KILLEEN

This document was produced
by scanning the original publication.

Ce document est le produit d'une
numérisation par balayage
de la publication originale.

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

MEMOIR 143

NORTH SHORE OF LAKE HURON

BY

W. H. Collins

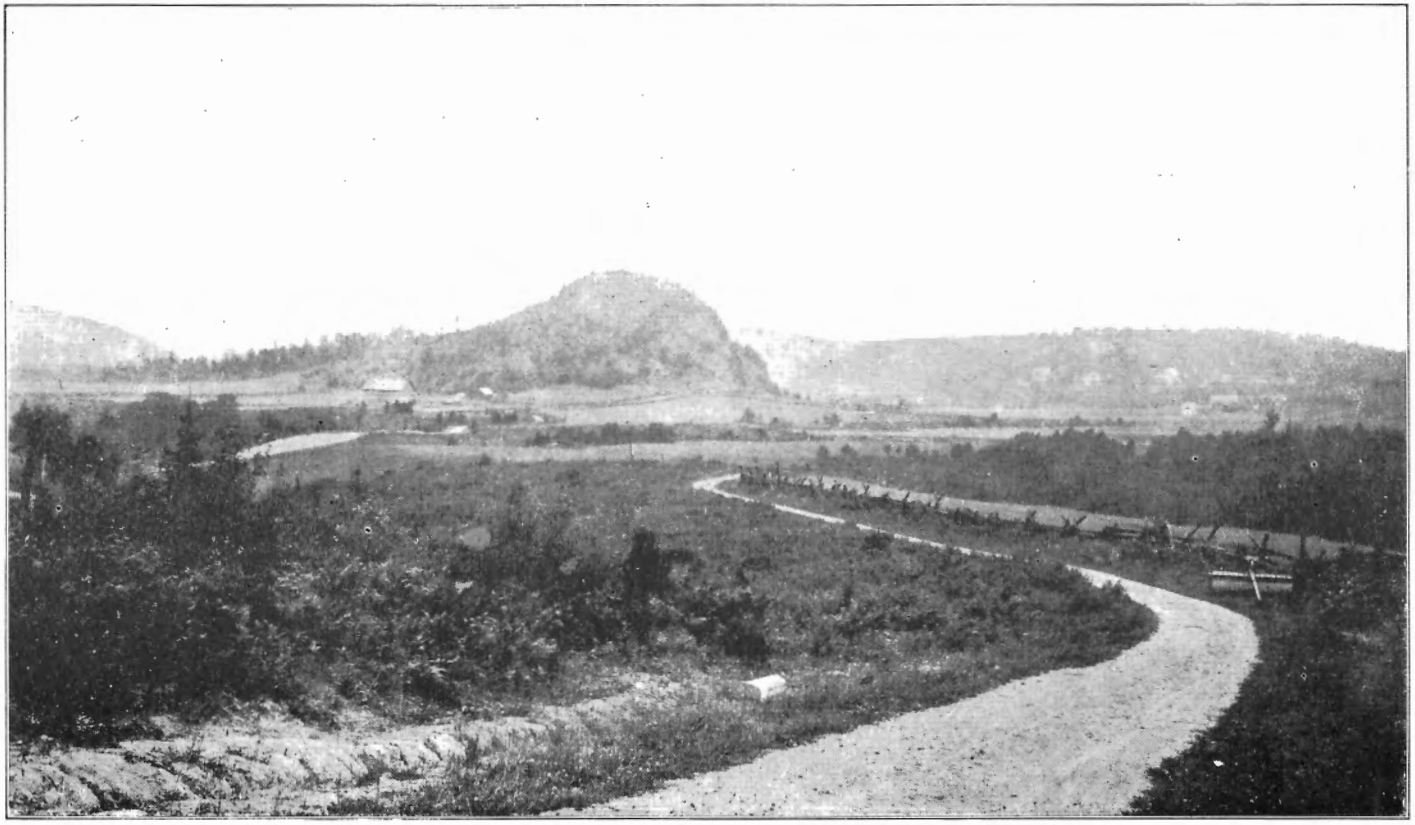
FIRST PRINTING 1925

—

REPRINTED BY

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1956

Price, 75 cents. No. 2052



View looking east from Thessalon River crossing, concessions II and III, Aberdeen township, characteristic of the higher parts of the North Shore district in which later beds occur. (Page 10.)

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

MEMOIR 143

NORTH SHORE OF LAKE HURON

BY

W. H. Collins

FIRST PRINTING 1925

REPRINTED BY

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1956

Price, 75 cents. No. 2052

CONTENTS

PAGE

CHAPTER I

Introduction 1

CHAPTER II

General character of the district 8

CHAPTER III

Stratigraphy 15

CHAPTER IV

Structural geology 98

CHAPTER V

Correlation 109

CHAPTER VI

Economic geology 115

Index 155

Illustrations

Map 1969. Bruce Mines, Algoma district, Ont ..... (Not available
" 1970. Blind river, Algoma district, Ont ..... for 1956
" 1971. Lake Panache, Sudbury district, Ont ..... Reprint)

Plate I. View looking east from Thessalon River crossing, concessions II and III, Aberdeen township ..... Frontispiece
II. Deforested sand-plain, Bridgland township, north of Thessalon 139
III. A. Irruptive contact of pre-Huronian granite gneiss with older schist-complex near Thessalon 140
B. Gradational contact between conglomeratic base of Mississagi quartzite and pre-Huronian granite gneiss near Thessalon 140
IV. A. Bruce conglomerate near Blind River 141
B. Photomicrograph of Bruce conglomerate 141
V. A. Bruce limestone, coast of lake Huron, just west of Bruce Mines. 142
B. Photomicrograph of iron-bearing basal part of the Bruce limestone 142
C. Photomicrograph of silty layer in Bruce limestone 142
VI. A. Detail of weathered surface of Espanola greywacke 143
B. Characteristic breccia in Espanola greywacke 143
VII. A and B. Quartzite "dykes" intersecting Espanola greywacke 144
VIII. A and B. Photomicrographs of Espanola greywacke: (A) unaltered; (B) recrystallized by contact action with Killarney granite 145
IX. A. Serpent quartzite showing characteristic thin lamellation 146
B. Photomicrograph of Serpent quartzite 146
C. Photomicrograph of quartzite dyke intersecting Serpent and Espanola formations 146
X. A, B, C. Types of conglomerate in Gowganda formation 147
XI. A. Photomicrograph of matrix of boulder conglomerate belonging to Gowganda formation 148
B. Photomicrograph of laminated greywacke conglomerate 148
XII. A. Conglomeratic phase of Lorrain quartzite (red jasper conglomerate) 149
B. Photomicrograph of red quartzite from near base of Lorrain quartzite 149
C. Photomicrograph of Lorrain quartzite from near top of formation 149

74009—1½

PAGE

Plate XIII. A. Photomicrograph of banded cherty quartzite 150
B. Contact of Gowganda conglomerate with Serpent quartzite 150
XIV. A. Photomicrograph of ordinary quartz diabase from a sill 151
B. Photomicrograph of aplitic differentiate from the quartz diabase intersected by a hornblende vein of still later differentiation .. 151
XV. A. Fragment of quartzite enclosed in and partly assimilated by diabase 152
B. Photomicrograph of interaction product between quartzite and diabase 152
XVI. A. Weathered surface of olivine diabase dyke, Magpie mine, Michipicoten district 153
B. Spheroidal weathering in olivine diabase dykes 153
XVII. A. View eastward along Lauzon lake, Blind River area 154
B. Plant of Martin International Trap Rock Company, Bruce Mines 154

Figure 1. Index map 3
2. Map-diagram showing probable distribution of schist-complex, sediments, and granite gneiss in the pre-Huronian basement, north shore of lake Huron 18
3. Diagrammatic vertical section of Mississagi quartzite 31
4. Diagrammatic vertical section of Bruce limestone 48
5. Vertical sections through the Gowganda formation 64
6. Sketch of pebble in laminated greywacke 66
7. Diagrammatic vertical section from north to south across the North Shore district showing effects of Killarnean diastrophism and batholithic intrusions 100
8. Map-diagram of North Shore district showing known extent and relative intensity of the Killarnean diastrophism 102
9. Vertical sections indicating topographic relief of the Precambrian surface upon which the Palæozoic sediments were deposited 108

North Shore of Lake Huron

CHAPTER I

INTRODUCTION

PURPOSE

Mining camps are for several reasons the locations around which intensive field studies in geology are mostly concentrated. Accurate information is essential for the direction of mining operations; geological and mineralogical problems of special interest are found in such places, and the mining operations themselves afford exceptional opportunities for detailed examination. Mining camps, however, are apt to be far apart and the geological data obtained from them are correspondingly difficult to correlate and reduce to common terms. Particularly is this true of data relating to stratigraphy and its allied subjects, classification and nomenclature, and more particularly in complex terrains like the Precambrian. It becomes necessary, therefore, for the geologist to supplement from time to time the detailed studies in mining districts with a certain amount of connective, or correlational work, in order that all can be woven together into larger contributions to earth history.

The point is well exemplified in northeastern Ontario, a Precambrian region of some 75,000 square miles lying to the northeast of lake Superior and lake Huron. Most of this region is poorly known by geologists. If its geological history were to be written now, that history would have to be based largely upon what is known about three comparatively small mineralized portions which alone have been more thoroughly studied than the rest. The first of these, once an important copper producer, lies along the north shore of lake Huron. This district—one of the first in America to be investigated in detail—was studied between 1847 and 1858 by Logan and Murray, the first officers of the Geological Survey. Murray discovered in it a thick sequence of Precambrian sedimentary rocks, not theretofore known to geologists, which he and Logan named the Huronian. The succession was so complete and so carefully described that it became a standard of reference for later workers, and the district containing it came to be known as the original Huronian district. A second district of like importance is that which contains the great copper-nickel ore deposits near Sudbury. Sudbury district has been investigated by many geologists since 1884, when the size and richness of its ore-bodies first began to be recognized. Through the efforts of Barlow, Coleman, Walker, and latterly of Knight, it has become the most intensively studied of all Precambrian areas in Canada, and its geology has proved to be complex and different in many respects from that of the original Huronian district. Cobalt district is the third. What the copper-nickel deposits did for the geological investigation of Sudbury, the silver-cobalt ore deposits have since done for Cobalt district. Its geology as interpreted by Miller and Knight of the Ontario Department of Mines, differs so radically from that of Sudbury and the original Huronian that a geological account of northeastern Ontario would be incomplete without reference to Cobalt district.

Some other parts of northeastern Ontario have been studied in like detail, but they contribute little additional information to the geology of the region. If what is known about these three districts can be combined and written in common terms the result will be as complete a geological history of the whole region as the present state of geological exploration admits. Sudbury district, however, is separated from the original Huronian district by 125 miles of country which, until the present investigation was concluded, had been very imperfectly explored. A gap 70 miles wide separates Cobalt from Sudbury. These gaps made it impossible to determine with certainty the equivalence of the geological successions in the three critical districts. It was this circumstance which forced Coleman to devise a special nomenclature for the Sudbury succession, and Miller another for that at Cobalt. The same circumstance greatly hindered all such attempts as were made from time to time to prepare general geological maps of northeastern Ontario.

The correlation of what is known concerning Cobalt, Sudbury, and the original Huronian districts is the most important step that has been taken recently toward obtaining a coherent geological conception of this area. Owing to the peculiar difficulties of Precambrian geology, this could be done with precision only by tracing formations from one district to another with as little interruption as the intervening country permits. The Geological Survey has been directly engaged with this problem for a number of years. Between 1908 and 1913 the 70-mile interval between Cobalt and Sudbury was explored,[1] and an equivalence was established between the geological sequence of these districts as defined by Miller and Coleman. In 1914 the work of linking up Sudbury with the original Huronian district was begun and after three seasons of field work it was possible to correlate the succession in both Cobalt and Sudbury districts with that in the original Huronian district.

This report deals with the results obtained in the original Huronian district during 1914-1916, and is, therefore, one phase of the larger correlation problem just outlined.

When linking up Cobalt and Sudbury districts the stratigraphy of these as stated by Coleman and Miller was assumed to be correct since it had been worked out recently and by geologists whose conclusions could be accepted with confidence. Accordingly, the Survey's attention was confined altogether to the little-known country between these districts. Something more, however, was thought advisable during 1914-1916. The original Huronian district had, it is true, also been investigated by two able geologists, Logan and Murray; but their work had been done sixty years before, at a time when the district was difficult of access, and was heavily forest covered, and when geological opinions were held which have since been discarded. It was not expected that Murray's results, after that lapse of time, would still satisfy modern stratigraphic requirements. Consequently, the work of 1914-1916 was undertaken with the object of revising the stratigraphy of the original Huronian district, and then by

[1] Geol. Surv., Can., Mems. 33, 95; Sum. Rept., 1912, pp. 307-309.

a study of the country between the two districts, correlating the revised succession with Coleman's succession at Sudbury.

Now that the work is completed it is apparent that these reservations about Murray's geology were not entirely justified. A good deal has been added to his results—that was only to be expected—but none of his results was found to be wrong. On the contrary, a number of important conclusions reached by Murray, and afterwards declared by geologists who succeeded him to be incorrect, have been substantiated; for instance, the Huronian age of the sedimentary formations southwest of Sudbury, and the existence of granites intrusive in the Huronian. It is highly gratifying to find that, after sixty years, Murray's work remains an unchanging memorial to the ability of this pioneer Canadian stratigrapher.

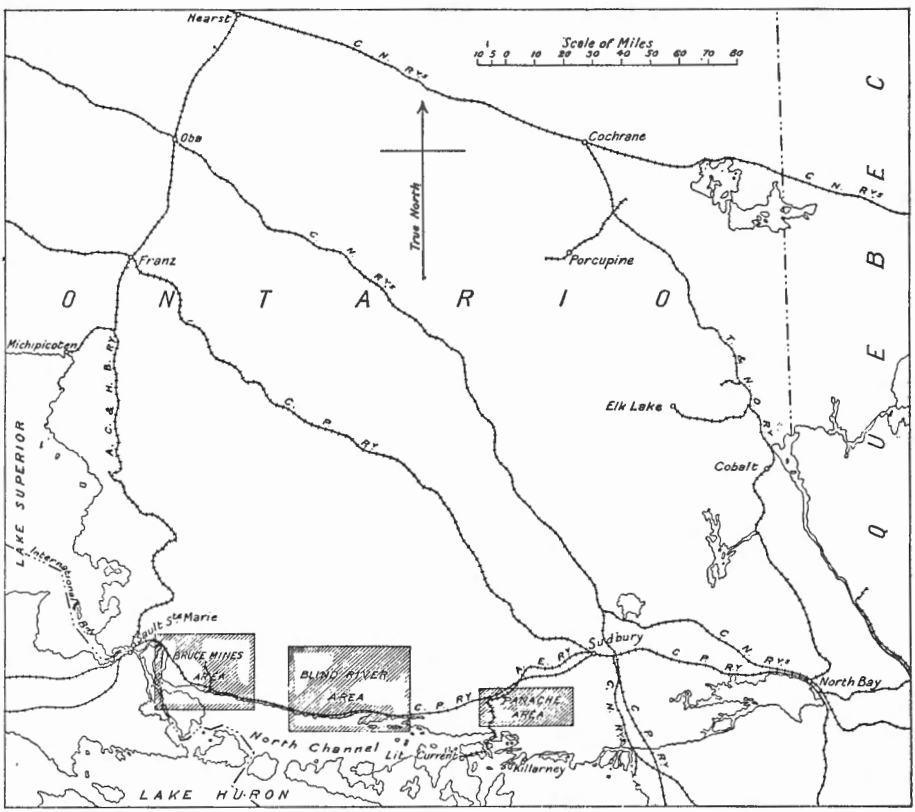


Figure 1. Index map showing positions of Bruce Mines, Blind River, and Panache map-areas, north shore of lake Huron.

WORK DONE

The original Huronian district, together with the interval between it and Sudbury district, is a strip of country 125 miles long and 4,000 square

miles in extent. Instead of devoting many years to the exploration of all this territory, the investigation was accelerated by selecting for rather detailed study a series of small key areas which would afford as complete a stratigraphical succession as possible and would at the same time be so closely spaced across the 125-mile strip that the geological succession in one area could be identified with that in the next without much liability to error. Key areas were begun at Echo lake, Bruce Mines, Thessalon, Blind River, Whiskey lake, Espanola, and Round lake. But, as the solution of the problem advanced, the correlational difficulties increased and it became necessary to enlarge some of these areas and to make supplementary explorations between them. In order to include as much of this supplementary work as possible and to make the relative positions of the key areas easily apprehended, the areas mapped have been combined to form the three coloured maps (Nos. 1969, 1970, 1971) which accompany this report.

One circumstance that chanced to obtain during the period of field work gives the writer confidence in the data and conclusions set forth in this report and in the three accompanying maps. His field work was done mainly in 1914-16, with some additional work in 1917 and 1918. During most of this time he had associated with him Dr. T. T. Quirke, of the University of Illinois, and during 1915 Dr. Quirke carried on his investigations independently in the western end of the Panache map-area.[1] In 1922, publication of the three maps having been delayed, Dr. Pentti Eskola, of the University of Helsingfors, and of the Geological Survey of Finland, undertook to fill in a number of blank patches on the Panache sheet, and some also on the Blind River sheet; townships 138 and 139; and on the islands in lake Huron. Again in 1923 and 1924 Dr. R. C. Emmons, of the University of Wisconsin, added materially to the geological information upon Bruce Mines map-area by mapping the eastern tier of townships from Otter southward and also from Otter township westward to Echo lake. The map-work, and conclusions regarding the geological succession and structure reached by these three geologists, are so completely in accord with those of the present writer that no need has arisen for expression of divergent opinion.

FIELD METHODS

The existing township and railway surveys supplied most of the information necessary for the geographical maps. Supplementary surveys of lakes and streams were made with a Rochon micrometer and prismatic compass, those of the roads with telemeter and compass. All the information on uncoloured parts of the maps was taken from earlier maps and plans.

The elevations given on the maps for lakes, and the heights of falls and rapids were determined with a mounted hand-level, the levels being run from well-established elevations on lake Huron and the Canadian Pacific railway.

[1] Geol. Surv., Can., Mem. 102.

Geological boundaries away from surveyed lines, roads, and shorelines were located by pacing. Wherever the thickness of a formation could be measured by tape or pacing this method was used, but where, as in most cases, the country was not hilly enough and the formations were not steeply enough inclined to afford sections measurable in this way, less reliable estimates had to suffice. The figures given are believed to be within 10 per cent of accuracy, except where thousands of feet are involved.

ACKNOWLEDGMENTS

During the three seasons spent upon the north shore of lake Huron much valuable assistance was given for one or more seasons by Dr. T. T. Quirke, J. R. Marshall, W. E. Cockfield, H. J. Heath, Angus McLeod, E. W. Todd, Arthur Benoit, O. D. Boggs, and W. F. Chisholm. The geology of Foster and Merritt townships was done independently by Dr. Quirke and forms the subject of a separate memoir (No. 102). Several unfinished parts of Panache area and also townships 138 and 139 and the islands in lake Huron within the Blind River map-area were mapped by Dr. Pentti Eskola. The eastern and northern parts of Bruce Mines map-area were surveyed by Dr. R. C. Emmons. A great deal of work which had been done in Bruce Mines area two years before by Mr. E. D. Ingall[1], was used in the preparation of that map-sheet. The geography and some of the geology in townships 137 and 138 are from earlier work by Professor A. P. Coleman[2]. During the whole period of field work the party had the benefit of courteous and valuable aid from the residents in the district.

BIBLIOGRAPHY

Barlow, A. E.—"On the Contact of the Huronian and Laurentian Rocks North of Lake Huron." Am. Geol., vol. 6, 1890, pp. 19-32.
"On the Relations of the Laurentian and Huronian on the North Side of Lake Huron." Am. Jour. Sc., 3rd ser., vol. 44, 1892, pp. 236-239.
"Relations of the Laurentian and Huronian Rocks North of Lake Huron." Bull. Geol. Soc. Am., vol. 4, 1893, pp. 313-332.

Bell, Robert.—"The Laurentian and Huronian Systems North of Lake Huron." First Ann. Rept., Bureau of Mines, Ont., 1891, pp. 63-94.
Geol. Surv., Can., Ann. Rept., vol. V, pt. I A, pp. 31-35.
Idem, vol. VI A, pp. 30-33.
Idem, vol. VII A, pp. 52-55.
"Report on the Geology of the French River Sheet, Ontario." Geol. Surv., Can., Ann. Rept. vol. IX, pt. 1, 1898, pp. 29.

Bigsby, J. J.—"Geological and Mineralogical Observations on the Northwest Portion of Lake Huron." Am. Jour. Sc., 1st ser., vol. 3, 1821, pp. 245-272.
"On the Cambrian and Huronian Formation." Quart. Jour. Geol. Soc., vol. 19, 1863. pp. 36-52.

Channing, W. F.—"Report of an Exploration of Several Points on the St. Mary's River." Exec. Documents 1st session 30th Congress, Washington, No. 2, vol II, 1847-48, pp. 199-209.

[1] Geol. Surv., Can., Sum. Rept., 1904, pp. 179-190.
[2] Ann. Rept., Ont. Bureau of Mines, 1913, pp. 146-160.

Coleman, A. P.—"Copper Regions of the Upper Lakes." Bur. of Mines, Ont., Ann. Rept., vol. VIII, pt. II, 1899, pp. 121-174.
"The Whiskey Lake Area." Bur. of Mines, Ont., Ann. Rept., vol. XXII, pt. 1, 1913, pp. 146-154.
"The Massey Copper Mine Area." Bur. of Mines, Ont., Ann. Rept., vol. XXII, pt. I, 1913, pp. 155-160.
"The Pre-Cambrian Rocks North of Lake Huron." Bur. of Mines, Ont., Ann. Rept., vol. XXIII, pt. I, 1914, pp. 202-236.

Collins, W. H.—Geol. Surv., Can., Sum. Rept., 1914, pp. 81-82; Sum. Rept., 1915, pp. 136-137; Sum. Rept., 1916.
"The Huronian Formations of Timiskaming Region, Can." Geol. Surv., Can., Mus. Bull. No. 8, 1914, pp. 27.
"The Age of the Killarney Granite." Geol. Surv., Can., Mus. Bull. No. 22, 1916, pp. 12.

Graton, L. C.—"Up and Down the Mississaga." Bur. of Mines, Ont., Ann. Rept., vol. XII, 1903, pp. 157-172.

Ingall, E. D.—"Geology of the Bruce Mines District." Geol. Surv., Can., Sum. Rept., 1902-03, pp. 244-254.

Ingall, E. D., and Denis, Theo.—"Geology of the Country Around Bruce Mines." Geol. Surv., Can., Sum. Rept., 1904, pp. 179-190.

Irving, R. D.—"Is There a Huronian Group?" Am. Jour. Sci., 3rd series, vol. XXXIV, 1887, pp. 204-216, 249-263, 366-374.

Knight, C. W.—"The North Shore of Lake Huron." Bur. of Mines, Ont., Ann. Rept., vol. XXIV, pt. I, 1915, pp. 216-241.

Lawson, A. C.—"The Correlation of the Pre-Cambrian Rocks of the Region of the Great Lakes." Univ. of California, Dept. of Geology, Bull. vol. X, No. I, pp. 19.

Logan, W. E.—"Report of the Geological Survey of Canada, on the North Shore of Michigan." Exec. Documents 1st session 20th Congress, Washington, No. 2, vol. II, 1847-48, pp. 183-189.

Logan, W. E.—"Report of the Geological Survey of Canada, on the North Shore of Lake Huron." 1849, pp. 8-20.
"On the Footprints Occurring in the Potsdam Sandstone of Canada." Quart. Jour. Geol. Soc., vol. VIII, 1852, pp. 199-213.
Geol. Surv., Can., Rept. of Prog., 1857, pp. 1-12.
"On the Division of the Azoic Rocks of Canada into Huronian and Laurentian." Proc. Am. Assoc. Adv. Sci., 11th Meeting, pt. 2, 1857, pp. 44-47.
Geology of Canada, 1863, pp. 50-66.

Murray, Alexander.—"On the North Coast of Lake Huron." Geol. Surv., Can., Rept. of Prog., 1847-48, pp. 93-124.
"On the Geology of Parts of the Coast of Lake Huron, the Spanish River, etc." Geol. Surv., Can., Rept. of Prog., 1848-49, pp. 7-46.
"On the Topographical and Geological Features of the Region between the Ottawa River and Georgian Bay, as well as North of Lake Huron." Geol. Surv., Can., Rept. of Prog., 1853-56, pp. 59-190.
"On the Coast at the Mouth of French River, Georgian Bay; on Echo Lake and Its Environs; and on the Limestone of Bruce Mines." Geol. Surv., Can., Rept. of Prog., 1857, pp. 13-27.
"On the Country between the Thessalon River and Lake Huron, and Between the Thessalon and Mississagui." Geol. Surv., Can., Rept. of Prog., 1858, pp. 67-100.

Pumpelly, Raphael, and Van Hise, C. R., "Observations Upon the Structural Relations of the Upper Huronian, Lower Huronian, and Basement Complex on the North Shore of Lake Huron." Am. Jour. Sci., 3rd ser., vol. XLIII, 1892, pp. 224-232.

Quirke, T. T.—"Espanola District, Ontario." Geol. Surv., Can., Mem. 102, 1917, pp. 87.

Special Committee on Pre-Cambrian Nomenclature for the Lake Superior Region. Geol. Surv., Can., Sum. Rept. 1904, pp. XVIII-XXVIII; Jour. Geol., vol. XIII, 1905, pp. 89-104.

Van Hise, C. R., and Leith, C. K.—"Pre-Cambrian Geology of North America." U.S. Geol. Surv., Bull. 350, pp. 403-447.

Winchell, Alexander.—"Observations in the Typical Huronian Region of Canada." Sixteenth Ann. Rept. Geol. and Nat. Hist. Survey of Minnesota, 1887, pp. 145-171.

"Recent Observation on Some Canadian Rocks." Am. Geol., vol. VI, 1890, pp. 360-370.

"A Last Word with the Huronian." Bull. Geol. Soc. of Am., vol. II, 1891, pp. 85-124.

Winchell, N. H.—"The Original Huronian." Sixteenth Ann. Rept. Geol. and Nat. Hist. Survey of Minnesota, 1887, pp. 12-40.

"Further Observations on the Typical Huronian and on the Rocks about Sudbury, Ontario." Eighteenth Ann. Rept., Geol. and Nat. Hist. Survey of Minnesota, 1889, pp. 47-59.

CHAPTER II

GENERAL CHARACTER OF THE DISTRICT

TOPOGRAPHY

The north coast of lake Huron coincides nearly with the boundary between two great geological and physiographical provinces. North of it the vast rocky peneplain or low plateau of Precambrian rocks, variously called the Canadian shield, the Archæan protaxis, etc., extends to the Arctic ocean. To the south is a smoother and slightly lower plain underlain by flat-lying Palæozoic strata, which continues southward into the United States. Most of the islands within 4 or 5 miles of the north shore belong to the Precambrian province; the Palæozoic plain is represented by the larger islands farther offshore, such as Manitoulin, St. Joseph, and Thessalon. Only near Sault Ste. Marie and near the east end of Manitoulin island does the Palæozoic province reach the mainland. The district considered in this report lies in the Precambrian shield, within sight of the overlapping Palæozoics and at one or two points actually including a little of them.

A third physiographic type is superimposed locally upon these. For 15 miles or so north of lake Huron, in river valleys and other low-lying parts, the Precambrian rocks are buried beneath stratified clay and sand laid down in post-Glacial stages of lake Huron when, during the recession of a continental ice-sheet, that lake stood much higher than it does now. These relatively modern lake beds are thick enough to mask part of the older solid rock surface and superimpose upon it their own characteristic topography. It is convenient, therefore, to distinguish three types of topography belonging respectively to the Precambrian, Palæozoic, and Pleistocene terrains.

Precambrian Shield

The coast of lake Huron from Sault Ste. Marie eastward for 80 miles to the mouth of Serpent river is not much higher than the lake, which is 581 feet above the sea. But in the first 25 miles north from the lake the country rises gradually to an average level of from 1,000 to 1,350 feet according to the locality. The mean southward slope—15 to 30 feet per mile—is steeper than is usual in the Precambrian shield. This whole Huronward slope is rough country with rock features of all shapes and sizes from easy undulations to rugged hills, and cliffs 350 to 400 feet high. Near the coast the solid rock surface is concealed to an important extent by the lacustrine deposits, but farther inland and at greater elevations there is only a thin covering of drift, collected mainly in the valleys, to soften the otherwise harsh relief of the rock floor. The drift-filled depressions are commonly swampy, or they contain rocky-shored lakes, of which there is an extraordinary number. Where the rock surface is bare, glacial polishing, and roches moutonnées are characteristic details. All this country is densely forested.

As far eastward as the mouth of Spanish river the Huronward slope presents no more outstanding features than occasional hills which rise 100 feet or so above their neighbours. Mount Victoria, just north of Cutler, is one of the most commanding of these landmarks, especially when viewed from out on lake Huron. It stands about 250 feet above the surrounding country. Another conspicuous hill lying some miles north of Tenmile lake is high enough to be seen from points 15 miles away, its conical outline and pure white colour making it easy to recognize.

But from the mouth of Spanish river eastward the southward-sloping terrain rises again near lake Huron in a range of hills so much higher and bolder than the adjacent country that it has earned the name Lacloche mountains. This range is by far the greatest and most impressive topographic feature in the North Shore district. It begins at the mouth of Spanish river. From there eastward it follows the coast of lake Huron to the Bay of Islands and then continues inland for another 30 miles in a direction slightly north of east. From that easterly tip it bends back sharply toward Georgian bay, where it terminates in a number of bold, finger-like peninsulas, near Killarney. The length from east to west is about 50 miles, and of the whole reflexed range about 75 miles. Its width varies from 2 to 3 miles. The summits gradually increase in height from 300 to 400 feet above lake Huron at the west end of the range, to between 600 and 800 feet near Killarney. The highest point is a hill in Carlyle township, reported by Dr. Robert Bell to stand 1,180 feet above lake Huron, or 1,760 feet above sea-level. From 30 miles away the range appears, on a clear day, as a brilliant, bluish-white band along the horizon. At closer range one is impressed by its broad base and low slopes. The angle of slope to the summit is somewhat over 5 degrees.

The massive, imposing character of Lacloche hills is enhanced by their unusual form and colouring and by their closeness to lake Huron. The entire range is carved in a single, closely folded formation of white quartzite (Lorrain), 6,000 feet thick. At even a short distance, it has the appearance of being snow-covered. Its slopes are bare of all vegetation except scattered patches of evergreen forest, which only accentuate the whiteness of the rocky parts. Unlike the serrated peaks of younger mountains, this range shows a curving, fantastically scalloped horizon-line. Its individual hills, which have stood since before Palæozoic time, have gently sloping sides and rounded tops. Seen across the archipelago that fringes the north coast of lake Huron this ancient range of snow-white hills forms the dominating feature in what is perhaps the most picturesque part of Ontario.

Palæozoic Plain

The contact between the Precambrian region and that underlain by the Palæozoic strata is seen best among the islands of North channel in the vicinity of Little Current and Killarney, where the two provinces meet. The skyline of the Palæozoic is perceptibly lower than that of

the Precambrian, and more even. In most places the actual junction between the rocks of the two provinces is concealed by lake Huron; but enough of it is visible between Killarney and Little Current to indicate its general character. The peninsulas west of Killarney, and the islands nearby, are Precambrian, with a fringe of horizontal Ordovician strata near the shore. The Precambrian rocks rise to 500 feet above lake Huron, the Palæozoic fringe only a few feet. The strata composing this fringe are undisturbed to within a few feet of the contact, except for a slight sag probably due to their slow subsidence (Figure 9). Closer than that the sag is more pronounced. The contact across Great Cloche island is similar. There is no rectilinear scarp such as marks the Precambian-Palæozoic contact in Ottawa valley.[1] The greater relief of the Precambrian on the north shore appears, therefore, to be a result of differential erosion, and not of faulting.

The horizontal stratification of the Palæozoic formations has been a governing factor in their erosion. Instead of a billowy or hummocky surface like that of the Precambrian, the Palæozoic plain is level country diversified by occasional rocky escarpments where the surface is stepped up or down from one gently inclined formation to another. Glacial effects are much less conspicuous than in the Precambrian. The drainage, also, is better and the multitude of lakes so distinctive of the Precambrian fail in the Palæozoic province.

Pleistocene Lake Beds

The stratified clay and sand laid down in post-Glacial stages of lake Huron occur nearly altogether within 15 miles of the lake and not over 190 feet above it. At greater elevations farther back in the country they give place to a few beach deposits and a much thinner mantle of glacial drift. The lake beds occur chiefly west of Blind River. East of that place there is only one extensive area, in the valley of Spanish river, and a little in the Serpent and Whitefish River valleys. The lake beds form a series of terraced, small plains rising one above another up to a little over 100 feet above lake Huron. Some of the lower beds slope gently towards the lake. A few terminate southward in terraces. Most of these at high levels are partly closed in by ridges of rock so as to form more or less separate, flat-bottomed valleys of elongated or highly irregular shapes (Plate I). Nearly all these alluvial plains are diversified by rocky knobs, representing protruding parts of the Precambrian rock floor.

The highest of these level deposits, standing 100 feet, possibly a little more, above lake Huron, is represented in a number of valleys in Galbraith and Aberdeen townships drained by Thessalon river (Bruce Mines map-sheet). The bottoms of these valleys are of stratified clay or sand, quite or nearly flat; the sides are lofty, in many places precipitous, hills of bare rock. Actual measurements would probably show that adjoining valley bottoms, which are connected by constrictions, differ as much as 25 feet in elevation. The nearest correspondent to this high-level stage in the eastern

[1] Kindle, E. M., and Burling, L. D., "Structural Relations of the Precambrian and Palæozoic Rocks north of the Ottawa and St. Lawrence Valleys." Geol. Surv., Can., Mus. Bull. No. 18, 1915.

part of the district is an extensive and notably flat sand-plain around Espanola, which stands 90 feet above lake Huron.

At many places in the district nearer the lake other deposits are found at lower elevations. Howry Creek valley, for example, is filled level with clay to 55 or 60 feet above lake Huron. The sand-plain in Rose and Kirkwood townships (Bruce Mines map-sheet), the clay flats near Dean Lake, and other clay flats southeast of Massey, are all from 40 to 80 feet above lake Huron. The lowest one of any importance is 8 to 15 feet above lake Huron and extends along the shore of lake George and up Echo river for some miles above Echo lake. It forms the level farming district around Thessalon, and is also represented at the mouths of Serpent and Whitefish rivers. This flat is made up of clay, or clay overlain by a few feet of sand. The Booth farm, on the shore of lake Huron just west of Blind river, is situated on a still lower and comparatively modern flat only 3 or 4 feet above the lake. It is, however, only about a square mile in area.

The lake beds in Spanish River valley slope gently, without interruption by terraces, toward lake Huron. On the other hand, there is a distinct terrace between the sand-plain of Rose and Kirkwood townships and the lower clay flat around Thessalon. At one place in section 15, Lefroy township, the base of this terrace is marked by an elevated beach of boulders and gravel. There is an equally strong terrace north of Blind River.

Since the recession of lake Huron the streams have begun to dissect the lake deposits, carving in them steep-sided gulleys and river channels with steep banks and moving the excavated materials down to new resting places in the present lake Huron. Part of the flats along the south side of Kehoe township, once excellent farm land, has been ruined by erosion of this sort.

DRAINAGE

All the streams draining the North Shore district empty into lake Huron. The Mississagi and the Spanish are each about 250 feet wide near their mouths, from 10 to 15 feet deep, and flow about 1½ miles an hour. Garden, Echo, Thessalon, Blind, Serpent, and Whitefish rivers have from one-fourth to one-half this volume. All except the Whitefish, and in some degree the Blind, are smooth-flowing and comparatively free of falls and rapids as far upstream as the Pleistocene lake-beds extend. Close to lake Huron, in fact, they are sluggish, and, in the case of Echo river between Echo lake and lake George, somewhat over-deepened by the spring freshets. Beyond the Pleistocene lake-beds, however, the unusually steep slope of the country toward lake Huron (15 to 30 feet per mile) gives rise to an unusual number of rapids and falls over obstructions in the rock floor. Whitefish river has almost no lake-beds in its valley, and is consequently an alternation of rapids, falls, and lake expansions from its mouth up. To a less pronounced degree this is true of Blind river.

The heights of falls and rapids on Whitefish and Blind rivers were measured with a hand-level; the results, which should be correct to within a few inches, are given on Maps 1969, 1970, 1971. The elevations along the other streams have been obtained from whatever sources were available and may not be uniformly accurate. It is evident from the size of the

rivers, the number and height of the falls and rapids, and the abundance of lake expansions which can be used as storage basins, that many good waterpowers are available. The largest, such as the fall on Spanish river at Espanola, and Aubrey fall on the Mississagi, can each be made to yield about 12,000 horsepower. The others range down to less than 100 horsepower. Very little of this power is being used. The fall at Espanola is used by the paper mill of the Spanish River Pulp and Paper Company, and White fall on Blind river supplies both light and power to the town of Blind River. In addition, a few small powers on Thessalon river and its tributaries are used to run small sawmills.

All the rivers, however, are used for floating logs down to lake Huron. The lumbering companies have built storage dams below the lake expansions and log slides at the falls and more troublesome rapids.

INDUSTRIES

Lumbering and farming are the chief industries. Mining, though begun as early as 1846, is not now as productive as in the past, being limited to prospecting and more or less successful attempts to take advantage of the war price of copper by reopening the old copper mines at Bruce Mines and Massey. Fishing in lake Huron is a steady but not large industry.

Lumbering

Large-scale lumbering operations date back only about thirty years and so far have been limited to the removal of pine and spruce. Hardwoods, such as maple and birch, are being cut only in the settled parts of the district, where there are good roads and a local demand for fuel and hardwood lumber. The pine is cut into logs during the winter, floated down the rivers to lake Huron during the following summer, and there sawn into lumber. From Thessalon eastward each town and village on lake Huron has one or more large sawmills. The lumber is marketed chiefly by way of the Great Lakes.

At the present time practically all the pine close to lake Huron has been cut: gradually lumbering has moved as much as 50 miles inland. No provision is being made for growing a new crop and the natural reforestation of pine appears to be ineffective (Plate II). This phase of the industry is already waning and apparently will disappear in another twenty-five years unless repletive or preventive action be taken. After the pine and spruce there remains a vast forest of maple, birch, hemlock, poplar, and some oak, which has not been touched because these woods cannot easily be floated down the rivers. Wagon roads or temporary railways will have to be built northward before these woods can be handled, but no doubt this will eventually be done.

In the western part of the district, and in Spanish River valley where the soil sheet is thick and fertile, the deforested country is used for farming. In the remainder, however, the soil is neither abundant enough nor rich enough to admit of farming. Lumbering is the only permanent industry the rocky part is capable of supporting. It is

doubtful, however, whether much of the country now lumbered over will ever be reforested, for, as the forest cover is removed, the thin drift-sheet becomes exposed to rain and wind, and is washed off the hills, leaving a barren rock surface. Unless steps are taken within a quarter century to preserve the present forest, the rocky, major part of the North Shore district is likely to become permanently useless, except for its water-powers and possible mineral deposits.

Farming

Farming is confined strictly to parts of the district where the Pleistocene lake-beds occur. The principal area lies west of Blind River and within 15 miles of the coast. Another large tract of agricultural land occupies the valley of Spanish river and its tributaries as far east as Nairn township, that is, the broad basin between Lacloche hills, on the south, and the rising Precambrian country towards the north. There are also a few farms along the lower part of Serpent river and one at the mouth of Whitefish river. Most of these areas are fertile clay land, though some parts are sandy or even gravelly. One large sand-plain of little agricultural value lies north of Thessalon, occupying parts of Kirkwood, Rose, Bridgland, and Haughton townships. Another, in Spanish River valley, extends more or less continuously from Massey east to Nairn and Foster townships.

The lake-beds are well drained, quite free of boulders, and yield excellent water. The climate admits of growing such crops as barley and oats, hay, small fruits, and the hardier varieties of apples. Mixed farming prevails and in the older settlements cleared land is valued at from $20 to $40 an acre. Most of the good land is already occupied, but in the outlying valleys some Crown land is still available.

The broken, discontinuous nature of the country is a serious handicap to farming. Much of the arable land occurs in valleys separated from one another by rocky hills or by sandy tracts not fit for farming. It is consequently necessary in many places to maintain roads across long stretches of unsettled country, where road-building is exceptionally difficult and costly. The larger rivers, also, necessitate costly bridges. To offset these difficulties financial aid is given to road-building by the provincial government, and a fine highway has recently been built, at government expense, from Sudbury to Sault Ste. Marie.

The difficulties which beset the agricultural development of the district might be alleviated in some other ways. A good deal of land which formerly supported a valuable forest and is now unproductive could be forested. The original forest on such land was so completely removed by the lumberman and by fires that natural reforestation since then has been ineffective. For instance, the great sand-plain north of Thessalon, thousands of acres in extent, is now either treeless or thinly overgrown with poplars, although the charred stumps and standing trunks prove that it was once heavily forested with white pine up to 3 feet in diameter (Plate II). It has become too arid for grazing and in places the sand has

begun to drift. It will probably never be reforested with pine by unaided natural processes, but tree-planting would likely be successful. Treated so, it could be made a source of revenue to the municipalities to which it belongs instead of an obstacle to their development.

A number of industrious but ill-advised settlers have taken up farms in parts of the country which are either sandy and unsuited for farming or are so remote and broken by rocky areas that they will never have proper communication with the larger settlements. An agricultural survey of the whole district would seem to be a desirable preliminary to any further wise allotment of Crown lands.

CHAPTER III

STRATIGRAPHY

OUTLINE

The rock formations in the North Shore district are grouped into four main structural elements, quite distinct in age and easily distinguished from one another. These four elements are, from oldest to youngest:

(1) A pre-Huronian floor or basement upon which the other groups rest.

(2) A thick succession of Huronian sedimentary formations and associated igneous formations lying in profound angular unconformity upon the pre-Huronian or—in the case of the intrusives—breaking through.

(3) Palæozoic sedimentary formations, which rest in quite as profound angular unconformity upon the Huronian.

(4) Unconsolidated Pleistocene glacial materials and lake beds, which lie unconformably upon all the older groups. The relationships of these groups, one to another, are shown in Figure 2 and in the sections on the accompanying geological maps (Nos. 1969, 1970, 1971).

The pre-Huronian basement has been so freed by erosion of Huronian and later formations that a fairly accurate idea can be obtained of it. It is made up of three subordinate groups of formations: (1) a complex association of lava flows, pyroclastics, and obscure sediments (iron formations), now complexly folded and altered to schists; (2) a series of sediments, apparently younger than the volcanic complex, but also greatly folded and altered to crystalline schists. The relationships of these sediments to the rest of the pre-Huronian has never been directly ascertained, but they are probably pre-Huronian since they are more deformed and more crystalline, on the whole, than the rocks in the younger divisions; (3) great bodies of granite gneiss which intrude the volcanic complex and probably also intrude the sedimentary series.

The areal relationships of the volcanic schist-complex sediments, and granite gneiss in the pre-Huronian floor underlying the North Shore district are shown in Figure 2, as well as the incomplete exposure of the floor permits. It can be seen that granite gneiss underlies by far the greater part of the district. The Volcanic schists occur in scattered patches, chiefly in the eastern half of the district. The sediments, so far as can be seen, are confined to a single belt also in the eastern half of the district. Both schists and sediments are elongated in a direction somewhat north of east. The pre-Huronian basement in the southeastern part of the district is either destroyed by later granite irruptions, or so involved in the close folding that affected the overlying Huronian group, that nothing can be ascertained regarding its original composition.

Current geological theory interprets this pre-Huronian floor as the base of a mountain system which was removed by erosion. Apparently, batholiths of the granite gneiss were. intruded into a crust composed of the volcanic complex and sendiments, which at about the same time was

folded and otherwise deformed in the manner characteristic of mountain-built formations. Afterwards the whole mountain-built terrain was eroded so deeply that the granite batholiths were exposed for hundreds of square miles and nothing remained of the crust of volcanic materials and sediments except infolded remnants. The surface of the region became a rocky plain.

A mantle of Huronian sediments 12,000 to 30,000 feet thick now rests in profound unconformity upon this planated pre-Huronian basement. The Huronian sediments and the igneous rocks irruptive in them constitute the second major structural division. The sedimentary mantle is divided into a lower Bruce series and an upper Cobalt series by an erosional unconformity of much less magnitude than that which lies between Huronian and pre-Huronian. Bruce and Cobalt series alike are intruded by sills and dykes of diabase regarded as equivalent to the Keweenawan diabases of the south shore of lake Superior. Along the south of the district, from Algoma towards Sudbury, sediments and diabase are invaded and powerfully metamorphosed by a second series of granite batholiths (Killarney) much younger than the pre-Huronian granite gneiss. These younger batholiths outcrop along an east-west zone of profound deformation, presumably of the nature of mountain-building, and still represented by Lacloche mountains. The Huronian strata in this zone are intensely folded and faulted. Going northward, however, the same strata become less disturbed and, 30 or 40 miles from lake Huron, are found lying gently folded upon the pre-Huronian basement (Figures 7 and 8).

In other words the Huronian is to be conceived as a great mantle of sediments, and associated irruptives, spread in the first place horizontally over the pre-Huronian crystalline floor, in part still horizontal or only gently folded, but in other parts intensely deformed by mountain-building agencies.

The third major geological element consists of Palæozoic (Ordovician) sediments that lie almost horizontally against the bevelled edges of the folded Huronian sediments and the Killarney granite irruptive in the latter. Between the irruption of the Killarney granite and the deposition of the Ordovician sediments there elapsed a period of erosion long enough to all but remove the mountains created by the deformation of the Huronian and to lay bare the granite lying at their roots. The unconformity between the Palæozoic and the Precambrian is, therefore, of the same nature and the same order of magnitude as that beneath the Huronian.

Consequently, after processes of sedimentation and erosion during the Palæozoic, Mesozoic, and much of the Quaternary, concerning which there is little record here, the region was subjected to continental glaciation, and afterwards, in the vicinity of lake Huron, to lacustrine submergence and final emergence.

Upon the eroded surface of Palæozoic, Huronian, and Precambrian alike lie the glacial debris and horizontally stratified lake-beds of the Pleistocene, constituting the fourth and topmost of the four main structural divisions. These Pleistocene deposits are unconsolidated and form the present rather thin and discontinuous drift sheet. There is no evidence within the North Shore district regarding what transpired between Ordovician and Pleistocene times, but such evidence as has been found about

the margin of the Precambrian shield points to prolonged existence as a land area.

A more detailed statement of the geological succession is given in the table below and in the sections which follow:

Quaternary	Recent	Swamps, etc.
	Pleistocene	Lacustrine clay, sand, and gravel beaches Glacial deposits
	Unconformity	
Palæozoic	Ordovician	Lowville and Black River limestone
	Great unconformity	
	Igneous intrusives (Keweenawan in part at least)	Olivine-diabase dykes Killarney granite batholiths Basic intrusives (chiefly sills and dykes, but including the basalt flow at Thessalon, which may be much older)
Huronian	Cobalt series	Upper white quartzite and cherty quartzite Banded cherty quartzite Lorrain quartzite Gowganda formation (boulder conglomerate, etc.)
	Unconformity	
	Bruce series	Serpent quartzite Espanola limestone Espanola greywacke } Espanola formation Bruce limestone Bruce conglomerate Mississagi quartzite
	Great unconformity	
Pre-Huronian		Granite gneiss batholiths Sediments (Sudbury series) Schist-complex (mainly volcanic)

Pre-Huronian Schist-Complex

DISTRIBUTION

The pre-Huronian green schists, as stated in the general outline above, occupy infolded areas in the pre-Huronian granite gneiss (Figure 2). In the Bruce Mines map-area they are represented merely by a swarm of angular, highly metamorphosed fragments embedded in the granite gneiss east of Thessalon (Plate III A). Panache map-area contains only one small area, in its northwest corner. The relationship of this patch to the adjoining formation is obscured by faults and by a heavy overburden of sand and clay.

Green schists occur much more extensively in Blind River map-area. Though not enough field work has been done to map them completely, there appear to be in the intrusive granite gneiss several insular areas of considerable size, each with its longer axis extending slightly north of east and schistified in the same general direction. Each is bordered by a brecciated metamorphic aureole of varying distinctness up to half a mile in width, consisting of granite gneiss filled with angular or drawn-out frag-

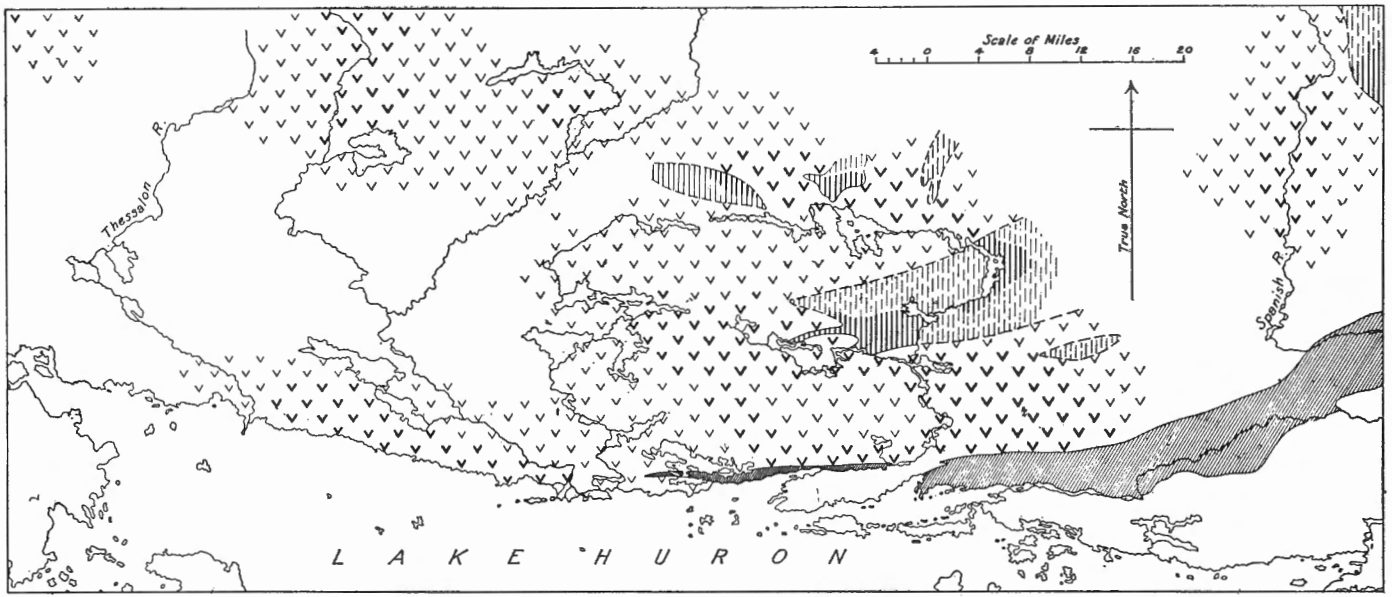


Figure 2. Map diagram showing probable distribution of the schist-complex (Keewatin), sediments (Sudbury series), and granite gneiss in the pre-Huronian basement, north shore of lake Huron. Symbols in heavy lines represent known exposed areas, the light ones areas partly concealed by Huronian and later formations. The clear spaces represent either parts of the pre-Huronian basement too completely buried under Huronian sediments for any knowledge of it to be obtained, or parts which have been destroyed by the irruption of later granites.

ments of the schist-complex and locally basified in composition by assimilation of the same materials. Smaller patches of green schist and swarms of block inclusions are also distributed throughout the granite gneiss. So abundant are these inclusions near some of the green schist areas (Plate III A) that a special colour has had to be used on the maps for parts of the granite gneiss which contain one-fourth or more of its volume of brecciated schists.

To account for so many widespread remnants of green schists in the granite gneiss, it seems unavoidable to conclude that the schist-complex was once far more extensive than now, if not wholly continuous over the district. When folded and invaded from below by the granite gneiss the invading magma shattered it along the surface of contact and floated off fragments in such quantities that no definite boundary can now be drawn between granite gneiss and schist-complex. Afterwards erosion removed all except the infolded bodies and smaller fragments which remain today.

DESCRIPTION

The Pre-Huronian schists are represented on the maps by a single colour, but they are in reality a group of formations too complex to be subdivided except, perhaps, by refined and detailed field study. Subdivision of this group is all the more difficult in the North Shore district because the schist areas there are all small, and the metamorphic influence of the granite gneiss has been intense enough to alter beyond recognition a large share of the original formations. They can still be recognized as almost wholly igneous, but it is only in the less metamorphosed interiors of the larger areas that volcanic, intrusive, and sedimentary (iron formation) members can be distinguished. Even there they are apt to be sheared and compressed into chloritic or sericitic schists. When so schistified or recrystallized there is a tendency to evolve a few metamorphic rock types from the many original volcanics. Hence, in the North Shore district there is not the same extraordinary variety of rock species, volcanic structures, etc., that characterize the large areas of schist-complex such as that in the Porcupine district.

Angular inclusions in the granite gneiss east of Thessalon are the only representatives of the schist-complex in Bruce Mines map-area. These are all composed of dark hornblende gneiss, a well-foliated, medium-grained rock made up about equally of glistening black hornblende and white feldspars—intermediate plagioclase and some microcline. These minerals make up from half to three-fourths of the rock. They are accompanied by some quartz and always by a considerable amount of titanite. Large grains of epidote are present except where the contact action of the granite gneiss has been severe enough to transform that mineral into feldspar and hornblende. Magnetite, pyrite, apatite, and large fractured garnets may or may not be present in small amounts. None of the constituents except apatite and magnetite have good crystal forms, a thin section appearing as a mosaic of mineral grains more or less elongated in the plane of foliation of the rock.

In Blind River area the margins of the schist areas consist of an entirely similar hornblende gneiss. Apparently hornblende gneiss results from any basic part of the schist complex if the latter is schistified and afterwards acted on strongly enough by the irruptive granite gneiss. It is at first sight remarkable that so varied a group of rocks as are found in the schist-complex should give rise almost invariably to a product so uniform; but a more careful examination of numerous samples of the hornblende gneiss reveals that, although practically the same minerals are present in each sample, these minerals occur in highly variable proportions. In other words, the convergence to a uniform composition is qualitative, not quantitative; mineralogical rather than chemical. The amphibolitic product of convergence is gneissic in some parts of the area, but more commonly massive and hard to distinguish from a coarse diabase. In fact some of it has quite possibly been mapped erroneously as Keweenawan diabase, and vice versa, especially in Esten and Proctor townships and around Rochester lake, where the similarity is marked.

Inside the broad contact margin of amphibolitic rock that encloses the larger areas of schist-complex, the schists become more varied, and preserve their original characters better. Chloritic green schists, striking about east and west and so highly schistose that they resemble sediments, are exposed on Serpent river between McCarthy and Picard lakes, and on the north side of Depot lake. It is possible that these were fragmental volcanics, and not as capable of resisting deformation as the more coherent lavas and intrusive rocks. A dark green chlorite schist, almost as fissile as these, was found 2½ miles south of McCabe lake, township 143. This rock, however, contains round to ellipsoidal bodies about half an inch in diameter which, by resisting shearing, have produced a lumpy structure like a dough filled with raisins. The lumps lie 1 or 2 inches apart. They prove, upon microscopic study, to be hard bodies similar in composition to the rest of the rock mass, probably varioles; but the rock is too much decomposed to admit of their certain determination. They leave little doubt that the rock is a lava.

Pillow lava occurs south of Serpent river between Whiskey and Picard lakes. An amygdaloidal lava was found on the north shore of Tenmile lake. It is a dark green, imperfectly schistose rock carrying unflattened amygdules of white quartz as much as an inch across. The rock was evidently a vesicular basaltic flow.

Acid rocks are much less abundant than the basic ones. A pale grey rhyolite, somewhat sheared, was seen a half mile north of the inlet to Quirke lake. Quite a similar but more schistose type is exposed on the south shore of Depot lake a little east of Esten township line.

Sediments are represented only by a few remnants of banded iron formation on Island lake, just north of Quirke lake. These are blocks enclosed in granite gneiss and are probably detached parts of an iron-formation belt which lies in alignment about 2 miles to the east. The granite gneiss 100 feet from the shore of Island lake contains one block about 150 feet long. The iron formation composing it is of the usual character, grey bands of fine-grained silica alternating with black bands

rich in magnetite. The layers are from ¼ to 1 inch thick. The formation is much crumpled and a good deal of green iron silicate (grünerite) has been developed by the contact action of the granite gneiss. There are probably other included fragments of iron formation in this neighbourhood, but the metamorphism caused by the granite gneiss makes it improbable that any commercially important concentration of iron ore will ever be found there.

The greenstones in the northwest corner of Panache map-area were examined by Dr. Quirke.[1] They are described as rather massive, black, hornblendic rocks, in all cases intrusive in the pre-Huronian sediments of the locality. One of these is filled with pink garnets as large as ¾-inch in diameter, and the others show similar indications of intense metamorphism. These rocks could not be found in contact with the granite gneiss, but since they are more metamorphosed than the Huronian or the basic rocks intrusive in the Huronian, Quirke has placed them in the pre-Huronian. It is possible, on the other hand, that they were metamorphosed by the younger, Killarnean granite and that, in spite of their metamorphosed condition, they may belong to the late Precambrian basic intrusives.

AGE RELATIONS

Wherever the pre-Huronian schists were found in contact with the pre-Huronian granite gneiss in the Bruce Mines and Blind River areas, the granite gneiss is intrusive with profound metamorphic effects and is unquestionably younger. The altered basic rocks in the northwest corner of Panache area, mapped as pre-Huronian schists, were not found in direct contact with the granite gneiss, but the granite gneiss is the only agent present which seems capable of having metamorphosed them so severely, unless, as suggested above, there are Killarnean granites present. Hence, they, too, are regarded as older than the granite gneiss.

The schist-complex is probably also older than the pre-Huronian sediments, though the two groups of rocks have not been found together except in the corner of Panache area. Only indirect evidence is adducible. From the mouth of Spanish river eastward to Sudbury the Huronian strata rest against the pre-Huronian sedimentary series without the intervention of igneous schists other than occasional greenstone intrusives like those north of Espanola (Figure 2). Moreover, the pre-Huronian sediments have no typical volcanic schists interbedded with them. That is to say, there is little evidence of prolonged vulcanism during the deposition of the pre-Huronian sediments, and none in the interval of time following before the deposition of the Huronian. The absence of igneous schist-complex within and above the pre-Huronian sediments seems to leave no other alternative than that of considering it to be beneath, and older than, these sediments.

[1] Geol. Surv., Can., Mem. No. 102, pp. 21-22.

Pre-Huronian Sediments

DISTRIBUTION

Coleman[1] has represented on maps of Sudbury nickel district and vicinity a great belt of sediments extending from Sudbury southwestward almost to Blind River, which sediments he calls the Sudbury series and regards as much older than any of the Huronian formations of this report. The present writer, after having inspected this belt at fairly close intervals, agrees in part with Coleman, but he believes that the Wanapitei quartzite formation of the Sudbury series is equivalent to the Mississagi quartzite in the Bruce series and should, therefore, be removed from the Sudbury series. There remains a continuous though much narrower belt of greywacke and quartzite (the McKim and Copper Cliff formations of Coleman's Sudbury series), reaching from Sudbury westward to Cutler, or possibly to Algoma (*See* Figure 2, also Geological Survey, Can., Map No. 155A). This belt crosses the northwestern part of Panache map-area. It also extends along the south part of Blind River map-area as far west as Cutler, and possibly to Algoma. In addition, a few square yards of highly metamorphosed stratiform materials, probably sediments, were found involved in the pre-Huronian granite gneiss at Dean Lake.

DESCRIPTION

According to Coleman the Sudbury series, omitting the Wanapitei quartzite, consists of a feldspathic quartzite (Copper Cliff arkose) possibly 2,000 feet thick, overlain by stratified greywacke (McKim) around 7,000 feet thick. It was not found possible to ascertain the sequence or thicknesses of the strata in Panache and Blind River map-areas. In the first place the series consists, in both areas, of a monotonous alternation of quartzite and greywacke with no characteristic horizon to show whether the succession has been repeated by close folding or disturbed by faults. The beds are extraordinarily folded, and in most places the materials composing them are altered in some degree to crystalline schists. Moreover, these sediments lie near lake Huron, where a heavy cover of stratified sand and gravel hides much of the solid rocks. In consequence it is not possible here to offer more than a general lithological description similar to what has been done for the pre-Huronian volcanic complex.

In Espanola area the pre-Huronian sedimentary series is represented by quartzites, argillites, or greywackes, and rocks intermediate in all degrees between these extremes. The strata dip invariably at high angles. Their strike is inconstant and greatly complicated by minor folds, but the axial direction of folding is shown to be between 20 and 30 degrees north of east, by the fact that the secondary schistosity maintains that course. Near Webbwood the total width across the strike is over 2 miles, but no part of the succession seen in that distance is distinctive enough to be

1 "The Nickel Industry." Pub. No. 170, Mines Branch, Dept. of Mines.
2 "The Pre-Cambrian Rocks North of Lake Huron," vol. XXIII, Ann. Rept., Ont. Bureau of Mines, pt. I, 1914, pp. 202-236.

identified in case it has been repeated by folding. Greywacke types predominate, showing a continuous width in places of many hundreds of feet. Quartzite as a rule occurs in beds 6 inches to 10 feet or so in thickness, alternating with darker beds. Thicker quartzite members were seen only in a few places.

All these materials have been metamorphosed, though in the most variable degrees, and seemingly by contact as well as by dynamic agencies. Some idea of the character and intensity of alteration can perhaps best be conveyed by describing representative outcrops in different parts of the area.

The quartzites are least changed. They range from pure white to various shades of grey, according to the amount of admixed argillitic matter. A white variety from a 2-foot bed in the greywacke north of Webbwood consists of quartz and some secondary white mica coating the cleavage faces. No trace of its original clastic texture can be found even under the microscope, thin sections appearing as a mosaic of angular quartz grains and parallel shreds of colourless mica.

At another quartzite outcrop just north of Espanola (Canadian Pacific railway) station the secondary cleavage is so well developed that the original bedding can be recognized only on surfaces where the crumpled parting planes between the purer layers of quartzite have weathered into shallow, intricately crumpled grooves. The rock cleaves easily across the bedding plane into plates half an inch thick. The cleavage planes are coated with silvery secondary mica, but fractures normal to the cleavage plane are quartzitic. A little more than half a mile north of this outcrop, between lots 6 and 7, concession II, Baldwin township, there is a gneiss-like, extraordinarily contorted rock consisting of alternating layers of white quartz and of quartz mingled with black hornblende crystals. This, which is probably the equivalent of a thin-bedded quartzite with impure partings, is the most advanced phase of metamorphism seen in the quartzites of Espanola area. It is probably a result of contact as well as dynamic action.

A rather quartzose greywacke exposed just at the right side of Espanola fall on Spanish river shows little change other than hardening due to thorough cementation. A finely stratified, more argillitic variety situated a quarter mile southwest of Espanola station (Canadian Pacific railway) and within a few yards of the contact with the Mississagi quartzite, has developed a good slaty cleavage vertically and at an angle of 60 degrees to its bedding. This slate contains abundant flat crystals of mica up to one-eighth of an inch across and oriented in various directions, in many places at a large angle to the cleavage. These crystals must have grown after the cleavage was developed. The surrounding groundmass is a finely crystalline aggregate composed chiefly of quartz grains and shreds of colourless and green secondary micas. The mica scales are oriented in the plane of cleavage.

A more highly metamorphosed phase of the greywacke occurs near Webbwood. It is a dark green schist, cleaving readily to show silvery micaceous surfaces, but having a lumpy, gnarled appearance on the glossy

cleavage faces, produced by staurolite crystals. In places the staurolites are 2 inches long. The foliated groundmass, which in many cases retains an original fine stratification, shows a more advanced stage of metamorphism than the groundmass of the preceding specimen. It has the same arrangement of quartz grains and mica shreds, but these minerals are coarser. Some of the chlorite has been replaced by hornblende needles and there are a few grains of albite mingled with the quartz.

At the eastern edge of Blind River area the pre-Huronian sediments are perceptibly more crystalline than those in Espanola area. A section from Spanish station northward for 2 miles to where these sediments are faulted against the Huronian, consists, most of the way, of mica schists interrupted by younger masses of altered diabase and tongues of granite from the Cutler batholith situated a few miles west. The mica schists, or fine gneisses, are regarded as the crystalline equivalent of the greywacke in Espanola area, for there is a transition from one to the other in the interval between the two map-areas. They are fine to medium-grained rocks consisting mainly of quartz, some feldspar, and biotite. A vertical foliation has almost completely disguised the original stratification, the latter structure being indicated only by the alternation of highly micaceous bands with bands poorer in mica. The present foliation cuts across the original bedding planes.

Towards the north side of Smith lake, next the Huronian, the mica-schist grows less crystalline, and merges into a dark, greywacke-like material. On the south shore of the lake this dark material becomes a boulder conglomerate, carrying rounded to angular inclusions of granite gneiss, and a few of greenstone. The inclusions are somewhat flattened by pressure. They range in length from 4 inches to 48 inches and are sparingly distributed through the greywacke matrix after the manner of the Cobalt series conglomerates. This conglomerate band is about 30 feet wide. It is succeeded to the north by 15 feet of quartzite, 100 feet or more of slaty greywacke, and then by the down-faulted Huronian.

The conglomerate on Smith lake has been described with some care, because it is the first member of the pre-Huronian series noted in tracing these rocks westward that differs much from the usual quartzites and greywackes. Farther west the series changes so much that its identity with the pre-Huronian becomes in doubt, and its similarity to the Cobalt series becomes rather striking.

From Spanish to Cutler the mica schists grow more gneissic and more mingled with apophyses from the intrusive Cutler batholith. Between Cutler and Spragge they are reduced to a thin band bounded on the south by the intrusive Cutler granite and on the north by the great Murray fault, on the north side of which is Mississagi quartzite. In this distance the pre-Huronian sediments are so crystalline that their original character can only be inferred. They are so bounded, by the Murray fault on the north and either by the Cutler granite or the waters of lake Huron on the south, that they cannot be proved by direct evidence to be pre-Huronian. Nevertheless, after having traced this belt of sediments all the way from Espanola area and seen it assume by degrees the crystalline

character which it possesses between Cutler and Spragge, no good reason arises for believing that the paragneiss at Serpent, midway between Cutler and Spragge, is not as justifiably called Sudbury series as the quartzites and greywackes at Espanola.

It is well to have shown upon what evidence correlation of the paragneiss at Serpent with the Sudbury sedimentary series rests, because there is more room for difference of opinion regarding that part of the belt which lies farther west. This belt continues, with an average width of half a mile, to the west end of Lauzon lake, near Algoma. It is in faulted contact with Mississagi quartzite and other Huronian formations on the north side. On the south, it is lost to view under lake Huron, Lauzon lake, and the drift cover, but at Lauzon lake Mississagi quartzite appears not far to the south, with evidence of another fault between.[1] West of Lauzon lake the drift cover is so heavy that not enough outcrops could be found to decide how this belt of sediments is related to the Cobalt formations that lie farther in that direction. So completely isolated is it by these circumstances that no way could be found to determine its stratigraphic relations to the adjoining Huronian and pre-Huronian formations.

Failing in that, the identity of the sediments has to rest upon lithological characteristics; and these appear only to complicate the problem. The sediments near Spragge are micaceous schists, quartzitic greywacke, and at a place 1¼ miles east of the village a band of conglomerate with flattened pebbles. West of Spragge the metamorphic influence of the Cutler granite fades out and the sediments between the Murray fault and lake Huron become interbedded quartzite, quartzitic greywacke, and greywacke-conglomerate. Associated with them is a black hornblende rock which appears to be a basaltic flow metamorphosed by the Cutler granite. The greywacke-conglomerate and, to a less extent, the greywacke and quartzite, resemble similar materials in the Gowganda formation of the Cobalt series. This resemblance, not very strong at first, becomes quite marked in the rocks nearer the east end of Lauzon lake. The large island in the south bay of Lauzon lake is composed of greywacke and bouldery greywacke conglomerate quite indistinguishable from Gowganda formation, but the peninsulas to the north consist of interbedded greywacke and quartzite more like some of the Sudbury series. On the north side of the southwestern bay, greywacke, schistose but not recrystallized, occurs within a few yards of a small outcrop of granite gneiss. Thus the western part of the narrow belt of debatable sediments consists of materials resembling the Cobalt series, whereas the eastern part, toward Cutler, resembles the Sudbury series. So far as could be seen one type passes gradually into the other. It does not reconcile all the evidence to call these sediments either Cobalt series or pre-Huronian. Their identification must be regarded as unsatisfactory and incomplete. But the available evidence slightly favours the hypothesis that they are pre-Huronian sediments that vary lithologically from greywackes and

[1] These faults are discussed in Chapter IV.

quartzites in the east to greywacke conglomerate, greywacke, and quartzite in the west, and that they were downfaulted along the south side of the Murray fault.

The pre-Huronian sediment seen at Dean Lake, just southeast of the railway station, comprises a few contorted and highly metamorphosed remnants melted into the granite gneiss. Their total area is only a few square yards. The rock is now a dark green hornblende schist showing greatly contorted parallel lines similar to the bedding planes of a shale or other thin-bedded sediment.

AGE RELATION

The Dean Lake sediment is plainly older than the pre-Huronian granite gneiss.

The series of quartzite, greywacke, etc., forming the belt that reaches from Algoma to Sudbury (Sudbury series), is older than the Bruce series. All the way from the mouth of Spanish river to Sudbury the basal conglomerate of the Bruce series rests against these rocks (*See* description of the Mississagi quartzite). But it is not so easy to ascertain whether the Sudbury series lies on the near or the far side of the great unconformity between Huronian and pre-Huronian, that is, whether it is an Huronian series beneath the Bruce series, or pre-Huronian in the same sense as the pre-Huronian volcanic complex or pre-Huronian granite gneiss. Its attitude inclines somewhat to the former opinion. There is no apparent discordance between the greywacke of the Sudbury series and the overlying conglomerate and quartzite of the Bruce series. Exact dip-measurements cannot be made immediately near the contact, because the Bruce series conglomerate is indistinctly stratified, but the general dip of both formations near the contact is from 75 degrees south to vertical. In the eastern part of Panache map-area the Mississagi quartzite is underlain by impure quartzite, staurolitic schist (an altered greywacke), and some conglomerate, resembling the McKim greywacke, but no definite plane of separation between the two could be found. Contacts were also seen in the northern part of Baldwin township and south of Walford (*See* Map 155A) in which the Mississagi conglomerate seems to be conformably upon the McKim greywacke. However, such appearances may be highly deceptive as proved to be the case with the contact between the Bruce and Cobalt series. Moreover, if the Sudbury series were Huronian it should occur between the Bruce series and the pre-Huronian basement at other places along the North Shore, but does not. The quartzites and greywackes of the Sudbury series are also, as a whole, more crystalline than the Huronian sediments. Near Espanola they are rather more crystalline, compared with the Mississagi quartzite nearby, than can well be accounted for by local variation caused by the same metamorphic influences. It is more likely that the older series was metamorphosed by agencies that had ceased before Huronian time.

Dr. Eskola, who spent the season of 1922 in Panache and Blind River areas and saw the Sudbury series there, favours the view that the Sudbury series is an Huronian series older than and immediately beneath the

Bruce series, and more local in distribution than the other Huronian sediments. Dr. Eskola's opinion is supported by the notable scarcity of pebbles and boulders of the Sudbury series (McKim greywacke) in the basal conglomerate of the Bruce series. It is also possible that the Sudbury series may be equivalent to the conglomerate and greywacke assemblages that occur at the base of the Mississagi formation in the northern part of Bruce Mines map-area and at some other localities. The writer is rather inclined to leave the Sudbury series in the pre-Huronian, where Coleman originally assigned it, because the evidence for moving it up into the Huronian is not yet convincing.

Coleman[1] placed the series on the far side of the epi-Huronian interval because it is closely folded and intruded by granite which he believed to be older than the Huronian. But the Huronian sediments are quite as severely folded as the Sudbury series and all the granites intrusive in the Sudbury series that the writer has been able to visit are, in his opinion, not pre-Huronian but intrusive in the Huronian (Killarnean). The evidence now available does not seem to warrant more than a tentative opinion that the metamorphosed greywackes and quartzites (Sudbury series of Coleman) beneath the Bruce series in Espanola and Blind River map-areas may form part either of the pre-Huronian basement or of the Huronian. Their age relation to the volcanic complex and the granite gneiss has not been determined, though they are surmised to be younger than the volcanics since they have no volcanics mixed with them.

Pre-Huronian Granite Gneiss

Granite gneiss is exposed in far greater amount than either the pre-Huronian sediments or schists, and probably forms much more than half of the pre-Huronian basement in the North Shore district (Figure 2). The granite gneiss in the northern and eastern part of the Blind River map-area is part of a vast batholith which extends northward, eastward, and westward for a hundred miles or more. This same batholith may also continue southward beneath the Huronian sediments to the granite gneiss which extends along the coast of lake Huron from the mouth of Mississagi river westward to Thessalon.

DESCRIPTION

These batholithic granites are rather monotonous in character. They are medium to coarse-grained, grey to pink, and contain biotite, hornblende, or a combination of these minerals as their dark constituents. They vary from quite massive to moderately gneissic, but do not possess the highly stratiform foliation which characterizes the gneisses found between Sudbury and North Bay and in southeastern Ontario generally.

In spite of their monotonous aspect they do possess, within narrow limits, a considerable lithological variety. It is quite likely, though difficult to prove, that the rocks which are biotite-bearing in one locality, hornblende-bearing in another, grey in one place, pink in another, are distinct intrusions and that the batholiths are the result of a complex

[1] "The Pre-Cambrian Rocks North of Lake Huron," vol. XXIII, Ann. Rept., Ont. Bureau of Mines, pt. I, 1914, p. 35 A.

series of intrusions. The aplite and pegmatite dykes which occur throughout the granite gneiss are presumably the further products of differentiation in the original, cooling magma.

The most pronounced variations, however, are due to digestion by the magma of quantities of the older schists and sediments which formed a roof for this magma while it cooled. Nearly everywhere the contact between the granite gneiss and the older rocks is a zone rather than a line. Let us suppose that the granite gneiss is being approached from a schist area. Its proximity is first indicated by dykes and fingers of granite in the schist, which tend to follow the schistosity planes where such planes are well developed. They become progressively larger and more numerous towards the granite. By degrees the relative proportions of schist and granite gneiss are reversed until there is a continuous matrix of granite gneiss holding masses and smaller fragments of recrystallized schist. At about this point it can be seen that the larger inclusions of schist have fractured into swarms of smaller ones which floated apart and began to be rounded and reduced in size by the digestive action of the granitic magma before it solidified (Plate III A). Here the granite gneiss, ordinarily poor in dark minerals, becomes so basified and charged with hornblende as to produce diorite and other rock types intermediate between diorite and granite.

Although the contact or "transition" zone so produced is most strongly developed as a fringe about half a mile wide around schist areas, there are not many square miles of granite gneiss, even far away from any schist area, in which some basic inclusions cannot be found. In most of the North Shore district the inclusions retain their block form fairly well (Plate III B). Less commonly they are drawn into ribbons so as to produce a more or less foliated black and white hornblende gneiss, presumably as a result of movement in the magma after it had become viscous. This "transition zone" material is shown on the accompanying maps, Nos. 1969, 1970, 1971, by one colour for granite gneiss and another colour for schist containing 25 per cent to 75 per cent of granite gneiss.

AGE RELATIONS

The relationship just described leaves no doubt that the granite gneiss is younger than the pre-Huronian schists. For the same reason it is younger than the pre-Huronian sediments at Dean Lake, and it is perhaps younger than the pre-Huronian sediments near Cutler and Espanola. It is much older than any of the Huronian sediments, for these were deposited upon it only after it had been exhumed from beneath the crust of schists and sediments into which it was irrupted, and after the mountains which were formed at the time of its irruption were reduced to a peneplain.

There is a small area of pre-Huronian granite gneiss shown in section I, Thompson township, the existence of which is not yet easy to explain. It was not seen by the writer but was found by his assistants, J. R. Marshall and W. E. Cockfield, who were quite satisfied that it was granite gneiss. Bedrock in the locality is heavily drift-covered, so that its extent was only approximately determined and it was not found

in contact with the other solid rocks. These latter, which belong to the Cobalt series, are, however, not metamorphosed, as they certainly would be if the granite gneiss were intrusive. Neither are they greatly folded, as are the Huronian formations in the zone of late Huronian mountain-building and granitic intrusion. Hence, the granite gneiss is believed to be pre-Huronian. It is the only case observed where a knob of pre-Huronian protrudes upwards into the Cobalt series. Everywhere else in the North Shore district the pre-Huronian basement was overlain by the Bruce series before the Cobalt series was deposited, and consequently Bruce series rocks always intervene between the Cobalt series and the pre-Huronian, except where faulting has juxtaposed these. This small area of granite gneiss surrounded by Cobalt series is one of a few seemingly anomalous occurrences in the district, which await further investigation.

Bruce Series

DEFINITION

The sediments included in this report under the Bruce and Cobalt series were called the Huronian series by Logan and Murray [1]. After 1892, when Pumpelly and Van Hise[2] had called attention to an unconformity at the base of the "Upper Slate Conglomerate" member, the part below the unconformity became known as the Lower Huronian series and the part above as the Upper Huronian series. These were the terms then in use on the south side of lake Superior and their application to rocks in the original Huronian district, of course, implied a geological correlation between the two regions. In 1902 Seaman found an unconformity within the Lower Huronian series in Marquette district which necessitated its subdivision into a Lower Huronian and a Middle Huronian series. From that time on, it was a matter for debate whether the Upper Huronian on the north shore of lake Huron was Upper Huronian or Middle Huronian as these terms were understood south of lake Superior. The uncertainty and confusion resulting from this usage induced the present writer[3], after he had verified the conclusions of Winchell, Pumpelly, and Van Hise regarding the unconformity within the Huronian on the north shore of lake Huron, to substitute the name Bruce series for Lower Huronian and Cobalt series for Upper Huronian in Ontario. The name Bruce was given to the lower series because these rocks are well exposed in the neighbourhood of Bruce Mines where they were studied by Logan and Murray. The upper series, having been correlated with the succession in Cobalt district, was called the Cobalt series[4], as named by Miller.

DISTRIBUTION

Before commencing a detailed description of the Bruce series it must be pointed out that the Huronian rocks in the North Shore district occur in

[1] Geology of Canada, 1863, p. 50.
[2] Am. Jour. Sci., 3rd ser., vol. XLIII, 1892, pp. 224-232; *see also* Bull. Geol. Soc. Am., vol. II, 1895, pp. 85-124.
[3] Geol. Surv., Can., Mus. Bull. No. 8, 1914.
[4] Ibid; See also Eng. and Min. Jour., 1911.

two distinct areas. The separation is due primarily to the Murray fault. This fault is discussed at some length in the chapter on "Structural Geology" and is represented in Figure 2. It need only be said here that it is a great arcuate fracture which has been traced fairly continuously from near Sault Ste. Marie eastward for 110 miles; and without finding any signs of termination in either direction (*See* Map 155A). A vertical displacement of as much as one mile in places resulted from this fault, the south side being upthrown. Subsequently, erosion brought to view on the upthrown side a narrow belt of pre-Huronian formations between the fault and the Huronian. This strip of pre-Huronian, together with the fault itself, and the waters of lake Huron, create an interval, never less than 6 miles across, between the Huronian in the northern and western part of the district and that to the southern and eastern part. Except for this narrow strip, the Huronian sediments extend uninterruptedly from Sault Ste. Marie to Sudbury.

The obstacle thus put in the way of stratigraphic correlation across the district is all the more troublesome because the Huronian formations in the northern area are not much folded or metamorphosed except near the fault, whereas those in the southern area are nearer the seat of Killarnean mountain-building and are powerfully affected. There are also some important differences in the thickness of certain of the Huronian formations. It will be in some cases necessary, therefore, in the descriptions which follow, to refer specifically to the northern or to the southern Huronian area. The southern area is represented in the Panache sheet, the northern area in the Bruce Mines and Blind River sheets.

The Bruce series comprises the following formations in order downward.

	Thickness in feet
Serpent quartzite	1,100 —
Espanola limestone	0 — 75
Espanola greywacke	250 — 400
Bruce limestone	150 — 250
Bruce conglomerate	20 — 500 or more
Mississagi quartzite	1,000 — 12,000

MISSISSAGI QUARTZITE

Name. The basal member of the Bruce series was called the Mississagui quartzite in 1888 by Alexander Winchell[1]. This name was accepted by the writer[2] in 1914, except that the spelling was changed to Mississagi to conform with the ruling of the Geographic Board of Canada.

Description. The Mississagi formation is mainly a feldspathic quartzite, although it also includes arkose, banded argillite, and several conglomerates of quite different characters. These minor components are all somewhat local in distribution and, in the case of the argillite and conglomerate, recur at different horizons. An effort has been made to express the essential stratigraphic features in the accompanying diagram (Figure 3) which applies particularly to the northern part of Blind River area,

[1] Sixteenth Ann. Rept., Geol. and Nat. Hist. Surv., at Minnesota, 1887, pp. 145-171.
[2] Geol. Surv., Can., Mus. Bull. No. 8.

where the Mississagi formation is only 1,000 to 3,500 feet thick. Towards the south and east, the thickness increases greatly, and certain differences appear which are referred to in the detailed description that follows. As far as possible the formation is dealt with from the base upward in this detailed description.

The basal member of the Mississagi is for the most part conglomeratic, but varies a great deal from place to place. In the northern Huronian area it ranges from 0 to 20 or 30 feet in thickness except in the northern

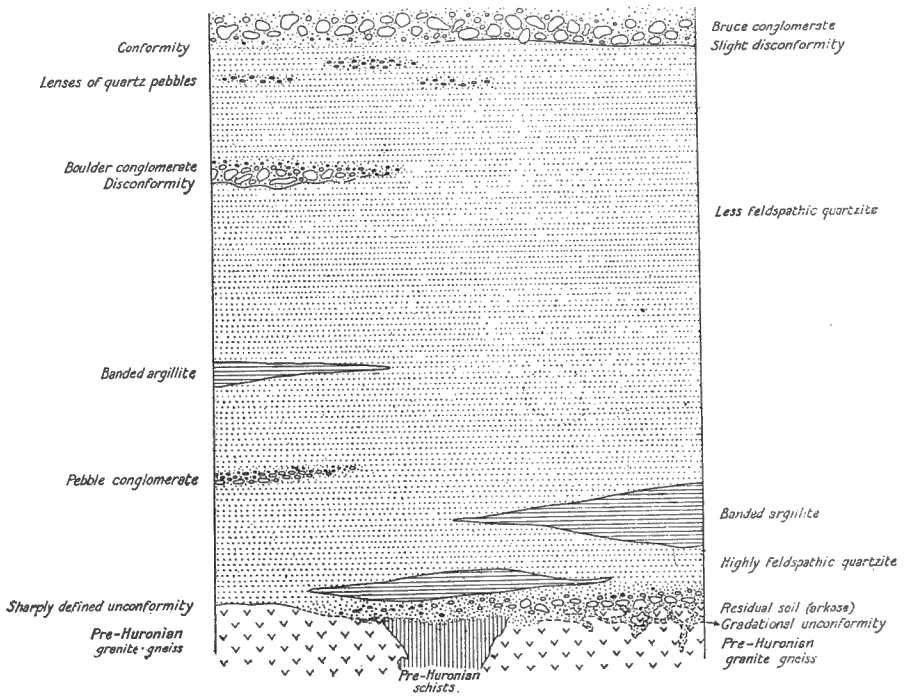


Figure 3. Diagrammatic vertical section of Mississagi quartzite in the "northern" Huronian area. It has been attempted on this diagram to indicate the characteristic stratigraphic features—local disconformities, conglomerates, and argillite members—and also to show the varying relationships of the formation to the pre-Huronian basement and to the Bruce conglomerate.

part of Bruce Mines map-area, where it is much thicker and diversified in character. It is nearly everywhere arkosic, and is as a rule more or less conglomeratic.

In the southern part of Bruce Mines map-area it is exposed only near Thessalon. A strongly conglomeratic phase is well exposed on an inlet (J. D. 178) in lake Huron about 3 miles east of Thessalon where the underlying pre-Huronian is granite gneiss, filled with angular inclusions of glistening hornblende gneiss derived from the still older schist-complex (Plate III A). The Mississagi resting upon this basement is a conglom-

erate composed of large and small boulders in a coarse arkose cement (Plate III B). There is no sharp line of demarcation between conglomerate and granite gneiss. A gradation from solid granite gneiss into conglomerate takes place in a thickness of 3 or 4 feet. At the bottom of this gradation-zone the granite gneiss still in place consists of angular pieces a foot or so across but separated by seams of decayed granite, light brown in colour. Higher up, the blocks of granite gneiss become somewhat rounded and the interstitial material takes on more the appearance of a slightly assorted arkose. In a thickness of a yard, or a little more, it is clear that the boulders, although composed only of materials from the floor beneath, have been moved and rolled considerably and that the cementing material is sand, although a very imperfectly assorted sand. Above this is a normal conglomerate made up of about three parts of moderately well-worn boulders and one part of coarse sand. The boulders consist largely, if not entirely, of materials from the pre-Huronian floor beneath. Because of the smallness of the islet the thickness of the conglomerate cannot be ascertained accurately; but it is probably not more than 10 or 15 feet thick, for on another islet a few yards away the conglomerate grades upward into feldspathic quartzite by the alternation of conglomeratic and quartzitic layers.

On a third neighbouring island only a hundred yards away the conglomerate is in quite sharp and undulatory contact with the gneiss. At another place, in a field in section 1, Thessalon township, half a mile south of the railway crossing, the boulder conglomerate is again seen in contact with the granite gneiss. There, also, the line of contact is definite and wavy, implying a worn granite gneiss surface.

There is a remarkable development of the basal member of the Mississagi formation in the northern part of Bruce Mines map-area. It approaches near to the north and northeast parts of Echo lake and was seen there by the writer; but although it was evidently beneath the Mississagi quartzite, its strong resemblance to the Gowganda formation caused some uncertainty regarding its identity. During 1923 and 1924 the northern part of the map-area was surveyed by Dr. R. C. Emmons, who concluded that the rocks in question form a thick, local basal facies of the Mississagi. In the geological map of Bruce Mines area this basal facies is represented by a separate colour. He described them as follows:

" The basal member of the Mississagi formation has been traced from the central part of Morin township west and northwest across McMahon, Chesley Additional, part of Kehoe, and Chesley townships. Southwest of this, where the formation is repeated in outcrop by faulting, it crosses Aberdeen, McMahon, and extends into northern Kehoe township. The basal member attains its greatest measured thickness in northern Kehoe and Chesley Additional townships, where it is 4,700 feet thick; southeastward it thins and changes considerably and progressively in characteristics, until it is essentially absent in Otter township.

In Otter township the basal member of the Mississagi quartzite consists of a coarse boulder conglomerate from 2 or 3 feet to 12 feet thick. At one point at least it is practically absent. Since the Mississagi in this township is flat lying, it can be deduced that there was a considerable

amount of relief to the granite surface of erosion and deposition before the quartzite was laid down, because of the various elevations at which the quartzite granite contact can be observed, and because of the observed steep inclinations of the actual contact at some places. Tilting of the contact is precluded by the fact that the quartzite is flat lying. A considerable range in the thickness of the conglomerate is to be expected if the surface of deposition had material relief—in this instance, 50 to 100 feet.

To the westward the basal member thickens markedly. Between the occurrence described above and that to the west which is to be described next, there is an interval of no outcrop, since the younger Gowganda formation overlaps the quartzite and itself comes directly into contact with the granite. A small outcrop of quartzite was found beneath the Gowganda conglomerate in western Otter. This quartzite is classified as Mississagi on the basis of its stratigraphic position and its lithologic resemblance to Mississagi rather than to Gowganda. It is interpreted as being either a tongue or an outlier of Mississagi in pre-Gowganda time. Although the actual contact with granite could not be found, at one point the two rocks occur so near together that a conglomerate member of only 10 feet at most could be present at the base of the quartzite.

Still tracing the formation westward toward the point of its greatest development, in eastern Morin there is a conglomerate approximately 50 feet thick below the quartzite. In central Morin the top of the conglomeratic member is not exposed, but indications are that it is considerably thicker than it is a few miles to the east. In eastern McMahon, along Thessalon River valley, the next good exposures occur. Here the conglomerate member is over 200 feet thick, of which 60 to 70 feet is a good conglomerate and the remainder a pebble-bearing, red, arkosic quartzite.

It seems desirable to digress here to point out that to the south where the formation is repeated in outcrop, it contains an important greywacke-like member, and since, as pointed out below, this greywacke is characteristic of the basal member of the Mississagi where prominently developed, it seems reasonable to suppose that the formation increases in thickness southward as well as to the west.

Westward from eastern McMahon, frequent exposures may be had northwest to Garden River. The basal member of the Mississagi increases in thickness noticeably to Patton lake. Between Patton lake and Chesley Additional, the structural conditions prevent accurate measurement of the thickness, but the thickness must increase over this distance, since the formation reaches its greatest thickness a few miles to the northwest. At Garden River the formation is cut off abruptly by a fault and was not picked up by the writer on the west side. The maximum measured thickness occurs in northeastern Kehoe township, it is approximately 4,700 feet. Of this figure 910 feet is covered by an extensive swamp.

From end to end of this belt shearing is quite marked and in many places so extreme as to preclude accurate estimates of thickness. Even in the sections where measurements were made and interpreted, there are a few shear zones whose importance can only be guessed at. Confidence in the estimates of the importance of specific shear zones is gained from

the fact that practically all the shears in the measured sections are at or near the contacts of competent and incompetent beds or against granite. It is concluded that the slipping took place in incompetent beds along competent beds, with the result that there is little or no loss or duplication of strata in outcrop.

In general the basal member of the Mississagi may be divided into five distinct phases, though all of these do not persist throughout the area studied. (1) At the base is a coarse boulder conglomerate with a typical greywacke matrix in which there is an abundance of chloritized hornblende. (2) Above this is a pebble conglomerate with a dark quartzitic matrix. (3) A transition zone to the argillite above consists of interbedded quartzite, quartzitic conglomerate, and argillitic material. (4) Above this is an argillite horizon of considerable thickness. (5) A transition zone from (4) to the normal Mississagi quartzite above consists of interbedded argillite and impure quartzite. Each of these will be described in turn.

(1) The basal boulder conglomerate carries boulders of larger diameter than 8 inches. It is not more than 20 feet thick wherever observed within the region of the thick development of the basal Mississagi; it is in most places only about 6 feet thick. At two places at least it is absent. the overlying pebble conglomerate coming directly into contact with the pre-Huronian formations. This boulder conglomerate appears to be continuous with the conglomerate generally found at the base of the Mississagi in the Bruce Mines map-area, though in the northwest part of the map-area the matrix appears in general to be less quartzitic and more greywacke-like. Even locally the composition of the matrix changes, appearing in one place to be almost an argillite, in another an arkose, in another a greywacke. As a rule it is massive, but in at least one place it is banded. The boulders are almost entirely of granite, though gneiss is well represented. Amongst the smaller associated pebbles other rock materials may be found, but rarely do these materials compose a boulder. The boulders and pebbles are angular to subangular in shape and do not characteristically show surface weathering.

Microscopic examination shows that the matrix of some specimens is composed of angular grains of feldspar and quartz, either separate or combined in the form of small rock fragments. The ferromagnesian minerals are almost completely chloritized. Colourless or light green shreds of mica are abundant, commonly coating the surfaces of the feldspar and quartz grains. There is a marked change in the matrix of the boulder conglomerate as one passes from the immediate vicinity of the granite contact upward; this change is brought out most strongly by the early decrease in the apparent percentage of the chlorite, and still farther upward by the noticeable increase in the percentage of quartz present. Feldspar is, however, seldom absent.

Lamination of the matrix of the boulder conglomerate, seen only in the southern part of concession I, Chesley, is due to rather thin bands of argillitic material, which grade into the main rock both upward and downward. The arrangement of pebbles and boulders does not clearly reflect this same banding.

The contact of the boulder conglomerate with the granite presents some points of interest. At most places it is sharply defined; but at one place at least there is a gradation from one rock to the other. Where sharply defined, the matrix, though consisting of different rock materials, is commonly a fine-grained greywacke or an argillitic rock. At one place in the western part of Otter township the matrix is a very light-coloured, and very fine-grained, cherty arkose with larger feldspar fragments through it; the matrix extends downward into the granite in dyke-like apophyses for a few feet. The boulders in this are rather angular. At a point about 30 chains northeast of Stuart lake the matrix of the conglomerate is mostly an argillite, but in places it is a greywacke. The argillite too extends in dyke-like masses downward into the granite, these apophyses probably corresponding to cracks in the ancient pre-Huronian surface. At a point in concession IV, Chesley Additional, the contact is shown by patches of coarse greywacke conglomerate on the prominent granite bluffs. It is steeply inclined and the granite surface appears to be relatively even.

In the extreme north of Chesley Additional, the contact shows the granite just below to be slightly weathered. It has a greenish hue imparted by chlorite, but this extends for only a few inches into the granite. The matrix of the conglomerate is thoroughly chloritized; but the pebbles and boulders appear to have been weathered very little indeed. West and northwest of Pearl lake the granite-conglomerate contact is again exposed. Here the granite surface is quite uneven, though the relief does not appear to have been very great. At a point due west of the lake there is evidence that the granite below the contact has been considerably weathered and that the conglomerate for about 3 feet above the contact is essentially a recomposed rock. It is impossible here to pick out a sharp boundary line between the two formations, since the matrix of the conglomerate is composed of the same minerals as the granite though more weathered, especially chloritized. By contrast, about one-half mile to the northwest the granite contact is particularly sharp. Along the contact of conglomerate and granite, one mile north of Patton lake there is a zone of rather thoroughly chloritized granite which grades into fresh granite at a distance of 2 to 3 feet from the contact. Along joints in the granite there are stringers of chloritized rock which lead to the granite surface. The conglomerate matrix here is a very fine-grained, green greywacke, considerably chloritized, in which feldspar and quartz grains stand out rather prominently.

Evidence was sought in studying each of the contact exposures described that might indicate intrusive relationships, but none was found. The granite is quite coarse grained up to the immediate contact and the conglomerate is not baked as would be expected. There are neither inclusions in the granite near the contacts nor apophyses of granite in the conglomerate.

(2) The basal boulder conglomerate is not sharply defined above, but passes by gradation into the overlying arkosic quartzite conglomerate. The lithological character of the gradational phase at different localities reflects clearly the diversity of type of the overlying member. The pebble conglomerate has certain variations which take place consistently from one

side of the area to the other. Locally, also, there are pronounced variations, some of which will be mentioned. The conglomerate member has the form of a large lens, one side of which has been cut off by the fault along Garden river. In western Otter township it was not found. In eastern Morin it is thin.

The general aspect of this conglomerate to the west near Garden River is quite different from that of the same member to the east in eastern McMahon or eastern Morin townships. In Morin it is an arkosic quartzite near the base with scattered pebbles, grading upward into a bedded quartzite, which is also arkosic but lacks the pebbles. Nothing higher in the Bruce series was seen in this locality. At the next exposure to the west, in eastern McMahon, there is a large development of arkosic quartzite, red near the base and containing abundant pebbles, but light coloured, white or grey, through most of its stratigraphic extent. The pebbles become so scarce a short distance above the base that the rock might better be termed an arkosic quartzite carrying a few granite pebbles. In the district north of Patton lake and east of Stuart lake much of the conglomerate is lithologically indistinguishable from a very common rock type in the Gowganda formation. This rock type may be found in abundant outcrop north nearly to Garden River. Microscopically, it is shown to be characteristically a greywacke. Angular grains of quartz, feldspar, and to a less extent hornblende, are embedded in a fine-grained matrix of the same minerals, together with an abundance of chlorite. Mica, in fine grains and shreds, presumably secondary, occurs rather generally. West of Pearl lake the member is a conglomerate of a type similar to the Gowganda-like phase. There, pebbles and small boulders are abundantly scattered through it. Toward Garden River the matrix becomes a massive argillite, though near the base the greywacke conglomerate type predominates.

The most extraordinary rock type formed within this member is a banded argillite conglomerate occurring near the point of junction of Chesley, Chesley Additional, and Kehoe townships. This rock being relatively incompetent, was considerably sheared during the folding, but not sufficiently to mask its original appearance. The pebbles are almost entirely granite, fairly well rounded, and quite plentiful. The matrix ranges from a fine-grained, finely-banded argillite to a coarse-grained greywacke and arkose. The more siliceous bands stand up on the weathered surface. This bed was traced for half a mile along the strike, and extends farther; its greatest thickness is 620 feet; it is bounded above by light arkosic quartzite with few pebbles, and below by coarse greywacke boulder conglomerate. The contact with each is poorly defined.

Rapid and marked changes in the lithological character of the conglomerate appear to be characteristic both along the strike and across it, but particularly across it. Probably the most common of these variations is in the percentage of pebbles and their size. In places pebbles are extremely plentiful. Also the matrix changes in size of grain and in mineral composition, being in various places an argillite, an arkose, a greywacke, or a quartzite. Many of these local changes are illustrated in the vicinity of lake Charley and Pearl lake, Kehoe township.

(3) The contact between this pebble conglomerate constituting the second member and the division next above is difficult to study. An extensive and persistent swamp lies along the contact from Garden River to Thessalon river. Near Stuart lake, however, on the east side, the contact is revealed. Toward the upper part of the conglomerate, more non-conglomeratic beds of argillite appear in the pebbly quartzite. The quartzite also grows darker and pebbles become scarcer. The number and thickness of the argillite beds increase over a stratigraphic thickness of about 200 feet, in the upper part of which the formation is an argillite with occasional beds of quartzite such as may be found at several horizons throughout the argillite.

(4) The argillite is best developed in northeastern Kehoe. To the east it was not found, and is believed to be missing. West of Pearl lake the argillite is present, but much of it is conglomeratic or quartzitic. Here it is also highly sheared and affords poor opportunity for study. The thickness of the section measured is 2,600 feet. Much of this phase of the basal Mississagi strongly resembles prominent rocks in the Gowganda formation and renders correlation difficult, especially when conglomerates of both the Mississagi and Gowganda formations occur in the neighbourhood.

In its typical development in northeastern Kehoe the argillite is finely banded and in places is quite slaty. The banding is of two types; coarse banding, and extremely fine banding or lamellation. The bedding is brought out by changes in character of lamellation, or the entire absence of lamellation in some beds, or it is brought out by changes in mineral composition, or textural changes. Some beds are to be measured in inches, and some in tens of feet. The lamellation is extremely fine and appears even under the hand lens to be merely a colour variation. The lamellæ are etched out, however, on the weathered surface. Microscopic examination shows the argillite to be extremely fine grained and composed mainly of quartz, chlorite, mica, and some limonitic material in small, cloudy patches. The lamellation is brought out by slight changes in the size of quartz grains. Some lamellæ which were measured are $\frac{1}{2}$ to 1 millimetre in thickness. One very dark specimen of the argillite taken from west of Pearl lake shows marked spotting under crossed nicols, though not otherwise.

Although the central part of the argillite member is almost entirely argillite, there are occasional beds of arkose, the largest seen being approximately 12 feet thick. These are not sharply bounded either above or below, and are doubtless to be regarded merely as more extreme variations of the sort already described. To the southeast of the typical section the argillite member becomes thinner and the more finely banded phases are apparently absent. In fact, finely banded argillite was not seen south of Echo river. The argillite member was not found east of Thessalon river. To the southwest of the typical section the argillite, as revealed in the section brought up by faulting west of Pearl creek, is mainly conglomeratic, though non-conglomeratic beds occur. Here, too, the finely banded argillite is very rare. However, shearing is so pronounced in this section that too much reliance cannot be placed upon surface observations.

(5) Toward the upper part of the argillite member there are numerous intercalated beds of impure quartzite. The argillite in this stratigraphic position is also much more siliceous, in places being merely a dark cherty quartzite, and less of the laminated variety is to be found. This represents the gradational rock between the argillite and the Mississagi quartzite. It is about 275 feet thick. This gradational member is well exposed in northeastern Kehoe and also on the islands of Island lake and southeast of Island lake. In northeastern Kehoe township there is a peculiar and easily recognizable horizon that extends from Garden River, nearly to Echo river. It is a coarse-grained, red-spotted quartzite having much the appearance of a quartzite in which garnet porphyroblasts have developed. It appears that the spots indicate the positions of former red feldspar grains from which the iron has been diffused together with the resulting kaolin, possibly by groundwater action. This horizon is very near the top of the gradational member, having only some very fine-grained, dark, cherty quartzite between it and the normal Mississagi quartzite."

The base of the Mississagi and its contact with the pre-Huronian were seen at many places in Blind River map-area. Along the north shore of Quirke lake the underlying rock, a rather massive granite, is visibly decomposed for from 4 inches to 2 feet below the Mississagi contact, and, in places former crevices in the pre-Huronian surface of the granite are indicated by fingers of the same decomposed material that extend farther downward. In this thickness of from 4 inches to 2 feet the broken-down granite merges imperceptibly upward into an arkose in which the individual grains of quartz and partly decayed feldspar are a little worn. The arkose is only a few inches thick and is changed to conglomerate by the presence of boulders of the underlying granite as well as a few of quartz and foreign schistose materials. The boulders vary up to 8 or 10 inches in diameter and are fairly well rounded. At most they are barely equal in bulk to the arkose matrix which holds them together. The passage of this basal conglomerate up into the feldspathic quartzite forming the main body of the Mississagi formation is concealed by the lake or by sand flats, so that its thickness cannot be precisely ascertained, but it is between 10 feet and 50 feet thick.

As seen repeatedly on the north shore of Lauzon lake, and elsewhere in Long township, the contact of the Mississagi formation with the granite gneiss is of the same nature, though less strikingly developed. The granite gneiss is disintegrated for only an inch or two. The arkose directly above is less than a yard thick and contains only a few scattered pebbles, all of quartz, well worn and not over 2 inches in size. The entire gradation from fresh granite gneiss through decayed granite gneiss and conglomeratic arkose to the typical feldspathic quartzite of the Mississagi is complete in about 4 feet.

In the southwest bay of Lauzon lake, concession III, Striker township, there is a perfectly definite wavy line between undecomposed granite below and typical feldspathic quartzite above. The ancient soil which covered the district at the inception of the Huronian must have been swept off at this place.

In each of the above instances the Mississagi rests upon granite gneiss. Along the north shore of Tenmile lake it overlies the pre-Huronian schists, and its basal part is somewhat different in appearance, though originating in the same manner. A gradational change takes place in a thickness of 2 or 3 inches from rather massive greenstone to a dark grey greywacke-like material carrying small pebbles and grains of quartz. This dark sediment, clearly a decomposition product of the greenstone, grades into the ordinary light-coloured feldspathic quartzite of the Mississagi which lies 3 or 4 feet above the greenstone. The base of the Mississagi south of McCabe lake, in township 143, where the underlying formation is also a pre-Huronian schist, is of the same character.

A series of thin sections was prepared from samples of rock taken at intervals of a few inches across the zone of gradation from granite into feldspathic quartzite in the northwest corner of Long township, where this zone is 2 feet thick. The lowermost sample is a granite, with its original texture perfectly preserved but all the feldspars except a few cores of microcline and orthoclase decayed to an aggregate of colourless shreds of kaolin. The other samples show a gradual abstraction of the clayey product of feldspar decay and a slight comminution and rounding of the quartz grains; a scarcely perceptible gradation from granite to quartzite. The final product is a quartzite much richer in quartz than the original granite and containing only about 20 per cent of feldspar, practically all of which is moderately fresh microcline and orthoclase. The plagioclase of the granite is gone. The kaolinic material from the decayed feldspars serves as a matrix for the subangular quartz and feldspar grains. It diminishes in quantity toward the top of the 2-foot gradation zone until a little more than enough remains to fill the interstices between the sand grains.

Where the underlying formation is greenstone the decomposition products are chlorite, iron oxide, etc., instead of kaolin, and consequently the resultant sediment is dark green instead of greenish-white. But there is the same concentration of quartz grains as in the case of the granite gneiss, presumably by the same process of carrying off the finely divided decomposition materials and leaving the coarser particles. It is clear in both cases that the basal member of the Mississagi is a residual soil produced in the first place by the disintegration and partial decay of the pre-Huronian granite gneiss or schists, but modified toward the top by an increasing amount of assortment and transportation.

In the southern Huronian area (Panache map-area) the Mississagi formation rests altogether against pre-Huronian sediments, principally greywacke and impure quartzite, which Coleman has named the Sudbury series. All the strata, Huronian and pre-Huronian, are more closely folded than in the northern Huronian belt; consequently, the contact is steep, and both Mississagi and pre-Huronian rocks are somewhat metamorphosed. The Sudbury series rocks, however, are more crystalline, probably indicating that they had been partly metamorphosed before Huronian time. By locating the contact at fairly short intervals it has been traced from the mouth of Spanish river to Sudbury (*See* Map 155A). It coincides fairly closely with Spanish river as far upstream as Massey, and continues from

there northeastward, passing just south of Espanola (Canadian Pacific railway) station and coinciding again with the Whitefish branch of Vermilion river from Naughton to Ramsay lake, near Sudbury, where the basal conglomerate of the Mississagi was locally called Ramsay Lake conglomerate.

In all this distance the basal member of the Mississagi formation is a conglomerate that grades upward into the ordinary feldspathic quartzite. Its matrix is invariably a coarse grit or impure quartzite much like the arkosic base of the Mississagi in the northern Huronian area, but distinctly lighter in colour and coarser grained than the matrices of the Bruce or Gowganda conglomerates. This matrix consists mainly of quartz and partly decayed feldspar grains, with enough other decomposition products to impart an earthy, light grey or brown colour. It carries pebbles and boulders in highly variable amounts. In some localities only half a dozen small pebbles can be found in a square yard of outcrop; in others there are pebbles and boulders up to 5 feet in diameter and abundant enough to constitute one-third of the rock volume. The pebbles and boulders are all fairly well rounded and comprise a considerable variety of materials. Granite or granite gneiss pebbles are commonest; several kinds of greenstone (basic igneous rocks), green schists, and quartz are well represented. A few of the schist boulders closely resemble the metamorphosed Sudbury greywacke, but their identity with it could not be placed beyond question. Certain other small boulders and pebbles may be quartzite, though they likewise could not be distinguished with certainty from others of granular quartz on the one hand and a highly feldspathic aplitic rock on the other hand. On the whole, pebbles or boulders of the underlying Sudbury series are certainly not abundant and have not in any single instance been positively identified.

The conglomerate appears to be several hundred feet thick in many places, but no great care was taken to ascertain its thickness at any one point or how much the thickness varies from place to place. Its contact with the Sudbury greywacke was observed 3 miles west of Massey, and again just west of Espanola (Canadian Pacific railway) station and can probably be found southwest and east of Sudbury. At each of the first two places the junction is indefinite, the somewhat metamorphosed greywacke changing in a thickness of 5 feet or so to a grit carrying an occasional small pebble. There is no evidence of unconformity in either case unless the pebbles of supposed quartzite and greywacke found higher up in the conglomerate are accepted as evidence. Better ground for believing that an unconformity exists lies in the general similarity of these contacts to the unconformity at the base of the Mississagi elsewhere. If at these other places the Mississagi overlay other sediments resembling it instead of such different materials as granite gneiss or schists, the residual soil at its base would probably mask the unconformity effectually. For the entire distance between Espanola and Sudbury the conglomerate lies between a quartzite on the south (which forms the lowest or Mississagi member of a typical Bruce series sequence of quartzite, boulder conglomerates, limestone, etc.) and the metamorphosed greywacke and impure quartzite of the Sudbury series on the north. The indefinite contact with the Sudbury series is

comparable with, and not more deceptive than, the gradational contacts of the basal conglomerate with the granite gneiss in the northern Huronian area. The basal conglomerate in the southern area, however, is not so obviously due to the working over of a pre-Huronian residual soil as it is in the northern area.

The basal part of the Mississagi may be summed up as from 0 to several hundred feet of boulder conglomerate derived from a residual pre-Huronian soil. The conglomerate grades insensibly up into a better stratified feldspathic quartzite, which constitutes the bulk of the formation. This main part is diversified by conglomerates and argillites (Figure 3); but excepting these, it consists of a white to pale sea-green quartzite of medium to rather coarse grain, in beds 1 to 6 feet thick. In places, e.g. near Bruce Mines, east of Blind River, and especially near Espanola (Algoma Eastern railway) the beds are separated by partings 1 to 4 inches thick, of a friable, rusty-coloured, argillitic quartzite. The partings weather into deep grooves, rendering the stratification conspicuous even from a distance. This feature is commoner in the southern Huronian area than in the northern.

Crossbedding is very common. The crossbedded planes are notably regular, are usually inclined 15 to 30 degrees to the bedding planes, and those in one bed do not extend across adjacent beds. Symmetrical ripple-mark is common throughout the formation. Another structure, for which no interpretation has been obtained, was observed in this quartzite on the west shore of Whiskey lake, and also on the south side of Bass lake, concession III, lot 9, of Striker township. At both places the bedding plane of the quartzite shows occasional faint annular depressions about $\frac{3}{8}$ inch in diameter, like casts of small disks with thickened edges. The depressed rings, which are about $\frac{1}{16}$-inch wide and relatively shallow, are slightly rougher than the quartzite inside or outside. A few of the rings are lightly stained with limonite. There are one or two rings to each square foot of quartzite in some places. They resemble and may be rain-drop impressions.

The lower part of the Mississagi quartzite above the conglomeratic or arkosic basal member is particularly feldspathic. Whether there is a gradual decrease of feldspar from bottom to top was not positively determined, but there appears to be such a tendency. Within 100 or 200 feet of the base, feldspar makes up a quarter or even a third of the rock, whereas rather pure, white quartzite seems to be confined to the upper part of the formation. This pure quartzite, in section 19, Lefroy township (Bruce Mines area), and in a few other localities, carries thin conglomerate lenses very similar to the quartz and jasper conglomerate of the Lorrain quartzite, described farther on. The conglomerate consists of well-worn pebbles of white quartz and of banded grey silica in a matrix of rather clean quartzite. Its pebbles are notably uniform in size—$\frac{1}{2}$ to $1\frac{1}{2}$ inches in diameter—and somewhat less in quantity than the quartzite matrix. The thoroughly rounded pebbles, implying long-continued transportation, contrast significantly with the imperfectly rounded sand grains in the lower part of the Mississagi.

Where the original texture of the quartzite has not been obscured by secondary growth of the individual sand grains, the grains are subangular.

Sixty to 90 per cent of them are quartz, the remainder mostly orthoclase and microcline. Plagioclase grains are not common, perhaps, as remarked in describing the arkose at the base of the formation, because plagioclase decomposes more easily than the potash feldspars. There is enough kaolinic matter in most of the thin sections examined to form a narrow border around each sand grain, besides filling the angular interstices. This kaolinic binding material is composed largely of colourless shreds from the decay of feldspars. On the whole the quartzite appears to have resulted from moderately complete rock decay and rather imperfect assortment, which, however, improves towards the top.

The argillite facies of the Mississagi within the main body of quartzite is found in such different thicknesses and at such widely different horizons in different parts of the North Shore district, that it is thought to form a series of laterally discontinuous members or thin lenses, as represented in Figure 3, rather than a single widespread member. It has been found only in the lower half of the formation. On Serpent river just below Quirke lake there is about 100 feet of argillite, beginning only a few feet above the pre-Huronian granite gneiss. On the west shore of Whiskey lake there is 150 feet of argillite 25 feet or so above the base of the Mississagi. Just above Picard lake there is a quite thin argillite member several hundred feet up in the quartzite. Again, the argillite at the narrows of Tendinenda lake is probably 100 feet up in the formation and 100 feet or so thick. A thinner member on Elliott lake must be not less than 800 feet up. No attempt was made in the field to trace any of these across country, but the various horizons at which they occur locally is taken to indicate that they are not continuous. All these occurrences are in Blind River map-area. Argillite was not found in Bruce Mines map-area. In Panache area, in the main part of Panache lake, it appears to be represented by about 20 feet of a thinly bedded sediment, which has, however, been so metamorphosed to hornblende schist that its original character has been largely lost. The rusty argillitic partings in the Mississagi quartzite at Espanola are of the same nature as the thicker argillite members.

The argillite is regularly laminated in layers from $\frac{1}{16}$ to $\frac{1}{2}$-inch thick. The upper and lower parts of each layer are slightly different in colour, giving the formation a finely banded appearance. The general colour is dark grey to dark brown. It is an exceptionally soft, weak material, being frequently crumpled and having a distinct slaty cleavage when the dip of the formation is not over 20 degrees.

Under the microscope it appears as an extremely fine-grained aggregate of colourless mica shreds (kaolin, sericite, paragonite?) and quartz particles. The rock is, unlike the majority of Precambrian rocks, the equivalent of a true shale and made up almost wholly of secondary minerals resulting from thorough weathering processes. Its banding appears to be due not only to the very fine stratification, but also to the fact that each lamina becomes progressively finer grained and more argillitic in composition from bottom to top. The lower three-fourths or so of each lamina carries a perceptible percentage of quartz particles

embedded in the paste of secondary micas, etc., and the upper part is apparently wholly of this argillitic paste. This variation is brought out conspicuously wherever a slaty cleavage has just begun to develop; the lower, faintly sandy part of each layer remains unaffected, but the upper argillitic part exhibits a distinct parallel orientation of its mica-shreds obliquely to the bedding plane. In some laminæ the change from bottom to top is gradual; in others, abrupt enough to give the appearance of two distinct parts. Occasional quartz grains 0·05 millimetre across are scattered here and there through the lower part of the coarser laminæ, but as a rule they are not over 0·01 millimetre. The argillitic materials are still finer grained.

Conglomerates of several kinds occur locally in the Mississagi, chiefly in the northern Huronian area. The quartz conglomerate lenses seen in Lefroy township, and the basal conglomerate, have already been sufficiently described. The most striking of the others was traced from the terminus of the Blind River Transport Company's railway on lake of the Mountains southeastward to within 2 miles of Algoma. It is a boulder conglomerate 20 to 50 feet thick. The boulders in it are rather well rounded, up to 18 inches in diameter, and consist of granite, gneiss, greenstones of several kinds, quartzite, conglomerate, and a greywacke-like stratified material. There are also angular blocks of friable brownish quartzite, beds of which occur in the Mississagi quartzite beneath. The boulders are packed closely together and their interstices filled with a coarse grit. This conglomerate clearly represents an erosion interval during Mississagi deposition, for, besides the blocks of brown quartzite in it, the quartzite surface on which it rests is in places definite and slightly uneven with respect to the bedding plane. At first this break was regarded as an important one and equivalent to the unconformity between the Bruce and Cobalt series in other parts of the North Shore district. That opinion has since been disproved; the conglomerate is certainly within the Mississagi formation and is, apparently, restricted to the neighbourhood of Lauzon lake and lake of the Mountains. The Bruce-Cobalt unconformity in the same neighbourhood is at a higher horizon.

One small outcrop of conglomerate of different character was found in the Mississagi just to the northwest of Thessalon. In that outcrop a well-worn pebble conglomerate, overlying ordinary Mississagi quartzite, is made up of well-rounded pebbles up to 4 inches diameter, packed closely and held together by a small amount of coarse quartzite. It cannot be more than 6 or 8 feet thick, for nearby outcrops higher up are of quartzite. The pebbles, principally of granite and gneiss, include a few of a distinctly clastic quartzite, which, however, does not resemble the underlying Mississagi quartzite. The contact is definite and uneven, but the disconformity between quartzite and conglomerate is probably of very local significance, since no other trace of the conglomerate could be found.

Slightly conglomeratic phases of the Mississagi quartzite occur in the northern part of Blind River village. A boulder conglomerate was

observed also on the east shore of Moon lake, but its relation to the adjacent Mississagi quartzite was not investigated.

The relations of the Mississagi formation to the pre-Huronian basement and to the other members of the Bruce series render its identity easy and certain in nearly all parts of the North Shore district. Around the east end of Panache lake, however, where the pre-Huronian floor is missing there are some quartzites and mica-schists, of doubtful identity, although mapped as Mississagi. The rocks in question are mainly impure greenish quartzites with smaller amounts of more argillaceous materials, altered to staurolite and garnet schists. One or two thin beds of boulder conglomerate are also present. These rocks appear to grade conformably up into the normal Mississagi quartzite which surrounds the main part of the lake. Nevertheless, they do not correspond exactly in lithological character with the lower part of the Mississagi elsewhere in the district. In part this may be ascribed to local contact metamorphism, for the Huronian formations in the eastern part of Panache map-area are intruded by the late Precambrian (Killarney) granite. These quartzites and argillites are partly converted into staurolite schist and mica-schist, but there lithological divergence from normal Mississagi types is not wholly ascribable to this cause. The difficulty of placing these rocks is increased by the fact that there are no nearby pre-Huronian formations with which their relations might be observed. They may belong to the Sudbury series, in which case that series would have to be regarded as Huronian; or they may be a lower part of the Mississagi formation.

Thickness. The great range in thickness of the Mississagi formation is one of its most interesting features. There appears to be a fairly uniform but extraordinarily rapid increase southward. On the north side of Quirke lake—the most northerly part of the district studied—the Mississagi is not much over 1,000 feet thick, judging from its width and average dip. Near Elliot lake, on the opposite side of the same syncline and 10 miles to the south, there is apparently 1,500 to 2,000 feet, though the low dip of the formation makes any estimate of the thickness very speculative. In Shedden and Victoria townships, 12 miles farther south, where the Mississagi dips 45 degrees to 80 degrees southward, the estimated average thickness is 3,500 feet. Then the Murray fault intervenes and the next Mississagi, 5 miles farther south, in the southern Huronian area, does not seem to be less than 10,000 feet thick, and throughout the southern area seems to maintain a thickness of 10,000 to 12,000 feet.

Of course, the formations near the Murray fault have been greatly compressed by close folding, and the fault itself may represent some crustal foreshortening. But allowing a shortening of 50 per cent, there still seems to have been a thickening of the Mississagi formation during deposition from 3,500 feet to 10,000 feet in an horizontal distance of 10 miles, apparently in a belt coinciding roughly in direction with the Murray fault. It does not seem likely, however, that the Murray fault had anything to do with this thickening, for the fault did not happen until long after the Mississagi was deposited, and besides, the wrong side was upthrown to explain thickening by crustal subsidence.

This sudden thickening of the Mississagi quartzite is one of a number of unsolved geological problems in the North Shore district. It is worth noting, however, in leaving it, that the thickening coincides with a zone of later Precambrian mountain-building (described later in this report). In that respect it conforms with the prevailing conceptions of the initiating causes of the mountains, and both it and the Killarnean mountains may have coincided approximately with an Huronian continental margin, with a sea to the south and southeast.

BRUCE CONGLOMERATE

Name. The conglomerate next above the Mississagi quartzite was called the Lower Slate conglomerate by Logan and Murray. The name Bruce conglomerate was substituted by the present writer in 1914.[1]

Description. The Bruce conglomerate is a massive boulder conglomerate (Plate IV A), consisting, typically, of subangular to round boulders of all sizes up to 3 feet in a dark grey matrix resembling greywacke. The boulders are largest and most abundant in the lower part of the formation. There they make up a third, possibly a half, of the rock mass. Toward the top of the formation they become smaller and less frequent, and in the upper part there may be only three or four pebbles to the square yard. At the top the nearly pebble-free greywacke grades into a thinly stratified siliceous silt which forms the base of the Bruce limestone.

Although the conglomerate itself shows no sign of stratification there is a small amount of well-stratified material associated with it in a few places. Thus, on the west shore of McLeod lake, the formation consists, in ascending order, of 4 feet of thickset, pebble conglomerate resting upon the Mississagi quartzite, then 8 feet of well-stratified silty quartzite, 35 feet of coarse boulder conglomerate, 6 feet of a well-stratified, calcareous silt resembling Espanola greywacke, and, finally, 30 feet of boulder conglomerate, which grades at the top into the stratified base of the Bruce limestone. A similar alternation of stratified silty quartzite and massive boulder conglomerate was seen on the north side of Panache lake.

The boulders and pebbles are mostly subangular; a few are well rounded. They consist mostly of granite, gneiss, a dioritic rock, green schists of various sorts, some of which may be sediments, but a few are composed of a glassy quartzite unlike the Mississagi in appearance. Some of the pebbles are more resistant than the matrix of the conglomerate, and weather into relief; others are softer and weather into pits. The conglomerate is so like the supposedly glacial Gowganda conglomerate that a lookout was kept for soled and striated boulders, but, except some which might be regarded as rudely faceted, no such evidence of glacial action was observed. This, however, should not be accepted as conclusive, for the rock is so well cemented that very few pebbles could be got out of the matrix for proper inspection.

The matrix that holds the boulders together is, for a short distance above the Mississagi quartzite, of practically the same character as that formation. But, in from 1 to 3 or 4 feet, or even as much as 40 feet in

[1] Geol. Surv., Can., Mus. Bull. No. 8, p. 19.

some places, it changes to greywacke. This greywacke is sufficiently different from the greywacke matrix of the boulder conglomerate in the Cobalt series that the two formations, otherwise remarkably alike, can be distinguished in the field in a great majority of cases, but only after intimate acquaintance with both. The matrix of the Cobalt boulder conglomerate is a homogeneous slate-coloured material, which proves on microscopic study to be pulverized rock matter in a virtually unassorted and undecayed state. The matrix of the Bruce conglomerate also seems to be a reconsolidated rock flour, but one that experienced some decay and a certain amount of washing-out of its finer clay-like components from the coarser part. It contains a higher proportion of coarse quartz and feldspar grains than the Cobalt type. These glassy particles are distinctly visible, giving the matrix of the Bruce conglomerate a gritty aspect that distinguishes it from the more homogeneous Cobalt type. Pyrite is rather characteristically scattered through the matrix in irregular grains and small bunches, and in many places also occupies the narrow spaces where the matrix has been pulled away from the boulders and pebbles. This tendency on the part of the matrix to draw away from the pebbles is also much more common in the Bruce conglomerate than in the Gowganda conglomerate of the Cobalt series.

Seen under the microscope the matrix of the Bruce conglomerate consists of large sand grains scattered through a finer greywacke basis. The sand grains—which constitute from one-fourth to one-half of the whole—are angular to subangular in shape, and up to 2 millimetres in size. They are mainly of quartz; the remainder are fresh feldspars of both potash and lime-soda varieties. The finer basis through which the coarse grains are distributed consists of chlorite and sericite shreds, epidote, minute grains of quartz and feldspar, besides more opaque indeterminate matter (Plate IV B).

So large a proportion of quartz grains in a paste of decomposition products is a condition very similar to that found in the feldspathic quartzite at the base of the Mississagi quartzite; and is probably due to the same process: decay of the other rock minerals originally associated with the quartz, incomplete removal of the light, fine decomposition products and consequent concentration of the residual quartz. The matrix of the Bruce conglomerate is probably a rock flour which, unlike much of the Gowganda conglomerate matrix, was considerably decomposed and sorted before it finally came to rest. The sorting agent, however, was a very poor one, as indicated not only by the matrix itself but also by the abundance of matrix relative to pebbles and boulders and by the ill-assortment of the boulders themselves.

Relation to Mississagi Quartzite. As observed on Echo lake, Quirke lake, Panache lake, and some other localities, the Mississagi quartzite passes conformably upward into the Bruce conglomerate in a distance of less than 2 feet. In this distance the quartzite becomes coarser-grained for a foot or so and changes to conglomerate by the inclusion of boulders, nearly all of granite and gneiss. In the next few feet (3 to 40) the matrix of the conglomerate changes from feldspathic quartzite to greywacke.

In many other places, e.g. the west shore of Bear lake in township 138, Blind River sheet, and south of Espanola, there is a sharply-defined disconformity. The top of the Mississagi shows as a clear-cut, wavy line. The Bruce conglomerate immediately above is composed of rounded boulders in a feldspathic quartzite matrix resembling the Mississagi quartzite; but in 1 or 2 feet up this matrix changes to the normal greywacke type. Just south of Espanola, one boulder of the conglomerate was found directly in the plane of disconformity, as if it had been pressed into the quartzite while that formation was still relatively soft.

In spite of this distinct disconformity it does not seem likely that sedimentation was interrupted for any great length of time, or more than locally. No pebbles or boulders from the Mississagi formation have been recognized in the Bruce conglomerate. In fact, the evidence of an erosion interval is less marked than beneath the conglomerates found locally within the Mississagi formation (*vide ante*). There certainly must have been a very considerable change in conditions of deposition for a till-like boulder conglomerate to be superposed upon a rather well-assorted, water-laid quartzite, and this change, it may be argued, would involve a considerable period of time. Yet, in such parts of the district where there is no disconformity and deposition was presumably continuous, only some 5 to 40 feet of coarse gravelly sediments were deposited during this change in conditions. No great length of time would be required to deposit that amount of coarse material. Such local disconformity as exists seems to be due to a somewhat abrupt change in the conditions of deposition rather than to an actual cessation of deposition and an appreciable interval of erosion.

Thickness. As in the case of the Mississagi quartzite there is a steady increase in the thickness of the Bruce conglomerate from the northwest side of the district southeastward. At Echo lake it is only 20 feet thick. Near Bruce Mines it is probably twice as thick, though actual measurements could not be made. Just west of Blind River, on the coast of lake Huron, it is 60 feet thick. Sections on McLeod and Quirke lakes vary from 90 to 125 feet. Near Espanola Quirke estimates the thickness, liberally perhaps, at 400 feet. Farther east, along Panache lake, only approximations can be made, on account of the complex manner in which the Bruce series is folded and faulted. It certainly attains a thickness of not less than 500 feet, and perhaps even 1,000 feet.

BRUCE LIMESTONE

Name. The name Bruce limestone was applied by N. H. Winchell[1] in 1891.

Description. The general character of the formation is indicated diagrammatically in Figure 4. The underlying Bruce conglomerate merges upward in a few feet into a thinly stratified siliceous dark grey material, which may be fairly described as an indurated silt. Although this is not calcareous it is more closely allied lithologically to the limestone formation

[1] Sixteenth Ann. Rept., Geol. and Nat. Hist. Surv. of Minnesota, 1887, pp. 145-171.

than to the conglomerate, and is consequently regarded as the base of the former. From 5 to 15 feet of this thin-bedded material at the base is non-calcareous, but above that it begins to show wafer-thin intercalations of limestone. Where exposed to the weather the limestone

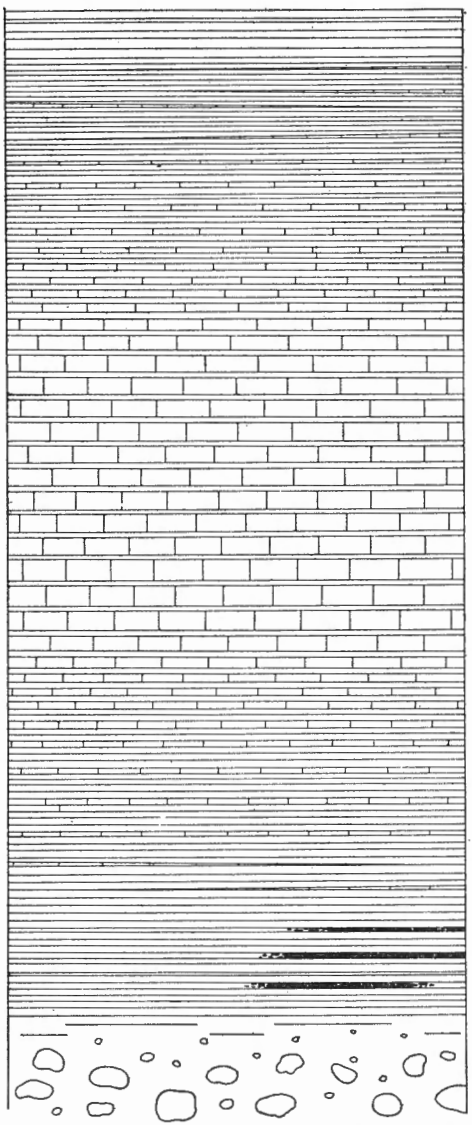


Figure 4. Diagrammatic vertical section of Bruce limestone, indicating the main stratigraphic features and its relations to the Bruce conglomerate beneath and the Espanola formation above.

leaches out so as to produce a regularly and deeply corrugated surface. From where films of limestone first appear, up to the middle of the formation, the limestone layers gradually increase in size and the siliceous material diminishes correspondingly. The middle part is about three-fourths limestone in beds a foot or less thick that alternate with siliceous layers ¼ inch or so in thickness, though occasionally 1 or 2 feet thick (Plate V A). From the middle upward the condition is reversed; the limestone layers diminish in thickness until a banded siliceous rock like that at the base of the formation results. Occasional limestone layers, however, recur to the top and throughout the Espanola formation above. The thin-bedded, dominantly silty material occupies approximately the bottom and top thirds of the Bruce formation, and the thicker bedded calcareous part the middle third. There are a few local variations from this general order. On the north side of Panache lake, for instance, and more or less generally in the southern Huronian area, the Bruce conglomerate passes through only a few feet of thin-bedded siliceous material into about 60 feet of limestone almost free from interbedded silt.

The siliceous, thinly stratified part of the formation is a dull grey to greenish-grey rock too fine grained to disclose much to the unaided eye. Microscopic study reveals a mixture of fine, angular sand and finer, clayey material (Plate V C). In an unconsolidated state it would be called a fine silt. The sandy part consists of sharply angular to subangular grains of quartz and feldspar, the largest not exceeding 0·5 millimetre ($\frac{1}{50}$ inch) in diameter and the majority under 0·1 millimetre. Feldspar grains are from ⅓ to ½ as numerous as the quartz grains and consist of plagioclase as well as orthoclase, both notably fresh. The much finer groundmass with which the sandy material is mingled consists of chlorite, sericite, and biotite shreds felted together and holding minute particles of quartz and feldspar. In addition there are occasional grains of pyrite, minute crystals of zircon, and small grains of an opaque white material not determined. The ratio of this groundmass to the coarser sandy matter varies greatly in different strata, but the groundmass is never less than half of the whole rock mass.

Where the silty material alternates with limestone layers it is more or less calcareous. Little grains of carbonate are sparingly disseminated through it. Nevertheless, the silty layers are sharply defined from the limestone layers.

The limestone beds are finely crystalline and practically devoid of silty impurities. All available analyses of Bruce limestone, as well as two of the Espanola limestone, are given below. Both formations are dolomitic. Knight[1] concludes that the Bruce limestone grades from a highly dolomitic variety at the base into limestone which toward the top of the formation contains only small quantities of magnesia.[2] Analysis I, of a sample taken from the middle of the formation, however, does not accord with that opinion. It may be pointed out also that the expressions "top," "6 inches from top", etc., used by Knight to indicate where his samples

[1] Knight, C. W., Ont. Bureau of Mines, 1915, Analyses II to VII.
[2] Ann. Rept. Ont. Bureau of Mines, vol. XXIV, pt. 1, p. 227.

for analysis were obtained, refer not to the top of the Bruce limestone formation but to the top of what has been left of it at Echo lake by pre-Cobalt erosion—in reality the lowermost third of the original formation. It is doubtful whether the magnesia content of the limestone bears any consistent relation to vertical position in the formation.

—	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
CaO	25·12	21·50	34·25	36·00	42·39	25·97	40·75	34·64	30·86	23·50	25·50
MgO	11·68	1·84	0·21	2·12	0·73	16·74	1·21	1·06	3·10	1·14	11·94
CO_2	32·61	18·82	27·05	30·39	33·78	38·22	33·03	28·47	27·64	19·23	33·17
FeO	1·61	1·61	0·96	0·52	0·93	0·84	0·32				3·79
Fe_2O_3		0·80	0·71	0·34	0·27	0·36	trace				
SiO_2		51·70	34·80	29·90	19·68	13·26	21·52				
Al_2O_3	28·79	2·65	0·63	0·30	1·51	3·90	2·64	35·50	38·40	55·63	
MnO		0·31	0·30								23·25
H_2O		0·73	1·50	0·62	0·76	0·83	0·65				
S	0·43										0·142
Total	99·88	99·96	99·96	100·19	100·05	100·12	100·12	99·67	100·00	100·00	97·79

I. Sample from middle of Bruce limestone, Quirke lake, tp. 144, Ontario. H. A. Leverin, analyst.

II. Sample from eroded upper surface of Bruce limestone, Echo lake, Ontario; *see* Ann. Rept. Ont. Bureau of Mines, vol. XXIV, pt. 1, p. 227.

III. Samples from 6 inches from eroded upper surface of Bruce limestone, Echo lake, Ont.; *see* Ann. Rept. Ont. Bureau of Mines, vol. XXIV, pt. 1, p. 227.

IV. Sample from 12 feet from eroded upper surface of Bruce limestone, Echo lake, Ont.; *see* Ann. Rept. Ont. Bureau of Mines, vol. XXIV, pt. 1, p. 227.

V. Sample from 20 feet from eroded upper surface of Bruce limestone, Echo lake, Ont.; *see* Ann. Rept. Ont. Bureau of Mines, vol. XXIV, pt. 1, p. 227.

VI. Sample from base of Bruce limestone, Echo lake, Ont.; *see* Ann. Rept. Ont. Bureau of Mines, vol. XXIV, pt. 1, p. 227.

VII. Average sample from 50 feet of strata near top of Bruce limestone, Garden River, Ont.; *see* Ann. Rept. Ont. Bureau of Mines, vol. XXIV, pt. 1, p. 227.

VIII. Sample from Bruce limestone, north shore of Panache lake; *see* Ann. Rept. Ont. Bureau of Mines, vol. XXIII, pt. C, p. 220.

IX. Sample from Bruce limestone, north shore of Panache lake; *see* Rept. of Prog., Geol. Surv., Can., 1853-56, p. 190.

X. Sample from Espanola limestone, west end of Panache lake; *see* Rept. of Prog., Geol. Surv., Can., 1853-56, p. 190.

XI. Sample from Espanola limestone, Quirke lake, tp. 144, Ontario. H. A. Leverin, analyst.

In townships 149 and 155 (Blind River area) the basal part of the Bruce limestone is a lean iron formation (Figure 4). The usual siliceous laminæ are interbedded with others either of fairly pure black iron ore or of siliceous material thickly sprinkled with small black crystals of ore (Plate V B). No large exposure could be found, so the thickness of this iron-bearing part of the formation could not be precisely ascertained; but it appears to be about 15 feet. It was first observed in township 155, one mile from the eastern boundary, and was afterwards found exposed at intervals eastward for 2½ miles.

The iron-ore layers range from thin lamellæ up to 2 inches thick, and altogether make up about one-fourth of the total 15 feet in which they occur. The ore is finely crystalline, black, and faintly magnetic. A sample taken from a 2-inch layer, analysed by H. A. Leverin of the Mines Branch, yielded:

SiO_2	Fe	TiO_2	P	S
31·08	40·26	0·34	0·037	0·040

A thin section made from a lean part of the iron formation shows a rude alternation of iron ore-bearing and ore-free layers. The ore-free layers consist of the normal silty aggregate of minute quartz and feldspar fragments in a scant paste of secondary mica shreds, etc. A considerable percentage of carbonate is disseminated through it; also occasional sharply octahedral crystals of black iron ore (magnetite) 0·1-0·3 millimetre in size. The iron-rich layers consist of the same aggregate of quartz and feldspar fragments, almost carbonate-free and carrying instead from 30 per cent up of disseminated black iron ore. A little of this ore is magnetite, in the same large, well-formed octahedra as occur in the ore-free layers. The bulk of it forms irregular masses and spongy clusters of much smaller, obscure crystals. On account of the weak magnetic effect of the iron formation, it is suspected that this finely crystalline material may not be magnetite, though an alternative identity has not been determined for it.

Another section of this iron-bearing material taken from within a few inches of an intrusive dyke of diabase, which appears to have metamorphosed it completely, is composed exclusively of garnet and sheaves of a highly pleochroic hornblende.

The economic significance of this iron formation is dealt with in Chapter VI.

Relation to Bruce Conglomerate. The Bruce limestone is everywhere conformable with the Bruce conglomerate, but the transition between them may take place in a couple of feet, as on the north shore of Panache lake, or may require as much as 15 or 20 feet.

Thickness. Unless thinned by pre-Cobalt erosion, the Bruce limestone maintains a thickness of 150 to 250 feet throughout the district.

ESPANOLA GREYWACKE

Name. The formation next above the Bruce limestone was first described in 1914, and called Espanola greywacke[1] because it is well exposed along the Algoma Eastern railway south of Espanola and was first recognized there as a member of the Bruce series. The name greywacke, employed before the rock had been examined under the microscope, is not very appropriate, for it has proved to be more nearly the indurated equivalent of a calcareous silt.

Description. This formation is closely allied to the Bruce limestone beneath it. It consists of the same silty material and limestone interlaminated, but the limestone constituent is reduced to an almost negligible number of thin layers occurring at irregular intervals and a variable amount of carbonate is disseminated through the silt. It is a thin-bedded siliceous-looking rock, ranging, in different beds, from pale grey to dark or greenish-grey. The beds are from less than an inch to a foot thick. Many of them are further separable into finer laminæ, down to films hardly distinguishable with the unaided eye. They weather unequally, producing an exceedingly harsh corrugated or serrated surface (Plates VI, VII). The

[1] Geol. Surv., Can., Mus. Bull. No. 8, p. 19.

layers which weather into relief are siliceous and as a rule dark-coloured; the sunken layers are lighter in colour and more or less calcareous. The occasional limestone layers found throughout the formation are never more than an inch or two thick, and appear to be quite local in extent.

Individual beds range from a non-calcareous silt or fine quartzite to quite calcareous varieties, besides which there are a few layers of pure, finely crystalline limestone. The quartzitic beds are mostly light-coloured, coarse-grained, and 6 inches to 12 inches in thickness. The quartz and feldspar fragments composing them are as much as $\frac{1}{4}$ to $\frac{3}{4}$ millimetres in diameter and collectively equal to, or somewhat in excess of, a paste of secondary mica shreds, etc., which cements them together. Thinner beds are apt to be finer-grained and more argillitic, containing from two to ten times as much paste as angular grains. The calcareous varieties have anywhere from a trace to 20 or 30 per cent of carbonate disseminated in small grains through the silt. The different layers are sharply defined even under the microscope; in fact, the delicate stratification so characteristic of the formation in the field continues down to exceedingly thin films. On the whole, microscopic examination of the Espanola formation shows it to differ from the Bruce limestone only in being less calcareous. It is not distinguishable in thin section from the silty, siliceous beds in the Bruce formation.

The general character of the stratification and the finer lamination within individual beds suggest the depositional work of gentle, shifting currents in shallow water (Plates VI, VII). The larger beds (2 to 12 inches thick) are somewhat uneven in thickness and wavy in outline. The finer laminæ composing them are still more irregular, and given to tapering out. Some of them are broken up into a string of plano-convex segments, as if their deposition had been succeeded by a brief process of erosion or ripple-marking, in shallow water, or exposed to the air before deposition of the next laminæ above commenced (Plate VI A). Ripple-marks which were seen in many places support the idea of intermittent shallow-water deposition and brief emergences, as do likewise what are taken to be mud-cracks. These tapering cracks are $\frac{1}{4}$-inch or less wide at the top and not over 2 or $2\frac{1}{2}$ inches deep. They intersect the more silty layers normal to their bedding planes and each is filled with the same sort of material that composes the layer immediately above.

Local Deformation. The Espanola formation is very commonly brecciated in the manner shown in Plate VI B. The breccia consists of angular to subangular blocks up to 4 or 5 feet in length, packed closely together. What little interstitial matter there is appears to have been derived by the grinding together of the large fragments. These lie in different attitudes, and the thin layers in each are no more distorted than in unbrecciated parts of the formation, indicating that at the time of brecciation the formation was sufficiently consolidated to behave as a rigid body. It is seldom possible to judge whether brecciation was confined to a particular horizon or not, but in one place on Quirke lake the beds both above and below a narrow belt of breccia are undisturbed.

Whether this is generally the case or not, it is difficult to conceive such brecciation to have taken place under any considerable load of overlying

formations, for in such case the blocks could not have been rotated as they have been without being pulverized or schistified. It is almost as difficult on the other hand to conceive of brecciation taking place during deposition, when the rock could hardly be well enough consolidated to behave as rigid blocks. Nevertheless, a breccia remarkably like this one, found in the laminated greywacke of the Gowganda formation[1], appears to have been formed during deposition of the greywacke. It has been suggested that the Gowganda greywacke was frozen solid at the time of brecciation.

There may be some genetic connexion between these brecciated zones in the Espanola greywacke and a series of extraordinary quartzite dykes which cut the Espanola greywacke, Espanola limestone, and Serpent quartzite (Plate VII). About a dozen of these dykes were found altogether; several on Quirke lake, several others in Merritt township south of Espanola, and two on islands in North channel. These are all from 4 to 10 inches wide, but there are probably some much wider. An outcrop of conglomerate just east of Quirke lake is thought to be part of a dyke of this sort about 10 feet wide. The locality is too drift-covered to admit of tracing the conglomerate farther and determining its form with certainty, but one vertical contact with the Espanola greywacke is exposed for a few feet. It is also known that the Espanola greywacke is the only formation exposed for a considerable distance on all sides of the conglomerate outcrop, thus reducing the chance of the conglomerate belonging to any other formation. Quirke also refers unqualifiedly to a conglomerate dyke 35 feet wide in the Espanola map-area[2], which he traced for 400 feet across the strike of the Serpent quartzite it intersects.

In no case could the full length of any of these dykes be ascertained. One, 8 inches wide, traced for 60 feet along the surface, showed no appreciable diminution in width, so its total length may be assumed to be much more. All of them have knife-sharp walls, and cut across the intersected formations in a manner indicating that they were originally vertical fissures. The narrower ones consist of a grey, impure quartzite containing some particles large enough to justify calling it conglomeratic. They are so much like the Serpent quartzite that, where they cut that formation, they are distinguishable from it only upon rather close scrutiny. The quartzitic material forming them is composed of grains of quartz and feldspar in a finer groundmass of chlorite and biotite shreds, fine particles of quartz and feldspar, and occasional grains of epidote, pyrite, and zircon (Plate IX C). The groundmass is about equal in quantity to the larger quartz and feldspar grains. The latter are angular, subangular, and rounded, subangular ones predominating. Those of feldspar are either perfectly fresh or only slightly decomposed. The two larger dykes referred to are much more coarsely conglomeratic. The 35-foot dyke as described by Quirke carries granite and quartzite pebbles up to 6 inches in size. The matrix in the supposed conglomerate dyke seen by the writer east of Quirke lake is a fairly dark grey, quartzose greywacke.

These dykes have not been found by the writer below the Espanola formation, nor in the Cobalt series above the Serpent quartzite. Dr. Eskola,

[1] Geol. Surv., Can., Mem. 33, p. 50.
[2] Geol. Surv., Can., Mem. 102, p. 39.

however, reports finding them in the Mississagi quartzite on Spanish River Indian reserve. Their walls are so sharply defined that the formations they cut must have been thoroughly consolidated when fractured in this manner. The narrower dykes, whether found in the Espanola silts or the Serpent quartzite, consist of an impure quartzite closely resembling the Serpent quartzite. It would seem, consequently, that they must have been formed before the deposition of the Cobalt series, but after the Serpent quartzite of the Bruce series had thoroughly solidified. They do not appear to have been filled from below, for, since very few were discovered lower down than the Espanola formation, there seems to be no underground source for their quartzite contents. Anyway, the Bruce series appears to have been too well indurated when so fractured to have been forced up in the form of loose sand and gravel. It is much easier to explain the formation of the narrow dykes and the resemblance of their contents to Serpent quartzite by regarding them as open fissures filled from above by surface erosion of the Serpent formation. If the two wide conglomerate-filled dykes are of the same origin as the narrow quartzitic ones, they at least must have been formed during the erosion interval between the Bruce and Cobalt epochs, since the Serpent quartzite could not supply the granite pebbles found in them.

On the assumption that the dykes which cut the Espanola formation reached to the surface, they are at least 1,200 feet deep. If that is so they are much too large and too infrequent to be regarded as shrinkage cracks. Earthquake shocks may have produced them. Modern earthquakes are known to have formed cracks comparable in size. Geikie, in his "Text Book of Geology," cites records of earthquake fissures at least 200 feet deep, and one in New Zealand which, though only 18 inches wide, was traceable for 60 miles. Possibly, then, the conglomerate and quartzite-filled fissures in the upper part of the Bruce series, the peculiar breccias in the Espanola formation, and a gentle deformation of the Bruce series as a whole before the Cobalt series was laid down upon it, are all attributable to earth movements during the period of erosion between the Bruce and Cobalt periods.

Relation of Espanola Greywacke to Bruce Limestone. It has been emphasized in the preceding section that the Espanola formation and the Bruce limestone are essentially similar in character and represent one continuous though not uniform process of deposition. In the following paragraphs the Espanola limestone will also be shown to be just a calcareous phase at the top of the Espanola greywacke. The three formations are, in fact, only variant phases of a single process of sedimentation. They have been distinguished in this investigation, however, for the purpose of strengthening the evidence for stratigraphic correlation from area to area, and also to call special attention to the existence of limestone at different horizons in the Huronian, a hitherto unrecognized fact which was chiefly responsible for stratigraphic errors made by earlier workers in the North Shore district, who used the limestone as an "horizon marker."

Thickness. Only rough estimates have been made of the thickness of the Espanola greywacke. It is about 350 feet thick on Quirke lake; but westward towards McLeod lake the apparent thickness diminishes

greatly, perhaps because of faults or of local intraformational erosion. In the Panache area it is 300 or 400 feet thick. In Bruce Mines area it is either eroded or outcrops too poorly to be measured satisfactorily. The thickness for the whole district may be placed at between 250 and 400 feet.

ESPANOLA LIMESTONE

Name. The limestone-rich upper 50 feet or so of the Espanola formation was called the Espanola limestone[1] in 1914. It was first observed southwest of Espanola, hence this particular name.

Description. The Espanola greywacke grades up into limestone by the appearance of an increasing number of thin limestone beds until limestone and silty material, in beds from a few inches to a couple of feet thick, are about equal in amount. Towards the top the limestone layers again diminish in number and thickness and finally disappear, and the rather dark grey silty material merges imperceptibly into the more quartzitic pale grey, thinly laminated base of the Serpent quartzite.

The Espanola limestone is corrugated in the same way as the Bruce limestone on weathered surfaces, owing to the unequal weathering of siliceous and limestone layers. The limestone beds weather to a brick-red colour instead of the dull grey of the Bruce. Analyses X and XI on page 50 show a considerably larger content of iron oxide in Espanola limestone than in Bruce limestone, which accords with the difference in weathering colours. Under the microscope the character is essentially the same as that already described for the Espanola greywacke and Bruce limestone. Somewhat more pyrite is present, the oxidation of which partly accounts for the red weathering.

Where this limestone and the Bruce limestone are exposed along lake shores they exhibit an interesting and highly characteristic honeycomb weathering. This has been described and figured by Dr. Quirke, who also offers an explanation for it.[2]

Thickness. Around Espanola and the west end of Panache lake the Espanola limestone is 50 to 75 feet thick, and is about the same thickness near Whiskey and Quirke lakes, but toward McLeod lake it decreases to a few thin limestone layers. Southwest of Bruce Mines, also, it is represented by just a few limestone layers. The thickness of the formation for the entire district, is, therefore, 0 to 75 feet.

SERPENT QUARTZITE

Name. Previous to 1914 no reference had been made to the quartzite at the top of the Bruce series. In 1914 it was named Serpent quartzite,[3] having been first recognized as a part of the Bruce series on Quirke lake, one of the headwaters of Serpent river.

Description. The indurated silt at the top of the Espanola limestone merges into Serpent quartzite in about 15 feet. It grows lighter in

[1] Geol. Surv., Can., Mus. Bull. No. 8, p. 19.
[2] Geol. Surv., Can., Mem. 102, p. 37, and Plate XI B.
[3] Geol. Surv., Can., Mus. Bull. No. 8, p. 19.

colour, a little coarser-grained, and more quartzitic in appearance, but the fine lamination, so characteristic of the silt, persists. The first stage of this gradation which deserves to be called Serpent formation is an exceedingly thinly laminated, fine-grained, greenish-white, impure quartzite. In the next few hundred feet the minute lamination grows less marked, and the quartzite becomes medium to coarse grained and nearly pure white. The fine lamination, dead-white colour, and a peculiar close-grained texture suggesting unglazed porcelain are so characteristic of the lower half of the Serpent formation that it can commonly be distinguished from other quartzites by these features alone. There is a tendency for the delicate lamination to be expressed on weathered surfaces by a slight corrugation. It was possible to photograph this structure (Plate IX A) at one place where wind-borne charcoal dust from forest fires had lodged in the minute furrows and brought the otherwise faint corrugation into strong visual relief. The Serpent quartzite is further distinguished from the Mississagi by an almost complete absence of false bedding and of conglomeratic phases. Only in one place, on the east shore of Quirke lake, was conglomerate found, and there just a few lenses of well-worn, white quartz pebbles in a quartzite matrix.

The above description applies to the first 1,000 feet of the formation, the only part that occurs in the Bruce Mines and Blind River map-areas. In the Panache area, where there is a much greater thickness, the dead-white, laminated quartzite continues up into a coarse-grained, pink variety of great thickness. Excepting its fine lamination the formation is massive, not being separated like the Mississagi by distinct partings into thick strata.

The Serpent quartzite is made up of quartz and feldspar grains, with a scanty amount of dusty kaolinic material filling the angular interstices (Plate IX B). The feldspar, which includes orthoclase, microcline, microperthite, and acid plagioclase, is quite fresh and makes up from one-fourth to one-half of the rock mass. Both quartz and feldspar grains have been enlarged by secondary growth in most of the thin sections examined and the shapes of the original sand grains cannot often be seen. Wherever they are still outlined by dust rims, however, the outlines are subangular or rounded. This is more particularly true for the lower 1,000 feet of the formation; the coarse, pink quartzite higher up is composed of more angular particles and is richer in feldspar. A little carbonate is present in most sections, but there are no dark minerals. The carbonate, which appears to be a fairly constant constituent, weathers to a light brown colour, suggesting the presence of a small percentage of siderite.

Thickness. The top of the Serpent quartzite is everywhere a surface of erosion, consequently its original thickness is not determinable. The lower part of thinly laminated, porcelain-white quartzite, as measured on Quirke lake, is 1,100 feet thick. On Panache lake it is possibly 1,500 feet thick and is overlain by coarse, pink quartzite probably several thousand feet thick.

RELATION OF BRUCE SERIES TO THE PRE-HURONIAN

In the northern and western parts of the North Shore district the Huronian sedimentary formations are folded only gently, dipping from 5 to 40 degrees. The pre-Huronian surface upon which they were deposited is, of course, deformed in the same moderate degree; consequently, there are excellent opportunities for studying the unconformity between the Bruce series and the pre-Huronian. In the southern and eastern parts of the district the Huronian formations are more closely folded, and the unconformity, though quite as profound as elsewhere, is less striking.

The contact between Huronian and pre-Huronian is best seen in Blind River map-area, where the comparatively unmetamorphosed Mississagi quartzite rests upon either granite gneiss or the crystalline, steeply tilted schists of the schist-complex. The base of the Mississagi is a consolidated bouldery soil formed by the decomposition in place of the pre-Huronian rocks just before the Huronian was deposited. This contact was traced with only slight interruptions for 2 miles along Lauzon lake, and for a still greater distance along the north shores of McLeod and Quirke lakes. In each case the line of contact was found to be notably straight, from which it may be inferred that the surface of the pre-Huronian upon which the Bruce sediments were laid was comparatively flat. Occasional embayments like that just west of Quirke lake probably represent pre-Huronian hills of no great size. The surface of contact between the Mississagi quartzite and the pre-Huronian granite gneiss is more steeply inclined in Lewis and Shedden townships, but there again, the contact line is notably rectilinear.

Some conception of what this unconformity means in time may be gained when it is remembered that the granite gneiss which constitutes so much of the pre-Huronian floor is a deep-seated intrusive and must have solidified under a heavy cover of schists. Before the Mississagi quartzite was laid down thousands of square miles of the granite gneiss had been laid bare by erosion and only small infolded remnants left of the schist-complex. If the granite gneiss batholiths and the closely folded and schistified volcanics of the schist-complex are accepted as proof of pre-Huronian mountain building, there must be imagined a period of time between irruption of the batholiths and deposition of the Bruce series long enough for these pre-Huronian mountains to be worn down to the peneplain upon which the Mississagi quartzite now rests.

In the northwest corner of Panache area and from there towards Sudbury the steeply dipping Mississagi quartzite lies against greywacke of the Sudbury series without apparent discordance. In fact, there is so little indication of unconformity that some ground is afforded for doubting whether the Sudbury series really lies on the far side of so vast an interval as the Huronian-pre-Huronian unconformity.

EROSION INTERVALS WITHIN THE BRUCE SERIES

The local disconformities within the Mississagi quartzite and a slight one at the base of the Bruce conglomerate have been described in the sections dealing with these two formations. None of these is believed to represent extensive or prolonged erosion.

There is one other break in the series, apparently of much greater importance, about which not much is yet known or can be learned, because of the heavy drift-cover where it occurs. It was first observed in lot 2, concession II, Aberdeen township. In that locality the Bruce series is represented in ascending order by a thick feldspathic quartzite, a boulder conglomerate, and banded limestone, the succession and appearance of which indicate them to be the Mississagi quartzite, Bruce conglomerate, and Bruce limestone. Normally, the Bruce limestone is 150 to 250 feet thick and is succeeded by the Espanola greywacke, Espanola limestone, Serpent quartzite, and then unconformably by the Cobalt series. At this place, however, the limestone is only 60 or 80 feet thick, and is followed disconformably by quartzite estimated at 800 feet thick, and then by the boulder conglomerate, greywacke, etc. (Gowganda formation), of the Cobalt series. The 60 or 80 feet of limestone, judging by the proportions of limestone and siliceous layers in it, represents the lower half of the Bruce limestone. At its termination it is a thick-bedded, fairly pure limestone like the central part of the Bruce limestone and is overlain by from 1 to 15 feet of conglomerate that constitutes the base of the overlying quartzite. This conglomerate consists of rounded granite boulders and small angular fragments of the limestone enclosed in a quartzite matrix. Its contact with the limestone is perfectly definite and evidently the original depositional surface, instead of one created by dislocative movements. In an upward direction the conglomerate becomes interbedded with the white quartzite and finally gives place to it entirely.

In 1914, when this break was first discovered, it was taken to be the unconformity between the Bruce and Cobalt series, and was correlated with the Bruce-Cobalt unconformity in other parts of the North Shore district. The 800 feet of quartzite between it and the boulder conglomerate, etc., of the Cobalt series was incorporated tentatively in the Cobalt series under the name Aberdeen formation. But, in 1915, an area around Echo lake was worked over without finding any trace of this quartzite, although Echo lake is only 10 miles northwest of the Aberdeen locality. Instead, the boulder conglomerate (Gowganda formation) of the Cobalt series was found unconformably upon the eroded lower part of the Bruce limestone. It also became clearer as the field work of 1915 proceeded that the real unconformity between the Bruce and Cobalt series had in many places so deceptive an appearance of conformity that it might easily have been overlooked in the Aberdeen locality. Accordingly, a second visit was paid to Aberdeen township to review the relations of this so-called Aberdeen quartzite with the Bruce limestone and with the Gowganda formation above it.

Not much additional information was gained because of the heavy drift-cover, though the contact between the Aberdeen quartzite and the Gowganda conglomerate was found in three places. At two of these there is an abrupt change from quartzite to greywacke conglomerate in a distance of less than a yard, but the actual contact was not visible. At the third the quartzite appeared to be interbedded with the conglomerate for a total thickness of 4 or 5 feet. This apparently conformable relation, it will be shown (page 71), is a rather common feature of the Bruce-Cobalt unconformity elsewhere in the North Shore district.

The country between concession II, Aberdeen township, and Echo lake was also partly explored in the neighbourhood of Bass lake, for further evidence; but again the drift cover proved baffling. There remained a distance of only 3 or 4 miles in this interval where additional evidence regarding the relationships of the Aberdeen quartzite might be exposed, but this was examined in 1923 by Dr. Emmons. It does not seem likely, therefore, that much additional data regarding these relationships can be obtained.

It is pretty safe to say that the quartzite called Aberdeen quartzite in 1914 is really Serpent quartzite, for no quartzite has been found at the base of the Cobalt series anywhere else in the North Shore district. It has the characteristic delicate lamination and dull porcelanic appearance of typical Serpent quartzite. Moreover, the abrupt change from this quartzite to the Gowganda boulder conglomerate above is similar to the Bruce-Cobalt unconformity in other parts of the country where the Serpent quartzite and Gowganda conglomerate are in contact (compare page 71). The disconformity at the base of this quartzite is accordingly to be conceived as an erosion gap representing half of the Bruce limestone, and all of the Espanola greywacke and limestone.

Until more of the North Shore district is systematically explored the full geographical extent of this important gap in the Bruce series cannot be ascertained. Little more can be learned about it in the Bruce Mines map-area because of the heavy drift-cover. There are, however, some indications of a lesser erosional break at about the same horizon in the Blind River map-area. On the largest island in Quirke lake there is in the Espanola greywacke a breccia which contains one piece of granite among the angular fragments of the greywacke. This granite fragment implies erosion and transportation. A conglomerate containing well-worn pebbles of granite and other materials was also found in the Espanola formation on an islet near the north end of Caribou lake, township 138, and at the outlet of the lake. The islet is only a few yards across and no trace of the conglomerate was seen on the main shore of the lake. It is possible that this conglomerate and breccia are related to one another and to the erosion gap in Aberdeen township and that further exploration of the country may reveal the same break in other localities.

Nevertheless, this break is apparently only a local disconformity. There is no sign of it in the Panache map-area. Moreover, the Bruce limestone, Espanola greywacke, and Espanola limestone are so clearly the result of deposition under the same conditions that they constitute in

effect a single formation, and any interruption within them such as represented by the conglomerate at Caribou lake and the breccia at Quirke lake, must be regarded as intraformational and presumably of brief duration. In spite of this disconformity and those in the Mississagi and the Bruce conglomerate the formations here grouped under the name Bruce series appear to constitute a single serial process of sedimentation.

CONDITIONS OF DEPOSITION OF BRUCE SERIES

The Bruce series in eastern Ontario is found within an area nearly 200 miles long from Sault Ste. Marie to lake Wanapitei, and 30 or more miles wide. Its original southward extension cannot now be determined, partly because it has been cut off by the late Precambrian (Killarnean) batholiths, and partly because it is concealed either by lake Huron or the overlapping Palæozoics; but, if the thickness of the series where it is last seen towards the south be taken as a clue, the basin of deposition must have continued far in that direction. West of Sault Ste. Marie it is also hidden by lake Superior and by Palæozoic beds as far as Marquette. But at Marquette and westward there is a series of quartzite, dolomitic limestone, and slate (the Lower Huronian series of the Lake Superior geologists) which resembles the Bruce series very closely and is with little doubt its stratigraphic equivalent.

In the Ontario part of this basin the series is rather notably uniform. The sequence of formations is constant, and each formation is uniform lithologically, though some vary greatly in thickness. About the same may be said of the Lower Huronian on the south shore of lake Superior. The Lower Huronian contains no correlative of the Bruce conglomerate and has a slaty formation (Wewe slate) in place of the Serpent quartzite; otherwise it resembles the Bruce series closely. It is clear, then, that the Bruce sediments were deposited in a basin certainly 200 miles from east to west and more likely 500 miles, and of an unknown but probably great width. Also that the conditions of deposition throughout this basin, whatever their nature, were fairly uniform.

What those conditions were must be deduced largely from the Bruce sediments themselves and to a less extent from the physiographic conditions attendant on their disposition. The pre-Huronian judging from its even contact with the Bruce series must have had a low, peneplain-like relief when Bruce sediments began to be deposited upon it. It must also have been a land surface for some time, in order to have produced the bouldery soil of arkose and greywacke at the base of the Mississagi.

From then until the close of the Bruce period the district appears to have been intermittently submerged in shallow water. The Mississagi formation, above its base of residual soil, is largely a medium to coarse-grained quartzite, in distinct even beds 1 to 6 feet thick, locally conglomeratic, and strongly crossbedded after the manner of water-laid sands. Associated with the quartzite are argillite deposits too delicately and regularly stratified to have been deposited by any known agency except a tranquil body of water. The upward gradation from a slightly sandy material to impalpably fine clay in each thin stratum may even imply

deposition in fresh rather than salt water.[1] And if each stratum be accepted as an annual accumulation, it follows that the body of water in which the argillite was deposited must have continued in existence for two or three thousand years at least. Most of the conglomerates in the Mississagi may be attributed to transient wave or current action since they are only thin pebbly phases of the quartzite. The boulder conglomerate noted on lake of the Mountains, however, has a distinct erosion surface beneath it and evidently coincides with a short interval of emergence.

The extraordinary thickening of the Mississagi towards the south and southeast of the district seems to involve a profound subsidence in that direction no matter what conditions of deposition are assumed. Subsidence may have continued during deposition of the Bruce conglomerate, which thickens in the same manner as the Mississagi. No further evidence of this sort is found above the conglomerate, but deformational crustal movements are indicated by the breccias and sandstone dykes in the Espanola and Serpent formations.

The Bruce conglomerate alone, even if other evidence did not point to the same conclusion, seems to preclude the idea of an exclusively marine origin for the Bruce series. It is difficult to imagine a process of marine uplift or subsidence that could give rise to a thick conglomerate between a quartzite (Mississagi) and a silty limestone (Bruce). The conglomerate is too ill-assorted to be marine. It is a heterogeneous assemblage of granite, gneiss, greenstones, and many other materials, which must have travelled a long distance—not less than 40 miles and probably very much farther—because these materials were derived from the pre-Huronian basement, and, therefore, from outside the basin of deposition of the Bruce series. For the most part this conglomeratic material was deposited without perceptible assortment, although occasional beds of quartzite and calcareus silt interstratified with it indicate localized conditions akin to those which obtained later during deposition of the Bruce limestone and Espanola formation. These are some of the outstanding features of the conglomerate which must bear upon its origin and on the whole they point to deposition on land rather than in a standing body of water.

Assuming that land conditions did prevail, it is hardly conceivable that such material could be carried so far by water without being much more thoroughly assorted, unless, perhaps, by torrential streams. But the pre-Huronian basement appears even at that time to have had a low, old-age relief hardly in keeping with the conception of torrential streams. Rock disintegration and creepage, although perhaps productive of such material, are hardly capable of such extensive transportation, especially over a surface of low relief. There is quite a strong resemblance between the Bruce conglomerate and the supposed glacial Gowganda conglomerate, but outside the till-like appearance of the former no confirmatory evidence has yet been found for a glacial origin, whatever future investigations may reveal. The evidence is too incomplete to decide in favour of one or

[1] DeGeer, G., A geochronology of the last twelve thousand years, Compte Rendu XI[e] Congrès Géologique International, Stockholm, 1910.

another of these agencies, but it leans strongly, at least, to continental and dominantly land deposition of some sort.

Towards the top of the Bruce conglomerate shallow water conditions reappear, and remain with few interruptions to the top of the series. The Bruce limestone and Espanola formations are thinly and very delicately stratified, ripple-marked, mud-cracked, occasionally crossbedded, on a small scale, and present tiny local disconformities (Plate VI A). They have the aspect of light sediments carried and spread out by gentle currents. The alternation of silt layers with limestone implies alternating periods of turbid and clear water. There is a notable lack of evidence of strong wave-action. Once at least there was a differential uplift of sufficient duration to allow the formation of a thin conglomerate within the Espanola greywacke in townships 138 and 144 (Blind River area) and a much greater erosion gap in Aberdeen and Galbraith townships (Bruce Mines area). The autochthonous breccias in the Espanola greywackes may be connected with this uplift or some related crustal disturbance. All this evidence from the Bruce limestone and Espanola formation seems to testify unequivocally to a time of tranquil deposition almost at water-level, interrupted by gentle earth movements and local emergences.

During the Serpent epoch the calcareous silts gave place gradually to sand of increasing coarseness, but a delicate regular stratification is perceptible for hundreds of feet up from the base of the formation.

To harmonize all this evidence it is necessary to conceive a large depositional basin of relatively great continuity for 3,000 to 15,000 feet of sediments were laid down in it, yet changing in form from time to time under the influence of earth movements. This basin does not seem to have been occupied by the open sea or a large lake, for neither of these would provide the conditions of tranquil shallow-water deposition, local emergence, etc., so strongly manifested by the Bruce sediments. The series is more like one laid down under slowly fluctuating continental conditions —conditions of dry land and of those other conditions found along the edge of a continent, where the land was fairly flat and not much above sea-level.

Evidence is accumulating to prove that the region of which north-eastern Ontario is part has been a continental area, a positive element in the earth's crust, as far back as the geological record has been translated. In the "Grenville province" of southeastern Ontario, on the other hand, the great succession of quartzites, limestone, and mica gneisses known as the Grenville series, have the character of a normal marine series of sediments. At some time in the Precambrian and somewhere in the fairly short geographical interval between the Grenville province and the region here under consideration there must have been a change from marine to continental conditions. The relative ages of the Grenville series and the Bruce series are not yet known; but it is not impossible that the Bruce series was laid down on the edge of a land mass that faced a sea in which the Grenville series was deposited.

Cobalt Series

DEFINITION

A brief outline of the circumstances which led in 1914 to the adoption of the name Cobalt series for the upper of the two Huronian series in the North Shore district is given on page 29. The Cobalt series comprises the following formations:

	Feet thick
Upper white quartzite and cherty quartzite (according to Murray)	— 2,100
Banded cherty quartzite	— 700
Lorrain quartzite	5,500 — 6,500
Gowganda formation	2,500 — 3,500

GOWGANADA FORMATION

Name. In 1905 Miller and Knight[1] divided the Huronian succession of Cobalt district into a lower, Cobalt series of boulder conglomerate, banded greywacke, etc., and an upper Lorrain series of feldspathic quartzite, on the strength of an unconformity found at the base of the quartzite. Subsequent field work in Cobalt and neighbouring districts proved the unconformity to be only a local one[2], so in later reports the Cobalt series was made to include the Lorrain quartzite, leaving no separate designation for the association of boulder conglomerate, greywacke, etc. As a name was really needed, Gowganda formation was suggested by the writer in a recent report[3].

Description. The Gowganda formation is a peculiarly heterogeneous assemblage of conglomerates of various sorts, greywacke, impure quartzite, and even a little siliceous limestone. The sequence of these materials varies so much from locality to locality that it would be tedious and costly to map them separately; indeed, the different rock types merge so imperceptibly into one another that it would be difficult in many cases to do so. The whole assemblage is distinguished, moreover, by certain characteristics, which, in the opinion of most geologists who have studied them, indicate a common origin under frigid climatic conditions. So, in spite of their lithological diversity the whole association of conglomerate, greywacke, etc., can be advantageously treated as one formation.

Some idea of the stratigraphic variability of the Gowganda formation is conveyed by the series of sections represented in Figure 5. The first section is compiled from information obtained by Dr. Quirke, from six closely spaced parallel traverses across the formation north of Rock lake, Aberdeen township. The lower part of the second section was obtained mainly by direct measurement of cliff faces along Blind river in concessions V and VI, Cobden township; the upper part is from Dean Lake. The third is partly a generalization, partly a measured section, from just west of Quirke lake. The fourth is composed from partial sections found in Whitefish river. Wherever the lines bounding the sections are broken the true thickness is known only approximately or not at all.

[1] Ann. Rept. Ont. Bur. of Mines, vol. XIV, pt. 3, 1905.
[2] Eng. and Min. Jour., 1911.
[3] "Onaping Map-area," Geol. Surv., Can., Mem. 95, 1917, p. 63.

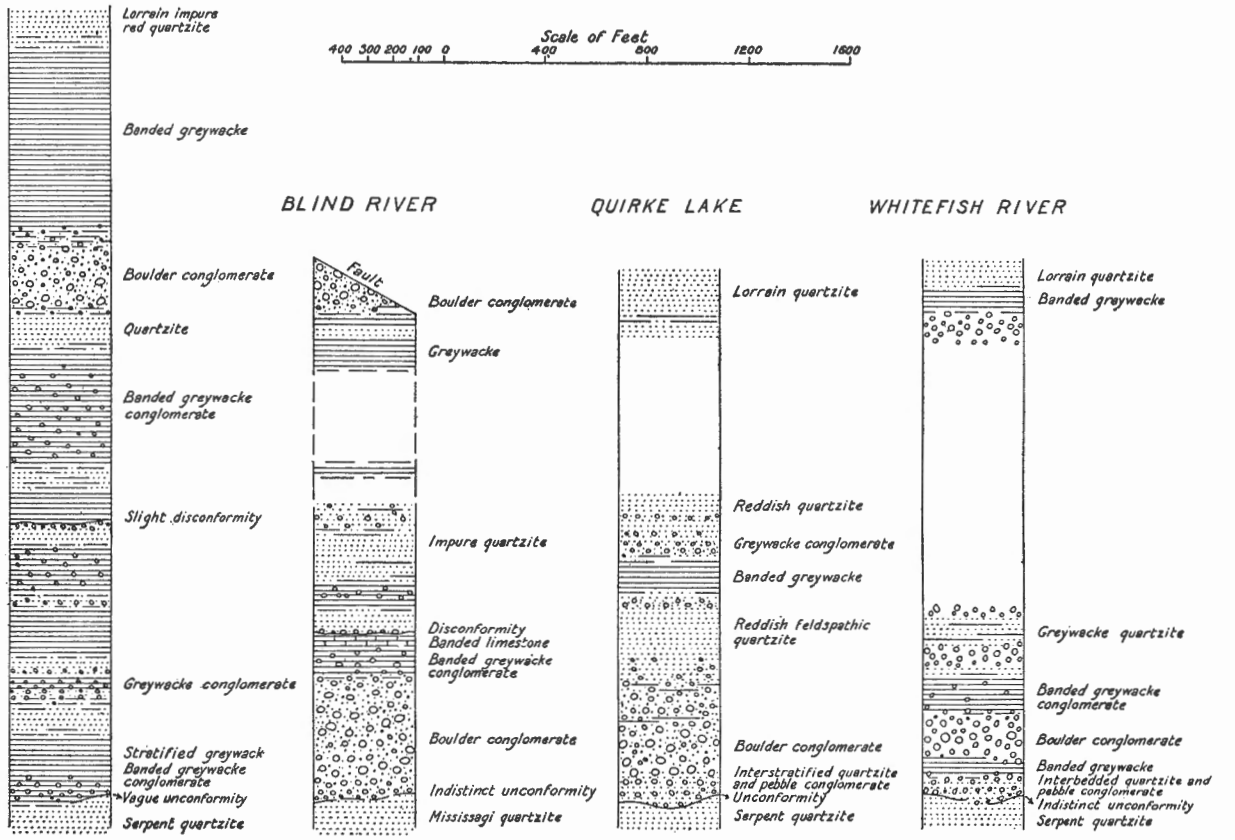


Figure 5. Vertical sections through the Gowganda formation along the north shore of lake Huron, showing its variable stratigraphic character. These sections are mainly from measured sections.

Conglomerates are abundant in the Gowganda formation and somewhat diverse in character. In many places the lowermost 10 to 25 feet of the formation is a thick-set pebble conglomerate (Plate X A) made up of pebbles under 3 inches in diameter closely packed together and cemented with smaller pebbles and sand. The pebbles are subangular to thoroughly rounded and consist of a great variety of granite, gneiss, greenstones, and other materials. The matrix of sand and fine gravel is practically free of argillitic or other fine sediments. Though the pebbles have not the flat shape characteristic of beach shingle, this conglomerate is evidently a well-washed water deposit. In the southwest bay of Quirke lake there is a basal pebble conglomerate interstratified with 1-foot beds of coarse quartzite.

A few thin beds of pebble conglomerate have been found higher up in the Gowganda formation, especially above local disconformities, but material of this sort is characteristic chiefly of the base of the formation. It invariably grades upward into boulder conglomerate, 200 to 500 feet thick. Thinner boulder conglomerates are also found higher up in the formation. The boulder type consists of pebbles and boulders of all shapes and sizes scattered rather sparingly through a relatively abundant matrix of fine-grained, slate-coloured greywacke (Plate X B). The matrix is rarely less in amount than the boulders; not uncommonly it is so abundant that less than half a dozen boulders can be found to the square yard. There is no sign of stratification in the conglomerate itself, though beds of quartzite and of boulderless greywacke are in some cases found within it.

The inclusions comprise a great variety of rock materials; granite, gneiss, amphibolite, many sorts of schists and fine-grained eruptives, quartz, and a few sedimentary ones of greywacke, quartzite, and limestone. Boulders more resistant than the greywacke matrix may be found in the same outcrop with less resistant ones, which weather into pits. In size they range from pebbles to boulders 3 or 4 feet across. The largest one seen by the writer measured 11 feet 4 inches in length. Subangular and rounded shapes are commonest, but quite angular ones, chiefly of Bruce limestone, also occur. A good many of the subangular ones have the appearance of soled boulders. One small scratched pebble, figured in Museum Bulletin No. 8, was found north of Rock lake. There may be plenty such, but as a rule it is so difficult to break the boulders out of the conglomerate that little opportunity is afforded to search for striations on them.

The matrix enclosing the boulder is a slate-coloured or dark greenish greywacke of medium to fine grain. In its least assorted condition (Plate XI A) it is a fine aggregate of quartz, feldspar, composite rock fragments, chlorite, and opaque dust, with larger angular grains of quartz and fresh feldspar scattered through this paste. The chemical analysis on page 66 indicates how little it has been weathered. The ratios of soda to potassa, of ferrous to ferric oxide, in this analysis, are more like those of igneous rocks than of a normal sediment. The lime-magnesia ratio, the alumina, and the slightly high content of chemically included water suggest a weathered sediment. Other samples of the matrix show an increasing proportion of quartz and feldspar grains relative to the dark paste in which

they are embedded, presumably in consequence of some of the fine materials being washed out during transportation.

Analysis of matrix of boulder conglomerate from Gowganda formation, Cobalt series, section 4, Thompson township. M. F. Connor, analyst:

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O (110°)
61·98	17·20	1·42	4·49	3·27	1·00	5·27	2·04	0·10

H_2O (above 110°)	TiO_2	MnO		Total
2·70	0·60	0·10	=	100·15

Even more characteristic of the Gowganda formation than the boulder conglomerate is a variety consisting of boulders and pebbles distributed sparingly through a matrix of thinly laminated greywacke (Plate X C). The inclusions constitute rarely one-fourth of the rock mass and usually only a few per cent of it. They range from small pebbles to boulders nearly a foot in diameter; no very large boulders have ever been found. The greywacke matrix is in regular layers usually about $\frac{1}{8}$-inch thick, but ranging from that down to $\frac{1}{40}$ of an inch. In some cases a coarse-grained layer alternates with a fine one, but ordinarily each layer is coarsest at the bottom and becomes steadily finer grained towards the top (Plate XI B). This produces a structure comparable to the annual rings of wood, and gives rise on weathered surfaces to a delicate banding. This banded or laminated greywacke consists of imperfectly

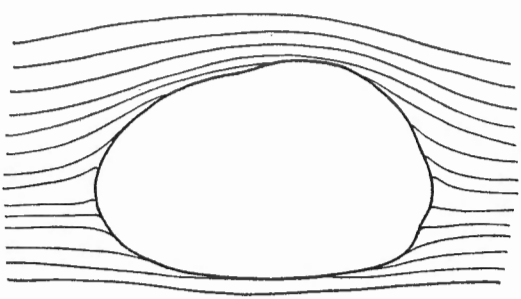


Figure 6. Sketch of pebble in laminated greywacke of the Gowganda formation, showing manner in which the pebble punched through some of the underlying laminæ and was covered by subsequent layers.

decomposed fragmental materials of the same greywacke character as the matrix of the greywacke conglomerate, but it presents some degree of assortment. The lower part of each lamina is somewhat gritty or sandy owing to an abundance of quartz and feldspar grains; towards the top the material becomes finer-grained and more like an indurated mud. This progression from coarse material upward into finer in each layer affords a means of distinguishing top from bottom in upturned strata. The lamination around pebble inclusions represented in Figure 6 and Plate X C, is also of considerable interest inasmuch as it seems to show that the pebbles dropped into the originally soft, finely stratified mud with enough force to punch through several laminæ and partly bury them-

selves. The laminæ near the base of a pebble inclusion terminate abruptly against it as if pinched out by the sinking pebble, whereas the upper part of the pebble is arched over by laminæ which only thin out somewhat toward the apex.

By a diminution and disappearance of pebbles the laminated greywacke conglomerate grades into laminated greywacke in the same manner as the boulder conglomerate merges into more massive greywacke. In other words the greywacke of the Gowganda formation is essentially the same as the matrix of the boulder conglomerate. It nearly always shows some evidence of bedding, ranging in this respect from an imperfectly stratified rock to a delicately laminated one. There are also gradations from greywacke to impure, feldspathic quartzite of lighter colour and more obviously clastic texture.

The quartzite members of the Gowganda formation range from quartzitic greywacke to true feldspathic quartzite. They are all rich in feldspar, containing as much as 50 per cent of orthoclase, microcline, and plagioclase. The quartz and feldspar grains are angular or slightly rounded, and the feldspar grains are either quite fresh or but little decomposed. Like the greywacke and the conglomerate the quartzitic members are imperfectly assorted and imperfectly weathered.

The only limestone found in the Gowganda formation on the North Shore is exposed at numerous places along Blind river between lake of the Mountains and Chiblow lake. It is a highly siliceous formation about 40 feet thick consisting of thin layers of sandy or silty material alternating with equally thin layers of limestone. These alternating layers weather like the Bruce limestone, producing a strongly corrugated surface. The limestone is underlain by laminated greywacke and overlain in places by greywacke, in places disconformably by boulder conglomerate. A similar limestone occurs in the Gowganda formation south of Wanapitei lake, and also in Demorest township,[1] closer to the original Cobalt area.

Thickness. There are only a few places in the areas studied where the thickness of the Gowganda formation can be determined at all closely. North of Rock lake, Aberdeen township, it is calculated to be between 3,000 and 3,500 feet thick. In Panache area, where it is more highly inclined, it appears to be from 2,000 to 3,500 feet thick. Elsewhere on the North Shore its thickness is undetermined, but of the same order, say 2,500 to 3,500 feet.

LORRAIN QUARTZITE

Name. The quartzite overlying the Gowganda formation in the North Shore district is correlated with the Lorrain quartzite of Cobalt district and, consequently, takes the same name.

Description. Murray originally divided what is here called the Lorrain quartzite into a lower red quartzite, a middle red jasper conglomerate, and an upper white quartzite of about equal thicknesses. This subdivision, however, is apt to convey the idea of three fairly distinct formations. As a matter of fact the red quartzite is only a local phase

[1] Geol. Surv., Can., Mem. 95, p. 69.

of the Lorrain peculiar to the Bruce Mines area, and the jasper conglomerate outside the Bruce Mines area is almost devoid of jasper pebbles. Instead of three distinct formations there is an imperceptibly easy gradation in the lowermost one-third or one-fourth of the Lorrain formation from an impure reddish or pale green quartzite into a purer white variety which continues to the top, and about the middle of the formation there is a zone of indefinite thickness which is distinguished by the presence of numerous thin beds of quartz conglomerate, locally rich in pebbles of red jasper.

The description which follows applies to the Bruce Mines area. There, the lowermost 200 or 300 feet is a rather fine-grained, dark reddish quartzite which represents a transition from the underlying Gowganda greywacke into the cleaner Lorrain quartzite above. Under the microscope it appears as an aggregate of quartz, feldspar, mica, hornblende, and other fragments in a rather dark paste of decomposition products (Plate XII B). The mica and hornblende are partly decomposed, but the feldspar grains are quite fresh. The quartz grains, which form about half of the rock, are angular.

In the next few hundred feet this dark, impure phase of the Lorrain changes to a light pink quartzite composed almost entirely of quartz and feldspar grains. Thence to the top of the formation it grows less feldspathic. The upper third, at least, is a pure white quartzite containing from 95 to over 99 per cent of silica, judging by its appearance under the microscope, and according to the following chemical analysis.

Sample of white quartzite from near head of Ottertail lake, Plummer township.

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	(Na_2O—K_2O)	Loss on ignition
95·32	2·85	0·05	trace	0·04	0·30	1·44
					Total	100·00

Analysed by M. F. Connor, Geological Survey.

This white quartzite has been so completely cemented that it appears in thin section as a mosaic of interlocking quartz individuals; but inside many of these individuals there can still be discerned faint outlines of the orignal sand grains, always thoroughly rounded (Plate XII C). About the middle of the Lorrain formation the white quartzite is diversified by beds of red jasper conglomerate. The conglomerate beds appear to be only from 1 to 5 or 6 feet thick. They occur at irregular intervals and are collectively less than the intervening white quartzite. According to Murray they occur through a vertical distance of 2,150 feet. No determination of the thickness was attempted during this investigation, but the idea was formed that the conglomeratic zone is thinner than Murray estimated it to be, and too indefinite to be measurable with any precision. The conglomerate consists of pebbles of white quartz, grey and red jasper distributed abundantly through a matrix of fairly coarse white quartzite (Plate XII A). The pebbles are subangular to well rounded and not over 2 inches in diameter.

The Lorrain quartzite in Bruce Mines area appears, therefore, to have been deposited under increasingly thorough conditions of assortment from beginning to end From bottom to top it is in massive beds 2 to 8

feet thick. Crossbedding and symmetrical ripple-marks are common except near the base. Rather characteristic of the white quartzite, also, are thin-bedded streaks and disseminated particles of specular iron ore. Occasionally, the specularite occurs in bodies large enough to have tempted their exploitation as mining prospects.

It is likely that the great area of quartzite beginning in township No. 162 of Blind River area is Lorrain, but only the edge of this area was mapped. With this exception, the Lorrain does not occur in the explored parts of Blind River area. The quartzite in township 162 is a white to pale green, feldspathic variety similar to the basal part of the Lorrain in Panache area and Cobalt district.

In Panache area Lorrain quartzite constitutes Lacloche mountains. The basal part is not so dark nor so impure as in Bruce Mines area. It is a coarse-grained, pink to pale green quartzite composed about equally of quartz and feldspar. Neither quartz nor feldspar grains show any sign of rounding. The passage from this ill-assorted feldspathic quartzite up into the purer, white quartzite at the top is less noticeable than in the Bruce Mines area owing to the slighter change in colour. The conglomeratic zone corresponding to the red jasper conglomerate is somewhat above the middle of the formation and is only a few hundred feet thick. There are almost no jasper pebbles in it, white and grey quartz pebbles predominating, but otherwise it does not differ from the jasper conglomerate in the Bruce Mines area. In all these respects the Lorrain formation of Panache area resembles the Lorrain of Cobalt, Gowganda, and adjacent districts more closely than that in the Bruce Mines area. In Frazer bay, west of Killarney, it contains a lean iron (specular hematite) formation which, according to diamond-drill tests made in 1914, is 75 feet or more thick.

Relation to Gowganda Formation. The topmost member of the Gowganda formation passes conformably up into the Lorrain at all observed points. North of Rock lake, in the Bruce Mines area, it is a banded greywacke which grades in about 30 feet into the red quartzite of the Lorrain. In Panache area, also, greywacke of the Gowganda formation gives place to feldspathic quartzite, either by an easy lithological gradation or by the alternation of greywacke and quartzite beds. No sign was found of the local disconformity with the Gowganda formation which occurs in Gowganda and Cobalt districts.[1]

Thickness. The Lorrain quartzite near Rock lake is between 5,500 and 6,000 feet thick, according to estimates based upon its exposed width, average dip, and allowances for a number of faults. In Lacloche mountains, where it stands nearly on edge, the same methods yield a result of about 6,500 feet.

BANDED CHERTY QUARTZITE

Description. The Lorrain quartzite passes gradationally up into several hundred feet of a thin-bedded formation which may be described as a banded cherty quartzite. It is made up of layers from one-fourth of an inch to 1 foot in thickness, which range in texture from a finely

[1] Geol. Surv., Can., Mem. 95, p. 76.

but perceptibly clastic quartzite to one so fine grained that it is outwardly indistinguishable from chert. The different layers range through light shades of grey, buff, and green, giving the formation a distinctly banded aspect. Where especially fine grained and thin banded it resembles in a general way the banded iron formation of the pre-Huronian. Well up in the formation a few layers of siliceous limestone, from 2 or 3 inches to a foot thick, are interbedded with the chert-like quartzite. Ripple-marks are rather common in all parts of it.

Under the microscope even the most chert-like varieties prove to be clastic. Plate XIII A represents part of an extremely fine-grained, chert-like layer overlain by one more coarse and more quartzitic. The fine layer, at a magnification of 200 diameters, just resolves into a felted aggregate of shreds and scales of colourless mica (or kaolin?) and chlorite, carrying occasional grains of quartz. It is equivalent to a fine silt composed of a little fine sand mixed with the micaceous decomposition products of feldspar and ferromagnesian minerals. The vertical line of quartz grains that crosses this layer is apparently the filling of a fine crack which was open when the next layer above was being deposited. This upper layer, shown in Plate XIII A, is much coarser than the layer beneath, but similar in mineral composition. It consists of quite angular particles of quartz, feldspar, and partly decayed ferromagnesian minerals in a much finer matrix of chlorite and sericite shreds, quartz and feldspar particles, etc. It is in perfectly sharp contact with the fine layer below, but merges upward into equally fine material by a diminution in size and number of the large particles. The tendency for each layer to grade upward from coarse to fine materials is, however, not so constant and well defined as in the laminated greywacke of the Gowganda formation. The larger particles of quartz and feldspar do not usually exceed half a millimetre in diameter. Those of feldspar, orthoclase, and sodic plagioclase are quite fresh, but biotite and hornblende grains are more or less altered to chlorite.

The banded cherty quartzite bears a rather notable resemblance to the Espanola formation, in the Bruce series. It is finely stratified, has much the same silty, locally calcareous composition, and the arenaceous part of it is composed of strikingly fresh and angular grains. It appears to have been laid down in water, judging from the fineness and regularity of the bedding, the occasional limestone layers, the ripple-marking, and the absence of pronounced false bedding or other evidence of atmospheric transportation. A rhythmic process of deposition, probably by current action, is also implied by the gradation from coarse to fine materials in each layer, as well as the clean-cut manner in which, in many cases, one layer is separated from the next.

Thickness. This formation was estimated to be 700 feet thick near Ottertail lake in Bruce Mines area. It also occurs in the middle of the Lacloche Mountain syncline south of Panache area, but is there so badly crumpled and so imperfectly exposed that the thickness cannot be reliably estimated. In the country between Cobalt and Sudbury districts it is estimated to be 200 or 300 feet thick.[1]

[1] Geol. Surv., Can., Mem. 95, 1917, p. 73.

UPPER WHITE QUARTZITE AND CHERTY QUARTZITE

In the northwest corner of Plummer township, Bruce area, the banded cherty quartzite described above is followed by white, thick-bedded quartzite similar in every respect to the top of the Lorrain. As the present investigation was not continued farther west, no complete description of this upper quartzite was obtained. Logan and Murray[1], however, estimate it to be 1,500 feet thick and to be overlain by 200 feet of yellowish cherty quartzite and limestone similar to the banded cherty quartzite described here. Above that is 400 feet more of white quartzite.

RELATION OF COBALT SERIES TO BRUCE SERIES

The unconformity between the Cobalt and Bruce series is clear cut and unequivocal in a good many places. For instance, on the boundary between Kehoe township and Garden River Indian reserve, immediately west of Echo lake, Gowganda boulder-conglomerate rests directly upon the lower part of the Bruce limestone. In fact it bevels the Bruce series in such a manner that on the south face of the steep-sided hill crossed by the reserve line the Gowganda conglomerate rests upon 40 feet of Bruce limestone, whereas one-quarter mile away, on the north side of the same hill, it rests upon the Mississagi quartzite. Where it overlies the limestone there is an inch or two of weathered calcareous material between the two formations. The first 1 to 3 feet of the Gowganda formation carries few boulder inclusions, but above that boulders are more abundant and include a few angular fragments of Bruce limestone and at least one well-rounded pebble of quartzite.

A still more sharply defined contact was found on the shore of lake Huron near the extreme southwest corner of Plummer Additional (Plate XIII B). There, the Gowganda conglomerate rests upon Serpent quartzite. The line of contact is knife-sharp and curves in such a manner as to indicate an undulatory, well-worn plane of contact. The conglomerate, which for the first 10 feet or so is a thick-set pebbly variety, was not observed to carry quartzite pebbles at this point; but worn pebbles of the characteristically laminated Serpent quartzite were found in it immediately above another contact half a mile inland.

Practically the same relations were seen on a small island in McLeod lake, Blind River area, near the outlet of the lake. The rather pebbly base of the Gowganda conglomerate is in knife-edge, discordant contact with Serpent quartzite, but was not observed to carry pebbles of the latter.

Likewise, in the southwest bay of Quirke lake the Gowganda conglomerate rests unconformably upon Serpent quartzite. The contact can be seen at the base of a conspicuous 300-foot bluff on the east side of the bay. It is quite definite and bevels at a low angle the bedding planes of the Serpent quartzite, which themselves dip about 20 degrees. The Gowganda formation for some distance above consists of alternating beds of pebble conglomerate and quartzite in slight discordance with the

[1] "Geology of Canada, 1863," p. 57.

Serpent quartzite, but finally passes into a coarse boulder conglomerate. The lower part carries many angular blocks and some subangular to rounded boulders of the Serpent quartzite.

A wavy, sharply-defined contact between the pebbly base of the Gowganda conglomerate and the Mississagi quartzite on the west shore of Chiblow lake may also be mentioned, to indicate at what widely different horizons in the Bruce series this contact occurs.

In a great many other places, however, the contact might pass readily, but erroneously, as a conformable one. Such is the case everywhere in the southeastern quarter of township 144 as well as in neighbouring parts of townships 143, 137, and 138. In these places the Serpent quartzite either passes quite gradationally in about 15 feet into the Gowganda boulder conglomerate, or in the same thickness it alternates with several thin beds of pebble conglomerate, which take on more and more the bouldery character of—and finally give place to—the great boulder conglomerate of the Gowganda formation. The gradational type is abundantly exposed on Lauzon lake and lake of the Mountains, the underlying formation in these cases being Mississagi quartzite. It is excellently exposed on Bear lake, Panache area, where the Gowganda formation overlies Serpent quartzite. It was this apparently conformable relation which led, during the first year's field work, to a mistaken recognition of the Bruce-Cobalt boundary in Aberdeen township (page 58).

The relationship is so positively one of unconformity in some places, and so like conformity in others, that it was finally decided to trace the contact between the two series continuously and with great care for a considerable distance, to see if it does not bevel two or more of the Bruce formations. This was carried out in the Blind River area, beginning near the middle of township 155 and continuing across township 149. At the west end of this section of contact the Gowganda conglomerate overlies the Bruce limestone, never less than about 20 feet above the base of the limestone and never more than 75 or 100. Where actually exposed, the contact is similar to that at Echo lake, already described. It is sharply defined, and angular fragments of limestone are abundant in the first 10 feet of conglomerate, though above that no included fragments of the Bruce series could be found. This relation persists eastward for several miles. Finally, south of Burnt lake the contact rapidly ascends across the Bruce limestone and Espanola formation to the Serpent quartzite, in which formation it remains all the way around to McLeod lake.

There can no longer remain any doubt that an erosional unconformity exists between the two series. And since this unconformity occurs all the way from the Mississagi quartzite up to the Serpent quartzite—a difference stratigraphically of not less than 1,700 feet—it can no longer be regarded as of slight importance,[1] although it is certainly less in magnitude than the profound unconformity at the base of the Huronian. The notable scarcity of Bruce series inclusions in the boulder conglomerate at the base of the Cobalt series may mean that the Bruce formations

[1] Ann. Rept. Ont. Bureau of Mines, vol. XXIV, pt. I, p. 226.

were not sufficiently hardened at that time to form durable pebbles or boulders.

It is rarely possible to determine the attitude of the Cobalt series with respect to the Bruce series since its basal member is a very thick and massive conglomerate lacking well-defined bedding planes. In only a few cases, where the bottom of the conglomerate is stratified, can such measurements be made at all, and then not very accurately. Consequently, it is not easy to determine just how much discordance there is between the two series; that is, to what extent the Bruce series was folded before deposition of the Cobalt series began. Such measurements as have been made indicate that there is discordance to the extent of 20 degrees or less in Blind River area.

It is not necessary, therefore, to regard the pre-Cobalt topography of the Bruce series as having had a total relief of 1,700 feet simply because the unconformity between the two series ranges from high up in the Serpent quartzite down to the Mississagi. The true relief was probably quite moderate. The persistent manner in which the unconformity remains within the Bruce limestone in township 155 and then abruptly ascends to the Serpent quartzite suggests that this pre-Cobalt surface was scarped, perhaps as the Palæozoic limestones on Manitoulin island are at the present time.

CONDITIONS OF DEPOSITION OF COBALT SERIES

The Gowganda formation of Cobalt district and vicinity, which is better known than that on the North Shore, is, in the opinion of most geologists who have studied it in the field, a continental, and in part a terrestrial, deposit. Coleman regards it as a result of continental glaciation. Miller questions this opinion, and suggests in very tentative terms, that deposition may have taken place under semi-arid conditions diversified by occasional torrential rains. Wilson and the present writer agree that the climate of that time was at least moist and frigid, and that Coleman's hypothesis, though not yet conclusively established, is the only one yet advanced which offers an acceptable explanation for all the observed phenomena.[1]

As the Gowganda formation on the North Shore resembles that at Cobalt in all essential respects, it is presumably also a continental deposit resultant from erosion under moist, frigid, possibly glacial, conditions. It is noteworthy, however, that every member of the formation except the boulder conglomerate is well stratified and apparently water-laid. Even the boulder conglomerate shows signs of stratification. Its base in many places is a beach-like pebble conglomerate, and thin beds of quartzite and greywacke occur higher up in it. Shallow, localized submergence seems

[1] For a full discussion of this subject, *See* especially:

Coleman, A. P., Am. Jour. Sc., vol. XXIII, 1907, pp. 187-192; Bull. G. S. A. vol. XIX, pp. 347-366; Jour. Geol., vol. XVI, 1908, pp. 149-158.

Miller, W. G., Ann. Rept. Ont. Bureau of Mines, vol. XIV, pt. 2, 1905, p. 41; Ibid, vol. XVI, pt. 2, 1907, pp. 57-58; Ibid. vol. XIX. pt. 2, 1909, pp. 86-87.

Wilson, M. E., Geol. Surv., Can., Mem. 39, 1913, pp. 88-98.

Collins, W. H., Geol. Surv., Can., Mem. 33, 1913, pp. 55-58.

to have been the dominant physiographic condition throughout Gowganda time. In Cobalt and neighbouring districts, on the contrary, a considerable part of the Gowganda formation is unstratified and apparently a land deposit. These differences, and the differences in conditions of deposition which they connote, are worth special attention, for nothing quite comparable with the Gowganda formation—or for that matter, with the Cobalt series—has been found still farther west, in the Huronian on the south shore of lake Superior.

With the coming of the Lorrain the shallow submergence apparently became general for this district and much of northeastern Ontario.

Late Precambrian Basic Intrusives and Extrusives

Under this head are grouped all the basic igneous rocks in the district which are intrusive in the Bruce and Cobalt series. They comprise, as the maps show, a large number of unconnected bodies, mostly intrusive dykes and sills, but also two which appear to be lava flows. Most of the diabase and noritic members of the group are regarded as correlatives of the Keweenawan diabases of Lake Superior region. Some are, however, younger than formerly believed, and others are probably older than the Keweenawan. A thorough study of the petrology and age relations of these basic rocks would probably prove them to vary rather widely in age and composition, but in this report they are simply grouped with respect to age under three main heads:

(1) Basalts having amygdaloidal and other structures indicative of an extrusive origin. The Thessalon greenstone is the chief representative of this group. A greatly metamorphosed basalt which extends along the railway from McFerson station to Cutler is also included in it.

(2) Dykes and sills of quartz diabase and closely allied rocks similar in composition to the diabase of Cobalt and neighbouring districts with which the silver-cobalt ore deposits are associated. These intrusives are generally believed to be Keweenawan. Dykes of quartz diabase cut the Thessalon greenstone.

(3) Dykes of olivine diabase, which cut all the other Precambrian formations in the district, including the quartz diabase.

(1) THESSALON GREENSTONE

This formation is confined to an area of 12 square miles in the immediate vicinity of Thessalon. It is well exposed in the islands that fringe the coast of lake Huron, but is largely concealed on the mainland by the level drift-sheet, through which it rises in low irregular patches.

The formation, as a whole, is composed of massive basaltic material, almost black, invariably fine-grained and rather poor in vesicular, tufaceous, and other structures indicative of its eruptive nature. Along lake Huron it is particularly massive and medium to fine in grain. Finer-grained phases showing amygdaloidal and other volcanic features are more common inland. The amygdaloidal parts, however, are never extensive. The amygdules in the vesicular parts are filled with quartz, or quartz

and pyrite, are round to elliptical, from one-half to 1 inch in diameter, and not abundant. The amygdaloidal parts do not appear to be at the top of the formation, for greenstone without amygdules occurs above as well as below them. In one place—lot 1, Thessalon township—the weathered surface of the greenstone shows a rather faint ellipsoidal or pillow structure. A coarse conglomerate phase was observed at only one place by the writer, but two other localities are mentioned by Mr. C. W. Knight[1], who has also studied the Thessalon greenstone. With the exception of occasional east-west shear zones the formation is unschistified, a feature which distinguishes it from the pre-Huronian volcanic complex. It is cut by a number of dykes of quartz diabase.

Either the Thessalon greenstone varies a great deal in composition from place to place, or it includes a number of independent members which have not yet been distinguished from one another. The first analysis given below is of a medium-grained sample obtained from an island in lake Huron 1½ miles east of Thessalon. According to a thin section, somewhat more than half of the sample consists of partly decomposed hornblende; the remainder is made up of an intermediate, unstriated plagioclase, brown biotite, and black iron ore altering the leucoxene. The prisms of hornblende are idiomorphic toward the plagioclase. Analysis No. 2, of a typical sample of the greenstone from the southwest corner of lot 22, Thessalon township, by C. W. Knight, differs radically from No. 1.

	I	II
SiO_2	49·24	52·18
Al_2O_3	10·35	17·26
Fe_2O_3	2·07	8·91
FeO	12·18	4·14
MgO	8·55	3·86
CaO	8·52	5·83
Na_2O	2·38	2·86
K_2O	1·39	1·76
H_2O (at 110°)	0·08	
H_2O (above 110°)	3·20	2·56
TiO_2	1·60	
MnO	0·09	
CO_2	.....	0·50
Total	99·65	99·86

No. I. Thessalon greenstone from island in lake Huron, 1½ miles east of Thessalon. M.F. Connor, analyst.

No. II. Thessalon greenstone from southwest corner lot 22, Thessalon township; *See* Ann. Rept. Ont. Bureau of Mines, vol. XXIV, pt. 1, p. 223.

No petrographic description of this sample is given by Mr. Knight, but a typical amygdaloidal specimen obtained by the writer may correspond to it. This specimen has the same general appearance as No. 1 and presents the same texture in thin section, but fully 75 per cent of it is untwinned intermediate plagioclase, and the remainder is brown biotite, black iron ore altering to leucoxene, and a small amount of hornblende.

[1] Ont. Bureau of Mines, Ann. Rept., vol. XXIV, pt. I, 1915, p. 223.

A third specimen, taken from a small dyke intersecting the main greenstone body just east of the mouth of Thessalon river, is a medium-grained, basaltic type carrying a few phenocrysts of feldspar. Under the microscope it is seen to consist of common hornblende, intermediate plagioclase, biotite, black iron ore, pyrite, apatite, and a little quartz. Hornblende makes up somewhat over half the rock mass. The plagioclase, which is next in abundance, is in thick plates that penetrate the hornblende ophitically.

The precise age of the Thessalon greenstone is a little obscure. It was found overlying Mississagi quartzite at two places in the western half of lot 1, Thessalon township, not far east of the road. In each case it is fine grained, free of amygdules, and in tight, obviously chilled, contact with the quartzite. The greenstone contains rounded inclusions of quartzite. Knight, who was the first to note its relationship to the Huronian sediments, describes a number of other similar contacts.

Since the greenstone has some of the characteristics of an extrusive lava, it might, at first glance, be regarded as a lava flow contemporaneous with the Mississagi. If that were the case, it should occupy a definite horizon in the Mississagi, which it does not. On the contrary, it appears to bevel the Mississagi; and on the coast of lake Huron it probably lies directly upon the pre-Huronian granite gneiss. There is no evidence of an erosion surface within the Mississagi over which the greenstone lava might have flowed. Moreover, no extrusive formations have been found in the Mississagi anywhere else. It seems more likely that the Thessalon greenstone was erupted some time after the Cobalt period, for only as late as that does there seem any possibility that an erosion surface reaching down through the Mississagi quartzite could have been provided. The greenstone is allied in composition to the quartz diabase and other younger Keweenawan basic intrusives and may be of about the same age. Even though it is intersected by quartz diabase dykes it is probably more nearly related in time with these intrusives than with the Bruce series.

The strip of basic rocks which extends from McFerson to Cutler is a good deal like the Thessalon greenstone. Near McFerson, it consists of a nearly black rock ranging from a massive, fine-grained diabase to a basalt or a chloritic schist, according to the coarseness of grain and the degree of deformation. Obscure agglomeratic and amygdaloidal structures were noticed very locally in fine-grained parts of the mass. Otherwise there is nothing to indicate whether it is intrusive or extrusive. In the direction of Cutler it changes gradually into a glistening black amphibolite and amphibolite schist, in consequence of the metamorphic effect exercised upon it by the Cutler granite.

The age of the sediments (supposedly Sudbury series) with which this basic mass is associated could not be positively established, consequently there is equal uncertainty regarding the age of the igneous formation. It is either contemporaneous with or younger than these sediments, and it is older than the Cutler granite, which, as shown later, is younger than the quartz diabase of the Keweenawan.

It is so changed by metamorphism that it can no longer be closely compared lithologically with the Thessalon greenstone; but so far as com-

parison is possible, they appear to be basaltic rocks of the same general character. Until contrary evidence appears it will be convenient to group the greenstones at Thessalon and those between McFerson and Cutler together as probably Keweenawan, but older than the quartz diabase intrusives of the Keweenawan.

(2) QUARTZ DIABASE AND ALLIED ROCKS

Distribution and Modes of Intrusion. A large majority of the late Precambrian basic rocks in the North Shore district are quartz diabase or closely related to it. Small areas of these rocks occur at short intervals throughout the district. Most of the areas shown on the maps that go with this report are believed to be the outcrops of sills. They have much the same forms and relation to the Huronian sediments as the diabase sills of Cobalt and Gowganda districts. They are overlain and underlain by the sediments and tend to outcrop in belts along the strike of these sediments. In a few places, where cliff-faces or hill-sides offer favourable conditions for observation, they can be seen to conform with the bedding planes of the sediments. Moreover, their contact metamorphic effects upon the sediments are insignificant and accord better with the idea of a relatively thin tabular irruptive mass than a more equidimensional one of large volume.

The diabase belts may be regarded as the bevelled edges of sills which continue underground along the bedding planes of the Huronian, reappearing possibly in other places. Portions of unknown extent have been destroyed by erosion. The original dimensions of these sills can only be conjectured, but it seems reasonable to believe that some of them attained hundreds of square miles in extent. The diabase belt in which the Bruce copper mine occurs, for example, is continuous for 15 miles, was probably formerly connected with diabase areas farther northwestward, and may have extended for similar distances in other directions.

Assuming that they are conformably between the Huronian strata the larger sills must be as much as 1,500 or 2,000 feet thick. The Bruce copper mine has been worked to a depth of 420 feet in a diabase mass, already deeply eroded without passing through it.

In addition to the sills there are a great many dykes. As these dykes are tedious to trace and not particularly important very few of them are shown on the maps. Some are known, however, to reach 100 feet in width and to extend for 4 miles, without signs of termination.

Description. Forty specimens of diabase for microscopic study were taken from dykes and sills at various points between Echo and Panache lakes. All but one of these are indistinguishable from the quartz diabase of Cobalt and Gowganda districts. The diabase sills and dykes from which the samples were taken are intrusive in Huronian formations, as at Gowganda and Cobalt. They have associated with them dykes of an acid aplitic differentiate, as in those districts, and also veins carrying ores of copper and cobalt. There is reasonable ground, therefore, to regard the diabase in all three districts as closely alike.

The quartz diabases of Gowganda and Cobalt districts have been studied with some care and found to be rather complicated, petrographically. A full discussion of those in the North Shore district would occupy much space and accomplish little more than a repetition of something already known. Consequently, the petrographical account which follows is limited to a general description of the diabases and their genesis. For a more complete treatment of this subject the reader is referred to petrographical discussions of the Cobalt and Gowganda diabases.[1]

The diabase is invariably a dark green rock, distinguished from the pre-Huronian greenstones in most cases by its massive character. Even in the southern Huronian area, where it has been involved in the close folding of the Killarnean mountain-building, it is quite massive, with the exception of a few narrow shear-zones caused by faults. But it varies greatly in texture according to the size of the dyke or sill in which it occurs, or, in other terms, to the time allowed for crystallizing. The edges of dykes less than 5 feet thick are mostly a black glass carrying occasional tiny crystals of feldspar and pyroxene. Sill diabase, on the other hand, is about as coarse as ordinary granite.

Corresponding with the coarseness, or rate of cooling, of the diabase, there are certain textural differences. The chilled edges of very small dykes are partly glass, more or less devitrified. Specimens from larger dykes and sills are holocrystalline, fine to coarse grained, and with corresponding gradations from a well-defined ophitic texture to a gabbroid one.

There are also certain mineralogical distinctions between the fine-grained and coarse-grained phases. An average fine-grained sample, seen under the microscope, consists of about equal parts (45 to 50 per cent) of augite and labradorite, together with a few per cent of black iron ore (titaniferous magnetite). Occasional small flakes of brown biotite, grains of yellow, copper-bearing pyrite, and minute rods of apatite are the usual accessory constituents. Rhombic pyroxene was not seen in any of the forty thin sections examined, though it accompanies augite rather frequently in the diabase from the country around and south of Gowganda. All fine-grained phases of the diabase have this composition. But, wherever the diabase exceeds an average coarseness of grain of 0·25 millimetre ($\frac{1}{10}$ inch) there appears another highly characteristic constituent, which becomes more abundant as the diabase grows coarser, so that in coarse gabbroid phases it makes up 10 to 15 per cent of the rock. This additional constituent is a micrographic intergrowth of quartz and andesine, which occupies angular interspaces between the labradorite and augite and was evidently the last constituent to crystallize.

The appearance of micrographic intergrowth is interpreted as an early effect of differentiation in the crystallizing diabase magma. Further development of the differentiative process leads to the formation of small segregations and narrow dykes, in the diabase of a light-coloured aplitic derivative, representing a more advanced phase of the initial micrographic-intergrowth material. Coincident with the appearance of micrographic

[1] Bowen, N. L., Jour. Geol., vol. XVIII, 1910, pp. 658-674.
Collins, W. H., Geol. Surv., Can., Mem. 33, pp. 59-93; Mem. 95, pp. 84-101.

intergrowth and increasing coarseness of the diabase the first-generation feldspar, which is a labradorite in all fine-grained phases of diabase, begins to vary from basic labradorite to andesine.

Aplite dykes appear to be about as numerous in the diabase in the North Shore district as at Gowganda or Cobalt. Those which were observed are from 2 inches to 2 feet wide and lie altogether within the coarse diabase of sills. The aplite is a fine-grained, pink to dirty brown material. Under the microscope it appears as a finely granitic aggregate of quartz and plagioclase (andesine to albite), with about one per cent of titanite and from a trace to 30 per cent of yellow mica, or mica and hornblende (Plate XIVA). Orthoclase is not present, but calcite, pyrite, and chalcopyrite are accessory constituents of rather sporadic occurrence. Both calcite and sulphides are believed to be primary constituents of the aplite, because the feldspar with which they are associated is quite fresh.

Dr. Eskola informed the writer that pegmatite dykes were found to be rather common in the diabase sills. "They are usually a few feet thick, and their rock is either a coarse-grained ordinary pegmatite or more aplitic. Feldspar and quartz are the main constituents; in one case (west of lake Wabagizig) was found pale green amphibole. The major part of the feldspar is albite. From its indices of refraction it seems to be very pure albite, having, in a specimen collected from the North line of mining claim 4782, north of Howry creek:

$$\alpha \quad D = 1{\cdot}526 \pm 0{\cdot}001$$
$$\gamma \quad D = 1{\cdot}535 \pm 0{\cdot}001$$

Some specimens contain microcline besides albite. It is a cross-hatched variety of the kind common in granite pegmatites."

He found numerous dykes of this kind in the large diabase sill north of Howry creek. "Gold-bearing quartz veins occur at the contacts and in the vicinity of this diabase sill. There is, however, nothing to point that the pegmatites would be directly connected with the origin of the gold-bearing veins, the latter being decidedly younger formations than the diabases. The albite pegmatite may probably be regarded as a crystallization out of the last residual part of the diabase magma."

The sill diabase is occasionally intersected by dykelets or veins composed entirely of dark green hornblende. These bodies, because of their unusually basic composition and their restricted association with the diabase, are believed to be genetically related to it, though in what manner there was no evidence to indicate until recently. Plate XIV B, however, shows a small hornblende vein cutting the aplitic differentiate of the diabase, so it is clear that the hornblende is of still later derivation.

The hornblende behaves optically as common hornblende, with an inclination towards actinolite. It forms bladed individuals aggregated into sheaves, and in veins of considerable width—4 to 6 inches—may grow to a length of an inch. As the general trend of magmatic differentiation in the diabase magma is from basic to acid it seems probable that the hornblende veins represent not a direct magmatic differentiate, but basic materials leached by primary hot waters from the crystallized diabase.

74009—6½

In exploring the country between Gowganda and Sudbury some years ago a rather complete gradation from quartz diabase (the typical rock at Gowganda) to quartz norite (the rock type at Sudbury) was found, and it was concluded that the quartz diabase and quartz norite of northeastern Ontario are intimately related both in origin and in age. No such gradation was found along the north shore of lake Huron. The diabase appears to be quartz diabase devoid of the rhombic pyroxene constituent which, when present in varying amounts, produces phases intermediate between quartz diabase and quartz norite. However, the basic intrusives in this district were not investigated nearly as carefully as those at Gowganda. A more detailed study, particularly of the country near Sudbury district, may reveal a transition from a quartz norite type to quartz diabase.

Metamorphic Effects. The micrographic intergrowth in the diabase and the aplite dykes is attributed to a process of differentiation which took place in the diabase magma while it was crystallizing. The diabase presents certain other peculiar features which are referable to contact metamorphism. All sizable masses contain occasional vaguely defined patches from 1 to 6 feet across, which are lighter in colour than the ordinary sill rock and much coarser grained. Their boundaries against the normal diabase are indefinite within a width of 1 to 2 inches. The patches are distributed quite irregularly. There may be none at all in one part of a sill and as much as 10 per cent of its volume in another part. They owe their light colour to a higher percentage of feldspar than is in the surrounding diabase. They are usually a little coarser than the diabase, and occasionally contain hornblende crystals an inch long.

Such patches were first observed by the writer in the diabase of Gowganda district, but no explanation was found for them.[1] In the North Shore district they are almost self explanatory. At Blind River, for example, the diabase contains many patches, some of light-coloured, coarse-grained diabase alone, others with cores of quartzite in all stages of absorption from ragged vestiges to but slightly corroded blocks (Plate XV A). Obviously, the quartzite cores are remains of blocks of the neighbouring Mississagi quartzite which were caught up by the diabase magma, and the light-coloured, coarse-grained diabase surrounding them is the product of interaction between the quartzite and the diabase magma. The interaction product is, in some cases, bounded by a zone, an inch or so wide, composed largely of hornblende and noticeably darker than either the interaction product or the normal diabase outside. The outer boundary of the dark rim is as a rule smoothly curvilinear; but in one or two cases it is so distinctly polygonal as to suggest that it may correspond to the original shape of the included block of quartzite.

The corrosion vestige of quartzite remaining in any such patch is sharply defined from the surrounding reaction material, no matter how deeply or irregularly corroded it may be. It is so recrystallized that no sign remains of its original clastic texture. It also contains as much as 2 per cent of epidote and chloritized biotite distributed through the recrystallized quartzite. These minerals may represent substances introduced from

[1] Geol. Surv., Can., Mem. 33, p. 62.

the diabase magma or they may be former impurities in the Mississagi quartzite.

The product of reaction between quartzite and diabase in some cases merges insensibly into the normal diabase around it; in other cases it is delineated from the normal diabase by the dark hornblendic border already referred to (Plate XV A). This interaction product is made up of hornblende, intermediate plagioclase, commonly intergrown graphically with quartz, and some epidote, the whole being marked by an extraordinarily irregular and intimate intergrowth of all these materials (Plate XV B). It becomes somewhat more basic and richer in hornblende from the quartzite core outwards and, in cases, strongly hornblendic at the margin. Regarding it as diabase which has been modified by assimilating some of the quartzite, the net mineralogical effect has been to increase the percentage of plagioclase ordinarily found in the diabase and change it from labradorite to andesine or oligoclase, the excess silica remaining as quartz. Whether the hornblende now present is an alteration product of pyroxene or a primary mineral could not be ascertained. A small share of this constituent is probably used up in forming the additional plagioclase. Epidote appears to be an ephemeral product representing an intermediate stage in the formation of the additional plagioclase; it is scant, or altogether lacking in patches where the original quartzite inclusion has been completely absorbed.

The diabase magma appears, locally at least, to have had a considerable capacity for assimilating inclusions from the older formations. At one place on Long lake, just outside the northeast corner of the Panache area, where an extensive wall of diabase rises from the water's edge, pale-coloured patches like those just described occupy between 5 and 10 per cent of the whole surface.

Where the diabase has invaded the older formations without breaking off and engulfing fragments, its metamorphic effects are, as a rule, much less intense. Even the large sills have had an insignificant effect. Quartzite within a few feet of them is rendered somewhat glassy and distinctly more brittle. The limestone near Bruce Mines is reported to be more coarsely crystalline than usual only within a yard or so of the diabase which cuts across it. Greywacke contacts are adinolized perceptibly for a few inches.

In two cases, however, much greater effects were observed. One of these occurrences is in the southwest corner of section 4, Rose township, the other at the south end of lot 12, concession III, Patton township. In Rose township a diabase sill 500+ feet thick dips at about 30 degrees under a member of the Gowganda formation intermediate in character between greywacke and quartzite. In the uppermost 30 or 40 feet of the sill there is an easy gradation from ordinary quartz diabase into a pale-red granitic-looking material which, under the microscope, is hardly distinguishable from the aplite already described. A sample from the top of the sill consists of about 50 per cent quartz, 35 per cent albite partly intergrown with the quartz, and the remainder oxidized pyrite, yellow mica changing to chlorite, and apatite, but no titanite.

This granitic material is in sharply defined but crenulated contact with the sedimentary roof above, as if it had eaten irregularly into the sediment.

The latter is changed, immediately above the contact, to a pale grey, rather finely crystalline material, which appears in thin section as a fine mosaic of acid plagioclase, quartz, and chlorite. This also resembles aplite. But in 15 feet it merges quite gradually into the normal quartzitic greywacke which appears in thin sections as a mosaic-like aggregate of quartz and feldspar grains, chlorite shreds, etc., but finer grained than that next to the sill, not quite so rich in feldspar, and distinctly clastic. Both intrusive and intruded formations are, in this place, intersected by many small quartz veins.

The Patton Township occurrence is so much like that in Rose township that an independent description of it is unnecessary.

Contact phenomena like those just described have been observed at Pigeon point[1] on the south shore of lake Superior, at Moyie[2], at Gowganda[3], and numerous other places where basic sills intrude sedimentary strata. The writers cited in this connexion are agreed that the red granitic material (red rock) composing the upper part of the intrusives represents a differentiated acid part of the magma which digested some of the overlying sediments; but they are not all agreed regarding the shares performed by the two processes, differentiation and assimilation, in producing this acid material. In the two cases described here, it is doubtful whether assimilation played any important rôle.

Long Lake Diorite. The intrusive mass near Long Lake gold mine, in the northeast corner of Panache area, is the only one included with the quartz diabases that differs from them in any notable respect. It is somewhat more irregular in form than the diabase sills in other parts of the North Shore district, but this is probably due, in large part, to folding and faulting subsequent to its injection. Most of it is a fresh-looking, medium-grained diorite made up of about equal parts of white feldspar and black hornblende; but this prevalent phase merges in some parts of the mass to a much paler, feldspathic one. The average type proves on microscopic examination to be a true diorite, made up of common hornblende and labradorite in proportions of 2 to 3. A little biotite, 3 or 4 per cent of black iron ore, and small rods of apatite are also present. The texture is granitic.

OLIVINE DIABASE DYKES

Olivine diabase, always in the form of dykes, has been found at many places throughout the North Shore district. None of these dykes is large, and as not more than a score of them have been recognized as such, they are not indicated upon the accompanying maps (1969, 1970, 1971). It is probable, however, that a great many others have not been distinguished from the quartz diabase, which they resemble, and that they are far more numerous than observations indicate. Neither are they restricted to the North Shore district. Dykes of the same character have been found in Sudbury, Cobalt, and Gowganda districts and along

[1] Bayley, W. S., U.S. Geol. Surv., Bull. 109; Daly, R. A. and Palache, Charles.
[2] Daly, R. A., Am. Jour. Sc., vol. XX, 1905, pp. 185-216.
[3] Bowen, N. L., Jour. Geol. XVIII, 1910, pp. 658-674.

the north shore of lake Superior. In each of these places they intersect all the other Precambrian formations present. No parent igneous masses of greater size, with which they can be related, have yet been recognized.

The dykes are from 2 feet wide to between 50 and 100 feet; correspondingly, the rock ranges in texture from a black glass containing occasional microscopic phenocrysts to a medium-grained diabase. The latter phase, which is the common one, can be distinguished from quartz diabase only by careful inspection. It is fresher. The feldspar in it is bright and glassy, distinctly rod-shaped, and more decidedly ophitic in habit than the feldspar of the quartz diabase, which is more nearly equidimensional in habit and either opaque white or greenish. The olivine diabase in large dykes also develops a conspicuous porphyritic habit never found in the quartz diabase. It carries stout phenocrysts of feldspar that attain lengths of 3 to 4 inches. These phenocrysts must have grown in the magma after its intrusion, for they are not found in dykes less than 20 feet wide and are largest and most numerous toward the middle of the wide ones.

The olivine diabase is also distinguished from the other basic rocks of the district by a tendency to weather ellipsoidally. One of these dykes on Tendinenda lake near the middle of timber berth 161 has broken down to a heap of rounded boulders and coarse reddish sand several feet deep; but, as a rule, disintegration is less advanced, the exposed surface of the dyke resembling a piece of rude masonry (Plate XVI B). Chemical alteration seems to play no important rôle in this process, because the residual bouldery masses are so fresh that samples taken only an inch beneath the surface show, under the microscope, practically no sign of decomposition. The reddish sand, likewise, is composed of angular grains of feldspar and augite not greatly decayed. What disintegration is now in evidence seems to have taken place since the last glaciation, for the sand lies quite unprotected, and would certainly have been carried away by an ice-sheet.

No explanation for this weathering was found in the North Shore district. It was observed in only a few of the olivine diabase dykes; and these do not seem to differ in other respects from dykes which are not so weathered. It is confined, however, to the olivine diabase. An incipient ellipsoidal weathering was seen in the quartz diabase only once, on the north side of a large island in Tendinenda lake, timber berth 161. At this place the diabase is smoothly glaciated and the surface is marked off into rudely polygonal areas, 2 to 6 feet across, by slightly depressed grooves an inch or 2 wide. Samples taken from the grooves were found to be more decomposed than the rest of the diabase, the augite being wholly replaced by chlorite. It is possible, in this case, that minute contraction joints served as vents for magmatic exhalations that acted upon the diabase close by, rendering it slightly more susceptible to weathering.

This explanation is given rather strong support by observations made on a dyke of the same diabase at Magpie mine, in Michipicoten district. The weathered surface of this dyke shows rounded areas of dark, fresh diabase separated by a wide network of a lighter-coloured phase of the diabase which weathers somewhat more rapidly than the dark phase, so

that the latter stands in slight relief (Plate XVI A). Although the two phases were not studied with the microscope it is clear that the light phase is an alteration product of the fresh, dark diabase. It is further easily seen, even in the photograph, that the dyke is polygonally jointed and that the light and dark areas are oriented in a definite relationship to the joint-planes. In fact the rounded dark areas are the unweathered cores of the polygonal blocks and the light-coloured parts are the altered peripheries of these blocks. The alteration has a fixed spacial relationship to the joints, and one naturally relates the joints to the process of alteration. It would seem that they must have been the channels along which the agent of decay travelled. This agent may have been one of the normal weathering agents that penetrated from the surface, but more likely it was the heated exhalations given off by the diabase itself. The exceptional depth to which some of these olivine diabase dykes crumble to pieces, as compared with any other of the Precambrian rocks, favours the idea of an internal agent.

In its extraordinary freshness the olivine diabase is unlike all other basic igneous rocks in this district, or for that matter, in any part of the Precambrian region. Even the olivine in it shows little or no sign of decomposition. It consists of 60-70 per cent labradorite, about 20 per cent of augite, half as much olivine, and accessory quantities of black iron ore, biotite, and apatite. The labradorite is in stout, lath-shaped sections that penetrate the augite and olivine in the ophitic manner characteristic of diabases. Where large phenocrysts of feldspar are present they have a pronounced zonary structure, the zones alternating from labradorite to basic andesine. The outer part of the phenocrysts usually encloses many small individuals of augite and olivine, but their interiors are free of such inclusions.[1]

When these dykes were found in Cobalt and Gowganda districts they were regarded by some geologists as genetically related to the quartz diabase, probably because the quartz diabase is the only intrusive of about the same composition which occurs in masses large enough to give off dyke-shaped apophyses. It was pointed out even then,[2] however, that the olivine diabase dykes had been intruded independently of the quartz diabase and later than it, though perhaps not much later. Evidence now available indicates them to be much younger than the quartz diabase. They intersect sills of that rock at Bruce Mines and near lake Panache. Near Long Lake gold mine in Panache area they also intrude the Killarney granite, a formation, to be described next, which is itself intrusive in the quartz diabase. The olivine diabase dykes are, therefore, much younger than any Keweenawan formation in the district. They are included along with the other late Precambrian basic intrusives for convenience rather than for chronological reasons. So far as known they do not cut the Ordovician strata along lake Huron.

[1] Chemical analyses of olivine diabase from Sudbury and Cobalt districts are given in Memoir 95, p. 103.

[2] Geol. Surv., Can., Mem. 33, p. 95.

Killarney Granites

NAME

Dr. Robert Bell, in 1897, referred to the granite at Killarney as the "Killarney belt of granite."[1] He considered it to be Laurentian (early Precambrian), as did other geologists both before and after that time. In 1913 Miller and Knight[2] applied the name Killarney granite to the areas of granitic rocks along the north shore of lake Huron between Killarney and Thessalon, believing all of them to be pre-Huronian. The writer concurred in this erroneous usage in 1914.[3] In the present report, however, the term is restricted to the original granite mass at Killarney referred to by Bell, and such other granites in the North Shore district as intrude the Huronian sediments.

DISTRIBUTION

The extent of the Killarney granites is not yet well known. The original Killarney granite, which Bell[4] and Barlow[5] traced northeastward for 20 miles, probably continues in that direction as far as Wanapitei station on the Canadian Pacific railway, since a massive red granite of similar appearance occurs there. It is not yet known how far southeastward it extends. The granite shown in the eastern part of the Panache map-sheet belongs to this batholithic mass; the smaller areas within the Huronian sediments are satellitic to it.

Granite very much like that at Killarney, and also intrusive in Huronian sediments, occurs on Eagle island and adjoining islands in lake Huron.[6] This is, apparently, not a large body.

Another granite, unlike the preceding in appearance, but also younger than the Huronian sediments, occupies the peninsula just west of Cutler, Blind River map-area. This oval mass has a total exposed length of 38 miles, from Round island in lake Huron to the eastern boundary of Victoria township. It fades away in rather interesting fashion across Shedden and Victoria townships, the continuous granite mass giving place by degrees to a multitude of smaller and smaller bands and shreds of granite arranged along the strike of the crystalline schists they penetrate. In walking across this batholithic tail one crosses alternating bands of granite and highly crystalline schists ranging from some hundreds of feet in width down to inches. Apparently the present surface intersects at a low angle the convex, eastward-pitching roof of the Cutler batholith, thereby throwing some additional light upon the manner in which such intrusive bodies work their way upwards.

The Killarney, Eagle Island, and Cutler areas are the only granite masses intrusive in the Huronian that the writer has examined. It is not unlikely, however, that the granite masses near the Murray and

[1] "Report on the Geology of the French River Sheet, Ontario," Geol. Surv., Can., Ann. Rept., vol. IX, pt. I, p. 6.

[2] Ann. Rept., Ont. Bureau of Mines, vol. XXII, pt. II. *See* correlation table facing page 126.

[3] Geol. Surv., Can., Mus. Bull. No. 8.

[4] "Report on the Geology of the French River Sheet, Ontario," Geol. Surv., Can., Ann. Rept., vol. IX, pt. I, pp. 6-9.

[5] Am. Geol., vol. VI, 1890, pp. 19-32; also Bull. G. S. A., vol. IV, 1893, pp. 313-323.

[6] *See* Geol. Surv., Can., Maps No. 605 and 155A, and Geol. Surv., Can., Mus. Bull. 22, Figure 1.

Creighton mines, Sudbury district, which Barlow, Coleman, and Knight have found to intrude the Sudbury norite, belong to the same period of intrusion. The same may be true of granite dykes on the coast of lake Huron south of lake Pakowkami, and a syenite dyke intrusive in the Gowganda formation near Batchawana bay, both described by Alexander Murray.[1]

KILLARNEY BATHOLITH

The granite at Killarney is, in the main, a coarse-grained, massive, red rock containing a very small percentage of quartz. Salmon-coloured feldspar, including orthoclase and smaller quantities of microcline and oligoclase, is by far its most abundant constituent, imparting a bright red colour to the rock. In places the feldspars are much larger than the other mineral grains, and distinctly twinned. About 5 per cent of biotite is present, and in thin sections small quantities of muscovite, titanite, and black iron ore can be seen. In some specimens the nests of biotite distributed through the granite contain another mineral which has altered to a soft orange powder. This mineral has not yet been identified. The granite ranges in texture from granitic to a coarse porphyritic variety containing square feldspar crystals half an inch across. The porphyritic phase is well developed in the southeast corner of Goschen township. Fine-grained aplitic phases also occur.

The granite all along its contact with the Huronian sediments from Killarney to Wanapitei is massive, and is easily recognized. But as one proceeds southeastward, away from the Huronian contact, a gneissic structure appears, and the formation assumes the diversified lithological nature so characteristic of the pre-Huronian granite gneiss. Doubt soon arises whether this complex of granite and gneiss is part of the Killarney batholith or whether the Killarney granite has given place unnoticed to a formation of different age. Some of the gneiss in the extreme eastern part of Panache area, for example, may be "Laurentian," as the older maps represent it; but no evidence therefor was found by the writer.

The little areas of granite in the Huronian just northeast of Panache lake present certain peculiarities apparently resultant from their small volume and satellitic relationships. The granite in the larger of these bodies is quite coarse; but in some which are too small to be represented on the map, and around the margins of others, there are gradations into a dense ash-grey material more like a lava than a plutonic rock. Chilled material of this kind can be seen in the narrow channel at the east side of the big island in Panache lake. All phases of these satellitic masses are grey instead of red, and much richer in biotite than the granite in the main Killarney batholith; but the mineral associations are the same. Parts of the coarse-grained areas are gneissic, and contain partly assimilated inclusions of the Huronian formations, so that they present the same heterogeneous aspect as the pre-Huronian granite gneiss. A gneissic structure, though certainly commoner in the pre-Huronian batholithic intrusives, is not a safe criterion for distinguishing them from the younger Killarnean irruptives.

[1] "Geology of Canada, 1863," p. 52.

The granite on Fox island in lake Huron is altogether like the syenitic granite at Killarney. Much of it is a handsome, coarsely porphyritic rock.

CUTLER BATHOLITH

The Cutler granite is a medium-grained, grey variety composed of orthoclase and some sodic plagioclase, quartz, and biotite. Quartz is distinctly more abundant than in the Killarney granite. A small amount of muscovite and some other accessory minerals are present. The granite is uniformly massive except marginally, where frayed inclusions of the older sedimentary formations give it a rudely foliated appearance. A pronounced banded structure obtains at the east end of the area, where the older formations are filled, lit-par-lit fashion, with thin apophyses of granite; but the granite parts are quite massive.

A great many small pegmatite dykes traverse the Cutler granite and adjacent crystalline schists. Good exposures are found along the railway west of Cutler. The pegmatite is composed of quartz, orthoclase, and muscovite. The muscovite, which occurs in plates up to 3 inches across, reacts faintly for lithia. An occasional wine-red garnet was seen, and thin sections show a few small crystals of staurolite. Staurolite is not recognized by petrologists as a constituent of igneous rocks, but in this case, the optical properties of the mineral seem to establish its identity satisfactorily. It occurs in small individuals, singly and in aggregates, some without regular outlines, others partly bounded by plane faces. It does not contain the inclusions of other minerals which are so characteristic of staurolite in metamorphic schists. It is weakly positive in optical behaviour, with C-A= 0·0012 ca. The pleochroism is: c,b=brown, a=colourless. Aggregates of the mineral are usually surrounded by a loose felt of hair-like crystals too fine to be identified. It is probable, though not susceptible of proof, that the staurolite and attendant felt of microlites are xenolithic in origin. Staurolite optically identical with this, but containing numerous inclusions of quartz, is found in highly recrystallized block inclusions of the older sediments around the margin of the Cutler granite.

In most of the pegmatite dykes referred to above, the constituent minerals are irregularly arranged, but in some of the smaller ones intrusive in the metamorphosed schists, the muscovite is concentrated in two marginal bands, with its cleavage planes more or less at right angles to the contact, and the quartz and orthoclase occupy the central part. The peripheral portions are distinctly coarser grained than towards the centres.

METAMORPHIC EFFECTS

The ellipse-shaped Cutler batholith intrudes greywacke and impure quartzite that belong, apparently, to the Sudbury series, and the greenstone associated with these sediments. It has developed around itself in these formations a metamorphic zone about half a mile wide but forming longer tips at the ends of the ellipse. The easterly tip continues well into Victoria township. The sediments close to the granite are completely recrystallized to mica-schists and (more or less) intersected by protrusions of granite and pegmatite, especially at the ends of the batholith, where the granite

tends to subdivide into slender fingers. At increasing distances away from the contact the apophyses disappear and the metamorphic effects fade out. For distances of up to a mile within it, the granite also contains fragments of the sediments altered to gneiss.

These inclusions in the granite are the extreme product of contact action. They are altered to quite coarse, highly foliated biotite gneiss. Nevertheless, an original stratification is still easily discerned in blocks more than 2 feet in diameter, owing to the fact that the alternating beds of impure quartzite and greywacke have been changed into mica gneiss correspondingly different in texture and composition. Quartzitic beds are changed into rather fine-grained, granular mica gneiss not particularly rich in biotite. Alternating greywacke beds are represented by highly micaceous bands darker in colour and very well foliated. As a rule the gneissic foliation crosses light and dark bands alike at a considerable angle

A thin section, representing one of the original beds of impure quartzite, is entirely recrystallized, and consists mainly of quartz, feldspar, biotite, and muscovite with much smaller quantities of staurolite, titanite, apatite, pyrite, zircon, etc. The quartz and feldspars constitute a mosaic of irregular, fairly equidimensional grains. The micas are distributed through this mosaic in flat plates of two distinct types; abundant small ones oriented in one plane corresponding to the plane of rock cleavage, and occasional larger ones of the nature of secondary phenocrysts which lie in various attitudes without respect to the plane of rock cleavage. The other constituents, except the staurolite, form small individuals scattered sparingly through the field. All these constituents vary considerably in amount, depending, no doubt, upon the degree of impurity of the original quartzitic sediment. As a rule, quartz and feldspars are about equal in amount, and together make up about two-thirds of the rock. The feldspars include plagioclase of about the composition of oligoclase, some microcline, and some orthoclase. Biotite is much more abundant than muscovite; but muscovite shows a distinctly stronger tendency to form secondary phenocrysts. Staurolite occurs in occasional crystals of about the same size as the other mineral grains, but partly bounded by plane crystal faces. Minute zircon crystals embedded in the biotite are surrounded by pleochroic halos, some of which show two concentric zones. In a few cases the biotite contains circular holes, somewhat larger than the pleochroic halos, and occupied by a cloudy grey material of indeterminate composition which may be a product of the destructive effect of radioactive emanations from the minute zircons. No zircons were observed in these circular areas, but their size and association with pleochroic halos suggests some genetic connexion with the latter.

A thin section from one of the more micaceous bands consists of the same minerals arranged in the same manner. Mica, however, is far more abundant. It is in larger plates and constitutes up to 50 or 60 per cent of the whole. Staurolite is also more abundant.

The sediments bordering the batholith are recrystallized in the same manner as the fragmental inclusions within, but not so thoroughly. They grow less and less crystalline away from the contact. Feldspar diminishes,

biotite and muscovite give place to chlorite and sericite, titanite, pyrite, and apatite disappear. Staurolite, however, does not appear to be altogether characteristic of the contact-metamorphic zone. It is somewhat irregularly distributed, being found only in beds of an original argillitic character, but it was found more abundantly and in larger and better-formed crystals away from the batholith than near it. It is quite possible that the staurolite individuals found within the contact-metamorphic zone are not so much products of contact metamorphism as products of dynamic metamorphism which resisted change in the contact zone.

The greenstone associated with the greywacke and quartzite is metamorphosed quite as intensely and for a somewhat greater distance away from the granite. Approaching the batholith from the west along the railway no contact effects are seen in this greenstone until McFerson siding is reached. The rock is simply a weathered, slightly schistose basalt. But from McFerson to Spragge it changes gradually into a glistening black amphibole schist. It grows coarser in this interval and within 1,000 feet of the granite its schistose structure gives way to a massive one. Next the contact, the amphibolite is penetrated by quartz veins and pegmatite dykes and for 6 to 18 inches adjacent to these it is crowded with garnets up to half an inch in diameter.

The Cutler batholith does not come in direct contact with the Mississagi quartzite north of it, but near Cutler, where these formations approach to within half a mile of each other, the quartzite is exceptionally brittle and glassy. Dr. Eskola, however, in 1922, examined the islands in lake Huron south of Cutler and found the Mississagi quartzite on John island distinctly metamorphosed by the Cutler granite, which occurs close by. There is, accordingly, no longer any doubt that the Cutler batholith is intrusive in the Huronian sedimentary formations.

The main Killarney batholith, between Killarney and Panache lake, cuts across the whole Huronian sequence. As at Cutler the granite carries highly recrystallized inclusions of the Huronian sediments, sends dykes into them, and has recrystallized them for a long distance away from the contact. Inclusions are extraordinarily abundant and widespread in the granite east of Panache lake.

The contact zone is not so definite or so uniform in width as that around the Cutler mass, probably because of the more diverse character and varying susceptibility to metamorphism of the Huronian formations. The rocks next the Cutler batholith were greywacke and impure quartzite, whereas the Killarney batholith invaded pure quartzite, greywacke, conglomerate, limestone, and calcareous silts. The quartzites show very little contact metamorphism except in the immediate vicinity of the granite. The more susceptible conglomerate, greywacke, and other argillitic members are affected for from 1 to 2 miles, and the calcareous silts and impure limestones for as much as 4 miles away from the nearest exposed granite. The writer was inclined at first to attribute these extraordinarily widespread effects partly to the intense folding which the Huronian formations in this locality have suffered. But the forma-

tions near Espanola, which are just as intensely folded, but 10 miles or more from the Killarney granite, show little or no signs of the type of metamorphism found nearer the granite, so the alterations described below are presumably due to contact action alone. It is possible that intrusive masses of granite not yet exposed by erosion may lie beneath some of the metamorphosed rocks and much nearer them than any visible granite.

The quartzites of the Serpent, Lorrain, and purer parts of the Mississagi formations have been affected slightly. As a rule they are more glassy and brittle only near the granite; but in a few places they have become spotted. The quartzite on the north side of Fox island in lake Huron is affected in this way for a few inches away from the granite contact. The spots, which are one-eighth to one-half inch across and rather abundant, represent local aggregations of chlorite apparently in process of altering to biotite. A mottled siliceous rock exposed on the islands in Killarney bay and Narrow bay is perhaps of the same nature, though it has not been examined microscopically. A very pronounced example of spotted quartzite occurs at Long Lake gold mine, about midway between the shaft and the manager's residence. In this case the metamorphosing agent is a diorite instead of granite. The quartzite for several feet away from the diorite is crowded with rudely spherical black bodies one-fourth inch across, which weather into relief, producing a harsh, pimply surface. They appear to consist largely of hornblende.

Near Wavy lake, just east of the Panache map-area, the Killarney granite contains several masses of Huronian quartzite 100 feet or more in diameter. The quartzite is converted into a very brittle, translucent material resembling vein-quartz in thin section. The granite, which is normally a bright salmon colour, changes to grey for several feet next the quartzite.

Argillitic materials, such as the matrix of the Bruce and Gowganda boulder conglomerates, the Gowganda greywackes, and the impure parts of the Mississagi formation at the east end of Panache lake, all tend to become coarse mica schist in proximity to the granite. Abundant examples of this transformation were found along Threemile lake and the small lakes east of Panache lake. The matrix of the Bruce and Gowganda conglomerates changes to a biotite-gneiss or schist composed principally of quartz, feldspar, and biotite. The more argillitic greywackes give rise to a more micaceous variety containing muscovite as well as biotite, and differing from the mica-gneiss near Cutler only in not containing staurolite. If staurolite is a contact metamorphic product it should be found here, for the composition of the greywacke and the intensity of contact action appear to be quite as favourable to its development as were the conditions near Cutler. Its absence may be due, as suggested in discussing the metamorphic zone of the Cutler batholith, to the fact that it is a product of dynamic metamorphism, not of contact metamorphism. Dr. Eskola found cordierite in metamorphosed phases of the Gowganda formation.

The Bruce limestone and the Espanola formation, which range all the way from nearly pure limestone to slightly calcareous silts, are metamorphosed more profoundly and have yielded more interesting crystalline products than any of the other Huronian materials. They are affected throughout the eastern half of Panache map-area and all the way from McGregor bay to Cutler among the islands in North channel. The limestone, though partly altered to lime-silicates, is usually still recognizable as a limestone; but the Espanola formation, especially in the vicinity of Killarney, is changed to an extraordinary looking, almost black rock that bears very little resemblance to the original. On weathered surfaces it develops an exceedingly harsh, serrated corrugation (Plate VII B). When the writer first saw the Espanola formation in Killarney and McGregor bays in 1915, he failed to recognize it until its identity had been established by working out the complete Bruce series succession of which it is part; Alexander Murray, who saw these rocks after having studied the limestone near Bruce Mines, comments in one of his reports upon their possible though obscure identity with each other.

The course of metamorphism seems to depend upon the proportions of carbonate and silicates present in the original sediment. Nearly pure limestone bands become more coarsely crystalline as the granite is approached, without developing any important amount of new minerals. Mixtures of limestone and silt, on the other hand, develop a variety of new silicates at the expense of the original constituents. If a good deal of carbonate is present there is a tendency to form scapolite, but if the carbonate is not abundant, biotite is the chief silicate.

A rather extensive collection of thin sections of these calcareous silts, in various stages of metamorphism, has been examined microscopically. The samples appear to have differed considerably in their original proportions of carbonate and silicates, thereby tending to mask any orderly metamorphic progression. Nevertheless, when a series of them is arranged according to intensity of metamorphism, an orderly tendency is recognized. The lists given below represent the minerals found in each of the series. The first is an unaltered Espanola silt, the last a highly metamorphosed product of the same within 2 feet of the Killarney granite, and the others represent successive intermediate metamorphic products. The percentages given in each case are approximations; it is virtually impossible to make precise Rosiwal estimates, owing to the minute and complicated textures of the rocks. These approximations indicate, however, the relative abundance of each constituent through the metamorphic series.

The feldspars, calcite, quartz, colourless secondary mica (sericite, probably), chlorite, and an opaque white material supposed to be leucoxene are all original constituents of the Espanola greywacke, and are the results of disintegration and rock decay. The tremolite, scapolite, titanite, biotite, and a mineral doubtfully determined to be epidote are the products of contact metamorphism (Plate VIII).

—	I	II	III	IV	V	VI
	%	%	%	%	%	%
Chlorite	20–35	10	—	—	—	—
Leucoxene?	2–3	2–3	—	—	—	—
Colourless secondary mica	25–30	20	—	5	—	—
Feldspars	5–10	5–10	2–3	trace	..	..
Pyrite	trace	2–3	trace	trace	—	trace
Calcite	5–25	5	—	5	—	5
Quartz	10–40	30	25	20	trace	10
Biotite	trace	25	30	25	30	65
Titanite	—	—	2–3	2–3	—	2–3
Scapolite	—	—	35	—	20	trace
Tremolite	—	—	—	35	45	—
Epidote?	—	—	—	—	—	15

I. Unmetamorphosed Espanola formation from Griffin lake near Espanola.
II. Slightly metamorphosed phase, west end of Panache lake.
III. Spotted hornfels phase, near milepost 4, north boundary, Goschen township.
IV. Crystalline phase, north shore of lake not far from milepost 2, on north boundary of Goschen township.
V. Crystalline phase, Killarney bay.
VI. Highly crystalline phase from xenolith enclosed in Killarney granite, Killarney bay.

Biotite is the first new mineral to appear, apparently mainly at the expense of chlorite. It comes in abundantly and persists through the remaining phases without any notable change in quantity. Scapolite appears next, coincident with which there is a decrease of calcite and the original silicates. At about the same time titanite replaces the opaque white mineral assumed to be leucoxene. The titanite persists to the end, but scapolite soon disappears, its place being taken by tremolite, or in some cases by actinolite. In the final intense stage of metamorphism at the granite contact even tremolite disappears, and epidote appears for the first time. Of the original constituents of the Espanola formation part of the calcite and quartz alone are found next the granite, possibly as surplus materials not needed in the process of silicate formation.

East of Panache lake the granite intrudes diabase, probably Keweenawan, which is irruptive in the Huronian sediments. Beyond observing that the weathered surface of the diabase near the granite is impregnated with garnets, no study was made of the contact-metamorphic effects.

AGE RELATIONS

It follows from the relationships described in the preceding section that the granite at Killarney and in the eastern part of Panache area is younger than the Huronian sediments and younger also than the presumably Keweenawan diabase which intrudes these sediments. It is cut, however, by the olivine diabase dykes. The Cutler mass invades the Bruce series and sediments of indeterminate, presumably Sudburian, age, and is accordingly included in the Killarney group of batholithic intrusives. This has since been confirmed by Dr. Eskola, who found the Cutler granite in intrusive relations with Mississagi quartzite on John island. At Killarney the Ordovician (Lowville and Black River) sediments, flat-lying and quite unmetamorphosed, lie not far from the granite. Clearly the

granite had been irrupted and subsequently exhumed by erosive action before these sediments were deposited. It may be regarded, therefore, as being younger than any other Precambrian formation in the district, except the olivine diabase, but very much older than the Ordovician.

The Killarney, Cutler, and Eagle Island batholiths, and probably those near Sudbury as well, though perhaps not exactly contemporaneous, are believed to belong to one late Precambrian period of batholithic invasion that is intimately related to the late Precambrian mountain-building diastrophism which will be described in the next chapter.

Palæozoic

Palæozoic formations do not occur in the geologically explored parts of any of the three map-areas under consideration. They were observed in relation with the Precambrian, however, on islands in North channel near Killarney, and at a single locality in Laird township, Bruce Mines map-area.

In the first of these two localities Badgeley, Partridge, and Centre islands and Badgeley peninsula consist of Lorrain quartzite fringed near the water's edge by grey limestone (Cf. Figure 7). It is quite clear that the limestone rests in profound unconformity against the sides of hills and ridges of quartzite which constitute the islands and peninsula mentioned. It dips away from these at about 5 degrees, except within a few yards of the contact where it is tipped up considerably more. The whole attitude of the limestone with respect to the protruding quartzite knobs indicates that this local dip was acquired by a process of downward sag in the limestone as it consolidated. Bell[1] regards this limestone as part of the Black River formation. There is no sign of conglomerate at its contact with the Huronian quartzite.

The second occurrence lies immediately north of the railway in the east half of section 3, Laird township. At this place a round hill of Lorrain quartzite, thinly crowned with Palæozic conglomerate, rises above the prevailing flats of lacustrine stratified clay. It is the only exposure of Palæozoic known in that district. As the Palæozoic crown is only from 0 to 6 or 8 feet thick, an excellent opportunity is afforded to inspect the surface of the Lorrain quartzite upon which it rests. This ancient surface conforms fairly closely with the upper part of the present, moderately steep hill. It is well scoured in places, yet diversified by great blocks and fissures now filled with the conglomerate. A prospect pit has been sunk for 6 feet in the Palæozoic material which fills one of these fissures, 3 feet wide.

The conglomerate resting in knife-edge contact upon this old surface is composed of spherical to ellipsoidal or even subangular pebbles and boulders up to 2 feet in diameter. Except for a rare one of granite the boulders are of Lorrain pink quartzite and jasper conglomerate. They are abundant enough to touch one another at two or more points. The cementing substance ranges from an impure grit of grey colour through shades of red to

[1] "Report on the Geology of the French River Sheet," Geol. Surv., Can., Ann. Rept., vol. IX, pt. I, p. 23.

a highly ferruginous arenaceous shale containing streaks and nests of specular iron ore. It is a comparatively weak material. The boulders break free so readily that they have accumulated on the side of the hill just beneath the conglomerate in a ring that was at first sight thought to be a high-level Pleistocene beach.

This conglomerate contains no fossils, but its arenaceous character, colour, and richness in iron oxide suggest it to be equivalent to the red sandstone at Sault Ste. Marie. Logan[1] regards this as possibly Potsdam, but more probably Chazy sandstone.

Pleistocene

The events of the Pleistocene are recorded in the glaciated Precambrian rock surface, in the thin mantle of drift which covers the higher parts of that surface, and in the stratified post-Glacial lake beds that border lake Huron.

It might be concluded, because the Precambrian rocks are powerfully glaciated and no trace is left of pre-Glacial rock decay, that the present topographic aspect of the country is mainly due to glaciation. Such a conclusion, however, does not accord with some of the evidence. For example, the diabase ridges in the northeastern part of Rose township, at the narrows of Tendinenda lake, and at other places, terminate in escarpments 200 to 400 feet high. These escarpments face the east and north as well as south, so they cannot all be ascribed to the plucking action of a southward-moving ice-sheet. Neither are there sufficiently large talus accumulations beneath some of them to account for their formation by post-Glacial disintegration. It is more in accord with the facts to regard them as pre-Glacial. Part of the talus slopes, even, may be pre-Glacial.

A topographic detail observed on Lauzon lake also seems to testify to the superficial nature of glacial erosion. The quartzite surrounding the lake is cut by a broad diabase dyke which extends along the south shore of the main arm. The dyke stands about 10 feet higher than the quartzite. Its contact edge forms a low escarpment recognizable more than a mile off (Plate XVI A). The diabase has not been eroded into its present relief since glaciation, for both diabase and quartzite are glaciated. Neither is its wall-like form likely due to glacial erosion alone, for, although the diabase is more resistant than the quartzite, glacial action would be more apt to have carved it into less abrupt relief, like that of the roches moutonnées and other products of glacial sculpture. Its shape seems to accord better with an assumption that the dyke had been brought into relief before the Glacial period by ordinary weathering agents and that glacial erosion modified it only slightly.

Another dyke near the Murray mine in Sudbury district illustrates the same point in reverse fashion. This dyke is of olivine diabase, a rock which readily weathers ellipsoidally (Plate XVI B). For that reason probably, it occupies a steep-sided trench 8 feet deep. The rectilinear section of this trench excludes any likelihood of it having been constructed by glacial

[1] "Geology of Canada," 1863, p. 84.

erosion. It is partly filled with drift, and is, therefore, not post-Glacial. Apparently, then, it can only be a pre-Glacial feature which survived glaciation.

If the topographic expression of these two dykes has been correctly interpreted, there are parts at least of the Precambrian rock surface which are only slight modifications of a pre-Glacial surface. And if this is true, it is highly probable that the peneplain-like character of the region as a whole also antedates glaciation.

Glacial drift is confined nearly altogether to the high country from 2 to 15 miles back from lake Huron. Any that remains nearer the lake is covered by the younger lake beds, or has been modified by submergence in post-Glacial stages of lake Huron. The drift cover in the high country is so thin that the Precambrian rocks are abundantly exposed; if evenly distributed it would probably be less than 15 feet thick. A good deal of it is ground moraine, composed of sandy till and boulders. There are a few esker ridges of gravel, and at least one flat sand-plain, at the upper end of Quirke lake.

This sand-plain, which occurs on Serpent river just above Quirke lake, is shown on the Blind River map (No. 1970). It is of small extent, quite flat, and the sand underlying it is stratified. It lies 1,210 feet above sea-level and 450 feet higher than the post-Glacial lake beds. As no other stratified deposits were found so much above the lake beds, this one is probably quite local in extent and formed in a temporary expansion of Serpent river.

The horizontal lake beds of clay and sand deposited in post-Glacial stages of lake Huron were found up to 180 feet above the present lake-level, and for distances back from it ranging from 2 to nearly 20 miles, depending upon the slope of the rock floor. They comprise a wide variety of materials; finely stratified clay, silt, sand, gravel, and boulder beaches, none of which are confined to a single horizon.

These materials were probably deposited in the same way as deposits are now being formed along the Lake Huron coast. The coast is very irregular, and in large part fringed by a barrier of rock islands. Streams of considerable size debouch at intervals of 15 to 25 miles. The shallow channels and bays behind the barrier of islands are being filled up with different materials and at different rates according to their proximity to an inflowing river and to the degree to which they are protected against currents and storms in the lake. For example, a strong boulder beach is being formed by wave-action upon Pleistocene bouldery deposits along the unprotected coast near Algoma, where no stream enters. Immediately west of Blind River, on the other hand, a level delta plain of clay and silt, only 3 feet above lake Huron, is being constructed by Mississagi and Blind rivers behind a barrier of rocky islands that lie just off the mouths of these streams. Thessalon river, having no such protection, is distributing its load of clay widely and at a lower level on the sloping bottom of lake Huron. Echo lake, which is virtually a land-locked bay of lake Huron, is being filled in with sand and clay by Echo river.

Now, the topography of the Precambrian rock floor is such that were lake Huron raised, say 50 feet, its coast would move inland several miles, but without losing its present character. It would still be irregularly embayed and protected by a fringe of islands. The rivers would continue at that level the same deposition of mud, silt, and sand, varying in rate and character according to local conditions. These appear to have been the circumstances responsible for the diversity of form, levels, and composition of the post-Glacial lake beds, during the recession of lake Huron. To a certain extent, of course, there was destructive as well as constructive action. Terraces have been cut in some of the deposits already laid down, as these emerged and became subject to wave-action. Since the deposits have passed out of reach of the receding waves they have been dissected to a small extent by the streams crossing them on their way to lake Huron. But, in spite of such obliterating processes, the original succession of partly localized lake beds rising one behind another is still quite recognizable.

The lowest and most modern of these deposits is the low flat at the mouth of Blind river, already alluded to. It is barely above the high-water level of lake Huron. A somewhat higher and much more extensive flat is found at intervals all along the coast. It is represented in the neighbourhood of Echo bay by many square miles of perfectly flat country standing from 8 to 12 feet above lake Huron and sloping gently toward the lake shore. It is underlain by stratified clay for the greater part, but is sandy close to lake Huron and consists of clay overlain by several feet of sand at the head of Echo lake. The level farming district around Thessalon also stands 10 to 15 feet above lake Huron and is underlain mainly by stratified clay. It rises slightly away from the lake. Clay flats of the same elevation were found in the valley of Serpent river for several miles up from its mouth, and in like relation to Whitefish river.

This series of flats at 10 to 15 feet above lake Huron is easily recognized because it borders the lake. Farther back the different levels are harder to correlate. There appears, however, to be a greater number of more or less localized areas standing at elevations ranging from 20 to 120 feet above lake Huron. Those nearly enclosed by rock ridges are quite level, whereas those without a retaining rock barrier slope gently toward lake Huron. Any differences of elevation between successive plains is likely due to the topography of the Precambrian rock floor rather than to an inconstant rate of recession of lake Huron. Clay or sand flats occur at 55 to 60 feet above lake Huron in Howry Creek valley, 90 feet at Espanola, and 100 to 120 feet in Dunn valley and other parts of Aberdeen township, and also at other intermediate levels not actually determined. In other cases, e.g. from Massey to the mouth of Spanish river, there is an easy sloping descent lakeward of 50 feet.

Very few definite terraces were seen. The sand ridge half a mile north of Little Rapids, Thessalon township, is a terrace, as are, also, the high sand ridge 2 miles north of Blind River on the road to lake of the Mountains, and the sandy ridges north of Massey. No beach deposits were seen at the foot of any of these terraces. A distinct boulder beach at about 40 feet

above lake Huron can be seen, however, at the north side of the road which runs along the south side of lot 9, Lefroy township.

At 180 to 200 feet above lake Huron the horizontally stratified clay and sand give place to 20 feet or so of crossbedded, foreset deposits of sand and fine gravel, evidently shore deposits. These are particularly well shown on the high hill just north of Ottertail lake, and in the hillsides near Rydal Bank. They appear to mark the upper limit of the lake beds and presumably also the limits of post-Glacial submergence, for above them boulder clay makes its appearance.

Although 180 feet above lake Huron (160 according to Murray) marks the general limit of the horizontally stratified lake beds along the North Shore, stratified clay was found 240 feet above just south of Whitefish lake, near Naughton. At that place it forms a narrow ridge between Whitefish and Blackwater lakes. The clay is stratified and similar in appearance to the lower-level deposits. But with the exception of this one small area stratified clay was not found more than 150 feet above lake Huron, anything above that elevation being sand and gravel. The country around Whitefish lake is underlain at about the same elevation as the clay by boulder clay. The clay ridge south of Whitefish lake may, therefore, be a remnant of a local deposit of stratified clay in a small body of water unconnected at any time with lake Huron. Marginal ponds of this sort may have existed around the edges of the ice-sheet during its retreat.

CHAPTER IV

STRUCTURAL GEOLOGY

It has been shown in the preceding chapter that the geological formations of the North Shore district are divided, in respect to age, into four main groups, separated from one another by erosional unconformities of the first magnitude. There is a pre-Huronian, or early Precambrian division composed of a volcanic complex, some crystalline sediments and batholiths of granite gneiss; a late Precambrian division comprising the Huronian sediments, the diabasic rocks intrusive in them and a younger series of granite batholiths; a Palæozoic division represented along lake Huron by the margin of the great Palæozoic plain to the south; and a Pleistocene division consisting of the unconsolidated glacial debris and lacustrine deposits laid down during and after the Glacial period. These are distinct structural elements as well, for, so great is the disparity in age among them, that each has had time to have impressed upon it enough deformational effects to distinguish it in the most conspicuous fashion from the next younger division. Only locally, in the case of the Huronian division, have the formations been deformed severely enough to approximate the structural complexity of the pre-Huronian. It is proposed in the following paragraphs to describe and discuss briefly the main structural characteristics of each division and of each intervening unconformity.

PRE-HURONIAN BASEMENT

The peculiar structure of the pre-Huronian, that is, the structure possessed by it before Huronian deformation was imposed upon it, is best preserved in the northern part of the district, where the overlying Huronian formations have been subjected to nothing more than gentle folding and where, consequently, little change in structure has taken place since pre-Huronian time. Towards lake Huron, and especially towards the southeast, Huronian and pre-Huronian become involved more and more in the late Precambrian diastrophism, and pre-Huronian structures proper tend to be obliterated.

The pre-Huronian basement in the northern part of the district is sufficiently bared of its Huronian cover by erosion for it to be seen that three-fourths or more consists of granite gneiss and the balance of belts and patches of the older volcanic complex or Keewatin (Figure 2). The volcanic complex, though not stratigraphically suited to reveal its own internal structure, is so schistified and contains enough closely folded and contorted stratiform members, such as the iron formation and tuffs, to indicate that it has undergone deformation of the most intense kind. It is also clear that this deformation took place in pre-Huronian time, since the neighbouring Huronian strata are only gently folded. The batholiths of granite gneiss, which intrude the volcanic schists, are generally regarded as deep-seated intrusives rather strictly associated with mountain-building.

Outside the Precambrian such a conjunction of intense deformation and batholithic invasion is found only in tectonic mountain regions and is presumably directly related to mountain-building. Unless conditions that do not obtain now are assumed to have obtained in Precambrian time, it seems necessary to regard the schistified, closely folded belts of schist complex and the granite gneiss in the North Shore district as the eroded base of a pre-Huronian mountain system. According to the direction of elongation and schistosity of the schist belts this system extended about east and west.

It is not yet possible to say positively whether the pre-Huronian sediments (Sudbury series) that extend from Algoma eastward to Sudbury took part in the pre-Huronian diastrophism. They are folded and schistified as much as the volcanic complex, and in the same direction, but they lie within the province of late Precambrian mountain-building activity, which operated in the same direction, and folded the Huronian sediments as closely as they are. There seems to be nothing in the attitude of the Sudbury series to decide whether it was deformed solely by late Precambrian mountain-building forces or whether it had already participated in pre-Huronian crustal disturbances. That can best be ascertained by discovering its relation to the pre-Huronian granite gneiss. If it is older than the granite gneiss as represented by Coleman[1] in his map of the Sudbury nickel range the latter alternative is correct; but nowhere west of Sudbury district was the writer able to find the Sudbury series in contact with pre-Huronian granite gneiss.

HURONIAN-PRE-HURONIAN UNCONFORMITY

Assuming that the pre-Huronian formations were mountain-built, it is necessary to conclude that the resultant mountains were completely eroded before the Bruce period, for the Bruce series was deposited upon a notably even surface. Near lake Tendinenda the pre-Huronian basement is overlain by almost horizontal beds of Mississagi quartzite which must be limited in thickness between 0 and 300 or 400 feet over many square miles. If the underlying basement had even a moderately high relief its highest parts should protrude through the quartzite; but they do not. Neither is the line of contact between quartzite and pre-Huronian scalloped, but a smooth, wide curve, suggestive of a low-relief pre-Huronian topography. The rectilinear contact of the Huronian and pre-Huronian formations north of Quirke lake points to the same conclusion.

In late Precambrian time, of course, this palæoplain was warped into folded with east-west axis, wide and fairly shallow in the northern part of the district but progressively closer towards the northeast. This relief, produced by diastrophic movements, is not to be confused with original topographic relief due to erosion.

LATE PRECAMBRIAN DIASTROPHISM

The Huronian formations, both Bruce and Cobalt series, are folded in all parts of the North Shore district, but with a noticeably increasing

[1] Ann. Rept., Ont. Bureau of Mines, vol. XIV, pt. III, 1905.

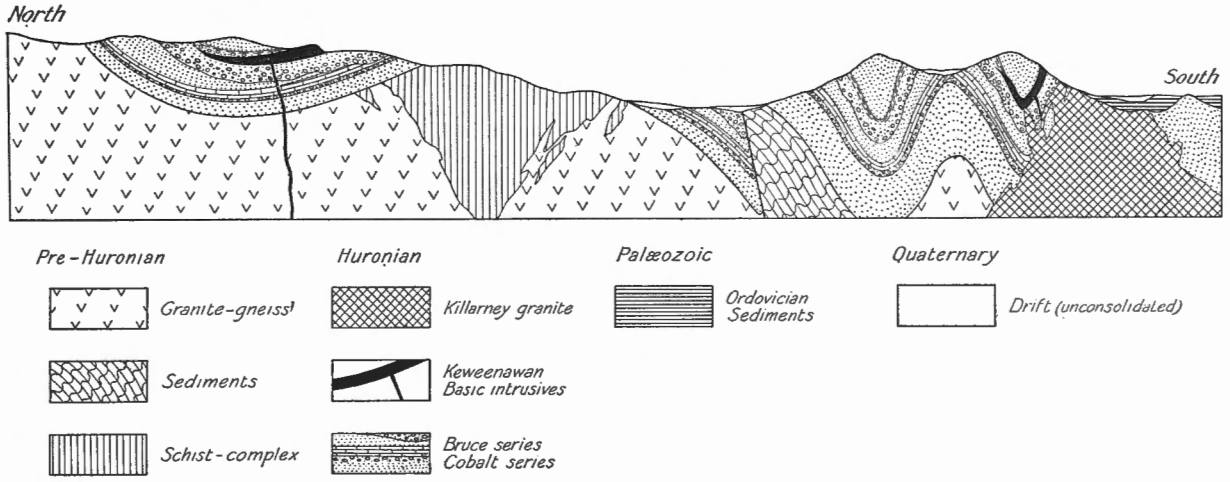


Figure 7. Diagrammatic vertical section from north to south across the North Shore district in the vicinity of Killarney, showing increasing influence southward of Killarnean diastrophism and batholithic invasion.

intensity from north to south (Figure 7). This increase is also shown in the sections and maps of Bruce Mines, Blind River, and Panache areas, taken in that order. A large part of Bruce Mines area is occupied by a broad syncline that extends at about south 65 degrees east. Near lake Huron the fold reverses to form a narrower, but equally gentle anticline which pitches towards the northwest. The syncline is slightly unsymmetrical, its northern limb dipping 30 to 50 degrees, and the southern limb only 30 to 35 degrees. It is also broken by the Murray fault, which traverses the trough from end to end. Near the fault the dips are variable and in many places very high.

The northern part of Blind River area is largely occupied by another shallow syncline which widens and pitches westward at an angle of 2 to 5 degrees. The nose on Whiskey lake is tilted up more steeply. This fold, like that in Bruce Mines area, is slightly symmetrical. Its northern limb dips 25 to 40 degrees, and the southern one 15 to 30 degrees. Towards the middle of the area the syncline changes to a low anticline, the formational dips decreasing from 15 degrees to zero, and then increasing southward until the fold is interrupted by a continuation of the Murray fault. Within the last mile or mile and a half of the fault the dip rises from between 20 and 40 degrees to between 60 and 100 degrees. The Huronian formations south of the fault, between Blind River and Algoma, are tilted 60 to 85 degrees northward, showing that the Murray fault has broken a second, much tighter synclinal fold.

In Panache area the Huronian beds are more closely folded even than those in the southern part of Blind River area, and broken by a veritable network of faults. The axis of faulting also, which was south 65 degrees east in Bruce Mines area, and almost east in Blind River area, has swung to north 75 degrees east. Commencing in the northwest corner of the area and proceeding southward across the strike, one crosses in the first 5 miles a tight syncline, much complicated by faults, in which the beds dip 60 to 80 degrees. The succeeding anticline is narrow and passes into a second tightly compressed syncline 10 miles across, which includes the entire Huronian succession from the base up to the banded cherty quartzite of the Cobalt series. Dips range from 60 to 90 degrees. The doubled thickness of the Lorrain quartzite in the middle of this syncline constitutes the main range of Lacloche mountains. The succeeding anticlinal structure, which occupies North channel, pitches rather steeply westward, so that it terminates in a nose at the east end of McGregor bay. Lacloche mountains, representing the middle of the preceding syncline, wrap around this anticlinal nose so as to reappear at Killarney.[1] At Killarney, and thence northeastward to Sudbury, the closely compressed Huronian formations are abruptly and obliquely truncated by the intrusive Killarney granite. Beyond this line of contact Huronian sediments are represented only by occasional rafts and blocks of quartzite and micaceous gneiss included in the Killarney granite.

Here in the Huronian is the same combination of batholithic invasion of granite and severe compressional folding which characterizes all the important tectonic mountain systems of the earth. Was a system of

[1] Well shown in French River map-sheet (No. 125) accompanying Geol. Surv., Can., Ann. Rept., vol. IX, pt. I; also in Map 155A.

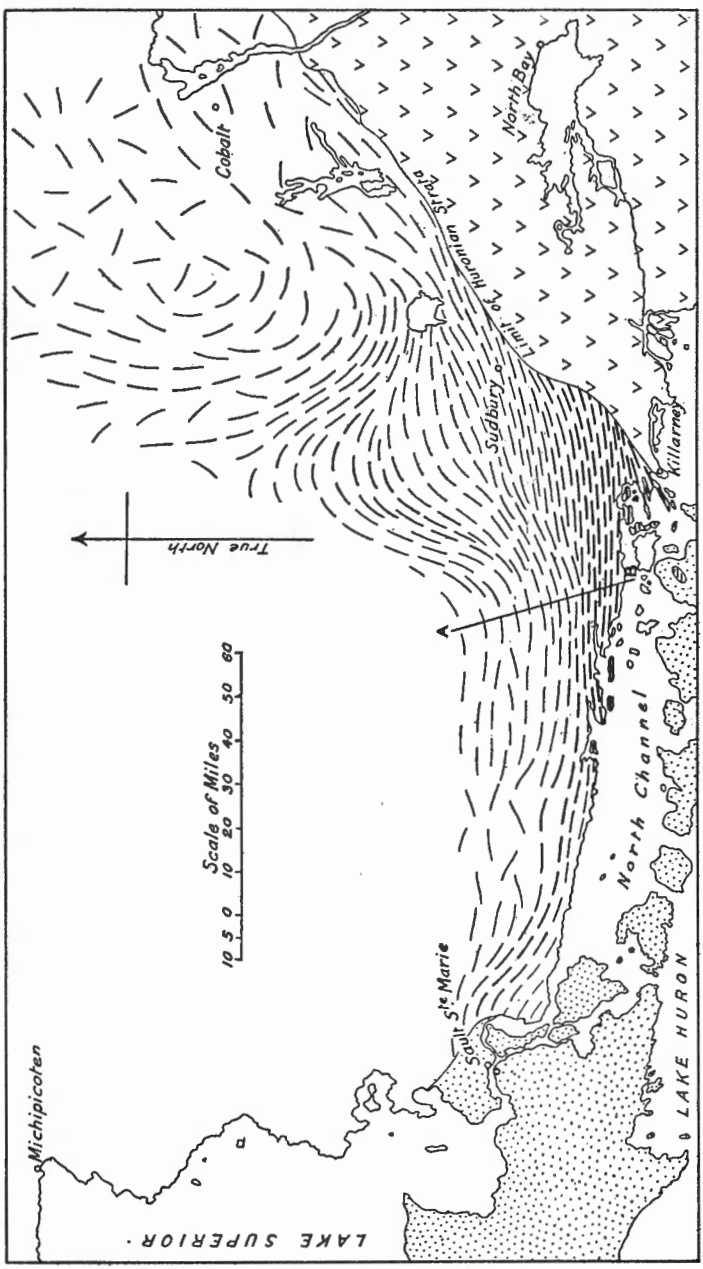


Figure 8. Map diagram of North Shore district showing known extent and varying intensity of the Killarnean diastrophism. The lines indicate the strike of the formations, and also, by their weight and closeness together, the intensity of deformation. The line A-B shows the general position of the section represented in Figure 7.

mountains built at the close of the Huronian? In the case of the pre-Huronian basement the former existence of a pre-Huronian tectonic mountain system rests solely upon this inferential ground, for its surface when finally buried was not mountainous, but planated. The evidence for Huronian mountains is somewhat more direct. The Huronian terrain still preserves, in Lacloche hills, a topographic relief approximating that of a mountain range. Lacloche hills appear to be the actual stumps of a tectonic mountain chain elevated late in the Precambrian, other manifestations of which are the tightly folded Huronian strata and the accompanying Killarnean granite batholiths.

An attempt is made in Figure 8 to indicate the extent, intensity, and axial direction of folding in the Huronian, in the North Shore district, and in other parts of northeastern Ontario as well, so far as they are known to the writer. The diagram is only qualitative in value, so far as it relates to the character of folding; the irregular arrangement of lines showing the strike of the formations near Cobalt represents a gentle doming, the heavy parallel lines near Killarney a compression into tight folds. The diagram brings out very well, however, some essential points regarding the extent of intense diastrophism. It indicates that close folding took place in a wide arcuate belt coinciding in a general way with the north shore of lake Huron from near Sault Ste. Marie to Killarney.

The northern limit of Killarnean diastrophism across Ontario is shown fairly continuously in this figure. The southern limit is concealed by lake Huron and the Palæozoics; but there is an increase in the degree of deformation in the Huronian as far in that direction as it remains visible. East of Killarney the compressed Huronian formations are abruptly truncated by Killarney granite, so it is impossible to trace the Killarnean folding farther in that direction. Nevertheless, it may reasonably be inferred that the folded Huronian once continued far eastward and southeastward, because where they now terminate they have a stratigraphic thickness of 20,000 to 25,000 feet and a maximum degree of deformation. A narrow zone of greatly deformed Cobalt series actually persists along the southern margin of the Huronian as far eastward as lake Timiskaming and may represent the northern edge of a great region of Killarnean diastrophism. West of Sault Ste. Marie, the closely folded strata disappear under Palæozoic formations; but in Marquette district[1] on the south side of lake Superior, a series wholly comparable with the Bruce series is invaded by granite batholiths and is tightly folded along an axis which is in alignment with the Killarnean folding in Ontario. Altogether, the Huronian has been severely folded along a curved east-west axis throughout a region 600 miles long and of an unknown, but almost certainly great, width.

It is too early to attribute all this diastrophic activity to a single period of time. In Ontario, all the Huronian sediments and the basic intrusives regarded as Keweenawan—in fact everything up to the Palæozoic, except the olivine diabase dykes—have participated in the folding and faulting; and Ordovician beds abut almost horizontally against deeply truncated edges of the uptilted Huronian and the exhumed Killarney granite. Allen[2] fixes the age of the Presqu'ile granite irruptive in the

[1] Van Hise and Leith, U.S. Geol. Surv., Mon. 52 and maps.
[2] Jour. Geol., vol. XXIII, No. 8, p. 689.

Huronian on the south shore of lake Superior as between Middle Huronian and Keweenawan. Presumably, therefore, the accompanying diastrophism on the south shore of lake Superior is of about the same age.

MINOR FOLDS

Some of the irregularities in the main folds of the Huronian formations are worthy of note. Owing to the cover of drift and forest most of those shown on the maps, particularly the Panache sheet, are represented on the strength of rather small numbers of exposures, and may not be faithfully drawn. Reference is accordingly confined to a few which were accurately outlined in the field.

A fold occurs close to the fourth milepost on the north side of Goschen township, Panache area. At that place the strata which strike east and west in the main fold are thrown into an acute Z-shaped flexure about 2 miles long, with its angles pointing northeast and southwest. The southwest angle is not so well exposed as the other, but the strata there are sheared and appear to be greatly thinned.

A second double flexure of about the same size, shape, and attitude occurs on the same major fold 5 miles farther east. Another, on a larger scale, occurs near the outlet of May lake in township 143, Blind River area, though it has not been traced out in sufficient detail to be shown on the map. Two smaller ones occur on the northern limb of the same major syncline, in township 150. A still smaller one was seen in the cliffs at the east end of Echo lake, Bruce Mines area.

All these minor structures are alike in shape and direction. It seems probable that they were originated by a common force operative over the whole district, as is almost certainly true in the case of the major folds. If these smaller flexures were arranged symmetrically with respect to the axes of the main folds they might be conceived as drag-folds formed at the same time as the major folds, and by the same forces. But they are not symmetrically arranged. They point in the same direction, whether on one side of a larger fold or the other, like independent structures merely superimposed upon the main fold structure.

FAULTS

The map of the original Huronian area published in the atlas accompanying the "Geology of Canada, 1863," shows a great fault extending from the mouth of Echo river southeastward to Blind River. The existence of this fault, which, it is suggested, should be called the Murray fault, after its discoverer, was amply corroborated during the field study of 1914-16.

Beginning at the west end of the district, the fault is indicated, west of Ottertail lake, by crumpling, shearing, and steep dips in the banded cherty quartzite across a zone about one-quarter of a mile in width. Southeast of Ottertail lake the basal part of the Lorrain quartzite, lying almost flat, is only a quarter mile away from outcrops of banded cherty quartzite that dip towards it at 20 degrees, implying a vertical displacement of about 6,500 feet in the drift-filled space between. The branch

shown on the map as extending west from the main fault at this place is indicated by a trench-like gully, with formations belonging to different horizons, on opposite sides of it, and by exceptional crumpling in the Gowganda formation close by. Thence to Thessalon township the fault evidently follows the clay-filled valley of Thessalon river, for in that distance Lorrain quartzite occurs on the north side of the river and Gowganda conglomerate and greywacke on the south side. At the sawmill in section VI, Lefroy township, Gowganda conglomerate can be seen within 100 yards of the upper conglomeratic part of the Lorrain quartzite, and Gowganda laminated greywacke in the same locality is greatly crumpled.

Just inside Thessalon township the fault diverges from Thessalon river in the direction of lake Pakowkami. Near the point of divergence, crumpled Bruce limestone is exposed south of it, and Lorrain quartzite to the north, implying a displacement of the same order as at Ottertail lake. There follows an interval of 10 miles to the east end of Pakowkami lake, which was not examined by the writer; but the atlas of 1863 shows the fault continuously across that distance.

From Pakowkami lake to the mouth of Mississagi river, conglomerate, greywacke, etc., of the Gowganda formation, lie next to pre-Huronian granite gneiss. This section of country is so heavily covered with lake clays that granite gneiss and sediments are not often seen closer together than 500 to 1,000 feet. At the west end of Dean lake, however, they outcrop continuously to within 100 feet. The granite gneiss shows no change towards the fault, but the Gowganda beds begin to increase perceptibly in dip half a mile north, and, near the fault, are closely folded and even overturned.

At Blind River extraordinarily deformed Gowganda beds lie on the north side of the lake expansion on which the village is situated, and steeply dipping Mississagi quartzite on the south side. The country between Blind River and Lauzon lake is so difficult to traverse, and presents so few rock outcrops, that the fault cannot be located at all satisfactorily. It appears, however, to fork somewhere in that interval, for there is direct evidence on Lauzon lake of two divergent faults. The southerly of these cuts across late Precambrian diabase on the south shore, schistifying it across a zone several yards wide, and causing a considerable, though not measurable, vertical displacement. This branch seems to traverse the southern bay of Lauzon lake and pass under lake Huron, but a sand-plain at the east end of Lauzon lake effectually conceals the solid rocks. The main branch skirts the south shore of the main part of the lake. Its presence is indicated by two finger-shaped bays in the main narrows, and at its first emergence on the main part of the lake, part of the fault zone is well exposed. At the latter place late Precambrian diabase is changed, for an exposed width of 10 feet or more, to a vertical chlorite schist. Elsewhere along this shore the course of the fault is indicated by the close juxtaposition of Mississagi quartzite on the north with conglomerate, greywacke, etc., belonging either to the Sudbury series or the Cobalt series on the south. The Mississagi, as it approaches the fault, dips south at angles increasing from 15 to 80 degrees in a quarter of a mile.

From the east end of Lauzon lake to Cutler a slender belt of Mississagi quartzite backed by granite gneiss lies against an association of greywacke, quartzite, and conglomerate—Sudbury series—about whose true position in the geological column there is some uncertainty (compare with section on pre-Huronian sediments). The line of juxtaposition is almost straight, but nowhere is the actual contact visible. Whether the sediments on the south side of this line are regarded as pre-Huronian or Huronian, the fault displacement has been great enough to cut off all the Bruce series except the lower part of the Mississagi quartzite.

Evidence of the Murray fault improves across the townships of Shedden and Victoria. The fault extends in an almost perfectly straight line at north 85 degrees east. It bevels the Huronian formations, which dip steeply southward, from about the middle of the Mississagi up to the Serpent quartzite and even, in Victoria township, the lower part of the Gowganda formation. These obliquely truncated formations are opposed to highly crystalline greywackes and impure quartzite representing a westward extension of the Sudbury series. The fault-plane is not observable in this section, though at Smith lake and at many places on Little Serpent river it was restricted to very narrow, drift-filled intervals. Near the east side of Victoria township it coincides closely with a conspicuous rectilinear escarpment, of Mississagi quartzite and other Huronian formations, that looks southward over a much lower area of Sudburian rocks.

On evidence of similar character to that found between Lauzon lake and Victoria township, the same fault has been followed across Salter and May townships, to the valley of the creek which flows southwestward across Shakespeare township in Panache map-area. There, one enters an area of highly disturbed rocks, mostly Sudburian, without well-marked stratigraphic horizons, and intruded by many bodies of igneous rocks—not an easy terrain in which to detect displacements. Nevertheless, by means of breccias and juxtaposition of areas of Mississagi quartzite against Sudburian greywackes the Murray fault was traced to a point in lot 3, concession II, Hyman township, where it crosses Spanish river. At this point no criteria could be found for measuring the vertical displacement except the rather long rectilinear fault-boundaries of the Mississagi quartzite areas. These imply an important throw.

According to the evidence just given the Murray fault is at least 115 miles long, and probably much longer, since it appears to have a large throw at each extreme. The vertical displacement, where it can be estimated, attains between 5,000 and 6,500 feet. As far as can be observed, displacement took place in a nearly vertical plane, under conditions of compression and local crumpling of the strata involved. Faulting took place late in the Precambrian, since the late Precambrian quartz diabase was dislocated. Probably it accompanied Killarnean diastrophism, for the Murray fault lies parallel to the main axis of Killarnean folding, and faults of smaller size are extremely numerous in the more closely folded Huronian formations.

Smaller faults, with throws ranging from a few feet upwards, occur throughout the North Shore district, but most abundantly in Panache

area (*See* Memoir 102). In all determined cases but one they are overthrusts, marked by shear zones or breccia. The small fault shown in township 155, Blind River map-sheet (No. 1970), may be a normal fault. There does not appear to be any uniformity in direction among them.

PALÆOZOIC-PRECAMBRIAN UNCONFORMITY

It was argued that the rectilinear contacts between Huronian and pre-Huronian, and the absence of pre-Huronian bosses protruding through thin parts of the Huronian, imply a low relief topography in the pre-Huronian basement that lies buried beneath the Huronian. The same reasoning, applied to the Precambrian surface upon which the Palæozoic formations rest, leads to the conclusion that it is one of considerable, even sub-mountainous, local relief.

In the first place the main Palæozoic-Precambrian contact which runs through North channel is not rectilinear.[1] Although much of it is concealed by lake Huron, quite enough can be seen to prove that it is irregular and deeply embayed. Moreover, for miles south of this main line of contact, bosses of Precambrian quartzite representing the higher hilltops in the pre-Palæozoic floor protrude through the Palæozoics. One of these small outliers near Sheguiandah, Manitoulin island, is 11 miles south of the main Palæozoic boundary. At that point the Palæozoic cover is around 800 feet in greatest thickness; the quartzite exposure, therefore, must be the upper part of a pre-Ordovician hill more than 800 feet high.

A fairly good idea of the profile character of the buried Precambrian floor is afforded by Badgeley, Partridge, and other islands, lying a few miles southwest of Killarney. Each island is composed of a low, hat-shaped dome of Precambrian quartzite, with a brim of low, flat-lying Palæozoic beds near the shore (Figure 9). The quartzite crown rises from 50 to 450 feet above the Palæozoic rim, according to the locality. There is a marked change in angle of slope where rim gives place to crown. It is clear that the quartzite crown is a pre-Ordovician hill. As now exposed it is lower in relief than the hill originally buried under the Palæozoic, by the amount which has been eroded since it was again exhumed. In other words the domes and ridges of quartzite which protrude through the Palæozoic near Killarney were higher and steeper at the beginning of the Ordovician than they are now. Allowing a depth of 100 feet for the channels between the islands, and ignoring altogether the effects of erosion, a local relief of 550 feet at least is indicated.

The angle of slope between Precambrian and Palæozoic is not as well shown near Killarney as it is near Sheguiandah. The latter neighbourhood has been examined by the writer's colleague, Dr. M. Y. Williams, who has kindly furnished the photograph used in making Figure 9 B, and a quantity of other information. According to Dr. Williams the Huronian quartzite boss at Sheguiandah stands considerably above the general level of the surrounding country, which is underlain by the Palæozoic. A boring through the Palæozoic beds about one mile away from the quartzite boss reached

[1] *See* Geol. Surv., Can., Maps No. 605 (Manitoulin Island sheet) and No. 570 (French River sheet).

the Precambrian only at 738 feet. The local relief between these two points is accordingly equal to 738 feet plus the present relief—say 800 feet

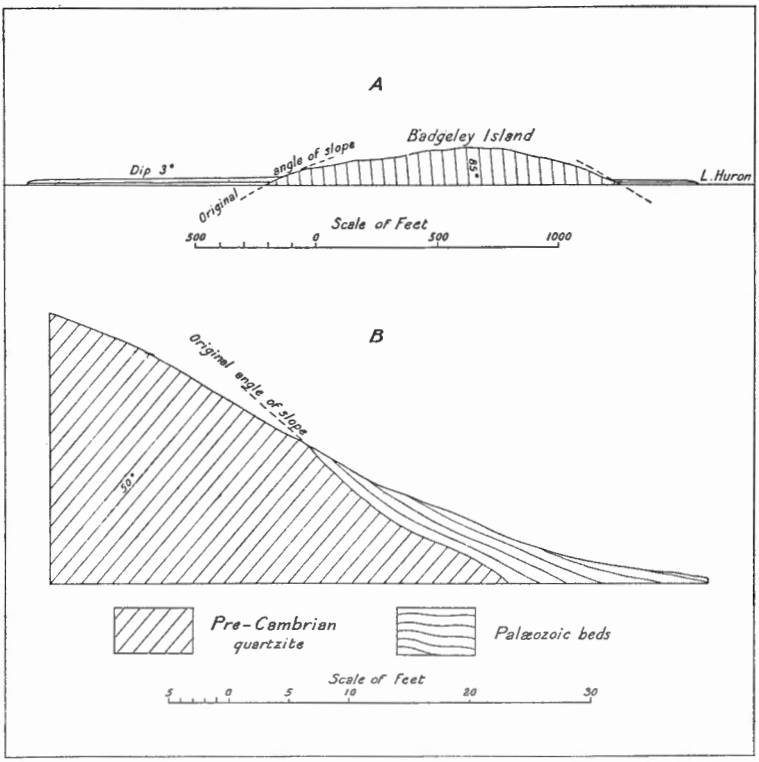


Figure 9. Vertical sections, somewhat diagrammatized, indicating the topographic relief of the Precambrian surface upon which the Palæozoic sediments were deposited.
A, section across Badgeley island in lake Huron near Killarney.
B, detail of contact of Palæozoic with Precambrian at Huronian outlier near Sheguiandah, Manitoulin island.

in all. An excavation made in one side of the quartzite boss exposed a section of contact between the quartzite and Utica shale (Figure 9 B). This contact plane is slightly sinuous and dips at 25 degrees in the photograph taken of it. The shale at this point dips at a lesser angle, but dips as high as this are confined to the vicinity of contacts and appear to be attributable to sag accompanying a decrease in volume of the Palæozoics, and not to general Palæozoic folding. Away from Precambrian contacts the Palæozoic dip does not exceed 5 degrees.

PLEISTOCENE

Except for slight local slumping the Pleistocene lake beds are horizontal and undisturbed. They rest upon a floor of solid rocks little different topographically from the exposed surface of the solid rocks.

CHAPTER V

CORRELATION

WITH THE HURONIAN OF LOGAN AND MURRAY

The north shore of lake Huron, studied between 1847 and 1858 by Logan and Murray of the Geological Survey, was one of the first places in North America where the stratigraphy of the younger Precambrian formations was worked out in any considerable detail. It was there that these geologists found the most complete sequence of the formations they afterwards called the Huronian. Since then it has become a classic place of reference for other geologists concerned with the correlation, classification, and nomenclature of late Precambrian rocks elsewhere in the Precambrian shield. It may be of interest, therefore, to compare the Huronian succession as set forth in this report with Logan and Murray's conception of the same.

Precambrian Formations North of Lake Huron

Logan and Murray[1]		Collins		
(Not mentioned)		Olivine diabase		
(Not mentioned)		Killarney granite		
Greenstone		Diabase intrusives		Keweenawan series
		Thessalon greenstone		
		Irruptive contact		
	Feet		Feet	
White quartzite	400	(Not fully investigated; Logan and Murray's statement accepted as substantially correct.)		Cobalt series
Yellow chert and limestone	200			
White quartzite	1,500			
Yellow chert and limestone	400	Banded cherty quartzite	700	
White quartzite	2,970			
Red jasper conglomerate	2,150	Lorrain quartzite	5,500 to 6,500	
Red quartzite	2,300			
Upper slate conglomerate	3,000	Gowganda formation	2,600 to 3,500	
(Not mentioned)		*Unconformity*		Bruce series
"		Serpent quartzite	1,100 +	
"		Espanola limestone	0 to 75	
"		Espanola greywacke	250 to 400	
Limestone	300	Bruce limestone	150 to 250	
Lower slate conglomerate	1,280	Bruce conglomerate	20 to 500	
White quartzite	1,000			
Chloritic slates[2]	2,000	Mississagi quartzite	1,000 to 12,000	
Grey quartzite	500			
Unconformity		*Major unconformity*		
Laurentian		Pre-Huronian granite gneiss Pre-Huronian sediments Pre-Huronian schist-complex		Pre-Huronian

[1] "Geology of Canada, 1863," pp. 55–57.

[2] Equivalent to the Thessalon greenstone in the second column.

The chloritic slates, regarded by Logan and Murray as the second Huronian formation, correspond to the Thessalon greenstone, at the top of the second column. There are no equivalents in the first column for the Espanola greywacke, Espanola limestone, and Serpent quartzite of the second column. Although these formations are present in the area examined by Murray they are in such small amount and so poorly exposed that it is not surprising he should have overlooked them. The red quartzite, red jasper conglomerate, and white quartzite of the first column are difficult distinctions to make in the field except in Bruce Mines map-area, so all three are grouped in column two, under the name Lorrain quartzite. The white quartzite, yellow chert, and limestone and topmost white quartzite in column one occur chiefly outside the areas examined by the present writer. Their thicknesses and relationships are known only from rather casual inspection; sufficiently well, nevertheless, to indicate that Logan and Murray's statements in column one are substantially true.

There is a fair agreement regarding the thicknesses of all the formations except the Bruce conglomerate (or lower slate conglomerate) to which Logan and Murray ascribe a figure much too high. This is probably due to the fact that in the neighbourhood of Dean Lake they confused a limestone member in the Gowganda formation with the Bruce limestone and consequently regarded the thick part of the Gowganda formation (their upper slate conglomerate) beneath this limestone as the lower slate conglomerate. A comparison of the Blind River map-sheet (No. 1970) accompanying this report, with Logan and Murray's map of the original Huronian area in the atlas of 1863, will make this matter clearer.

WITH THE COBALT SERIES OF COBALT DISTRICT

The names Cobalt series, Gowganda formation, and Lorrain quartzite were first applied in Cobalt and Gowganda districts; their usage in the North Shore district, therefore, implies an equivalence between the formations so-named in the two districts. For convenient comparison the sequence of formations composing the Cobalt series at Cobalt and vicinity and the same sequence for the north shore of lake Huron are placed in parallel columns below. The equivalences expressed in the table are based not only upon the similarity in succession and lithological character of the respective formations, but also upon the fact that the formations have been traced almost continuously from Cobalt to Sault Ste. Marie.

Cobalt Series of Cobalt and Gowganda Districts[1]

	Feet
Erosion surface	
White quartzite	?
Banded cherty quartzite	200+
Lorrain quartzite: thick-bedded quartzite, impure and feldspathic at base and grading upward into a pure white variety; a conglomeratic zone containing white and grey quartz pebbles about two-thirds way up	3,000+

[1] Geol. Surv., Can., Mem. 95. *See also* various reports in the Annual Reports of the Bureau of Mines, Ontario, by Miller and Knight, who were the first to state the sequence of formations at Cobalt.

	Feet
Local disconformities	
Gowganda formation: a complex succession of boulder conglomerate, greywacke, laminated greywacke, laminated greywacke conglomerate, impure quartzite, and one thin band of siliceous limestone. Occasional striated pebbles in conglomerate	0 to 3,000
Major unconformity	
Pre-Huronian schists, granite gneiss, etc.	

Cobalt Series on the North Shore of Lake Huron

Erosion surface	
White quartzite	400
Yellow chert and limestone	200
White quartzite	1,500
Banded cherty quartzite	700
Lorrain quartzite: thick-bedded quartzite, impure and feldspathic at base and grading upward into a pure white variety; a conglomeratic zone containing white, grey, and red quartz pebbles about half-way up	5,500 to 6,500
Conformable sequence	
Gowganda formation: a complex succession of boulder conglomerate, greywacke, laminated greywacke, laminated greywacke conglomerate, impure quartzite, and one thin band of siliceous limestone. Occasional striated pebbles in the conglomerate	2,600 to 3,500
Unconformity	
Bruce series	

The thicknesses given in the first table are approximate and too much weight should not be laid upon their comparison with the corresponding thicknesses given in the second table. Lithologically, the formations in the two districts are so much alike that with one or two exceptions a representative suite of hand-specimens from one district would serve for the other. This similarity is most pronounced in the case of the Gowganda formation. Such unusual and distinctive materials as the laminated greywacke conglomerate, the boulder conglomerate, and the thinly laminated limestone from the two districts are indistinguishable in appearance. In the case of the Lorrain quartzite, however, the basal part varies from dingy red to sea-green in the North Shore district, but is always sea-green at Cobalt. Likewise the conglomeratic part of this formation near Bruce Mines contains red jasper pebbles as well as white and grey ones, whereas only white and grey pebbles are found in it near Cobalt.

At Cobalt the Cobalt series rests directly upon the pre-Huronian, but in the North Shore district the Bruce series intervenes, a difference which led the first investigators in Cobalt district to regard the Cobalt series as equivalent to the Lower Huronian series of other places.

Cobalt and Sault Ste. Marie are about 200 miles apart. The Cobalt series extends continuously from Cobalt nearly to Sudbury, a distance of 75 miles. There follows a gap of 35 miles from Falconbridge township east of Sudbury to Panache lake, in which the Cobalt series is lacking, but in which the Bruce series is uninterrupted. From Panache lake the Cobalt series is continuously exposed almost to Sault Ste. Marie, except for one narrow gap near Cutler.

WITH THE HURONIAN ON THE SOUTH SHORE OF LAKE SUPERIOR

As far back as 1890 American geologists working on the south shore of lake Superior recognized a similarity between the formations found near Marquette and those in the original Huronian district. The Canadian term Huronian was adopted there and since then the Huronian of the south shore has been subdivided into three parts, the Lower, Middle, and Upper Huronian series. Even in the latest papers[1] dealing with Precambrian correlation, the Lower Huronian of Marquette district is accepted as equivalent to the lower part (Bruce series) of the Huronian on the north shore of lake Huron.

This equivalence is of particular interest to Canadian geologists working in the Precambrian. The Precambrian sequence in northeastern Ontario and adjacent parts of Quebec must eventually be correlated with the Precambrian sequence in northwestern Ontario; and apparently this will be accomplished either by tracing formations around the north shore of lake Superior or by way of the south shore. The north shore route is so imperfectly known that in any case many years' work must be done along it before enough dependable information is at hand. But even if such work is done it may not yield adequate results. From what is now known about it, the region will probably prove to contain great areas of granite gneiss which will hamper the effective correlation of what few belts of sedimentary formations may also be found there. It is questionable whether a sufficiently firm geological connexion can ever be established in that direction. The south shore route is much more promising, for that region has been studied more thoroughly than any other large part of the Precambrian shield, and is known to contain a complete and extensive succession of formations, extending almost without interruption into western Ontario.

The greatest barrier to widespread correlation via the south shore is a cover of Palæozoic rocks between Marquette and Sault Ste. Marie which entirely conceals the Precambrian for 130 miles. The geological sequences in the Precambrian on either side of this gap are given on page 113.

[1] Lawson, A. C., "The Correlation of the Precambrian Rocks of the Region of the Great Lakes": Bull. Dept. of Geology, Univ. of Cal., vol. X, pp. 1-19.

Marquette District

(Van Hise and Leith)

		Feet
[1]Presqu'île granite		
Upper Huronian	Michigamme slate: slate and greywacke	1,000±
	Bijiki schist: iron-bearing	520
	Goodrich quartzite: mainly quartzite with subordinate conglomerate	1,500
	Unconformity	
Middle Huronian	Negaunee iron formation: iron formation, slate, etc.	1,000±
	Siamo slate: gradations between quartzite, greywacke, and slate	600 to 700
	Ajibik quartzite: mainly quartzite, with subordinate conglomerate, greywacke, and slate	750
	Unconformity	
Lower Huronian	Wewe slate: slate and arenaceous slate	100 to 1,000
	Kona dolomite: dolomitic limestone interbedded with siliceous material	250 to 700
	Mesnard quartzite: mainly quartzite with some conglomerate and slate	150 to 700
	Major unconformity	
Archæan	Granite gneiss and schists	

[1] *See* Allen and Barrett: Jour. Geol., vol. XXIII, No. 8, p. 689.

North Shore of Lake Huron

		Feet
	Killarney granite	
	Diabasic intrusives	
	Thessalon greenstone	
Cobalt series	Quartzite and chert	2,800
	Lorrain quartzite: mainly quartzite, with conglomeratic phases	5,500 to 6,500
	Gowganda formation: a complex assemblage of boulder conglomerate, greywacke, laminated greywacke, impure quartzite, and some limestone, probably of glacial origin	2,600 to 3,500
	Unconformity	
Bruce series	Serpent quartzite: all quartzite	1,100+
	Bruce limestone and Espanola formation: dolomitic limestone interbedded with siliceous material	500 to 700
	Bruce conglomerate	20 to 300
	Mississagi quartzite: mainly quartzite, with some conglomerate and slate	1,000 to 12,000
	Major unconformity	
Pre-Huronian	Granite gneiss and schist	

There is a marked resemblance between the Lower Huronian series at Marquette and the Bruce series. Each is the lowermost sedimentary series in the Huronian and rests in profound unconformity upon a much older Archæan or pre-Huronian basement of granite gneiss and volcanic schists. The basal member of each is a residual soil. With the exception of the topmost formations (Wewe slate and Serpent quartzite) they consist of very similar materials arranged in similar order. Both the Mesnard and Mississagi quartzites are conglomeratic at the base and contain a certain amount of conglomerate and slate higher up. The Kona dolomite is remarkably similar to the interbedded silt and limestone represented by the Bruce limestone, Espanola greywacke, and Espanola limestone. There is not as much difference lithologically between the Wewe slate and the Serpent quartzite as their names imply: the Wewe slate is inclined to be arenaceous. The Bruce conglomerate of the North Shore district is not represented at Marquette; but its absence is not surprising. It will be remembered that the Bruce conglomerate, earlier in this report, has been described as decreasing steadily in thickness from 500 feet or more at the east side of the North Shore district to 20 feet near Echo lake, thus foreshadowing its ultimate disappearance somewhat farther west.

Both Lower Huronian and Bruce series are invaded by granite (Presqu'île and Killarney granites) and are severely folded along east-west axes. In fact, the axes of folding lie almost in direct alignment.

Upon these lithological, successional, and structural grounds, it seems very likely that the Lower Huronian at Marquette and the Bruce series are equivalents. It is just as obvious, however, that the Cobalt series bears no such close resemblance either to the Middle or to the Upper Huronian. Possibly when more becomes known about the late Precambrian sediments in northeastern Ontario, other bonds of similarity may be established between the Huronian there and on the south shore of lake Superior; but at present its correlation depends almost entirely upon the similarity of the Bruce series to the Lower Huronian.

CHAPTER VI

ECONOMIC GEOLOGY

SCOPE

This investigation was undertaken primarily to ascertain the sequence of events in the geological history of the North Shore district and to correlate them with the events in other parts of the Precambrian region. The areas to be mapped were selected rather for their stratigraphic interest than for their ore-deposits, but the investigation included a considerable share of those deposits. All three of the areas mapped happen to contain a variety of ore deposits—gold, copper, silica, brick-clay, building and ornamental stone, etc.—that is fairly representative of the district as a whole. In a few cases the limits of the map-areas were extended beyond stratigraphic requirements so as to include important ore-bodies such as the Long Lake gold mine. Examinations were also made of deposits, such as the Howry Creek gold prospects and the Massey copper mine, which lie outside the map-areas.

Ore deposits that came under observation were examined with a view to their commercial usefulness. Individual descriptions of the more promising ones are given here or in earlier summary reports.[1] They were also studied to ascertain what relations they bear to the main events of geological history, that is, how they were formed, when, and in association with what geological formations. It is becoming more and more clear, as systematic geological knowledge of the Precambrian shield enlarges, that the ore deposits of the Precambrian belong in time to certain metallogenetic epochs and in place with certain geological formations. The successful application of systematic areal geology in prospecting for ore deposits depends in the first degree upon a recognition and knowledge of these relationships. Unless the ore-producing episodes during Precambrian time can be rightly connected with other more obvious Precambrian events a stratigraphical and correlational study such as the present one fails in practical utility. The importance of this matter for Ontario has already been appreciated by the Ontario Bureau of Mines[2] in an interesting and suggestive paper.

It is not yet possible to apply the idea of metallogenetic epochs infallibly and to all ore-bodies in the North Shore district, but a majority of them can be satisfactorily classified in the following table. The relationships implied in this table are discussed in the pages that follow.

[1] Geol. Surv., Can., Sum. Repts. 1916 and 1917.

[2] Miller, W. G., and Knight, C. W., "Metallogenetic Epochs in the Precambrian of Ontario, Ann. Rept., Ont. Bureau of Mines, vol. XXIV, pt. I, 1915, pp. 243-248.

Formation	Ore deposit	Geological habit
Pleistocene lake beds	Brick-clay	Stratified clays
Palæozoic sandstone	Iron ore	Veins in subjacent Precambrian formation
Olivine diabase		
Killarney granite	Gold-arsenic (?)	Veins in adjacent older formations
	Feldspar	Dykes in adjacent older formations
	Ornamental stone	The granite itself
Diabasic (Keweenawan?) intrusives	Copper	Veins in or adjacent to sills
	Gold	" " "
	Silver-cobalt	" " "
Cobalt series		
Upper white quartzite and yellow cherty limestone		
Banded cherty quartzite		
Lorrain quartzite	Specular iron ore	Thin beds and veins
	Quartzite pure enough for supply of silica	Uppermost 1,000 feet of formation
Gowganda formation	Ornamental stone	Red jasper conglomerate
Bruce series		
Serpent quartzite		
Espanola limestone		
Espanola greywacke		
Bruce limestone	Iron ore	Thin beds of magnetite at base of formation
Bruce conglomerate	Marble	Crystalline parts of formation
Mississagi quartzite	Quartzite pure enough to form supply of silica	Silicified xenoliths of this formation in the Killarney granite
Pre-Huronian		
Granite gneiss		
Sediments		
Schist-complex	Iron ore	Iron formation

GOLD

ASSOCIATED WITH KEWEENAWAN DIABASE

There are two ore deposits in the district which belong in this category, the Havilah, or Ophir, mine, in lot 12, concession III, Galbraith township, and the Payton prospect on the west side of Whiskey lake, township 139.

Havilah Mine

Although this mine is not working now, it still holds sufficient possibilities to warrant a review of its history. Gold is reported[1] to have been discovered in lot 12, concession III, Galbraith, in November, 1899, by William Moor, a neighbouring farmer. Following this the property fell into litigation and changed ownership a number of times, without any development other than trenches and test pits. In 1892 it was purchased for $100,000 by the Ophir Gold Mining Company, capitalized at $3,000,000, subscribed mostly by residents of Duluth. Work was begun in October.

[1] Most of the historical information given here has been obtained from the Annual Reports of the Bureau of Mines, Ontario, particularly vol. 3, 1893, pp. 39-45.

Two shafts were sunk and a 20-stamp mill was erected. Mill samples aggregating 5,170 pounds of ore, which were sent to the School of Mines, Houghton, Michigan, are said to have yielded 9·7 ounces of gold and 6·15 ounces of silver. In spite of such encouraging reports, a financial depression in 1893 so discouraged the sale of stock that the mine fell permanently into difficulty. It was operated in 1893 and 1894 with a force of about thirty men.

Little can be learned about it during the next few years. In 1899 the mine, then in the hands of Peter McArthur, of Toronto, was being worked with fifteen men. In December, 1902, after another period of inactivity, a 4-drill air-compressor was installed and work resumed. This enterprise does not appear to have continued long. In February, 1909, possession was secured by the Havilah Gold Mining Company, the old shaft and adit cleaned out and mining resumed. This attempt seems to have been no more successful than the earlier ones, for the mine has been idle since 1912.

The gold-bearing veins are situated in a high bluff of Keweenawan diabase to the west and south of which is a flat of Pleistocene lake-clays which has been cleared for farming. A contact between the diabase and Mississagi quartzite, mostly concealed by the clay, corresponds in a general way with the foot of the bluff. The principal vein cuts across the diabase bluff in a direction 15 degrees south of west and continues in that direction across the lower ground to the quartzite contact, where it is said to finger out. This vein is 1,300 feet or more long, from 18 inches to 7 feet wide, and dips about 80 degrees south. Branching away from its north side in the diabase bluff is a series of three smaller, more or less parallel veins, which rise at about 45 degrees to the surface. These lateral veins were known as the ore-chimney. They lie within an arcuate zone not exceeding 43 feet in width and 450 feet in length, both ends of which spring from the main vein. All the veins consist of quartz, of white to bluish-grey colour, mingled with a grey carbonate and linear streaks and bands of dark-green chloritic material representing sheared diabase. This gangue is speckled with small patches of chalcopyrite and pyrite, and an occasional particle of free gold. Where exposed to the weather, the carbonate tarnishes to a rich bronze-red, strikingly like the carbonate found at the Crystal mine near lake Wanapitei,[1] which is a mixture of iron and magnesium carbonate (breunerite). Indeed the Havilah and Crystal ore deposits are remarkably alike in composition and geological relationships.

According to the mill tests at Houghton some of the ore must have been exceedingly rich in gold, and have carried a considerable amount of silver. The average tenor appears, however, to have been much lower. The ore raised during 1894 is reported by the Ontario Bureau of Mines to have run between $5 and $6 a ton. Mr. John Black, manager of the neighbouring Hudson copper property, informed the writer in the spring of 1917 that samples taken by him yielded from $6 to $19 a ton. The gold is partly in a free state and partly associated with the sulphides in a manner which requires concentration and chemical treatment of the sulphide.

[1] Geol. Surv., Can., Mem. 95, pp. 114-116.

From the first, attention was given to the oblique branching veins (ore-chimney) as well as to the main vein. A vertical shaft was sunk on the main vein at the base of the diabase bluff. An incline shaft, at 40 degrees south for 65 feet and beyond that at 50 degrees, was sunk along the foot-wall of the chimney. Four short adits were driven into this chimney from points in the north face of the bluff above the mouth of the inclined shaft, with a view to stoping out the chimney. At the present time, so far as can be learned from earlier descriptions and from what can be seen at the mine, the vertical 6-foot by 8-foot shaft is 100 feet deep. From its floor an adit, according to the caretaker of the property in 1916, runs east along the main vein for over 300 feet. From near the bottom of the shaft a drift also runs east along the main vein for 120 feet and from this is a raise up to an irregular stope 50 by 150 feet in the ore-chimney. This stope, inclined at about 45 degrees southward, communicates with the north face of the diabase bluff by the four short adits referred to above. It is said that the inclined 6 by 6-foot shaft was intended to connect with the drift at the 100-foot level, but this shaft was stopped at 105 feet. The mill in 1916 was rather badly out of repair.

Payton Prospect, Whiskey Lake

Gold was discovered on this property (Mining location W.R. 94)[1] in the spring of 1912. A good deal of exploration work was done during the next few years, but the property is now idle.

One large quartz vein and several smaller ones have been found intersecting an argillite member of the Mississagi quartzite, or basal formation of the Bruce series. A sill of quartz diabase occurs only a short distance to the west, but the veins are not known to extend into the diabase. The argillite is an exceedingly weak material and has been fractured, crumpled, and schistified to an extraordinary degree by the deformational forces that have affected the Huronian rocks. The veins are, consequently, faulted and bent so much that their general attitude and probable underground extension cannot be determined in the present state of development of the property. The large vein is 6 feet wide in one place, where it has been cut diagonally by a trench. Only a few feet away a trench 40 feet long has been made along what is probably a bent or faulted extension of the same vein. In this distance it is from 36 to 60 inches wide. A pit has been sunk 30 feet deep in the argillite nearby, exposing another body of quartz of seemingly small size.

The veins are composed of white quartz containing occasional patches of disseminated pyrite. Fine specimens of free gold have been obtained from them, but the average gold content is reported to be rather low.

Geological Relationships

The Havilah veins intersect a sill of late Precambrian (Keweenawan) quartz diabase, and are, therefore, younger than the diabase. Those in the

[1] Geol. Surv., Can., Sum. Rept., 1917, pt. E, *See* Figure 1.

Payton claim are later than the Mississagi quartzite. Their relationship to the nearby diabase sill is not directly determinable, but there is no other igneous agent, except the diabase, to which they can be referred.

Reviewing the gold occurrences in northeastern Ontario, quite a number of instances can be found in which there is a similar, suggestively intimate association between gold-bearing quartz veins and the late Precambrian diabase. A group of such deposits occurs near Wanapitei lake. The Crystal mine,[1] at the west side of that lake, is located on quartz veins extraordinarily similar in composition to those at the Havilah, which intersect sediments of the Cobalt series and an intrusive mass of diabase. The old McKenzie mine, situated one-quarter mile south of Kukagami lake, in the same neighbourhood, is located on quartz veins that cut Cobalt series greywacke not far away from another sill-like mass of diabase. The Mount Aetna mine, in lot 12, concession II, Davis township, is similar; quartz veins carrying pyrite, chalcopyrite, some barite, and a little free gold intersect Cobalt conglomerate in close proximity to intrusive diabase. In the Wellington copper vein at Bruce Mines as much as 2½ ounces of gold were found in one sample and an average of 0·3 pennyweights of gold for the whole vein.[2] A small percentage of gold is reported to have been found in veins of the cobalt-silver type that cut a quartz diabase sill in North Williams township.[3] Baker[4] records auriferous quartz veins in quartz diabase near lake Abitibi, and Hopkins[5] refers to another occurrence of gold, in the same district, which is associated with diabase of probable Keweenawan age. Appreciable amounts of gold also occur in the copper-nickel ores of Sudbury district.

Beyond question gold was deposited widely through northeastern Ontario at some time subsequent to the intrusion of the Keweenawan diabase. There is considerable ground, moreover, for believing that these deposits are directly connected with the intrusions of diabase. They are all found within, or close to, large bodies of diabase. In the case of the Bruce mine the gold occurs as an accessory in copper-bearing veins which are commonly accepted as derivatives from mineralized solutions from a cooling diabase magma. If the copper in the veins at Bruce Mines originated from the diabase it is more than likely that the gold in them had the same source. And, if such an origin be granted for the gold at Bruce Mines, a similar interpretation must be placed upon the gold at the Havilah, and the mines near lake Wanapitei, for any differences between them are differences of degree only. All these veins consist of the same association of quartz, carbonate, some barite, chalcopyrite, pyrite, and gold; but in one case chalcopyrite so predominates over gold as to make copper the most important metallic constituent, and in the other cases gold is first in value.

A like argument applies in the case of the gold found in the cobalt-silver mines in North Williams township and at the Mann mine, of Gow-

[1] Geol. Surv., Can., Mem. 95, pp. 114-116.
[2] Ann. Rept. Ont. Bureau of Mines, vol. XXIV, pt. 1, p. 233.
[3] Geol. Surv., Can., Mem. 95, p. 115.
[4] Ann. Rept., Ont. Bureau of Mines, vol. XVIII, pt. 1, pp. 262-283.
[5] Ibid, vol. XXVII, pt. 1, p. 203.

ganda district. The cobalt-silver veins are primary deposits generally regarded as the last products of magmatic differentiation in the diabase sills of Cobalt and Gowganda districts. If gold in some cases accompanies the other metallic constituents it may be assumed to have come from the same source.

Gold found in the primary copper-nickel ores of Sudbury district must also be regarded as coming, with the copper and nickel, from the Sudbury norite.

It might be expected that these late Precambrian basic intrusives should exhibit certain petrological differences to explain the association with them of ores of cobalt, silver, nickel, and arsenic in one part of the country, of copper and nickel in another, copper in another, and gold in still another district. In the first two cases there is such a difference. The copper-nickel ores of Sudbury district emanate from a quartz-norite, whereas the cobalt-silver ores of Cobalt, Gowganda, and other districts appear to be associated only with quartz diabase.[1] But, if there be any difference between the quartz diabase at Cobalt and that in the Bruce Mines area with which the copper and gold-bearing veins occur, it is not readily perceptible. Even under the microscope slices of diabase from the two districts cannot be distinguished.

ASSOCIATED WITH KILLARNEY GRANITE

The Long Lake gold deposit, those along Howry creek (Panache area), and perhaps also the Shakespeare ore-body, just north of Webbwood, were formed in late Precambrian time, and apparently not in connexion with the diabase intrusives. Such evidence as has been collected regarding the source of these ores, though not conclusive, points to a genetic relationship with the late Precambrian (Killarnean) granites.

Long Lake Gold Mine

This property, belonging to the Canadian Exploration Company, is situated at the extreme east side of Panache area, and one mile south of the foot of Long lake. It was worked, with minor interruptions, from the spring of 1909 until the end of June, 1916, when the known ore-body, terminated by a fault, became exhausted. Following this the ground was explored with a diamond-drill for the faulted extension of the ore-body, but without success. During its active period of about five years this mine is said by the manager, Mr. R. W. Brigstocke,[2] to have produced about $800,000 of gold. Mr. M. B. Baker[3] reports a total output of about 200,000 tons of ore containing an average gold value of $8 a ton.

At the time mining operations ceased the underground workings had reached a depth of 345 feet. A vertical, two-compartment shaft had been sunk 225 feet, and from the second level to the bottom of the mine a winze inclined at 45 degrees along the faulted foot-wall of the ore-body. From the 80, 180, 260, and 330-foot levels rather complex systems of drifts and stopes had been made within the confines of the ore-body. In

[1] Geol. Surv., Can., Mem. 95, pp. 121, 122.
[2] Personal communication.
[3] Ann. Rept. Ont. Bureau of Mines, vol. XXVI, pt. 1, 1917, p. 157.

addition, a glory-hole about 100 feet in diameter reached down to the second level. The ore raised was treated in a 20-stamp mill, and a cyanide plant capable of handling about 140 tons a day. Excellent photographs of these buildings are shown in the Annual Report of the Bureau of Mines, Ontario, for 1917 (pages 122 and 218). The plant was operated with electric power supplied by the Wanapitei Power Company. A 9-mile wagon road connected the mine with Naughton station on the Canadian Pacific railway.

Although the ore-body is mined out there is still some possibility of a further recovery of gold. During the first years of operation much difficulty was encountered in obtaining a good extraction of gold owing to the arsenic and copper in the ore. It is said that a considerable share of the tailings retain enough gold to be worth retreatment, provided some further improvements can be made in the method.

The geological features near the mine are shown in the Panache sheet accompanying this report (No. 1971), and in greater detail by Map No. 26e, accompanying a report by M. B. Baker in the Annual report of the Bureau of Mines, Ontario, for 1917. The mine is situated on the main line, or zone, of contact between the Huronian sediments and the intrusive Killarney granite. It lies near the middle of a wedge-shaped salient of Mississagi quartzite, 2,000 feet wide, that protrudes into the granites. This quartzite tongue is also intruded by an irregularly linear, possibly sill-shaped, mass of diorite older than the granite. The ore-body occurs in a mass of the quartzite which is either partly or entirely enclosed by the diorite. Several dykes of olivine diabase intersect all these formations.

The rocks are less altered than might be anticipated from the variety and intensity of the geological forces that have operated along the contact zone. The quartzite lies on edge, but its bedding and crossbedding are still distinct. No trace remains of the original sand grains, the rock appearing under the microscope as a mosaic of angular, interlocking quartz and feldspar grains. Feldspar is about half as abundant as quartz. The Killarney granite in this neighbourhood is the typical coarse red variety, rather rich in potash feldspars and poor in quartz. It contains a multitude of angular fragments of the Mississagi formation, ranging in size from small blocks to masses hundreds of feet long. The diorite is mainly a massive, nearly black rock composed of black hornblende and white feldspar, but locally it grades into a lighter-coloured syenitic variety and, south of the mine, appears to merge into the Killarney granite. Both Baker and Coleman[1] appear to have considered the possibility of the diorite being a basic, marginal phase of the Killarney granite. Certainly it does not closely resemble any of the other late Precambrian basic intrusives in the North Shore district.

Baker has represented two faults that displace even the olivine diabase dykes. The more northerly of these faults dips about 45 degrees southeastward, dislocating the ore-body in such a manner that its lower part is displaced an unknown distance down-dip.

[1] Ann. Rept. Ont. Bureau of Mines, vol. XXIII, pt. I, 1914, p 219.

The ore-body is merely a part of the Mississagi quartzite that was impregnated with mispickel, pyrite, and other metal-bearing minerals. It has no definite walls. Mining operations were stopped only when the gold values in the quartzite became too low to be profitably recovered. The body mined out is a stout chimney-shaped mass, roughly elliptical in horizontal cross-section with diameters of about 150 and 250 feet. It pitches steeply towards the southwest to an extreme depth of 340 feet, at which it is sliced off obliquely by the fault mentioned above.

Mineralization appears to have been confined to the quartzite. The ore consisted of quartzite impregnated with a fine dust of arsenopyrite and pyrite particles. It varied considerably in colour, depending upon compositional differences. The common variety was a light grey. Unusually feldspathic parts were inclined to red, and parts strongly impregnated with arsenopyrite were dark bluish-grey. To a certain extent these colour differences served to indicate the tenor of the ore. In addition to the fine, cloudy impregnation of arsenopyrite and pyrite, pyrite occurred in larger, well-formed crystals. Chalcopyrite, pyrrhotite, and galena were present in small quantities, often aggregated in small patches. A few vug-like nests of native arsenic were also found, in which the arsenic occurred as splendid tabular crystals with triangular markings on the faces. Small splashes and veinlets of quartz were seen towards the bottom of the mine. Little, if any, of the gold was visible. It was associated with the arsenic in a form requiring cyanide treatment. Values ranging from $8 to $11 were obtained from the ore raised.

Geologists who have examined the deposit are agreed that it is due to action upon the quartzite of hot solutions emanating either from the diorite or the Killarney granite. J. A. Dresser, who examined the property for the owners, concluded, after studying microscope preparations of the ore, that the ore minerals introduced by these solutions had replaced the feldspars in the quartzite and that the ore-body corresponded with a particularly feldspathic part of the Mississagi formation. Baker, in his report, also refers to " a noticeable increase in gold values with increase of feldspar in portions of the quartzite."

Howry Creek Prospects [1]

Gold was found near Howry creek in 1911. In the next two years about one hundred claims were staked and some further discoveries made. During 1916, the Bousquet vein, the most promising one in the area, was optioned to J. S. Wilson, of Massey, and A. L. Kemp, Gore Bay, Ontario, who sampled it thoroughly. It was proposed at that time to erect a small mill which would save the arsenic, then in demand for war purposes, as well as the gold, but this enterprise was not carried out. As far as known, no other attempts have been made to operate the Howry Creek deposits.

The mineralized area is 6 miles long from east to west and 1 mile wide.[2] It is situated within the closely folded belt of Huronian forma-

[1] Descriptions of the individual claims are given in Geol. Surv., Can., Sum. Rept., 1917, pt. E, pp. 10-13.

[2] Geol. Surv., Can., Sum. Rept., 1917, pt. E, *See* Figure 2.

tions next to the Killarney granite batholith. It is underlain by quartzite, greywacke, and conglomerate belonging to the upper part of the Gowganda formation and lower part of the Lorrain quartzite. These formations are on edge and strikes east and west. They are cut by a few dykes and larger masses of diabase. Although the Killarney granite is some miles away, the Huronian formations are so metamorphosed in places as to suggest that granite, not yet exposed by erosion, may occur nearer.

There are two somewhat dissimilar types of ore deposit. The first type includes all but one of the ore-bodies. These are well-defined quartz veins, from 1 inch to 6 feet in width, and up to 350 feet in length. They strike east and west like the sedimentary formations and dip about vertically. One of them cuts across a body of late Precambrian diabase, but the others are in the Huronian sediments. They consist of white quartz and ankerite carrying arsenopyrite, pyrite, free gold, and occasionally specularite, but in very different proportions. Some are virtually barren quartz veins; others, as the Bousquet vein, contain as much massive arsenopyrite as gangue, besides considerable proportions of ankerite and pyrite. The wall-rock, especially if it be greywacke or conglomerate, is bleached, heavily impregnated with ankerite, and slightly mineralized with the same ore minerals as the vein-stuff for 2 or 3 feet on each side. Gold values range from nil to $8 or $10, and in occasional samples are very much higher.

The deposit in mining claims 3180-81-82 is a schistified zone in Cobalt conglomerate which has been impregnated with ankerite and pyrite, and filled with a plexus of veinlets similar in composition to the larger veins. The mineralized zone is 40 feet or more wide, and is said to extend east and west for half a mile. Apparently the mineralizing agents were the same as those which filled the larger veins, but the sheared conglomerate formation was incapable of forming large impervious fissures. Instead of the vein material being confined in one well-defined fissure it saturated and percolated through the country rock. In consequence, the mineral values are lower than in the veins.

Geological Relationships. The Howry Creek veins intersect Cobalt series sediments and the diabase that is intrusive in these sediments, so they must have been formed late in Precambrian time. The age of the Long Lake deposit cannot be fixed so closely. It is at least younger than the Bruce series in which it occurs. Although it differs in many respects from the Howry Creek deposits it resembles them in the essential matter of mineralization. Both are gold-arsenic deposits, carrying gold in combination with arsenopyrite.

In this respect they differ conspicuously from deposits of the Havilah type, which contain no arsenic and are genetically related to the late Precambrian diabase. It seems necessary on this ground alone to assign them to some other source. Coleman and Baker are both inclined to regard the diorite at the Long Lake mine as the cause of that ore-body, apparently because the diorite is the nearest igneous agent which could provide hot, mineralizing solutions. As a matter of fact there is little to choose between the diorite and the Killarney granite.

Turning to the Howry Creek deposits, there are no basic intrusives nearby that correspond with the Long Lake diorite. The only basic rocks near the veins are quartz diabase and these, as discussed above, do not appear to be the source of the ores. However, the veins lie in the belt of disturbed Huronian formations next to the Killarney batholith, though much farther away from the nearest visible granite than the Long Lake mine. It is also significant, perhaps, that veins carrying arsenic and gold occur at another point along this contact belt intermediate between Howry creek and Long lake. Reference is made to the Bedard prospect on the south shore of lake Panache, half a mile east of the boundary line between townships 83 and 75. At this place a shallow pit at the water's edge has exposed a number of narrow quartz veins in calcareous Espanola greywacke. Mispickel, pyrite, chalcopyrite, and pyrrhotite are present in small quantities and encouragement to excavate the pit is reported to have been given by assay returns of gold. Although the Bedard prospect is too small to warrant further development its mineralogical resemblance to the Long Lake and Howry Creek deposits and the alignment of all three along the contact of the Killarney granite offer some tentative basis for the opinion that they may have originated from the granite.

SILVER-COBALT

Although the Keweenawan basic intrusives north of lake Huron are not distinguishable from the corresponding quartz diabase intrusives of Cobalt district they are not known to be accompanied by any important deposits of the silver-cobalt association of minerals found at Cobalt. The only known representatives of this type of deposit are a number of veins in Otter township at the extreme northeast corner of Bruce Mines map-area. These deposits as described by A. G. Burrows[1] are quartz veins in a large sill of quartz diabase. "On the Kerr claim, SE. ¼ of S. ½ lot 1, con. IV, there are two quartz veins which strike north 65 degrees west. The northerly vein, which at one point has a width of 12 feet, contains copper pyrites and specular iron ore, in addition to the quartz and calcite. The southerly vein has been stripped over a distance of 230 feet, and at one place a pit has been sunk 13 feet. In the pit the vein is 7 feet wide, consisting for the most part of quartz, or quartz and diabase in a reticulated structure. Calcite occurs in lesser amount and cobalt and native bismuth have been found in small masses. To the east and west of the pit the vein is much narrower.

"On the adjoining claim to the east there is a quartz vein with a similar strike averaging a foot in width. It has a decided comb structure, some of the quartz crystals being an inch in diameter. Calcite and occasionally cobaltite and native bismuth have been deposited between the quartz layers, and thin sheets of bismuth sometimes occur on the smooth faces of the quartz crystals.

"One sample from the Kerr claim, consisting mostly of bismuth, gave on assay: gold, 0·03 ounce; silver, 15·9 ounces; bismuth, 59·5 per cent; cobalt, trace. A sample of massive cobaltite gave on assay no gold or silver."

[1] Ann. Rept. Ont. Bureau of Mines, vol. XIX, pt. II, p. 196.

Burrows' description of these veins fits in quite a remarkable way the veins typical of the outlying districts in the Cobalt region, e.g. Duncan lake, Shiningtree lake, Rosie creek, etc., where the association of vein minerals differed considerably from that at Cobalt and the silver values were much lower. The veins in all these marginal camps contain quartz growing from each wall and in cases filling all but a narrow central space. Chalcopyrite is fairly abundant, but the characteristically rich association of native silver and arsenides of cobalt and nickel found at Cobalt is rather poorly represented. They are, in fact, intermediate in composition between the typical silver-cobalt veins of Cobalt district and the equally typical copper veins of Bruce Mines district.

COPPER

Copper ore deposits are the most numerous and most widespread of all metallic deposits in the North Shore district. Old mines, prospect pits, and undeveloped veins are scattered in extraordinary number all the way from Sault Ste. Marie to the Sudbury nickel district, and from 1848 until comparatively recently, copper mining was an important industry. The industry has declined, however, with mounting costs and a decrease in the price of copper from 24 cents in about 1850 to 14 cents in 1914. In 1914 none of the properties was in operation.

There has been some renewal of activity, due to the war price of copper. In 1915 the old Bruce mine and the Massey mine were reopened. During 1916 development work was commenced by the Hudson Copper Company on the Wilmot claim in Galbraith township, and some further attention was given to the copper prospects near Whiskey lake. In a considerable degree, however, the future of copper mining in the North Shore district depends upon the ability of the various properties to produce collectively enough ore to assure them better local smelter accommodation. The ore from the Bruce mine is a lean mixture of chalcopyrite and quartz well adapted for mixing with the basic copper-nickel ore of Sudbury district and is shipped without concentration to the Mond Nickel Company's smelter at Coniston. But the other properties have not been able to maintain a sufficiently large or steady supply of ore either to secure favourable entry to the Sudbury smelters or to support an independent furnace. As a consequence the Massey mine found it necessary to concentrate its ore and ship the concentrates to New Jersey or Virginia or to Trail, B.C., at a transportation cost of $5 or more a ton. With copper selling at around 23 cents a pound the small copper mines in the district found this unprofitable. A small furnace intended to meet their needs was erected at Thessalon in 1907, but appears not to have operated satisfactorily.[1]

Bruce Mine

The account of this famous old mine given by C. W. Knight[2] is sufficiently complete to require no further description here. The mine

[1] Wilson, A. W. G., "The Copper Smelting Industries of Canada": Dept. of Mines, Can., Mines Branch, Pub. No. 209, p. 15.

[2] Ann. Rept., Ont. Bureau of Mines, vol. XXIV, pt. I, pp. 230-235.

has been operated more or less continuously from 1848 to 1916 and has produced copper variously valued at from $3,500,000 to $7,000,000. It is now owned and operated by the Mond Nickel Company, the ore going to Coniston smelter.

Rock Lake Mine

This abandoned property is situated in lot 2, concession I, Aberdeen township, just northeast of Rock lake. Operations were begun in April, 1898, upon a vein up to 12 feet in exposed width and said to be traceable for nearly 3 miles in a direction 75 degrees west of north. Two exploratory adits were first driven, 1,200 feet apart, in the side of a ridge traversed by the vein. These indicated the vein to be 16 feet wide and to dip towards the southwest at 45 to 55 degrees. Mining then commenced; a concentrating mill capable of handling 200 tons of ore a day was erected at Rock lake, and a tramway about 1½ miles long was built to carry the ore from the mine to the mill. The Bruce Mines and Algoma railway, 13 miles long, was also constructed from Bruce Mines to the mill, mainly for the purpose of hauling out the concentrates. The whole plant was put in operation at the beginning of 1901. Mining operations were continued until 1903. A vertical shaft was sunk 420 feet, and working levels were established at 100-foot intervals, leaving a 20-foot sump at the bottom. At the 100-foot level, drifts were run 169 feet northwest and 140 feet southeast along the vein, extensive stoping was done, and two ventilation shafts were run to the surface. The second-level drifts were run 128 feet northwest and 92 feet southeast, with considerably less crosscutting and stoping. Nothing was done below this except crosscuts 39 and 38 feet from the shaft at the third level.

In July, 1903, all work ceased. It is said that profits were not being made, not because the ore-body was unsatisfactory, but that the expense of building the mill and railway was great, the mine had not been developed on a scale large enough to supply the mill, and adequate reserves of blocked-out ore had not been maintained. Since then the mine workings have filled with water and fallen out of repair, nothing remains of the tramway to the mill except rotting sleepers, and the mill has been looted of most of its machinery. The railway to Bruce Mines, however, has passed into the hands of the Lake Huron and Northern Ontario Railway Company and all of the original line except 1½ miles next the concentrating mill is in operation.

Practically nothing can be seen of the ore-body at the present time; but according to Bureau of Mines descriptions it is a vein striking 15 degrees west of north and dipping 45 to 55 degrees southwest. It has been traced for about 3 miles and apparently maintained a width in the mine of 12 to 20 feet. It intersects greywacke and conglomerate belonging to the Cobalt series and also a sill of diabase intrusive in these sediments. It consists of quartz and some ankerite mingled with blocks and schistified streaks of country rock, all these gangue materials being impregnated with grains and small splashes of chalcopyrite and minor amounts of bornite. Nothing is said regarding the percentage of copper in the ore. The vein is displaced by a number of faults with horizontal displacement of from 2 to 10 feet.

Wilmot Claim

A description of this property, exploration of which was begun in 1916, is given in the Summary Report of the Geological Survey, 1917.[1]

Cheney and Other Prospects in Gould Township

There are in and near Gould township various copper deposits which may become productive if the Lake Huron and Northern Ontario railway be extended from its present terminus in Aberdeen township to Mississagi river. These deposits are situated immediately east of the Bruce Mines map-area and about 20 miles by road northeast of Thessalon. Over 200 tons of selected ore, carrying 12 to 17 per cent copper, were hauled out to the Canadian Pacific railway during the winter of 1916, but it is unlikely that the average product can be profitably marketed in this manner.

The Cheney property, held by the Cheney Copper Mines, Ltd., Toronto, is situated in lots 6 to 10, concession V, Gould township. Exploration work has been confined mainly to lot 7, where a mineralized zone about 16 feet wide occurs in greywacke and conglomerate of the Gowganda formation. This deposit has been stripped at intervals for one-third of a mile in a direction almost due east and west. An open-cut 25 feet long and 12 feet deep crosses it, and a shaft has been sunk about 70 feet. The mineralized zone is made up of country rock traversed by many parallel, anastomosing quartz veins ranging from less than an inch to several feet in width. Calcite and some siderite accompany the quartz. Chalcopyrite is distributed somewhat unevenly through this gangue, giving rise to bands and pockets of ore. A sample channelled across one band 32 inches wide yielded 8.2 per cent of copper. At other points on the vein, notably one-third of a mile west of the shaft, specular iron ore accompanies the chalcopyrite.

Another prospect situated in lot 4, and owned by the Copper Range Company, is described by Knight as small but exceptionally rich: It "consists of several more or less parallel and irregular veins having a width of from 2 inches to 3 feet or more. Some of the veins consist of solid chalcopyrite about 12 inches wide. The veins, which occur in beautifully bedded greywacke slates, strike southeast with a steep dip to the southwest. A shaft has been sunk to a depth of 45 feet, and a drift run at that level a distance of 45 feet.[2]"

The abandoned Grand Portage mine, situated in mining location 1, concession I, Gould township, at the side of Grand portage on Mississagi river, is described fully in the Bureau of Mines reports;[3] likewise a vein in lot 12, concession III.

Other Prospects in Bruce Mines Map-area

The Austin mine, located a mile northwest of Echo lake, was operated about thirty years ago. An adit 75 feet long, a short shaft, and several

[1] Geol. Surv., Can., Sum. Rept., 1917, pt. E, pp. 7 and 8.

[2] Ann. Rept., Ont. Bureau of Mines, vol. XXIV, pt. I, 1915, p. 235.

[3] Ann. Rept. Ont. Bureau of Mines, vol. VIII, pt. 1, 1899, pp. 37-38 and 148-149; vol. XXIV, pt. 1, 1915, p. 236.

exploratory pits were made on two intersecting quartz veins carrying some chalcopyrite and pyrite.[1] The road from Echo lake can still be followed, but the workings are filled with debris.

Unimportant veins of chalcopyrite have been found and prospected at various points in the great diabase ridge that extends along the southeast side of Echo lake.

The old Stobie mine near Desbarats is comparable with the Austin mine in respect to the nature and importance of its ore-body and the work done thereon.

In McMahon township quartz veins carrying chalcopyrite have been found in lot 6, concession III, and lot 5, concession I. Knight describes the deposit in lot 6 as a system of anastomosing veins and veinlets in greywacke conglomerate, which has been traced for 300 feet and explored to a depth of 30 feet at one place. Chalcopyrite and pyrite are not abundant, but specular iron ore occurs in masses 1 to 4 inches in diameter. The deposit in lot 5 is about 4 feet wide, has been traced for 150 feet, and is mineralized with chalcopyrite and pyrite for 60 feet.

The Rising Sun and Copper Queen mines, situated respectively in lot 9, concession II, and lots 3, 5, 6, 7, and 8, concessions IV and V, Morin township, adjacent to McMahon, are abandoned workings of considerable magnitude[2] in veins rather poorly mineralized with chalcopyrite.

Veins 6 to 10 feet in maximum width occur in lots 11 and 24, Rose township. Both of these have been test-pitted without very promising results. They are typical of the district, consisting of a fractured zone filled with quartz veins carrying ankerite, chalcopyrite, and some pyrite.

The old Two Lake mine, situated in lot 8, concession IV, Day township, about 9 miles northeast of Thessalon, according to Knight[3], operated a vein of the usual type; the dump contains some 25 tons of ore containing chalcopyrite in a gangue of quartz, siderite, and calcite.

Mineral Deposits in Otter Township

Dr. Emmons reports as follows respecting observations made during 1924: "Mineral possibilities in this township are largely limited to an east-west strip across the centre of the township where there is a large diabase intrusive. This diabase mass has at the time of crystallization been rich in rock juices, as indicated by the high content of pegmatitic material which is unevenly distributed through it. Signs of mineralization on a small scale are not uncommon and it is quite probable that systematic prospecting will reveal more important deposits.

Two somewhat successful attempts to expose mineral veins are those by Burden in concession III, lot 12, and by Taylor on Clear lake, concession III, lot 1.

Taylor's claim is centred on a quartz vein ranging from 3 feet to 10 feet in width, striking slightly north of west, and dipping steeply. In places the vein is imbricated and in places stringers penetrate the footwall. Much of the vein is barren milky quartz on the surface, though

[1] Report of Royal Commission on Mineral Resources of Ontario, 1890, pp. 91-92.
[2] Ann. Rept., Ont. Bureau of Mines, vol. XIII, pt. I, 1904, pp. 79-81.
[3] Op. cit.

specularite is rather generally present in it. At one point on the shore of the east end of the lake a pit has been dug in a promising shoot on the vein, where the wall-rock (foot-wall) is much shattered and where stringers of the vein penetrate the foot-wall. Here native bismuth is disseminated, in places rather plentifully. Since the pit was flooded at the time of examination and the surface of the vein is barren, study was largely limited to the dump. Accordingly, assay samples were not taken. The property appears to warrant further development.

Burden's claim is in an area of very poor surface exposures and very little development work has been done on it. In a creek bed, a small vein about 3 feet in width, with a few associated stringers and veinlets, contains a moderate amount of sulphide, mainly chalcopyrite and pyrite. A few similar small veins are exposed in the same creek bed. These veins contain much gouge and appear to be small mineralized shear zones. Many such may be expected in the vicinity, but their size and value can be determined only by systematic stripping."

Prospects in Blind River Map-area

A prospect pit, known as the Moosehorn mine, was sunk, apparently many years ago, upon a mineralized fault zone in section 11, Thompson township. There is a distinct brecciated zone 5 to 10 feet wide, striking 15 degrees north of east, bounded by quartzite on the south and greywacke conglomerate on the north. The breccia is cemented with quartz and calcite carrying a considerable percentage of chalcopyrite and pyrite. Some fine specimens of chalcopyrite remain in the dump.

Chalcopyrite veins are reported to have been found in timber berths 168 and 163, but these were not visited and no particulars regarding them can be obtained.

The deposits near Whiskey lake, in timber berths 137 and 138, are described in the Summary Report of the Geological Survey, 1917, Part E.[1]

Massey and Hermina Mines

These two mines are situated in the township of Salter about 3 and 5½ miles, respectively, northwest of Massey station on the Canadian Pacific railway. A fairly detailed description of both has been given by Professor Coleman in the Annual Report of the Bureau of Mines, Ontario, for 1913, so that it is only necessary to add here an account of subsequent developments. The Hermina mine has remained closed and there does not appear to be much likelihood of its operation in the immediate future. The ore—chalcopyrite in quartz—is too low in copper to be utilized except, perhaps, as a combination ore and acid flux for mixture with the Sudbury nickel ores.

The Massey mine, which had been idle since 1906, was leased by its owners, The Massey Station Mining Company, to the Sable River Copper Company and was reopened in 1915. When visited in September, 1917, the Elmore oil-flotation system formerly used in the concentrating mill had been replaced, with satisfactory results, by an adaptation of the Callow system. The mine had been cleaned out and, according to the

[1] Geol. Surv., Can., Sum. Rept., 1917, pt. E, pp. 8-10.

report of a consulting engineer, 60,000 tons of workable ore was available. Mining operations were being postponed, however, until a more satisfactory financial reorganization of the company could be made.

Other Prospects

Various small copper deposits may be enumerated which have been subjected to surface exploration, but without encouraging results. These are all quartz veins carrying small percentages of chalcopyrite. One of this sort occurs in section 15, Victoria township, near the west end of Sugar lake. A second one, known as the Grant property, is situated in the north half of lot 10, concession V, May township. A few tons of ore were shipped from this deposit to New Jersey for treatment, the results indicating an average copper content of 4 per cent across a width of 4 feet. At least two deposits are reported to occur in concession 4, Baldwin. A sample from one of these, owned by J. B. Andrew, Massey, yielded nearly 2 per cent of nickel in addition to copper.

Genesis

All the copper ore deposits just mentioned, except those of the Massey and Hermina mines, possess characteristics in common that suggest a genetic relationship with the Keweenawan diabase intrusions. They are veins carrying chalcopyrite or chalcocite, less frequently bornite, in a gangue of quartz, accompanied by small proportions of carbonates—calcite, ankerite or breunerite, and in a few cases by barite. The veins are found in the diabase sills or in the older formations never far away from the diabase. Moreover, the diabase is accompanied by dykes of an acid, aplitic differentiate, which also contain notably large amounts of chalcopyrite. Aplite, particularly rich in chalcopyrite, was found at the Moosehorn pit west of Blind River and also in lot 11, Rose township. The aplite in these cases is quite undecomposed, a condition which precludes any likelihood of the chalcopyrite having been introduced after the rock had crystallized. It is suggested that the quartz veins are merely later and still more siliceous differentiation products of the cooling diabase.

This explanation has been offered and worked out in greater detail for the silver-cobalt veins of Cobalt and Gowganda districts[1], and in this connexion certain related features of the silver-cobalt deposits and the copper-bearing veins of the North Shore district may be mentioned. There is apparently no lithological difference between the diabase of the North Shore and Cobalt districts. The copper-bearing veins in the former district do not as a rule carry any of the arsenides characteristic of the Cobalt ore deposits; nevertheless, cobalt bloom has been found in McMahon township, and in Otter township cobaltite and native bismuth are found in association with chalcopyrite in quartz veins. Conversely, in Gowganda and adjoining districts the typical silver-cobalt veins graduate into quartz veins mineralized chiefly with chalcopyrite, as if the two types are simply

[1] Geol. Surv., Can., Mem. 33, pp. 104-5; Ann. Rept. Ont. Bureau of Mines, vol. XIX, pt. 2, 1913, p. 8.

variations of a single process of mineralization dependent, perhaps, upon original differences in the diabase magma which have not yet been discovered.

There is some reason for thinking that the Massey and Hermina ore-bodies originated from late Precambrian granite instead of from the diabase. The Massey ore-body is closely associated with green schist and a quartzite which, in the writer's opinion, is Mississagi quartzite. These formations are intruded by granite, which must accordingly be late Precambrian. The Hermina veins occur in a small mass of green schist invaded and surrounded by this granite, no diabase occurring nearby.

IRON

IN THE PRE-HURONIAN SCHIST-COMPLEX

Banded iron formation, with which the iron ores of the pre-Huronian are chiefly associated, was found at only one place, just north of Quirke lake, in Blind River map-area. This occurrence has already been described in the section dealing with the pre-Huronian schist-complex and the opinion is expressed that no commercially important concentrations of iron ore are likely to be found in it.

Information was obtained in the field from prospectors that a more continuous range of iron formation occurs in township 138. It is said to be between 1 and 2 miles long and to extend in a general northerly direction parallel to the western boundary of the township and about 1 mile from the fourth milepost.

AT THE BASE OF THE BRUCE LIMESTONE

It has been pointed out in the section dealing with the Bruce limestone that the basal part of this formation, in townships 155 and 149, constitutes a variety of iron formation. The usual thin siliceous layers alternate with layers of pure black iron ore or of siliceous material carrying black iron ore in small disseminated crystals. The iron-ore layers range in thickness from paper-thin lamellæ to 2 inches. They occur through a total thickness of about 15 feet and constitute about one-fourth of that thickness. A sample from one of the richer 2-inch layers yielded: Fe, 40·26 per cent; SiO_2, 31·08 per cent; TiO_2, 0·34 per cent; P, 0·037 per cent; S, 0·040 per cent. The iron is contained largely, if not entirely, in the form of magnetite.

The proportion of ore to siliceous rock is probably not more than 1 to 4 at any point observed, so the formation is much too lean to be a merchantable iron ore. It was examined, however, only at intervals of about 1,500 feet along the strike; there is, therefore, a possibility of finding richer concentrations if a more intensive examination be made. The iron-bearing formation was traced for over 2 miles from a point within township 155 eastward into township 149. At no other place in the district, however, is the base of the Bruce limestone known to carry iron ore.

IN THE LORRAIN QUARTZITE

The Lorrain quartzite is characterized, especially in its upper half, by disseminated flakes and threads of specular hematite. Just north of Frazer bay on lake Huron, this constituent is sufficiently concentrated in certain horizons to constitute a lean hematite ore. The Huronian formations in this part of the district are closely folded, so the iron-bearing strata outcrop in bands that dip steeply and strike about north 70 degrees east. One of these bands, situated near the water's edge at the head of Frazer bay, was diamond-drilled in 1914. Its true thickness could not be ascertained, but the drill-cores showed nothing resembling iron ore except a fine-grained quartzite coloured dark grey by disseminated iron oxide.

A sample of much better hematite, probably carrying 40 per cent of iron, was subsequently shown the writer by a prospector. It is reported to have been obtained just north of Princes bay, a minor indentation in the coast line of Frazer bay. Iron-bearing bands up to 3 and 4 feet in width alternate with quartzite for a total width of 40 feet. This property is held by Thomas Sayer, Garden River, Ontario.

It is probable that some of the hematite deposits in parts of the Bruce Mines map-area not geologically examined belong to this class. Lindeman and Bolton[1] describe one of these as follows: "Stretching through lots 11 and 12, concession IV (Aberdeen) and the north halves of lots 1, 2, and 3, concession IV, the south half of lot 3, concession V (Aberdeen Additional), there is a belt of grey slate in which there is a ferruginous zone along the contact with the quartzite to the southwest. In this zone the hematite where it occurs in pockets or veins is iron-black and bluish in colour and compact, and where disseminated is of the specular variety. The best showing (not over 100 feet in length) has a maximum width of 6 feet of merchantable ore, and on either side the ore becomes increasingly siliceous. A shaft 32 feet deep (on the south half, lot 12) encountered seams of high-grade specular ore from 6 inches to 4 feet in width.

"Four diamond-drill holes with an aggregate depth of 1,000 feet were put down in 1903 to explore the most promising portions of this ore-band. Iron ore was encountered in three holes at depths of 150, 60, and 160 feet, respectively. At these depths the respective widths of the ore were as follows: 3 bands 1 foot wide in an 8-foot width of the formation; 2 bands 2 feet wide separated by 2 feet of quartzite; and 10 feet in one band. The slate on one or both sides of the iron-bearing quartzose rock is ferruginous for widths of several feet." The quartzite referred to is Lorrain.

VEINS SUBJACENT TO ST. MARYS (PALÆOZOIC) SANDSTONE

The St. Marys sandstone which rests in profound angular unconformity upon the Precambrian is a dark red, notably ferruginous formation, especially in its conglomeratic basal part, the matrix of which contains abundant streaks and nests of specular hematite (*See* foregoing description of the Palæozoic). It is not unlikely that this has a direct bearing upon the origin of various deposits of specular hematite which occupy fissures in the Huronian formations of Johnson and adjoining townships

[1] "Iron Ore Occurrences in Canada," Dept. of Mines, Mines Branch, Pub. No. 217, vol. II, p. 88.

in the Bruce Mines map-area. Isolated patches of St. Marys sandstone are still to be found resting upon the Precambrian, so it is fair to assume that the sandstone was originally continuous over the Precambrian in the western part of Bruce Mines map-area. It is also a reasonable conclusion that the water in which the sandstone began to be deposited was distinctly ferruginous, and that fissures and other narrow-mouthed cavities in the Precambrian rock surface of that time may have collected the precipitating iron oxide. That fissures did exist at the time is shown in the foregoing description of the Palæozoic-Huronian contact in section 3, Laird township. Iron oxides collected in such receptacles would remain sealed until the overlying Palæozoic sandstone had been eroded.

The ore-body of the old Stobie mine is the only notable example of this type visited by the writer. It is situated in concession I, Aberdeen township, just north of the west end of Gordon lake. The mine was worked in the eighties. Ore of good quality was shipped to Detroit, but after some diamond-drill exploration in 1894 operations were abandoned. All that can be seen now of these workings is an open-cut about 50 feet long, from the end of which an adit, blocked with debris, can be followed for another 40 feet. The ore deposit consists of a number of irregular veins and veinlets of hematite in Lorrain quartzite, the largest attaining a maximum width of 5 feet. The ore ranges from dull red hematite to specularite, and when picked free of quartzite appears to carry 50 per cent, or better, of iron. The walls of the veins are sharply defined.

The Armstrong-Henry property in section 31, Meredith township, and section 36, Macdonald township, is apparently of the same general character. Hard and soft hematite occurs in small quantities in Lorrain quartzite.

Still smaller veins of specular hematite occur in lot 6, concession 3, Aberdeen township, section 3, Laird township, and at other points. Probably others will eventually be found along the margin of the Palæozoic sediments, but the nature of these deposits somewhat precludes a likelihood of finding any large bodies of ore.

SILICA

The uppermost 1,000 feet or so of the Lorrain quartzite is an exceptionally clean quartzite, sufficiently pure to be used as acid fluxing material in nickel-copper smelting at Sudbury and even for the manufacture of ferro-silicon. It is probably also sufficiently indurated to serve for making silica-brick, especially in the eastern part of the North Shore district, where it is most closely folded and affected by contact-metamorphic agencies. Microscopic study of thin sections and chemical analysis of samples from this 1,000-foot part of the formation indicate that a considerable part of it contains between 95 and 99 per cent of silica.

The distribution of the Lorrain quartzite in the western part of the district is shown in part by the Bruce Mines map-sheet. In the eastern part of the district the Lorrain formation extends in a closely-folded belt 3 miles wide along the coast of lake Huron from the mouth of Spanish river eastward as far as Goschen township, constituting Lacloche moun-

tains. In a general way the purer upper part of the formation may be said to coincide with the crest of the range. Lorrain quartzite also forms Badgeley peninsula and the other slender finger-shaped projections along the coast of lake Huron west of Killarney. Almost all of it is conveniently situated with respect to lake Huron, and the Algoma Eastern railway crosses it. Quartzite is now quarried on Badgeley peninsula and shipped by boat to Welland, Ontario, for the manufacture of ferro-silicon by Electro-Metals, Limited. Ship-load lots are said to contain about 98 per cent silica. Brief descriptions and excellent photographs of the quarry are shown in the Annual Reports of the Bureau of Mines, Ontario, for 1914 and 1915, by Professor Coleman and Mr. Knight. An extensive area along the Algoma Eastern railway near mile 64 is said to have been acquired by the International Nickel Company at Sudbury to furnish a future supply of quartzite for smelting purposes. At the present time this company obtains its supply from a great mass of Mississagi quartzite embedded in the granite near Quartz station on the Canadian Northern railway.

FELDSPAR

A pegmatite dyke containing large quantities of fairly well segregated potash feldspar is reported in the Canadian Mining Journal[1] by Mr. A. G. Morrison, former superintendent of the Massey copper mine. According to Mr. Morrison this dyke extends for 1,400 feet in a northeasterly direction across parts of lot 4, concession 4, and lots 3 and 4, concession 5, Shakespeare township. It varies in width from 25 feet to several times that amount. Orthoclase and microcline are the principal constituents of some parts, but in other parts these minerals give place almost entirely to quartz. The lumber road from Webbwood up Spanish river passes within a quarter mile of the dyke.

The dyke is reported to occur near the contact of granite with green schist, and is presumably derived from the same magma as the granite. According to observations made by the writer in the course of a brief examination of the formations along Spanish river, this granite is intrusive in Huronian (Bruce series) sediments and is, therefore, more probably Killarnean than Laurentian in age.

BUILDING-STONE

An attempt was made to quarry the Bruce limestone, near Garden River, for marble. According to Mr. Knight[2] "some work was done on a bed of light grey marble, and at one time a spur line was built from the Canadian Pacific railway to the quarry, which is distant about a mile from the railway; the track, however, has since been removed."

This formation outcrops at various other places in the Bruce Mines and Panache map-areas, as shown on the accompanying maps (Nos. 1969, 1970, 1971); but the interbanding of siliceous material with the limestone militates against its employment as an ornamental stone.

[1] "A New Feldspar Discovery"; Can. Min. Jour., 1916, p. 481.
[2] Ann. Rept. Ont. Bureau of Mines, vol. XXIV, pt. I, 1915, p. 241.

The conglomeratic middle part of the Lorrain quartzite in Bruce Mines area furnishes an ornamental stone of unusual qualities. This conglomerate phase in other parts of the North Shore district is an uninteresting rock of light grey or pink colour, consisting of white and grey quartz pebbles in a quartzite matrix; but towards Sault Ste. Marie pebbles of dark grey and bright red quartz (jasper) become more abundant. A huge boulder of this jasper conglomerate can be seen in one of the streets of Bruce Mines village. The formation was found in place in section 12, Lefroy township, section 28, Rose township, lots 3 and 4, concession IV, Plummer township, and southeast of Rock lake. The rock is very hard, but polished specimens have a variegated and exceptionally brilliant appearance.

The Killarney granites deserve consideration as building and ornamental stones, not only for their own qualities as such but also because of their convenience to shipping points on lake Huron. The granite at Killarney and on Eagle island is a salmon-coloured rock lightly speckled with black mica. It ranges from gneissic to quite massive and from an even granitic texture to a coarse porphyritic one with salmon-pink feldspar crystals three-fourths of an inch across. The Cutler granite forming the peninsula west of Cutler is a light grey rock more plentifully speckled with black mica. It is finer-grained, as a whole, than the Killarney type and less jointed.

The Keweenawan quartz diabase at Bruce Mines and at Humbug point on St. Joseph island is quarried and crushed for use in concrete construction and for building macadamized roads. The crushed rock from Bruce Mines has been shipped as far east as Cleveland for the latter purpose and was used extensively in building the new United States ship-canal at Sault Ste. Marie. Tests applied to the Bruce Mines diabase indicate a specific gravity of 2·95 to 3·01; absorption of water, 0·10 to 0·25; toughness, 18 to 20; hardness, 18·7-19·1; French coefficient of wear, 20; and good cementing qualities.

The crushing plant at Bruce Mines (Plate XVII) was built by the Martin International Trap Rock Company, Bruce Mines, in 1913, and 1914. It was operated by this company in 1914 until August, then lay idle until May, 1916, when operations were resumed under the trusteeship of W. S. Edwards, Sault Ste. Marie, Michigan. As operated in 1914 the rock was quarried by drilling with churn-drills, blasting down and loading the broken rock with a steam shovel into tipple-cars, which were hauled about a quarter mile by a steam locomotive to the crusher. This rock was fed to a 5-foot by 7-foot jaw crusher, the product passed through a gyratory crusher and rolls, screened to 6 sizes in trommels and jig screens and then stock-piled, the transmission from one operation to another being effected with belt conveyers. For loading on lake boats concrete tunnels were stoped under each stock-pile, so that by opening a hopper the crushed rock fell upon a belt conveyer which elevated and carried it to the water's edge. The plant is capable of handling about 500 tons of rock an hour.

BRICK-CLAYS

The Pleistocene stratified clay that occurs up to 180 or 190 feet above lake Huron and as much as 20 miles back from the crest is in places of sufficiently good quality and conveniently located to serve for the manufacture of ordinary clay-brick and drain-tile. The clay is mostly finely laminated, grey or reddish, free from boulders, pebbles, or sand. Clay of this sort is widely distributed from Dean Lake westward to Bruce Mines and from Massey eastward to Espanola. Towards Espanola it becomes buried under an increasingly deep cover of sand, but good sections are exposed in the banks of Spanish river at Espanola. At this place the clay carries so much soluble magnesium salts that during the dry summer months an efflorescence of magnesium sulphate (Epsom salts) collects upon the face of the bank; but in the Bruce Mines district the wells and springs in the clay contain excellent water free of any appreciable quantity of these salts.

In order to test the value of the Pleistocene clay for brick or tile manufacture, two samples were taken from the farm of Mr. R. J. Heath just south of Rydal Bank in concession I, Plummer township. A small creek has cut banks 10 to 30 feet high at this place, affording a good section of the clay deposit. One sample, of reddish colour, was taken from the bank 8 feet above the water; another, of bluish colour, from the water's edge. The two samples were submitted to Mr. J. Keele, chief of the Ceramics Division, Mines Branch. Mr. Keele's report is given below.

"Laboratory No. 587. From upper part of stream bank. Reddish brown, laminated, non-calcareous clay, free from pebbles or coarse grit.

It is very plastic and rather sticky when wetted; its working qualities are good. It dries slowly after moulding, with a high shrinkage. It burns to a compact red body at cone 010 (1,742 degrees F.), becomes vitrified and shrunken at cone 03 (about 2,000 degrees F.), and fuses at cone 1 (2,100 degrees F.). Laboratory No. 587a. From lower part of stream bank. Grey clay with an occasional brown layer, non-calcareous and free from pebbles.

This sample contains a considerable amount of silt and consequently is not so plastic as the upper clay. It dries readily after moulding into shape, and the shrinkage on drying is much less than the upper clay. It burns to a light red, porous body at cone 010 and does not become dense and hard until burned as high as cone 03. It stands a little more heat than the upper clay before softening, but the colour at any temperature is not so good.

The following results were obtained in burning the samples at various temperatures:

Laboratory No.	Per cent total shrinkage			Per cent absorption		
	Cone 010	Cone 05	Cone 03	Cone 010	Cone 05	Cone 03
587	9	9	17	17	17	0
587A	4	4	11	15	14	7

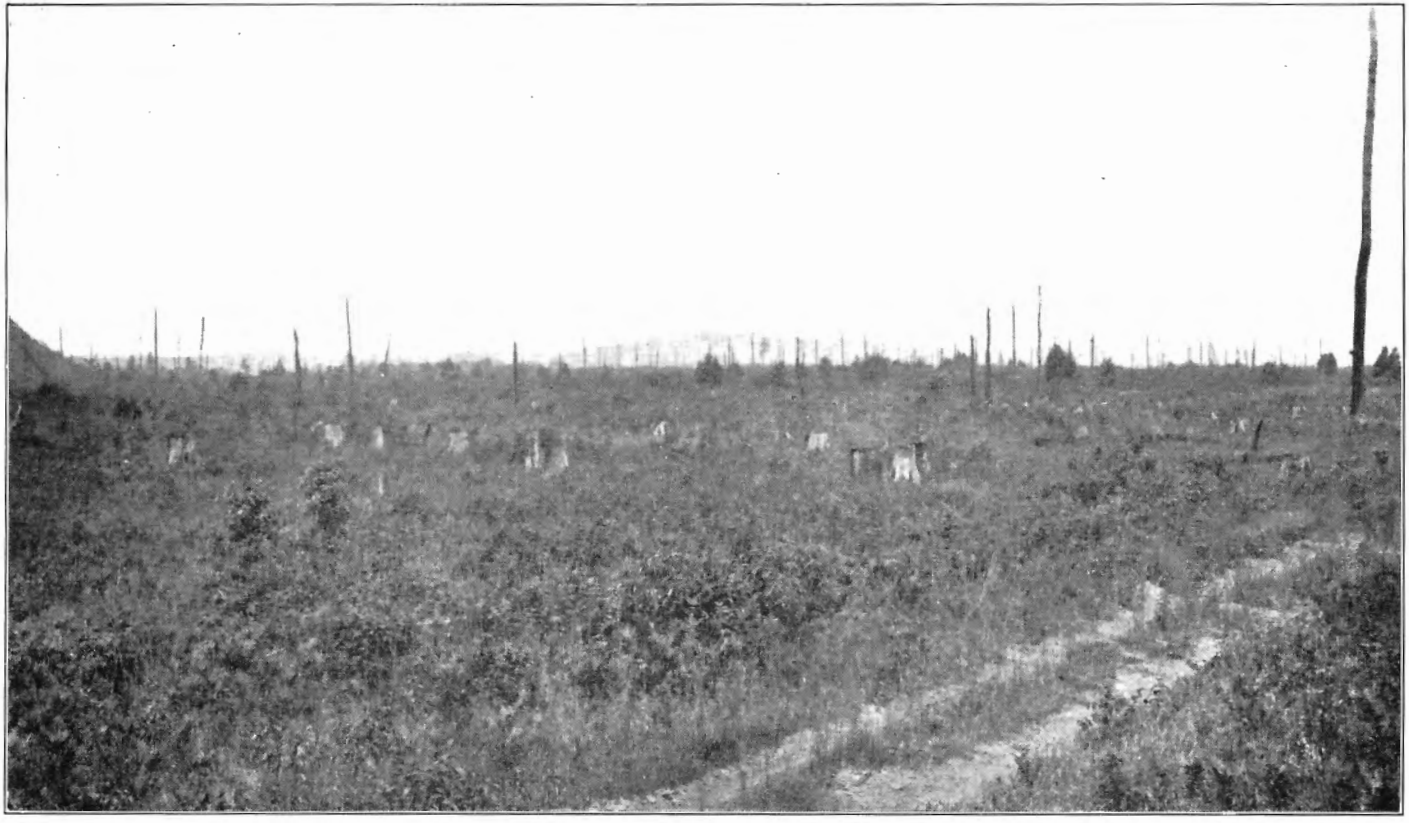
These clays are useful for the manufacture of common brick and field drain-tile. The upper clay when used alone is hard to dry and has too much shrinkage. It is also liable to check in the firing, which results in too many broken brick. The lower clay stands drying and firing well and has low shrinkages, but its working qualities, especially for the manufacture of tile, are not good.

A mixture of equal parts of the two clays will be found to give good results, as the defects of one are offset by the good qualities of the other.

If for any reason the lower clay can not be worked to advantage, either on account of drainage or other causes, then about 25 per cent of sand should be added to the upper clay in order to assist in the drying and reduce the shrinkage."

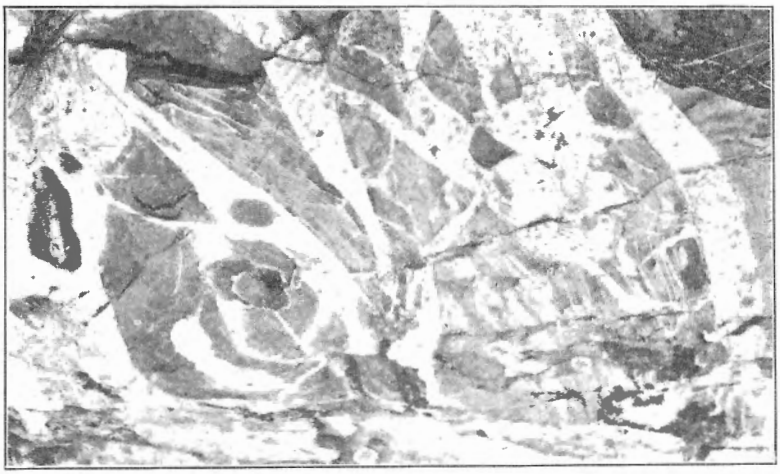
From what the writer has seen of the Pleistocene deposits along the north shore of lake Huron, clays equally suitable for brick or tile making can be obtained in many places between Echo Bay and Blind River, and between Massey and Espanola. Maple, birch, and other woods for fuel are abundant within easy reach of the clay areas and can be obtained for little more than the cost of cutting and hauling. The Canadian Pacific and the Lake Huron and Northern Ontario railways furnish convenient means of transportation.

7400—11

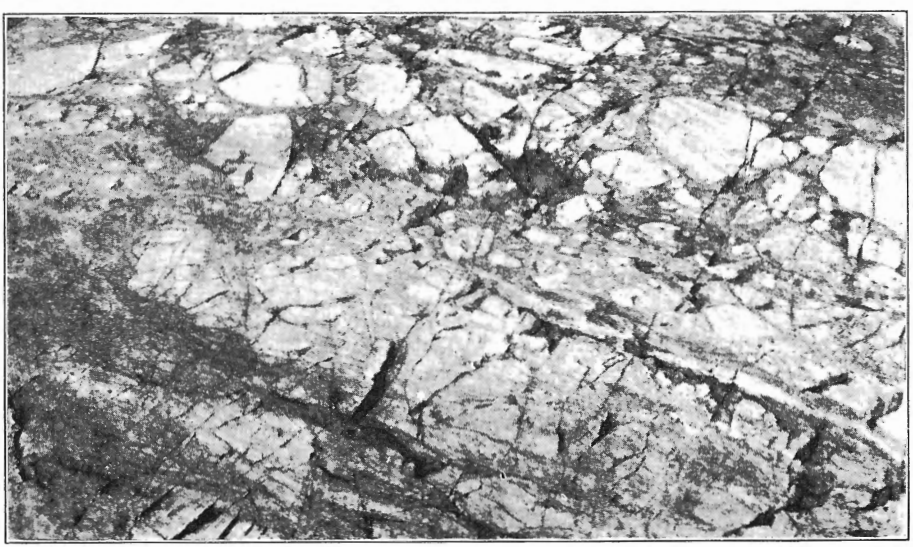


Deforested sand-plain, Bridgland township, north of Thessalon. A second growth of white pine will apparently not succeed the original splendid forest without cultivation. (Page 12.)

PLATE III



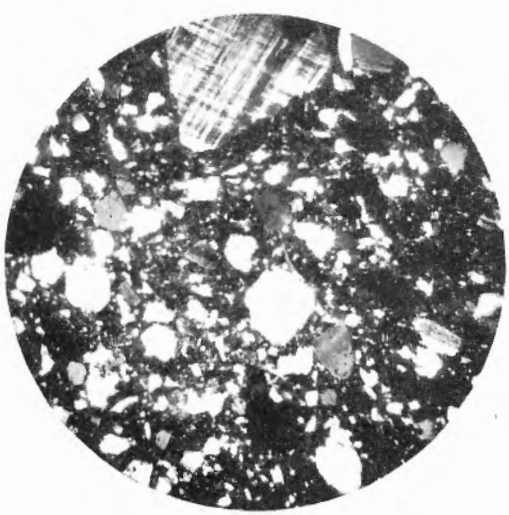
A. Irruptive contact of pre-Huronian granite gneiss (light) with older schist-complex (dark), on coast of lake Huron, 3 miles east of Thessalon. Scale $\frac{1}{10}$. (Pages 17, 19, 28, 31.)



B. Gradational contact between conglomeratic base of Mississagi quartzite and pre-Huronian granite gneiss on island J.D. 178, lake Huron, 3 miles east of Thessalon. Scale $\frac{1}{17}$. (Pages 28, 31.)

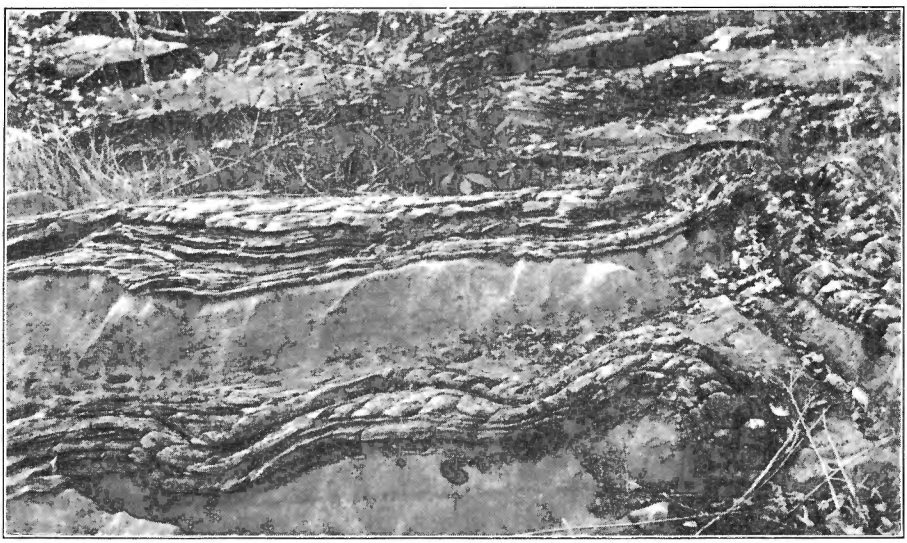
PLATE IV

A. Bruce conglomerate, coast of lake Huron, 1 mile west of Blind River. Scale $\frac{1}{5}$. (Page 45.)

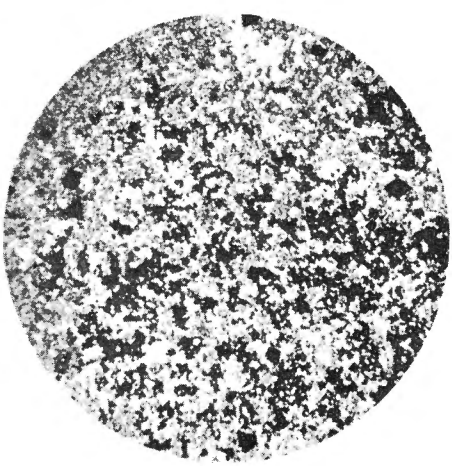


B. Photomicrograph of matrix of typical Bruce conglomerate. Crossed nicols. Compare with Plate XI A. Magnified 15 diameters. (Page 46.)

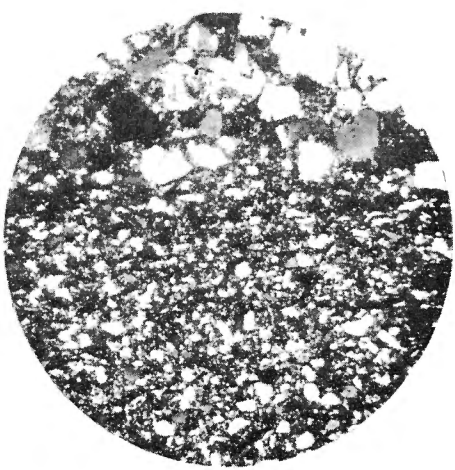
74009—11½



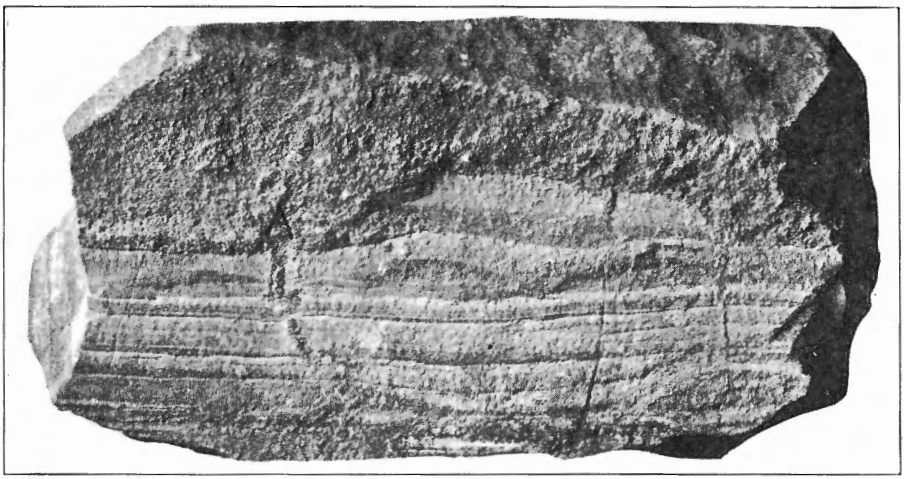
A. Bruce limestone, coast of lake Huron, just west of Bruce Mines, showing characteristic corrugation of weathered surfaces produced by the calcareous beds weathering faster than the alternating silty beds. Scale ⅓. (Page 49.)



B. Photomicrograph of iron ore-bearing calcareous silt from base of Bruce limestone. Ordinary light; magnified 21 diameters. The iron ore (magnetite) appears black against a lighter background of silicates and carbonate. (Page 50.)



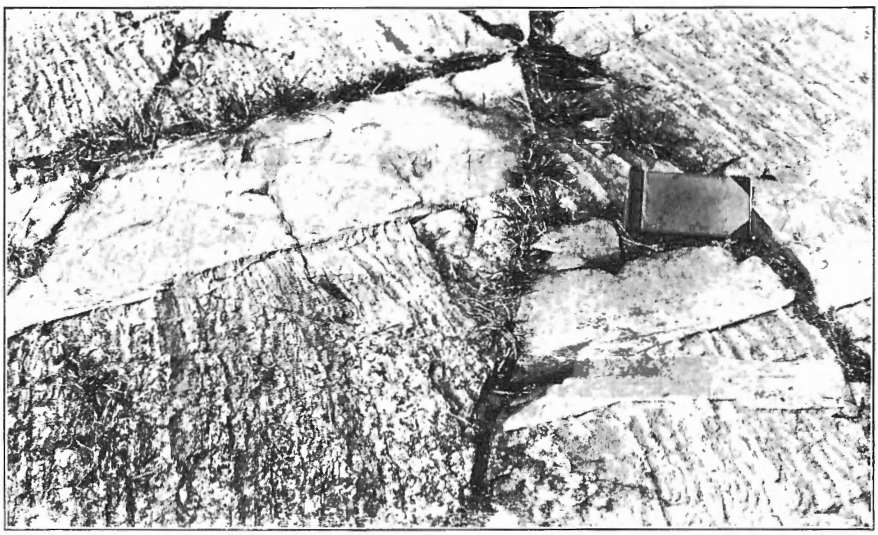
C. Photomicrograph of coarser siliceous phase of Bruce limestone showing alternation from a coarse sandy layer to a finer, silty one and also showing the very angular shapes of the quartz and feldspar particles. Magnified 22 diameters. (Page 49.)



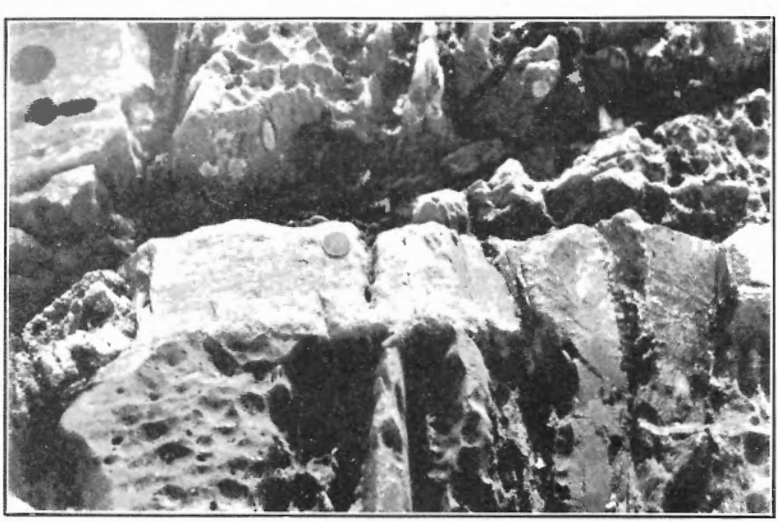
A. Detail of weathered surface of Espanola formation showing small mud-cracks (A) and other evidences of shallow water deposition. Natural scale. (Pages 51, 52, 62.)

B. Characteristic breccia in Espanola formation. The nature of the stratification is shown by some of the breccia fragments. Scale $\frac{1}{14}$. (Pages 51, 52.)

PLATE VII

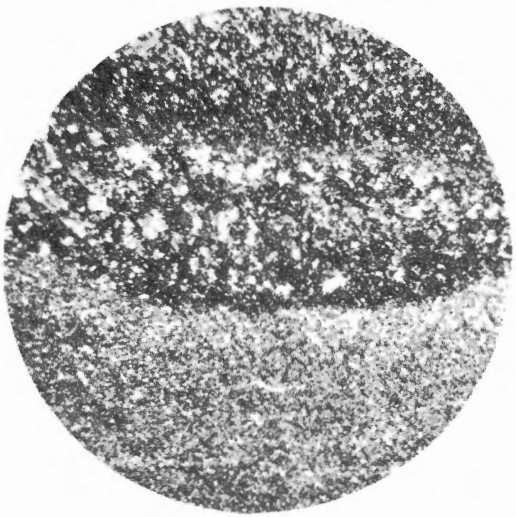


A. Quartzite "dyke" intersecting Espanola formation, near east end of Griffin lake, Panache map-area. The dyke is offset by a small fault. Showing the thin bedding and harshly corrugated weathered surface of the Espanola formation. Scale $\frac{1}{12}$. (Pages 51-53.)

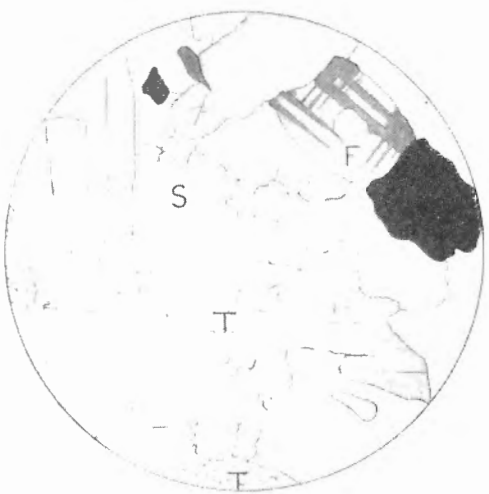


B. Quartzite "dykes" intersecting Espanola formation on islet in lake Huron, 1 mile south of Fort Lacloche. A peculiar pitted or honeycomb weathering common in the limestone is imperfectly exemplified. Scale $\frac{1}{8}$. (Pages 51-53, 91.)

PLATE VIII

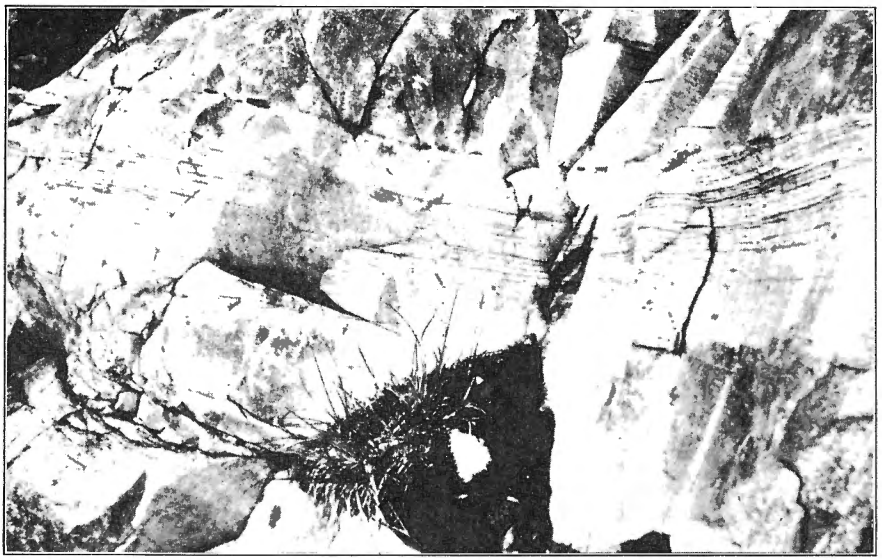


A. Photomicrograph of the unmetamorphosed calcareous silt of the Espanola formation. Although not magnified highly enough to indicate the mineralogical composition, the stratified and clastic nature of the rock is recognizable. Magnified 18 diameters. (Page 91.)

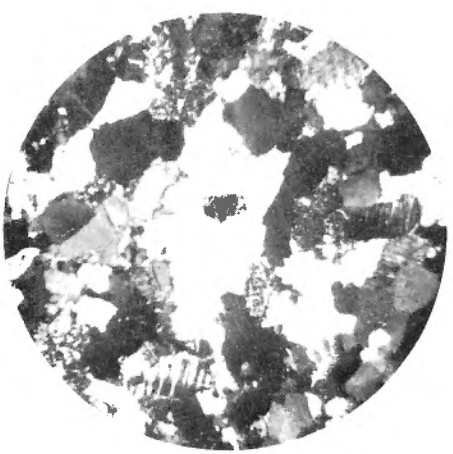


B. Camera-lucida drawing of calcareous silt from Espanola formation which has been converted into hornfels by contact action of the intrusive Killarney granite. Magnified 65 diameters. S = scapolite. M = mica. F = feldspar. T = tremolite. and the black area is pyrite. (Page 91.)

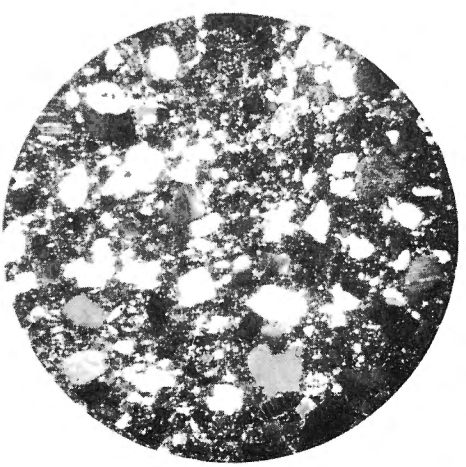
PLATE IX



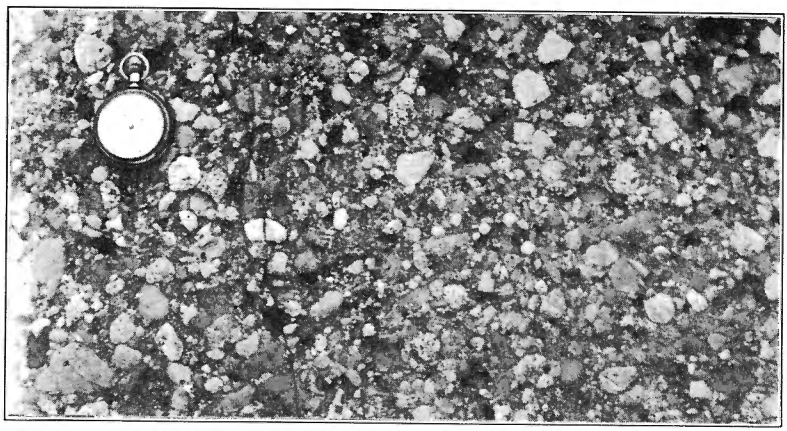
A. Serpent quartzite from south of Espanola, showing characteristic thin lamellation. Scale $\frac{1}{15}$. (Page 56.)



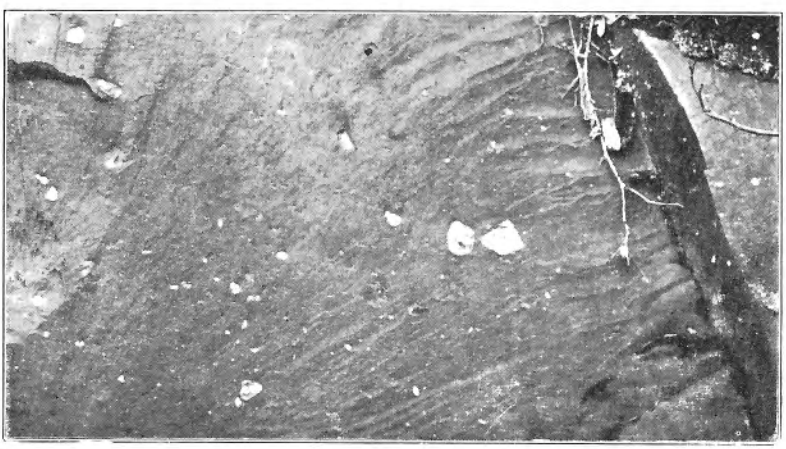
B. Photomicrograph of typical Serpent quartzite. Note the abundance of fresh feldspar grains. Magnified 18 diameters. (Page 56.)



C. Photomicrograph of impure conglomeratic quartzite from one of the quartzite dykes (See Plate VII A) which intersect the Bruce series. Crossed nicols. Compare with Plates XI A and IX. B. Magnified 15 diameters. (Page 53.)

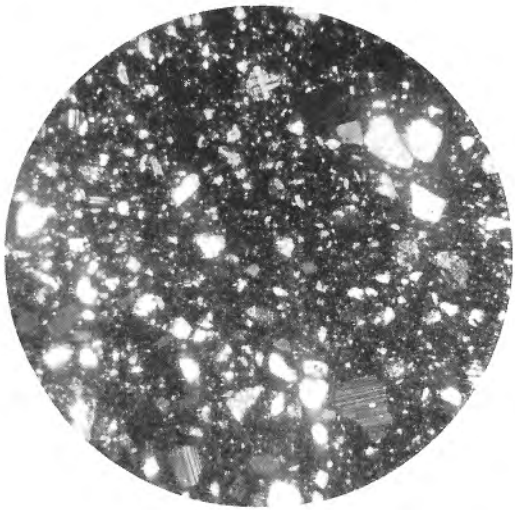


Types of conglomerate in Gowganda formation.
A. Pebbly variety from base of formation, Bear lake, Panache map-area. Scale $\frac{1}{5}$. (Page 65.)



B. Bouldery greywacke variety, near Bruce station, Bruce Mines map-area. Scale $\frac{1}{10}$. (Page 65.)

C. Laminated greywacke variety, south shore of Cataract lake, Cobden township, Blind River area. Scale $\frac{1}{5}$. (Pages 66, 67.)

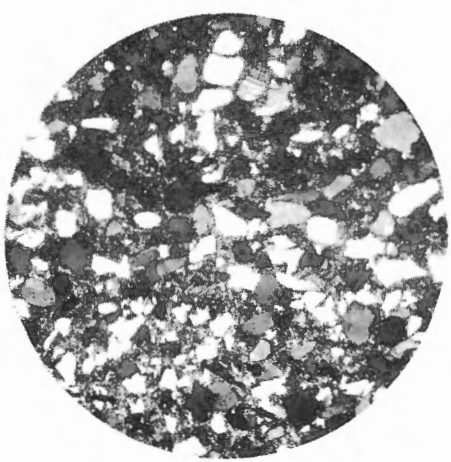


A. Photomicrograph of matrix of typical boulder conglomerate from Gowganda formation. Compare with Plate IV B. Magnified 30 diameters. Crossed nicols. (Page 65.)

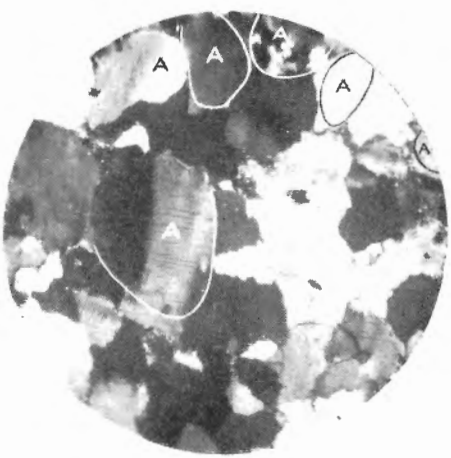
B. Photomicrograph of laminated greywacke conglomerate showing cross-section of two complete laminæ and a pebble of quartzite belonging to the upper lamina. The gradation upward in each laminæ from coarse to fine materials furnishes a means of distinguishing top from bottom. (Page 66.)

PLATE XII

A. Conglomeratic phase of Lorrain quartzite, (red jasper conglomerate) just north of Little rapids, Bruce Mines area. Scale $\frac{1}{10}$. (Page 68.)

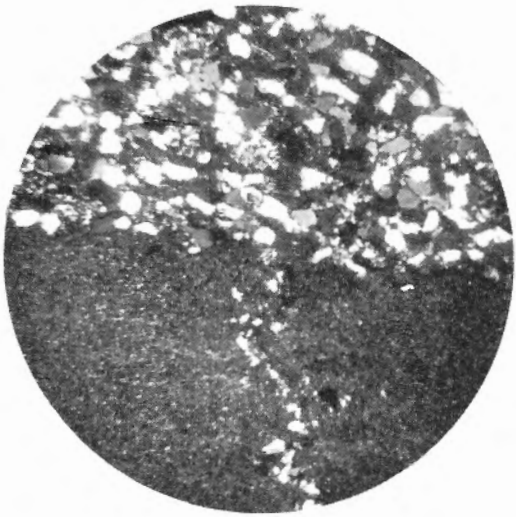


B. Photomicrograph of impure red quartzite from near base of Lorrain formation, Rock lake, Bruce Mines area. Magnified 27 diameters. (Page 68.)

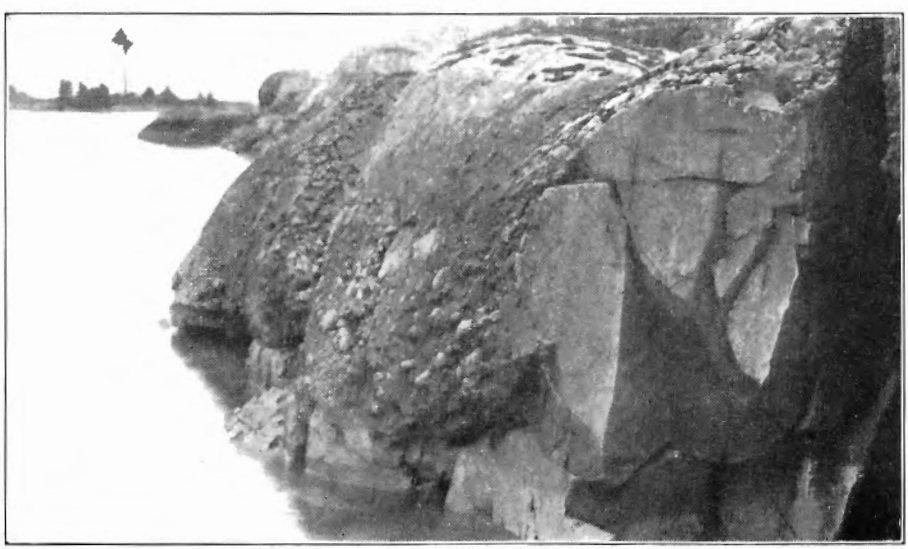


C. Photomicrograph of pure white quartzite from upper part of Lorrain formation. The dusty outlines of some of the original well-rounded sand grains (A), being too faint to be photographed through crossed nicols, have been drawn in by hand. Magnified 21 diameters. (Page 68.)

PLATE XIII

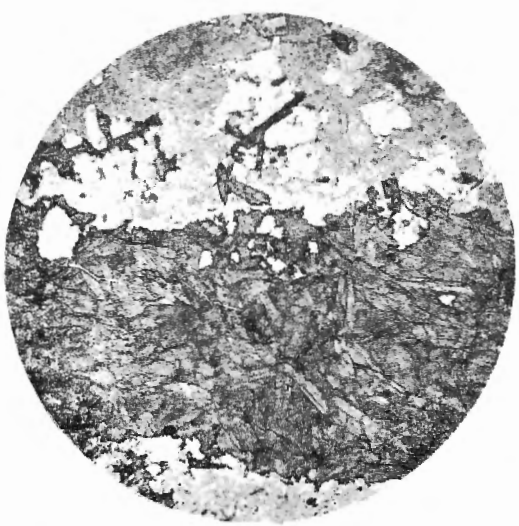


A. Photomicrograph of banded cherty quartzite, from Cobalt series, cut normal to bedding. The photograph shows the upper very fine-grained silty part of one bed overlain by the coarser, sandy, basal part of the next bed above. A fine crack in the lower bed is filled with material from the upper bed. Magnified 20 diameters. (Page 70.)

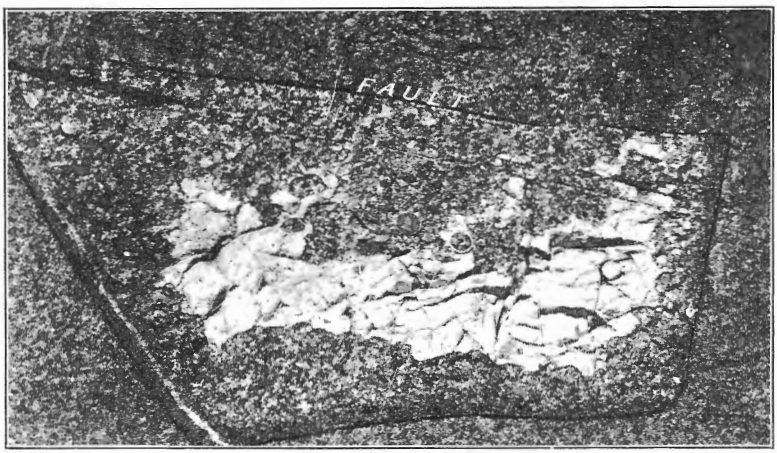


B. Contact of Gowganda conglomerate (A) with Serpent quartzite (B), coast of lake Huron near southwest corner of Plummer Additional, Bruce Mines map-area. (Page 71.)

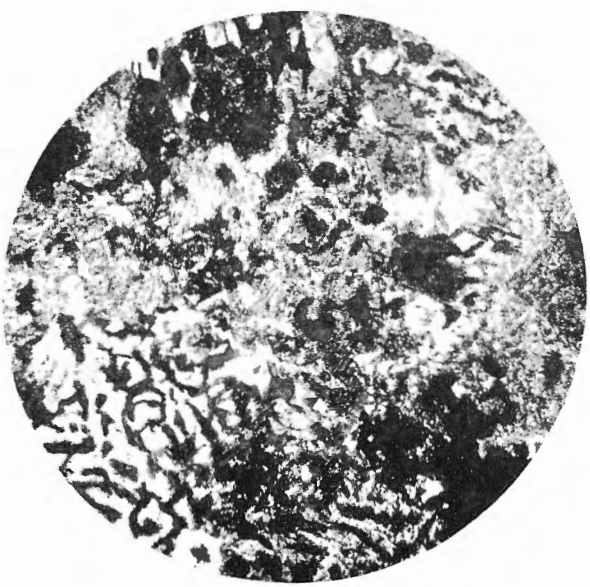
A. Photomicrograph of ordinary quartz diabase from a sill. Magnified 30 diameters. L = labradorite, Au = augite, Mg = micrographic intergrowth of quartz and andesine. (Page 79.)



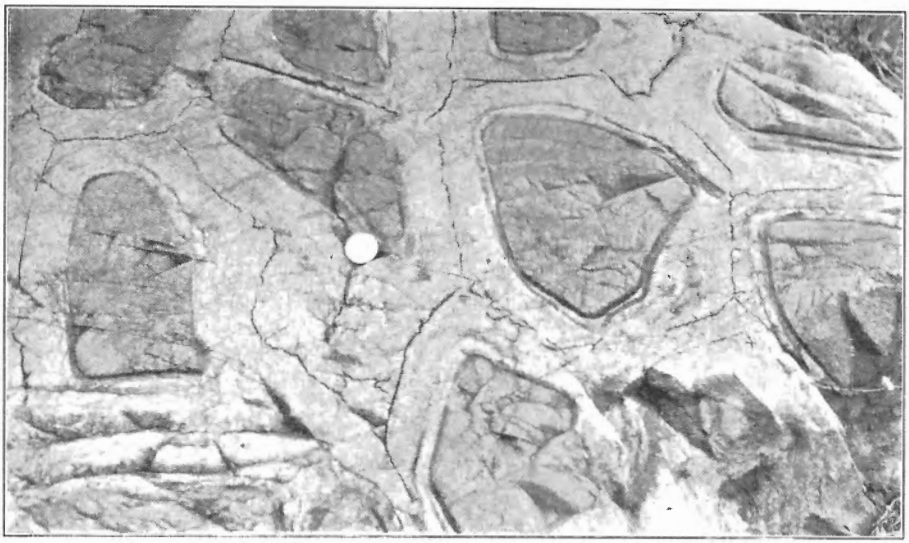
B. Photomicrograph of aplitic differentiate from quartz diabase (light) intersected by a hornblende vein (dark) representing a still later derivative from the diabase magma. Magnified 14 diameters. (Page 79.)



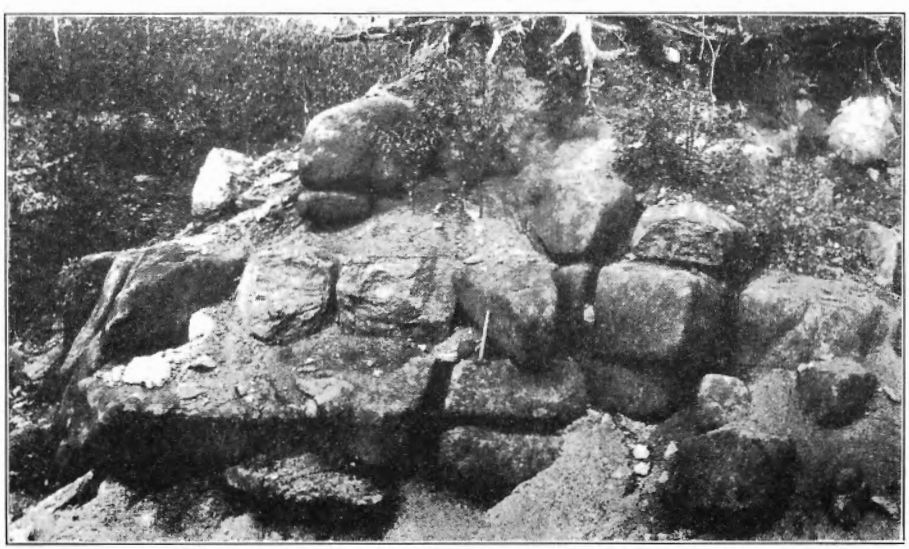
A. Fragment of quartzite enclosed in, and partly assimilated by, diabase, Blind River, Ontario. Scale $\frac{1}{5}$. The unassimilated vestige of quartzite and the product of interaction between quartzite and diabase lie within the inked line. The interaction product is bordered next the normal diabase by a dark hornblende-rich rim, perceptible in the photograph. (Page 80.)



B. Photomicrograph of the interaction product. An irregular intergrowth is its textural characteristic. Magnified 15 diameters. (Page 81.)

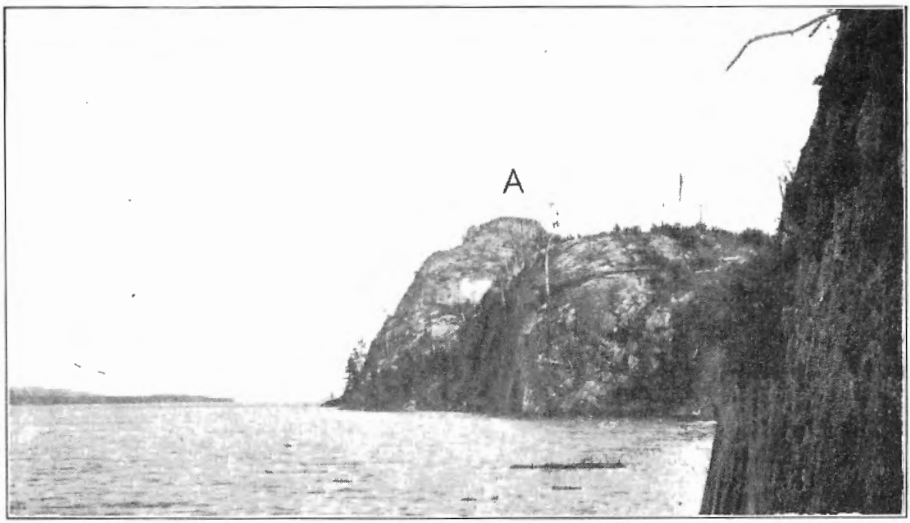


A. Weathered surface of olivine diabase dyke at Magpie mine, Michipicoten district, showing rims of weathered material (light) enclosing less weathered cores (dark). The black fracture lines visible in the middle of some of the weathered zones are basaltic joint-planes, from which weathering apparently proceeded laterally. A narrower rim which appears to represent a first stage in the weathering may be seen around the residual cores. (Cf. Plate XVI B.) Scale $\frac{1}{6}$. (Page 84.)

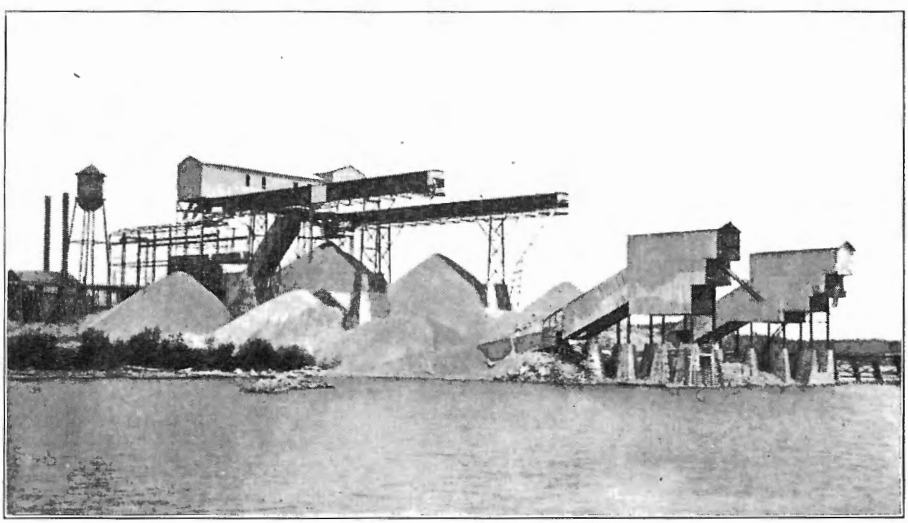


B. An olivine diabase dyke on the Algoma Eastern railway just north of Espanola Mills, showing characteristic weathering. (Pages 83, 94.)

PLATE XVII



A. View eastward along Lauzon lake, Blind River area, showing a vertical dyke (A), of quartz diabase, which stands higher than the adjacent Mississagi quartzite, apparently as a result of pre-Glacial erosion. (Page 94.)



B. Plant of Martin International Trap Rock Company, Bruce Mines, in process of construction, June 1914. (Page 135.)

INDEX

PAGE

Aberdeen formation.....58, 59
See also Rock l.
Serpent formation
Aberdeen tp.
Copper..... 126
Hematite.....132, 133
Photo of parts of.....Frontis.
Pleistocene deposit..... 10
Rocks..... 32
Bruce series, erosion interval.....58, 62
Abitibi l., auriferous quartz..... 119
Acknowledgments..... 5
Ajibik quartzite..... 113
Algoma, rocks..... 26
Analysis
Conglomerate (matrix)..... 66
Greenstone..... 75
Iron formation..... 50
Limestone..... 50
Quartzite..... 68
Andrew, J. B..... 130
Aplite dykes..... 79
Archæan protaxis. *See* Precambrian shield
Armstrong-Henry iron claim..... 133
Aubrey fall, waterpower..... 12
Austin copper m.....127, 128

Badgeley is. and pen., rocks....93, 107, 108
Baker, M. B.....120, 121
Baldwin tp., copper..... 130
Banded cherty quartzite
Correlation..... 109
Microphoto..... 150
Thickness, description.....63, 69–71
Barlow, A. E..... 5
Bass l., rocks.....41, 59
Batholiths. *See* Cutler batholith
Granite gneiss
Killarney batholith
Bear l., Panache Lake area
Conglomerate, photo..... 147
quartzite..... 72
Bell, Robt..... 5, 9
Benoit, Arthur..... 5
Bigsby, J. J..... 5
Bijiki schist..... 113
Bismuth.....124, 130
Black, John..... 117
Black River limestone. *See* Ordovician formation

PAGE

Blackwater l, Pleistocene deposits.. 97
Blind r.
See also White fall
Current..... 11
Gowganda formation.....63, 67
section..... 64
Map.....In pocket
Blind River
Bruce conglomerate near, photo. 141
Delta plain near..... 95
Rocks
conglomerate, photo..... 141
diabase, notes, photo, and microphoto.....80, 81, 152
quartzite..... 47
Blind River fault..... 105
Boggs, O. D..... 5
Bolton, L. L..... 132
Booth farm..... 11
Boulder conglomerate, microphoto.. 148
Brecciation
Espanola formation, notes and photo.....52, 143
Brick-clays.....136, 137
Bridgland tp.
Sand-plain..... 13
photo..... 139
Brigstocke, R. W..... 120
Bruce conglomerate
Correlation and thickness.....30, 109
Description and age relation.... 45–47
Marble in..... 116
Photo and microphoto..... 141
Bruce copper m.
Depths, diabase..... 77
Description and geology.....125, 126
Limestone in, character..... 81
Bruce limestone
See also Espanola formation
For building..... 134
Iron ore in.....116, 131
Name, description, and anal.... 47–51
Photo and microphotos..... 142
Thickness and correlation.....30, 109
Bruce series
Correlation.....109–114
Distribution, description, and age relation..... 29–62
Relation to Cobalt series..... 71–73
Subdivisions..... 17
Bruce station, greywacke near, photo..... 147
Vertical section near Killarney.. 100

PAGE

Bruce Mines
- Building-stone....134, 135
- Diabase quarry.... 135
- Map....In pocket
- Rocks.... 41
  - limestone, photo and microphotos.... 142
  - quartzite.... 47

Burden copper claim....128, 129
Burling, L. D.... 10
Burnt l., rocks.... 72

Canadian shield. *See* Precambrian shield
Canadian Exploration Co.... 120
Caribou l., conglomerate....59, 60
Carlyle tp.... 9
Cataract l., greywacke, photo.... 147
Centre is., rocks.... 93
Chalcopyrite. *See* Copper
Channing, W. F.... 5
Charley l., rocks.... 36
Cherty quartzite. *See* Banded cherty quartzite
Chesley tp., rocks.... 32–36
Chiblow l., rocks....67, 72
Chisholm, W. F.... 5
Clays, brick....136, 137
Clear l., copper prospecting.... 128
Cobalt. *See* Silver-cobalt
Cobalt, Ont., cobalt series.... 111
Cobalt bloom.... 130
Cobalt series.... 63–74
- Correlation....109–114
- Economic products.... 116
- Photo.... 150
- Subdivisions.... 17
- Vertical section.... 100

Cobalt silver area, rocks....74, 77–79
Cobaltite.... 130
Cobden tp., rocks.... 63
See also Cataract l.
Cockfield, W. E.... 5, 28
Coleman, A. P.... 5, 27
Connor, M. F.... 68
Copper....125–131
Copper Cliff arkose, thickness.... 22
Copper Queen copper m.... 128
Copper Range Co.... 127
Correlation....109–114
Crystal gold m., Wanapitei l.....117, 118
Cutler
- Building-stone.... 135
- Rocks....24, 25, 76, 77
  - granite.... 85–89
  - mica-gneiss.... 90

Cutler batholith.... 87

Day tp., copper.... 128
Dean l., rocks....63, 105

PAGE

Dean Lake
- Pleistocene deposit.... 11
- Sediments, pre-Huronian.... 26

DeGeer, G.... 61
Demorest tp., limestone.... 67
Depot l., rocks.... 20
Diabase. *See* Olivine diabase
Diastrophism, late Precambrian....99–107
Diorite, Long l., notes.... 82
Drainage.... 11
Dresser, J. A.... 122
Dykes, quartzite, notes and photos..53, 54

Eagle is., granite....85, 135
Earthquake fissures.... 54
Echo l.
- Copper near....127, 128
- Filling with sand and clay.... 95
- Rocks.... 32
  - folded.... 104
  - limestone, anal.... 50
  - quartzite....46, 47

Echo r.
- Pleistocene deposits; current.... 11

Economic geology....115–137
Edwards, W. S.... 135
Elliot l., rocks....42, 44
Emmons, R. C.....4, 5, 32, 59
Epsom salts.... 136
Erosion intervals, Bruce series..... 58–60
Erythrite.... 130
Eskola, Dr. Pentti..4, 5, 26, 27, 53, 79
Espanola, Ont.
- Altitude.... 11
- Brick-clay.... 136
- Rocks....23, 40, 41, 51

Espanola fall.... 23
Espanola formation
- Analyses.... 92
- Illustrations....143–145
- Subdivisions.... 17

Espanola greywacke
- Name; description.... 51–55
- Thickness; correlation....30, 109

Espanola limestone
- Analyses.... 50
- Correlation and thickness.....30, 109
- Description and name.... 55

Esten tp., rocks.... 20

Farming.... 13
Faults and folds....104–107
Feldspar.... 134
Field methods.... 4
Fine bay. *See* Narrow bay
Forests, depletion of....12, 13
Formational table.... 17
Fort Lacloche, quartz dykes, near, photo.... 144
Foster tp., sand-plain.... 13
Fox is., rocks....87, 90

PAGE

Frazer bay, iron ore near..... 132
Fruit..... 13

Galbraith tp.
Copper..... 125
Erosion interval..... 62
Gold. *See* Havilah gold m.
Pleistocene deposits..... 10
Garden r., character..... 11
Garden River, Ont.
Building-stone near..... 134
Rocks..... 36
Bruce series..... 33
limestone, anal..... 50
Garden River Indian reserve, rocks.. 71
Geology, economic.....115–137
structural.....98–108
George l., Pleistocene deposit..... 11
Glaciation. *See* Pleistocene
Gold.....116–124
Goodrich quartzite..... 113
Gordon l., hematite..... 133
Goschen tp., rocks.....86, 104
Gould tp., copper..... 127
Gowganda conglomerate
Contact with Serpent quartzite, photo..... 150
Gowganda dist.
Aplite dykes..... 79
Cobalt series..... 110
Diabase sills and dykes.....77, 78
Gowganda formation
See also Cobalt series
Composition and thickness..... 111
Correlation..... 109
Descriptions and sections..... 63–67
Ornamental stone in..... 116
Photos and microphotos.....147, 148
Grand Portage copper m..... 127
Granite gneiss
See also pre-Huronian
Contact with schist-complex, photo..... 140
Distribution, map showing.... 18
Pre-Huronian, description and age relations..... 27–29
Vertical section near Killarney. 100
Grant copper claim..... 130
Graton, L. C..... 6
Greywacke. *See* Espanola formation
Greywacke conglomerate, micro-photo..... 148
Griffin l., rocks, anal., and photo...92, 144

Haughton tp., sand-plain 13
Havilah gold m.....116–118
Heath, H. J.....5, 136
Hematite. *See* Iron ore
Hermina copper m..... 129
Howry ck.
Gold prospects.....122–124

PAGE

Howry ck. (contd.)
Pleistocene deposits.....11, 96
Rocks north of..... 79
Hudson copper claim..... 117
Hudson Copper Co..... 125
Huronian
Marquette dist., correlation.... 113
Subdivisions (which see)..... 17
Vertical sections near Killarney. 100
Humbug pt., quartz diabase..... 135
Hyman tp., fault..... 106

Index map..... 3
Industries.....12, 13
Ingall, E. D..... 5, 6
International Nickel Co..... 134
Iron formation.....20, 50
Iron ore.....131–133
Irving, R. D..... 6
Island l., rocks.....20, 38

Jasper conglomerate
Bruce Mines..... 135
Photo..... 149
John is., L. Huron..... 89
Johnson tp., hematite.....132, 133

Keele, J..... 136
Kehoe tp., rocks.....32, 33, 37, 38, 71
Kemp, A. L..... 122
Kerr silver claim..... 124
Keweenawan formation
See also Thessalon greenstone
Gold and silver in.....116–124
Subdivisions and correlation...17, 109
Vertical section near Killarney.. 100
Killarney
Granite for building..... 135
See also Killarney granite
Palæozoic formations near..... 93
Quartzite near..... 107
Vertical section near..... 100
Killarney batholith.....86, 87
Killarney bay, rocks.....90, 91
Killarney granite
Distribution and discussion on.. 85–93
Economic product..... 116
Kindle, E. M..... 10
Kirkwood tp., Pleistocene deposit...11, 13
Knight, C. W...6, 49, 63, 75, 125, 134
Kona dolomite..... 113

Lacloche mts., notes, rocks.....9, 69, 101
Laird tp.
Hematite..... 133
Rocks..... 93
Lake Huron, altitude..... 8
Lake Huron and Northern Ontario railway..... 126
Lake Superior
Correlation of rocks with those on N. shore of L. Huron..112–114

74009—12½

PAGE

Lauzon l.
Faults..... 105
Glaciation.....94, 153
Photo..... 154
Rocks.....25, 38, 43, 57, 72, 106
Lava. *See* Schist-complex
Lawson, A. C..... 6
Lefroy tp.
Beach..... 97
Fault..... 105
Pleistocene deposits..... 11
Rocks..... 41
Leith, C. K..... 7
Leverin, H. A..... 50
Lindeman, E..... 132
Little rapids, Lorrain quartzite, photo..... 149
Locke, John..... 6
Logan, W. E.....6, 29, 109
Long tp., rocks.....38, 39
See also Lauzon l.
Long Lake gold m.
Description and geology.....120–122
Rocks.....82, 84, 90
Lorrain quartzite
See also Cobalt series
Silica for flux
Correlation..... 109
Description..... 67–69
Iron ore in..... 132
Lacloche mts., thickness..... 9
Photo and microphotos..... 149
Lower slate conglomerate. *See* Bruce conglomerate
Lowville formation. *See* Ordovician formations
Lumbering.....12, 13

McArthur, Peter..... 117
McCabe l..... 39
McCarthy l..... 20
Macdonald tp., iron ore..... 133
McFerson, rocks.....74–77, 89
McGregor bay, rocks.....91, 101
McKim greywacke, thickness..... 22
McLeod, Angus..... 5
McLeod l., rocks..45, 47, 54, 57, 71, 72
McMahon tp.
Cobalt bloom..... 130
Copper..... 128
Rocks.....32, 33, 36
Magnesium sulphate..... 136
Magpie iron m..... 83
Mann silver m.....119, 120
Maps, geological
Blind r.....In pocket
Bruce Mines.....In pocket
Panache l.....In pocket
Showing Killarnean diastrophism..... 102
Sketch..... 18

PAGE

Map, index..... 3
Marble. *See* Building-stone
Marquette, Mich., rocks..... 60
Marquette dist.
Correlation of rocks with those on N. shore of L. Huron..112–114
Marshall, J. R..... 5, 28
Martin International Trap Rock Co.....135, 154
Massey, Pleistocene deposits..... 11
Massey Station Mining Co..... 129
May l., fold..... 104
May tp., fault, and copper.....106, 130
Meredith tp., iron ore..... 133
Merritt tp., quartzite dykes..... 53
Mesnard quartzite..... 113
Metallogenetic epochs..... 116
Michigamme slate..... 113
Miller, W. G.....29, 63
Mines and mining.....115–137
Mississagi quartzite
See also Bruce series
Correlation and thickness.....30, 113
Description and discussion..... 30–45
Section, vertical..... 31
Silica from..... 116
Mississagi r.
See also Aubrey fall
Width; current..... 11
Moon l., rocks..... 44
Moor, William..... 116
Moosehorn copper claim..... 129
Morin tp., rocks..... 32–36
Morrison, A. G..... 134
Mount Aetna gold m..... 119
Mountains, lake of the.....43, 61, 72
Murray, Alexander.....3, 6, 29, 109
Murray fault.....30, 104, 105
Murray nickel m..... 94

Nairn tp., sand-plain..... 13
Narrow bay, rocks..... 90
Naughton.....40, 97
Negaunee iron formation..... 113

Olivine diabase dykes
Notes and photo.....82–84, 153
Ophir gold m. *See* Havilah gold m.
Ordovician formations
Subdivisions..... 17
Vertical section near Killarney.. 100
Otter tp.
Cobaltite and bismuth..... 130
Copper.....128, 129
Quartzite..... 32–35
Ottertail l.
Pleistocene deposit near..... 97
Quartzite, anal. and thickness..68, 70

Pakowkami lake, fault..... 105
Palæozoic formations..... 93–97

PAGE

Palæozoic plain..... 9, 10
Panache l.
Map.....In pocket
Rocks.....42–47, 51, 56, 111
Killarney granite.....86, 89
Limestone, anal..... 50
Partridge is., rocks.....93, 107
Patton l., rocks..... 33
Patton tp., rocks.....81, 82
Payton gold claim..... 118
Pearl ck..... 37
Pearl l.....35–37
Pegmatite dykes..... 79
Feldspar in..... 134
Picard l., rocks near.....20, 42
Pigeon pt., U.S..... 82
Pleistocene deposit..... 94–97
Pleistocene Lake beds.....10, 11
Plummer tp.
See also Ottertail l.
Contact with conglomerate, photo..... 150
Quartzite..... 71
Precambrian
Late, basic intrusives and extrusive..... 74–84
Precambrian shield..... 8, 9
Pre-Huronian
See Granite gneiss
Schist-complex
Sudbury series
Princes bay, iron ore near..... 132
Proctor tp., rocks..... 20
Pumpelly, Raphael..... 7, 29
Purpose of report..... 2

Quartz, Ont..... 134
Quartz diabase..... 151
Description and notes..... 77–82
Microphotos..... 151
Quartzite
See Bruce series
Cobalt series
Lorrain quartzite
Serpent quartzite
Quirke, T. T..... 4, 7
Quirke l.
Iron ore near..... 131
Rocks.....20, 38, 44
breccia.....52, 60
Gowganda formation.....64, 71
greywacke.....54, 59
limestone, anal..... 50
quartzite.....46, 47, 53–57

Ramsay l..... 40
Rising Sun copper m..... 128
Roads..... 13
Rock l., rocks..... 63–69
Microphoto..... 149
Rock Lake copper m..... 126

PAGE

Rose tp.
Copper..... 130
Diabase ridges.....81, 82, 94
Pleistocene deposits.....11, 13
Round is., granite..... 85
Rydal Bank.....97, 136

Sable River Copper Co..... 129
St. Joseph is., quartz diabase..... 135
St. Marys sandstone.....132, 133
Salter tp
Copper.....129, 130
Fault..... 106
Sayer, Thos..... 132
Schist-complex
Contact with granite gneiss, photo..... 140
Distribution, description, and age relations..... 17–21
Iron ore in.....116, 131
Vertical section near Killarney.. 100
Sediments, pre-Huronian
See also Sudbury series
Discussion..... 22–27
Distribution, map..... 18
Serpent, Ont., rocks..... 25
Serpent quartzite
See also Bruce series
Contact with Gowganda conglomerate, photo..... 150
Correlation..... 109
Description and relation to pre-Huronian..... 55–57
Microphoto..... 146
Thickness..... 30
Serpent r.
See also Quirke l.
Agricultural land in valley..... 13
Character..... 11
Pleistocene deposits.....11, 95, 96
Rocks.....20, 42
Shakespeare tp.
Fault..... 106
Feldspar..... 134
Shedden tp.
Fault..... 106
Rocks..... 44
Sheguiandah..... 107
Siamo slate..... 113
Silica for flux.....133, 134
Silver-cobalt.....124, 125
Smith l., rocks..... 24
Spanish r.
Brick-clay..... 136
Character; waterpower.....11, 12
Farming in valley..... 13
Rocks.....21, 39
faulted..... 106
Spanish station, rocks..... 24
Spanish River Indian reserve, rocks. 54
Spragge, rocks.....25, 89

PAGE

Stobie copper m., Johnson tp.....128, 133
Stratigraphy..... 3–97
Striker tp., rocks.....38, 41
Stuart l., rocks.....35, 37
Sudbury, rocks..... 39
Sudbury nickel area..... 21
Sudbury series
  Distribution, description, and age relation..... 22–27
Sugar l., copper..... 130

Table of formations..... 17
Taylor copper claim..... 128
Tendinenda l., rocks.....42, 83, 94
Tenmile l., rocks..... 39
Terraces.....95, 96
Thessalon
  See also Thessalon greenstone
  Basalt flow..... 17
  Conglomerate..... 43
  Mississagi quartzite..... 31
  Pleistocene deposits..... 11
Thessalon greenstone
  Description and anal..... 74–77
Thessalon r.
  Character; waterpower.....11, 12
  Rocks in valley.....33, 76
Thessalon tp.
  Rocks..... 32
    greenstone, anal..... 75
Thompson tp., conglomerate (matrix) anal..... 66
Threemile l., rocks..... 90
Timber. *See* Lumbering
Todd, E.W..... 5
Topography..... 8–14

PAGE

Two Lake copper m..... 128

Unconformity
  Huronian-pre-Huronian..... 99
  Palæozoic-Precambrian..... 107
Van Hise, C. R..... 7, 29
Victoria tp.
  Copper..... 130
  Fault..... 106
  Rocks.....44, 87
Volcanics. *See* Schist-complex

Wabagizig l..... 79
Wanapitei l..... 119
  See also Crystal gold m.
  Limestone near..... 67
Waterpowers..... 12
Wavy l., quartzite..... 90
Webbwood, rocks near.....23, 24
Wewe slate.....60, 113, 114
Whiskey l.
  Copper near.....125, 129
  Gold. *See* Payton gold claim
  Rocks.....20, 41, 42
White fall, Blind r..... 12
Whitefish l., Pleistocene deposits.... 97
Whitefish r.
  Agricultural land; character...11, 13
  Gowganda formation, section...63, 64
Williams, M. Y.....107, 108
Williams, N., tp..... 119
Wilmot copper claim.....125, 127
Wilson, J. S..... 122
Winchell, Alexander..... 7, 30
Winchell, N. H..... 7, 47