THE GEOLOGY OF STEELE, BONIS, AND SCAPA TOWNSHIPS, DISTRICT OF COCHRANE, ONTARIO

by

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ABSTRACT

Steele, Bonis, and Scapa townships, in the District of Cochrane, Ontario, are underlain by a steeply inclined Precambrian metavolcanic-metasediment assemblage that is intruded by sills, dikes, stocks, and batholiths.

The metamorphosed Bonis volcanics and Steele Lake volcanics are chiefly intermediate to basic lavas. The Scapa and Steele metasediments are composed mainly of metamorphosed greywacke, calc-silicate rocks, and iron-formation. Metamorphosed ultrabasic and basic intrusions occur in the Bonis volcanics and Scapa metasediments.

The metasediments and Steele Lake volcanics show a regional metamorphic zoning relative to the Case batholith on the north margin of the area. Chlorite, biotite, garnet, and staurolite zones are distinguished over an area up to eight miles wide south of the batholith. The regional metamorphic zoning is attributed to intrusion of the Case batholith. The Bonis volcanics have been metamorphosed at their contact with the Sargeant batholith that underlies the southeast part of the area. The Bonis volcanics have acted as a "resistor" in protecting the metasediments from metamorphism by the Sargeant batholith. A narrow contact aureole occurs in the Scapa metasediments adjacent to the Scapa stock. Potash metasomatism and high water pressures have prevented the formation of alumina-rich minerals within the aureole.

Diabase dikes of two ages cut all other rocks in the area.

The easterly trending rocks of the metavolcanic-metasediment assemblage are locally deflected around the western end of the concordant Sargeant batholith.

A spodumene-bearing pegmatite dike found in the Case batholith is of economic interest.

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ACKNOWLEDGMENTS

The writer is indebted to Dr. M.E. Hurst, Provincial Geologist, Ontario Department of Mines, for permission to use field work carried out for the Department of Mines as a basis for this thesis. Many helpful suggestions and criticisms during the preparation of the thesis by Dr. K.C. McTaggart and Dr. J.V. Ross are gratefully acknowledged. Assistance in the field was given by Mr. W. Leszezyszyn, Mr. J.J. Cavarzan, and Mr. L. Carlson. Mr. Leszczyszyn, as senior assistant, was responsible for part of the field mapping. Assays were made by the staff of the Provincial Assay office, Ontario Department of Mines.

CHAPTER I

INTRODUCTION

Steele, Bonis and Scapa townships are located in the District of Cochrane about 50 miles due east of the town of Cochrane, which is located at the junction of the Ontario Northland railway and the northern branch of the Canadian National Railways. The southern part of Steele township and the southwest corner of Bonis township together comprise a major portion of the north shore of Lower Lake Abitibi.

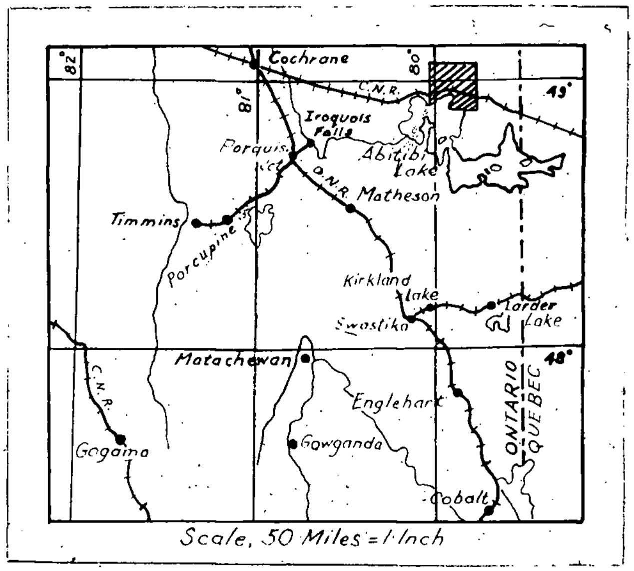

Figure 1. Key map showing the location of Steele, Bonis and Scapa townships.

Recorded interest in the map-area dates back to 1906, when, according to Baker,[1] many prospectors travelled to Lake Abitibi in search of gold, following the staking rush at Cobalt. Copper was discovered in the metavolcanic rocks occurring in northern Steele township in the late 1920's. Since this time prospecting activity has been more or less continuous and a variety of exploration work performed. No mineral production has been reported from the three townships.

MEANS OF ACCESS

The Abitibi Power and Paper Company's Trans-Limit road and main haulage road together give direct access from Iroquois Falls to northern Steele township, the southern part of Scapa township, the northwestern corner of Bonis township and Eades, a flag stop on the Canadian National Railway. The roads are gravel surfaced and passable in all seasons.

The northern branch of the Canadian National railways traverses the southern part of Steele and the central part of Bonis townships. Daily, except Sunday, train service links Eades with Cochrane, 54.5 miles to the west, and various points within the province of Quebec, 17 miles to the east.

There are numerous old logging haulage roads within the three townships and except where they cross muskegs,

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1 Baker, M.B., Lake Abitibi Area, Ont. Bur. Mines, Vol. XVIII, pt. 1, 1909, p. 268.

most of them are overgrown. They still provide easy access by foot to many parts of the map-area, as they have now become major game trails.

A good trail, once along a telephone line, runs due north from Mace on the C.N.R. to the fire tower in northern Steele township. An old portage extends from 50 feet east of milage 58 on the Trans-Limit road to the northern boundary of Scapa at Kabika Lake.

FIELD METHODS

The present survey was conducted by the writer for the Ontario Department of Mines during the summer of 1959. The manuscript map used for the compilation was provided by the Ontario Department of Lands and Forests and compiled from air photographs taken in 1946 and 1947 for the Forest Resources Inventory. Further topographic details have been added from information collected during the course of the field work. The field mapping of the townships was carried out on a scale of 1 inch to 1320 feet. Geological information, obtained by shoreline geology and pace-and-compass traverses tied to the C.N.R., roads, and surveyed lines, was plotted on air photographs. This information, in turn, was plotted on the manuscript map. As the final map was produced on a scale of 1/2 mile to the inch, many of the outcrops had to be generalized and slightly enlarged.

That portion of the Trans-Limit road in Steele township was surveyed by chain and compass, and tied to available iron bars and wooden survey posts. Chained and picketed lines run in Steele and Scapa townships by the Abitibi Power and Paper Company during the winter of 1959 were also used in the field work.

Plans of prospects and diamond drill logs, obtained from property owners, and assessment work data filed at Timmins with the resident geologist, Ontario Department of Mines, were also used in plotting geological data.

TOPOGRAPHY AND DRAINAGE

The area lies within the large undulating Barlow-Ojibway clay plain and is flat to gently rolling. A prominent rock ridge (Steele Ridge) with intermixed Pleistocene deposits extends across the northern part of the area, from the western boundary of Steele township eastward into Hepburn township. To the north of the ridge the area is low and swampy, interrupted at intervals by rocky knolls and deposits of glacial origin. To the south, the land slopes gently towards Lake Abitibi.

Altitudes[2] in the three townships range from 1395 feet[3] at the triangulation station under the Steele fire tower to 868 feet, the elevation of Lake Abitibi. Mace on the C.N.R. has an elevation of 880 feet. A bench mark on

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2 Altitudes are from sheet No. 32 D/NW, National topographic series, unless otherwise stated.

3 J.E.Lilly, Dominion Geodesist, reports this elevation to be accurate to within 15-20 feet and to refer to the tablet under the fire tower.

the culvert where the C.N.R. crosses Forks Creek has an elevation of 886.2 feet. Bench marks along the C.N.R. in Bonis township indicate the general elevation rises slightly to about 908 feet just east of the eastern boundary of Bonis township. Although the highest point along Steele ridge is under the fire tower, another prominent high is located in the southern part of lot 2, concession III, Steele township. This is reported to be about 150 feet lower in elevation than the hill on which the fire tower is located.[4] The ridge is composed of less resistant rocks in Scapa township than in Steele township and, as a result, the elevations here are lower.

ROCK EXPOSURES

Rock exposures are confined almost entirely to the hilly areas. The main hills include Steele ridge, a rocky knoll in the northeastern corner of Steele township, a low ridge in the west-central part of Steele township, and rocky knolls in the northwestern and northeastern parts of Bonis township. Elsewhere, rock outcrops are widely scattered and few.

The volcanic and basic intrusive rocks are best exposed and most resistant to erosion. Nearly all of Steele ridge in Steele township is composed of volcanics and on Lake Abitibi the volcanic and basic rocks are better exposed

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4 Herbert J. Beatty (O.L.S.), from township surveys filed with the Ontario Department of Lands and Forests.

Plate I

A--View of Steele ridge, looking north from Peat's Point. The prominent hill just to the left of the centre of the photograph has an elevation of 1395 feet.

B--View looking north towards Little Joe and Case Lakes from the fire tower on Steele ridge. Note the low muskeg area surrounding Case Lake.

along the shore than the other rock types. A glance at the geological map will show the strong influence that the diabase dikes have had in preserving outcrops of the metasedimentary rocks. At most exposures the metasedimentary rock is cut by diabase dikes. Diabase dikes also form conspicuous elevations along Steele ridge and in southern Bonis township.

Outcrops of acid intrusives are almost entirely confined to northeastern Bonis township where they form a prominent series of rocky knolls, and to the area north of Steele ridge in Steele township. The granite stock in Scapa township forms a low, rounded knoll and probably helped preserve the metasedimentary exposures in this part of the area.

GLACIOFLUVIAL DEPOSITS

A prominent triangular apron, composed of sand, pebble gravel, and boulder gravel, stratified in places, and thinning to the south, extends from the southern slope of Steele ridge in Steele township to about the southern boundary of concession I. Several small hills and ridges occur within the apron and in places it is interrupted by low muskeg areas. The apron is widest directly south of the fire tower on Steele ridge, the highest elevation in the area. Where elevations are less along Steele ridge the apron is proportionately narrower.

An esker with associated outwash deposits trends southward from Kabika Lake in the northwest corner of Scapa township to a point on the C.N.R., due south of Bonis Lake in Bonis township. Numerous kettle lakes are scattered along the trend of the esker and tributaries of Forks Creek have cut through it in many places. A tributary of Forks Creek occupies a hollow found at the intersection of the esker and Steele ridge.

Another esker, somewhat lower than the one mentioned above, crosses the main haulage road at the gravel pits in Scapa township. This ridge dies out about half a mile to the south of the road. To the north it appears to blend into the Pleistocene deposits occupying the southern slope of Steele ridge in Scapa township.

DRAINAGE

Pinnate drainage predominates in the area, although poorly developed radial drainage occurs about the granite stock in northern Scapa township. Interfluvial areas are poorly drained. Most of the streams are consequent on the Barlow-Ojibway clay plain and are in a youthful stage of development, characterized by V-shaped valleys and rapids. In the low areas, particularly in Bonis township many of the larger streams appear to have attained early maturity. The water of many streams and Lake Abitibi has a turbid appearance due to finely suspended clayey particles derived from the clays underlying much of the area.

Steele ridge is an effective water divide. All streams draining the southern slopes of the ridge flow into Lake Abitibi, whereas all those on the north slope flow northward or westward. Mace Creek and West Mace Creek, together with their tributaries drain most of southern Steele township. The west-central part of Steele is drained by the Kaminisinakwa River which flows southwest through Pliny and Purvis townships to Lake Abitibi.

Little Joe Creek drains the area about Little Joe Lake. It flows around the western end of Steele ridge and continues southwestward where it joins the Circle River in Pliny township. The drainage in the remainder of Steele township is to the north via Case Lake and the Case River, which ultimately flows into the Burntbush River, 25 miles to the north of Steele township.

The area north of Steele ridge in Scapa township is drained by the Kabika River, a tributary of the Burntbush River. Forks Creek and Departure Creek, along with its tributaries West Departure Creek and Balkam Creek, drain the remainder of Scapa township and much of Bonis township. The southeastern corner of Bonis township is drained by the Aylen River.

NATURAL RESOURCES

The map-area is situated within the timber limits of the Abitibi Power and Paper Company. Most of the trees in

Bonis and the southern parts of Steele and Scapa townships have been cut for pulp. As a result, these areas are now covered chiefly by poplar, birch and alder. In places, enough time has elapsed since the end of logging operations to allow the growth of young spruce and balsam.

The remainder of the area, except for muskegs, is covered by a mature growth of spruce, balsam and jackpine. In the muskegs black spruce, tamarack and alder are commonly found. Cedar was seen only in muskeg and wet areas inland from the eastern shore of Northeast Bay.

Moose, black bear, rabbit, fox, beaver and skunk are common in the area. Deer, bush caribou, mink and martin are rarely seen. Numerous beaver dams occur in the streams and in places flooding makes travel difficult. Whitefish, pickerel, pike and suckers can be caught in Lake Abitibi and many of the streams contain brook trout. Commercial fishermen have operated from Mace but during the 1959 field season no commercial fishing was done. Trapping in the area has fallen off considerably in recent years because of poor fur prices.

CHAPTER II

GENERAL GEOLOGY

PREVIOUS GEOLOGICAL WORK

Except for Bonis township and that part of the map-area bordering on Lake Abitibi, no previous geological map or report has been published on the three townships. Almost the entire region to the east, west and north is unmapped geologically. A few early reports by the Geological Survey of Canada and the Ontario Bureau of Mines contain brief references to the geology of the area along the shore of Lake Abitibi. M.B. Baker and N.L. Bowen made a reconnaissance geological survey of the Lake Abitibi area in 1908 and they produced a generalized geological map of the southern part of Steele and all of Bonis township. It is unlikely, however, that they actually traversed much of Bonis township. Most of the interpretation was probably based upon outcrops found along the shore of Lake Abitibi and the Canadian National railway. C.W. Knight et al, have given a complete bibliography of the Abitibi region up to 1918 and numerous references to the map-area are made in their report. Mr. W.H. Thompson of Kennco Exploration (Canada) Limited, kindly made available to the writer a private report and map on the geology of parts of Steele, Bonis and Berry townships.

Other government reports and publications dealing with the geology of the map-area are included in the following bibliography:

McOuat, Walter, Geological Survey of Canada, 1872-3.

Ogilvie, Wm., Report of Exploration Survey to Hudson Bay, 1891.

Baker, M.B., Lake Abitibi Area, Ont. Bur. Mines, Vol. XVIII, pt. 1, 1909, pp. 263-283.

Knight, C.W., Burrows, A.G., Hopkins, P.E., and Parsons, A.L., Abitibi-Night Hawk Gold Area, Ont. Bur. Mines, Vol. XXVIII, pt. 2, 1919, pp. 1-70.

Gledhill, T.L., Ben Nevis, Munro, Kamishkotia, and Other Base Metal Areas, Districts of Cochrane and Timiskaming, Ont. Dept. Mines, Vol. XXXVII, pt. 3, 1928, p. 49.

Kindle, E.D., Gold Occurrences of Ontario East of Lake Superior, Geol. Surv. Can., Memoir 192, 1936, pp. 1-4.

Map 48G. Geophysics Paper 48, Geol. Surv. Can., 1948.

GENERAL GEOLOGY

Rocks of the Steele, Bonis and Scapa map-area are entirely Precambrian in age. They comprise a complex of metavolcanic and metasedimentary rocks, intruded by sills, dikes, stocks and batholiths that vary widely in composition and age.

The metavolcanic-metasediment assemblage underlies about two-thirds of the area and consists of an unknown thickness of steeply inclined metamorphosed greywacke, iron formation, basic to intermediate volcanics and acid volcanics. The base of this assemblage has not yet been found. The metavolcanics and metasediments are in part conformable and in part either nonconformable, or in faulted contact. The assemblage has been divided into four rock units by the writer, for which the names Scapa metasediments, Steele Lake volcanics, Steele metasediments and Bonis volcanics are proposed.

A variety of intrusive rocks ranging from ultrabasic to basic in composition occur in the Bonis volcanics and Scapa metasediments. These rocks form narrow sills, dikes and irregular masses. Some of the sills appear to be differentiated into basic and ultrabasic portions, others are complex in origin. Some of the basic intrusions occurring in the Bonis volcanics are sheared and the trend of the schistosity differs radically from that of the surrounding volcanic flows.

Two batholithic intrusions have invaded and metamorphosed the rocks of both the preceding groups. The Case batholith to the north differs markedly in composition and texture from the Sargeant batholith to the south. The Case batholith is granodioritic to granitic in composition and in part pegmatitic whereas the Sargeant batholith is dioritic in composition and in places gneissic. The Steele and Scapa metasediments together display a well-developed metamorphic zoning relative to the Case batholith.

Associated with the two batholiths are a number of porphyry dikes and a granite stock (Scapa stock). Most of the porphyry dikes which occur in the Steele metasediments along the shore of Northeast Bay are metamorphosed and sheared and are therefore considered as early manifestations of the Sargeant batholith. The relative ages of the two batholiths is unknown but both are younger than the meta-volcanic-metasediment assemblage and the ultrabasic and basic intrusives.

Two sets of diabase dikes intrude all other rocks in the area. One set composed of quartz diabase trends north and the other, composed of diabase and olivine diabase, north-eastward. Outcrops of their intersection were not found but evidence from other areas to the south, where the same trend in late basic dikes has been noted, indicates the north-south set to be the older.

Most of the Precambrian rocks are buried by extensive deposits of clay, boulder clay, sand, and gravel. Much of the clay, as shown in sections along Lake Abitibi and in road cuts, is varved indicating the deposition of material in a post-glacial lake. Inland from Lake Abitibi boulder trains, eskers, and outwash deposits are common. These deposits are all Pleistocene in age and owe their origin to the extensive Wisconsin ice-sheet.

Recent deposits consist chiefly of peat formed in the swamps, river, and beach deposits.

In the following summary of the geological succession the terms Keewatin, Timiskaming, Algoman, Matachewan and Keweenawan have been avoided and other names, descriptive of the rock units, have been used instead. As pointed out by

Gunning and Ambrose[1] and more recently by Gill[2] the terms Keewatin, Timiskaming, etc., have little stratigraphic significance, and indeed they tend to confuse the issues involved. No attempt has been made to separate the rocks into Late Precambrian (Proterozoic) and Early Precambrian (Archean) as these terms imply absolute age, the evidence for which is lacking at the present time. Correlation with other areas must await further mapping.

TABLE OF FORMATIONS

CENOZOIC

Recent: Peat, beach deposits, river deposits.

Pleistocene: Varved clay, boulder clay, silt, sand, pebble gravel, boulder gravel.

UNCONFORMITY

PRECAMBRIAN

Late Basic Intrusions

Late Diabase: Olivine diabase and diabase dikes

Early Diabase: Quartz diabase dikes.

Intrusive Contact

Acid Intrusions

Scapa Stock: pink medium-grained granite

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1 Gunning, H.C., and Ambrose, J.W., The Timiskaming-Keewatin Problem in the Rouyn-Harricanaw Region, North-Western Quebec, Trans. Roy. Soc. Can., Sec. 4, Vol. XXXIII 1939, pp. 19-49.

2 Gill, J.E., Precambrian Nomenclature in Canada, Trans.Roy.Soc. Can., Vol. XLIX, Sec.4, 1955, pp. 25-29.

Case Batholith: Hybrid rocks, leucogranodiorite, leucocratic quartz monzonite, pegmatite, aplite, Quartz-feldspar porphyry and feldspar porphyry dikes.

(Age relationship between Case batholith and Scapa stock, and Sargeant batholith is unknown)

Sargeant Batholith: Hornblende and pyroxene diorite quartz diorite, gneissic quartz diorite, quartz monzonite, granodiorite, hybrid rocks. Feldspar porphyry and quartz-feldspar porphyry dikes, rare pegmatite.

Intrusive Contact

Ultrabasic and Basic Intrusions: Serpentinite, uralitized pyroxenite, amphibolite, diorite.

Intrusive Contact

Metavolcanic - Metasediment Assemblage

Bonis volcanics: Intermediate to basic lavas; pillow lavas; amphibolite; porphyritic basalt; acid lava and agglomerate; some tuff and flow breccia; rocks of indefinite origin.

Fault (?) (Age relationship between the Bonis volcanics and the divisions listed below is not known.)

Steele metasediments: Metamorphosed greywacke; interbedded calc-silicate rocks; hornblende-plagioclase schist.

Steele Lake volcanics: Amphibolitized intermediate to basic lava, pillow lava, porphyrytic basalt; amphibole schist; rocks of indefinite origin; some interbedded metasediment.

Scapa metasediments: Metamorphosed greywacke, garnet and staurolite schists; interbedded calc-silicate rocks, iron formation; rare arkose.

CHAPTER III

METAVOLCANIC-METASEDIMENT ASSEMBLAGE

INTRODUCTION

Nearly all of Scapa township, about three-fourths of Steele township and the extreme northern and northwestern parts of Bonis township are underlain by rocks belonging to the metavolcanic-metasediment assemblage. The structural trend and general characteristics of the assemblage closely resemble those of Archean rocks which occur within the Superior Province[1] of the Canadian Shield.

The stratigraphy of the individual units is only imperfectly known. For reasons to be discussed later under "Structural Geology", the Steele metasediments are considered to lie conformably on top of the Steele Lake volcanics which, in turn, appear to be conformable upon the Scapa metasediments. A fault zone may separate the Bonis volcanics from the rest of the units in the assemblage.

Metamorphic zoning developed in the metasediments resembles the Barrovian type of zoning[2] developed in the

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1 The map-area lies within the Superior Province as defined by Gill (Trans. Roy. Soc. Can.) vol. 43, Sec. IV, 1949, pp. 61-69.

2 Read, H.H., The Granite Controversy (Interscience Publishers, Inc., 1957) p. 203. Gives an excellent review of the zonal concept and modifications applied to it. (Numerous additional references may be obtained from Read's discussion).

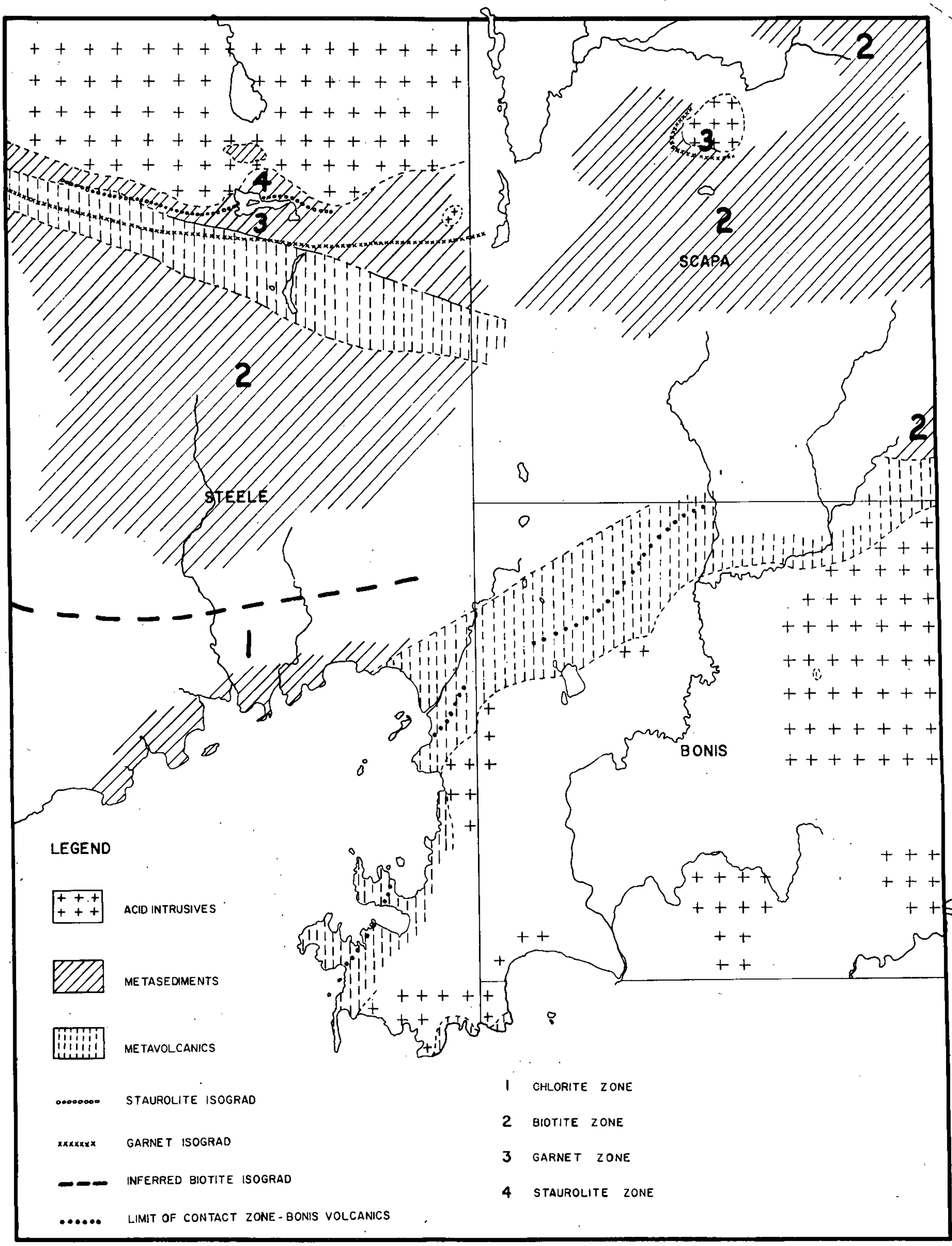

Figure 2. Sketch map showing the distribution of metamorphic zones developed within the metavolcanic-metasediment assemblage. Scale: 1 inch to 2 miles.

Grampian Highlands of Scotland. Four of the six zones defined in the Grampian Highlands are represented in the zones recognized within the map-area. The most southerly exposures of the Steele metasediments lie within the chlorite zone and these are assumed to grade into the biotite zone developed in both the Steele and Scapa metasediments to the north and northeast of the chlorite zone. Garnet and staurolite zones occur in the Scapa metasediments adjacent to the Case batholith in Steele township.

The distribution of the various zones are indicated in Figure 2, together with the approximate position of the garnet and staurolite isograds. Accurate delimitation of the isograds was not possible owing to the poor quality and rarity of rock exposures. Because the area is generally flat no information could be obtained regarding the probable dip of isogradic surfaces.

The biotite isograd is entirely hypothetical as no outcrops were found which showed the first appearance of biotite. The metasediments occurring near the boundary between concessions I and G are in the lower part of the biotite zone and therefore nearer the biotite isograd than other rocks within this zone in Steele township.

Figure 2 also shows the approximate limit of a contact zone adjacent to the Sargeant batholith within which the Bonis volcanics have been amphibolitized, sheared, recrystallized, or hornfelsed. In addition, a narrow contact aureole developed in the Scapa metasediments bordering the Scapa Stock in Scapa township is indicated.

In describing the petrology of the metasediments and the Steele Lake volcanics, the plan of treatment will be based on the progressive changes which take place with increasing metamorphism. Because the lithology and metamorphism of the metasediments are much the same, these rocks will be discussed before the metavolcanics.

METASEDIMENTS

SCAPA METASEDIMENTS

The Scapa metasediments separate the Steele Lake volcanics from the Case batholith in Steele township and underlie much of the northern half of Scapa township. A one and a half mile area of drift separates the Scapa metasediments from a few exposures of similar metasediments occurring in the southeastern corner of Scapa and adjacent parts of Hepburn township. These latter rocks will be described with the Steele metasediments, although their relationship to the two metasedimentary units is at present unknown.

Metamorphosed, grey to black greywacke and interbedded calc-silicate rocks make up most of the Scapa metasediments. Layered iron-formation and magnesium-rich rocks occur sporadically. Massive greywacke and greywacke showing graded bedding are both found in most outcrops. Arkose is rare.

Greywacke

Greywacke with graded beds commonly contains a narrow zone of slate or phyllite at the top of the individual couplets and such metasediment has frequently been referred to as "greywacke-slate."[3] The interbedded slate probably forms less than 15 per cent of the total volume of the rock. For purposes of this thesis, the definition of greywacke will be that used by Pettijohn[4] in his description of Archean sedimentation. Of the various definitions put forth this one appears to summarize the greywackes of the map-area the best. The definition is reproduced below:

> "Greywacke connotes a type of sandstone marked by (1) large detrital quartz and feldspar ("phenocrysts") set in a (2) prominent to dominant "clay" matrix (and hence absence of infiltration or mineral cement) which may on low-grade metamorphism(diagenesis) be converted to chlorite and sericite and partially replaced by carbonate, (3) a dark color (4) generally tough and well indurated, (5) extreme angularity of the detrital components (microbreccia) (6) presence in smaller or larger quantities of rock fragments, mainly chert, quartzite, slate, or phyllite, and (7) certain macroscopic structures (graded bedding, intraformation conglomerates of shale or slate chips, slip bedding etc), and (8) certain rock associations."

The original clay matrix of all the greywackes within the map-area has been converted to chlorite, sericite and/or micas by metamorphism. Rock fragments are rare and quartz predominates over feldspar in nearly all the rocks. The greywackes

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3 Pettijohn, F.J., Archean Sedimentation, Bull. Geol. Soc. Am., Vol. 54, 1943, pp. 944-945.

4 Ibid, p. 957.

are therefore feldspathic according to Pettijohn's classification of sandstones.[5]

Individual graded beds are commonly less than one-quarter inch to several inches thick but a few are a foot or two thick. Massive greywacke, without bedding, is less common than greywacke with graded beds. Within the biotite zone porphyroblasts of mica up to one-quarter inch in size occur in the fine silty and shaley parts of the beds and in the higher grades of metamorphism the biotite is accompanied or displaced by idioblastic garnet and staurolite. The fine-grained parts of the individual graded bed thus become coarser in grain than the sandy portions, and the bed as a whole has undergone metamorphic inversion. Sedimentary structures such as cross-bedding, channelling and intraformational conglomerate were not seen in the Scapa metasediments. Graded bedding and clastic textures are well preserved in the lower grades of metamorphism but the increased schistosity in the upper part of the garnet zone and in the staurolite zone destroys these features.

Silty or shaley parts of the graded beds are more susceptible to deformation than the coarser parts. Schistosity is well developed in all the fine-grained rocks occurring in the Scapa metasediments and it increases in intensity with rising metamorphic grade. In places the incompetent silty or shaley parts of the couplets have been intricately drag-folded between the competent sandy parts.

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5 Pettijohn, F.J., Sedimentary Rocks, Second ed. Harper and Bros. New York, 1957, pp. 290-293.

Concordant quartz veinlets, commonly less than one inch wide, are ubiquitous in the sheared greywackes and they increase in number and width with an increase in the intensity of shearing. In many places where the greywacke is highly sheared, boudinage structure is found in the quartz veinlets. Narrow discordant quartz veins, which are wider than the concordant types, and of all orientations, cut the greywackes in a number of places. These increase in number and size near the Case batholith, the Scapa stock and adjacent to porphyry dikes. Except for faulting, the discordant quartz veins are undeformed.

(1) Biotite Zone

The massive greywackes are non-foliated in the lower part of the biotite zone and slightly schistose in the upper part of the zone. The massive greywackes consist chiefly of biotite, feldspar and quartz. Chlorite is rarely an essential constituent and muscovite and sericite are not common. Muscovite occurs only in the upper part of the zone. Rock fragments (mainly chert) are present but invariably form less than 5 per cent of the whole. Accessory minerals include tourmaline, epidote, sphene, magnetite, ilmenite, pyrite and apatite.

In rare instances quartz and feldspar occur in about equal amounts and constitute about 80 per cent of the rock. Such rocks, referred to as arkose, are pinkish in colour and occur in narrow layers about two inches thick. Quartz, which forms up to 45 per cent of the whole, occurs as relatively large clastic grains (up to 0.7 mm) with sutured borders and also as fine grains scattered through the groundmass. The larger quartz grains are markedly elongate and are grouped in lenticular aggregates or narrow veinlets in the upper part of the zone. The feldspar is mainly untwinned, porphyroblastic and recrystallized albite, containing many inclusions of quartz and clouded by sericite. In the higher part of the zone albite is clear and the porphyroblasts are larger (up to 0.4 mm) than in the lower part of the zone. Some detrital oligoclase and rare potash feldspar occur in the lower part of the zone but were not seen in the upper part.

Reddish-brown biotite with X=pale to yellowish and Z and Y=reddish brown forms 15 to 25 per cent of the rocks. It occurs as evenly distributed porphyroblasts, characterized by numerous pleochroic haloes, and as fine-grained oriented flakes intergrown with chlorite in the groundmass. Chlorite is most abundant in slightly schistose originally massive greywackes which suggests that biotite becomes unstable with increasing shearing stress as pointed out by Turner.[6] Distinct grains of muscovite intergrown with biotite were found in the massive greywackes from the upper part of the zone.

Rock fragments lose their identity with increasing schistosity. Tourmaline, in stumpy prisms, is ubiquitous in the greywackes and has a blue-green pleochroism with O=

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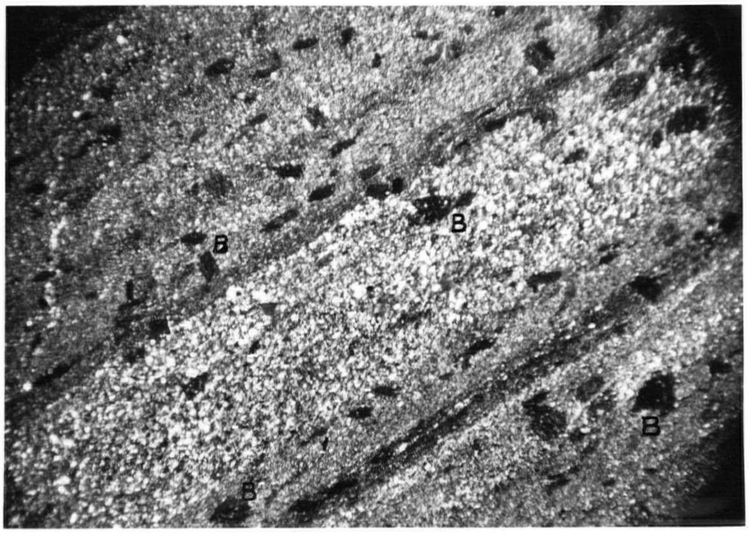
6 Turner, F.J., Progressive Regional Metamorphism in Southern New Zealand, <u>Geol. Mag.</u>, Vol. 75, 1938, pp. 160-174.

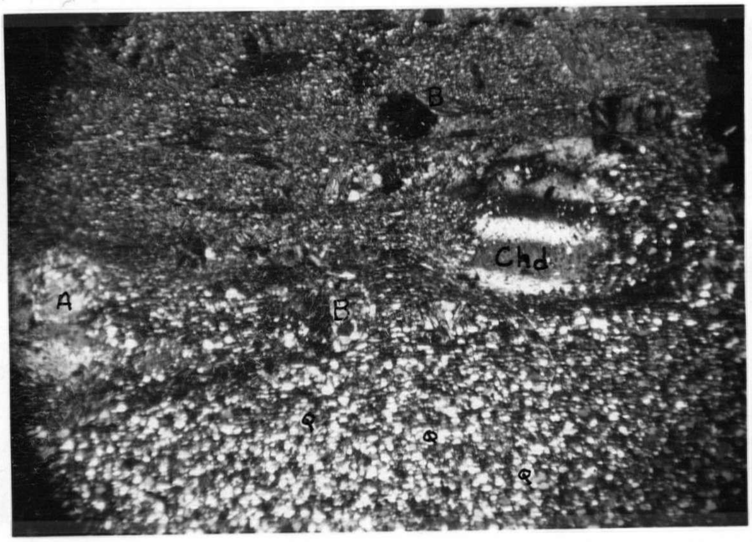
blue-green and E=colourless to pale yellow. Variation in colour within a single grain of tourmaline was also noted with the different colours arranged in zones. Epidote and apatite are rare in the massive greywackes. Magnetite, pyrite, and ilmenite (rimmed by sphene) occur as anhedral grains with the planes of foliation sweeping around them.

The greywackes showing graded bedding have a good schistosity parallel to the bedding and they contain the same minerals as the massive greywackes, but the micaceous components and chlorite play a more important role. The coarser sandy parts of the graded-beds have a smaller average grain size (about 0.1 mm), than that of the massive greywackes. Quartz and feldspar are elongate in habit and usually completely recrystallized with the former mineral often occurring in lenticular aggregates and narrow veinlets. Some clastic quartz occurs in the lower part of the zone but the grains have sutured borders or they are strained and crushed. No clastic feldspar or rock fragments were noted. Albite, which is clouded by sericite in the lower part of the zone, increases in grain size and is clear in the upper part of the zone. A few porphyroblasts of chloritoid with a very weak pleochroism were seen in one thin section.

In the lowest grade rocks biotite, intergrown with chlorite and white mica, is confined to incipient porphyroblasts occurring in the argillaceous layers. With increasing metamorphism the biotite porphyroblasts become more homogeneous and display numerous pleochroic haloes around minute indistinct



A. Photomicrograph of graded bedding in greywacke, Scapa township. Incipient biotite porphyroblasts (B) are concentrated in the argillaceous layers containing quartz, sericite, muscovite, and chlorite. Polarized light X16.



B. Photomicrograph showing a porphyroblast of twinned chloritoid (Chd) in an argillaceous layer of a graded bed, Scapa township. B=biotite, A=albite, Q=quartz. Polarized light X16.

inclusions, while flakes of biotite appear in the groundmass of both the argillaceous and sandy parts of the graded-beds. As the amount of biotite increases the white mica content decreases but the chlorite content remains more or less unchanged. In the upper part of the biotite zone, biotite porphyroblasts are less numerous and the rock more homogeneous. The micas and chlorite are coarser-grained and the argillaceous layers become markedly phyllitic.

All the minerals except quartz and some opaque minerals crystallized either wholly or in part after shearing movements ceased. The albite is a product of neocrystallization as indicated by its sutured borders against other minerals, its uncleaved, untwinned character, and the sieve texture which it displays.

A rather unusual phyllitic greywacke was found within the biotite zone in the eastern part of Scapa township. Black speckled argillaceous layers predominate in the rock. In thin section considerable fine, dusty graphite can be seen scattered throughout the argillaceous layers. Biotite, occurring as porphyroblasts, constitutes about 25 per cent of the rock. Graphite is rare or absent elsewhere.

(2) Garnet Zone

The typical rocks of the garnet zone are garnetiferous chlorite-biotite-feldspar-quartz schists and biotite-muscovite-feldspar-quartz schists. Garnet is best developed in the originally argillaceous parts of graded beds. Except for the narrow aureole about the Scapa stock, garnets were found only in the Scapa sediments occurring within Steele township.

The garnet is the common pinkish variety, presumably almandine. It occurs as idioblastic grains up to 2 millimeters in size and is generally more abundant and coarser in grain away from the biotite zone. Helicitic structure occurs in a few of the garnets in the lower part of the zone but most show no evidence of rotation during growth. Some garnet has partly altered to chlorite but most is fresh.

Chlorite is abundant in many of the rocks in the lower part of the zone but is rare in the upper part. Muscovite increases as the amount of chlorite decreases. Secondary penninite has grown across biotite and muscovite grains in some of the rocks from the upper part of the zone.

Quartz is completely recrystallized and occurs in narrow elongate lenses and in veinlets, or as individual elongate grains, commonly with sutured borders. Albite is present in the lower part of the zone but oligoclase (An_{25-30}), showing reversed zoning, is common in the upper part of the zone. Both the oligoclase and albite are clear and untwinned and occur as anhedral grains more or less elongated parallel to the schistosity.

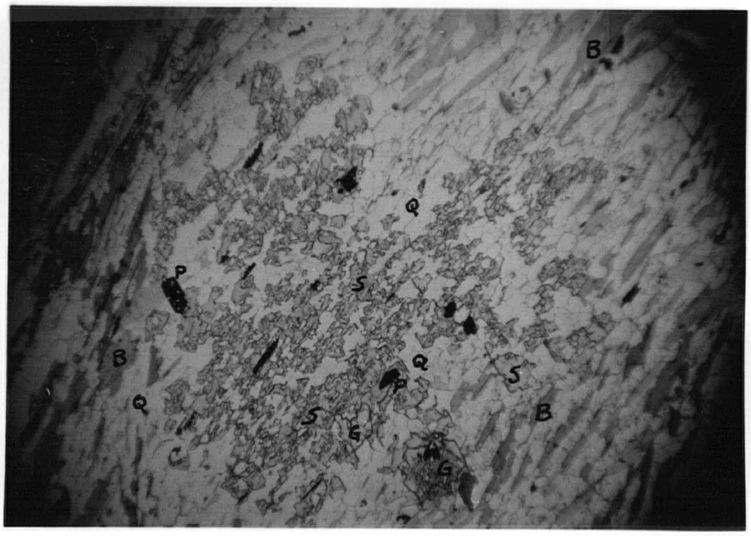
Biotite forms about 20 to 25 per cent of the whole, and is the reddish-brown variety noted in the biotite zone. It occurs as small, deformed flakes, oriented parallel to the schistosity and as undeformed porphyroblasts which grow across the schistosity and usually related to the metamorphosed argillaceous parts of the original sediment.

Accessory constituents include tourmaline, opaque minerals (mainly pyrite), epidote and apatite. Pyrite occurs as elongate anhedral grains lying parallel to the schistosity.

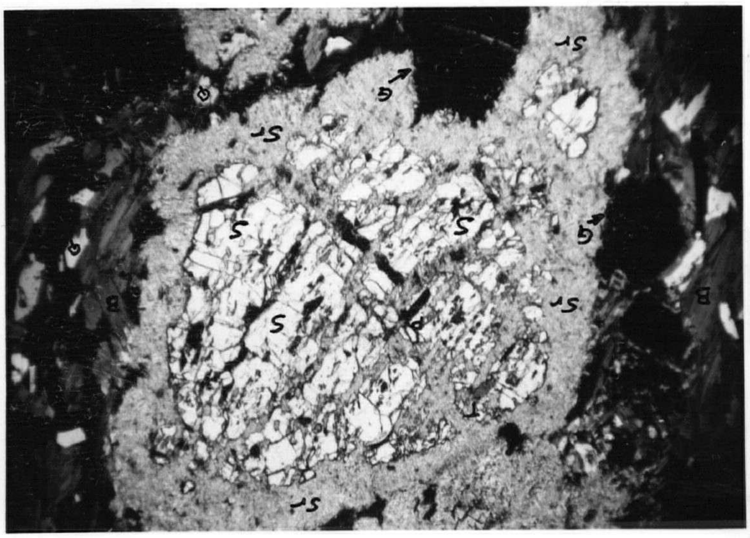
(3) Staurolite Zone

Most of the rocks within the staurolite zone possess a well-developed schistose and gneissic structure. Original sedimentary structures are absent and coarse quartz stringers and lenses, up to one inch or more in width, lying parallel to the foliation, are abundant. Some of the quartz veinlets contain minor plagioclase (About An_{30}). The staurolite is idioblastic, occurring as crystals up to one inch in diameter which are commonly interpenetrating twins that stand out in relief on weathered surfaces of outcrops. The garnet occurs as idioblastic grains, usually about 1/8 inch in size, and is a more deeply coloured variety than that within the garnet zone. Several inclusions of metasediment were found within the Case batholith, particularly near the contact with the Scapa metasediments. Granoblastic texture is common in the inclusions, as well as in the metasediment adjacent to the contact.

The typical rock types developed are quartz-plagioclase, garnet-biotite-staurolite schist, garnet-biotite-plagioclase-quartz schist, biotite-quartz-plagioclase hornfels and biotite-muscovite-quartz-plagioclase hornfels. The biotite forms oriented, undeformed flakes up to 1 mm. in length, and contains numerous pleochroic haloes around discernable zircon inclusions. The pleochroism is less pronounced than in the lower grades



A Photomicrograph of a "spongy" staurolite porphyroblast in staurolite-oligoclase-biotite-quartz schist. Lot 5, concession IV, Steele township. S= staurolite, G=garnet, B=biotite, Q= quartz, P=pyrite. Plain light X16.



B Photomicrograph of an altered staurolite metacryst in garnet-quartz-oligoclase-biotite-staurolite schist. Lot 6, concession IV, Steele township. Sr= sericite, S=staurolite, G=garnet, B= biotite, Q=quartz, P=pyrite. Polarized light X16.

with X= light yellow, Z and Y= light reddish brown. Chlorite is absent, except where the rocks have undergone retrograde metamorphism. Muscovite is confined to the rocks containing no staurolite and little or no garnet.

The matrix of most of the rocks consists of a granoblastic aggregate of quartz and plagioclase. The plagioclase (about An_{28}) is zoned with a sodic core and a calcic rim. In the hornfelses and the schists adjacent to the contact with the Case batholith, zoned plagioclase gives way to clear unzoned and frequently twinned plagioclase which varies in composition from about An_{28} to An_{32}. The plagioclase of the sedimentary inclusions occurring well within the Case batholith is more calcic, having a composition of about An_{37}.

Staurolite appears first as small spongy porphyroblasts but it forms large idioblastic crystals near the contact with the Case batholith. In some rocks the staurolite has altered in part to sericite which forms a wide rim around a central core of relatively fresh staurolite. (See Plate III B). Garnet forms idioblastic crystals, some of which are sieve-textured, and contain numerous inclusions of quartz. Both staurolite and garnet have only rarely thrust aside other minerals during growth. The inclusions indicate that no rotation of garnet and staurolite crystals has occurred.

Accessory constituents include apatite, tourmaline, opaque minerals, and rare epidote. Coarse euhedral apatite and tourmaline are particularly common and perhaps more abundant than in the metasediments within the lower metamorphic zones.

Because of the bulk compositional requirements for the formation of staurolite, this mineral is not widely distributed in the staurolite zone. It is abundant, however, in the originally argillaceous parts of graded beds. Oligoclase and sodic andesine are widely distributed and appear to be the typical index minerals of this zone. Vogt[7] has also noted oligoclase or more calcic plagioclase to be the typical index mineral in the highest grades of metamorphism in the Sulitelma region of Norway. As noted earlier, calc-silicate rocks are commonly found interbedded with the Scapa metasediments and the greywackes are always feldspathic. It is therefore possible that the poor development of staurolite in many of the rocks is due to an original calcic and feldspathic nature of the metasediments.

James[8] has indicated that the similarity in composition between staurolite and chloritoid would suggest that chloritoid would be equally common in a lower zone of metamorphism and that staurolite might be expected to develop from chloritoid. Chloritoid is extremely rare in the Scapa metasediments so that no paragenetic relationship could be established.

Absence of kyanite and andalusite in the metasediments suggests that the bulk composition of the rocks was not appropriate for the development of these minerals. This

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7 Vogt, T., Sulitelmafeltets Geologi og Petrografi (with English summary), Norges. Geol. undersakelse, 121, 1927.

8 James, H.L., Zones of Regional Metamorphism in the Precambrian of Northern Michigan, Bull. Geol. Soc. Am. Vol. 66, 1955, p. 1465.

absence together with the scarcity of potash feldspar and the abundance of chlorite in lower grades of metamorphism, strongly suggests that the rocks as a whole are deficient in potash and do not contain excess alumina.

Scapa Stock Aureole

A narrow contact aureole, ranging between 300 and 650 feet in width occurs within the Scapa metasediments bordering the Scapa granite stock. The contact is exposed only at intervals along the southern margin of the stock. Two zones can be distinguished within the aureole - an outer garnet zone, which grades away from the stock over a distance of up to 600 feet into the metasediments of the biotite zone in Scapa township, and an inner zone of hornfels about 100 feet wide, which grades into fine-grained granite and the typical medium-grained granite of the stock.

In approaching the aureole from the south or west the first obvious contact effects of the stock on the metasediments are (1) an increase in the number of both concordant and discordant quartz stringers, (2) an increase in the intensity of shearing of the fine-grained greywackes, and (3) a coarsening of the biotite porphyroblasts occurring in the argillaceous parts of graded beds. Within the outer part of the aureole the strike and dip of the bedding and schistosity show significant variations from the normal and in many places the fine-grained metasediments are highly folded and crenulated. Garnet occurs as idioblastic crystals in the argillaceous layers up to 600 feet from the stock, and the metasediments appear to be largely recrystallized with original sedimentary structures becoming vague or entirely obliterated within the aureole.

Numerous microscopic fractures cut all the rocks in both the garnet and hornfels zones. Chlorite and sericite alteration occurs in the garnet zone metasediments up to 2 mm. from the fractures which are filled with a very fine-grained fibrous material with low birefringence and relief (zeolite?). Cubes of pyrite are also associated with the altered portions of the rocks. A colourless amphibole with a positive optic sign and inclined extinction, tentatively identified as cummingtonite, was found scattered through a massive greywacke containing oligoclase near the hornfels zone. A few slightly twinned and sieve-textured grains resembling altered feldspar were noted in one rock. The grains could not be identified with certainty, but they may represent cordierite.

The strike of relict bedding at the outer margin of the hornfels zone is quite variable, ranging between N50°E and N70°W. Granite porphyry dikelets and granitic stringers, usually less than 4 inches wide, intrude the hornfelses up to 50 feet or so from the contact.

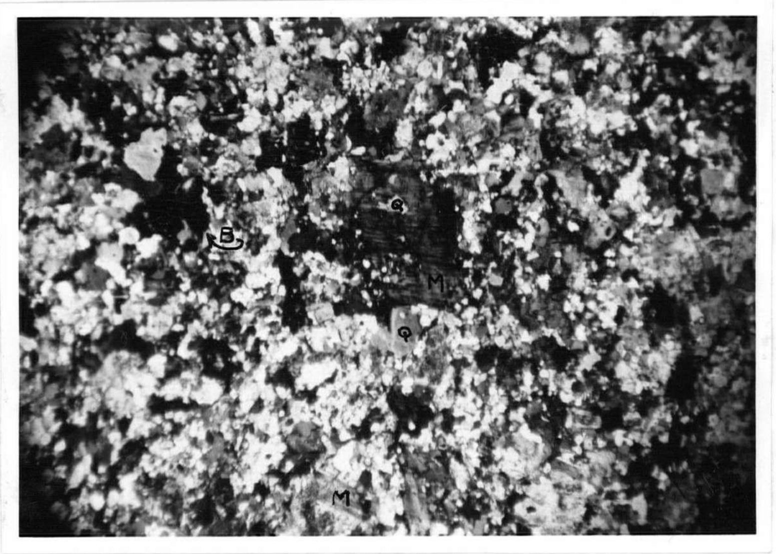
At the outer margin of the hornfels zone the rock, which resembles massive greywacke, is non-foliated, greyish-brown in colour, and is spotted with many flakes of biotite. In thin section the groundmass of the rock is completely recrystallized and has a granoblastic texture. Original clastic quartz grains are grouped together in elongate aggregates, and poiciloblasts of oligoclase, poorly oriented flakes of reddish-brown biotite, and idioblastic pale green amphibole are also present. About 50 feet from the granite contact the rock is light green in colour, slightly foliated, even-grained, and is highly altered, containing abundant chlorite and sericitized plagioclase.

All vestige of bedding is lost about 20 feet from the fine-grained granite, and the rock is pinkish in colour, and granitic. In thin section, numerous idioblastic oligoclase and microcline grains, with inclusions of quartz, biotite and tourmaline, lie in a fine granoblastic aggregate of quartz and feldspar. Greenish to dark brown biotite with X= light yellow, Z and Y= dark brown to green, and pistacite are evenly distributed throughout the rock.

Adjacent to the fine-grained granite the hornfels differs from the preceding description only in being coarser and even-grained, and fresher, and it contains muscovite as well as biotite. Epidote is not present and accessory sphene and apatite are abundant.

The occurrence of porphyroblastic microcline up to 20 feet from the granite suggests that potash has been added to the sediment from the granite. The alteration of the rocks within the aureole is indicative of the action of late-stage volatiles and solutions eminating from the stock into the metasediments and facilitated by the development of

Plate IV



Photomicrograph of hornfels, 20 feet south of the Scapa stock contact. The rock is composed of albite and altered plagioclase, microcline (M), biotite (B), quartz (Q), and accessory muscovite, sphene and apatite. Polarized light X16.

small fractures. Of particular interest is the apparent absence of cordierite a mineral typical of contact aureoles.

Iron-Formation

Gross[9] has recently defined iron-formation as follows:

> "Iron-formation is considered to include stratigraphic units of bedded or laminated rocks which contain 15 per cent or more iron in which the iron minerals are commonly interbedded with quartz, chert or carbonate, and where the banded structure of the ferrugenous rocks conforms in pattern and attitude with the bedded structure of the adjacent sedimentary, volcanic, or metasedimentary rocks."

This definition is used in designating the following rocks as iron-formation. Also, all the iron in the iron-formation of the map-area has combined with silica to form amphiboles, garnet, stilpnomelane and other silicate minerals of metamorphic origin. Little or no magnetite or other iron-ore minerals occur in the iron-formation rocks of this area.

The best exposures of iron-formation are cut by the prominent north-south diabase dike near its southern end in Scapa township. At this locality the iron-formation has been stripped at intervals along strike. The iron-formation strikes parallel to the metasediments and dips 20° to 90° south. It was traced along strike for 870 feet and its width averages about 10 feet.

The rock comprising the iron-formation is essentially

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9 Gross, G.A., A Classification for Iron Deposits in Canada, Can. Min. Journ. Vol. 80, 1959, pp. 88.

a layered grunerite-quartz rock. In places massive rocks composed of grunerite, hornblende and quartz, and chlorite, biotite, muscovite and epidote are abundant. Muscovite-albite-biotite-chlorite-quartz schist also occurs interbedded with the above rock types. Pyrite and pyrrhotite are found disseminated throughout the iron-formation and are commonly found up to 120 feet away from the iron-formation in the metasediments.

The layered grunerite-quartz rock consists of narrow bands of rusty quartz up to 2 inches in width alternating with bands consisting mainly of grunerite and blue-green hornblende. The iron-formation is highly contorted in places and the quartz layers accentuate drag folding. In thin section the quartz layers are composed almost entirely of interlocking quartz grains, averaging about 0.7 millimeters in diameter, which contain a limonitic stain around their boundaries. Grunerite, occurring as laths commonly arranged in rosettes, is concentrated next to the quartz layers. Blue-green hornblende is also abundant in the amphibole layers and commonly predominates over grunerite. Trains of fine-grained magnetite, bounded by fine hair-like fractures containing a brownish stain are common. Stilpnomelane, associated with the grunerite and hornblende is an alteration product.

The grunerite is optically negative with X= colourless, Z and Y= pale yellow to colourless. Z occasionally has a greenish tinge. Nearly all the grunerite shows polysnythetic twinning along the plane (100). Blue-green hornblende is found in parallel orientation with grunerite and in the massive grunerite-hornblende-quartz rock, grunerite prisms appear to have terminated in their original growth in the blue-green hornblende. The blue-green hornblende also occurs in independent individuals and is optically negative with X= yellowish, Y= green and Z= blue-green. The hornblende contains many inclusions of apatite and other unidentifiable minerals, around some of which pleochroic haloes have been developed. The identification of both amphiboles was checked by X-ray diffraction.

Richardz,[10, 10a] has described a similar relationship between grunerite and blue-green hornblende from the Lake Superior region iron ores. In both the Lake Superior and Scapa township localities the grunerite and hornblende are fresh and the transition from one to another is very sharp. It is unlikely that the blue-green hornblende is due to alteration of the grunerite.

James[11] has shown that layered grunerite-quartz rocks in Northern Michigan have been derived from primary sedimentary silicate and carbonate iron-formation. James further correlates the grunerite-rich rocks with his carbonate and

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10 Richardz, S., Grunerite Rocks of the Lake Superior Region and their Origin, Journ. Geol. Vol. 35, 1927,pp. 690-707.

10a Richardz, S., The Amphibole Grunerite of the Lake Superior Region, Am. Journ. Sci. Vol. 14, 1927, pp. 150-154.

11 James, H.L., Zones of Regional Metamorphism in the Precambrian of Northern Michigan, Bull. Geol. Soc. Am. Vol. 66, 1955, pp. 1455-1488.

silicate facies of primary iron-formation.[12]

The iron-formation of Scapa township lies within the biotite zone and its metamorphism differs markedly from the northern Michigan iron formations described by James. Grunerite, epidote and garnet are not found within the biotite zone in northern Michigan and the quartz of layered iron-formation is markedly finer in grain than that occurring in Scapa.

Other rocks possibly derived from an original ferruginous sediment occur within the garnet zone in lots 1 and 2, concession IV of Steele township. These are interbedded with the metasediments and are layered with narrow layers rich in garnet alternating with quartz-rich and amphibole-rich layers. Disseminated pyrite and pyrrhotite are common. The rock in lot 1, concession IV is composed largely of garnet, biotite and quartz, with chlorite and minor grunerite, cummingtonite, and blue-green hornblende. Grunerite and cummingtonite are commonly found as inclusions in large garnet porphyroblasts. The chlorite is a secondary alteration product of garnet and amphibole.

Amphibole-rich layers of the rock occurring in lot 2, concession IV are composed of 15 per cent garnet and biotite, 65 per cent blue-green amphibole, containing numerous pleochroic haloes and inclusions of apatite, and accessory quartz and muscovite. The garnet is partially altered to chlorite and pistacite.

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12 James, H.L., Sedimentary Facies of Iron-Formation, Econ. Geol. Vol. 49, 1954, pp. 235-293.

An unusual massive rock was found near the Case batholith in lot 3, concession IV of Steele. This rock is petrographically similar to manganiferous schists described by Tilley[13] from the Lewisian of Scotland. The rock occurs as a narrow layer about 5 feet wide interbedded with the metasediments and is composed of 40 per cent garnet, 17 per cent cummingtonite (rarely with intergrown blue-green hornblende), 30 per cent quartz and accessory pyrite and sphene.

The garnet is indistinctly anisotropic and pale pink under uncrossed nicols, properties suggestive of spessartite. Helecitic structure is common in the garnet, which contains numerous quartz and greenish amphibole inclusions. Some of the garnet is altered partially to chlorite and epidote. Quartz forms large interlocking grains up to 1.5 millimeters in size which are highly fractured in places.

To summarize, the iron-formation resembles the Huronian type rather than the Keewatin type as described by Bruce[14] and in many particulars, except metamorphism, it is similar to the Northern Michigan iron-formations. The Scapa iron-formation was derived from a ferruginous sediment, probably interbedded sideritic chert and ferruginous shale, which upon metamorphism, was changed to the layered and massive silicate-rocks now found interbedded with the metamorphosed greywackes.

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13 Tilley, C.E., Cummingtonite-bearing Rocks from the Lewisian, Geol. Mag., Vol. 75, 1938m pp. 76-81.

14 Bruce, E.L., Precambrian Iron Formations, Bull. Geol. Soc. Am., Vol. 56, 1945, pp. 589-602.

Calc-Silicate Rocks

Calc-silicate rocks occur as narrow layers intercalated with the metamorphosed greywackes. The layers range in thickness from less than 1 inch to 6 inches and are traceable for considerable distances in the outcrop. A few layers pinch and swell along strike, but uniformity of thickness is the rule rather than the exception.

The calc-silicate layers are similar to those described by Pettijohn[15] from the Thunder Lake area of Ontario and called hornblende granulite by him. In handspecimen the rock resembles diorite with numerous needles of greenish amphibole scattered in a fine-grained light coloured matrix. The rock weathers a buff colour but is light grey on a fresh surface. In thin section the layers are composed of a granoblastic matrix of quartz, calcic plagioclase and epidote in which are randomly oriented rosettes and sheaves of blue-green amphibole. The plagioclase is usually clouded by sericite, making its determination difficult, but it appears to be near andesine in composition. Sphene, pyrrhotite, and carbonate are frequent accessories. Some specimens contain small amounts of garnet.

Pittijohn found biotite in some of the layers occurring at Thunder Lake. Zoned calcareous nodules also occur in

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15 Pettijohn, F.J., Archean Metaconcretions of Thunder Lake, Ontario, Bull. Geol. Soc. Am., Vol. 51, 1940, pp. 1846-1847.

Thunder Lake area and although no nodules were found in the Scapa metasediments, they do occur in the Steele metasediments.

Buff-coloured, amphibole-bearing, massive greywackes, containing conspicuous, randomly oriented, greenish amphibole grains are either associated with the calc-silicate layers, or interbedded with the metasediments. In thin section the amphibole-bearing greywackes are similar to the "normal" massive greywacke described above occurring in the biotite zone except for the occurrence of 10 - 20 per cent blue-green amphibole, found as poikiloblastic crystals and rosettes, and oligoclase. Accessory clinozoisite and carbonate are also common.

A rock composed almost entirely of tremolitic hornblende was found about 1/2 mile due south of the western boundary of the Scapa stock. Clinozoisite and pyrite are accessories and much of the amphibole is partially altered to talc. The amphibole has a negative optic sign and is mainly colourless under uncrossed nicols, although a few greenish patches do occur.

No calc-silicate rocks were seen within the stauro-like-zone.

Prehnite Veins

Prehnite veins were noted cutting a number of the metasediments in Scapa township. The veins appear to be most abundant near basic intrusives and diabase dikes, although in some places no correlation between basic igneous rock and the occurrence of prehnite in the metasediments could be made. The metasediment adjacent to the veins is moderately to highly altered. Where the veins are numerous and bunched together in the rock, the alteration is quite intense and pyrite and garnet are found.

STEELE METASEDIMENTS

The Steele metasediments are exposed only within Steele township, where they occur as widely scattered low outcrops in the higher areas and along the north shore of Northeast Bay. In this latter locality the metasediments are separated from the remainder of the Steele metasediments by an area of varved clay and muskeg, about 1.5 to 2 miles wide. However, the metasediments along the lake shore have the same strike and face in the same direction as those to the north. It is possible that all these rocks do not form a continuous unit and therefore the metamorphic zoning in this part of the map-area should be considered tentative.

Both concordant and discordant quartz veins, having identical characteristics to those occurring in the Scapa metasediments are ubiquitous. Near the assumed contact with the Bonis volcanics the discordant quartz veins are commonly faulted. No iron-formation or manganese-rich rocks were found within the Steele metasediments. Hornblende-and plagioclase-rich schists of uncertain origin occur interbedded

Plate V

A Intraformational breccia layer in Steele metasediments. Lot 8, concession D, Steele township. The fine lines cutting across the outcrop are glacial striae.

B Massive greywacke overlying greywacke with graded beds, indicating the top of the succession faces south (away from the observer). Lot 7, concession D, Steele township.

with the metasediments adjacent to the Steele Lake volcanics.

Massive, and amphibole-bearing greywackes are more abundant than greywacke with graded beds, in contrast to the Scapa metasediments, although greywacke with graded beds occurs in nearly all the outcrops. Individual shale or phyllite beds, except for those occurring in the graded-bedded greywackes and arkose, were not seen.

Greywacke

(1) Chlorite Zone

In the outcrop the greywackes are mainly unsheared and greenish-grey to dark grey in colour. In places the fine-grained slaty portions of graded beds are schistose and the schistosity increases in degree and frequency towards the Bonis volcanics contact. At the railway cut in lot 3, concession F, the finer-grained greywackes are phyllitic. In places the greywackes have been pyritized and on a weathered surface such rocks are speckled with small rusty spots. Contorted bedding and drag folding are common adjacent to shear zones, porphyry dikes and near the Bonis volcanics contact.

The individual graded-beds range from less than 1/8 inch to 2 feet or more thick. Cross-bedding occurs in graded-beds north of the railway track in lot 8, concession E. Structures suggestive of cross-bedding were also noted in numerous other localities but most of these, when examined in detail, proved to be minor crenulations or variations in the strike of the bedding. (See Plate V B).

Channelling, local unconformities between massive greywacke and greywacke with graded beds, and intraformational breccias are common. All these structures are compatable with the turbidity current theory for the formation of graded beds.

Some of the intraformational breccias resemble tail and underplight described by Shrock.[16] They consist of tabular and angular pieces of fine-grained greywacke and silt-stone in a sandy matrix, which are found at the base of the sandy parts of graded beds. The fragments range from less than 1/8 inch to over 2 inches in size. The breccia zones rarely exceed six inches in width and are lenticular along their strike. A layer of intraformational breccia up to 40 feet wide occurs in an outcrop along the shore in lot 8, concession D. The fragments have an identical composition to the adjacent greywacke and the layer as a whole has been sheared and pyritized with pyrite cubes up to 3/4 of an inch occurring along the boundaries of the fragments.

In thin section the greywackes are composed mainly of quartz, clastic feldspar, albite, chlorite, sericite, rock fragments and carbonate. Pyrite and tourmaline are common accessory minerals, and zircon, magnetite-ilmenite, sphene, epidote and apatite are rarely found. Biotite occurs in some greywackes adjacent to porphyry dikes. Muscovite is

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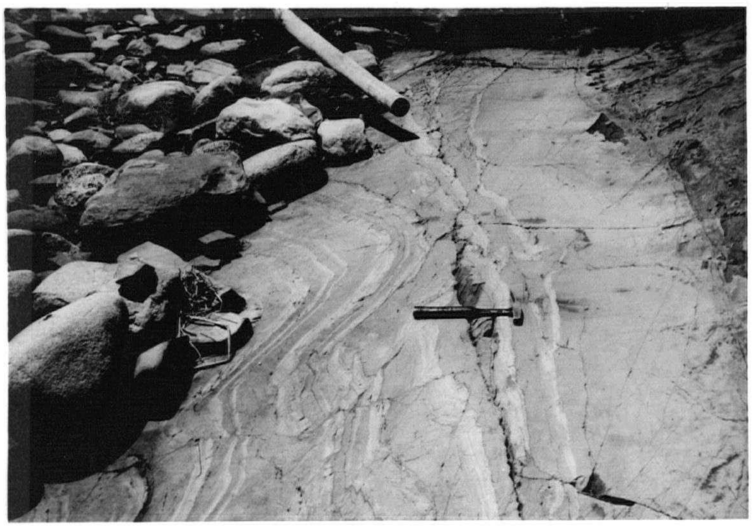
16 Shrock, R.R., Sequence in Layered Rocks, (McGraw-Hill Book Co.), New York, 1948, pp. 161-162.

Plate VI



Contorted bedding in the Steele metasediments near a porphyry dike (to the right). Lot 6, concession E, Steele township.

rare and occurs only in the more highly sheared rocks near the Bonis volcanics.

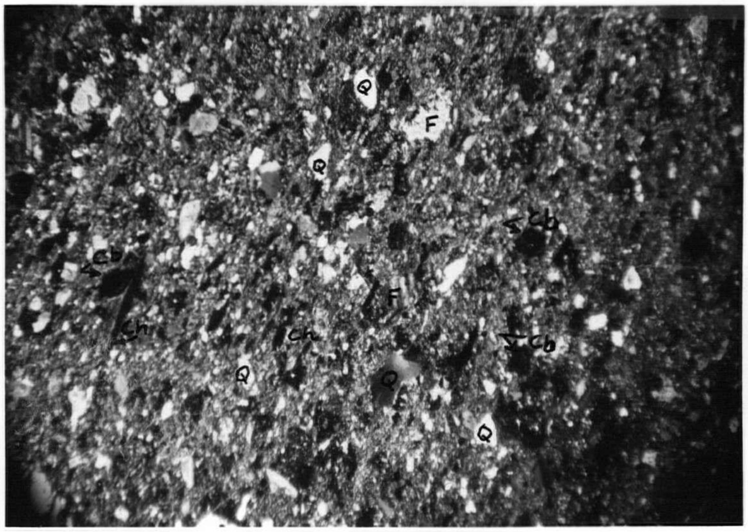
Original clastic texture is well preserved in all but the fine-grained greywackes. In nearly all the specimens examined, chlorite and sericite envelope and embay the clastic grains. In some rocks, particularly near the Bonis volcanics, preferred orientation of chlorite and sericite is pronounced and appears to be of metamorphic origin.

Quartz, ranging from 20 to 40 per cent of the whole, is the most abundant mineral in all the rocks examined. It occurs mainly as subangular, inequidimensional, slightly to markedly strained grains up to 0.9 mm. in size.

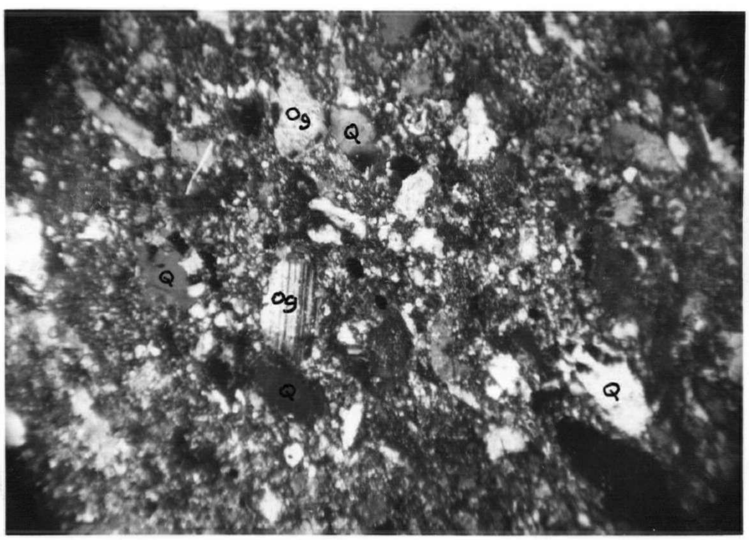
Feldspar which consists of clastic oligoclase, rare K-feldspar, and recrystallized albite forms 15 to 20 per cent of the greywackes. Albite, clouded by sericite, is less abundant than clastic feldspar, except near porphyry dikes. It is uncleaved and untwinned, and contains inclusions of quartz.

White mica, ranging from 20 to 35 per cent predominates over chlorite in all the rocks. Chlorite, forming 6 to 20 per cent of the whole, occurs in two optically distinct varieties. The most common variety has a light green to light yellow pleochroism and a higher birefringence than the other variety, which has a deeper green pleochroism and exhibits the anomalous ultra-blue interference color typical of penninite. Both chlorites are optically positive. The more highly pleochroic variety, possibly rich in iron and

Plate VII



A Photomicrograph of massive greywacke, lot 10, concession D, Steele township. Subangular, strained quartz (Q) and feldspar (F) fragments lie in a fine-grained matrix of chlorite (Ch), sericite and quartz. Polarized light X16. Cb = carbonate.



B Photomicrograph of massive greywacke, showing detrital oligoclase grains (Og). Lot 9, concession D, Steele township. Q= quartz. Polarized light X47.

Plate VIII

A Sheared metasediments in the railway cut, lot 3, concession F, Steele township. The metasediments lie directly west of the assumed contact with the Bonis volcanics.

B Cross-bedding in graded beds overlain by massive greywacke. The top of the succession is to the south (Direction of the arrow). Lot 8, concession E, Steele township.

magnesium, is common in rocks occurring in the western part of the outcrop area. With an increase in schistosity and degree of recrystallization the lighter-coloured variety (aluminum chlorite?) predominates. Chlorite also has a deeper pleochroism adjacent to pyrite and magnetite grains.

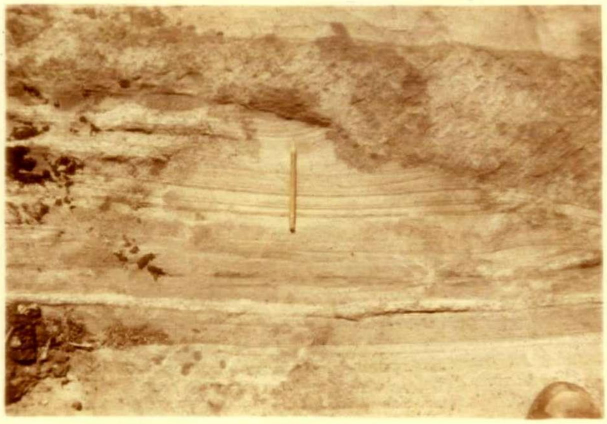
Carbonate which occurs in clots or veinlets in the greywackes in amounts ranging from 2 to 20 per cent, is commonly iron-stained and more abundant in the coarser greywackes and in the greywackes near the Bonis volcanics than elsewhere. It is especially common in and adjacent to altered porphyry dikes, where it replaces many of the other minerals. Most of the carbonate was probably introduced into the metasediments.

A narrow vein of prehnite was found in one specimen of greywacke adjacent to an altered lamprophyre (?) dike in lot 9, concession D.

(2) Biotite Zone

Many of the sedimentary structures noted in connection with the greywackes of the chlorite zone are present in the lower part of the biotite zone. No intraformational breccia or cross-bedding were seen, however. Fresh and unusually clean exposures of the greywackes occur on an old logging road that crosses the outcrops in lot 10, concession I. Here, the fine, graded bedding structure of the greywackes is excellently preserved. In a few places massive greywacke cuts across the graded beds forming local unconformities, a feature possibly

Plate IX



A Graded bedding truncated by massive greywacke. The light-coloured band in the graded beds near the bottom of the photograph is a calc-silicate layer. Lot 10, concession I, Steele township.

B Amphibole-plagioclase schist interbedded with metamorphosed greywacke near the southern contact with the Steele Lake volcanics. Lot 9, concession IV, Steele township.

due to scouring brought about by the action of turbidity currents (See Plate IX A).

In outcrops to the north many of the detailed sedimentary structures have been destroyed by shearing but graded-bedding is visible and distinct. Near the contact with the Steele Lake volcanics the metasediments are highly sheared and contorted, and traversed by numerous patchy quartz veins up to 4 feet wide.

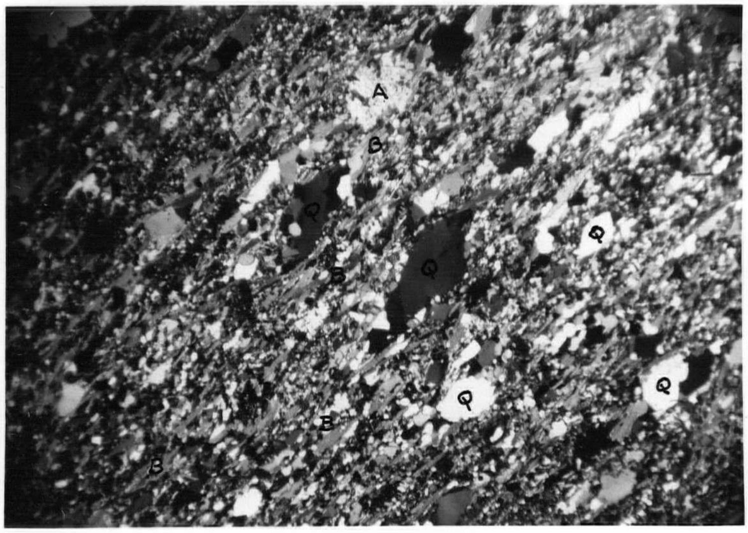
In thin section, quartz, albite, chlorite and biotite predominate. Sericite is uncommon and muscovite was seen only in a few rocks near the Steele Lake volcanics. Some clastic oligoclase was noted in the massive greywackes occurring in the extreme southern part of the outcrop area. Pyrite, magnetite (and ilminite), sphene, tourmaline, epidote and rarely apatite are accesory minerals.

A few shear zones, which trend parallel to the strike of the metasediments were found south of the Steele Lake volcanics. The rocks within the shear zones are mainly quartz-chlorite-albite schists and some contain fine dusty graphite. Biotite is a minor constituent.

Calc-Silicate Rocks

Amphibole-bearing greywacke and thin calc-silicate layers interbedded with greywacke are common in the biotite zone. In addition, calc-silicate nodules, similar to those described by Pettijohn from Thunder Lake occur in massive greywacke in outcrops occurring in lot 10, concession I.

Plate X



A Photomicrograph of sheared massive greywacke. Lot 6, concession I, Steele township. A= albite, Q= quartz, B= biotite. Polarized light X16.

B Photomicrograph of a quartz veinlet (Q.V.) in sheared greywacke. Lot 5, concession II, Steele township. The rock consists of quartz, albite, muscovite, and biotite. Polarized light X16.

Amphibole-bearing greywacke is especially abundant in the outcrops occurring east of Mace Creek. These rocks resemble the amphibole-bearing greywacke in the Scapa metasediments in most respects, although epidote (clinozoisite) and carbonate are more abundant, and the coarse sandy parts of graded beds, as well as massive greywacke are amphibole-bearing in the Steele metasediments.

Some of the amphibole-bearing greywackes are layered containing quartz-and plagioclase-rich layers up to 1/4 inch thick, which alternate with slightly thicker amphibole- and biotite-rich layers. Carbonate is most abundant (up to 5 per cent) in the layered varieties which may have originally contained cherty beds.

Examination in thin section of the amphibole-bearing greywackes occurring in graded beds shows a sharp transition from amphibole to non-amphibole-bearing rock. The coarse parts of the individual graded beds contain abundant blue-green hornblende, plagioclase (about An_{30}) and epidote, whereas the finer-grained parts are composed essentially of biotite, chlorite, quartz and albite. This suggests that the sandy parts were originally calcareous and more permeable to groundwater flow.

The nodules are etched into relief by weathering of the outcrops. No internal structure was noted in the nodules, except for the faint suggestion of zoning. In general the nodules are coarser-grained than the enclosing rock and the abundance of large unoriented hornblende crystals gives the material a diorite-like appearance. No detailed thin section study was made of the nodules or matrix.

Pettijohn[17] and others consider nodules, such as described here, to be the product of metamorphism of calcareous concretions.

Amphibole-and Plagioclase-Rich Schists

Amphibolitic schists contain abundant blue-green hornblende, calcic plagioclase, epidote, and carbonate. Some of the rocks resemble the amphibolites of the Steele Lake volcanics while others resemble the calc-silicate rocks.

The calcareous types form a narrow zone about 6 feet wide at the contact between the Steele Lake volcanics and the Steele metasediments. These are typically epidote-plagioclase-quartz-hornblende schists containing scattered grains of accessory carbonate and sphene. The rocks resembling the metavolcanics occur as narrow layers, less than a foot thick and are typically quartz-chlorite-plagioclase-hornblende schists. In both varieties amphibole constitutes 30 per cent or more of the rock, while plagioclase ranges from 17 to 25 per cent and quartz from 20 to 25 per cent.

The origin of these rocks is uncertain. They may represent metamorphosed calcareous beds, basic to intermediate lavas, or intrusive rocks. The calcareous nature of

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17 Op. cit., p. 1849.

these rocks bordering the Steele Lake volcanics may be due to the mobilization of carbonate from the volcanics into original sedimentary rocks during metamorphism.

Miscellaneous Metasediment

A few outcrops of metasedimentary rocks occur in the extreme southeast corner of Scapa township and adjacent parts of Hepburn township. These rocks are essentially biotite-albite-chlorite-muscovite-quartz schists and metamorphosed greywackes, identical to those occurring in the lower part of the biotite zone of the Steele and Scapa metasediments.

The rock occurring adjacent to the assumed contact with the Bonis volcanics in Scapa township is highly sheared, and contains scattered cubes of pyrite. The platey minerals are contorted but some biotite lies across the foliation planes, indicating it developed after the shearing movements in the rock had ceased.

It is not possible, as yet, to correlate these rocks with either the Steele or Scapa metasediments. Because they occur near the Bonis volcanics contact, these rocks have been grouped with the Steele metasediments.

METAVOLCANICS

STEELE LAKE VOLCANICS

The Steele Lake volcanics, which lie within the biotite, garnet, and staurolite zones as defined by the metasediments, form a narrow lenticular band composed of amphibolite with some interbedded metasediment and metamorphosed rocks of indefinite origin. The band is slightly less than one mile wide in lot 4, concession III, Steele township. From this point it thins to less than 1/2 mile at the western boundary of Steele township. The band also thins to the east but just across the boundary between Steele and Scapa townships it is covered by glacial debris and does not outcrop again within the map-area.

Amphibolite

Some of the amphibolites are schistose and contain garnet, but most are poorly foliated and exhibit relict volcanic structures. Amygdaloidal, pillowed, massive, diabasic, and porphyritic types were distinguished. All of the amphibolites are believed to have been derived from basic to intermediate lava flows.

Although the diabasic types were mapped as flows, some may be intrusive. The volcanic structures are best preserved within the biotite zone, but they do occur in the higher grades of metamorphism. Porphyritic lava was found only along the southern margin of the volcanics adjacent to the Steele metasediments.

The pillow structure is similar to that described from other areas within the Canadian Shield. Most pillows are highly deformed, rendering them of little value in determining tops in flows. Some pillows have a bleached core surrounded by a dark-green rim adjacent to their selvege. Excellent exposures of this type of pillow occur along the Trans-Limit road in lot 9, concession IV of Steele township.

The origin of pillows has been the subject of much debate. Cooke, James and Mawdsley[18], Henderson[19], Moore[20], and more recently Wilson[21] have reviewed the problem adequately. The evidence now appears to favour a subaquous origin for pillow structure. There is still some question as to the mechanism whereby pillow lava is formed at the top of non-pillowed flows showing grain gradation. A limited search of the literature failed to uncover a satisfactory explanation of this sequence which is commonly encountered in Precambrian volcanic terrains.

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18 Cooke, H.C., James, W.F., and Mawdsley, J.B., Geology and Ore Deposits of Rouyn-Harricanaw Region, Quebec, Geol. Surv. Canada, Memoir 166, 1931.

19 Henderson, J.F., On the Formation of Pillow Lavas and Breccias, Trans. Roy. Soc. Canada, Vol. XLVII, Sec. 4, 1953, pp. 23-32.

20 Moore, E.S., Notes on the Origin of Pillow Lavas Trans. Roy. Soc. Canada, Vol.XXIV, Sec. 4, 1930, pp.137-139.

21 Wilson, M.E., Origin of Pillow Structure in the Early Precambrian Lavas of Western Quebec, Jour. Geol. Vol. 68, 1960, pp. 97-102.

Schistose amphibolites are confined to the garnet and staurolite zones of metamorphism. The occurrence of garnet in metamorphic derivatives of basic igneous rocks has been described from a number of areas, but perhaps the classical work in this regard, and indeed on the metamorphism of basic igneous rocks in general, is that by Wiseman.[22] The progressive metamorphism of the Steele Lake volcanics differs from that of Wiseman's Scottish epidiorites in the almost complete absence of chlorite and the abundance of hornblende in the biotite zone.

(1) Biotite Zone

Within the biotite zone the amphibolites are fine- to medium-grained and light-grey or pale- to dark-greenish black in colour. Slight foliation, accentuated by hornblende grains is visible in many of the rocks. Microscope study indicates the light colours are due to the abundant development of epidote, albite, and quartz which was probably in part introduced. The dark colours are due to abundant hornblende and some biotite. Except where it has formed from the alteration of hornblende, no chlorite was found in the thin sections examined. Accessory sphene, iron-ore and carbonate are common.

The hornblende is optically negative and distinctly

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22 Wiseman, J.D.H., The Central and Southwest Highland Epidiorites. A Study in Progressive Metamorphism, <u>Geol. Soc., London Quart. Journ.</u>, Vol. 90, 1934, pp. 355-417.

pleochroic with X= light yellowish-green, Y= green and Z= light bluish green. The pleochroism varies markedly within a single grain, some areas being colourless or only faintly pleochroic. Hornblende ranges from 30 to 60 per cent in the amphibolite studied and it forms the largest grains in these rocks.

The feldspar is fine-grained and contains many inclusions of clinozoisite, quartz and carbonate. Relict, polysynthetically twinned, calcic plagioclase occurs rarely in the diabasic amphibolites, with the twin lamellae invariably bent. The feldspar is usually albitic but accurate determinations of the composition were remdered difficult owing to the fine-grained character, numerous inclusions, sericitic alteration, and lack of twinning in the feldspar. Amphibolite is highly recrystallized adjacent to the diabase dike in lots 1, 2 and 3, concession III, Steele township, and contains zoned plagioclase with a composition of about An_{30}.

Epidote, ranging from 2 to 25 per cent, occurs as granular aggregates in the groundmass of most of the amphibolites and as coarse grains filling amygdules. Most of the epidote is pistacite showing very slight or no pleochroism. Clinozoisite is confined to inclusions in feldspar.

Biotite is the reddish-brown variety noted in the metasediments. It is found in association with hornblende and may therefore be an alteration product of that mineral. The amount of biotite in the amphibolites ranges from 0 to 15 per cent.

Sphene commonly rims magnetite-ilmenite-grains. In a few rocks "leucoxene" occurs intergrown with magnetite and has presumably replaced original ilmenite intergrown with magnetite.

(2) Garnet and Staurolite Zones

In handspecimen many of the amphibolites in the garnet and staurolite zones differ from those in the biotite zone only in having a coarser grain. Pillow structure and grain gradation within individual flows can be seen in many places, particularly in lots 8 and 9, concession IV, Steele township. Deformation of the pillows render them of little use in determining the tops of flows.

Garnet, occurring in definite layers, is well developed in the amphibolites in lots 10, 11 and 12, concessions IV and V, Steele township. The garnet-bearing amphibolites possess a good schistosity and are frequently associated with highly schistose amphibolites which display feathery hornblende grains and contain no garnet. Where the amphibolites are markedly schistose the only relict volcanic structure noted was highly deformed pillow lava. Garnet was found only within shear zones in other localities within the Steele Lake volcanics.

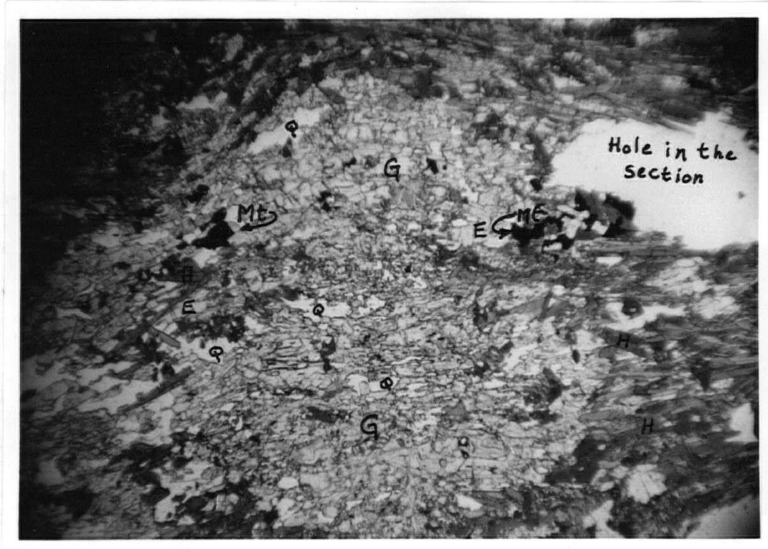
In thin section, the amphibolites are similar to those in the biotite zone. Biotite and epidote are less abundant and the former mineral is absent from most of the specimens examined. The principal constituents are blue-green hornblende, plagioclase, quartz and locally, garnet. Accessory carbonate, sphene and iron ore are common. Within the staurolite zone apatite, probably introduced, becomes an important accessory constituent.

Hornblende displays the patchy pleochroism noted in the biotite zone but the pleochroism is more intense with X= yellowish green, Y- green and Z= deep blue-green. The lighter areas within the individual hornblende grains have a less intense pleochroism but no colourless patches were seen. Hornblende has a uniform pleochroism and forms porphyroblasts displaying helicitic structure or feathery grains in the schistose amphibolites.

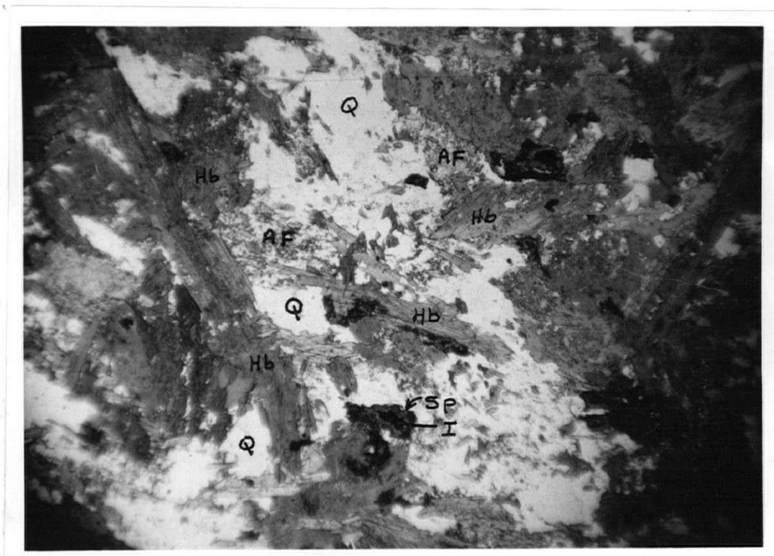
In both the garnet and staurolite zones quartz appears to be less abundant than in the biotite zone. Albite is not common in the garnet zone but zoned and twinned plagioclase with an average composition of An_{35} is abundant. In the staurolite zone the plagioclase averages about An_{40}. The plagioclase is usually clear, relatively free from inclusions, and coarser in grain size than the albite of the biotite-zone. Feldspar was not found in garnet amphibolite.

Epidote, which is rare or lacking in the staurolite zone, is commonly found in abundance in the garnet zone where it forms up to 25 per cent of the garnet amphibolites. The garnet of the garnet amphibolites is anhedral, sieve-textured, and forms large porphyroblasts up to one inch in

Plate XI



A--Photomicrograph of garnet amphibolite showing a large porphyroblast of garnet. Lot 11, concession IV, Steele township. G=garnet, E=epidote, Q=quartz, H=hornblende, Mt=Magnetite. Plain light X16.



B--Photomicrograph of diabasic amphibolite. Lot 7, concession IV, Steele township. Note sphene (Sp) rimming illmenite (I) grains. Hb=hornblende, Q=quartz, AF=altered feldspar. Plain light X16.

size (see Plate XI A). Inclusions of pistacite, carbonate and quartz are common and helicitic structure, indicating the garnets rotated during growth is present.

Only a small proportion of the amphibolites lie within the staurolite zone. The rocks examined from this zone are granoblastic with relatively large randomly oriented hornblende prisms lying in a fine-grained groundmass of recrystallized quartz and plagioclase. Accessory apatite is evenly distributed in the groundmass.

Interbedded Metasediment

Two narrow layers of metasedimentary rocks interbedded with the amphibolites were found in lot 9, concession IV and in lots 1 and 2, concession III of Steele township. The metasediment layer in lot 9 is one to three feet thick. The layer in lots 1 and 2 is three to ten feet thick and was traced for a distance of 3/4 of a mile. It is possible that both occurrences are part of one continuous layer which marks an interruption in the volcanic activity.

The rocks are essentially biotite-quartz-feldspar schists. Garnet is an accessory in the metasediments occurring in lot 9 and also in lots 1 and 2 near the wide porphyry sill. A specimen from lot 2, concession III was examined in thin section and found to contain considerable microcline and sphene in addition to biotite, quartz, albite and accessory epidote. The metasediment in lot 1, concession III is composed of about 25 per cent biotite, 52 per cent quartz and albite, 10 per cent chlorite and accessory apatite, tourmaline, sphene, opaque minerals, and muscovite.

Miscellaneous Rocks

Included under miscellaneous rocks are a number of rocks of uncertain origin. A rock containing numerous coarse, randomly oriented hornblende lathes embedded in a fine-grained bluish-grey matrix is widely spread throughout the amphibolites. The rock contains large irregular patches of carbonate which upon weathering leave behind conspicuous cavities up to 1/2 inch in size.

In thin section the rock is typically composed of about 15 per cent idioblastic blue-green hornblende, 30 per cent red-brown biotite, 10 to 15 per cent epidote, 15 to 20 per cent quartz and about 15 to 20 per cent feldspar. Idioblastic garnet and opaques are common accessories. Irregular veinlets and lenses of quartz are present in the granoblastic groundmass. The rock may originally have been a tuff.

Other rocks of indefinite origin occur near the southern edge of the volcanics in lots 7 and 8, concession III, Steele township. These rocks are prominently layered and form a zone about three feet wide. Dark green to black layers, composed of about 30 per cent blue-green hornblende, 15 per cent biotite, 35 per cent quartz and albite, and 18 per cent epidote, alternate with light-grey to white layers composed of a granoblastic aggregate of quartz, feldspar, biotite and epidote. The dark layers resemble the normal metavolcanics. Quartz predominates in the lighter coloured layers with most of the feldspar, epidote and some carbonate confined to a narrow zone adjacent to the black layers. The material of the light layers appears to partially replace adjacent parts of the dark layers. In addition to the minerals already mentioned, a few pinkish, indistinctly anisotropic grains of garnet are found scattered through the lighter layers. The light layers may represent original cherty horizons in the volcanics.

Pegmatite dikes, feldspar porphyry dikes and sills, and quartz veins also occur in the amphibolites. The pegmatite dikes are especially common in the western part of the metavolcanics which lie closest to the Case batholith.

BONIS VOLCANICS

Good exposures of the Bonis volcanics occur on the islands lying off the mouth of Forks Creek and along the eastern shoreline of Northeast Bay. A few scattered exposures also occur inland north of the railway track in Steele township, in the northern part of Bonis township and in the southeastern corner of Scapa township. The assumed contact between the Bonis volcanics and the Sargeant batholith is based mainly on meager geophysical data and should be considered tentative. The same is true for the northern contact which has only been partly defined due to the scarcity of outcrops.

The original mineral assemblages of the lavas have been destroyed and it is usually not possible to determine petrographically whether a given specimen is basaltic or andesitic. For this reason the darker, more basic volcanics will be referred to as basic to intermediate lavas. Basic to intermediate lavas can readily be distinguished from acid lavas, however, because of greater differences in the original mineral composition between these two groups.

Attempts have been made to find criteria to distinguish between highly metamorphosed basalts and andesites. (See for example Satterly[23]). It appears that the only solution to the problem is detailed microscopic work accompanied by numerous analyses. Bienvenu[24] has made a study of the metavolcanic rocks of the Abitibi region in Quebec and concludes that many of the volcanics were normal plateau types. Satterly[25] and others have expressed the opinion that many metavolcanic rocks mapped as andesites are actually basalts.

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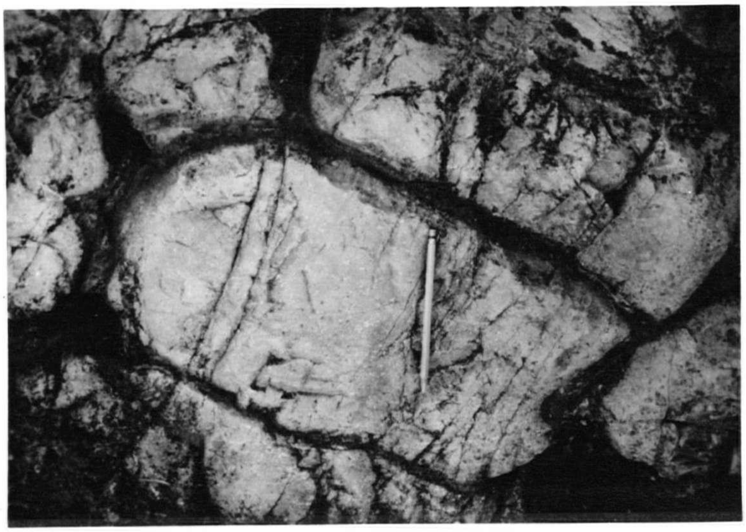
23 Satterly, J., Pillow Lavas from the Dryden-Wabigoon Area, Kenora District, Ontario, Univ. of Toronto Studies, Geol. Ser. No. 46, 1941, pp. 119-136.

24 Bienvenu, R., The Chemical Composition of some Metavolcanic Archean Rocks, Univ. of Laval. M.Sc. Thesis, 1955, pp. 1-59.

25 Ibid., p. 132.

Plate XII



A--Pillowed, porphyritic, intermediate to basic lava (andesite?) in an island off the mouth of Forks Creek.

B--Pillowed non-porphyritic lava in an island off the mouth of Forks Creek. Tops face northwest (towards the observer).

Basic to Intermediate Volcanics

Basic to intermediate volcanics range in colour from dark greyish-green to pale green. Non-porphyritic and porphyritic varieties are recognized. Both occur as interbedded flows ranging from 12 to 35 feet thick. The flows are occasionally amygdaloidal and frequently pillowed, and a few show flow breccia tops, thus making possible definite top determinations.

A lava flow exposed in a lumber road in lot 9, concession V, Bonis township, was studied in detail as the variation within it is typical of all the flows found within the Bonis volcanics. The sequence, from top to bottom is as follows:

1.5 feet	flow breccia
2 "	pillow lava
17 "	massive lava
12 "	diabasic lava
1 "	massive lava

The contact between each part is gradational. The thickness of the various units varies considerably from flow to flow. Unless definite evidence of intrusion was found, the diabasic or gabbroic rocks seen were mapped as flows.

In thin section, the <u>non-porphyritic variety</u> is seen to be composed of 25 to 45 per cent blue-green hornblende, 0 to 20 per cent chlorite, 1 to 40 per cent epidote and 15 to 35 per cent fine-grained quartz and feldspar. Biotite is rarely present and sphene, found as rims about magnetite-ilmenite-grains, and pyrite are common accessory minerals. In some carbonatized rocks, carbonate forms as much as 35 per cent of the whole.

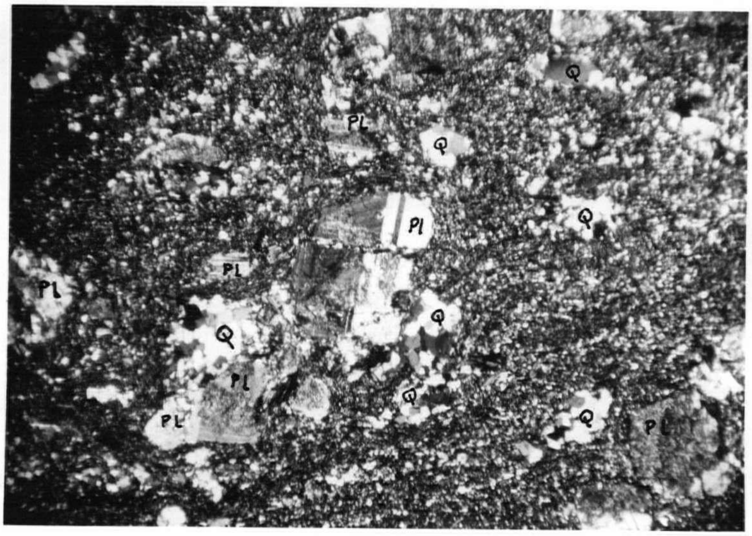
Epidote is mainly the iron-rich variety pistacite, although clinozoisite is not uncommon. Cores of pistacite grains found in veinlets or amygdules contain dusty inclusions. The hornblende is commonly fibrous, but in coarse parts of flows it is prismatic or in laths with X= yellowish green, Y= green and Z= blue-green.

Feldspar and quartz are finely divided throughout the groundmass. Some rocks, which appear to have no feldspar, contain abundant chlorite. Relict microscopic laths of feldspar, ranging in composition from An_{25} to An_{38} and displaying polysnthetic twinning, and corroded borders, are abundant in a few rocks. Recrystallized feldspar is albitic.

The amygdules of the amygdaloidal types are filled with quartz, epidote, albite, chlorite and rarely talc. They are commonly ellipsoidal, and rarely spherical. Relict textures other than amygdules are rare. One specimen showed a faint ophitic texture. The minerals form a felted aggregate in most of the non-porphyritic rocks, with hornblende generally being the coarsest mineral and chlorite, epidote, quartz, feldspar and the accessory minerals scattered through the groundmass. Foliation is present but not well developed.

The <u>porphyritic variety</u> is composed essentially of the same minerals as the non-porphyrytic variety but feldspar and quartz are more abundant, forming 35 to 50 per cent of the rock. Epidote and hornblende are proportionately less abundant and chlorite is invariably present constituting

Plate XIII



A--Photomicrograph of porphyritic intermediate to basic lava (andesite ?). Fractured and oscillatory zoned plagioclase (Pl), and quartz (Q) lie in a fine-grained groundmass of hornblende, quartz, chlorite, epidote, and biotite. Polarized light X16.

B--Photomicrograph of schistose amphibolite, lot 12, concession V, Bonis township. Sieve-textured hornblende (H), containing inclusions of quartz and carbonate (Cb) lie in a groundmass of quartz, plagioclase and epidote. Polarized light X16.

5 to 15 per cent of the whole.

The feldspar is calcic (An_{23-32}) and occurs as relatively fresh to highly altered phenocrysts up to 3 mm. in size. One rock shows particularly fresh, twinned phenocrysts of plagioclase (See Plate XIII A).

A detailed study of the plagioclase phenocrysts showed that they are original phenocrysts and not developed during metamorphism. This is indicated by the following: (1) Some of the phenocrysts display intricate oscillatory euhedral zoning. (2) Many of the phenocrysts are partly to wholly altered to sericite and epidote. (3) Most phenocrysts have corroded borders and are fractured or crushed. (4) Relatively unaltered phenocrysts are completely free from inclusions. (5) The phenocrysts are aligned parallel to the foliation of the rock. (6) Carlsbad and albite-Carlsbad twins, which according to Gorai[26] are characteristic of the volcanic and plutonic rocks, are common and (7) Zoned crystals, similar to those described by Ross[27] from the Garibaldi volcanics are found.

The original porphyritic character and a quartz and feldspar content of up to 50 per cent suggests that the porphyritic variety was originally andesitic. Chemical analyses coupled with the petrographic evidence obtained

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26 Gorai, Masao, Petrological Studies on Plagioclase Twins, Am. Min., Vol. 36, 1951, pp. 884-901.

27 Ross, J.V., Combination twinning in Plagioclase Feldspars, Am. Journ. Sci. Vol. 255, 1957, pp. 650-655.

would go far to strengthen this conclusion. The relatively low quartz and feldspar content of the non-porphyritic variety is indicative of original basalt.

Other rocks grouped with the basic to intermediate volcanics are exposed along the shore near the railway in lot 3, concession F, Steele township, and in the Mace Crab Islands. The rocks are chlorite-feldspar schists, composed predominantly of chlorite, quartz, plagioclase (albite and oligoclase), carbonate and biotite. In thin section, oriented, elongate masses, up to 3 millimeters in size, composed of fine plagioclase laths, or chlorite, epidote and greenish biotite, lie in a fine-grained matrix of angular quartz, feldspar and chlorite. The chloritic masses are larger than those of plagioclase and give the rock a spotted appearance. The rock occurring near the railway track is less deformed and is composed of elongate chlorite-biotite-epidote masses lying in a groundmass of fine plagioclase laths and quartz. Much of the carbonate appears to have been introduced in all the rocks examined.

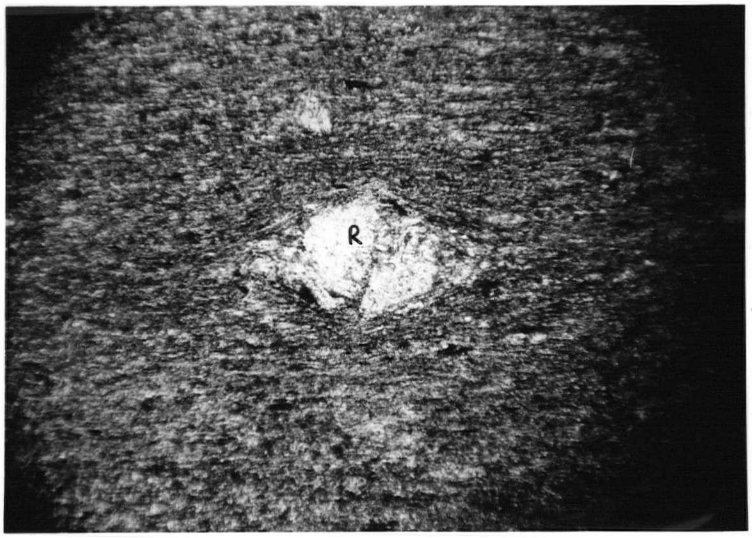
Within the contact zone, with the Sargeant batholith the basic to intermediate volcanics are completely recrystallized, well-foliated and coarse in grain, resembling the amphibolites developed in the Steele Lake volcanics. At the contact with the Sargeant batholith the rocks are hornfelsed. A few of the rocks have a gneissic banding that is due possibly to metamorphic differentiation. Volcanic structures are rare within the contact zone and all original textures are destroyed.

The hornblende becomes intensely pleochroic in approaching the Sargeant batholith, chlorite is rare or absent and the plagioclase is calcic and completely recrystallized. In the outer part of the contact zone, porphyroblasts of sodic plagioclase and hornblende are not uncommon

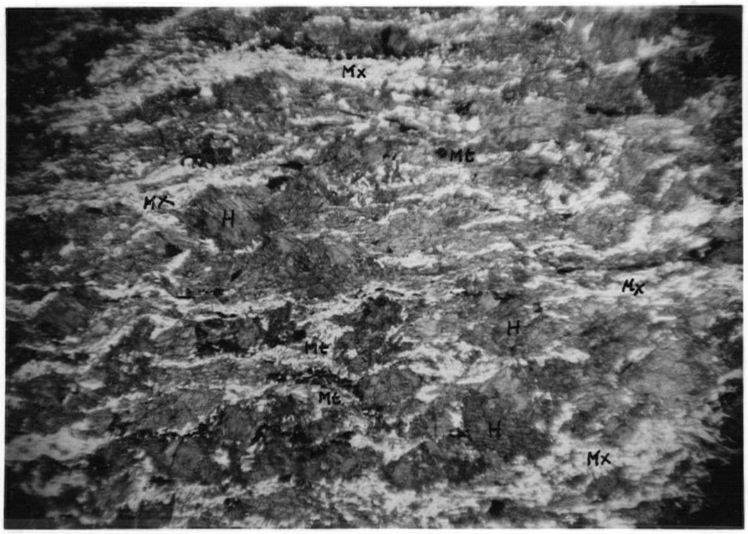
The contact between the Sargeant batholith and the Bonis volcanics is well exposed in an outcrop occurring in lot 1, concession VI, Bonis township. Here a granoblastic quartz-plagioclase-hornblende rock is cut by a few mineralized fractures containing pyrrhotite and chalcopyrite. The plagioclase is commonly twinned and has a composition of about An_{35}.

A few tuffaceous layers are interbedded with the basic to intermediate lavas. One of these is particularly well exposed along the shore of Northeast Bay in lot 2, concession D, Steele township. The tuff and adjacent lavas are cut by numerous basic sills and dikes, near which the tuff has been metamorphosed to varying degrees. The least metamorphosed tuff is sheared and composed of biotite, chlorite, quartz, feldspar and minor muscovite with accessory opaques and carbonate. It is fine-grained and displays graded bedding which indicates tops to the north, in agreement with the determinations made from the pillow lavas. A few rounded volcanic rock fragments also occur in the rock. Near the basic intrusives large, sieved porphyroblasts of hornblende

Plate XIV



A--Photomicrograph of tuff interbedded with the basic to intermediate volcanics, lot 2, concession D, Steele township. The rounded rock fragment (R) lies in a fine-grained matrix of quartz, feldspar, mica, chlorite, and carbonate. Plain light X16.



B--Photomicrograph of schistose amphibolite, lot 8, concession VI, Bonis township. Hornblende (H), magnetite (Mt), and minor biotite lie in a fine matrix of epidote, quartz, and feldspar (MX). Plain light X16.

up to 3 mm. long are developed. Interbedded with the porphyroblastic hornblende-rich rock is a garnetiferous quartz-chlorite-hornblende rock with a well developed helicitic structure.

Acid Volcanics

Nearly all the exposures of acid volcanics occur within the contact zone with the Sargeant batholith and as a result they are generally highly altered, making it impossible to tell the original nature of the rock. The more highly altered types are discussed below under a separate heading.

The acid volcanics are best exposed in lot 4, concession A, Steele township. The rocks are mainly fine-grained, massive to porphyritic, and light green to light grey in colour, with a red or pinkish tinge. Banding, suggestive of flow lines, is commonly present in the massive rocks. In places an agglomerate, containing light coloured drawn-out fragments up to 3 inches long set in a greenish-grey matrix, is interbedded with the massive and porphyritic varieties.

A specimen of a reddish banded rock (rhyolite?) from lot 4, concession A was examined in thin section and found to contain numerous crushed and altered phenocrysts of oligoclase and rare potash feldspar, set in a fine-grained, felty matrix of quartz, feldspar, muscovite and chlorite. Biotite and small cubes of pyrite are not uncommon. The groundmass has a streaked appearance, brought about by trains of epidote and chlorite which probably represent poorly preserved flow lines.

A pale felsitic rock displaying prominent banding, accentuated by fine garnet grains occurs in lot 1, concession D, Steele township. In thin section the rock is well-foliated and composed of elongate quartz and feldspar grains with aligned biotite, muscovite and chlorite scattered through the groundmass. The garnet is associated with quartz in layers which are slightly coarser in grain than the rest of the rock.

Rocks of Indefinite Origin

Most of the rocks described below occur adjacent to the Sargeant batholith in lot 1, concession D, Steele township. The rocks range from pyritized phyllitic types to garnetiferous quartz-feldspar-mica schists and highly contorted gneissic amphibolites. A garnet-magnetite-hornblende rock was found at the contact with the batholith. The rock has a pronounced granoblastic texture and contains about 15 per cent finely disseminated magnetite. This was the only iron-rich rock found within the Bonis volcanics, although Knight et al[28] refer to "much iron-formation" in the vicinity of lot 1, concession D.

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28 C.W.Knight, et al., Abitibi-Night Hawk Gold Area, Ont. Bur. Mines, Vol. XXVIII, pt. 2, 1919, p. 25.

Plate XV

A--Porphyritic intermediate to basic lava in an island off the mouth of Forks Creek.

B--Contorted tuffaceous sediment (?) folded around a porphyry dike (to the left) and containing quartz-filled gash fractures. Lot 4, concession C, Steele township.

Highly sheared and contorted rocks occur in lots 3 and 4, concession C, Steele township, interbedded with basic to intermediate lavas and cut by porphyry dikes and basic intrusives. M.B. Baker[29] has called the rocks "rusty-weathering dolomite". Where they are cut by porphyry dikes, tension cracks filled with quartz have formed from which low gold values have been reported.[30]

A thin section study of four typical specimens shows the rock to be a carbonatized quartz-feldspar-sericite-chlorite schist containing abundant epidote and cubes of pyrite. One of the specimens studied contained numerous elongate, highly altered fragments up to one inch in size. The interbedded lavas are only slightly deformed and the rock in question is dragged against the lavas, suggesting it was less resistant to deformation than the lavas. The rock may have originally been a tuffaceous sediment.

SUMMARY OF THE METAMORPHISM

The mineral assemblages of the greywackes and amphibolites in the metamorphic zones of the metasediments and Steele Lake volcanics are summarized in Table 2. Unfortunately the lack of both bulk analyses of the various rock types and chemical analyses of the various metamorphic minerals

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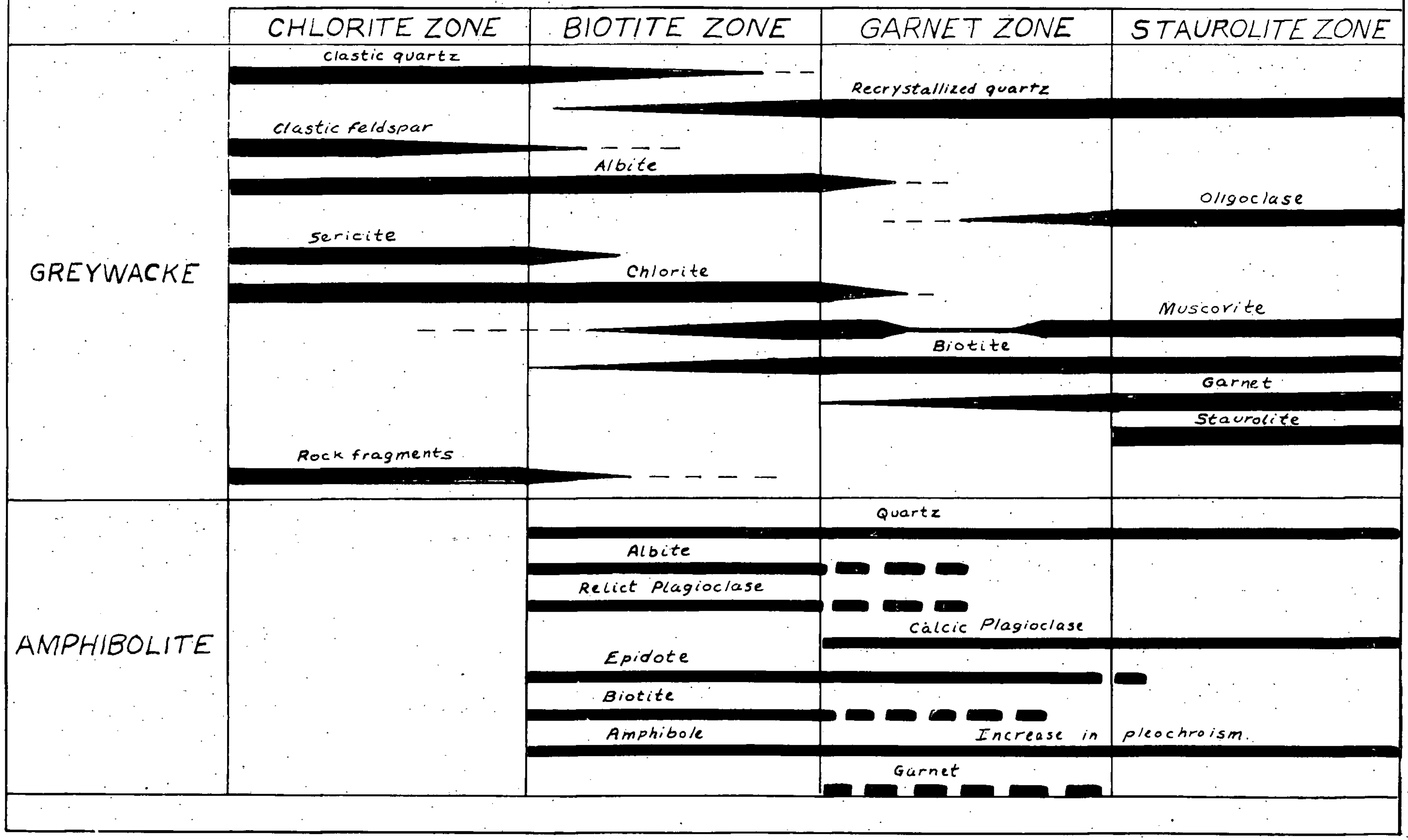
29 Baker, M.B., Lake Abitibi Area, Ont. Bur. Mines, Vol. XVIII, pt. 1, 1909, p. 270.

30 Baker, M.B., *Ibid*., p. 270.

Table 2

TABLE 2

Mineral Assemblages of the Greywackes and Amphibolites in the Metamorphic Zones of the Metasediments and Steele Lake Volcanics



precludes a thorough discussion of the mineral assemblages.

The calc-silicate rocks, iron-formation, and amphibole and plagioclase-rich schists occurring in the Scapa and Steele metasediments, and rocks of indefinite origin occurring in the Steele Lake volcanics are excluded from the table. These rocks will not be discussed further.

METAMORPHISM OF THE GREYWACKES

Quartz forms strained, and slightly elongate detrital grains up to 0.9 mm in diameter in the chlorite zone which are mechanically crushed and drawn out and slightly recrystallized in the biotite zone; at the garnet isograd the quartz is completely recrystallized with remnant detrital quartz visible only in the massive greywackes. In the upper part of the garnet zone and in the staurolite zone no recognizable detrital grains are left. In the finer-grained varieties detrital quartz is destroyed in the biotite zone and it occurs either in elongate spindle-shaped aggregates and individual grains that lie with their long axes parallel to the schistosity, or as narrow veinlets. This habit is maintained and intensified in the upper part of the biotite zone and in the garnet and staurolite zones. Recrystallization is therefore a much more active process than mechanical processes in the higher grades of metamorphism.

Clastic feldspar is common in the chlorite zone but occurs only in the massive greywackes in the lower part of the biotite zone. It is apparently absent in the higher grades of metamorphism. Albite is clouded by sericite and contains numerous inclusions in the chlorite zone. In the upper part of the biotite zone the sericite is resorbed and alumina expelled, the albite forming clear, untwinned porphyroblasts which are slightly larger in size than those occurring in lower grades. Oligoclase, showing reversed zoning, is common in the garnet zone. In the upper part of the garnet zone and in the staurolite zone, plagioclase is commonly unzoned and twinned, particularly near the Case batholith contact.

Concomitant with an increase in calcic plagioclase and the occurrence of abundant garnet and staurolite, epidote and chlorite show a decided decrease and are apparently absent in the staurolite zone. Epidote, however, is only an accessory in the greywackes and in many rocks occurring in the lower grades of metamorphism it is entirely lacking.

The occurrence of plagioclase in the garnet and staurolite zones poses a problem. The mineral assemblage present in the greywackes in the lower grades of metamorphism appears quite adequate to supply all the constituents except calcium for the formation of calcic plagioclase. (Epidote is apparently not present in sufficient quantities to supply all the calcium needed). If calc-silicate rocks were originally present in the upper part of the garnet zone and in the staurolite zone, then these rocks, upon metamorphism, could have supplied calcium for the formation of calcic plagioclase.

Cordierite was not found in the metasediments bordering the Case batholith and it appears to be rare or lacking in the narrow contact aureole developed in the Scapa metasediments adjacent to the Scapa stock. In the latter locality the absence of cordierite may be due in part to alteration. The evidence cited in connection with the contact aureole shows that the rocks have been fractured and altered, presumably by hydrothermal solutions from the granite forming the stock. Water pressures were therefore probably high.

W.S.Fyfe and F.J. Turner[31] indicate that at temperatures below 490°C, cordierite is stable at low water pressures, but if water pressures are high it is unstable. Therefore, within the cooler outer portions of the Scapa stock aureole high water pressures could account for the absence of cordierite. Petrographic study of the hornfelses within the inner part of the aureole shows that microcline (and therefore potash) has been introduced into the metasediments. Yoder's theory that cordierite is unstable in the presence of an excess of potash[32] would thus explain the lack of cordierite within the hornfels zone of the aureole.

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31 Fyfe, W.S., and Turner, F.J., Correlation of Metamorphic Facies with Experimental Data, in Metamorphic Reactions and Metamorphic Facies, Memoir 73, Geol. Soc. Am. 1958, p. 165.

32 Yoder, H.S., The MgO-Al_2O_3-SiO_2-H_2O System and the Related Metamorphic Facies, Am. Jour. Sci., Bowen Vol., 1952, pp. 569-627.

The absence of cordierite in the Scapa metasediments near the Case batholith may be due to the nature of the rock comprising the Case batholith. In this connection the following statements by Yoder[33] are significant.

> "It is probable that in those cases where the micas are stable, as in muscovite - biotite granite, cordierite will not form in the aureole in the presence of an excess of K_2O. The micas in the metamorphosed rock will persist up to the contact. In those cases in which the micas are not stable even in the presence of an excess of K_2O, as in a pyroxene - or amphibole - bearing granite, cordierite would be stable."

As will be shown later, the rocks comprising the Case batholith in Steele township do not contain amphibole or pyroxene but all contain biotite and muscovite. If the Scapa metasediments adjacent to the Case batholith contain an excess of potash, Yoder's explanation accounts for the lack of cordierite.

Sedimentary structures are well preserved in the chlorite zone and the lower part of the biotite zone. In the upper part of the biotite zone and in the garnet and staurolite zones, they are gradually obliterated by shearing and recrystallization.

Schistosity commonly parallels bedding in the greywackes, which suggests that bedding provided the surfaces of minimum strength along which slip was initiated. Biotite and muscovite are undeformed in many of the greywackes but

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33 Yoder, H.S. Op. Cit., p. 624.

chlorite is usually bent. Garnet and staurolite rarely show indications of movement during growth and both minerals are commonly idioblastic.

METAMORPHISM OF THE STEELE LAKE AMPHIBOLITES

The most important changes which take place in the amphibolites from the biotite through to the staurolite zones are:

1. A slight decrease in the amount of quartz.
2. An increase in the anorthite content of plagioclase, together with a decrease in the amount of inclusions in the plagioclase.
3. The appearance of zoning and twinning in the plagioclase.
4. A decrease in the amount of epidote, particularly near the staurolite zone, together with a slight increase in the anorthite content of the plagioclase in the staurolite zone.
5. A marked increase in the pleochroism of amphibole.
6. Local occurrence of garnet independent of shear zones in the garnet zone.
7. An increase in overall grain size of the amphibolites.
8. The development of schistosity in the garnet zone.

Relict micro-textures derived from the original volcanic rocks are rarely seen in the biotite zone and they are absent in all the higher grades. Volcanic structures, as seen in the outcrop, are more or less preserved in all three zones, although they appear to be more abundant in the biotite zone. Pillow lava is moderately to highly deformed, but its degree of deformation does not appear to be related to the grade of metamorphism.

The occurrence of garnet in the amphibolites is not restricted to the garnet zone. It was found near and in shear zones which are ubiquitous in the Steele Lake volcanics. However within the garnet zone, garnet is locally developed in apparent independence of shear zones. Poldervaart[34] has given a brief summary of the role of garnet in metamorphosed basalts and it appears that the formation of garnet depends upon many factors, which for the most part are only imperfectly known. It is not confined to a particular grade of metamorphism within basaltic rocks and its value as an index mineral is open to question.

METAMORPHISM OF THE BONIS VOLCANICS

The basic to intermediate volcanics occurring near the outer margin of the contact zone with the Sargeant batholith lie within the albite-epidote hornfels facies as

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34 Poldervaart, Arie, Metamorphism of Basaltic Rocks: A Review, Bull. Geol. Soc. Am., Vol. 65, 1953, pp. 259-274.

defined by Turner[35]. The volcanics in the inner part of the contact zone lie within Turner's hornblende hornfels facies, and contain recrystallized calcic plagioclase and less relict plagioclase than the rocks within the albite-epidote hornfels facies.

No pyroxene was found in the basic to intermediate volcanics. Water pressures were therefore high enough to allow hydrated silicates to crystallize, even at the contact with the Sargeant batholith. The occurrence of tourmaline in the basic intrusives cutting the lavas (see page 97) indicates that boron has been introduced into the rocks. Increase in the pleochroism of amphibole with an increase in metamorphic grade as observed in the metavolcanic rocks of the map-area, has also been reported by Turner[36] and Compton[37]. The more deeply coloured amphiboles are commonly high in alumina.

The fabric of many of the pillow lavas occurring in the Bonis volcanics shows a linear orientation but in places the pillows themselves are not noticeably deformed. In addition, the fabric of some highly deformed pillows displays

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35 Turner, F.J., Mineral Assemblages of Individual Metamorphic Facies in Metamorphic Reactions and Metamorphic Facies, Memoir 73, Geol. Soc. Am. 1958, pp. 199-239.

36 Williams, H. Turner, F.J., and Gilbert, C.M., Petrography (W.H. Freeman and Co. 1955), p. 242

37 Compton, R.R., Significance of Amphibole Paragenesis in the Bidwell Bar Region, California, Am. Min., Vol. 43, 1958, pp. 890-907.

the same degree of linear orientation as that of the non-deformed pillows. Ellipsoidal amygdules are also well-preserved in some foliated lavas. These features suggest that the linear orientation is not due to para-metamorphic deformation. It is also possible that some pillows were deformed shortly after their formation, while still in a plastic state.

CAUSE OF THE METAMORPHISM

The metasediment-metavolcanic assemblage has been subjected to raised temperatures and probably strong compressive forces, as suggested by the metamorphic zoning and the regional deformation which the assemblage displays. It would seem there are two possible causes of metamorphism. First, the assemblage has been metamorphosed by the batholiths, and second, the assemblage has been subjected to regional metamorphism during deep burial and deep-seated magmatic activity.

The evidence in support of both possibilities is meagre. If the second mechanism is envoked, then it is reasonable to assume that the Case batholith has destroyed some of the regional zonation within the metasediments which it intrudes. This would account for the absence of kyanite and sillimanite zones within the metasediments near the contact with the Case batholith. However, as suggested on pages 32 and 33, the bulk composition of the metasediments may be such as to preclude the formation of kyanite and sillimanite.

The occurrence of hornfelses in places along the contact between the batholith and the Scapa metasediments could be interpreted as a contact effect of the batholith on previously metamorphosed metasediments.

The writer favours the intrusion of the Case batholith to account for the metamorphic zonation in the metasediments and Steele Lake volcanics. The best evidence in favour of this hypothesis follows:

(1) Static crystallization of most of the garnet, staurolite, and micas within the metasediments. If the metamorphism is syntectonic as implied in the second mechanism, then these minerals could be expected to show evidence of movement or deformation.

(2) The garnet and staurolite isograds are arranged parallel to the contact of the Case batholith in Steele township and they cut across lithological boundaries.

The metamorphic zones can be correlated with metamorphic facies as follows:

Chlorite zone Biotite zone Garnet zone	Greenschist facies
Staurolite zone	Almandine Amphibolite facies

Few of the rocks within the metamorphic zones display "stable" assemblages, except in the chlorite zone and in the upper parts of the biotite, garnet and staurolite zones. Rarity of stable assemblages is what one would expect in the progressive metamorphism of the metavolcanic-metasediment assemblage as the result of heat and pressure effects exerted by the Case batholith.

The close spacing between the contact of the batholith and the staurolite isograd, and between the staurolite and garnet isograds (see Figure 2) suggest that both isogradic surfaces have a very steep gradient and the contact of the batholith in Steele township also probably dips steeply.

The garnet and staurolite isograds intersect the regional trend of the Scapa metasediments at a low angle but tend to follow the regional trend of the Steele Lake volcanics at their western end. The isograds are in effect slightly refracted where they enter the Steele Lake volcanics. This refraction is probably due to the greater resistance which the volcanics show to changes in metamorphism.

The Sargeant batholith has profoundly metamorphosed the Bonis volcanics at their contact. The metamorphic grade, however, drops off sharply from the contact zone and the Sargeant batholith has apparently had little or no effect on the Steele and Scapa metasediments. This effect again, is possibly due to the resistance of the basic to intermediate lavas to metamorphic change. The volcanic rocks occurring within the map-area are probably examples of Read's "resisters"[35].

The narrow aureole superimposed upon the rocks occurring in the biotite zone in Scapa township is the result of the intrusion of the Scapa stock. The width of the aureole suggests that the contacts of the stock dip steeply.

The superimposition of the Scapa stock aureole upon the regionally zoned Scapa metasediments suggests that the stock was intruded after the Case batholith.

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35 Read, H.H., Metamorphism and Granitization, in <u>The Granite Controversy</u>, Interscience Publishers, Inc., New York, 1957, p. 347.

CHAPTER IV

INTRUSIONS

ULTRABASIC AND BASIC INTRUSIONS

Small irregular masses, narrow sills and dikes of ultrabasic and basic intrusions cut both the Bonis volcanics and the Scapa metasediments and are themselves cut, in turn, by the acid intrusives and late basic intrusives. They consist of serpentinite, amphibolitized gabbro and diabase, and possibly diorite. Some of the rocks of this group may represent the fillings of conduits for the earlier extrusive activity.

SERPENTINITE

The serpentinites are greenish-black on a fresh surface and a bright bluish-green on a weathered surface. With the aid of a hand lens, numerous specks of magnetite and chromite can be distinguished. Most of the serpentinites are hard and massive but a few are highly sheared.

Microscopic study shows these rocks to be composed largely of fibrous antigorite, pseudomorphous after olivine, cut by chrysotile and serpophite veinlets and containing scattered subhedral to anhedral chromite grains. The antigorite pseudomorphs are commonly altered about their borders to talc and magnesite. Magnetite occurs both as distinct crystals and in irregular grains, and in bands outlining the original olivine crystals. Tremolite and magnetite are associated with carbonate veins and occur together in masses interstitial to antigorite pseudomorphs (altered pyroxene?).

Chromite is commonly opaque but in some specimens a translucent, red-brown core can be seen. Clusters of three or more grains of chromite occur interstitially to altered olivine grains. An unusual chlorite was found in one rock associated with finely disseminated opaque material and streaks of a reddish-brown isotropic substance (Maghemite?). The chlorite has a very pale lavender to pinkish pleochroism that is possibly due to chromium[1].

Serpentinite occurs at Peat's Point and on the islands and adjacent mainland near the mouth of Forks Creek. At the latter locality the serpentinite is in contact with uralitized pyroxenite (or peridotite) and metagabbro in one of the islands, and appears to be part of a differentiated sill about 650 feet thick. Baker[2] obtained an analysis of the serpentinite at Peat's Point and found it to conform to a typical dunite.

AMPHIBOLITE

Amphibolite, derived by metamorphism from gabbro and

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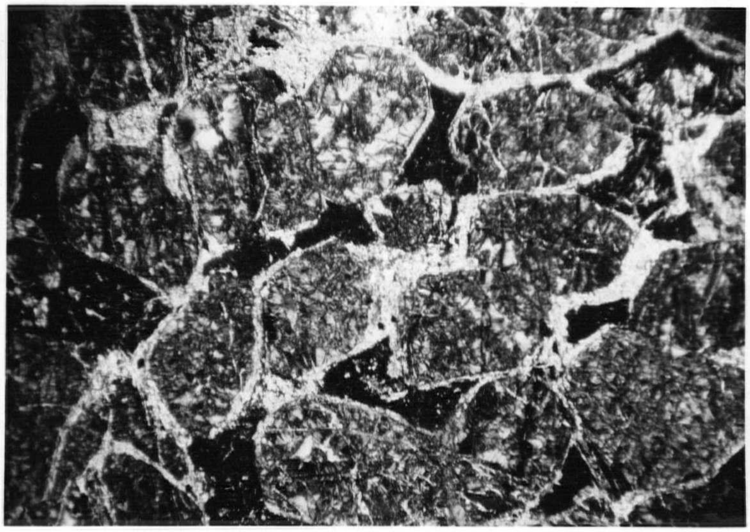
1 Winchell, A.N., Winchell, H., Elements of Optical Mineralogy Part II, Descriptions of Minerals, (John Wiley and Sons Inc., 1951), p. 386.

2 Baker, M.B., Lake Abitibi Area, Ont. Bur. Mines, Vol. XVIII, pt. 1, 1909, p. 274.

Plate XVI



A--Photomicrograph of serpentinite, lot 4, concession C, Steele township. Pseudomorphs of antigorite after olivine are rimmed by talc and magnesite. Polarized light X16.

B--Photomicrograph of amphibolite showing relict ophitic texture. Lot 3, concession B, Steele township. H= hornblende, Pl= plagioclase. Also present are chlorite, epidote, quartz and opaque minerals, Polarized light X16.

diabase, is the most abundant rock type of the basic intrusives. The amphibolites are composed of 40 to 65 per cent blue-green hornblende, ranging in size from less than one millimeter to one centimeter, set in a fine-grained groundmass of epidote, quartz and feldspar. Relict laths of plagioclase up to one millimeter long are present and where these are abundant, the rock shows ophitic texture. Biotite and carbonate are common and altered magnetite-ilmenite is an accessory. Tourmaline is rare.

The hornblende and relict plagioclase laths are deformed and broken. In many of the amphibolites hornblende forms large rounded aggregates, giving the rock a porphyroblastic appearance, or it is fibrous and pseudomorphous after pyroxene. Foliation is not well-developed, although many of the amphibolites are sheared near the contact zone with the Sargeant batholith.

Evidence of multiple intrusion of the sill-or dike-like bodies is present in many localities. The best example of multiple intrusion occurs in a well-exposed outcrop at the eastern boundary of Scapa. Here, a metagabbroic sill, about 10 feet wide, showing chilled contacts against the metasediments, is intruded by irregular dikes of a second metagabbroic rock, ranging from 1/2 inch to 4 feet in width, which display chilled margins against the first. Disseminated pyrite, pyrrhotite and chalcopyrite are abundant at the contact between the two rocks.

Altered quartz diabase is exposed in a few rock reefs lying off Peat's Point and to the southwest of the prominent point to the south of Peat's Point. In thin section the rock has a well-preserved ophitic texture but all the original pyroxene has been uralitized and the plagioclase altered. Micropegmatitic intergrowths of quartz and plagioclase can still be seen.

DIORITE

Possibly dioritic rocks occur in the Mace Crab Islands and cutting the differentiated sill in the islands off the mouth of Forks Creek. At the latter locality the rock is slightly altered and porphyrytic. The phenocrysts are oscillatory zoned oligoclase set in a fine-grained felty aggregate of quartz and feldspar. Pale blue-green hornblende prisms up to 2 mm. long are also abundant.

ACID INTRUSIONS

SARGEANT BATHOLITH

The name Sargeant batholith is proposed for a granodioritic to dioritic mass centered in Sargeant township and covering an area of about 400 square miles. The batholith extends to the eastern shore of Lower Lake Abitibi, the northern shore of Upper Lake Abitibi and across the Interprovincial boundary into Desmeloizes township. Its northern and eastern extent into Sargeant and Desmeloizes township is only approximately known.

M.B. Baker made a reconnaissance of that portion of the batholith bordering on Lower and Upper Lake Abitibi in 1908[3]. He described the rock comprising this part of the batholith as hornblende granite, which in places becomes a hornblende syenite. Until the present survey, no other work has been published on the batholith.

In Bonis township the rocks vary considerably in composition. Pyroxene and hornblende diorite,[4] gneissic quartz diorite, quartz diorite, quartz monzonite and granodiorite are the principal rock types. In general, the more acid rocks occur near or at the western margin of the batholith. Numerous quartz-feldspar porphyry and feldspar porphyry dikes, granite dikes and pegmatitic dikes extend from the batholith into the enclosing Bonis volcanics. Intrusion breccia and a variety of hybrid rocks occur at the contact with the Bonis volcanics in Steele township. The batholith is poorly exposed within the map-area making it difficult to correlate the various rock types.

Many of the batholith rocks contain amphibolite inclusions, possibly derived from the Bonis volcanics. Pegmatite and aplite are rare.

The hornblende diorites and quartz diorites are

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3 _Op_. _cit_., p. 238

4 The acid intrusives of both the Sargeant batholith and Case batholith are classified according to Brown (_Trans. Can. Inst. Min.and Met_., Vol. LV, 1953, pp. 53-56).

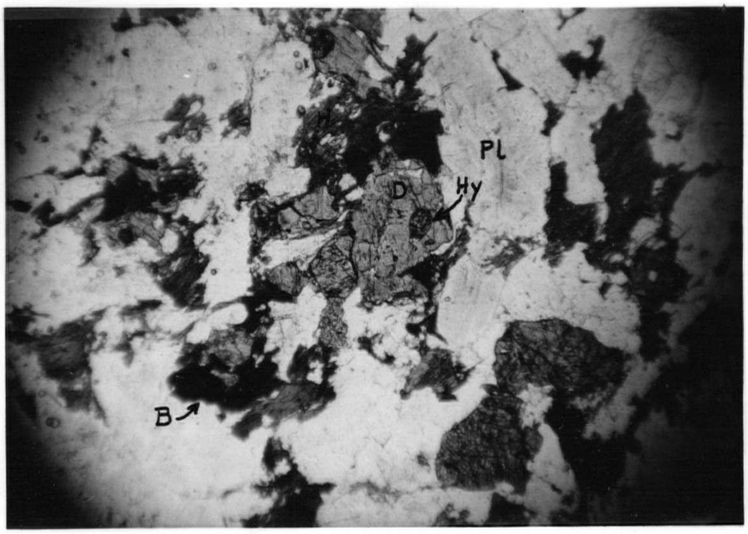
similar in handspecimen. They are both coarse to medium-grained, grey to pinkish, mesocratic rocks with a pronounced foliation, due to a sub-parallel alignment of individual hornblende crystals, biotite and chlorite flakes, and inclusions of amphibolite. Pyroxene diorite is poorly foliated, medium-grained, leucocratic and pinkish with a distinct blue-grey tinge. Pyroxene quartz diorite also has a blue-grey tinge. Diorite and pyroxene-bearing quartz diorite were found only in lots 1 and 2, concession V, Bonis township. The pyroxene-bearing rocks form irregular patches in the pinkish quartz diorites and may represent assimilated inclusions.

Although foliation is pronounced in nearly all the rocks examined, it was difficult to measure in the outcrop owing to the thick vegetation cover.

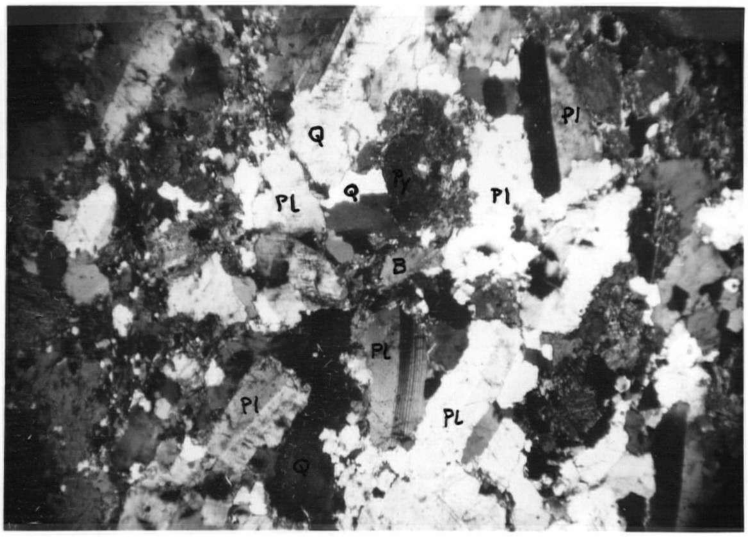
The composition of the diorites and quartz diorites is approximately 35 to 60 per cent plagioclase, 3 to 25 per cent hornblende, 0 to 20 per cent biotite, 5 to 15 per cent quartz with accessory epidote, chlorite, apatite, muscovite, sphene, tourmaline and opaques. Where pyroxene is present it varies from 7 to 15 per cent. All specimens examined in thin section were stained in order to detect the presence of potash feldspar, but this mineral was found in only one quartz-diorite and in very small percentages.

Zoned and twinned plagioclase, forming subhedral grains up to 4 mm., is most abundant in the pyroxene diorites.

Plate XVII



A--Photomicrograph of pyroxene diorite showing hypersthene (hy) surrounded by diopside (D). Lot 2, concession V, Bonis township. Pl= plagioclase, H= hornblende, B= biotite. Plain light X16.



B--Photomicrograph of quartz diorite, lot 1, concession V, Bonis township. Pl= plagioclase, Q= quartz, Py= pyroxene, B= biotite. Other constituents include hornblende, epidote, apatite and rare K-feldspar. Polarized light X16.

Poorly zoned grains exhibit carlsbad-albite twins. In composition the plagioclase varies from An_{30} to An_{33} and in all but the pyroxene-bearing types it is moderately to highly sericitized. In the more highly altered rocks the plagioclase is partly replaced by albite.

Quartz and muscovite occur as anhedral grains interstitial to the plagioclase. Dark green hornblende occurs in large euhedral to subhedral crystals, most of which contain numerous inclusions. Euhedral pyroxene is rimmed by hornblend and/or biotite, and in the more highly altered rocks the pyroxene is completely replaced by hornblende. The pyroxene is diopsidic and some grains contain a pinkish pleochroic core of hypersthene. Biotite is most abundant in the pyroxene-bearing types.

Hypidiomorphic-granular texture is common but one of the quartz diorites is markedly unequigranular and slightly porphyritic. Quartz and feldspar are fractured or crushed.

Gneissic quartz diorite is common in lots 1 and 2, concession IV, Bonis township. In handspecimen, the rocks are medium-grained, greyish in colour, and possess a prominent gneissic banding. Some appear to have rounded porphyroblasts of feldspar while others have narrow pinkish bands up to 1/4 inch wide composed largely of feldspar and trending parallel to the foliation. The gneissic diorites appear to be large inclusions in quartz monzonite.

In thin section the composition is not unlike that of the quartz diorites. Epidote and biotite are generally more abundant and pyroxene was not seen. Cataclastic texture is well-developed. Plagioclase is twinned and zoned and has a composition identical to that of the diorites and quartz diorites.

The quartz monzonites are medium-grained, massive to well-foliated, pinkish, leucocratic to mesocratic rocks. The mesocratic varieties occur in the eastern part of Bonis township, whereas the leucocratic varieties are confined to the outer margins of the batholith.

In thin section the quartz monzonites are composed of approximately 30 to 40 per cent plagioclase, 2 to 20 per cent blue-green hornblende, 10 to 20 per cent quartz, 15 to 25 per cent K-feldspar, and accessory epidote, chlorite, biotite, sphene, apatite, and opaques. Euhedral pyroxene, rimmed by hornblende was found in one quartz monzonite, occurring in lot 1, concession IV, Bonis township. K-feldspar comprises about 1/3 of the total feldspar of this rock so that it is close to quartz diorite in composition. In all the other rocks examined K-feldspar formed more than 1/3 but less than 2/3 of the total feldspar.

Zoned and twinned plagioclase, varying in composition from An_{28} to An_{33} forms large euhedral to subhedral grains up to 3 mm. Where twinning is well-developed, zoning is only faintly present or absent. Nearly all the plagioclase is moderately to highly sericitized, the sericitization being most intense in the cores of zoned crystals.

Twinned microcline forms small subhedral grains, more or less interstitial to plagioclase. The microcline is partly replaced by albitic feldspar and where this process is almost complete small blebs of microcline, all in optical continuity, are left in an antiperthitic intergrowth with albite (See Plate XVIIIA). Many of the microcline grains contain small inclusions of plagioclase which have commonly developed myrmekitic intergrowths with the microcline. Myrmekite was also seen at the contact between individual plagioclase and microcline grains. Quartz is interstitial to the feldspars and commonly replaces other minerals.

Hornblende is optically identical to that of the diorites and quartz diorites. It is poikilitic with inclusions of quartz and feldspar, and partly altered to chlorite, epidote and biotite.

Most of the quartz monzonites have a hypidiormorphic-granular texture, although a few are slightly porphyritic. Prehnite-filled fractures were found in one specimen near the eastern margin of the batholith. Plagioclase and hornblende appear to have crystallized early. Much of the potash feldspar and quartz crystallized after the major crystallization period of plagioclase. Granulation of the quartz and feldspar is rare or absent and this rock type is generally more highly altered than the diorites, quartz diorites and gneissic diorites.

Rocks of granodioritic composition were found only at the contact with the Bonis volcanics. They are pink, leucocratic medium to coarse-grained, massive to porphyritic rocks, which contain abundant quartz. The granodiorites form the matrix to intrusion breccia in Steele township and they occur as irregular dikes and masses extending into the Bonis volcanics in both Steele and Bonis townships. Much of the batholith outcropping along the shore of Lake Abitibi in concession A, Steele township is granodiorite, which grades into hybrid rocks at the contact with the amphibolite.

Microscopic study shows the granodiorites to be composed of approximately 45 to 50 per cent oligoclase (An_{28-30}) 20 per cent K-feldspar, 20 to 25 per cent quartz and accessory biotite, muscovite, epidote, hornblende, sphene, apatite, zircon chlorite and opaques.

The plagioclase occurs as zoned and twinned subhedral to anhedral grains which in the massive varieties is moderately altered to sericite and in the porphyritic varieties relatively fresh. Oscillatory zoning is common in the porphyritic granodiorite plagioclase. The K-feldspar is commonly albitized, particularly in the non-porphyritic rocks. Myrmekite is present and one specimen showed the rectilinear type described by Spencer[5] and attributed to direct crystallization. As in the quartz monzonites, much of the K-feldspar

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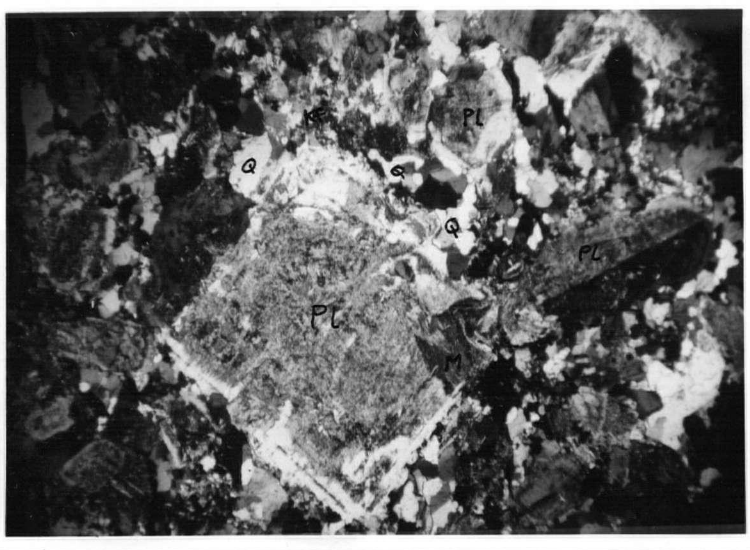
5 Spencer, E., Myrmekite in Graphic Granite and in Vein Perthite, Min. Mag., Vol. XXVII, 1945, pp. 79-98.

Plate XVIII

A--Photomicrograph of quartz monzonite showing K-feldspar (Kf) replaced by albite (Ab). Lot 3, concession IV, Bonis township. Quartz (Q) hornblende, biotite, epidote, sphene and apatite are also present. Polarized light X47.



B--Photomicrograph of granodiorite showing an altered zoned plagioclase crystal. Lot 1, concession D, Steele township. Pl= plagioclase, Q= quartz, M= muscovite, Kf= K-feldspar. Epidote, chlorite, apatite and sphene are also present. Polarized light X16.

appears to have crystallized after the main crystallization period of the plagioclase. Hornblende, muscovite and biotite are the most abundant accessories. The hornblende is partly altered to chlorite and epidote.

Western Contact of the Batholith

Granodioritic dikes cutting amphibolite are abundant along the shore and in the adjacent islands of concession A, Steele township. Numerous inclusions of amphibolite are found within the granodiorite along the shore and in places the amphibolites have been partially assimilated by the granodiorite forming hybrid rocks, with a gneissic banding and containing large porphyroblasts of feldspar. No thin section study has been made of the various hybrids developed but they are indicated on the geological map by the symbol "4h".

Intrusion breccia is well-exposed in granodiorite outcrops bordering on Northeast Bay in lots 1 and 2, concession D, Steele township. Angular blocks of amphibolite up to 3 feet in size display varying degrees of assimilation. Some of the amphibolite blocks show a mineralogical zoning with a pinkish rim, presumably containing a high proportion of feldspar, enclosing a dark green to black amphibolitic core. Other blocks contain abundant epidote, while still others show randomly oriented gneissic banding. Many of the blocks have been broken and rotated and a few are cut by irregular granodiorite dikelets.

Plate XIX

A--Intrusion breccia, lot 2, concession D, Steele township. Note the variable degree of assimilation of the amphibolite blocks and the complex nature of the block in the foreground.

B--Intrusion breccia, lot 1, concession D, Steele township. Note the granodiorite dikes cutting through the amphibolite gneiss inclusion and the apparent higher degree of assimilation of the lower part of the inclusion.

Numerous feldspar porphyry dikes, many of which have a general east-northeast trend, occur in the Steele metasediments along the northern shore of Northeast Bay up to four miles from the western contact of the batholith. Nearly all the dikes are moderately to highly altered and some are sheared and may be offset by cross-faults. The dikes range in width from a few feet to about 100 feet and in general they conform to the bedding of the metasediments, although local cross-cutting relationships exist. Some of the dikes show a slight grain gradation from fine- to medium-grained at the margins to coarse-grained in the centre of the dike. A few porphyry dikes, less than two feet wide cut across the bedding of the metasediments at low angles.

Where the feldspar porphyry dikes are highly altered and sheared, they resemble the greywacke which they intrude and could be mistaken for conglomerate bands interbedded with the greywacke. Indeed Knight et al[6] refer to a "conglomerate schist" occurring in lot 6, concession E, Steele township. No conglomerate was found at this locality but sheared porphyry dikes do occur.

In thin section the porphyry dikes are composed of about 25 to 40 per cent iron-stained carbonate, 5 to 15 per cent chlorite and accessory amounts of biotite, muscovite, apatite and pyrite.

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6 Knight, et al., Abitibi-Night Hawk Gold Area, Ont. Bur. Mines, Vol. XXVIII, pt. 2, 1919, p. 23.

Plate XX

Photomicrograph of feldspar porphyry, lot 6, concession E, Steele township. Twinned, altered plagioclase phenocrysts (Pl) lie in a fine-grained matrix of quartz, feldspar, sericite, chlorite, and carbonate (Cb). Polarized light X16.

The plagioclase occurs as zoned and twinned euhedral phenocrysts up to 3 mm in size. It is moderately to highly sericitized and partly replaced by albite. The fresher grains appear to be about An_{25} in composition. In the sheared porphyries the plagioclase phenocrysts are crushed, and fractured, and zoning in the phenocrysts is rare. Fractured phenocrysts are healed by carbonate.

The remaining constituents commonly form a fine-grained matrix to the plagioclase phenocrysts but in some specimens chlorite occurs in coarse patches up to 2 mm in size which may represent altered ferro-magnesian minerals. The ratio of plagioclase phenocrysts to matrix is commonly low but in a few specimens this ratio is quite high and the porphyrytic character of the rock is not apparent in hand-specimen. The carbonate occurring in the feldspar porphyry dikes has been introduced as it occurs in veins and lenses or it replaces other minerals.

A feldspar porphyry dike cutting the metasediments at the western end of the railway cut in lot 3, concession E, Steele township is only slightly carbonatized, although it has been sheared. It consists of euhedral plagioclase (albitic) phenocrysts up to 1 mm in size set in a fine-grained schistose groundmass composed mainly of quartz, chlorite and muscovite. The plagioclase phenocrysts are oriented parallel to the schistosity and they display a well-developed discontinuous patchy twinning which, according to Emmons and Mann,[7] is due to strain and cataclasis. The phenocrystw are free from inclusions and some are broken. Mineralized quartz veins containing pyrite, pyrrhotite and chalcopyrite cut the dike in a few places but they also appear to be deformed.

Other porphyry dikes cut the Bonis volcanics along the eastern shore of Northeast Bay. Some resemble the feldspar porphyry dikes cutting the Steele metasediments in that they are sheared and carbonatized and strike roughly east-northeast.

A few quartz-feldspar porphyry dikes trend north-south and are little altered, coarse in grain and unsheared. They contain phenocrysts of quartz as well as plagioclase. Granular epidote, a mineral absent in the feldspar porphyries, is common.

Northern Contact of the Batholith

The northern contact is exposed in only two localities within the map-area, in lot 9, concession V and in lot 1, concession VI, Bonis township. The northern contact of the batholith appears more regular than the western contact with only a few porphyry dikes present and no intrusion breccia.

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7 Emmons, R.C., and Mann, V., A Twin-Zone Relationship in Plagioclase Feldspar, in Selected Petrogenic Relationships of Plagioclase, Memoir 52, Geol. Soc. Am., 1953, pp. 41-54.

In lot 1, concession VI, the contact between the batholith and the Bonis volcanics is exposed on the side of a small rock knoll. The contact is sharp and appears to dip vertically. The rock in contact with the Bonis volcanics is syenodioritic in composition and grades abruptly into hornblende plagioclase hornfels developed in the Bonis volcanics.

In handspecimen the syenodioritic rock contains numerous porphyroblasts of plagioclase up to 4 mm in size set in a matrix predominantly composed of hornblende crystals up to 3.5 mm in size. The rock is composed of 35 per cent zoned and twinned plagioclase porphyroblasts, 30 per cent blue-green idioblastic hornblende, 8 per cent quartz, 15 per cent epidote and accessory sphene, apatite and opaques. Epidote (pistacite) and quartz envelope hornblende and plagioclase grains and occur as inclusions in hornblende and plagioclase. The composition of the plagioclase is about An_{28} but the cores of zoned porphyroblasts appear to be more sodic. The texture is granoblastic.

Summary of the Sargeant Batholith

The principal rock types of the Sargeant batholith, as exposed within the map-area, are foliated quartz diorite and quartz monzonite. Hornblende and pyroxene diorites possibly developed by the assimilation of amphibolite, occur locally in association with the quartz diorites. At the western contact of the batholith in Steele township the rocks are more acid, consisting mainly of granodiorite.

The occurrence of intrusion breccia at the western contact of the batholith, together with numerous amphibolitic inclusions within the body of the batholith, the zone of hornfels developed along an apparently sharp northern contact, the many granodiorite and porphyry dikes extending into the Bonis volcanics from the batholith, and the lack of migmatites in the associated country rock, particularly in the metasediments, are all features strongly suggestive of an intrusive origin for the Sargeant batholith.

Altered and sheared feldspar porphyry dikes occurring in the Steele metasediments were probably an early manifestation of the batholith and they were sheared and altered as a result of the main intrusion of the batholith. The north-south quartz-feldspar porphyry dikes appear to have been emplaced after the main period of intrusion of the Sargeant batholith. The concordant nature of the altered feldspar porphyry dikes with the Steele metasediments and the apparent overall elliptical shape of the intrusion, with its long axis trending parallel to the regional structure of the metasediments and metavolcanics, suggests that the batholith is a concordant intrusion.

The writer is of the opinion that the batholith is similar to the circumscribed granitic plutons described by Read[8] and other European geologists. These plutons are

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8 Read, H.H., The Granite Controversy, Interscience Publishers, Inc., 1957.

supposedly formed from a semi-crystallized viscous magma moving past mostly stationary walls and make their way into the country rocks, by "plain pushing and shoving." Such an origin for the Sargeant batholith would account for many of the features noted within the map-area.

The more acid character of the batholith near its western margin may be due to post-intrusion alteration or to differentiation of the magma. Not enough data are available to decide between the two alternatives but the albitization of the K-feldspar and rarely of the plagioclase feldspar, plus the general overall altered nature of the rocks suggests comparison with the Bourlamaque-Granodiorite batholith in Quebec, described by Gussow.[9] The original quartz-gabbro of the Bourlamaque batholith was altered to albite-tonalite by sodic hydrothermal solutions, guided by shear and breccia zones.

CASE BATHOLITH

The granitic rocks occurring in the northern part of Steele township are considered to be part of a large batholith centred in Case township to the north of Steele. The name Case batholith is proposed for this mass. The full extent of the batholith is unknown, but from reconnaissance surveys made by the writer during the 1959 field season, it

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9 Gussow, W.C., Petrogeny of the Major Acid Intrusives of the Rouyn-Bell River Area of North Western Quebec, Trans. Roy. Soc. Canada, 1937, Sec. 4, pp. 129-161.

is known to extend at least 10 miles to the northwest of the northern boundary of Steele township and to underlie much of Case township.

Within Steele township the rocks comprising the batholith range in composition from leucogranodiorite near the contact with the Scapa metasediments, to leucocratic quartz monzonite away from the Scapa metasediments. The rocks are pink in colour, massive and coarse-grained. Numerous pegmatite dikes and irregular pegmatitic patches occur in the granodiorites and quartz monzonites.

A pegmatite dike occurring in quartz monzonite in lot 5, concession V contains spodumene, columbite-tantalite and molybdenite. Pegmatites occurring in the metasediments and metavolcanics near the contact with the Case batholith in lots 8 to 12, concession IV, Steele, commonly contain scattered plates of molybdenite but no spodumene or columbite-tantalite was found in them.

Albitized quartz-feldspar porphyry dikes and feldspar porphyry dikes are abundant in the Scapa metasediments both in Steele and Scapa townships. A few also occur in the Steele Lake volcanics. The porphyry dikes strike parallel to the regional structure. They differ from the porphyry dikes associated with the Sargeant batholith in containing abundant K-feldspar and rare accessory rutile.

The composition of the granodiorite is approximately 50 to 55 per cent plagioclase (An_{28}), 15 to 25 per cent quartz, 7 to 15 per cent K-feldspar and accessory epidote, muscovite, biotite, chlorite, sphene, zircon, apatite, tourmaline and rare opaques. The percentages of K-feldspar were estimated from stained specimens.

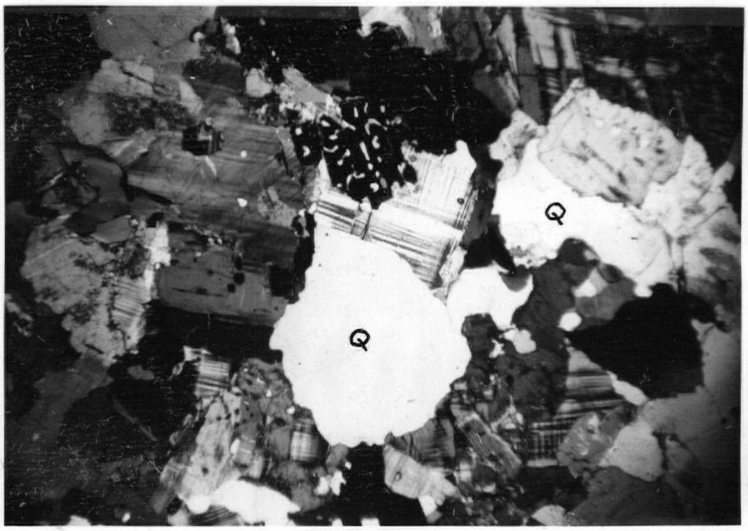
Some of the granodiorites are porphyritic, containing large phenocrysts of plagioclase. In all the granodiorites the plagioclase occurs as euhedral to subhedral, twinned and zoned grains up to 3 mm. in size. In twinned grains alternate twin lamellae are sericitized, suggesting a difference in composition between adjacent twin lamellae. Some of the plagioclase is replaced by albite.

The K-feldspar is both twinned and untwinned and perthitic. Film, string, rod, patch and vein perthite occur in both twinned and untwinned K-feldspar. Where albite has almost entirely replaced K-feldspar grains antiperthite is formed. The K-feldspar is finer-grained than the plagioclase and myrmekite is found developed at grain contacts between these minerals.

Quartz occurs as anhedral grains, many of which are strained and fractured with the fractures commonly abutting against adjacent plagioclase and K-feldspar grains. Unfractured and unstrained quartz heals the fractures commonly.

Both quartz and K-feldspar are interstitial to plagioclase, indicating they crystallized after the main crystallization period of the plagioclase. Adjacent to aplitic and pegmatitic dikelets and veins cutting the

Plate XXI



Photomicrograph of quartz monzonite showing myrmekite developed in a small inclusion of plagioclase in K-feldspar. Lot 9, concession VI, Steele township. Q= quartz. Polarized light X16.

granodiorites the plagioclase, K-feldspar and quartz are all markedly fractured and crushed. The albite occurring in these rocks is largely due to replacement. The film and string perthites are probably due to exsolution.

The composition of the quartz monzonites is approximately 25 to 35 per cent plagioclase (An_{25-28}), 30 to 40 per cent K-feldspar, 25 to 35 per cent quartz and accessory muscovite, biotite, chlorite, apatite, zircon and opaques. As in the case of granodiorite the percentage of K-feldspar was estimated from stained specimens.

The character of the plagioclase, quartz and K-feldspar is essentially the same in the quartz monzonites as in the granodiorites. Inclusions of K-feldspar in plagioclase are common, however, and in places quartz and plagioclase inclusions were seen in K-feldspar. Thin rims of sodic plagioclase were noted on some borders of plagioclase grains. The thin rims are both twinned and untwinned with the rest of the individual plagioclase grains. Sodic plagioclase borders are especially common around plagioclase inclusions in K-feldspar.

Most of the perthite seen is of the exsolution variety (film string and rod perthite) and in general, albitization is less pronounced in the quartz monzonites than in the granodiorites. The rocks are fresh but all the quartz and feldspar is fractured adjacent to pegmatitic dikelets.

Biotite and muscovite form large conspicuous grains in the quartz monzonites and together they form as much as 10 per cent of the rock. Some rocks contain little or no biotite, but abundant muscovite, and in others, the reverse relationship holds.

Although accessory epidote is common in the granodiorites, none was found in the quartz monzonites examined in thin section.

Homogeneous hybrid rocks occur in a number of places within the batholith, particularly at or near the contact with the Scapa metasediments. All these rocks are porphyroblastic and they contain no K-feldspar. They are essentially quartz-plagioclase rocks but all contain minor blue-green hornblende and greenish brown biotite.

The composition of the hybrid rocks is approximately 55 to 70 per cent plagioclase (An_{28-32}), 15 to 20 per cent quartz, 10 to 12 per cent biotite, 2 to 8 per cent hornblende, and accessory chlorite, sphene, apatite and epidote (pistacite with cores of allanite).

The plagioclase occurs as twinned and zoned anhedral porphyroblasts and idioblasts, up to 3 mm. in size in a fine-grained matrix of quartz, plagioclase, biotite, hornblende and the accessories. Biotite frequently envelopes plagioclase porphyroblasts.

Inclusions of partially assimilated metasediments are commonly associated with the hybrid rocks and it would appear that the hybrids owe their origin to the mixing of sedimentary material with the "magma" of the batholith.

No detailed study was made of the pegmatites, although special attention was given to those containing minerals of economic significance. The pegmatites vary widely in size and shape. Some are tabular or dike-like in form, others are quite irregular. The pegmatite-dikes occurring within the batholith range in width from less than one inch to about 100 feet. Sharp contacts of many of the dikes suggests intrusion into the host rocks (granodiorite and quartz monzonite). In thin section the rock adjacent to the dikes is invariably fractured and embayed by aplitic material which commonly forms a border phase to the pegmatites.

The origin of the irregular pegmatitic bodies is unknown. Both the irregular masses and dikes of pegmatite are more or less evenly distributed throughout the Case batholith in Steele township. The largest dikes were found near the contact with the Scapa metasediments.

The contact between the pegmatite and aplite is gradational. The border phase is commonly scalloped and contains trains of garnet. Hexagonal quartz grains, and plates of muscovite up to two inches in size are conspicuous constituents of the pegmatites in handspecimen.

The spodumene-hearing pegmatite dike occurring in lot 5, concession V is complex[10] and zoned. This is the

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10 Complex in the sense of Landes (Am. Min., vol. 18, 1933, pp. 95-103).

Plate XXII

Spodumene-bearing pegmatite dike, lot 5, concession V, Steele township.

only complex pegmatite noted within the batholith. The pegmatite displays a narrow aplitic border phase in places and contains numerous quartz-rich patches which appear to form the core of the pegmatite. Spodumene crystals up to 3 feet long and 6 inches across are most abundant in the quartz-rich patches. Columbite-tantalite, muscovite and tourmaline are found with the spodumene. Molybdenite is rare.

Pegmatites occurring in the Steele Lake volcanics and Steele metasediments in the vicinity of lots 7 to 11, concession IV, Steele township, are composed largely of coarse quartz with only minor amounts of feldspar and mica. Molybdenite is sparsely distributed in these pegmatites, usually in association with aplitic and feldspathic portions of the pegmatite.

In summary, the Case batholith as exposed in Steele township is decidedly more acid than the Sargeant batholith. The porphyry dikes associated with the Case batholith differ significantly from those associated with the Sargeant batholith in containing appreciable K-feldspar. The pegmatitic character of the Case batholith is also in marked contrast to that of the Sargeant batholith. The development of a contact metamorphic aureole, an apparent concordance with the intruded rocks, and lack of associated migmatites suggest that the Case batholith may also be a circumscribed pluton. It may therefore belong to the same orogenic cycle as the Sargeant batholith.

The apparent differences in composition between the Case and Sargeant batholiths may be due to original differences in the initial magmas giving rise to the batholiths. However both batholiths could conceivably have been derived from a common magma in which case the compositional differences could be brought about by the different contamination effects of sediment as opposed to basic to intermediate lava.

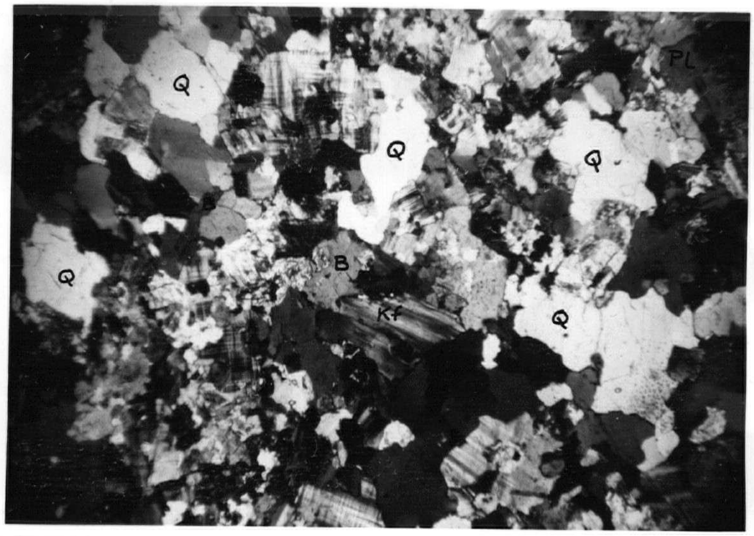
SCAPA STOCK

The Scapa stock is composed of a medium-grained, massive, uniform, pink, leucogranite. The composition of the granite is approximately 40 to 45 per cent K-feldspar (mainly twinned microcline) 25 per cent plagioclase, 20 to 25 per cent quartz, 6 to 10 per cent biotite, and accessory muscovite, chlorite, epidote, sphene, zircon and opaques. The percentages of K-feldspar were estimated from stained handspecimens.

The K-feldspar is perthitic. String and rod perthites are common, as well as patch and vein varieties. The former two types are thought to be formed by exsolution, whereas the latter two types by replacement. The anhedral K-feldspar is intergrown with, and interstitial to, plagioclase. Myrmekite has been developed at the junction of some plagioclase and microcline grains, as well as in inclusions of twinned plagioclase in K-feldspar.

The plagioclase is subhedral to anhedral, occurring

Plate XXIII



Photomicrograph of the Scapa stock leucogranite. Q= quartz, B= biotite, Kf= K-feldspar, Pl= plagioclase. Polarized light X16.

in well-twinned and zoned grains up to 1.5 mm. in size. Most of the plagioclase is sericitized and in many places it is partly replaced by albite. The composition is about An_{25}. Quartz, which occurs as anhedral grains, is interstitial to both the feldspars.

The biotite has a reddish-brown to brownish-green pleochroism and appears to be partly altered to chlorite. It commonly contains inclusions of zircon and epidote (pistacite with allanite cores).

The granite has a hypidiomorphic-granular texture. Plagioclase probably began to crystallize early, followed by concomittant crystallization of plagioclase and K-feldspar. The alteration in the rock may have been deuteric in part.

The acid character of the Scapa stock suggests it may be a satellitic off-shoot of the Case batholith.

LAMPROPHYRE

A few highly altered, rusty-weathering, greenish-grey rocks, which occur as dikes intruding the Steele metasediments along the northern shore of Northeast Bay are grouped together under the general heading lamprophyre. The origin of these rocks and their original character are unknown. The dikes are commonly less than 2 feet wide, although one dike measured about 3.5 feet.

In thin section a sample collected from lot 7, concession E, Steele township, was found to consist of approximately 30 per cent carbonate, 30 per cent quartz, 25 per cent chlorite, 15 per cent muscovite, and rare biotite and opaques.

All the minerals occur as a medium-grained massive aggregate and all but carbonate and muscovite, are anhedral. The muscovite occurs as randomly oriented laths, while the carbonate is found as small rhombs. A few irregular quartz veinlets also cut the rock.

The relationship between the lamprophyre(?) and the intrusive rocks is not known. The dike rocks could be related to either the ultrabasic and basic intrusives or to the acid intrusives. In one locality a lamprophyric dike was noted to be offset by a shear zone in the Steele metasediments.

No lamprophyric rocks were found in the Steele metasediments north of Lake Abitibi, in the Scapa sediments, or in the metavolcanic rocks.

LATE BASIC INTRUSIONS

Diabase dikes trending north and northeast and ranging in width from a few feet to 460 feet intrude all other rocks within the map-area. The dikes cut cleanly across the various rock units and have sharp chilled contacts, with fine-grained, glassy margins and medium to coarse-grained centres. No evidence of stoping or replacement was found and each individual dike has a uniform composition. Where the dikes cut the bedding of metasedimentary rocks at oblique angles the metasediments have been displaced at right angles to the walls of the dike. The dikes are sinuous along strike and their dip is vertical or nearly so. There appears to be no relationship between the regional structure developed in the earlier rocks and the orientation of the diabase dikes.

Numerous workers in mapping areas to the south and southwest of Lake Abitibi have noted the same trend in late diabase dikes as noted above. Invariably the north-trending group is cut by the northeast-trending group and is therefore older. No exposed intersections of the dikes were found within the map-area but it is inferred from the areas to the south and southwest that the north-trending group is the older. Accordingly, this group is called early diabase and the other late diabase. Within northeastern Ontario the earlier diabase is commonly referred to as Matachewan in age and the late diabase as Keweenawan in age.

In handspecimen the early and late diabase are much alike. They all weather a characteristic "foxy"-brown colour, which is slightly more pronounced in olivine diabase. In addition purplish augite and coarse magnetite grains are readily seen only in the olivine diabase. Diabasic texture is well-developed in all but the fine-grained varieties found at the margins of the dikes.

The early diabase dikes are all quartz diabase, containing andesitic labradorite (An_{50}) in micrographic intergrowths with quartz and ophitically intergrown with euhedral to subhedral augite. Pyrite and magnetite are also present, the former mineral filling fractures in plagioclase laths. Most of these rocks are more or less altered, the augite is uralitized and chloritized, plagioclase is saussuritized and biotite is found in association with the opaques.minerals.

The late diabase dikes are diabase and olivine diabase. The dike striking through Steele and Scapa township is diabase, whereas the one in Bonis township is olivine diabase.

In thin section the diabase is moderately to highly altered and secondary quartz is present. The plagioclase is more calcic than in the quartz diabases, about An_{58-60}. The amount of quartz present varies with the degree of alteration. Where the plagioclase is intensely saussuritized up to 4 per cent quartz occurring in irregular blebs, but never in micrographic intergrowths, is found. Augite is commonly altered to serpentine and chlorite and the opaque constituents are rimmed by sphene, indicating the presence of titaniferous magnetite or ilmenite. Pyrite is also found.

Plate XXIV

A--Photomicrograph of olivine diabase,
lot 7, concession II, Bonis township.
A= augite, O= olivine, Pl= plagioclase.
Polarized light X16.

B--Photomicrograph of quartz diabase
showing micrographic intergrowths of
quartz and plagioclase. Polarized
light X47.

The olivine diabase differs little from the ordinary diabase, except for the presence of up to 15 per cent olivine, occurring in fresh to highly altered granular grains. The plagioclase has a composition of about An_{63}, slightly more calcic than that of the ordinary diabase. Magnetite, commonly rimmed by biotite in altered varieties comprises up to 10 per cent of the whole. Pyrite is rarely seen. Augite has a reddish to slightly violet pleochroism (titanaugite?), and frequently forms reaction rims about olivine, indicating the olivine began to crystallize before augite. Both olivine and augite are ophitically intergrown with plagioclase.

The plagioclase in all the diabases is well twinned and zoning is not uncommon.

J.E.Gill and R.L'Esperance[11] in a review of diabase dikes of the Canadian Shield have summarized the various suggestions put forth to account for the origin of quartz and olivine diabase. The best hypothesis appears to be one involving differentiation of a uniform basaltic magma during crystallization. The dikes formed from magmas injected along fractures brought about either by pressure transmitted through the magma or by external tensional forces acting across the fractures or both together.

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11 Gill, J.E., and L'Esperance, R., Diabase Dikes in the Canadian Shield, Trans. Roy. Soc. Canada, Vol. XLVI, Sec. 4, 1952, pp. 25-36.

CHAPTER V

STRUCTURAL GEOLOGY

GENERAL FEATURES

Much of the data used in the interpretation of the structural geology came from outcrops exposed along the lake, in roads, and at the bases of overturned trees. The general structural relations are summarized in Figure 3, which shows the position of structural trend lines based upon measured attitudes of bedding and/or schistosity, the strike of secondary cleavage possibly developed as the result of the intrusion of the batholiths, and all top determinations made.

The metavolcanic-metasediment assemblage can be divided structurally into two main units. The Bonis volcanics which face to the north, comprise one unit, and the Steele metasediments, Steele Lake volcanics and Scapa metasediments face south and together comprise the second unit. Both units are steeply inclined and have undergone folding and compression caused by the intrusion of the batholiths and the Scapa stock.

The strike of schistosity and bedding in the assemblage ranges from S.70°E. in northern Steele township to east in Scapa township. The Steele metasediments along the shore of Northeast Bay have a general N.70°E trend. The Bonis volcanics are markedly deformed around the western margin of the Sargeant batholith.

No conclusive evidence could be obtained to indicate in which direction the Steele Lake volcanics face. Because they appear to be interbedded with the metasediments which in turn appear to face south, it is tentatively concluded that the Steele Lake volcanics overly the Scapa metasediments and are themselves overlain by the Steele metasediments.

From the above it would appear that the second unit forms a monoclinal structure facing south. However, the evidence is too incomplete to form such a conclusion. It is a good possibility that major folds do exist within this unit which would complicate the stratigraphy and make the general relationship between the rock units considerably more complex than indicated.

No closures are apparent within the metavolcanic-metasediment assemblage which suggest that the assemblage as a whole, does not plunge steeply. Drag folds and lineations plunge steeply to the east.

FAULTS

Numerous small faults were noted in many of the metasediment outcrops examined. In general two main sets appear to be present, a northeast and a northwest-trending set. The northeast set is better developed than the northwest and in a few outcrops the northeast set was noted to cut across and displace the northwest set. Left-handed movement is

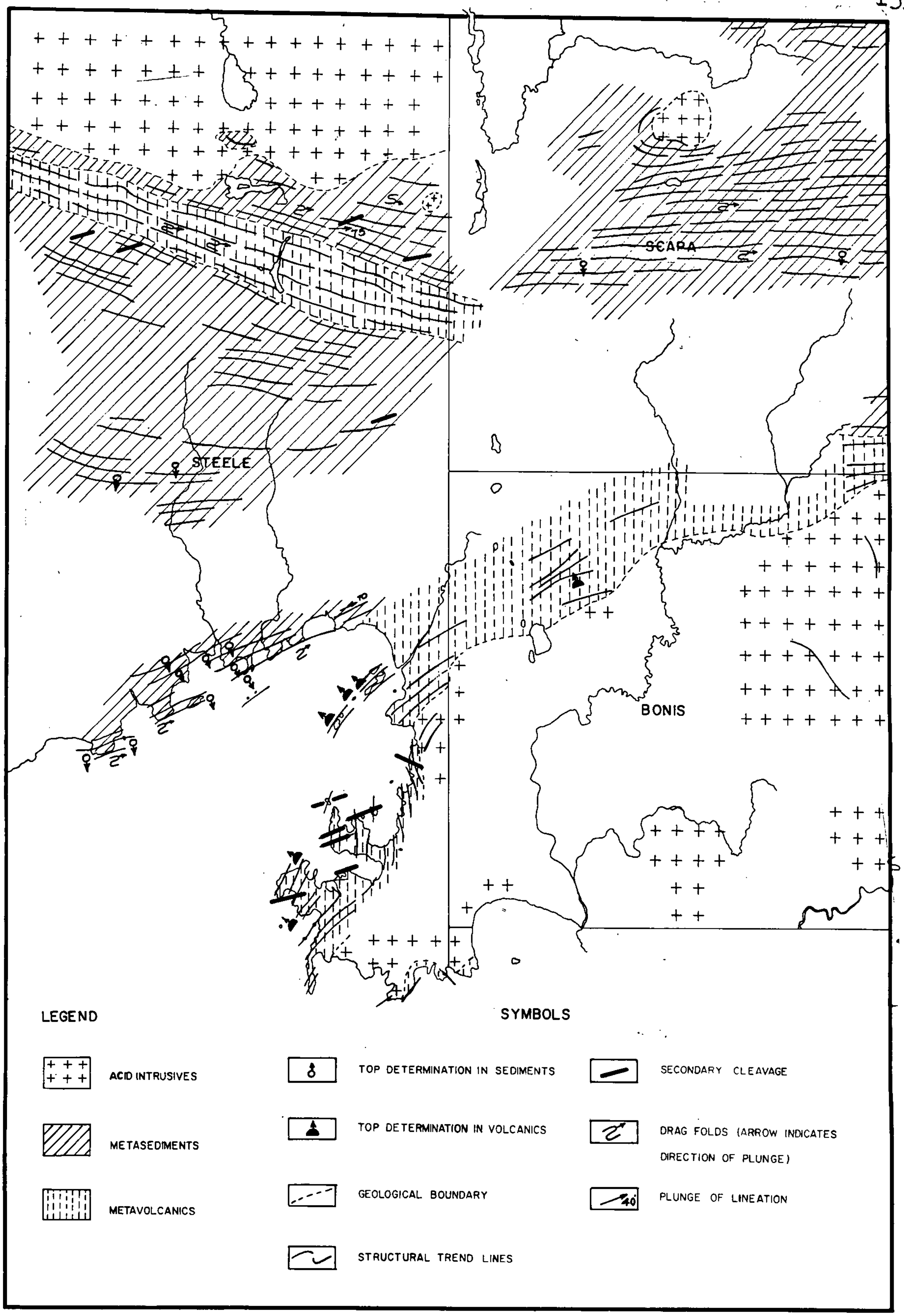

Figure 3. Sketch map showing the structural geology of Steele, Bonis and Scapa townships. Scale: 1 inch to 2 miles.

Plate XXV

Northeast-and northwest-trending faults in an outcrop in eastern Scapa township. The dark layer is a narrow basic sill. Note that the north-east set (offsetting the basic sill) is better developed than the northwest set.

common in the northeast set, and right-handed movement predominates in the northwest set. Plate XXV shows the typical development of these faults as seen in the outcrop.

Other faulting, indicated by mylonite zones, occurs in lot 1, concession E, and lot 9, concession D, Steele township and at the northern boundary in the northeast corner of Scapa township. In the latter locality the mylonite zone is about 1/2 inch wide while in the other two localities it is 1/2 to 3 feet in width. In each case the mylonite zones strike parallel to the trend of the enclosing rock. Other small faults were seen near some of the contacts between the ultrabasic and basic intrusives and the Bonis volcanics, along the eastern shore of Northeast Bay.

Numerous shear zones parallelling the regional trend of the metavolcanic-metasediment assemblage were found in the Steele Lake volcanics and the Steele and Scapa metasediments. These range greatly in width from a few inches to many feet. The largest and most consistent were found in the Steele Lake volcanics where they appear to be related to incompetent zones within the volcanics and probably formed as a result of stress exerted on the volcanics during folding and the intrusion of the batholiths. The largest shear zone (up to 700 feet wide) occurs near the southern contact with the Steele metasediments. All the shear zones within the Steele Lake volcanics are mineralized and can readily be seen in the outcrop owing to the development of rusty gossans. The shear zones dip steeply and many are vertical.

The reversal of attitudes found in the Steele metasediments and Bonis volcanics near their contact is suggestive of a fault, possibly a thrust fault. The Bonis volcanics are highly deformed and possess a poorly developed cataclastic texture near the assumed contact. The Steele metasediments are markedly sheared in the railway cut immediately west of the assumed contact and both the Bonis volcanics and Steele metasediments are moderately to strongly carbonatized there.

All these features are suggestive of a fault but they may also be explained in part by the intrusion of the porphyry dikes into the Steele metasediments, and to contact effects in the outer part of the contact zone with the Sargeant batholith. However if a fault was formed at the contact between the Bonis volcanics and the Steele metasediments as a result of the intrusion of the Sargeant batholith it would be difficult to explain the reversal in attitude.

It is more likely that this reversal is the result of thrust faulting coupled possibly with folding prior to the intrusion of the batholith. It is improbable that strike faulting would bring the two units together with their present attitudes.

The northeast-trending diabase dike occurring in

Scapa township is apparently cut by a northeast fault near the eastern boundary of the township. The evidence for the fault was obtained mainly from air photographs. The fault occupies a narrow gully to the east of which the dike is sharply dragged to the south. To the west of the fault the dike lies about 200 feet north of its position on the eastern side.

The offset of late diabase dikes by northeast-trending faults has been noted in Quebec[1] and faulting of the diabase dikes occurring to the south of Lake Abitibi appears to be common.

STRUCTURES RELATED TO THE ACID INTRUSIONS

The regional structure of the metavolcanic-metasediment assemblage has been sharply deflected around the western end of the Sargeant batholith. Both the Sargeant and Case batholiths appear to be concordant with the metavolcanics and metasediments. The shape of the Case batholith is not known but the Sargeant batholith is roughly elliptical in plan with its long axis trending parallel to the regional structure.

Plotting the planes of schistosity, occurring in the Bonis volcanics, on a stereogram shows that these rocks

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1 Gill, J.E., The Canadian Precambrian Shield, Jubilee Volume, Can. Inst., Min. Met., 1948, p. 29.

plunge steeply around the western margin of the Sargeant batholith. The steep plunge is probably due to the intrusion of the batholith.

The Scapa stock has highly crumpled and folded the metasediments at its contact but does not appear to have had any marked effects on the general trend of the metasediments away from the contact. The metasediments display erratic dips in the contact zone, although near the western end of the intrusion the bedding appears to dip about 40° towards the contact. This body is probably a concordant intrusion.

Numerous smaller structures have been formed in the metasediments and metavolcanics possibly as a result of the intrusion of the batholiths. A regional or secondary cleavage occurs in the metasediments and ultrabasic and basic intrusives, particularly in the vicinity of the Sargeant batholith and the borders of the Steele Lake volcanics. The strike of the cleavage trends east-northeast.

JOINTING

Jointing was noted in a few places. From the few readings made it appears that there are two major sets, one striking to the north and dipping nearly vertically and the second lying horizontally and approximately at right angles to the first.

CHAPTER VI

CENOZOIC

PLEISTOCENE

During the Pleistocene Epoch four glacial stages occurred south of the Great Lakes. Within the map-area record of only the last stage, the Wisconsin ice-sheet is found.

When the ice-margin of this ice-sheet had retreated from south of the Great Lakes to a point beyond the continental divide, north of the Upper Great Lakes, glacial Lake Barlow-Ojibway was impounded between the height of land and the retreating ice-margin. This lake expanded northward beyond the map-area and attained a maximum width of 150 miles and a length of about 600 miles.[1] Lake Abitibi is one of the larger remnants to be found in the clay belt of Northern Ontario of glacial Lake Barlow-Ojibway.

Before the glacial lake drained completely, a re-advance of the ice-sheet (Cochrane advance) occurred from a point at least 35 miles north of the town of Cochrane. The southern limit of the advance has not been completely mapped. No indication of the Cochrane advance was found in the map-area.

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1 Geology and Economic Minerals of Canada, Economic Geology Series, No. 1 (4th ed), Geol. Surv. Canada, 1957, p. 480.

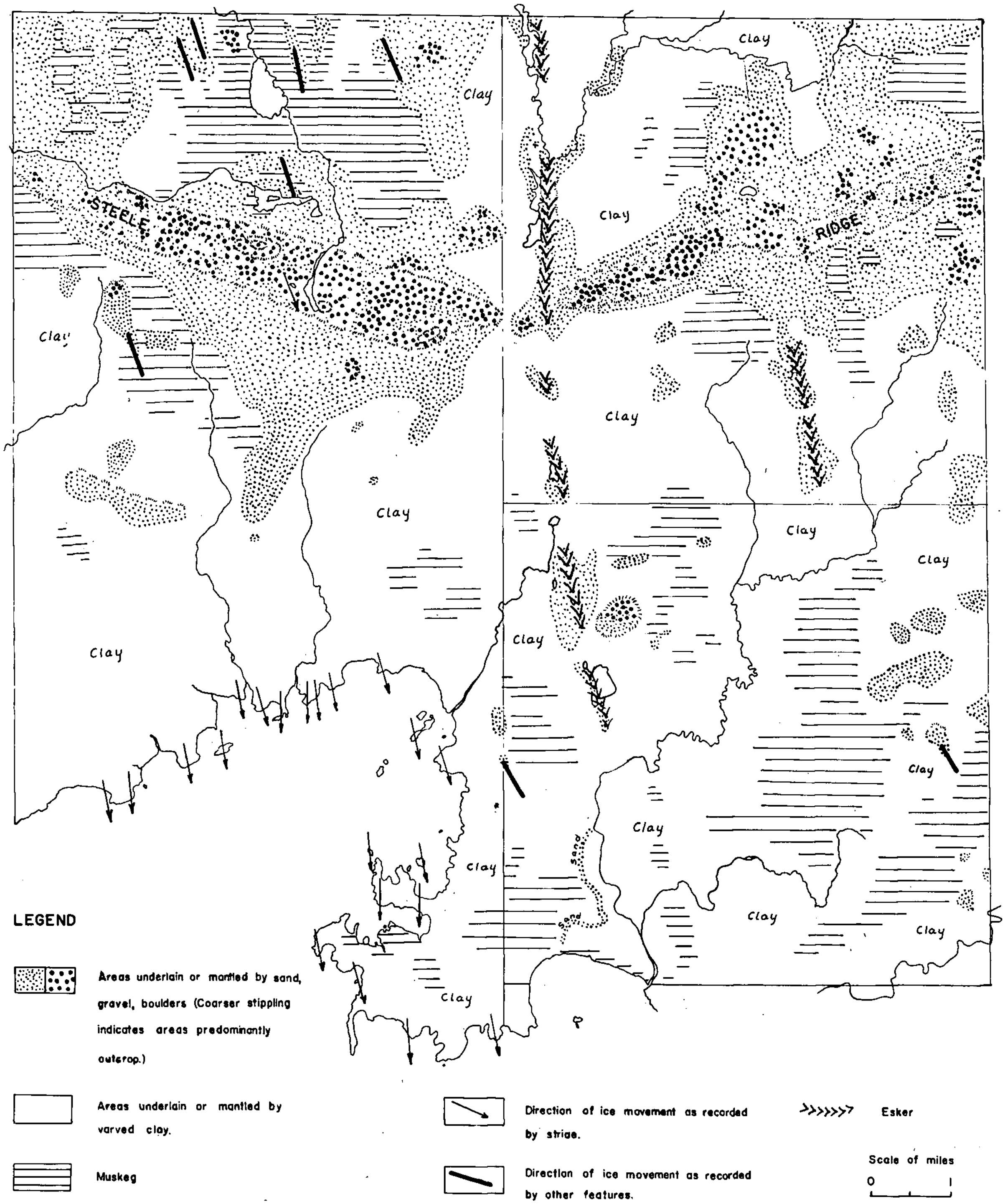

Figure 4. Sketch map of the Pleistocene geology of the map-area showing the latest movement of the Wisconsin ice-sheet and the distribution of glacial, glacio-fluvial, and Barlow-Ojibway deposits.

O.L. Hughes,[2] in mapping the surficial geology to the west of Steele township, has divided the Pleistocene deposits into several categories, most of which were recognized within the map-area. These deposits are described below and their distribution is shown in Figure 4.

The average of some 70 readings of glacial striae obtained from storm-washed outcrops along the shores of Northeast Bay indicate that the latest direction of movement of the Wisconsin ice-sheet was S.9°E. Glacial striae were noted on inland outcrops only in lot 5, concession III, Steele township and the direction measured agrees with that determined from the striae on outcrops along the lake shore. In addition, the orientation of modified glacial deposits and eskers also indicate that the latest movement of the ice-sheet was south-southeast. The latest direction of movement of the ice-sheet, as determined within the map-area, agrees favourably with that determined by Hughes.

GLACIAL DEPOSITS

Glacial deposits were seen on the flanks of many of the bedrock exposures and they are particularly well scattered about Steele ridge, both in Steele and Scapa townships. Most of the glacial deposits have been modified by wave-action of glacial Lake Barlow-Ojibway to large concentrates of boulders and in places to beach deposits of boulders and

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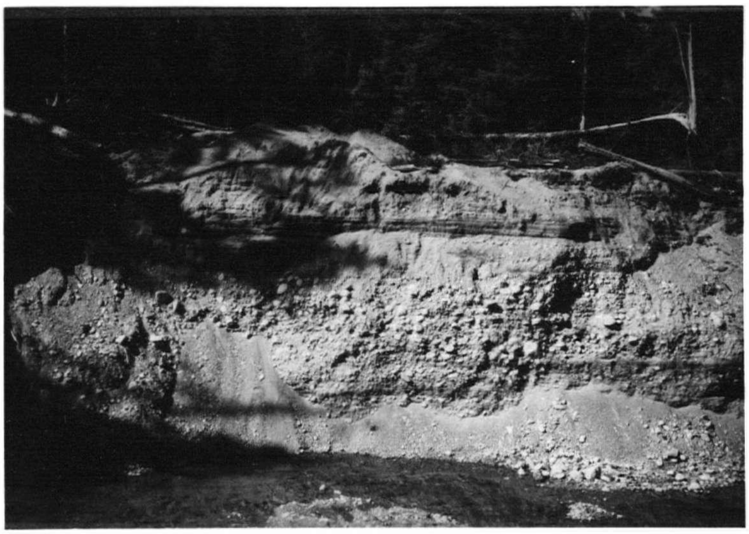
2 Hughes, O.L. Surficial Geology, Iroquois Falls, Cochrane District, Ontario, Map 46-1959, Geol.Sur.Canada,1959.

Plate XXVI

A--Gravel pit in the prominent esker striking south through the centre of the map-area. Lot 11, concession V, Bonis township.



B--Stratified gravel as seen in a gravel pit on the southern slope of Steele ridge. Lot 2, concession II, Steele township.

gravel. Examples of the latter type of deposit occur in lots 2 and 3, concession VI, Steele township.

GLACIOFLUVIAL DEPOSITS

The main glaciofluvial deposits are the prominent esker in the centre of the map-area, lying immediately to the east of the eastern boundary of Steele township and the small esker in the south-central part of Scapa township. Both eskers have been more or less modified, presumably by the waters of glacial Lake Barlow-Ojibway.

Numerous Kames were seen in the northwestern corner of Steele township and scattered through the apron extending south from Steele ridge in Steele township.

Some of the sand and gravel deposits adjacent to the southern slope of Steele ridge in Steele township are stratified and may be in part of glaciofluvial origin.

BARLOW-OJIBWAY VARVED CLAY

Varved clay, deposited in glacial Lake Barlow-Ojibway by subglacial streams, underlies most of the area. Varved clay is particularly abundant in southern Steele township and in Bonis and the southern part of Scapa townships. Varved clay lapped up onto the flanks of the eskers was noted in road cuts along the main haulage road in lot 11, concession V, Bonis township, and in Scapa township. Fine sand and silt were seen interbedded with the varved clays where they lap the flanks of the eskers. Thin beds of silt also occur intercalated with the varved clays in the north-central portion of Bonis township.

BARLOW-OJIBWAY SAND AND GRAVEL

The triangular apron extending south from the southern slope of Steele ridge appears to overlie the varved clay in many places. The apron probably originated from sand and fine gravel washed from the glacial and glaciofluvial deposits bordering Steele ridge by the waters of glacial Lake Barlow-Ojibway. Sand deposits overlying clay on the flanks of the eskers probably have a similar origin. Other sand and gravel deposits north of Steele ridge in Steele township may also have originated from the wave-action of Lake Barlow-Ojibway but owing to their poor exposure it could not be confirmed that these deposits overlie the clay.

The sparse distribution of sand and gravel along higher elevations in Steele ridge and a few of the other rock knobs occurring in the map-area suggests that these were at one time islands in glacial Lake Barlow-Ojibway. The beach deposits noted in lots 2 and 3, concession VI, Steele township are at a lower elevation than the bare rock knobs along Steele ridge. This indicates that the glacial lake probably shallowed considerably as the result of isostatic adjustments following the retreat of the ice-sheet and was broken up into several smaller lakes. Case Lake could be a remnant of such a lake.

RECENT

Recent deposits consist mainly of woody sphagnum peat and other organic material now collecting in the swamps and muskegs. Boulder gravel, sand, and pebble gravel beaches are being formed along the shores of Northeast Bay and some detrital material is also being deposited along stream valleys.

CHAPTER VII

ECONOMIC GEOLOGY

Prospectors and exploration companies have been active in the map-area for more than 50 years. Stripping, surface trenching, diamond drilling, air-borne and ground geophysical surveys, and geochemical surveys have been carried out but no deposits of economic value have, as yet, been proved. Most of the exploration work has been confined to the areas underlain by the metavolcanic rocks.

SULPHIDE MINERALIZATION

Sulphide mineralization occurs mainly as replacement deposits in shear zones and in association with quartz veins in the metavolcanics. Minor amounts of pyrite, pyrrhotite, and chalcopyrite are found in quartz veinlets cutting porphyry dikes.

The majority of mineralized quartz veins were seen within the contact zone between the Bonis volcanics and the Sargeant batholith. The veins are commonly less than 3 inches wide and irregular, with scattered pyrite, and rare chalcopyrite and pyrrhotite mineralization occurring near their walls. Molybdenite is rare in quartz veins cutting the Steele Lake volcanics.

Fifty mineralized and concordant shear zones, ranging from less than one foot to 350 feet wide, were mapped in the Steele Lake volcanics. The shear zones are most abundant near the northern and southern contacts with the metasediments and the widest shear zones occur near the contact with the Steele metasediments in lots 2 and 3, concessions II and III, Steele township. Shear zones are also well-developed near the metasediment interbedded with the volcanics. Here and there, the shear zones appear to have formed in the vicinity of flow contacts.

The longest shear zone mapped measured about 1900 feet along strike but most are considerably shorter than this. Although some shear zones may be continuous with one another, most appear to be unrelated and to grade abruptly into non-sheared volcanics. Mineralization within the shear zones consists mainly of massive and disseminated pyrite and pyrrhotite, occurring as layers up to 8 inches wide and concordant with the strike and dip of the shear zones. Chalcopyrite is rare and sphalerite very rare.

Silicified massive rocks, alternating with amphibole, chlorite, and mica-rich schists, and quartz stringers occur in the shear zones. Narrow trains of garnet are common in the silicified rocks but rare in the schists. The metavolcanics adjacent to the shear zones are silicified and markedly amphibolitized.

Twenty-four grab samples taken from shear zones showed only traces of copper, lead, zinc, nickel, gold and cobalt, upon assay. The low assays appear to confirm the apparent scarcity of copper, lead, and zinc mineralization noted in the outcrop and they further indicate that nickel and gold are not present in economic proportions.

IRON

The iron-formation occurring in the Scapa meta-sediments is of very low grade and limited in extent, with most of the iron occurring in the form of silicates. It is not at present of economic interest.

LITHIUM

The most interesting rock in the map-area from an economic standpoint, appears to be the complex pegmatite occurring in the Case batholith in lot 5, concession V, Steele townhip. The pegmatite has been described in connection with the discussion of the Case batholith. The dike was traced in an east-west direction for a distance of 825 feet along strike and it attains a maximum width of 100 feet. The dike "horse-tails" into several stringers at its western end and is covered by vegetation and glacial debris at the eastern end of its outcrop area.

The only mineral of economic significance in the dike appears to be the spodumene which occurs as well-formed crystals up to 3 feet long and 6 inches in cross-section. The spodumene content of the dike is estimated at 10 to 15 per cent. It is best developed in the quartz-rich core of the dike, although a few crystals were noted in pegmatitic stringers extending from the dike into the surrounding quartz monzonite. A grab sample taken from the dike assayed 0.65 per cent lithium and showed a trace of beryllium. Carefully selected spodumene gave 7.63 per cent Li_2O upon analysis.

The presence of spodumene pegmatite in the Case batholith suggests comparison with the Lacorne batholith some 110 miles to the southeast of the map-area in the province of Quebec. Recent studies of the Preissac-Lamotte-Lacorne region by Siroonian, Shaw and Jones[1] shows it to constitute a Li-rich geochemical province. The occurrence of spodumene pegmatite in the Case batholith deserves the attention of prospectors and exploration companies and further work may reveal a similar Li-rich geochemical province within the region underlain by the batholithic intrusives partly mapped during the 1959 field season.

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1 Siroonian, H. A., Shaw, D.M., and Jones, R.E., Lithium Geochemistry and the Source of the Spodumene Pegmatites of the Preissac-Lamotte-Lacorne Region of Western Quebec, Can. Min., Vol. 6, pt. 3, 1959, pp. 320-338.

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