augite alter to a greenish amphibole, serpentine, or biotite. The alteration occurs in more than one way.

a) The replacement is made by long tongues of actinolite which penetrate the pyroxene grain.

b) The amphibole occurs in patches throughout the crystal, leaving only relics of pyroxene at the most altered stage.

c) The alteration to serpentine is generally at the periphery or along cracks.

d) The transformation to biotite occurs generally at the contact with grains of iron oxides.

Biotite is commonly altered to chlorite and white mica, and epidote-zoisite is common in small grains as alteration product of labradorite. The iron ores break down to biotite and leucoxene, and, in a few large grains, the titaniferous phase of the magnetite has separated as leucoxene which has commonly recrystallized to titanite, and the magnetite now appears as large skeleton crystals.

Dykelets and stringers of pink aplitic rock occur in the olivine diabase of the southern section of the west half of the map-area. Those dykelets and stringers vary in width from four inches to mere films and cut both the diabase and the Waswanipi granite in which the diabase outcrops.

The aplite is a very fine-grained rock which appears to the naked eye as composed exclusively of pink feldspar and a low content of fractured quartz. Under the microscope, the rock has a well-defined granitic texture, and the grains are generally stressed and fractured. Albite (An_8) makes over 60 per cent of the rock, and a potassic feldspar, apparently sanidine, and quartz about 15 and 20 per cent respectively.

The two types of feldspar are almost opaque, owing to the extreme abundance of very fine red iron oxide disseminated through them. Partly chloritized biotite constitutes about two per cent of the rock,and epidote, allanite, titanite, and apatite occur in small amount. Long needles of dark green hornblende are present at the contact of the fresh diabase with the aplites.

The presence of microcraphic intergrowths of quartz and sodic plagioclase in some diabases, and the occurrence of aplitic dykes cutting others has been studied and discussed by many geologists. The aplites were regarded as effusive acidic sediments by Bayley (163) in his studies on Pigeon Point and Bowen (28) came similar conclusions during his work on the Cobalt district of Ontario. Most of the other geologists who have written on the subject, including Barlow (13), Collins (4), Hore (77), and others, regard the aplites and diabases as magmatic differentiations from a single magma. In connection with the process of differentiation in the diabases, Collins remarked in 1910 (164) that:

> "the diabasic magma behaves as a homogeneous mixture or, more probably, a mutual solution of two chemically and mineralogically definite rock species designated diabase and aplite" (p. 549).

"After intrusion, when a sufficiently low temperature was reached, the two series crystallized, diabase somewhat in advance of aplite. Simultaneously they commenced to segregate from each other. Owing however to the exceedingly unlike dimensions of the various injected bodies of magma (in the Nipissing District), and consequent differential rate of cooling, also to imperfect fluidity, segregation was accomplished in highly different degrees. A portion of the aplite did escape, forming dikes and irregular masses in the diabase but much of it was emprisonned within the latter, chiefly in the form of a micrographic intergrowth of quartz and acid plagioclase. This gave rise to a confusing variety of hybrid rock forms, of which the commonest is quartz diabase" (p. 55).

Also in 1917 (42)

"The micrographic intergrowth (of quartz and sodic plagioclase) seems best accounted for as an incipient form of aplite that had not sufficient time to segregate from the diabase before the latter congealed" (p. 96).

"It appears .... that the principal ultimate differentiation products of the quartz diabase magma are

(1) A diabase series consisting of augite, basic plagioclase, and titaniferous magnetite.

(2) An aplite series consisting of yellow mica, acid plagioclase, quartz, and titanite. The proportion of aplite to diabase as seen in the field is insignificant probably less than 1 per cent" (p. 97).

However as pointed by Hore (77) if such a magmatic segregation takes place while the constituents of the diabasic magma are still in the liquid form, it would mean that liquid sodic plagioclase would mix with liquid calcic plagioclase only on a very limited scale, and this is considered as contrary to the facts which have been determined by experimental synthesis and by examination of the end products found in nature. If the plagioclase silicates are miscible in all proportions, the segregation of the different constituents occurred during crystallization.

Chapter XI

CENOZOIC DEPOSITS

The whole of the Caposisit-Inconnu Lake map-area is north and west of the southeastern limit of the glacial lake Barlow-Ojibway as defined by Norman in the Opémisca (113) and Mistassini regions (114), and the occurrence of raised beaches together with the character of the unconsolidated deposits of the present area confirms that the waters of that lake all but completely covered it during the final stages of the Pleistocene glaciation.

Raised beaches were found on the sides of many of the higher rocky hills and ridges, the highest of them being the one located on the south side of the series of ridges immediately north of Capisisit lake and on the east slope of the high ground just west of Renault lake. The one just north of Capisisit lake stands at an elevation of about 250 feet above the present level of the lake, and the one west of Renault lake is slightly lower. Well rounded boulders and pebbles are the main constituents of those beaches which, in some instances, can be easily seen from an airplane or on the air photographs.

Very fine-to medium-grained unconsolidated deposits are very abundant throughout the lower sections of the district, and clays are particularly thick in the southwestern and eastern parts of the map-area. Varved clays are present along most of the length of the small creek draining the south-western section of the map-area, at a few localities along Maicasagi river, especially in the western half of the map-area, and in the lower sections of Renault creek where grey clays, generally faintly varved, are seen in cross-section to be about 30 feet thick.

Clays, sands, and fine gravels are very widespread in the area around, east, and southeast of Inconnu lake and in the central part of the northeast quadrangle. In the northwestern section of the area, coarse sands and gravels predominate. A large sand plain is present about one mile south of Maicasagi river at the western boundary of the map-area in which low dune-like ridges are disseminated.

La Rocque suggested in a recent paper (169) that a marine connection may have existed between Lake St John and James Bay in early Post-Pleistocene times, and, according to his sketch map (p. 377) the boundaries of the Champlain Sea , as defined by him, would pass very close to the present area. However no evidence of the presence of definitely marine clays was found within the limits of the present area.

Smooth, oval, and parallel hills composed of unassorted sandy till and generally less than 100 feet high are abundant especially in the northern half of the map-area. These hills vary in length from a few hundred feet to about two miles, and their width rarely exceeds one thousand feet. They are generally very close to parallel to the observed glacial striae of the region, *i.e.*,about S.30°W. and are taken to be mainly drumlins formed probably by the accumulation of deposits beneath heavily-loaded ice. Small eskers also occur in association with them. Boulder trains made of angular to rounded constituents were frequently observed throughout the area. They trend between S.20°W. and S.35°W.

The most interesting of the glacial topographic forms of the area consist of numerous broadly parallel moraining ridges trending at right angle to the known movement of the last Pleistocene ice sheet. Those transverse moraines are particularly well represented in the low ground south, southeast, and east of Veto lake (see plate XI, A and B). Moraines of this type have been described at various localities within the Precambrian Shield, especially in the Waswanipi-Chibougamau district. As Mawdsley puts it (99):

> "Seen from the air or in aerial photographs, the general impression is that of a wash board in which the ridges are much narrower than the inter-ridge spaces" (p. 9).

As seen from air photographs, the ridges are relatively straight and parallel one to the other. They vary in length from a few hundred feet to over two miles, south of Veto lake, and their height usually averages about 15 feet. They are generally 600 to 700 hundred feet apart, although there may be intervals of only 200 feet or over 1000 feet between two successive ridges. The inter-ridge areas are generally muskegs although glacial ridges trending parallel to the ice movement and approximately at right angle to the transversed ridges are not infrequently seen associated with them. In such cases, the transverse moraines are seen to ride over the longitudinal glacial ridges and so are younger than them. The transverse ridges are generally composed of unsorted, boulder-bearing till or sandy material with frequent large striated boulders perched on their crest.

Mawdsley, in 1936 (99), Sproule, in 1939 (137), and Longley, in 1948 (92), have suggested that the transverse moraines result from deposition of debris in large cracks parallel to ice front "just before the final disappearance of the ice, and after it had ceased to move, as any movement would have destroyed them" (Mawdsley (99), p. 11). Norman, in 1938 (113), gave another and apparently more satisfactory explanation of the occurrence of those transverse morainic accumulations which he considers as being successive annual recessional moraines. The interval between the individual transverse moraines which is, as stated above, about 600-700 feet, is of the same order as the interval between successive yearly fronts of the ice during its retreat as calculated by Antevs (6) from marine measurements. This similarity of spacing, the fact that the transverse ridges ride across the longitudinal drumlins at a higher level than their summits in the intervening inter-drumlin valleys, and the occurrence of large striated boulders on their crest oppose the crack-filling hypothesis and suggest that their development was the result of pushing up of loose drift by an annual slight advance of the ice front.

Many glacial striae and occasional glacial chatter marks were observed on the rocky hills and lake shores of the area. They indicate that the main direction of the last ice movement was 25° to 30° west of south.

Chapter XII

STRUCTURAL GEOLOGY

Folds

The volcanic and sedimentary formations of the area and the sill-like gabbroic intrusives have been intensely deformed and tightly folded together by probably more than one period of orogenic activity. The resultant structure is complex, and considerable difficulty was encountered in trying to decipher it owing to the lack of definitely positive criteria permitting to ascertain the attitude of the different folds and the positions of their axes.

The recognition of one or more key beds which can be followed from one exposure to the next or from one locality to another represents the ideal condition in the working out of the structural geology of an area. Unfortunately such condition is very seldom realized in the Canadian Shield, and the area under study does not constitute an exception to this rule. It is almost always impossible to trace a given bed of greywacke or argillite beyond the limits of a single exposure on account of the close similarity between successive beds and the paucity and the limited extent of their exposures. Cherty and iron-bearing formations could have given better results if they were more abundant and better exposed. However, they were observed at only so few localities and on so small a scale that it was found impossible to use them as keys to the structure of the area.

The lava flows are not any more useful for that purpose owing mainly to the difficluty in determining the upper and lower surfaces of the individual flows. These are generally thick, varying little from one flow to the other, and are commonly intruded by conformable sill-like masses of intrusive rock frequently very similar to them in texture and composition. These intrusive masses are not suitable for more detailed structural determinations than the local strike of the rock formations in which they occur on account of their lenticular shape and their commonly poorly-defined contacts with the intruded lava flows.

Thus the regional structure cannot be worked out by following a single bed or a series of beds, a definite flow or a series of flows, or concordant intrusive masses. It must be determined by other means such as observations on strikes and dips, cross-bedding, grain gradation, drag folds, pillows, and other minor structural features of the rocks. Observations on the strike of the beds, flows, or concordant intrusive masses are liable to give much better information than those on the dips because of the general steepness of the latter and, undoubtedly, the beds and flows have at many localities been overturned.

The largest structural unit of the area, i.e., the main belt of sedimentary rocks, strikes about S.25°E., and this may be taken as representing broadly the general trend of the structure of the area. The dips of the folded formations are, as stated above, generally steep or vertical. The bedding and the foliation or schistosity of the deformed volcanic and sedimentary rocks are very generally parallel with only few exceptions in which there may be a small angle between the two.

In the northwest quadrangle of the map-area, the general trend is also roughly east-southeast. The strike of the schistosity and bedding of the volcanic rocks and of the foliation of the Maicasagi River gneiss is closely parallel to the strike of the sedimentary beds to the south, and no evidence of discordant contact between these two types of rocks was anywhere found in the field. The dips are very steep in this section of the area and vary between 70°N. and 70°S.; however, most of them are vertical.

Farther east, the strike of the northern section of the large belt of sedimentary beds backs towards the east, and the adjacent lavas to the north follow a similar pattern with the strike of their schistosity and of the flows becoming east-west. The dips are there vertical or steep towards the north.

The structure is quite different in the northern section of the eastern half of the map-area, where the strike of the schistosity of the volcanics, of the foliation of the gneissic intrusive, and of the contact between the two types of rock backs furthermore of over 90° and becomes successively northeast-southwest, north-south, and, close to the northern boundary of the area, almost northwest-southeast. The dips generally remain southward or eastward and vary in steepness from 50° to 85°. A few are vertical, and, towards the center of the large exposures of volcanic rocks, slightly south of La Trève river, in the northeast corner of the map-area, the strikes and dips vary very abruptly between wide limits on account of the intense drag-folding and crumpling of the rock.

Immediately south of McDonald lake and east of it to Colette lake, the sedimentary beds strike close to east-west and dip steeply north or south, immediately west of Colette lake, and between 45°N. and 70°N., just south of McDonald lake. South of the western section of McDonald lake, the sedimentary rocks trend close to northeast, and the foliation of the diorite-syenite complex generally strikes parallel to the bedding of the sedimentary formations and, in general, to the contact between the two rocks. The dips are there generally towards the north or northeast and average a steepness of 60°.

The strike of the lava flows of the southern belt of volcanics, of the interbeds of sedimentary and tuffaceous rocks, and of the concordant intrusive masses is generally east-west in the section between the west end of Capisisit lake and the western boundary of the map-area, and the dips are generally close to 45°N. Eastward, the strike veers to a general east-southeast direction with considerable local variations, however, such as around the western extension of the Capisisit Lake granite body, and southeastward from the south shore of Capisisit lake to Renault lake. In this latter section of the area, the schistosity and bedding of the volcanics and gabbroic bodies wraps around both the Capisisit Lake and the Renault Lake intrusive masses, and the resulting structure is very confused. The dips of the lava flows, of the interbeds of tuffaceous or sedimentary rocks, and of the tabular gabbroic intrusive masses are between 45°N. and 75°N., north and south of Capisisit lake.

Farther southeastward, theyare mostly vertical, and near the west shore of Renault lake, they vary from 75°S.E. to 80°N.W.

Thus it is seen that a satisfactory interpretation of the structural features of the area based solely on strike and dip determinations would be difficult to obtain. It is evident that probably the majority of the beds and flows have been overturned, and other criteria must be sought and used in conjunction with strike and dip determinations in order to reach satisfactory conclusions.

Cross-bedding was not observed anywhere in the sedimentary, conglomeratic, or tuffaceous rocks of the area, and grain gradation was in no case found to be sufficiently well defined for determinations of tops and bottoms of either beds or flows.

Drag folds occur fairly abundantly throughout the area, but most of them are very small, and their axes show inconsistant and highly variable strikes and plunges even within the limits of a single rock exposure. Consequently, most of them had to be neglected as too unreliable for structural determinations.

Observations on drag folds occurring in three localities within the limits of the map-area are, however, considered as giving better information on the major structure of at least a section of the present area. The first locality is about two miles southwest of the northeast corner of the map-area. There, basaltic to andesitic lava flows are exposed on a large "plateau" having the shape of the nose of a fold, possibly a large drag fold, and show an extraordinary amount of smaller drag folds distributed throughout the exposed surface of the schistose lava flows. Some of the smaller drag folds are much deformed or trend parallel to the schistosity of the volcanics. There is, however, a marked tendency in the great majority of them to have approximately parallel axial planes, and these strike about S.65°E. and dip generally 80° to the southwest. Their axes plunge, with very few exceptions, towards the southeast at angles between 45° and 65°, suggesting that the large fold is an anticline with axial plane striking about S.65°E. and dipping about 80°S.W., and axis plunging about 55° to the southeast. The beds on the northern limb of the fold, according to this interpretation, would be overturned.

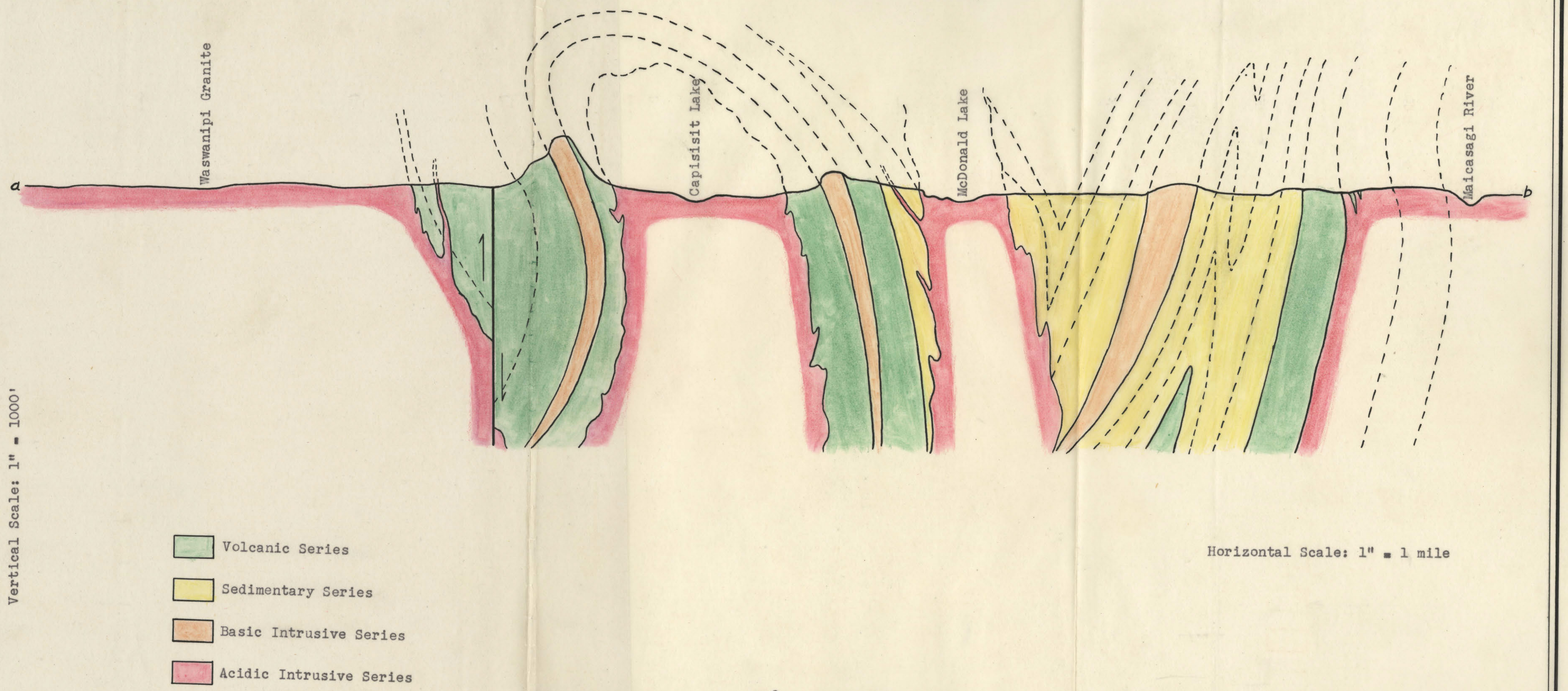
The other localities mentioned above contain much larger drag folds than ones found elsewhere which probably present more accurate relationships between the major and minor structural features of the area. One lies about three miles north-northeast of the east end of McDonald lake, in sedimentary rocks, about one thousand feet south of their contact with the northern belt of volcanics. One drag fold is there 50 feet long along its axis and 25 feet wide. The axis of the fold strikes S.75°E., plunges 45° towards the southeast, and its axial plane dips 80°S. The shape of the drag fold itself suggests that the beds on the north have moved eastward and those on the south westward, indicating that the drag fold is on the northern limb of an anticline or on the southern limb of a syncline.

In the other locality, just north of the west end of Colette lake, smaller but relatively well-developed drag folds occur in fine-grained, buff-colored, feldspathic and cherty sedimentary beds. The average strike of the axis of the drag folds is east-west, their plunge averages 65° towards the east, and the axial planes of the better-defined of the drag folds dip from 85°S. to 90°. The shape of the folds suggests the presence of a synclinal axis towards the north.

It is thus possible that synclinal and anticlinal axes of folds lie between these two localities of drag-folded sedimentary beds, and that the sedimentary and volcanic rocks of the northern section of the western half of the map-area at least have been tightly folded into a series of closely-spaced synclines and anticlines trending close to east-west and plunging somewhat steeply towards the east (see fig. 5, p. 224).

Despite the great development of ellipsoidal lavas throughout the volcanic rocks of the area, few reliable top and bottom determinations by means of pillows were made during this investigation. As stated above, the pillows, although generally well visible, have been almost universally flattened and elongated, and their shape is such that their bottom and top contacts have become absolutely similar, and the downward projection of the bottom of an individual pillow between the two adjacent underlying ones has been, with very few exceptions, totally obliterated.

The best attitude determinations by means of pillows were obtained in the ellipsoidal lava flows north and south of Huguette lake, in the northeast section of the map-area, and on the southern limb of the large anticlinal fold, about three miles north-northeast of the same lake. All those determinations indicated that the tops of the flows are towards the south, and the beds are upright or vertical.



SECTION 'a b', TRENDING N.10°E., AND PASSING ACROSS CAPISISIT AND McDONALD LAKES

fig. 5

Three other somewhat reliable attitude determinations by pillows were made from a small series of low exposures of basaltic flows interbedded with basic greywacke, about four thousand feet southwest of the large drag fold mentioned above, i.e., slightly less than three miles N.10°E. of the eastern extremity of McDonald lake. Those pillows indicate that the tops of the flows are towards the south. The beds are here again upright but close to vertical. It is thus possible that an anticlinal axis is present between these exposures of interflows of basaltic lavas and the drag-folded greywacke beds to the northeast, and a synclinal axis between those same basalts and the locality containing the smaller drag folds, north of Colette lake (see fig. 5, p. 224).

Somewhat less reliable top determination by pillows were made in highly ellipsoidal flows, about three miles south of the central part of Capisisit lake. There, the ellipses seem to indicate that the tops of the flows are north. Here again, the beds are apparently upright.

Well-developed fracture cleavages in dark, slaty beds on the eastern shore of Gilles bay indicate that the tops of the beds are towards the north. Since pillowed lavas around Huguette lake, slightly north of Inconnu lake, indicate tops as being towards the south, a synclinal axis is presumed to lie somewhere near the center of the main belt of sedimentary rocks or slightly north of it.

The shape, the distribution, and to a smaller extent, the composition of some of the intrusive masses of the area also permit inferences to be made. It is seen that the gabbroic intrusive bodies north of Capisisit lake and Inconnu river in the western half of the map-area are remarkably similar to those south of the lake and of the river. The gabbro is considered to have been introduced as sill-like masses in the volcanic and sedimentary rocks prior to their folding, and the pattern of the basic intrusive tabular masses in the southern half of the area suggests the presence of a dome localized in the Capisisit Lake area and in the section to the southwest including the whole of the Capisisit Lake intrusive mass. Such a dome would explain the curved strike of the intruded formations around both ends of the intrusive, and the fact that the dips are towards the north on both the south and the north sides of the lake does not infirm this hypothesis as shown on figure 5 (p. 224). It is believed that the active force displayed by the granitic intrusive mass was mostly responsible for this structure. However it is also conceivable that the domical structure might have been there before the emplacement of the granite mass which was guided and partially controlled by the preexisting features in the intruded rocks.

Another peculiar type of structure occurs around the nose of the Renault Lake intrusive which appears somewhat similar to the one around the Capisisit Lake granite and is probably of a similar origin. The volcanic and gabbroic rocks sweep around the nose of the granitic intrusive, and zones of volcanic rocks probably underlie the low ground west of the main gabbroic hill just west of Renault lake, wrapping around the nose of the granitic intrusive and joining the narrow zone of lavas northeast of the lake.

The difference in composition and the banding in some of the larger masses of "old" gabbroic intrusive rocks of the area may, as said before (p. 90), be considered as a fairly reliable check on the interpretation of the structural features of the area. As it has been stated above in the chapter on the pre-granitic basic intrusives, the anorthositic and dioritic facies of the gabbroic masses on the north shore of Capisisit lake are towards the north, and along the southern edge of the masses south of the lake. Southeastward, a plagioclase-rich gabbro is exposed close to the northern edge of the long south-easterly-trending tongue south of Inconnu lake, and the light-colored facies of the layers in the banded gabbro northwest of Renault lake is towards the northeast. If the light-colored or plagioclase-rich facies of the gabbro either in an individual layer or in the whole tabular mass of the intrusive can "be used to determine the direction in which the top lies in complex structures" (35, p. 91), the following conclusions are suggested by the compositional features of the "old" gabbroic rocks of the south central part of the map-area.

a) The Capisisit Lake intrusive mass is along the axis of an elongated southeasterly-trending dome. The tops of the gabbroic sills are away from the granitic intrusive north and south of Capisisit lake and around the south-eastern extension of the granitic body.

b) The elongated southeasterly-trending mass of gabbroic rocks south of Inconnu lake and Gilles bay is on the southern limb of a synclinal or on the northern limb of an anticlinal fold.

c) A narrow zone of volcanic rocks is probably present in the low ground between the gabbroic hills slightly west of Renault lake and the main mass of basic intrusives to the west. This suggestion is based on the fact that a marked gradational decrease in the content of ferromagnesian minerals and a corresponding increase in the tenor of plagioclase can be seen in the gabbro masses just west of Renault lake. Close to the contact with the volcanic rocks on the west shore of the lake, the intrusive is a pyroxenite or an amphibolite containing from 0 to 10 per cent plagioclase. The feldspathic constituents increase westward, and, on the last exposures seen on the west slope of the hill, about fifty-five hundred feet west of the lake and just north of the southern boundary of the map-area, the rock contains about 65 per cent creamy white plagioclase and 35 per cent ferromagnesian minerals.

The shapes of the hills and valleys in this section of the area also suggest the presence of a deep synclinal valley between the nose of the two masses to the northwest and southeast. Unfortunately not a single exposure of volcanic rocks was located in this section, and, since it is possible that the zone of lavas may be very small or completely eroded away, the whole area was mapped as underlain by basic intrusive rocks.

The areal pattern of the rock masses may also be considered as an indication of the structure of the rocks themselves. The occurrence of two belts of volcanic rocks separated by a continuous band five to eight miles wide of waterlaid sedimentary rocks suggests the presence of a large synclinal basin in which lavas were extruded and subsequently overlain by sediments. As stated above, nowhere in the present map-area was there found evidence of a structural disconformity between the volcanic and sedimentary formations, and both types of rocks are very frequently found interbedded, especially near the contact of the northern zone of volcanics with the sedimentary belt to the south, in the western half of the map-area. Those two facts suggest a conformable contact between the two types of rocks, and it is considered probable that lavas were first poured into a synclinal basin and that, with decreasing intensity and frequency of extrusion of igneous rocks, thin interbeds of waterlaid tuffs and clastics had time to form which grew thicker and the lava flows thinner in later stages until extrusion of molten magma ceased almost but not completely as indicated by widespread thin interflows of lavas in the main belt of sedimentary rocks.

Beach (17, 18, 19, and 20) and Norman (112 and 115) distinguish two ages of sedimentary rocks in the area extending from the eastern extremity of Lac La Trève, about eleven miles east of the eastern boundary of the present map-area, eastward into the Mechamego, Michwago, and Opémisca regions. These two groups of sediments are represented by the Pre-Opémisca and the Opémisca series. As Norman puts it in 1938 (112):

> "The sedimentary rocks (of the West Half Opémisca Map-Area) are separated into two groups by an unconformity. The lower group (Pre-Opémisca) conformably succeeds the lavas and consists of well-banded, fine- to coarse-grained and light-coloured feldspathic rocks. The upper group (Opémisca) contains several conglomerate beds 10 to 20 feet or more thick, interbedded with arkose and greywacke (?). The boulders of the basal conglomerate beds are large and rounded, and consist of granite and of the underlying sediments. The difference in strike between the two sedimentary groups at the one observed contact is 22 degrees, and the truncated edges of the lower feldspathic sediments are clearly exposed against the overlying conglomerate. The rocks above this unconformity may correspond to the Timiskaming; those below the unconformity with the considerable thickness of sediments in their uppermost part are considered to belong to the Keewatin" (p. 3).

Beach also states (19 and 20):

> "Toward the top they (Keewatin-type lavas) include increasing amounts of more siliceous volcanic rocks and are overlain with apparent conformity by a thick series of altered, feldspar-rich tuffaceous sedimentary rocks and greywackes, locally altered to phyllites and sericite schists, bedded cherts, breccias, agglomerates and conglomerates".

> "The Opémisca series consists of greywacke, arkose and tuffaceous sediments intercalated

with and overlain by pale-green andesitic rocks that contain conspicuous crystals of pyroxene and, in places, abundant feldspar phenocrysts. The series overlies the pre-Opémisca rocks with marked angular unconformity, a relation best shown about one-half mile east of the east end of Lac La Trève. In the lower part of the series boulder conglomerates form conspicuous and readily traceable beds. The basal member at most observed points, is, however, a thin porphyritic lava. The similarity of the boulders in the conglomerate to the hornblende granodiorite that forms an extensive mass along the southern border of the area might be taken to indicate that the granodiorite is of pre-Opémisca age".

"The major structural feature of the area is a large, east-west trending, westerly plunging anticline, bounded on the north and south by synclinal troughs of isoclinally folded pre-Opémisca and Opémisca rocks".

The "pre-Opémisca" series of Norman and Beach is quite probably the one represented in the Capisisit-Inconnu Lake area by at least the main part of the large sedimentary belt extending across the area. It has similar relationships with the underlying Keewatin-type volcanics and, essentially a similar composition. The strike of the main structural units of the present area is fairly similar to the strike of the major structure of the Mechamego Lake area (19), but the plunge is opposite. It is quite possible that the reversing of the plunge takes place in the eleven miles wide area between the two localities, and the central part of the basin-like structure is possibly located in that section of the country.

The few exposures of conglomeratic material on the south shore of McDonald lake and on the north shore of Inconnu lake call for a comparison with the occurrences of similar type of rock at the base of the Opémisca series farther east. As stated above (p. 60) most of the pebbles of the conglomerate exposed on the south shore of McDonald lake are made of basic igneous material, probably basaltic lava, and the rock is probably a small lenticular basal conglomeratic member of the "pre-Opémisca" series. After the lava had ceased to accumulate in the synclinal basin and along its flanks, it is very possible that fragments of it were locally caught and covered by the sediments during their deposition, especially at or near the base of the series. There is no evidence that the pebbles of this conglomerate were ever rounded, and its presence can be explained without the occurrence of any erosional unconformity between the lavas and the overlying sedimentary series.

The conglomeratic rocks exposed on the north shore of the eastern half of Inconnu lake and found as angular boulders in the neighbouring section of the district have somewhat different characteristics. Their pebbles and boulders are highly rounded, (see plate 1X, B and plate X, A) and consist mostly of acidic intrusive rock and of feldspathic sedimentary material very similar to some of the rocks of the "pre-Opémisca" series. The thorough rounding of the pebbles suggests considerable wearing either by wave action or by rolling for long distances by streams.

No evidence of angular unconformity between the finer-grained clastic beds and the conglomeratic formations was found within the limits of the present area, and no occurrence of conglomeratic beds were noticed farther south. It is possible that further work in the Lac La Trève area to the east may make possible a correlation between these exposures of conglomerate and the basal members of the Opémisca series in the Mechamego Lake area. For the time being, such a correlation would be highly hypothetical on account of the large intervening distance between the two areas.

Faults and Shears

There are probably many faults in the area. It is unlikely that the lava flows, the sedimentary beds, and, to a lesser extent, the gabbroic sills could have been so closely and complexly folded without development of fractures. Many shear zones were found during this investigation, but direct evidence of faulting is very scarce in the area because of the complexity of the structures, the lack of key beds or flows, the thickness and similarity in composition of the flows, and, above all, the heavy drift cover over the weak and easily-eroded zones of fractures and breaks. The strike faults, especially, would be detectable only under extraordinarily favourable circumstances.

The best-seen fault in the area occurs close to the south shore of Capisisit lake. A sharp, V-shaped, depression over three hundred feet deep is visible in the series of ridges south of the lake, slightly east of its center. This depression is a very conspicuous feature and can be seen at its best from the air as a very straight break about one and a half miles long and striking close to N.45°E. The rocks on either side of the depression are well-exposed basaltic lavas intruded conformably by numerous small and one larger sill-like gabbroic body which is offset by the fault. The strike separation along the fault, as shown by the offset of the body of gabbro, is about fifteen hundred feet, and the relative movement is of the southwest block northeastward. No slickensides were observed along the sides of the depression, and the fact that the hill on the west side of the fault is somewhat higher than the one of the east wall is not considered as giving any indication as to the vertical component of the movement along the plane of the fault. This difference in altitude between the two hills is undoubtedly the result of differential erosion, the hard, brittle, hornfel-like rock of the western hill being much more resistant to weathering than the relatively soft amphibolite schis t of the western wall. Rough calculations based on the slight differences in the steepness of the dips on each side of the offset large sill-like gabbroic body and on the assumption that the fault plane dips at 90° suggest that the southeast side moved up relative to the northwest wall of the fault.

Slightly south of the summit of the ridge, on the west side of the fault, and about two miles along the trail leading southward from Capisisit lake, there occurs a series of outcrops showing two well-developed intersecting shear zones. One of them strikes N.45°E. *i.e.*, parallel to the V-shaped depression between the two hills, and the other shear occurs parallel to the local bedding and schistosity, *i.e.*, at about S.45°E. There is a suggestion that the northeast shear is older since it is displaced by the southeasterly-striking zone of displacement. The offset is about 15 feet, and the southwestern wall has moved northwestward or the northeastern wall southeastward.

The distribution of exposures of volcanic and granitic rocks in the locality about three quarters of a mile south-southwest of the two shear zones just discussed, points to the presence of a break extending across the granite-volcanics contact in a probable northeast direction and on the southeast side of which the volcanics are offset to the southwest. Although no physiographic depression confirms the presence of a fault there, the postulation of a break seems justified. Its direction is assumed as northeast from the prevailing northeast trend of the known neighbouring fractures, such as the large fault lying to the northeast and one prominent set of joints in the granite. The evidence of movement along the strike shear, as indicated above, points to the possibility that the two faults may have constituted only one break the southern extension of which was displaced westward or the northern section eastward by later movement parallel to the local strike of the rock formations.

Northeastward along the main fault and just south of Capisisit lake, physiographic features as well as the general trend of some of the joints in the Capisisit Lake granite seem to warrant the inference that the fault is post-granitic and extends into the granite in the general manner shown on the accompanying map.

Renault lake, on the south boundary of the eastern half of the area, is probably located on a zone of faulting trending N.40°E. The volcanics on its east shore and just north of the southern boundary of the map-area are highly sheared, parallel or nearly so to the elongation of the lake. The shores of the lake themselves are generally high and rocky, especially on the east side of the lake. Faint slickensides are also visible on the cliffs along the east shore and they suggest a near vertical movement along the fault plane.

A major shear zone appears to extend northeastward from the western boundary of the map-area, half a mile south of Inconnu river, to about one mile north of McDonald lake. An extensive northeasterly-trending depression is present there, and most of the exposures of volcanic and sedimentary rocks of this section of the area show considerable shearing and fracturing. The usually massive rocks of the coarse-grained facies of the diorite-syenite complex become gneissic close to this zone of fracturing, and the gneissic structure parallels the trend of the depression.

A zone of shearing trending generally east-west follows the south shore of McDonald lake and extends eastward towards Inconnu lake, in the eastern half of the map-area. The western section of this zone also follows approximately the contact between the diorite-syenite complex and the intruded sedimentary rocks. Exposures of the latter on the south shore of McDonald lake, slightly east of the end of the portage from Capisisit lake, show considerable shearing and fracturing. At the very contact between the intrusive complex and the sedimentary formations, close to the south shore of the lake, movement has occurred as evidenced by brecciation of the intruded sedimentary formations prior to their granitization and by highly-fracturing zones in the intrusive itself. Evidence of movement also is seen in the interruption of a dyke cutting through the sheared and altered intrusive rock along the south shore of the lake, three quarters of a mile west of its eastern extremity. The strike separation, as evidenced there by the fractured dyke, is of the order of three feet, and the north wall of the dyke has been displaced westward relatively to the south wall.

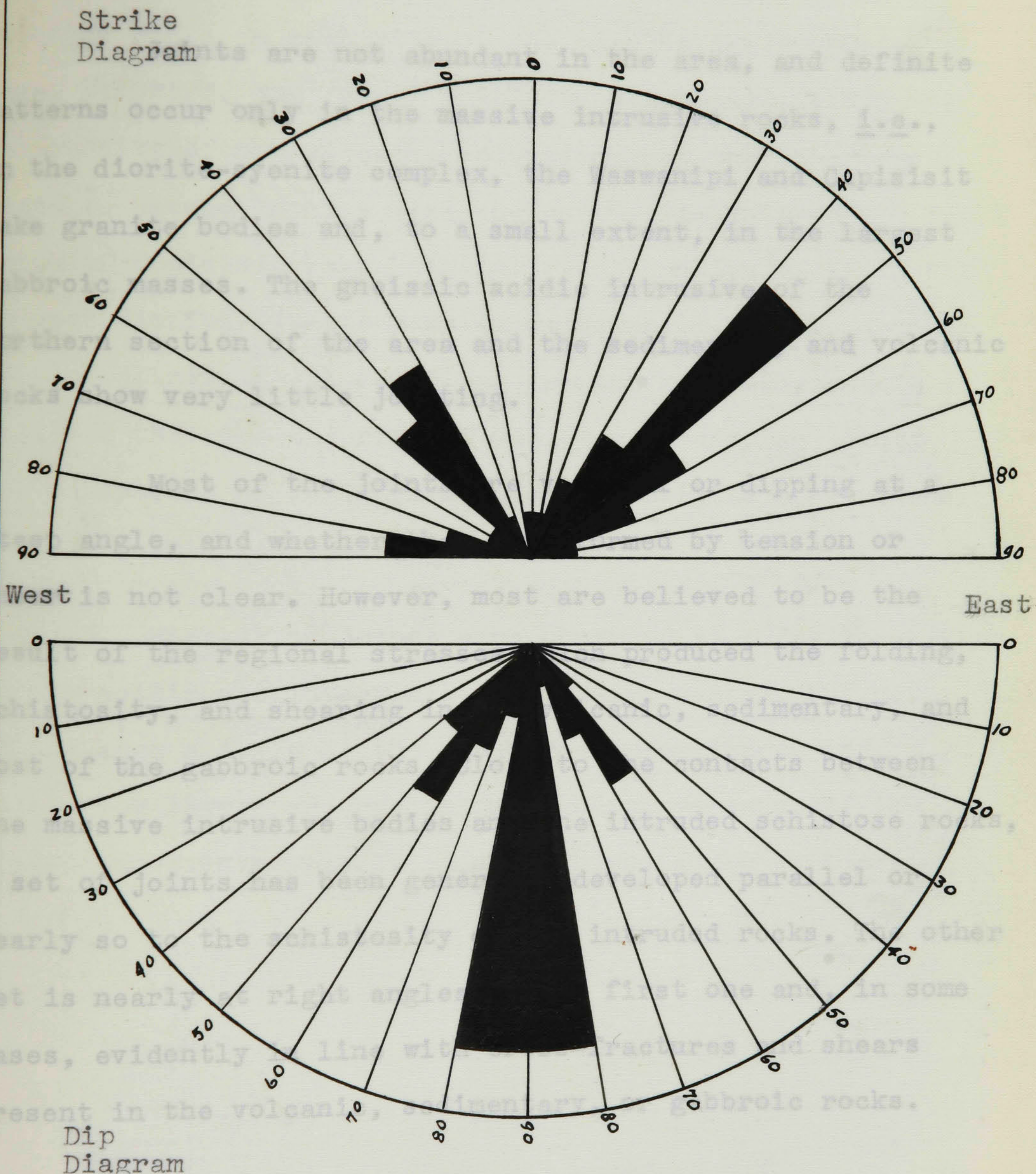
Eastward from McDonald lake, a rather sharp physiographic depression extends to Colette lake, and outcrops of gabbroic rocks are there very schistose and much altered. Farther east, the shear zone appears to veer slightly towards the southeast and it is seen across Inconnu river at a locality some four thousand feet downstream from the outlet of Inconnu lake, where much sheared and fractured porphyritic intrusive and sedimentary rocks are exposed on the east shore and across the river. This shear zone was not traced further east on account of the thicky-covered ground and the paucity of rock exposures.

Exposures of sheared sedimentary rocks also occur along the lower half of McDonald creek and especially from one to one and a half miles south of Maicasagi river. There, fine-grained greywacke, ferruginous chert, and feldspar porphyry sills have been intensely fractured and, in places, reduced to a gouge-like soft mass. Very little evidence of direction of movement was found in these exposures of sheared rocks, but faint slickensides seemed to indicate that the eastern side was displaced northward relatively to the western side.

As stated above, numerous shear zones are present on the east shore of Renault lake, and one just at the southern boundary of the map-area is 55 feet wide and shows extremely crushed volcanic material with much carbonate and some pyrite. A shear at least seven feet wide was also seen along the eastern flank of the large gabbro hill west of Renault lake, at a locality about three quarters of a mile west of the kidney-shaped bay along the west shore of the lake.

Numerous other smaller shear zones, mostly parallel to the local strike of schistosity or bedding, were found in the volcanic and sedimentary rocks of the area. A few exposures of sheared gabbroic rocks were encountered, and most of the small porphyritic intrusive bodies of the area are schistose and some are highly sheared.

A circular diagram representing the main shears and faults of the area (fig. 6, p. 242) indicates that the majority of them strike around N.45°E. and a smaller but still considerable proportion at about N.45°W. The dips of all the zones of fractures are predominantly close to vertical.



Scale: 1/5"= 1 shear

Circular Diagram of Shears and Faults.

fig. 6

Joints

Joints are not abundant in the area, and definite patterns occur only in the massive intrusive rocks, *i.e.*, in the diorite-syenite complex, the Waswanipi and Capisisit Lake granite bodies and, to a small extent, in the largest gabbroic masses. The gneissic acidic intrusive of the northern section of the area and the sedimentary and volcanic rocks show very little jointing.

Most of the joints are vertical or dipping at a steep angle, and whether they were formed by tension or shear is not clear. However, most are believed to be the result of the regional stresses which produced the folding, schistosity, and shearing in the volcanic, sedimentary, and most of the gabbroic rocks. Close to the contacts between the massive intrusive bodies and the intruded schistose rocks, a set of joints has been generally developed parallel or nearly so to the schistosity of the intruded rocks. The other set is nearly at right angles to the first one and, in some cases, evidently in line with cross-fractures and shears present in the volcanic, sedimentary, or gabbroic rocks.

Good exposures of jointed granite occur on the north shore of Capisisit lake. The two sets of joints in the granite in the western extension of the lake are closely parallel to the schistosity and bedding of the volcanic rocks on each side of the nose of the intrusive mass. Eastward, one set of joints is still parallel to the schistosity of the adjacent volcanics, but the other one tends to become in line with the northeasterly-trending fault south of Capisisit lake. Similar relationships occur in the jointed diorite-syenite complex on McDonald creek. In other sets of joints, these relations are not so clear, but it is believed that the majority of the steeply-dipping joints are the result of regional stresses on brittle rocks where lateral relief was easiest.

Flat-lying joints were observed at a few localities in the acidic and intermediate intrusive masses, but not on as large a scale as the steeply-dipping types, and, where flow layers are present in the intrusive rock, the flat-lying joints usually occur at right angle to them.

Chapter XIII

ECONOMIC GEOLOGY

Discoveries of gold in the Opawica region, just south of the eastern half of the Capisisit-Inconnu Lake map-area, in 1932, attracted the attention of prospectors in the area for a few years. Between 1932 and 1938, some work was done in the present area but with little success, and all activity died down before 1940.

Interesting occurrences of gold and base metals located in the Bachelor Lake area, immediately south of the western half of the map-area, after W. W. Longley's investigation during the summer of 1946, brought the prospectors back to the region. Most of these discoveries were made in the southern section of the Bachelor Lake area, but, towards the end of the field season of 1947, a narrow, rich gold vein in sheared gabbroic rock was discovered at a locality about a quarter of a mile south of the southern boundary of the map-area, and a quarter of a mile west of the seventy-sixth meridian. In the subsequent weeks, many claims were staked northward and northeastward from this discovery into the southern section of the present map-area. During the field season of 1948, much prospecting was done especially in the western half of the area, around Capisisit lake and Inconnu river.

Both the Bachelor Lake and the Capisisit-Inconnu Lake areas are included in the wide zone of volcanic and sedimentary rocks which extends from the west to Chibougamau lake, and, to some extent, the two areas have similar geological characteristics. This is particularly true for the northern section of the Bachelor Lake and the southern half of the Capisisit-Inconnu Lake areas.

Much disseminated mineralization was observed in the region during the investigation upon which this thesis is based, and many of the volcanic and, to a smaller extent, of sedimentary and altered gabbroic rocks show scattered pyrite crystals with concentrations of sulphides at a few localities. Iron stains were quite frequently seen throughout the volcanic, sedimentary, and gabbroic rocks, with copper colors at a few scattered points. Several shear zones were observed which contain disseminated or concentrated sulphides.

White quartz veins are fairly abundant and a few of them contain concentrations of metallic compounds. There is unfortunately not much silicification and hydrothermal alteration of the rocks in the area. The tuffaceous and sedimentary rocks may show replacement by silica, but, in general, the greenstone rocks do not have the alteration and silicification shown in the southern half of the Bachelor Lake area, and this is considered as an important difference between the two. It seems that most of the silica was introduced as white quartz along numerous tension fractures, whereas the pyrite was disseminated through the rock. Opalescent quartz eyes are, however, disseminated in the folded and schistose rocks between Inconnu and Renault lakes.

Some interesting exposures of volcanic, sedimentary, and gabbroic rocks were nevertheless found in the area which contain small shear zones and quartz-carbonate veins somewhat similar to some seen in the Bachelor Lake area. The most promising of them were sampled, and the specimens assayed in the laboratories of the Department of Mines, Quebec. The result of those assays are shown below.

Table of Assay Results

Sample No.	Gold (oz./ton)	Silver (oz./ton)	Copper %	Nickel %
1	none	none	traces	-
2	none	none	traces	0.01
3	none	none	-	-
4	traces	0.034	0.10	-
5	none	traces	-	-
6	none	none	-	-
7	traces	0.035	-	-
8	traces	0.040	-	-
9	0.005	0.015	-	-
10	traces	0.030	-	-
11	0.003	0.047	-	-
12	traces	0.060	-	-
13	none	none	-	-
14	none	traces	-	-
16	traces	0.020	-	-
17	none	none	-	-
18	none	none	-	-
19	none	traces	-	-
20	none	none	-	-
21	none	none	-	-
22	none	traces	-	-
23	none	none	-	-

Table of Assay Results

ample No.	Gold (oz./ton)	Silver (oz./ton)	Copper %	Nickel %
24	none	0.054	-	-
25	none	none	-	-
26	none	traces	-	-
27	none	none	-	-
28	none	none	-	-
29	none	0.020	-	-
30	0.007	0.820	-	-
31	none	none	-	-
32	none	none	-	-
33	none	traces	-	-
34	none	none	-	-
35	none	none	-	-
36	none	traces	-	-
37	none	none	-	-
38	none	none	-	-
39	none	traces	-	-
15	Manganese: 0.15%	Zinc: 0.05%		

Copper and nickel determinations were made only on samples where results are shown.

The location of the exposures from which the assayed specimens were collected is indicated on the accompanying map by a small circle surrounding the number of the assay. A brief description of the samples is given below.

Description of Samples

No. 1 - Sheared and silicified volcanic tuffs containing scattered pyrite mineralization with small amount of white quartz and carbonates, about half a mile north of Capisisit lake.

No. 2 - Sheared, fine-grained gabbro about one mile north of the southern boundary in the south central section of the area. Heavy pyrite, pyrrhotite, and magnetite mineralization.

No. 3 - Small, slightly-mineralized, sheared volcanic exposure, about half a mile north of the east end of Capisisit lake.

No. 4 - Sheared, porphyritic andesite containing iron and copper stains with lenses of quartz and disseminated pyrite, pyrrhotite, and chalcopyrite, about two and a half miles south of the central part of Capisisit lake.

No. 5 - Silicified and fractured lava along Inconnu river, two and a quarter miles west of Capisisit lake. Scattered pyrite mineralization.

No. 6 - Heavy pyrite replacement in sheared greywacke, on south shore of McDonald lake.

No. 7 - Mineralized and sheared andesitic lava, one mile south of Maicasagi river and near the center of the western half of the map-area.

No. 8 - Iron-stained, garnetiferous sedimentary bed with abundant pyrite, one mile southwest of No. 7.

No. 9 - Mineralized and sheared porphyritic intrusive, one mile north of No. 8.

No.10 - Sheared and mineralized iron-rich sediments. Along McDonald creek, half a mile south of Maicasagi river.

No.11 - Same location as No. 10. Sheared and mineralized porphyritic dyke.

No.12 - Same location as Nos. 10 and 11. Heavy pyrite replacement in iron-rich sediments.

Nos. 13 and 14 - Slightly mineralized quartz lenses in sheared volcanics, one and a quarter miles west of Capisisit lake.

Nos. 15 and 16 - Heavy pyrite replacement in iron-rich, cherty, sedimentary beds, one and three quarters miles north-northeast of the east end of McDonald lake.

No.17 - Highly altered and carbonatized lamprophyre dykes, close to the western boundary of the map-area and about a quarter of a mile south of the east-west township line.

No.18 - Disseminated pyrite in schistose and injected basic igneous rocks, four thousand feet slightly north of east of the northern extremity of Renault lake.

No.19 - Small shear zone containing disseminated pyrite and opalescent quartz eyes in fine-grained feldspathic sedimentary rock, slightly less than two miles north of east of the northern extremity of Renault lake.

No.20 - Carbonatized, sheared basic intrusive rock containing disseminated pyrite and a small tenor of chalcopyrite, four hundred and fifty feet from the west shore of the northern section of Renault lake.

No.21 - Slightly mineralized, quartz-carbonate-rich, small shear zone in fine-grained feldspathic sedimentary rocks, four and a half miles east of the northern extremity of Renault lake.

No.22 - Mineralized gabbroic inclusions in granitic rock, slightly less than three miles east of the central section of Renault lake.

No.23 - Mineralized, sheared lava, on the east shore of Renault lake, about half a mile north of the southern boundary of the area.

No.24 - Small shear zone in medium-grained gabbro, containing abundant quartz and carbonates with heavy pyrite and low chalcopyrite mineralization, slightly over two miles west of Renault lake and a quarter of a mile north of the southern boundary of the area.

No.25 - Quartz-ankerite vein in altered and sheared gabbro and containing disseminated pyrite, about one mile north-northwest of No. 24.

No.26 - Seven feet wide, silicified and carbonated shear zone in gabbroic rocks, about three quarters of a mile west of the kidney-shaped bay along the west shore of Renault lake.

No.27 - Altered and carbonated zone in highly mineralized sedimentary rocks, two and a half miles north of the east end of Colette lake.

No.28 - Mineralized wall rock adjacent to the vein of No. 27.

No.29 - Massive sulphides (pyrite, pyrrholite, some chalcopyrite), same locality as Nos. 27 and 28.

No.30 - Narrow shear zone in volcanics containing quartz and carbonate with some pyrite and a few chalcopyrite crystals, two miles south an one mile east of the northwest corner of Kreighoff township.

No.31 - Heavy pyrite mineralization in sheared, fine-grained, basic igneous rocks, just south of Inconnu river and on the north-south surveyed line between Kreighoff and No. 616 townships.

No.32 - Sheared and much altered lava containing abundant ankerite and disseminated pyrite and located on the south shore of the little lake at the eastern boundary of the map-area and one and a half miles north of Inconnu lake.

No.33 - Narrow, mineralized, carbonate-rich shear zone in altered and schistose volcanic rocks, about two and three quarters miles north of Branssat lake.

No.34 - Slightly mineralized quartz vein, same locality as No. 33.

No.35 - Mineralized small quartz lens in drag-folded and altered volcanic rocks, one and a half miles southwest of the northeast corner of the map-area.

No.36 - Quartz, carbonate, and pyrite in a small lens at the nose of a small drag fold in lavas, half a mile west of No. 35.

No.37 - Small quartz lens containing disseminated pyrite in sheared sedimentary rocks, one and a half miles east and three quarters of a mile north of Huguette lake.

No. 38- Heavily mineralized, quartz-carbonate vein in contorted and drag-folded volcanic rocks, three quarters of a mile northeast of No. 37.

No. 39- Mineralized volcanic wall rock, same locality as No. 38.

A strong magnetic anomaly was noted between Renault lake and Inconnu river, abour four miles north of the southern limit of the eastern half of the area. A line was blazed from the river to this locality, as indicated on the accompanying map, and a dip needle survey was made in the area of the anomaly. It was found that the maximum readings were obtained, not in the massive gabbro exposed nearby, but in a low and thickly-covered area between higher gabbroic exposures.

Although no encouraging assay results have so far been obtained from the present area, the writer believes that it deserves continuous search not only for gold and silver, but also for base metals such as copper, nickel, zinc and lead.

The tightly-folded and crumpled volcanic rocks of the northeastern section of the map-area appear to provide very suitable structures for the localization of metallic mineral deposits. The vicinity of an acidic intrusive is another favorable factor, and the occurrence of exposures of intensely-carbonatized rock, near the eastern boundary, about four miles south of the northeast corner of the map-area, indicate that hydrothermal solutions were active in this region. The sheared volcanic and sedimentary rocks in the western section of the map-area, from south of Inconnu river to McDonald lake, and the region surrounding the lower course of McDonald creek appear to be also fairly promising. However, the rest of the area underlain by volcanic, sedimentary, and gabbroic rocks should not be neglected by prospectors.

Chapter XlV

SUMMARY AND CONCLUSIONS

General Considerations

The area described and studied in this thesis is located in the Temiscamian sub-province of the Canadian Shield, slightly over one hundred miles a little east of north of the town of Senneterre, in the province of Quebec.

The topographical features of the area are characteristically similar to those of the rest of the Canadian Shield and consist in a few low rocky hills surrounded by strikingly-flat lowlands covered with abundant detrital material brought in by the successive advances of continental ice sheets during the Pleistocene period or deposited behind the retreating ice sheets in post-glacial lakes.

Three physiographical districts can be distinguished within the limits of the area under study. These are:

a) a district of low relief underlain by sedimentary and massive granitic rocks.

b) a district which shows slightly more considerable differences in elevation and in which the surficial rocks are volcanic or foliated acidic intrusive rocks.

c) a more rugged district underlain by resistant rocks of the gabbroic series.

The largest streams of the area are generally controlled by the structural features of the underlying rocks, and their course has not been greatly disturbed by the passage of the ice sheets of the Pleistocene period. Two outstanding exceptions are the present outlets of Inconnu and McDonald lakes which are believed to have come into existence following the jamming of the pre-Pleistocene outlets of those two lakes by detrital material accumulated across them by ice sheets.

General Geology

All the consolidated rocks of the area are of Precambrian age,and their exposures are more abundant than is generally the case in this section of the Canadian Shield. Approximately 65 per cent of the surficial rocks are folded and generally schistose volcanic, sedimentary, and "old" gabbroic rocks, and the remainder of the area is underlain by massive or foliated acidic intrusive rocks of various types which, with one exception, constitute marginal facies of more extensive masses lying outside of the map-area. A few late Precambrian diabasic dykes occur widely scattered throughout the area.

Volcanic Series

Lava flows and associated breccias, tuffs, and basic sediments generally called "greenstones" by the earlier workers underlie between 25 and 30 per cent of the area. The volcanic rocks naturally fall into two major belts and two minor zones separated each from the other by sedimentary, gabbroic, or granitic rocks.

The lavas occur as an extensive series of flows of variable thickness including massive, ellipsoidal, fragmental, amygdaloidal, vesicular, and porphyritic types. They are overwhelmingly basaltic to andesitic in composition, and more acidic flows are very rare. Massive and ellipsoidal flows are the most abundant, and vesicular or amygdaloidal types are less common. Fragmental lavas generally make thin flows, and a porphyritic facies occur at only very few localities. Thin interbeds of tuffs and basic sediments are fairly abundant.

Rounded, light-colored inclusions are found disseminated in all types of lavas but more abundantly in the slightly schistose basalts about three miles south of Capisisit lake. These nodules are almost exclusively composed of epidote, secondary amphiboles, and quartz.

Their composition is closely similar to that of the angular fragments of the fragmental lavas, and the writer believes that the rounded inclusions represent re-worked and partly re-fused angular fragments of a more acidic or already-altered lava caught in thick flows of the new extrusion.

Sedimentary Series

Sedimentary rocks make about 30 per cent of the surficial rocks of the area, and most of them occur within the limits of a four to eight miles wide, southeasterly-trending belt extending right across the map-area.

To the naked eye, the typical sedimentary rock of the area appears as a very fine-to medium-grained, highly feldspathic rock generally showing a well-pronounced banding. The very fine-grained facies are commonly very finely laminated whereas the medium-grained types tend to occur in beds to at least 20 feet thick. All the gradational types of beds are found between these two extremes.

The medium-to fine-grained sedimentary rocks are arkose or greywacke and argillite; impure chert, ferruginous chert, slate, and probably sedimentary tuffs constitute the fine to very fine-grained varieties.

Exposures of conglomerate occur at two localities, and abundant angular boulders of similar rock are present just off the eastern boundary of the map-area. At the first locality, about 150 feet from the south shore of McDonald lake, the pebbles consist of highly flattened and altered amphibolite fragments. Well-rounded but fresh large boulders and pebbles of granitic material or greywacke make between 15 and 70 per cent of the constituents of the conglomerate at the second locality, along the north shore of the eastern half of Inconnu lake.

Basic Intrusive Series

Basic intrusive rocks of the "old" gabbro type are abundantly represented in the areaunder study and they occur as very small to very large tabular masses showing concordant contacts with the intruded volcanic and sedimentary series. The largest and best-exposed masses of gabbroic rock occur in the south central section of the area, on both sides of Capisisit lake and westward along Inconnu river, and between Inconnu and Branssat lakes in the eastern half of the map-area.

A notable feature of the basic intrusive rocks of the area is their differentiation and, although they are described in this thesis under the heading of "basic intrusives", they really constitute an intrusive complex ranging in composition from serpentines or pyroxenites to anorthositic or dioritic gabbros and even, in places, almost pure anorthosites. Some of the basic intrusive masses show a well-defined banding caused by the alternation of mafic-rich and plagioclase rich-layers, and lenticular segregations or secretions of creamy white plagioclase are found disseminated in the larger gabbroic bodies of the area.

The gabbro of the area is a coarse-to medium-grained generally massive rock whose feldspathic and mafic constituents vary between extreme limits. The normal type exhibits in the field a mottled appearance due to the differential weathering of the light-colored plagioclase and dark green ferromagnesian minerals. A diabasic texture is occasionally recognizable on slightly-weathered surfaces of the last-altered varieties, and the dark minerals partly surround the light-colored constituents. The rock generally weathers light green to rusty brown.

Under the microscope, the gabbro shows a faint diabasic or poikilitic texture and is seen to consist mainly of pyroxene (generally diopside) and labradorite (about An_{60}). Olivine was found in small amounts in some of the masses. In the more altered varieties, uralite replaces the pyroxenes, and the labradorite is more or less saussuritized.

The gabbroic magma is believed to have been injected in numerous thin to relatively thick sills in the flat- or nearly flat-lying volcanic flows and sedimentary beds and, in the larger masses, a certain amount of magmatic differentiation took place *in situ* before the final consolidation of the magma. This seems to be the most plausible hypothesis of the ones suggested to explain the occurrence of banded gabbro and of the ultrabasic and anorthositic facies of the gabbroic intrusives.

Metamorphism

Regional metamorphism has been an effective agent in the alteration and deformation of the pre-granitic rocks of the area, and these have been more or less transformed mineralogically, texturally, and structurally according to the intensity of the stresses, the rise of temperature, and the resistance of the rocks.

The highest degree regional metamorphism reached in the pre-granitic rocks of the area is the garnet-andesine-hornblende grade or zone, and all the gradational types of metamorphosed rocks can be studied from the slightly uralitized and saussuritized gabbros to the granular types of the highest grade of metamorphism.

The massive and resistant masses of the gabbroic series were less deformed by dynamic metamorphism than the adjacent volcanic and sedimentary rocks, and the larger basic intrusive bodies are fairly fresh. Some of the volcanic and of the sedimentary rocks were also less metamorphosed than others, but their original mineral constituents are generally changed over to secondary minerals, and the rocks have taken a schistose structure. Pale green to green acicular actinolite or uralite is the low grade ferromagnesian mineral in the basic igneous and sedimentary rocks, and granular green-blue hornblende is the corresponding mineral of the higher grades. Biotite is the commonest mafic mineral of the more acidic sedimentary rocks, and chlorite, white mica, and hornblende are in places associated with it.

Effects of thermal or retrogressive metamorphism were recognized in some sections of the area.

Granitic Intrusives

Granitic intrusives underlie close to 35 per cent of the Capisisit-Inconnu Lake area and they include various types belonging probably to more than one period of magmatic activity. They comprise:

a) A foliated and slightly-banded oligoclase granite to quartz diorite abundantly exposed in the northern section of the map-area and called the Maicasagi River gneiss after of the large river flowing over it near the northern boundary of the map-area. The rock is a fine- to medium-grained biotite gneiss varying in color from light to dark grey and in texture from slightly to intensely foliated. The texture of the gneissic intrusive in generally protoclastic, and it is intruded by dykes and small bosses of sodic oligoclase and albite granite, and by dykes of aplites and pegmatites. Fresh or partly-digested greenstone inclusions are relatively abundant in the intrusive, and the foliation of the rock is believed to be due mainly to movements which occurred in the partly-crystallized magma and ceased during the acidic oligoclase-albite stage of differentiation. The presence and partial digestion of inclusions of greenstone served to emphasize the foliated structure of the rock.

b) A medium-to coarse-grained intrusive complex varying in composition from a gabbro to an albite granite and underlying a roughly triangular area around and west of McDonald lake in the western half of the map-area. This complex is generally massive and is believed to have been originally a diorite with an occasional gabbroic facies. This diorite was, after its emplacement, profoundly altered by soda-and silica-rich solutions and made over to an albite-oligoclase granite. The different phases of this process of alteration are visible in thin sections of the complex, and the occurrence of younger granitic and pegmatitic dykes cutting the altered complex are other manifestations of the presence of a late acidic and sodic magma. It is not possible to state definitely if both the gabbroic or dioritic and the granitic facies are differentiates of the same magmatic intrusion or if the gabbro-diorite was intruded by small bosses and dykes related to a much larger albite granite mass at depth.

c) A fine-to medium-grained, pink, generally massive albite granite occurring in the form of an elongated south-easterly-trending mass surrounding Capisisit lake and extending in the south central section of the area. It is the only granitic mass completely included within the limits of the map-area.

The fresh facies of the Capisisit Lake granitic is composed of about 50 per cent albite (An_8), 15 to 35 per cent microcline, 10 to 25 per cent quartz, and about 15 per cent dark green, highly-pleochroic hornblende. Southeastward, the granite is more altered, biotite replaces the hornblende, and the albite becomes much saussuritized.

The texture of the rock is essentially protoclastic, and microcline is with some of the quartz of a post-kinematic crystallization.

d) A medium-to coarse-grained border facies of the Waswanipi granite more extensively exposed to the west and south of the present area. The Waswanipi granite varies considerably in appearance, composition, and texture within the limits of the map-area, but it is essentially a medium-to coarse-grained, generally massive, quartz-rich, albite granite containing variable amounts of well-twinned, interstitial microcline and about 15 per cent brown and highly-pleochroic biotite.

A protoclastic texture is generally present in the granite, and microcline is a post-deformation mineral commonly forming large crystals containing unoriented fragments of all the other mineral constituents.

e) A small marginal facies of a large oligoclase granite mass south of the present area underlying about ten square miles of the southern section of the east half of the area. Within the limits of the map-area, the rock varies in composition between an albite granite and a diorite.

f) A coarse-grained syenite occurring as a small oval mass about one and a half miles west of Huguette lake. The main characteristic of the rock is the occurrence of euhedral, very large microcline crystals surrounded by interstitial, dark blue hornblende.

g) A series of acidic dykes, generally porphyritic which intruded the volcanic, sedimentary, and gabbroic rocks prior to their folding and metamorphism. They include granite, feldspar porphyry, syenite porphyry, diorite porphyry, and quartz porphyry dykes.

Post-Granitic Intrusives

The post-granitic rocks of the area include medium- to coarse-grained olivine diabase, quartz diabase, and diabasic gabbro, and they occur at disseminated points in the area. The diabase are generally very fresh, and a good study of the order of crystallization of the different constituents is possible in thin sections of this type of rock. In one occurrence, aplitic differentiates of the diabasic magma constitute small veins and dykelets cutting across the olivine diabase. Quartz and sodic oligoclase micrographic intergrowths are well developed in the quartz-diabase.

Structural Geology

The general trend of the main structural units of the area is about S.25°E., but many variations are found. The dips are generally vertical or steep towards the north or south.

The large belt of sedimentary rocks of the area appears to lie in a synclinal fold conformably over the Keewatin-type volcanics, and the two series are found interbedded in their zone of mutual contact. The bulk of the sedimentary rocks of the area can be apparently correlated with the pre-Opémisca series of Beach and Norman, and the conglomerate exposed on the north shore of Inconnu lake seems to possess a series of characters very similar to those of the basal conglomerate of their Opémisca series. However, the conglomerate appears conformable with the fine-grained sedimentary rocks of the present area, and a definite correlation with the Opémisca series is not yet feasible.

A well-defined fault is present just south of Capisisit lake, and Renault lake seems to occupy a depression along a fault zone. Shear zones of various sizes occur fairly abundantly throughout the area.

Economic Geology

No encouraging results have so far been obtained by prospectors in the present area, but some sections underlain by volcanic, sedimentary, or gabbroic rocks look somewhat promising and should not be neglected. The complexly-folded volcanics of the northeastern section of the area seem to deserve a particular attention.

PLATE 1

A. - Maicasagi river near the western boundary of the map-area. In the background, sharp knoll on the north shore of the river.

B. - Maicasagi river slightly west of plate 1, A.

PLATE 11

A. - Gilles bay on Inconnu lake. Note the low shores of the lake and the general flatness of the area.

B. - Inconnu lake looking northward. Note the shallowness of the lake and its low shores.

PLATE 111

A. - Ridges south of Capisisit lake, looking southward.

B. - Ridges south of Capisisit lake, looking southward.

PLATE 1V

A. - Ridges south of Capisisit lake, looking northward.

B. - Ridges north of Capisisit lake, looking northward.

PLATE V

A. - Flat rapid on Maicasagi river.

B. - Large "brulé" north of McDonald lake. On the horizon, ridges south of Capisisit lake.

PLATE V1

A. - Large "brulé" north of McDonald lake. On the horizon, hills south of Capisisit lake.

B. - Part of a 40 foot-fall on Chibougamau river.

PLATE V11

A. - Summit of a typical gabbroic hill.

B. - Rounded inclusions in relatively massive basalt. Note the chilled contacts and cross-fractures in the inclusions.

PLATE V111

A. - Rounded inclusions in relatively massive basalt. Note the white quartz in the fractured inclusion.

B. - Banded, fine-grained sedimentary rocks, northeast of McDonald lake.

PLATE 1X

A. - Banded, fine-grained, basic sedimentary rocks, north of Colette lake. Note the concordant porphyritic intrusive.

B. - Boulder of conglomerate from half a mile east of Inconnu lake.

PLATE X

A. - Boulder of conglomerate from half a mile east of Inconnu lake.

B. - Coarse-grained syenite. Note the euhedral crystals of microcline and the interstitial hornblende.

PLATE Xl

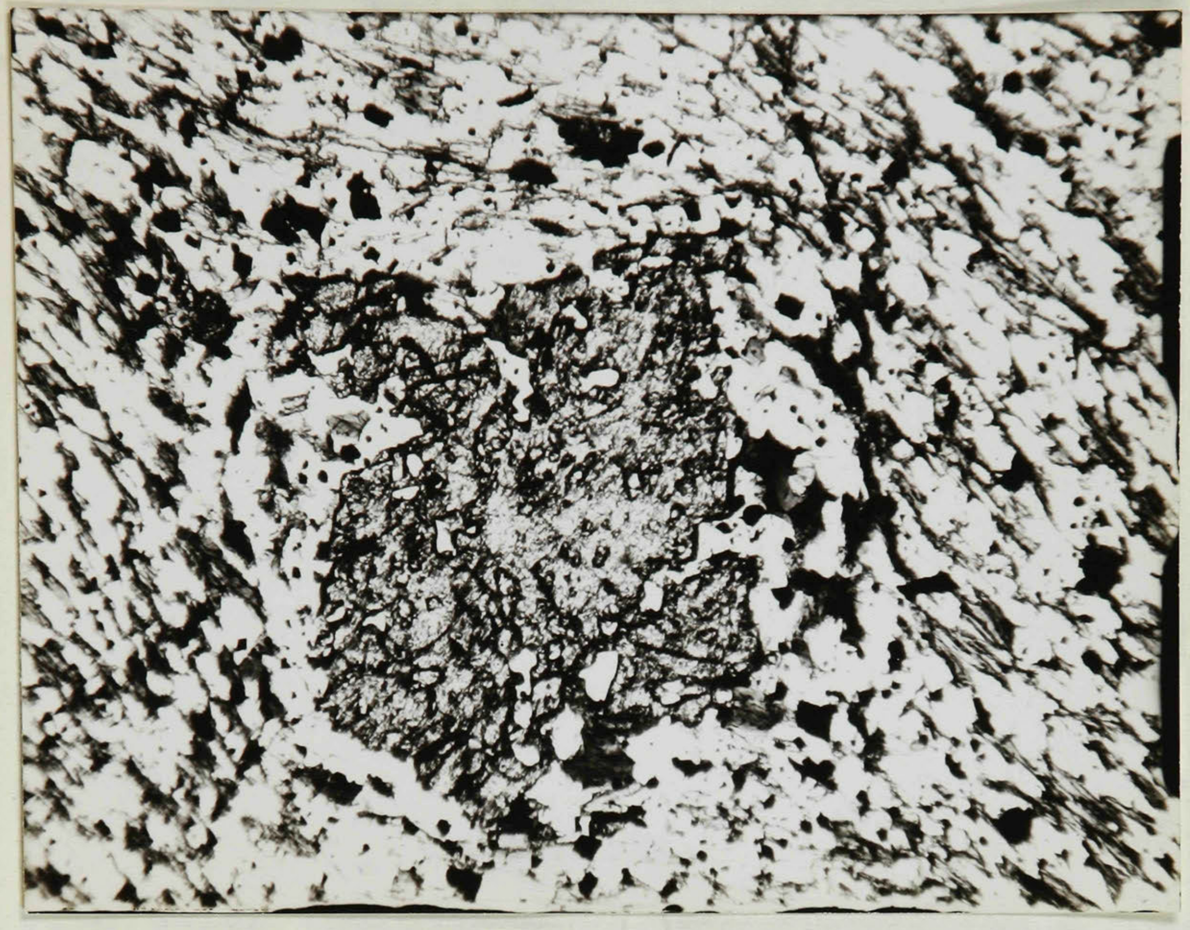
A. - Wash-board moraines, west of Huguette lake.

B. - Wash-board moraines, southeast of Veto lake.

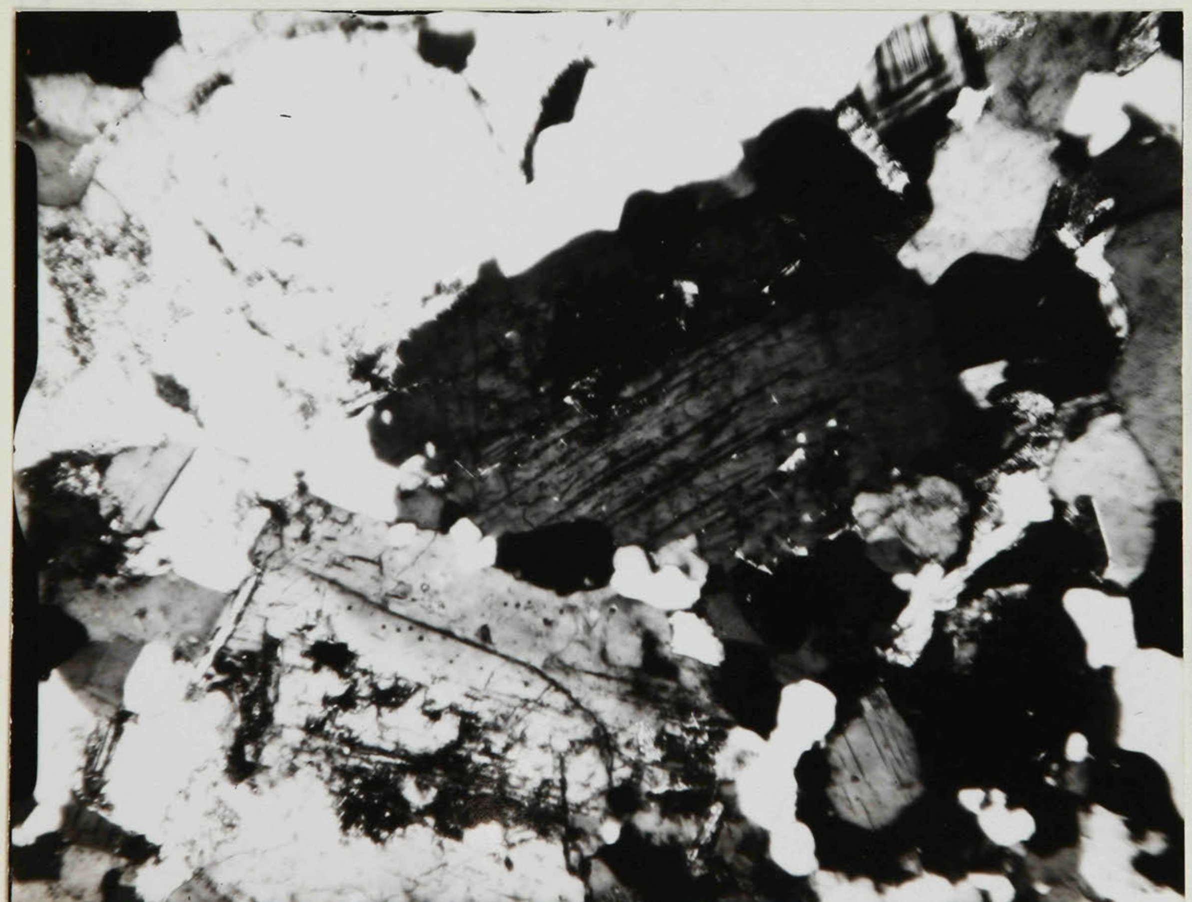
PLATE XII

A. - Pale green, acicular amphibole in low grade metamorphism of basaltic lava. The colorless grains are albite. x45, ordinary light.

B. - Blue-green, granular amphibole in highest grade of metamorphism of basaltic lava. The colorless grains are andesine. x45, ordinary light.



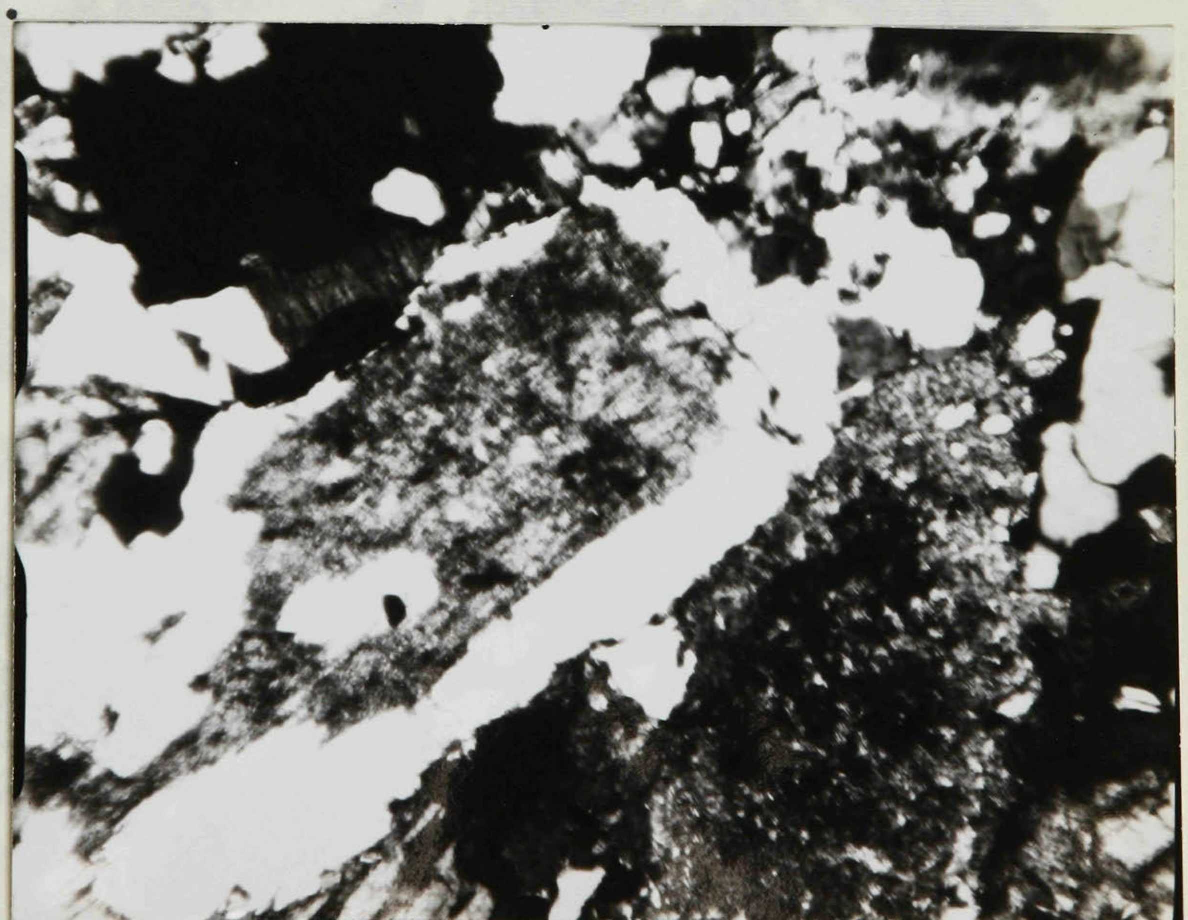
A. - Porphyroblast of garnet showing clockwise rotational movement. The rock is a metasediment of the andesine-garnet zone and the lineation of the rock is at about N.45°W. x45, ordinary light.



B. - Protoclastic texture in Maicasagi River Gneiss. Note the granulation between the two large oligoclase grains, in the center of the photograph. x45, ordinary light.

PLATE XlV

A. - Fresh dioritic facies of the Diorite-Syenite Complex. The large grain in the north central section is hypersthene with thick inclusions of iron oxides and a narrow rim of uralite at the periphery. The very dark mineral in the center is biotite which is associated with hypersthene and with diopside in the northeast and southwest corners. The colorless mineral is fresh andesine. x45, ordinary light.



B. - Altered dioritic facies of the Diorite-Syenite Complex. Note the saussuritized andesine core surrounded by fresh, colorless albite. x45, ordinary light.

PLATE XV

A. - Colorless quartz and slightly altered albite grain included in very large microcline crystal. x45, polarized light.

B. - Olivine diabase. Plagioclase laths included in two large crystals of augite. Note also small cracked olivine grain in northwest quadrangle. x45, polarized light.

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