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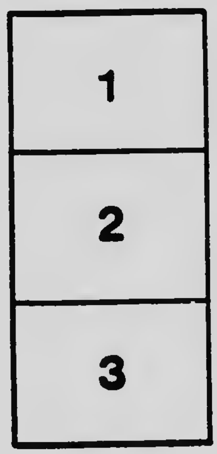
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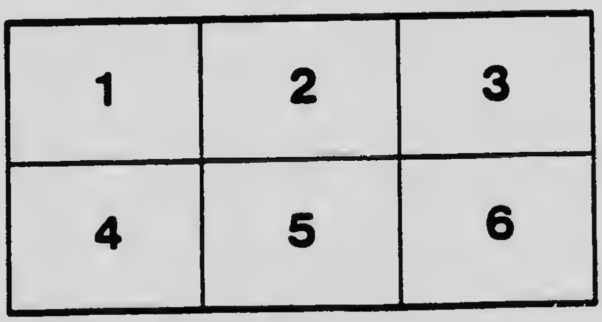
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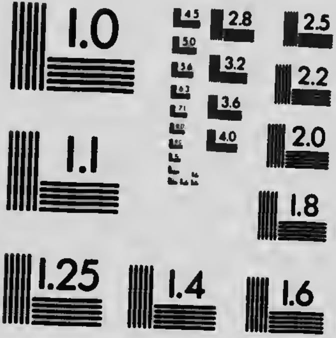

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GEOLOGICAL SURVEY

MEMOIR 60

No. 47, GEOLOGICAL SERIES

Arisaig-Antigonish District, Nova Scotia

BY
M. Y. Williams

OTTAWA
GOVERNMENT PRINTING BUREAU
1914

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CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT AND ACKNOWLEDGMENTS.

The subject matter of this work has to do with a geological district situated in Nova Scotia, which has already been given much careful attention by geologists. Within the area studied lies the key to the stratigraphy of a considerable region; here critical data bearing upon the inter-relations of formations ranging in age from lower Ordovician to Pennsylvanian (Upper Carboniferous) may be sought and found.

The purposes in further examining the district and making the present report, were mainly two-fold: first, to work out in greater detail than had hitherto been done, the stratigraphic relations of the sedimentary formations to one another and by means of such relations and from palæontologic evidence to determine more closely the age of the sediments; and second, to classify and work out the relations and ages of the intrusive and extrusive igneous rocks of the district.

In pursuit of data relating to the objects sought, the necessary surveys were made to permit the remapping of the geology of the district, and much information was secured relating to the geological problems of the region. Additional data were also obtained bearing upon the physiographic forms as described by previous writers. A careful survey was made of the iron-ore prospects near Doctors brook, and of the gypsum deposits south of the Intercolonial railway.

The writer desires to acknowledge his indebtedness for advice and assistance to Professor Charles Schuchert of Yale University and Prof. W. H. Twenhofel of the University of Kansas, who were present in the field during the early part of the work.

Professor Schuchert has supervised the examination of the fossils collected from several formations by the writer, and of the detailed collection made by Professor Twenhofel from the Silurian section at Arisaig.

The writer is also under obligations to the following professors of Yale University: L. V. Pirsson, under whose guidance the petrography of the district was worked out; Joseph Barrell, whose advice and criticisms have been of great assistance in the structural studies undertaken; Isaiah Bowman, who has given useful suggestions and criticisms relating to physiography; and J. D. Irving for criticisms on the economic conclusions presented herewith.

Mr. George E. Corbitt gave assistance in the examination of the iron-ore prospects which were under his management.

Owing to the entrenched nature of the stream courses, and the second-growth timber covering the higher lands, traversing was difficult and the pace and compass method seemed best adapted to the conditions. A 4-inch tripod compass was used. Traverses were tied to definitely located points and wherever practicable, they were run between fixed locations. In the survey of the iron-ore prospects of Doctors brook, a careful compass and chain traverse was made. Barometric measurements were taken at many places to facilitate the study of the physiography of the region and the making of structure sections. In the absence of a barograph, it was seldom possible to check the barometer readings oftener than morning and evening, and they are accordingly to be considered only approximately correct.

Work in the field was begun by the writer on June 22, 1910, and continued until September 20 of that year. Mr. M. H. McLeod of Northeast Margaree, Cape Breton island, who acted as field assistant, began work on July 6 and continued in the field until October 8. Mr. McLeod rendered valuable assistance in the mapping of the geological formations and took charge of the revision of the base map.

LOCATION AND AREA OF ARISAIG-ANTIGONISH DISTRICT.

The Arisaig-Antigonish district fronts on Northumberland strait and is situated about one-third of the way from Cape Breton to Pictou harbour. The area studied includes 10 miles of coast line, with Arisaig point at its centre, and extends inland southeast about 11½ miles to the Intercolonial railway, including also the gypsum deposits south of that railway. The approximate area of the district is 115 square miles.

GENERAL CHARACTER OF ARISAIG-ANTIGONISH DISTRICT.

The name of the district is derived from the small settlement along its front, whose name has long been associated with the Silurian formations of the vicinity; and from the town of Antigonish, which is situated in the southeast corner of the district. With the exception of a small area along the southwest side, which is in Pictou county, the district is entirely within the county of Antigonish. This county was settled during the last quarter of the eighteenth century by Highland Scotch pioneers, whose descendants still occupy most of the farms.

Besides farming, lobster, salmon, and mackerel fishing are important industries and some lumbering is still carried on although nearly all the timber is second-growth. Red spruce rapidly encroaches upon the cleared fields, especially along the shore, and hardwood including red maple, beech, and yellow birch commonly forms the deciduous growth of the highlands. Lobster canning and the manufacturing of dairy products are carried on to some extent in the district.

MEANS OF COMMUNICATION.

Communication is furnished along the south border of the area by the Intercolonial railway, and stage routes from East Merigomish and Pictou reach the interior and the shore settlements. Steamboat communication is somewhat irregularly maintained between Arisaig and Malignant cove, and Pictou and Cape Breton ports.

CHAPTER II.

PREVIOUS WORK.

As a result of its favourable location on Northumberland strait, Antigonish county was easily accessible to naturalists and was one of the first parts of Canada to be studied geologically. As early as 1827, Francis Alger, a mineralogist from Massachusetts, commenced work on the iron ores and mineralogy about the Bay of Fundy. For several years following, Alger and Charles F. Jackson, who later became State Geologist of Maine, New Hampshire, and Rhode Island, continued the work in Nova Scotia, extending it to cover the broader geological features of the whole province. These gentlemen, along with the well known Canadian geologists, Abraham Gesner, Sir J. W. Dawson, and Reverend D. Honeyman, were the pathfinders in the geological study of northeastern Nova Scotia. They were followed in the work by Hugh Fletcher, H. M. Ami, and R. W. Ells, all of them officers of the Geological Survey of Canada. The fossils obtained from time to time were described by E. Billings and J. F. Whiteaves, palæontologists to the Geological Survey of Canada, and James Hall of the Geological Survey of New York State.

Other investigators whose work has added to the geological knowledge of this district are: Professor R. A. Daly, of Harvard; Professor J. E. Woodman, of New York City University; Professor W. H. Twenhofel, of the University of Kansas; and Professor Charles Schuchert, of Yale University.

The first systematic geological study of Nova Scotia was made by Francis Alger during his exploration of the iron ores of Annapolis county. Besides the iron ores, various mineral and rock occurrences were described and remarks were made on the erosive action of the tides, etc. His results were published in 1827 under the title "Mineralogy of Nova Scotia."[1] Two years later, Jack-

[1] Alger, Francis. Amer. Jour. Sci. and Arts, Vol. XII, pp. 227–232, 1827.

son and Alger[1] published an account of their more extended explorations, and also a geological map of the whole province. Their geological subdivisions, which were fourteen in number, were based on lithological distinctions; the occurrence of beds of gypsum, iron ore, or coal; the presence of marine fossils, limestone, etc. It is evident from the text that their more detailed explorations extended into Pictou county, but stopped short of what is now Antigonish county. The metamorphic lower Ordovician formations of the uplands, together with intrusive igneous rocks and some younger Palæozoics, were mapped as "Transition Clay Slate." The younger Palæozoics, as a class ranging from Silurian to Lower Carboniferous, were included under "Red and Grey Sandstone alternating with black and red shale containing impressions of vegetables, beds of coal, etc." The above were respectively divisions III and IV and as mapped were rather inaccurately bounded. A number of locations of gypsum, iron ore, and coal were fixed, giving the map a practical value.

Notes on the topography of the country occurred in the text. The "South Mountains" were described as passing into Pictou district, while the remaining uplands of Pictou and those of Cumberland county and Colchester district were described as "rounded hills of inconsiderable elevation."

In a later publication[2] "gypsum of practical worth" was described as occurring near the head of the "Basin of Minas" and also near Windsor. Limestone containing marine shells was mentioned as occurring at the latter place. Among many other interesting observations is one on the relations of what are now known to be Carboniferous sandstones and the metamorphic lower Ordovician rocks, seen at East river (of Pictou). Because of the high dip of the "clay slate" to the northwest and the gentle dip of the sandstone, the relative ages of the formations were determined although no contact was observed.

Jackson and Alger continued work in Nova Scotia for a short time longer; a new edition of their report appeared in 1833[3];

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[1] Jackson, C. F., and Alger, Francis. Am. Jour. Sci. and Arts, Vol. XIV, pp. 305–330, 1828.

[2] Jackson, Charles F., and Alger, Francis. Amer. Jour. Sci. and Arts, Vol. XV, pp. 132–160; 201–217, 1829.

[3] ————. Mem. Amer. Acad. Arts and Sci., 1833.

and their new geological map was published in Boston in 1841. Their later work was not concerned with problems relating to the district now under consideration and so need not be reviewed here.

The first man of British birth to undertake the task of unravelling the geology of Nova Scotia was Abraham Gesner, a native of the province, whose birthplace was at Cornwallis. By profession a physician and surgeon, he became more and more interested in geology and finally was made provincial geologist of New Brunswick in 1838.

In 1836 a book by Gesner entitled "Remarks on the Geology and Mineralogy of Nova Scotia" was published at Halifax. After the work of Jackson and Alger this was the first treatment of the subject. It gave a fairly accurate impression of the geology of the province as it was then known and set forth some original ideas relating to the district about Arisaig. In the geological map of the province the rocks were divided in descending order into: (1) Red sandstone, (2) slate, greywacke, and greywacke slate, and (3) primary granite, gneiss, and mica slate. The highlands of Antigonish, composed of lower Ordovician and igneous rocks, were included in the slate, and the remainder were put in the red sandstone division. It was also noted that coal occurred near Pictou, south of Antigonish harbour, and elsewhere.

An 18-foot bed of iron ore occurring south of Pictou was described as containing marine organic remains. These are mentioned (page 61), but from the names there used no correlation can be made. The ore and containing greywacke held the same fossils and were recognized as being of the same age. It was suggested that the ore bed was a deposit of iron-bearing sand such as occurred on Sable island.

Greywacke and greywacke-slate were described as extending from the East river of Merigomish to Arisaig pier, where they were penetrated by a bed of porphyry. The last statement is very interesting, for if the reference be to the volcanic rocks, as it doubtless is, Gesner was the one man among all the early workers to recognize the true origin of the old rhyolite flow, so commonly described in later reports as an altered sedimentary.

The derivation of the Carboniferous conglomerates from the older formations was recognized, and the materials were thought to be worn down and deposited by currents in the depressions of the older rocks.

Gesner described the limestone and gypsum of Windsor and Antigonish, recognizing their stratigraphic relations and mentioning the sink holes and general karst topography accompanying them. The formations were named in ascending order: Old Red sandstone, Carboniferous limestone, Millstone Grit, and coal. These in the late literature are known respectively as Horton and Riversdale formations, Windsor group, Millstone Grit, and Coal Measures; the first two divisions being referred to the Lower Carboniferous and the other two to the Upper Carboniferous or Pennsylvanian.

Born (1820) and brought up at Pictou, Nova Scotia, J. W. Dawson received his early training at the Pictou Academy. After graduating from the University of Edinburgh, Scotland, he returned to his native land in 1847. Even before this he had written on the coal formation of his home county with which he was so familiar. During the period between 1855 and 1893, Dawson was principal of McGill University, also holding the chair of natural history. During his life he published many books and articles relating to the geology of northern Nova Scotia. From among them those will be considered which are most directly related to the problems in hand.

In 1845[1] Dawson published his first work on northeastern Nova Scotia, accompanying it with a map by Gesner. The article contained a concise account of the "coal formation" and the "gypsiferous formation," giving their general geological relations and their relations to other groups. Of the sections illustrated and described, the one extending from Merigomish to Malignant cove is of special interest to us. The band of Carboniferous rocks included between the shores of the gulf and the hills to the southward, was described as having a thickness amounting to 10,000 or 12,000 feet.

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[1] Dawson, Sir William. Quart. Jour. Geol. Soc., London, Vol. I, pp. 26–35, 1845.

The limestone west of McAras brook was misinterpreted as consisting of two beds having an aggregate thickness of 80 feet, duplication by faulting not having been recognized. Numerous fossils were obtained among which were "*Productus Martini* and *Spirifer glabra* all common to these beds and the limestones of East River." The "amygdaloidal trap" at the mouth of McAras brook, now recognized as intrusive, was described as "two conformable beds, whose lower sides are more compact than their upper. Their upper surfaces are also partially broken up and intermixed with conglomerate." The Devonian strata of McAras brook were mentioned as probably underlying the Carboniferous rocks.

The section between McAras brook and Arisaig, Dawson wrote, "is occupied by dark shales and thin layers of limestone, with a few beds of reddish shale and conglomerate. These rocks dip southwest, but become more fractured as they approach Arisaig." He stated that these formations abounded in fossils, some of which he mentioned by their names, and concluded that "though mostly Silurian a few of these species appear to be the same with those of the slates of the East River."

The volcanic rocks east of Arisaig point were mentioned as being "without doubt Lower Carboniferous rocks (perhaps a little lower in the series than those last seen at McAras brook), but in a much altered condition." The associated intrusive amygdaloid was referred to as "evidently interstratified with the accompanying rocks." "Syenite greenstone" was mentioned as being present on the shore towards Cape George, while "compact feldspar and other igneous rocks" were described as occurring on the hills to the east and south of Malignant cove.

The Carboniferous rocks of Antigonish harbour were then dealt with and a section was given of the strata exposed along Rights river. Dawson also noted an outcrop of gypsum nearly 200 feet thick occurring at the outlet of Ogdens lake, which he illustrated and described in considerable detail.

Gesner's map divided Nova Scotia into: (1) Coal Measures, (2) Old Red sandstone and Gypsiferous series, (3) Metamorphic and Silurian, and (4) Igneous rocks. Within divisions 1 and 2, the Arisaig-Antigonish district is included.

It will be seen that in this paper, Dawson laid a firm foundation for the more detailed geology which was later supplied by Honeyman, Fletcher, and others.

In 1847[1] a letter written by Dawson to Professor Johnson, gave a careful treatment of the geological age and relations of the gypsum of Nova Scotia, with descriptions of sections as exposed at Ogdens point, in Antigonish harbour, and elsewhere. In summing up Dawson wrote:—

"Its constant association with limestone of the Carboniferous system containing marine fossils proves that it was deposited in the sea, and from the present relations of the Carboniferous rocks to older systems, in this province, it is probable that the sea basins in which the gypsum was deposited were not very extensive. In these sea basins the deposition of gypsum alternated with mechanical deposits of sand and marl and with the growth of shells and corals; but the conditions which produced beds of gypsum were unfavorable both to the transport of sediment and the existence of animals or plants."

Following these apt remarks were suggestions that "springs and rivers" bearing free sulphuric acid from decaying iron pyrites may have flowed into seas where lime had been deposited and thus gypsum was thrown down. As an instance of such rivers the Rio Vinaigre of South America was cited.

In a paper entitled "On the Metamorphic and Metalliferous Rocks of Eastern Nova Scotia,"[2] published in 1850, Dawson made mention of the Arisaig rocks and stated that a small collection of fossils from their upper beds had been sent to Professor Hall of Albany, who gave it as his opinion that they belonged to the age of the Hamilton and Chemung groups. This correlation Hall himself later showed to be wrong, referring the rocks to the Silurian. A description was also given in this paper of the slates, quartzites, and igneous rocks of Cape George, and the Antigonish and Merigomish hills.

In the first edition of the "Acadian Geology," Dawson briefly described the Arisaig region and stated that some fossils obtained

[1] Dawson, Sir William. Proc. Acad. Nat. Sci., Phila., Vol. III, pp. 271–274, 1847.

[2] Dawson, Sir William. Quart. Jour. Geol. Soc., London, Vol. VI, pp. 347–364, 1850.

from the Arisaig rocks were considered by Sir Charles Lyell to agree specifically with those of the Hamilton group of the United States, the identical error made earlier by Hall. In his map Dawson classed these rocks as Devonian and Upper Silurian.

In 1860[1] Dawson described the Gold-bearing series of Nova Scotia as "Lower Silurian," referring the "lower Ordovician" metamorphic rocks of the Cobequid mountains to the "Silurian" also. The "Silurian" and Devonian were described as having east to west and northeast to southwest folds along which anticlinal and synclinal valleys had been formed by denudation. In these valleys beds of the Carboniferous system and "New Red Sandstone" were deposited.

The Arisaig Silurian strata were referred to as "one of the most instructive sections of these rocks in the province" and a description of their extent, structure, and lithological characters followed. The volcanic rocks at the base of the Silurian were included as a basal member which had been metamorphosed by the intrusion of a great dyke of "augitic trap of Carboniferous date." Lists of fossils were given, along with the horizons from which they came. Those from the lower shaly beds were placed in the Clinton group, and those from the upper or calcareous portion were considered of probable Upper Silurian age. The latest work, which is that by Schuchert,[2] differs from this conclusion in correlating the highest formation with the Ludlow, the nearest American equivalent in time being the Guelph of interior America.

In the second edition of the "Acadian Geology" (1868, pages 572–573), Dawson went back to his original opinion that the Arisaig rocks were "Middle and Upper Silurian" in age, and compared them with the "Silurian" of New Brunswick, Maine, Anticosti, and New York State. He concluded that the "Upper Silurian" of Arisaig and Anticosti did not compare directly with either that of England or the other "Silurian" areas of America, but considered that the fossils were, in their broader relationship, intermediate between those of Europe and America. The

[1] Dawson, Sir William. Can. Nat., Vol. V, pp. 132–143, 1860.
[2] Schuchert, Charles. Amer. Jour. Sci., (4), Vol. XXVIII, p. 163, 1909.

upper Arisaig series were thought to be equal to the Clinton of New York and the Upper Llandovery of England and perhaps a portion of the time represented by Wenlock and Niagara. He stated that the strata of the lower part of Doctors brook might be equivalent to an older member of the "Upper Silurian," but probably was not so low as the Medina and Oneida of New York or the Lower Llandovery of England.

Dawson still referred most of the rocks of the Cobequid mountains to the Arisaig series, basing his opinion upon fossils collected at Earlton and New Annan.

In 1875, writing on the "Geological Relations of the Iron Ores of Nova Scotia,"[1] Dawson described a 30-foot bed of laminated, more often oolitic iron ore occurring on the East branch of East river. The rocks contained characteristic fossils of the "Arisaig group" and were thought to be equivalent to the American Lower Helderberg or the English Ludlow. Peroxide of iron was found in minute concretions enveloping grains of sand and the ore graded into ferruginous sandstone. The iron content of the ore was 43–54 per cent.

Writing in 1878, in the third edition of the "Acadian Geology" (page 58), on the Post-Pliocene period, Dawson recognized the following deposits in descending order:—

(1) Gravel and sand beds, and ancient ridges and beaches, indicating the action of shallow water and strong currents and waves.

(2) Stratified clay with shells, indicating quiet deposition.

(3) Unstratified boulder clay, showing united action of ice and water.

(4) Peaty deposits of land surface before deposition of boulder clay.

The account included the directions of a number of glacial scratches, tending mostly to the south and southeast. Floating ice and glacial action were considered as possible agents producing the deposits noted, but Dawson favoured the theory that the deposits were due to the action of floating ice during maritime conditions of the land, and explains "horse backs" and "boars' backs" ridges as due to currents during the retreat of the sea.

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[1] Dawson, Sir William. Can. Nat., new ser., Vol. VII, pp. 129–138, 1875.

In 1881[1] Dawson described the Silurian iron ores of Pictou, and stated that the horizon was traceable to Arisaig but that here it was less rich in iron. A list of fossils found in the ore was given. Two beds of ore were described, both newer than the Clinton.

The metamorphic rocks of the highlands were spoken of as the Cobequid series and were thought to be newer than the gold series of the Atlantic coast, but at least as old as the Cambro-Silurian.

In 1888[2] Dawson gave a table of comparison of the formations of England and the Maritime Provinces from the Laurentian to the top of the Silurian. No true Laurentian or Ordovician strata had so far been found in Nova Scotia.

Dawson's "Handbook of Canadian Geology," published in 1889, dealt with the principles of the science and geological chronology, but devoted one of its three parts to the geography and geology of Canada. The pages dealing with the Acadian region contained a concise, pointed description of the various formations of the country. Besides containing much information common to Dawson's earlier writings, the book had a number of statements which were either new or important because of their clearness. The age of his Cobequid series, including an upper member of slates and quartzites (now known to be of lower Ordovician age) and a lower volcanic member, was determined on stratigraphic evidence to be pre-Silurian. However, it was thought that there was a possibility that these rocks might be correlated with the Huronian of New Brunswick and Newfoundland. In conclusion, Dawson referred them to the "Siluro-Cambrian."

The Carboniferous system was divided into:—

(1) Horton series, or Lower Carboniferous shales and conglomerates.

(2) Windsor series, or Lower Carboniferous limestone.

(3) Millstone Grit.

(4) Coal formation.

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[1] Dawson, Sir William. Can. Nat., new ser., Vol. IX, pp. 313–314, 1881.

[2] ————. Quart. Jour. Geol. Soc., London, Vol. XLIV, pp. 797–816, 1888.

The areas of Carboniferous strata were described and the earth movements bringing about the varying conditions of sedimentation were compared with those movements which produced the great unconformities below and above this system. To explain irregularities in sedimentation within the system itself, current action was called upon.

Under Pleistocene, Dawson discussed rock scratches and transported materials, explaining them by supposed denudation of the lower lands, which were "traversed by northern currents of ice-cold water, bearing floating ice throughout the year." Local glaciers were supposed to have existed on the hills but the author says, "I fail to find, either in the Acadian Provinces or in Canada proper, any indication of a great continental glacier." He made the statement that "Glacial striation is very frequent wherever fresh surfaces of rock are exposed." Then followed a table giving the location and direction of fourteen examples of such striation, with the statement that there is "a tendency to a southerly and southeasterly direction, which accords with the prevailing course in most ports of northeastern America."

Taking the Pleistocene of Prince Edward Island as an illustration, Dawson stated that the deposits here consisted of "Post-Pliocene boulder clay composed of red sand and clay derived from the waste of the red sandstones, * filled with boulders of red sandstone derived from the harder beds." The latter were described as being "more or less rounded, often glaciated, with striæ in the direction of their longer axis." Later the text went on, "No marine remains were observed in the boulder clay; but at Campbellton, above the boulder clay * * * there is a limited area occupied with the beds of stratified sand and gravel, at an elevation of about 50 feet above the sea, and in one of the beds there are shells of *Tellina Graenlandica*."

Boulders on the surface of the country were referred to a newer "boulder drift" and were correlated with the Saxicava sand. Some of the boulders were supposed to have come from Labrador, others from Cape Breton, and still others from the mainland of Nova Scotia.

The existence of the boulder clay and native boulders was thought to be due to one of two hypothetical processes. Either the Gulf of St. Lawrence was formerly filled by a glacier which moved only towards the centre of the basin, or the results were due to floating ice when Labrador "was too thoroughly enveloped in snow and ice to afford many travelled stones." The later boulder drift was attributed to the work of "coast ice carried by the tidal currents sweeping up the coast, or by the Arctic current from the north."

The remarks on the Acadian region closed with a discussion of the similarity of the geology of the Maritime Provinces to that of Europe, and its decided contrast with the geology of the rest of Canada or the United States. A complete table of formations for the region was appended.

D. Honeyman was a minister in the town of Antigonish, and began his geological work as an amateur collector of fossils among the interesting rocks along the Arisaig coast. Enlightened as to the real geologic problems of the country by reading the first edition of Dawson's "Acadian Geology," and by personal acquaintance with its author, Honeyman's work gained in purpose and accuracy. He published many papers on the geology of the Arisaig region in various scientific magazines, and finally was called from his pastoral duties in Antigonish to superintend the Nova Scotia Department at the Exhibition in London in 1862. Becoming acquainted with English geologists and having access to European collections, Honeyman interested himself deeply in the task of correlating the Silurian formations on the two sides of the Atlantic ocean. As a direct outcome of his further studies the Silurian formations of Arisaig were subdivided into five zones, as set forth on another page.

In 1868, Honeyman surveyed much of Antigonish county for the Canadian Geological Survey, and later he became Director of the Provincial Museum at Halifax. From this city as a centre, he made extensive studies on superficial deposits and glaciation with which phases of geology his later writings mostly deal.

Honeyman's first geological publication, appearing in 1859[1], contained a somewhat popular account of the Arisaig rocks and their contained organisms. Of the fossils mentioned, *Productus*

[1] Honeyman, D. Trans. Nova Scotian Lit. and Sci. Soc., Halifax, pp. 10–29, 1859.

depressa (= *Leptaena rhomboidalis*), *Spirifer elevatus*, *Calymene blumenbachii*, and *Homalonotus* are the only ones that are now significant.

From the prevalence of *Calymene blumenbachii* and *Homalonotus* and the general resemblance of the fauna to that of the Upper Ludlow, the author rightly concluded that the rocks were of "Upper Silurian" age.

Five years later[1] fresh from his studies and comparisons in England and Europe, this persevering worker published the results of one of the most important pieces of geologic work done on the Silurian rocks of Nova Scotia. Having consulted Salter, an English palæontologist, Honeyman proceeded to divide the Silurian rocks into five subdivisions, which he designated by letters and correlated in ascending order as follows:—

A. The approximate equivalent of the Mayhill sandstone.

B and B′. The equivalent of the Lower Ludlow of England.

C. The equivalent of Aymestry limestone.

D. The equivalent of Upper Ludlow.

According to this correlation the Wenlock group or the whole Middle Silurian, is missing between divisions A and B. Dawson agreed to the above with the exception of D, which he considered equivalent to the Lower Helderberg of New York State.

Honeyman traced his divisions inland and carefully mapped them. Three cross-sections were added to interpret the structure. The synclinal arrangement was recognized, but was somewhat perplexing to the author who believed it to be due to the intrusion of the "augitic trap" seen along the shore. Thicknesses of the various divisions were estimated, and many fossils were named with the localities from which they were obtained. Dawson's theory that the old volcanics were metamorphosed sediments was perpetuated in this article, and these rocks were thought to belong to division A.

In 1866[2] the strata extending up from the mouth of McAras brook were recognized by Honeyman as lying unconformably

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[1] Honeyman, D. Quart. Jour. Geol. Soc., London, Vol. XX, pp. 333–345, 1864.

[2] Honeyman, D. Nova Scotian Inst. Nat. Sci., Vol. I, pt. IV, pp. 106–120, 1866.

above the Silurian and below the Lower Carboniferous and so were thought to be of probable Devonian age. This was the first recognition of actual Devonian rocks in the northeastern part of the province, as the so-called Devonian formations of Hall and Lyell turned out to be Silurian in age. However, Honeyman was decidedly wrong when he included with the Devonian the lower Ordovician grey slates at the falls of James river and at the Sugar Loaf hill of Antigonish.

Honeyman speculated on the probable depth beneath the sea at which the horizons were deposited, and believed that continued subsidence was responsible for the great thicknesses. Because of the lack of recognition of any marked unconformity between the Silurian and Devonian formations, no great uplift of the land was thought to have occurred until after the deposition of the Devonian sediments. Then, following emergence, an important erosion interval was recognized before the Lower Carboniferous strata were laid down. The uplift was supposed to be related to the intrusion of the trap sheets seen at the mouth of McAras brook. The extensions of the Carboniferous rocks with the included limestone and gypsum occurring about the town of Antigonish were discussed, and the isolated limestone, etc., of Doctors brook and the silicified conglomerate of Malignant cove were referred to the Carboniferous. The latter is probably of Ordovician age, as will be shown later in this report under the description of the Malignant Cove formation.

Under superficial deposits, the clay and gravel mounds of Maryvale were described as being of possible glacial origin, and the "intervales" or flat bottom-lands along West river near the town of Antigonish were thought to be of the same age, being probably equivalent in time to the "intervale" of Middle river, Cape Breton, in which the thigh bone of *Mastodon Ohioticus* was found.

In 1870[1] Honeyman referred all of the "Upper Silurian" of Nova Scotia to the Arisaig series and correlated this with the Anticosti group. He also claimed to have found Laurentian

[1] Honeyman, D. Quart. Jour. Geol. Soc., London, Vol. XXVI, pp. 490–492, 1870.

rocks containing the dawn animal or ***Eozoon***, east of Malignant cove.

Passing over some publications in which little new material was given, we shall consider Honeyman's paper of 1875.[1] Not confining himself to the shore lowlands, he described ten sections including much of the plateau to the south of Arisaig with its metamorphic sedimentaries and varied igneous rocks. The Silurian strata of Doctors brook were found to be fossiliferous. Those near the shore road were recognized, from north to south, as belonging to A, B, and B′ divisions of the Arisaig series, and across a syncline nearer the Hollow, strata of B′, B, and A divisions were found.

Honeyman observed on the Old road south of Arisaig, a syncline axis and thought the strata were higher than D or Upper Ludlow, calling this division E.

Mention was made of salt springs near the town of Antigonish, which had been tested but were found not to be permanent.

Later papers appearing before 1888 added little information. In a publication of that date[2] Honeyman discussed the superficial geology of Nova Scotia, dividing the country for convenience into five topographic districts. He described moraines, perched boulders, and the clay under the town of Antigonish bearing fossil plants, etc. The gravel hills near Maryvale were classified as of Champlain age, a classification based upon certain types of valley formations and the northward transportation of material. The "intervale" of Antigonish, along with the marshes and dyke land of Amherst and Grand Pre, was considered of recent origin.

In 1860[3] James Hall described thirty-seven "New Species of Fossils from the Silurian Rocks of Nova Scotia" accompanying his publication with twenty illustrations. On other occasions he gave valuable opinions on the fossils from Silurian localities, and assisted Dawson and Honeyman in fixing the age of the rocks.

In 1860[4] E. Billings described a new starfish found by Honeyman at Arisaig in his zone C, and named it *Palaester parviusculus.*

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[1] Honeyman, D. Nova Scotian Inst., Vol. IV, pp. 47–79, 1875.
[2] Honeyman, D. Nova Scotian Inst., Vol. VII, pp. 131–141, 1888.
[3] Hall, James. Can. Nat. and Jour. Sci., Vol. V, pp. 144–159, 1860.
[4] Billings, E. Can. Nat. and Geol., Vol. V, pp. 69–70, 1860.

In 1874[1] Billings published two plates with twenty-five illustrations, describing seventeen new species of Lamellibranchiata from the Arisaig rocks.

Hugh Fletcher, of the Geological Survey of Canada, had been engaged in the exploration and mapping of Nova Scotia since 1875. In the summer of 1885[2], working south from Cape Breton, he reached the harbour of Antigonish and did some work as far west as the East river of Pictou.

In his preliminary statement of that year, he gave a brief description of the extent of the formations; recognized two periods of volcanic activity; and remarked that the thickness of Silurian rocks present on the coast of Arisaig represented only a small part of the volume of the formations older than the Carboniferous existing in the counties of Pictou and Antigonish.

In 1886[3] Fletcher in his report on surveys and explorations in Guysborough, Antigonish, and Pictou counties, gave a detailed account of the geology of the region including the Arisaig-Antigonish district. The general, stratigraphic, igneous, and economic phases of the geology were carefully dealt with and Fletcher's maps and reports were so reliable that they stand to-day unchallenged in their main interpretations.

Perhaps the most detailed work was done on the Silurian formations. The subdivisions of the Arisaig series were carefully mapped, Honeyman's work being used as a basis. However, the formation-names of Medina, Lower Clinton, Upper Clinton, Niagara, and Lower Helderberg were substituted for divisions A, B, B′, C, and D of Honeyman, while for the whole group instead of Arisaig series, Fletcher used the term Silurian. The section along the beach was re-measured and described, but the results for the first three divisions, which had been measured by Honeyman, did not quite agree with the previous work. The boundary between the Lower and Upper Clinton was placed higher than the boundary between divisions B and B′ of Honeyman.

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[1] Billings, E. Can. Geol. Surv., Vol. II, pt. I, pp. 129–144, 1874.
[2] Fletcher, Hugh. Can. Geol. Surv. Summ. Rep., 1885, p. 62 A.
[3] ————. Canada, Geol. and Nat. Hist. Surv. Report for 1886, Part P, pp. 1–128.

Fletcher named no fossils found at Arisaig but it may be inferred from the report that the correlation (and hence the names) of the formations was based upon evidence obtained from the collections made for the Geological Survey of Canada by Honeyman, Weston, and Robert.

In his interpretation of the structure, Fletcher agreed essentially with Honeyman. He recognized, however, an up-thrust block between Smith brook and a point east of the Trunk road and thought it was bounded by two north and south faults.

It is worth noting that Fletcher divided the "Cambro-Silurian" rocks (included by Dawson in the Cobequid series and thought to be of Siluro-Cambrian age) into three formations. These were in ascending order:—

"(1) The lower flinty slates, quartzites, and 'whin'-like rocks of James river and Eigg mountain.

"(2) The soft reddish and olivaceous slates of Baxters brook and Brian Dalys brook.

"(3) The reddish and grey sandstone, grit, and conglomerate of Bears brook."

The red slates of the metamorphic area south of Doctors brook were placed in the second division and the silicified conglomerate of Malignant cove was referred with some doubt, to either division 2 or 3. Fletcher thought that in some localities he recognized an unconformity below division 2.

The Carboniferous rocks were divided, in ascending order, into, Carboniferous conglomerate, Carboniferous limestone, and Millstone Grit formations. Two sections of these rocks were carefully measured and described. The first extended from the ponds of Merigomish to Knoydart, and the second was along Baileys brook.

The igneous rocks of the region were described as they occurred in the field. The volcanic rocks of Arisaig point and Frenchman's Barn were described as being felsitic, but Fletcher was noncommittal as to their origin, being content to say that they "have been regarded both as metamorphosed sedimentary and as volcanic rocks." He did, however, recognize that the trap of McAras brook was intrusive and not interbedded as affirmed by Dawson. The Devonian rocks were described and many other topics were dealt with such as iron ore, copper ore, etc., but the above synopsis includes the interpretations most important in the present study of the Arisaig-Antigonish district. As a comprehensive treatise on the geology of the region discussed and as a handbook for a student entering the field this is by far the best work yet published.

In 1897, Fletcher measured the Devonian section exposed along McAras brook and described the strata. In all he found a thickness of 683 feet of rock without having seen either the base or summit of the formation. (The above work was included in an article by Ami[1] published in 1900).

As palæontologist to the Geological Survey of Canada, H. M. Ami has published a number of descriptions of fossils collected near Arisaig and has done much to work out the stratigraphic relationships.

In 1892[2] he presented a list of fossils found in the Silurian strata of Arisaig.

In 1900[3] in an article on "Subdivisions of the Carboniferous in Eastern Canada," Ami dealt with the formations recognized by previous writers, and attempted to fix their ages and correlations. Ami used the term Windsor formation for the marine limestones with the accompanying sandstones and shales which, he stated, overlay unconformably the Union and Riversdale formations. In this he simply followed the usage of Dawson, who in his Handbook of 1889 applied the name Windsor series to the limestones, sandstones, and shales above the Union and Riversdale formations and below the Millstone Grit. The Union and Riversdale formations, on the evidence of animal and plant remains, were placed by Ami in the Carboniferous and David White was quoted as confirming his opinion, but Ami was not sure whether the Windsor formation was "eo-Carboniferous or meso-Carboniferous." The Millstone Grit overlay the Windsor formation, but although an unconformity was described by Fletcher, Ami found none in the Cumberland basin. He con-

[1] Ami, H. M. Trans. Nova Scotian Inst. Sci., Vol. X, Pt. 2, p. 177, 1900.

[2] ———. Ibid., Vol. I, new ser., pp. 185–192, 1892.

[3] ———. Ibid., Vol. X, Pt. 2, pp. 162–178, 1900.

sidered the Union and Riversdale formations, as well as the Millstone Grit and Coal Measures, to be of estuarine origin, while he recognized the Windsor formation as marine.

In the same year[1] Ami proposed a new subdivision of the Silurian rocks of Arisaig. In descending order his proposed formation names were Stonehouse, Moydart, McAdam, and Arisaig, a terminology retained to this day with the exception of the last name which has been used by the present writer to designate the whole group. Ami did not definitely fix the boundaries of his subdivisions and so no exact correlations with the previous subdivisions can be given.

In an article[2] dealing with the Devonian strata, Ami discussed the question of their correlation and age. On the basis of fossil evidence obtained during a palæontological survey of the Silurian and Devonian rocks made by Weston and Robert, he decided that the Devonian correlated with the "Old Red Sandstone" of Europe and proposed the name Knoydart formation for the strata exposed along McAras brook.

The fossil fish remains referred to were identified by A. Smith Woodward and Henry Woodward of the British Museum as *Pterygotus*, *Onchus murchisoni* Agassiz, *Pteraspis* cf. *crouchii*, *Psammosteus* cf. *anglicus* Traquair, and *Cephalaspis* n. sp. ?; impressions made by a pair of sharp organs probably pertaining to a fish were named *Ichthyoidichnites acadiensis*. In his report, Smith Woodward stated that "the McAras Brook specimens represent the base of the Lower Old Red Sandstone of Britain," and the fossils present "seem to indicate clearly the presence of a fauna precisely similar in facies to that of the Hereford beds, referable to the lower Devonian (Old Red Sandstone) or Cornstone." On the evidence of *Pteraspis*, which was considered closely allied to if not identical with *P. crouchii*, the horizon indicated was thought to be low down in the Devonian and not far from the summit of the Silurian.[3]

From faunal and lithologic characters, Ami correlated the Knoydart formation with the strata near Ledbury in Herefordshire, rather than with the American Devonian.

[1] Ami, H. M. Trans. Royal Soc., Canada, Vol. VI, Sect. 4, p. 203, 1900.
[2] Ami, H. M. Bull. Geol. Soc. America, Vol. XII, pp. 303–312, 1900.
[3] For a fuller discussion by Ami, see Knoydart formation below.

While acting in the capacity of palæontologist to the Canadian Geological Survey, J. F. Whiteaves described fossils collected near Arisaig and did considerable work in correlating the Devonian formations of Canada.

In 1897[1] he described a well preserved fish tooth collected in 1869 from the Silurian rocks at McDonalds brook by T. C. Weston. He regarded it as a dendrodont tooth probably of a Crossopterygian, perhaps allied to *Holoptychius*, and named it provisionally *Dendrodus Arisaigensis*. On the evidence of this and a large number of other fossils, the "Arisaig" series was held to be of about the same age as the Lower Helderberg of New York and the Ludlow group of England. From work already quoted it is seen that the Arisaig series begins much earlier than the Ludlow.

Writing in 1899[2] Whiteaves sketched the work already done on the Devonian system in Canada, beginning with the time when Gesner, depending upon stratigraphic and lithologic evidence, recognized Devonian beds at Advocate harbour and Moose river. The work of Dawson, Honeyman, Fletcher, Ami, and Weston in discovering the extent and working out the age of the Devonian formations in Nova Scotia was briefly reviewed, making the paper valuable from a correlation standpoint.

In 1901[3] R. A. Daly made a brief field study of Acadia and combined his results with those of earlier students in such a way as to give a comprehensive account of the main physiographic features of Nova Scotia and New Brunswick.

After summarizing the geology of the areas discussed, he dealt with the main erosion cycles as expressed in the physiographic forms. He concluded that these were two in number, one culminating in the Cretaceous, the other in the Tertiary. The Cretaceous peneplain uplifted and dissected, was represented in the upland plateau. Tertiary lowlands were local in character and were developed mainly upon the Carboniferous and Triassic rocks.

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[1] Whiteaves, J. F. Brit. Assoc. Adv. Sci., pp. 656–657, 1897.
[2] Whiteaves, J. F. Science, new ser., Vol. X, pp. 402–412, 1899.
[3] Daly, R. A. Museum Comp. Zool. Bull., Vol. XXXVIII, pp. 73-103, 1901.

The features of Acadia are so suggestive of the topographic forms of New England that attention should be directed to the appended table showing "Homologies of Land-Form and of the Determining Structures in Acadia and New England." This table is remarkable for the way in which it brings out the close resemblance of the regions compared.

In his report on the iron ore deposits of Nova Scotia (Pt. I),[1] J. E. Woodman described the occurrence of ore in the Silurian rocks near Arisaig and also the ore beds in the lower Ordovician rocks of the Doctors and Iron Brooks area. Thicknesses of ore, results of assays, etc., were given, making the report of economic value.

In his summary report of 1908, R. W. Ells, who was working for the Geological Survey on the oil-shales of Canada, made mention of the occurrence of oil-shale at Big Marsh, Antigonish county, Nova Scotia; and quoted How's "Mineralogy of Nova Scotia" (1868) as a reference on thickness of the formation and the yield of oil per ton of shale. Besides How, Honeyman and Fletcher had described this occurrence of oil-shale. In 1910[2] a fuller description was given by Ells of the two groups of oil-bearing shale underlying the Lower Carboniferous limestone. The lower group, 70-80 feet in thickness, consisted of 20 feet of good oil-shale and 5 feet of curly cannel, rich in oil. The upper was 150 feet thick and contained a large percentage of oil. It was in immediate contact with limestone.

The black shales were found to be associated with light grey micaceous shales containing impressions of broken plants. In places the strata were much faulted and sometimes steeply inclined.

During the summer of 1908 W. H. Twenhofel made a careful zonal collection of fossils from the rocks of the Arisaig series exposed along the shore east and west from Arisaig point. Fossils were gathered from over 200 horizons representing a thickness of 3,465 feet. In the following year[3] he described the struc-

[1] Woodman, J. E. Canada, Dept. Mines, Mines Branch, 1909.

[2] Ells, R. W. Oil-shales of New Brunswick and Nova Scotia, Canada, Dept. Mines, 1910.

[3] Twenhofel, W. H. Amer. Jour. Sci. (4), Vol. XXVIII, pp. 143–164, 1909.

ture and the general geologic relations of the Silurian strata. He recognized three "raised beaches" preserved along the shore east of McAdam brook, and called attention to the manner in which the land forms responded to the structure of the underlying formations and their relative resistance to erosion.

In subdividing the Silurian section, Ami's work of 1901 was accepted, but a lower formation equivalent to division A of Honeyman or the Medina of Fletcher was added. Twenhofel described in detail the various formations, dealing in all with 41 zones and their contained fossils.

The "volcanic rocks" at the base of the Silurian were investigated microscopically and chemically, with the result that their volcanic origin was established, thus finally settling a much disputed question as to the origin of these rocks, which were long thought to be metamorphosed sedimentaries. This was the first careful petrologic work done on the igneous rocks of northeastern Nova Scotia.

Twenhofel's article was accompanied by a correlation note by Charles Schuchert. Division I was found to contain no faunal evidence for its correlation with the Medina of New York and was regarded as of Clinton or Lower Llandovery time. Division II or the Arisaig formation, was thought to be equivalent to the lower beds of the eastern New York Clinton and all of the Lower and possibly a part of the Upper Llandovery of Norway (as described by Kiaer). Division III or the McAdam formation, was held to be best correlated with the Rochester and the Upper Llandovery, including probably also the Lower Wenlock. Division IVa or the Moydart formation, was thought to be about equivalent in time to the middle Niagaran, or Waldron and Louisville formations, and the Upper Wenlock of Norway. Division IVb or the Stonehouse formation, was correlated with the Ludlow, having its nearest time equivalent in the Guelph of interior America.

The work done by Twenhofel and Schuchert immediately preceded that undertaken by the present writer in 1910,[1] of which this report is the outcome.

[1] See Geol. Surv. Canada, Summary Rept., 1910, pp. 238–247.

CHAPTER III.

SUMMARY AND CONCLUSIONS.

GENERAL STATEMENT.

In order to facilitate the understanding of the succeeding longer and more detailed chapters, a summary will be given here of the main facts bearing upon the geological problems of the Arisaig-Antigonish district, followed by the conclusions drawn from these facts. Detailed descriptions and all information not necessary for the clear understanding of the arguments presented, will be excluded from this chapter and should be looked for under their appropriate headings elsewhere.

PHYSIOGRAPHY.

Observations.

The land forms of the district fall into two classes; a plateau between 800 and 1,000 feet in height, underlain by resistant igneous and folded metamorphic rocks; and a rolling lowland between 200 and 400 feet in elevation underlain by soft sedimentary formations. The streams are deeply entrenched below the general level of the plateau but flow in shallow valleys across the lowlands.

Near the mouths of the streams and where they first come to grade after leaving the highlands, deposits of gravel 6 feet or more thick have been laid down. The streams meander in small flood-plains below the gravel surfaces which often have preserved in them remains of old meander cusps. Scattered over the region are a number of hog-back ridges and banks of unsorted clay and gravel deposits which contain sub-angular and scratched pebbles.

Along the shore of Northumberland strait three terraces are well preserved between 15 and 145 feet above high tide, and another at an elevation of about 10 feet is less perfectly preserved. Glacial scratches have been observed on the plateau and on the lowlands at an elevation about 500 feet below the plateau surface.

Conclusions.

The plateau areas are evidently dissected remnants of a former peneplain, and they stand at elevations that would correlate them with the Cretaceous peneplain recognized by Daly as once having extended over the whole of the Maritime Provinces.

The entrenched stream valleys of the plateau are evidence of post-Cretaceous rejuvenation of the land, and the lowland areas are a further outcome of rejuvenation. These lowlands, although higher in part than the Tertiary base-level recognized by Daly in Pictou county and elsewhere in Nova Scotia, belong to the same cycle of erosion. This conclusion is supported by the fact that the continental ice sheet which passed over the highlands scratched rocks of the lowlands 500 feet below the plateau, thus indicating a difference of elevation without doubt due mainly to Tertiary erosion and not to differential abrasion brought about by the ice.

The raised terraces are probably old sea beaches which record halts in the negative movement of the strand line in post-Glacial time. The deposits of unsorted gravel forming mounds and ridges in various places represent the work of the glaciers probably during their retreat. The thin deposits of gravel along stream beds were probably formed for the most part by spring freshets and floods, but the cut-off meanders occasionally preserved on the higher levels suggest a slight rejuvenation of the land which may be still progressing.

SEDIMENTARY FORMATIONS.

BROWNS MOUNTAIN GROUP.

Observations.

This group of rocks falls naturally into two divisions: a lower greywacke-slate, and an upper red slate formation. The lower rocks are highly silicified and the upper are cleaved and compressed. Near the top of the lower division are three "beds" of oolitic hematite, and "beds" of iron ore also occur lower down in the formation. The strata generally strike northeast, and dip most commonly at high angles either to the northwest or to the southeast. In one locality the strike is more nearly north and south. The base of this group has not been observed and it is overlain unconformably by all the other formations. Fossil linguloids, one species of which occurs at Belle isle, in Conception bay, Newfoundland, were obtained from the iron ore and a sandy schist near an iron-ore "bed."

Conclusions.

The Browns Mountain group are highly metamorphosed and have been folded into great anticlines and synclines with a general northeast trend. Minor folds extending north and south also exist.

These rocks are the oldest known in the district, and are evidently of marine origin. On the evidence of the fossils found (See page 55) they belong to the lower Ordovician period and the iron ore occurring in them may be directly correlated with the deposits of iron of Great Belle isle, Newfoundland.

MALIGNANT COVE FORMATION.

Observations.

Coarse, cr[illegible]ed conglomerates and grits, dark red and purple in colour, rest upon cleavage surfaces of slates of the Browns Mountain group. Fragments of slate, rhyolite, quartz, and various other materials make up this formation, which closely resembles the Browns Mountain rocks in being highly silicified. No upper contacts have been observed and a thickness of only about 20 feet of the formation has been clearly recognized.

Conclusions.

A time interval of considerable length followed the deposition of the Browns Mountain rocks, during which rhyolite intrusion and extrusion probably took place. Rejuvenation of the land followed and active erosion set in, succeeded closely by continental deposition during which process the Malignant Cove formation was deposited. Disturbed conditions of like character existed in the Ordovician period, and it is to this period that the silicification of the deposits would also favour their reference. The Malignant Cove formation is as a consequence tentatively classified as middle Ordovician.

ARISAIG SERIES.

Observations.

The strata of the Arisaig series consist of more than 3,500 feet of carbonaceous shales, arenaceous shales, and impure limestones. Towards the top of the series ripple-marks are common. At Arisaig and eastward the base of these strata rests upon the somewhat uneven surface of an old rhyolite flow (termed *aporhyolite* in this report), and in places the lowest bed consists of conglomerate derived from the rhyolite. Outside the Arisaig-Antigonish district, no rhyolite has been reported in connexion with the Arisaig series.

The structure of the Arisaig rocks is indicated by the attitude of the strata and further by the recognition at various places (by means of fossil contents and lithologic characters) of the different formations making up the series. The sections exposed along the shore and in the stream valleys show the rocks to be crumpled, faulted, and in places overturned. The Arisaig rocks at the front of the Arisaig-Antigonish district are separated from the older formations by a great fault which is expressed in the topography by a scarp several hundred feet in height and more than 10 miles long.

The strata of this series are highly fossiliferous and have yielded to previous collectors large and distinctive faunas. From a thin bed of iron ore the writer obtained fossils not found in the other strata.

Conclusions.

The Arisaig sediments were laid down at the bottom of a shallow sea amidst varying conditions of clear and muddy water. In part the underlying stratum was an old rhyolite flow which probably had been reduced considerably in thickness and extent by erosion. It is thought by the writer that parts of the result of this erosion were preserved in the Malignant Cove conglomerate, which may elsewhere underlie the Arisaig series.

The structure of the Arisaig strata is the direct result of the major dislocation along the fault zone of the Hollow. The main structure is that of a syncline broken and faulted along its axis. North and south faults of readjustment have divided the area into a series of blocks, and much minor adjustment has been expressed in small folds and faults.

The fauna represented in the rocks of this series is, as already shown by Twenhofel and Schuchert, more nearly related to the Silurian faunas of Europe than to those of the corresponding period in America. It represents a period of time in Europe between the Lower Llandovery and the Ludlow, and in America between the Clinton of eastern New York and the Guelph of interior America.

KNOYDART FORMATION.

Observations.

A thick series of soft, red, arenaceous slates, including some grey impure sandstones, overlies the Arisaig strata. At the shore the contact is with the upper formation of the Arisaig series, but as worked out from structural data, the contact farther inland is with the second highest formation of the Arisaig series. Fletcher measured 683 feet of exposed strata of the

Knoydart formation, and it is thought from structural evidence that 1,000 feet is nearer the true thickness.

The Knoydart formation, like the Arisaig series, is separated from the Browns Mountain rocks by the fault at the Hollow. The strata along the north dip to the south at an average of about 30°, although high dips also occur. In the southwest the strata strike with the direction of faulting and dip to the northwest. Some minor faulting has been observed along the stream courses.

The red slates are unfossiliferous, but one bed of greywacke or impure grey sandstone has furnished remains of Ostracoderm fishes. Ripple-marks have been observed in the formation.

Conclusions.

The Knoydart formation is of continental, and probably of estuarine origin, and was deposited unconformably upon the preceding strata of the Arisaig series.

This formation was down-faulted along the major fault zone of the region and as a consequence assumed the structure of a more or less broken syncline pitching southwest.

The age of the Knoydart formation is, as already shown by Ami, lower Devonian and may be closely correlated with some of the Old Red Sandstone formations of Great Britain.

MCARAS BROOK FORMATION.

Observations.

The coarse conglomerates and limy grits of the McAras Brook formation, as exposed along the shore of Northumberland strait, measure (according to Fletcher) about 940 feet in thickness. They overlie the Knoydart formation with a marked angular unconformity, so that in places the Knoydart strata are overlain by the Ardness or the formation overlying (apparently conformably) the McAras Brook strata. The McAras Brook formation also overlies the Arisaig series, but the contact is obscured by intrusive sheets of diabase. In the south and west of the district the conglomerates rest on steep contact surfaces of the metamorphic slates and quartzites of the Browns Mountain group, and on intrusive rocks cutting the metamorphics. The lowest beds of the McAras Brook formation are mostly composed of angular fragments of the older rocks. In the eastern part of the district beds of oil-shale are interstratified with the grey grits overlying the red sandstone and conglomerates. Towards the top of the formation at Big marsh, which is east of the area of special study, thick beds of oil-shale and "coal" have been reported.

The McAras Brook strata dip away from the older formations at low angles, and but rarely have disturbed conditions or dislocations been observed. The great fault along the Hollow did not disturb the strata and in places the fault zone has been overlapped, according to the work of Fletcher, by the Ardness formation.

The sediments of the McAras Brook formation, especially in its upper part, are essentially the same as the sandstone and grit deposits that succeeded the basal limestone of the Ardness formation.

No evidence was obtained by the writer that could be interpreted as indicating that the Ardness formation overlies the McAras Brook formation unconformably.

Conclusions.

An erosion interval preceded the deposition of the McAras Brook strata, which everywhere overlie the older formations unconformably. The sediments of the formation probably were the result of continental deposition under climatic conditions of seasonal rainfall. Later, however, shallow marine conditions followed, as is indicated by the lime contained in the upper beds, and more especially by the bed of limestone which forms the base of the succeeding formation. The oil-shale and associated grey sandstone containing plant remains were probably deposits laid down in local basins and swamps.

The deposition of the McAras Brook sediments was after the time of the great fault located along the Hollow, and the strata have suffered only gentle flexing, forming shallow synclines or basin structures where they are bounded on two sides by older formations.

The McAras Brook formation is probably of Mississippian (Lower Carboniferous) age. A period of erosion and dislocation followed the laying down of the lower Devonian strata and preceded the deposition of the McAras Brook sediments. These were apparently immediately succeeded by the Ardness formation of undoubted Mississippian age.

ARDNESS FORMATION.

Observations.

The Ardness formation is made up of a 20 foot basal member of limestone, and 2,025 (Fletcher) feet of red sandstone and red and grey sandy shale, as exposed in section along Northumberland strait. In the south of the district the limestone is followed by about 200 feet (estimated) of red sandstone, shale, etc., which is overlain by perhaps 200 feet of gypsum deposits, succeeded by an amount of sandstone and shale as yet unmeasured.

The contacts with the McAras Brook formation were, as already stated, apparently conformable. The strata of the Ardness formation in the north dip to the northwest and those in the south to the southeast, in all cases at low angles. No important disturbances of any kind have been observed in the beds.

Numerous brachiopods and some ostracods were obtained from the limestone west of McAras brook (see page 78) and plant remains are common in some of the grey shales higher up in the formation. The latter remains are generally very poorly preserved.

Age and Correlation.

From the evidence furnished by the brachiopods obtained from the limestone, this formation is definitely correlated with the Windsor series, which contains several beds of limestone and much gypsum and is of Mississippian (Lower Carboniferous) age.

LISTMORE FORMATION.

Observations.

Red and grey sandstones, 982 feet in thickness (as measured by Fletcher), make up the Listmore formation. These strata outcrop on the seashore at the extreme northwest corner of the district of special study, but were examined for a considerable distance farther to the west. In general characters of colour and composition this formation can scarcely be distinguished from the preceding one, but it tends to have a larger proportion of beds of grev colour. Numerous imperfectly preserved plant remains are embedded in the sandy shales.

The one contact examined is confused by a small fault, but the beds on each side strike and dip the same and no unconformity with the Ardness formation could be detected. The beds of the formation dip to the northwest at angles varying from 10° to 20° and with the exception noted, no faulting or flexing was observed.

Conclusions.

The origin of the Listmore sandstones and shales is clearly continental, and so far as this region goes they appear to represent a continuous deposition with the Ardness formation.

The Listmore formation was previously set off by Fletcher and called the "Millstone Grit," and in deference to his wider experience it is provisionally correlated with that formation as occurring in Nova Scotia, and hence is considered of Pennsylvanian (Upper Carboniferous) age.

QUATERNARY DEPOSITS.

Observations.

Something has already been said in this chapter, under "Physiography," about clay and gravel deposits. Red, marly clay overlain by unbedded, clay-gravel deposits in places 40 feet or more in thickness, hog-back ridges, and blanket deposits of clay and gravel occur in many places in the district. The pebbles of such deposits are sub-angular and frequently scratched. Stream gravel deposits are found along the lower courses of many of the brooks and small rivers.

Conclusions.

Glacial ice traversed the whole region, taking a course about 34° east of south on the plateau and nearly southwest on the northern lowlands of the Arisaig-Antigonish district. It has been stated by other observers that transportation was northward, but the evidence furnished by rhyolite blocks scattered over fields south of the rhyolite outcrops and many feet above their source does not admit of such a theory. When the ice retreated, numerous till deposits were left behind, and these appear to have been modified near their surfaces by water action, doubtless by streams that had their source in the vanishing glacial ice.

The recent stream gravels, as already stated, are probably mostly due to the result of spring floods, but may suggest a recent rejuvenation of the land.

IGNEOUS INTRUSIVES AND EXTRUSIVES.

ACID ROCKS.

Observations.

Granite of a dense contact character cuts the lower Browns Mountain rocks, in the form of a stock. Small pink rhyolite dykes cut the metamorphic rocks in many places, and dark purple rhyolite, with tufaceous phases, cuts these rocks as irregular intrusions breaking through the slate and forming in one case, a small neck. The purple rhyolite was found to grade into quartz porphyry, which cuts the Browns Mountain rocks as irregular intrusions and small stocks or necks. At the base of the Silurian section is an old rhyolite flow, probably about 200 feet in thickness. Upwards the rhyolite grades into flow breccia and the upper portion is a decided breccia. Considerable devitrification of the rhyolite has taken place. Monzonite as an irregular intrusion or small stock has cut the lower Browns Mountain rocks.

Fragments very similar to all the above igneous rocks, with the exception of the quartz porphyry, have been recognized in the Malignant Cove conglomerate of supposed middle Ordovician age. (The examination was carried on both megascopically and microscopically). The microscopic examination of the various rocks showed a similarity in the mineral composition and texture of all the phases of rhyolite as well as the quartz porphyry.

Conclusions.

As a result of the observations synopsized above, it is thought that all the acid intrusives belong essentially to one main period of disturbance. If the age of the Malignant Cove conglomerate is rightly interpreted as being Ordovician, and if its fragments really represent all the intrusive rocks, then the igneous activity occurred in post-Browns Mountain and pre-Malignant Cove time, which would probably confine it to the early Ordovician period.

BASIC INTRUSIVES.

Observations.

Diabase in the form of small vertical dykes, and occasionally as large dykes and irregular intrusive bodies, cuts all the sedimentary rocks (as well as nearly all the igneous rocks) as high up as the Ardness, the upper formation assigned to Mississippian time. Basalt generally occurring as irregular intrusions but perhaps in cases representing flows, has been recognized in a number of localities, generally associated with diabase. Soft "earthy" intrusives, usually of a dark red colour, have been observed in a number of cases, and a dark red fissile dyke varying in width from a few inches to 10 feet or more, has been traced for about 2 miles. This dyke cuts the rhyolite flow at the base of the Silurian strata and also cuts a large irregular diabase dyke which extends for 3 miles along the shore. In places the dyke branches and penetrates the diabase along joint planes. The material of this intrusive proves when examined microscopically, to be mainly a mass of secondary iron oxide; but fragmental material is also present, including shards that were probably once glassy. In one place, amygdaloidal basalt cuts diabase and the red dyke cuts both diabase and basalt.

Conclusions.

No intrusives of any kind have been observed to cut the Ardness formation. Diabase does cut the McAras Brook formation and hence diabase activity probably occurred in Mississippian time after the deposition of the McAras Brook conglomerate and before the laying down of the Ardness limestone. So far as evidence goes, the diabase intrusion took place during one period of eruption. Both basalt and the red dyke are later than the diabase where the three occur together, but as none is known to cut the Ardness formation it is probable that they all belong to the same period of eruption.

The red dyke is clearly of a breccia character and its association with the basalt suggests that its origin was the result of pulsating injections of molten magma into a fissure which approached the surface of the earth.

TUFF AND BRECCIA.

Some small deposits of tuff and breccia have been observed in various places. One in connexion with an iron ore "bed," is apparently interbedded with the lower formation of the Browns Mountain rocks, and, if so, is the oldest rock of igneous origin recognized in the district. Tuff phases have been observed in connexion with the rhyolite intrusions which have probably come nearly to the surface, and the conclusion is that extrusive activity accompanied the intrusion of rhyolite.

ECONOMIC DEPOSITS.

COPPER.

Observations.

In many places green copper stains occur in the Mississippian formations in connexion with plant remains, and some serious prospecting for copper has been done near Brierly brook. Ore is said to have been taken from one of the shafts sunk here, but only green stain of copper could be observed on the dump.

Conclusions.

So far as present indications go, there is no hope of finding workable deposits of copper in the Arisaig-Antigonish district.

IRON ORE OF ARISAIG AND ROSS BROOKS.

Observations.

An iron-ore bed over 2 feet thick on an average, occurs in the Silurian strata south of Arisaig. It contains many distinctive fossils and is loose and friable at the surface, but when fresh is firm and finely oolitic. The attitude of the strata is nearly vertical. Some ore has been removed from this bed, but the prospects are now abandoned, presumably because of the low grade of the ore.

Conclusions.

The bed is in a badly faulted zone and could not be depended upon to continue unbroken for any great distance. From its characters it is without doubt of sedimentary origin, and is approximately of the same age as the Clinton ores of the Appalachian region.

IRON ORE OF DOCTORS BROOK AND BROWNS MOUNTAIN.

Observations.

Near Browns Mountain post-office and in the locality of Doctors brook, oolitic hematite is apparently interbedded with the greywacke of the lower formation of the Browns Mountain rocks. In the former locality the ore "beds," which are two or more in number, vary from about 5 to 20 feet or more in thickness. The ore is evidently very siliceous. A part of the thicker "bed" is merely a grit impregnated with iron.

The ore "beds" of Doctors Brook vicinity are three in number and vary from 2 to 8 feet in average thickness. The thickest "bed" is very siliceous, but the thinner "beds" are freely oolitic, sparingly fossiliferous, and contain a fair percentage of iron (40-48 per cent). The iron-ore horizon is found near the base of the upper formation of the Browns Mountain group, which occupies a narrow belt to the south of the ore zone. The iron-ore "leads" have been traced for about 3 miles, the ore "beds" being nearly vertical all the way. Numerous small faults intercept the ore and its thickness is variable.

Conclusions.

From the evidence obtained, the ore is most probably sedimentary, is of lower Ordovician age, and may be directly correlated with the bedded hematites of Great Belle isle, Conception bay, Newfoundland. Small faults have been demonstrated as cutting the ore, but there appears to be no evidence of either extensive faulting or dislocation due to igneous intrusion between the East branch of Doctors brook and the west brook flowing out of the Little hollow. The ore beds are on the north side of a syncline and probably extend downwards without any serious change in attitude for several hundred feet. The faulting of the region appears to be mainly vertical, so horizontal displacements are not thought probable, but may exist. Much ore is already in sight and the main consideration is one of the grade of the ore, and expense in mining and transportation.

OIL-SHALE.

Observations.

Oil-shale has been discovered within the district in the vicinity of Pleasant valley and Maryvale. It is interbedded with the lower strata of the McAras Brook formation.

Conclusions.

As the formation containing the shale lies at a low angle, the oil-shale beds should not be buried to great depths. However, the thicker upper beds of shale found at Big marsh lie immediately below the basal limestone of the Ardness formation and probably have been removed entirely from the region about Pleasant valley and other localities in this district.

GYPSUM.

Observations.

According to the breadth of karst, or sink-hole, topography and the general dip of the formation, the gypsum beds in the vicinity of Brierly Brook station are estimated to measure about 200 feet in thickness. The gypsum stands as exposed cliffs 30-40 feet high for more than 1 mile along the Intercolonial railway near Brierly brook, and at other places similar exposures occur. The deposits are for the most part little mixed with foreign matter. However, water action has honeycombed the surface and doubtless much sand and gravel have fallen into the openings.

Conclusions.

Large quantities of gypsum are situated close to the railway inviting exploitation, and as soon as there is a sufficient demand for this material these deposits will be extensively worked.

LIMESTONE.

Observations.

Old lime kilns and lime quarries exist at a number of places along the limestone horizon north of the Intercolonial railway. The quality of the lime formerly burnt here is said to have been good.

Conclusions.

The workable limestone is probably not more than 20 feet thick, but the strata dip at low angles and much stone could be taken out by following along the strike of the bed.

GRAVEL.

Water worn gravel suitable for road metal and concrete work may be obtained from accumulations in the beds of the streams.

OTHER ECONOMIC DEPOSITS.

Although silver has been prospected for, none of any account has been obtained, and there are no indications of the presence of silver ores in the district.

Veins of calcite or quartz are not common and the chances are small for finding workable ores of any of the finer metals.

CHAPTER IV.

PHYSIOGRAPHY.

REGIONAL.

Northeastern Nova Scotia naturally falls under two main types of land forms, plateau-like uplands, and rolling lowlands. Of the former, the Cobequid plateau is the most conspicuous example, attaining a height of more than 1,100 feet, the maximum elevation on the mainland for the province. These "moun-' as they are termed, have an average width of 9 or 10 ..s and extend from Cape Chignecto on the Bay of Fundy, about 75 miles east to a point 10 or 15 miles southwest of Pictou. Here the flanking lowlands unite, occupying the country to the east for 10 or 12 miles. Farther to the eastward the plateau, usually spoken of as a part of the Cobequid mountains, again occupies a broad belt and continues without ,reak to Cape George. This second division of the plateau has been grouped by Daly[1] with the other highlands forming his great Southern plateau. The various highlands of the province have been recognized by him as remnants of an old land surface of slight relief which formerly included the whole of the Maritime Provinces of Canada. The remains of this surface to-day are preserved only on the resistant metamorphic and igneous rocks.

The lowland topography is everywhere rolling, and is marked by well graded slopes associated with meandering streams. Variations occur where low, crumbling gypsum cliffs with honeycomb tops grade off into ponds and sink holes; or where hogback ridges of gravel stand isolated and apparently unrelated to the land forms about them. The rocks underlying the lowlands are soft shales, sandstones, limestones, etc., of Silurian to Triassic age.

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[1] Daly, R. A. Bull. Mus. Comp. Zoology, Harvard Col., Vol. XXXVIII, pp. 75–104, 1901.

The transition from lowland to highland is generally abrupt. It is true that the lowlands increase in height towards their boundaries, but the eye seldom fails to detect the line along which the more abrupt slope springs, a slope which does not change in general character until it reaches the elevation at which it becomes tangent to the plateau level above.

LOCAL.

LAND FORMS.

GENERAL STATEMENT.

The Arisaig-Antigonish district contains both the highland and the lowland features characteristic of the Acadian region. Probably two-thirds of its area is highland. The lowlands form a border on the north and south, and occupy a broad tract across the southeast corner, which broadens to form the whole eastern-central area.

HIGHLANDS.

The highlands are underlain by metamorphic slates and quartzites of lower Ordovician age, which have been planed off irrespective of the great anticlines and synclines which are their chief structural features. From distant vantage points the surface is seen to deviate only little from a plain. Nearer examination discovers a mature topography, with gently rounded elevations now in process of dissection, and exhibiting stream gorges in places more than 100 feet deep. Above the gorge walls the slopes are in many places steep to the height at which they blend with the older surfaces.

Hills rising from the upland surface are rare, but are not unknown. McNeils mountain, 2 miles south of Malignant cove, is such a hill and is directly related to a resistant quartz porphyry neck which forms its centre. The peculiar rolling topography to the north of McNeils mountain falls below the general elevation of the plateau surface. Its characters are due to the stripping away of altered sedimentaries and fragmental volcanics from intrusive rocks that had approached close to the old surface. The best example of these conditions is to be seen in the Sugar Loaf hill of Malignant cove. As its name implies, it is an oblong cone in shape, or more accurrately two cones intersecting for three-fourths of their height. The base is the outer edge of a rolling highland which increases in elevation to the south and west until it attains the full height of the plateau surface. The centre of the hill is composed of altered rhyolite which forms two crests, one to the east and one to the west. These are separated by a sag with portions of the old slate cover still attached high up on its sides.

Westward the rhyolite is exposed to the base of the hill, but on the north and south, vertical slate walls stick to the rhyolite neck. Thus the preservation and shape of the hill are seen to depend upon the intrusive rock body. Likewise mounds and irregular outcrops nearby are characteristic of intrusive areas, streams and hollows existing above the slate rocks.

Conditions similar to that at Malignant cove prevail at the Sugar Loaf hill north of the town of Antigonish. Here the neck is of diabase.

According to previous measurements, the highest point of the plateau is McNeils mountain, which has an elevation of 1,010 feet. The divide of the plateau extends towards the southwest keeping close to the northern border, and gradually decreasing in elevation, the average height being probably about 900 feet. Judging from the direction of the stream courses there is a gentle slope of the plateau surface to the southeast, but as the direction of the streams may be due to former conditions it is not a trustworthy indication of the present slope. The barometric elevations taken, indicate merely that the plateau slopes gently to the south, the grade being not more than a small fraction of one per cent. The average elevation of the surface is probably a little over 800 feet.

The highlands of Antigonish county were clearly included by Daly in the plateau extending over Acadia and considered by him, from its analogy with regions to the south, to be of Cretaceous age. No evidence of the age of peneplanation is available in this district other than that it was post-Carboniferous. This is shown by the fact that Carboniferous formations occupy valleys whose sides were truncated by the peneplain.

LOWLANDS.

General Statement.

The contrast between the topography of the highlands and that of the lowlands, is responsible perhaps more than anything else for the peculiar beauty of the landscape in this part of Nova Scotia.

No matter what the characters of the underlying rocks, the lowland topography consists of confused groupings of rounded hills and knolls, separated at intervals by meandering streams. However, as the topography falls into natural subdivisions corresponding to differences in the underlying rocks, these subdivisions will be described in turn.

The Shore Front.

The area lying between Northumberland strait on the north and the Hollow with its rising wall of metamorphic rocks on the south, is a physiographic unit. Westward the high rolling hills above the Devonian rocks give place to gentle seaward slopes at the border of the Carboniferous area. Eastward the hills become successively lower, being cut off by the sea at Malignant cove, where the Hollow becomes tangent to the shore.

The highest elevations of this area lie on a line south of the centre and extend approximately parallel with the sea coast. In the west the elevations approach that of the plateau to the south, while in the east the higher hills are about 200 feet above the sea. The main features of the topography are characteristic of a mature erosion cycle. Beneath the well graded valley bottoms the streams were later incised and now occupy rock walled gullies many feet in depth. In the west of the area these are characterized by falls or rapids a short distance back from the sea shore. On the less resistant Silurian rocks to the east falls and rapids are unknown and the lower portions of the brooks often meander through a flood-plain deposit of gravel 4 to 6 feet in thickness.

Besides land forms related to rock structures, a number of hog-back gravel ridges are common in the vicinity of Arisaig. Such a ridge to the east of Arisaig brook extends from a hillside northward for many rods. The top, which is at an elevation of more than 200 feet, is only a few feet wide and is almost perfectly straight. Small sub-angular pebbles derived from the Silurian rocks and embedded in a matrix of clay make up these hills, and although critical evidence was not obtained the material appears to be of glacial origin. Such an origin seems probable since these land forms cannot be harmonized with the present drainage system; and glacial striæ occur on the Silurian rocks but a short distance to the south. Similar gravel deposits from 50 to 70 feet thick are exposed along the shore. Rough sorting and even distinct bedding are occasionally present, but more generally large boulders and fine gravel are intermixed.

The gravel banks along the shore rest upon bevelled rock formations reaching a height of 10 to 20 feet above the sea. This bevelling appears to be related to the old "sea beaches" at the mouth of McAdams brook which were described by Twenhofel.[1]

To the east of this brook three well-defined terraces are exposed for 350 yards along the north-sloping hillsides. The lowest lies between the approximate levels of 15 and 25 feet, the second between the levels of 60 and 85 feet, and the third between the levels of 125 and 145 feet above high tide. There is an apparent tilt of the terraces to the east. However, it should be noted that although the levelling upon which these observations are based, was done with considerable care, the secondary slopes and terraces confuse the larger features to such an extent that accurate conclusions based upon these limited exposures cannot be drawn.

Two hypotheses are proposed to explain the terraces: (1) that they are due to differential erosion on hard and soft rocks and (2) that they are old sea beaches cut by the waves and tides

[1] Twenhofel, W. H. Loc. Cit., p. 147.

during halts in the uplift of the coast, relative to the sea-level. In support of the first hypothesis we have the evidence that hard irregular outcrops of rock are exposed along the inner edges of the terraces, and the strike of the strata corresponds roughly to the direction of their edges. However, the outcrops have steep seaward slopes suggesting active abrasion directed from the north. In support of the sea beach origin of the terraces, the gradients of the cross sections are very significant. It is readily seen that the present sea beach has a slope to seaward corresponding to that of the terraces, and the rise from it to the first terrace is of the same general character and magnitude as the rises between the successive upper terraces. Furthermore, to the west of the area mapped, Knoydart or Mill brook flows in its lower course through a gravel flood-plain about 30 yards wide which is cut below the surface of a much wider flood-plain approximately 10 feet higher. This would indicate either that there has been a comparatively recent climatic change which has increased the erosive activity of the stream, or else an uplift has occurred, corresponding in amount to one-half the present elevation of the first terrace described.

Along one line of section, a small intermediate terrace occurs between the present sea-level and the first terrace. The elevation of the intermediate terrace is about 10 feet above high tide, and while poorly preserved here corresponds almost exactly in level to the bevelled top of the soft Silurian shales overlain by gravel but well exposed eastward as far as Ross brook. Small gravel flood-plains along McNeils and neighbouring brooks, now stand 6 or 7 feet above the present stream channels and may or may not be related to this 10-foot terrace.

The balance of evidence for this locality is plainly in favour of the old sea beach origin of the terraces, as already proposed by Twenhofel. However, such limited observations as the above are of value only as they become part of the broader study of the relations of the land to the sea along the coast line of the Maritime Provinces.

The "Hollow" has already been mentioned as forming the southern boundary of the shore-front lowlands. It is a structural valley which extends in line with the coast from Cape

George, southwest from Malignant cove across the area mapped and several miles beyond. Along its extent the Hollow divides the plateau of lower Ordovician rocks from the lowlands of later age and has long been recognized as the location of a great fault. The bottom of the valley is flat, occasionally swampy, and is followed by streams (part of which flow northeast and part southwest) for nearly its entire length. To the south rises the formidable scarp which extends to the plateau level above, and to the north rise more gentle slopes, the sides of the hills surmounting the younger formations.

Carboniferous Lowlands.

On the east and south of the Arisaig-Antigonish district, lowlands underlain by rock formations of Mississippian (Lower Carboniferous) age, are the prevailing type of topography. As already described, the southeastern quarter of the area is for the most part lowland. To the southwest the highlands extend far south, leaving only a narrow belt of lowlands within the area studied.

Rolling hills with smooth contours and complex stream systems, exhibiting meanders and gravel flood-plains, are characteristic of the Carboniferous lowlands. Along the extreme south, extending only as far north as the Intercolonial railway, the surface of the country is made up of low gravel covered domes lying between the crooked branches of a complex drainage system. The underlying rooks are composed of sandstone belonging to the Windsor series and the topographic forms are the same as those over the same rocks west of the Devonian area along the shore. The Intercolonial railway has followed a valley immediately above the outcropping of the limestone and gypsum beds at the base of the Windsor series. Seldom is the solubility of rocks so expressed in a continuous valley form as may be here seen. Sinkholes, ponds, gypsum cliffs, and stream courses are followed by the railway across the whole district. Karst topography is very characteristic of this narrow valley which is generally less than one-half mile wide.

It appears like a coincidence that to the westward the valley eroded from he gypsum horizon should join a narrow valley of similar breadth eroded from a narrow deposit of Lower Silurian strata lying in a trough in the lower Ordovician metamorphic rocks. In this western valley, karst topography is absent.

The remainder of the Carboniferous lowlands, underlain by the lower conglomerate (McAras brook) formation, rise to considerable heights. West of North Grant an elevation of 500 feet is probably attained. The hills north and south of this place consist of interstream domes and north-south ridges, corresponding in arrangement to the direction of the stream valleys. Gravel covers most of the hills and near Maryvale forms whole ridges which are unrelated in origin to the present drainage. In some cases these hills have influenced the courses of streams.

The transition between the Carboniferous lowlands and the highlands is everywhere abrupt. The elevations of the lowlands increase as foothills rise on a mountain's flanks, but these cannot be confused with the scarp-like slopes of the sides of the plateau. Although the boundaries between the two formations are sinuous, the head of Pleasant valley is the only place where the contact of Carboniferous and lower Ordovician rocks, although covered by drift, cannot be mapped with reasonable accuracy from the surface forms.

The geological period during which the lowlands received their characteristic shapes cannot be told from this region owing to the lack of all sedimentary records representing the time from the Carboniferous to the Quaternary. Daly has provisionally correlated the Carboniferous lowlands of Pictou county and elsewhere with the Tertiary lowlands of the eastern United States. The lowlands of Antigonish county agree in their main characters with those of Pictou, but rise to greater elevations in certain parts. Thus Daly speaks of an average elevation of 200 feet for Pictou, and a number of the hills of Antigonish are over 400 feet in height. It is worthy of note, however, that the higher hills lie in a valley between plateau areas and descend to stream courses between 100 and 200 feet above sea-level. Again, the highest hills are topped by glacial materials and just how much of their height is due to glacial upbuilding has not been determined. The lowlands of the Silurian and Devonian areas correspond closely to the higher divisions of the Carboniferous areas and are probably related to the same erosion cycle.

DRAINAGE.

The streams draining the front of the area start in the highlands about 4 miles from the shore and flow in a northerly direction. In a short distance they leave the gentle slopes of the plateau surface and enter deep gorges. In one instance a descent of more than 400 feet occurs in less than a mile. Bouldery beds, interrupted by rapids and falls, are followed to the fault scarp of the Hollow. Here the smaller streams cascade down rocky beds worn but a few rods back from the scarp front.

The larger streams have come more nearly to grade and flow across the Hollow or turn along it without irregularity in their beds. From the Hollow onwards, the stream channels are well graded, until they approach the shore, although all brooks flow through rocky ravines in crossing the Devonian and Silurian hills. Near the shore, rapids and falls occur over which the water tumbles on its way to the ocean. In the larger streams these falls are frequently one-half mile inland, but the smaller streams of local origin in many cases tumble over the present sea cliff. Gravel flood-plain deposits have already been described in relation to the raised terraces. There is plenty of evidence that spring freshets carry down considerable volumes of gravel and deposit it along the lower graded portions of the streams.

The south flowing streams start from the highland divide near the heads of the north flowing streams. They make their way southward across the plateau for several miles and then collect in the tributaries of the West river, which flows eastward through Antigonish harbour into George bay. On the plateau the stream courses are comparatively straight and appear to be consequent upon a tilt of the old peneplain surface. As a result of uplift of the region they have become incised, often occupying narrow valleys 100 feet or more in depth. Rapids and falls are common in the upper reaches, particularly where tributary streams join the main channels. The highest known fall is that on the James river which, with the rapids below, is 75 feet. The lower portions of the streams, before reaching the lowlands, are well graded and in the case of James and Rights rivers full of meanders. On the Carboniferous lowlands, some of the streams become lost in the karsted country, but most of them meander to the eastward over gravel beds flanked by grass grown bottom lands.

Near Antigonish various streams unite with West river. At the junction and for some distance up these streams, the bottom lands are wide and being very fertile yield large crops of farm and garden produce. These rich bottom lands are locally known as "intervales," a word common in the early literature of this district. At Antigonish and to the east, the intervales become [illegible] distances from the river and no further explanation of their origin seems necessary than that they are flood-plains which have received the finer deposits brought down by the streams during flood or during a period when the land was relatively nearer the level of the water than at present.

Malignant brook is an example of a stream flowing for its whole length, with the exception of the last mile, over Carboniferous rocks. It is well graded and has meanders and gravel deposits characteristic of the lowland streams. An interesting case of reversed direction of flowage is seen west of Maryvale, where a tributary flowing southeast across the plateau joins Malignant brook on the lowlands and flows with it to the northwest.

CHAPTER V.

STRATIGRAPHY.

INTRODUCTION.

The purpose of this chapter is to desciibe the various sedimentary formations found in the Arisaig-Antigonish district, to explain as far as possible their origin, and to fix their age and correlation as far as can be done with the evidence at hand. References to location and extent will be brief and no more will be said about structure than is essential to the understanding of the relationships of the formations to each other. The general and structural geology will be dealt with in the succeeding chapter.

Table of Formations.

Era.	Period.	Formation.	Former name (Fletcher).	Lithological description.	Thickness (feet).	Associated igneous rocks.	Correlation.
Quaternary	Recent..........	....	....	Stream gravels and residual soils; modified glacial gravels.	0–15	....	....
	Pleistocene.......	....	....	Unstratified clay-gravel deposit..	0–40	....	....
Palæozoic..	Pennsylvanian (?) (Upper Carboniferous).	Listmore........	Millstone Grit.	Grey and red-brown sandstones; thin argillaceous shale; thin green conglomerate.	982±	....	Millstone Grit ?
	Mississippian (Lower Carboniferous).	Ardness........	Carboniferous Limestone.	Red-brown and green, sandy shale; ripple-marked sandstone and shale; gypsum; grey limestone.	2,045±	....	Part of Windsor series.
		McAras Brook..	Carboniferous conglomerate.	Limy, grey shale; green shale; cross-bedded conglomerate; breccia and basal conglomerate.	1,145±	Intrusive diabase sheets.	
	Lower Devonian	Knoydart......	Upper Devonian.	Red, sandy slate; hard grey sandstone.	683+ (probably 1,000+	Small diabase dykes.	Lower Old Red sandstone.
	Silurian..........	Arisaig Series Stonehouse.	Lower Helderberg.	Red and grey shale, argillaceous limestone.	1,075	....	Ludlow (in part).
		Moydart.......	Niagara.......	Red shale; argillaceous limestone; grey shale.	379	....	Louisville (U. S.) Wenlock (Eng.)
		McAdam......		Black shale; argillaceous limestone; iron ore.	1,120±	....	Rochester (U. S.) Up. Llandovery (Eng.)
		Ross Brook....	Upper Clinton. Lower Clinton.	Green shale with thin sandstone; dark, papery shale.	833+	Basalt (?) Obscure intrusives.	Clinton (U. S.) Low. Llandovery (Eng.)
		Beechhill Cove	Medina........	Sandstone; limestone; shale.......	200±	....	
	Ordovician (?)....	Malignant Cove (upper contact not known).	Bears Brook...	Silicified grit; coarse, cross-bedded conglomerate.	20+	Irregular basalt dykes.	
	Close of lower Ordovician (?)	....	....	Volcanic breccia; aporhyolite flow	200±	Diabase, basalt, and breccia dykes	
	Lower Ordovician	Browns Mountain Group. Baxters Brook.	Baxters Brook.	Red and grey, sandstone and schist; red and green slate.	500± (estimated)	Intrusive rhyolite, quartz porphyry, diabase, and basalt.	
		James River....	James River....	Flinty greywacke and grit; silicified, banded slate.	5,000± (estimated)	Intrusive rhyolite, quartz porphyry, granite, monzonite, diabase, and basalt.	

REMARKS.

In the accompanying table, a number of new formational names have been used instead of the older terms of Fletcher. For the most part the stratigraphy and larger questions of geological structure as described by Fletcher, are adhered to, but since the old formational names, in certain cases, imply the acceptance of views concerning correlation and general geological conditions that are not supported by the information at hand, it has seemed best to adopt the proposed scheme of nomenclature. In the table the older usage of Fletcher is indicated.

For the metamorphic rocks of the highlands the term *Browns Mountain group* is proposed. The formational names James river and Baxters brook are retained, as Fletcher quite clearly defined his terms and included these rocks specifically under them in his report of 1886. Fletcher himself was not sure that any of his Bears Brook formation occurred within the Arisaig-Antigonish district and *Malignant Cove* is proposed as the name of the formation represented by conglomerates and grits at the place of that name.

Arisaig series is retained, in the sense used by Dawson, to include all the formations of Silurian age. For the lowest member of the Arisaig series, the name *Beechhill Cove formation* (from the place where the best exposures occur) is proposed instead of the term Medina used by Fletcher. For the next formation the term Arisaig proposed by Ami has to be discarded in order to retain it for the name of the series, and the name *Ross Brook* is proposed in its stead (near the mouth of this brook the formation is well exposed). For the upper three formations the names McAdam, Moydart, and Stonehouse as proposed by Ami and defined by Twenhofel are adopted. Ami's term Knoydart is likewise used as he defined it, as the formation name of the Devonian rocks of McAras brook.

For Fletcher's Carboniferous Conglomerate and Limestone formations, the names McAras Brook and Ardness are respectively applied. The latter is certainly equivalent to a portion of the Windsor series as defined by Dawson and Ami; but because of local variations and uncertainty as to limits, and because of the various interpretations connected with the older terms, it seems best to use local formational names. Likewise, instead of Millstone Grit as used by Fletcher for the formation above his Carboniferous limestone (Ardness), the term *Listmore* is proposed.

BROWNS MOUNTAIN GROUP.

EXTENT AND AREA.

The rocks of the Browns Mountain group occupy the plateau areas of the district, that is, the central and western part and the southeast corner. Their lower contacts have not been observed, but they everywhere unconformably underlie the younger formations. The greywacke, slate, etc., of the group are highly metamorphosed and have long been recognized as forming a metamorphic province.

GENERAL CHARACTERS.

The Browns Mountain rocks consist of a lower member of great thickness (estimated at 1 mile±) of greywacke varying to impure quartzite, interbedded with banded slate of a very siliceous nature; and an upper member, perhaps 500 feet thick, of red slates, and some sandstone. These rocks have been intruded by a granite stock at James river, by a monzonite stock east of Malignant cove, by rhyolite and quartz-porphyry necks south of Malignant cove, and at various places by irregular intrusions of diabase and basalt, and by rhyolite and diabase dykes.

MODE OF ORIGIN.

The alternation of greywacke and slate suggests that these thick deposits were the work of a transgressing sea. The red slates of the upper division may be the result of a change from a cooler and moister to a warmer and drier climate, so that the land waste was oxidized before it reached the sea, as the fine, even character of the slates hardly suggests subaërial conditions of deposition.

FOSSIL CONTENTS AND AGE.

Fossils were obtained from the iron ore zone placed in the lower but situated near the boundary of the two divisions. Both the iron ore north of the Little hollow, and a schistose, micaceous sandstone associated with the ore on the East Branch of Doctors brook furnished fossils. These have been determined by Professor Schuchert as *Obolus* (*Lingulobus*) *spissa* and *Lingulella* (?). The former occurs at Belle isle in Conception bay, Newfoundland, in strata which are of lower Ordovician age.[1] The lower division (James River formation) is, therefore, regarded as belonging to lower Ordovician time; and because of the conformable succession of the upper division and the position of the fossils close to its lower contact, there seems little doubt that the Browns Mountain group all belongs to this period of deposition.

CORRELATION.

Dawson (see "Historical Geology") included the Browns Mountain group in his Cobequid series, which was made up of a lower group of volcanic and intrusive rocks and an upper group of altered sedimentaries. Fletcher has referred the group to the Cambro-Silurian system, using Silurian in the sense of "Lower Silurian" or Ordovician.

JAMES RIVER FORMATION.

The James River formation underlies all the area of the metamorphic province excepting a belt south of Malignant cove,

[1] Since the preparation of this manuscript A. O. Hayes has found *Didymograptus nitidus* along with *Obolus* (*Lingulobus*) *spissa* in the iron ore horizon of Belle isle, Newfoundland, and consequently the age of the formation is to be considered lower Ordovician.

which is occupied by the next higher formation and by igneous rocks, and areas at James river and elsewhere occupied by intrusive rocks. Granite, monzonite, rhyolite, diabase, and basalt cut the James River formation.

From the broad surface extent of strata that are thrown into great regional folds, it is estimated that this formation is at least 1 mile in thickness.

The James River formation is thought to be the same as the James River division of the "Cambro-Silurian" rocks as described by Fletcher. With the exception of the grits of Rogers brook, he clearly included in his division all the rocks at present described under this heading. The grits of Rogers brook were correlated with the grits and conglomerates of Malignant cove. However, the writer cannot agree with such a correlation, as the Malignant Cove formation is clearly unconformable with the James River slates, whereas the Rogers Brook grits are interbedded with those slates and in reality never reach a conglomeratic stage, being little coarser than some of the greywacke elsewhere observed.

The James River rocks consist of interbedded greywacke and slate, the latter probably predominating. Towards the top of the formation and also probably at a lower horizon, iron ore beds occur, and in one instance a tuff bed is associated with the iron.

The greywacke varies from impure grey-green and occasionally nearly white quartzite, to a rather coarse grit showing small points or angular grains of jasper (?). The grey phase when studied microscopically, may be seen to consist of small rounded to sub-angular quartz fragments about 0·1 mm. across, similar fragments of plagioclase (andesine was recognized) occasionally as coarse as 0·2 mm. across, and finer quartz, mica, and other materials.

The slate is usually banded, dark grey and light olive grey alternating in layers less than 1 inch in thickness. In places the colour is entirely greenish grey. The texture is very fine and even, and as a result of silicification the slate is in many cases harder than steel. Jointing is common, but cleavage usually follows the bedding planes.

Iron-ore "beds" occur near Browns Mountain settlement and in the vicinity of Doctors brook. The ore "beds" of Browns mountain are exposed in a limited number of prospect trenches and are two or more in number. The western exposures represent a broad zone of coarse grit perhaps 20 feet thick, impregnated with hematite. The "beds" exposed to the east are only a few feet thick and are less siliceous than those farther west. In the vicinity of Doctors brook at least three "beds" of iron ore have been discovered and although varying greatly in thickness from place to place, the "leads" have been shown to extend in a northeast-southwest direction a distance of more than 3 miles. These "beds" vary from 10 feet to less than 1 foot in thickness, the thicker "beds" consisting of iron impregnated grit, and the thinner "beds" being made up of oolitic hematite occasionally containing fossils and always more or less siliceous. On the hill where an old wooden tram-way previously terminated, volcanic breccia occurs in association with iron ore and is apparently interbedded with it. The writer obtained fossils from ore north of the Little hollow and Woodman (1909) mentioned the ore as containing "shells" at several places. The wide extent of the iron ore, its oolitic character in many of the "beds," and its content of marine fossils show a marked similarity to the well known Clinton iron ores which are now regarded by the best authorities[1] as of contemporaneous deposition with the sedimentary formations.

BAXTERS BROOK FORMATION.

The rocks of this formation are confined to a portion of the metamorphic province south of Malignant cove, extending about 5 miles east and west and 1½ miles north and south at its widest part. They are interrupted by belts of the James River forma-

[1] Eckel, E. C. U. S. Geol. Surv., Bull. 400, pp. 26–39, 1910.

Newland, D. H. Amer. Inst. Mn. Engrs., Bull. 27, pp. 265–283, 1909. N. Y. State Mus., Bull. 123, pp. 1–18, 41–53, 1908.

Smyth, C. H., Jr. Amer. Jour. Sci. (3), Vol. XLIII, p. 487 et seq., 1892.

McCallie, S. W. Geol. Surv. Ga., Bull. 17, pp. 29–35, 104–194, 1908.

tion and by many intrusive bodies, including rhyolite, quartz-porphyry, diabase, and basalt. The thickness of the formation is estimated to be approximately 500 feet as here represented.

The red slates and sandstones of this area agree with Fletcher's description of his Baxters Brook rocks and were included by him in his description of that formation (1886, pp. 25–26 P). Many igneous rocks and grits are also described under this formation, but in the present work the term is restricted so as to include only the red slates (and leached slates of light creamy colour) with thin beds of sandstone and sandy schist as represented in the area described.

The red slates are of fine texture and readily cleavable. In the vicinity of intrusive bodies they are frequently much twisted and contorted. In some of the streams, notably a small brook northwest of Maryvale, the colour of the slates has disappeared, evidently as a result of reduction and leaching of the iron during weathering.

In the vicinity of the iron ore "beds," greenish-grey, micaceous, schistose sandstone occurs and in McNeils brook, brown grits and fine grained sandstone are found. It was in the schistose sandstone that linguloids were seen and this is probably near the base of the Baxters Brook formation. Fletcher has also included the iron-ore "beds" in this formation, but because of the constant presence of greywacke, generally on both sides of the iron ore, the ore "beds" are included in the James River formation.

MALIGNANT COVE FORMATION.

This formation of coarse conglomerates and grits, outcrops east of the pond at Malignant cove and for one-half mile south of the cove along the Gulf road. It rests, as seen at the pond, upon cleavage surfaces of James River slate, the contact dipping southwest at a high angle. The observed thickness of these sediments is about 20 ± feet, but the original thickness was probably much greater. Along the Gulf road irregular basalt dykes have cut the grit and conglomerate, and diabase has penetrated it at Malignant pond.

The coarse conglomerates lie in irregular beds, exhibiting pockets of finer material and cross bedding. Almost no sorting is to be seen, although the cobbles and pebbles are well rounded. The grits to the south are of uniform character and no bedding could be distinguished. The formation is of a dark red, or purple colour. The above characters suggest subaërial deposition, marked at first by strong current action and later by quieter, less turbulent stream conditions.

The coarse conglomerate is made up of rounded cobbles, some as large as 6-8 inches in diameter, mixed with fine gravel and sand. The coarse material consists of purple rhyolite, pink quartz, greywacke, etc. The finer grit, when studied under the microscope, is seen to consist of sub-angular fragments of rhyolite, quartz, tuff, and greywacke, besides isolated fragments of micropegmatite and plagioclase feldspar. Many of the fragments show evidence of crushing. The secondary products are iron oxide, chlorite, calcite, sericite, and much fine interstitial quartz.

This formation was included by Fletcher in his "Cambro-Silurian" system and was thought by him to belong either to the Bears Brook or the Baxters Brook division (1886, pp. 19 P and 24 P). Because of the lapse of time between the James River deposition and that of the Malignant Cove formation as represented by the unconformable contact along cleavage planes of James River slate, it does not seem probable that this formation was deposited during earliest Ordovician time. On the other hand, in degree of silicification the Malignant Cove conglomerates and grits resemble no other rocks of the region so closely as those of the Browns Mountain group. Until further evidence of the age of these rocks is produced they will be classified provisionally as belonging to the middle part of the Ordovician period.

Fletcher compares these rocks with conglomerates and grits at Georgeville and at Marshy Hope, but as the writer has not seen these occurrences definite correlation cannot be made at the present time.

Divisions and Correlation Table of Arisaig Series.

Honeyman	Dawson	Fletcher	Ami	Twenhofel 1909.				Williams 1912
1864.	1868, 1891.	1886	1901.	Divisions.	Characters.	European equivalent.	American equivalent.	Nomenclature and additions.
Division D (Upper Ludlow).	Upper Arisaig (Lower Helderberg or Ludlow).	Lower Helderberg 1038′	Stonehouse formation	Division IVb or Stonehouse formation.	Red shales and limestones 97′ Argillaceous limestones and shales 978′	Ludlow.	Guelph of interior America.	Stonehouse formation 1075′
Red Stratum.		Red Stratum.	Moydart formation.	Division IVa or Moydart formation.	Red Stratum 32′ Argillaceous limestones and shales 347′	Upper Wenlock of Norway.	Middle Niagaran (Waldron and Louisville).	Moydart formation 379′
Division C (Aymestry limestone).		Niagara 1293′	McAdam formation.	Division III or McAdam formation. Fault.	Dark shales Dark shales and argillaceous limestones 1020′	Upper Llandovery including probably Wenlock.	Rochester	McAdam formation including iron-ore horizon 1120+′
Division B′ (Lower Ludlow).	Lower Arisaig Clinton or Upper Landovery.	Upper Clinton 148+′	Arisaig formation.	Division II or Arisaig formation.	Green shales with thin sandstones. Dark shales with thin sandstones 833+′	Lower and possibly part of Upper Llandovery of Norway.	Eastern New York Clinton.	Ross Brook formation 833+′
Division B 170′ (Lower Ludlow).		Lower Clinton 345+′						
Division A (Mayhill sandstone) approx. 200′ (included basal volcanics).		Medina 182′		Division I	Sandstones limestones and shales 160′(?)	Lower Llandovery	Clinton	Beechhill Cove formation 200±′

ARISAIG SERIES.

EXTENT AND AREA.

The rocks of the Arisaig series occurring in the Arisaig-Antigonish district, occupy an area along Northumberland strait from Malignant cove west to McAras brook. On the southeast they are cut off from the lower Ordovician formations by the great fault along the Hollow, and on the west and south they are overlain by Carboniferous and Devonian strata. The area extends 6 miles along the shore and is about 1½ miles wide.

CHARACTER.

The formations of the series are composed of shales, thin bedded sandstones, and arenaceous and argillaceous limestones. Near the base of division III is a bed of hematite containing many fossils. The shales vary in character from black and carbonaceous with papery cleavage, to grey or red with coarse arenaceous texture. The limestones are rarely pure and are grey to greyish green in colour.

The conformable relations of the formations and the gradual evolution of the entombed faunas are evidence that the 3,500± feet of the Arisaig series were formed during one continuous period of sedimentation.

MODE OF ORIGIN.

The arenaceous character of nearly all the sediments, the lenticular deposits of fine-grained sandstone, together with cross bedding, red shales and many examples of ripple-marks, especially in the higher formations, indicate varying degrees of shallow water, littoral conditions.

FOSSIL CONTENT.

Twenhofel says of the fossil content of the series:—

"The rocks, in general, are fossiliferous throughout; only one stratum, the 'Red Stratum' of authors, being without organic remains. They are particularly abundant in the upper red shales and flags, and at many horizons in the middle and lower shales. The impure limestones as a whole contain few fossils, but a series of intercalated nearly pure limestone lenses have them in more than ordinary abundance. These lenses are of two classes: the one wide, but thin, contains merely fragments; the other, about three times as wide as thick, contains many well preserved fossils, usually of only one species."

DIVISIONS OF ARISAIG SERIES.

Following the work of Twenhofel, the Arisaig series is divided into five formations. The boundaries of these were examined with Twenhofel, in the field, and are used as he delimited them. Most of the fossils have been re-examined by the present writer, but until a complete description of all the new species is at hand, and especially of the lamellibranchs, there are no new palæontologic data to offer. The species as named below and the stratigraphy as worked out are based directly upon the previous work of Twenhofel and Schuchert.

AGE AND CORRELATION.

As is given in considerable detail in the discussion in Chapter II of the work of Honeyman and Dawson, the age of the Arisaig formations was early recognized as Silurian, but the fossils were found to be more closely related to European than to American species. Later, due to the presence of certain fossils from the higher beds, both American and English palæontologists decided that these rocks were of Devonian age, and Dawson was constrained to accept their view. Still later, however (1868), he returned to his previous opinion and decided that the Lower

Arisaig division was of Clinton or Upper Llandovery age, and his Upper Arisaig was of Lower Helderberg or Ludlow age. Honeyman in 1864 correlated his division A with the Mayhill sandstone, divisions B and B′ with the Lower Ludlow, and division C with the Aymestry limestone. In 1886 Fletcher, using what were essentially Honeyman's divisions, correlated and named them in ascending order as follows: Medina, Lower Clinton, Upper Clinton, Niagara, Lower Helderberg. Thus the matter stood until the work of Twenhofel and Schuchert in 1909. As a result of their work the age of the series is fixed between the Lower Llandovery of Europe or the Clinton of America, and the Ludlow of Europe or the Guelph of interior America. As there are no Helderbergian fossils in the Arisaig series it is concluded that no strata occur here of this time, which is earliest Devonian. The lower Devonian of the Arisaig region, or Knoydart formation, rests with an angular unconformity upon the Silurian strata.

DIVISION I, BEECHHILL COVE FORMATION.

On the shore at Beechhill cove, 160 feet (Twenhofel) of calcareous sandstone and thick-bedded limestone are exposed. These strata of the Beechhill Cove formation stand nearly vertical and are succeeded by black shales of division II similar to those exposed on the shore near the mouth of Ross brook. East of Frenchman's Barn at an exposure recently made by the sea, the sandstone and limestone strata are seen to overlie the volcanic rocks unconformably. The surface of the volcanics has been irregularly eroded and the shales bend around the irregularities. The flexures are probably the result of movement along the contact, but the unconformable relation between the shales and the volcanics is clear. At Doctors brook upwards of 200 feet of nearly vertical sandstone and limestone strata occur between the volcanic rocks and the overlying black shales. The contact of the sandstone with the volcanic flow is marked by a conglomerate derived from the volcanics. How much of this fragmental material is really erosion conglomerate and how much of it is the volcanic breccia which normally overlies the volcanic flow (aporhyolite), is hard to determine. The well water worn pebbles of rhyolite, however, at the base of the shale furnish good evidence that there is present at least some conglomerate that is the result of erosion.

The sandstones and impure limestones at the base of the Arisaig series, with the associated volcanic rocks, were included in Honeyman's division A. By him the formation was thought to be approximately equivalent to the Mayhill sandstone of England. The Beechhill Cove formation was included in Dawson's Lower Arisaig division, and was correlated with the Clinton of America or the Upper Llandovery of Europe. Fletcher thought these beds were of Medina age and named them the Medina formation. Twenhofel and Schuchert found no evidence for placing the formation in the Medina and referred it to Clinton time, separating it as a formation on lithologic grounds. Schuchert regarded the time represented as Clinton or Lower Llandovery and stated: "As yet no *Anoplotheca hemispherica* have been gathered here, but the other fossils are those of Division II" (1909, p. 160).

There is no faunal break between this and the succeeding formation, the separation being based merely on the change in sedimentation. Clear water and limy conditions were characteristic of the time during which the Beechhill Cove formation was deposited; but muddy waters were characteristic of the time represented by the overlying formation.

The characteristic fossils of the formation as collected from the upper 75 feet of strata exposed at Beechhill cove are: *Zaphrentis* cf. *bilateralis*, *Lingula* cf. *oblonga*, *Orbiculoidea*, *Dalmanella elegantula*, and *Cornulites flexuosus*.

Helopora (2 sp.) *Cornulites*, and *Tentaculites* were obtained from green micaceous shales about three-quarters of a mile up from the mouth of Doctors brook. These strata probably belong near the base of the Beechhill Cove formation.

DIVISION II, ROSS BROOK FORMATION.

The second division of the Arisaig series, or the Ross Brook formation, consists of more than 800 feet of dark carbonaceous paper shales, with some green shales and fine-grained sandstones near the top. The contact of this formation with division I is best exposed at Doctors brook and Beechhill cove. The formation itself is exposed in section on the shore between a point a little west of the mouth of Ross brook and a fault zone about 300 yards west of the mouth of Smiths brook. A portion of the section outcrops along lower Arisaig brook, being separated from the iron-ore zone by a vertical northeast–southwest fault. The beds of this formation are tilted at high angles and have suffered much crumpling. The total thickness of the formation is, as Twenhofel suggests, probably more than the 833 feet observed along the shore, as some thickness was lost by faulting.

The Ross brook formation coincides with Honeyman's divisions B and B′ which he correlated with the Lower Ludlow of England; includes a portion of Dawson's Lower Arisaig, correlated by him as Clinton or Upper Llandovery; includes somewhat more than Fletcher's Upper and Lower Clinton; forms the upper part of the Arisaig formation of Ami; and is the same as the Arisaig formation defined by Twenhofel.

The guide fossils of the Ross Brook formation are: *Monograptus clintonensis*, *M. priodonc hapmanensis*, *Retiolites geinitzianus venosus*, *Chonetes tenuistriatus*, *Anabaia anticostiana*, *A. depressa* (= *Atrypa depressa* Sowerby), *Anoplotheca hemispherica*, *Cornulites distans*, and *Acaste downingiae*. As has already been stated by Schuchert (1909, p. 161), "the time equivalent of these fossils is clearly Clinton. * * * Division II is thought to be equivalent to the lower beds of the eastern New York Clinton, i.e., beds having *Anolootheca hemispherica*, and all of the Lower and possibly a part of the Upper Llandovery of Norway as recently described by Kiaer (Das Obersilur im Kristianiagebieta, 1908)."

Division II has been subdivided by Twenhofel into twelve zones. In the present work but three subdivisions will be made and these are based upon faunal differences.

Zone 2 (including zones 2, 3, and 4 of Twenhofel) consists of black carbonaceous shales and dark grey and green shales, and has an approximate thickness of 415 feet. In the first 100 feet fossils are scarce, but higher up they are plentiful. They are: *Monograptus clintonensis*, *Lingula* cf. *oblonga*, *Anabaia anti-*

costiana, Anoplotheca hemispherica, Cornulites flexuosus, Calymene cf. *tuberculata*, and *Acaste downingiae*.

Zone 3 (including zones 5, 6, and 7 of Twenhofel) consists of papery shales with some hard bands, dark grey splintery shale and green arenaceous shales and fine-grained sandstones in beds up to 6 inches thick. The appearance of a variety of species of graptolites, besides *Orbiculoidea, Dalmanella, Schuchertella*, and *Chonetes*, distinguishes this zone from the lower ones. The fossils present are: *Monograptus clintonensis, M. priodon chapmanensis, Retiolites geinitzianus venosus, Lingula oblonga, Orbiculoidea tenuilamellata, Dalmanella elegantula, Schuchertella* sp., *Chonetes tenuistriatus, Camarotoechia* near *equiradiata, Anoplotheca hemispherica, Anabaia anticostiana, A. depressa, Cornulites flexuosus, C. distans, Avicula emacerata*, fragments of *Dalmanites* sp. and *Eurypterus*.

Zone 4 (including zones 8, 9, 10, 11, and 12 of Twenhofel) consists of green shales and lenticular fine-grained sandstones, arenaceous shales, light green papery shales, greenish-grey shales, and dark grey shales. The zone is marked by the first appearance of *Leptaena rhomboidalis* and *Modiolopsis* (?) cf. *primigenia*. The other fossils present are: *Monograptus clintonensis, M. priodon chapmanensis, Retiolites geinitzianus venosus, Lingula oblonga?, Orbiculoidea tenuilamellata, Schizocrania* n. sp. cf. *helderbergia, Pholidops implicata?, Dalmanella elegantula, Chonetes tenuistriatus, Camarotoechia* near *equiradiata*, C. cf. *obtusiplicata, Rhynchonella* cf. *robusta, Wilsonia* cf. *saffordi, Atrypa marginalis, Anoplotheca hemispherica, Serpulites* cf. *dissolutus, Cornulites distans, Avicula* cf. *rhomboidea, Pterinea honeymani, Modiolopsis* (?) cf. *primigenia, Conularia, Calymene, Dalmanites* sp., and *Eurypterus* fragments.

DIVISION III, MCADAM FORMATION.

The strata of the McAdam formation consist of arenaceous shales, a 2½ foot bed of fossiliferous iron ore, and argillaceous and arenaceous limestones, mixed with carbonaceous and arenaceous shales. The section measured by Twenhofel was 1,020 feet thick and the thickness of the iron-ore zone is estimated at

100 feet ±, making the whole thickness of the formation more than 1,100 feet.

Besides the section exposed along the shore of Northumberland strait from the fault at the top of division II west of Smiths brook to a point about 300 yards west of McAdam brook, there is also a section of these rocks containing the bed of iron ore, exposed in the valley of Arisaig brook. The strata here stand on edge and have been apparently much reduced in thickness by strike faults.

This formation includes approximately the lower three-quarters of Honeyman's division C which he correlated with the Aymestry limestone. In his description[1] of the section passing across the area from north to south along Arisaig brook, he clearly placed the iron-ore zone in division C, making the formation begin at the hard shales below the iron ore. Thus the lower boundary as recognized by Honeyman both on the shore and in McAras brook is the same as that here adopted.

The McAdam formation includes about three-fourths of Fletcher's Niagara although it does not start quite so low in the shore section. However, Fletcher included within the Niagara the iron-ore zone.

This formation is thought to coincide in the main with the McAdam formation of Ami and is the same as that of Twenhofel excepting that it includes the iron-ore horizon of Arisaig and Ross brooks.

Throughout this and the succeeding formations the faunas are of one continuous development. Following, however, a previous subdivision based on lithologic differences, the strata consisting essentially of shales, have been retained as the McAdam formation. The fauna is not large, but contains many pelecypods, not yet described. The guide fossils of division III are: *Monograptus riccartoensis*, *Camarotoechia neglecta*, *C.* cf. *obtusiplicata*, *Dalmanella* cf. *edgelliana* (sometimes compared with *D. subcarinata*), *Chonetes tenuistriatus*, *Spirifer crispus*, and *Atrypa reticularis*. As stated by Schuchert, "these fossils, and the absence of the guide Clinton or Lower Llandovery fossils, seem

[1] Honeyman, D. 1864, p. 340, line 10.

to indicate that Division III is to be correlated with the Rochester (probably within the lower Rochester) and the Upper Llandovery including probably also the Lower Wenlock" (1909, p. 162).

Twenhofel subdivided the McAdam formation for description purposes into fifteen zones. In the present work but three zones will be described, the iron-ore horizon being dealt with by itself and the first nine and the last six zones of Twenhofel being described together. The latter division is mainly one for convenience, but is also based on faunal and stratigraphic differences. The zones 15–21 of the former work consist of alternating limestones and shales with *Camarotoechia* cf. *obtusiplicata* as their distinctive fossil. Zones 22–27 consist of concretionary and slaty shales giving place to impure limestones. *Camarotoechia obtusiplicata* is still found in zone 22, but that is its last appearance, and in the same zone *Spirifer crispus* makes its first appearance and extends through the fossil bearing strata of the remainder of the formation.

Zone 5, or the iron-ore zone, as exposed in the gorge of Arisaig brook, consists of firm shales and thin-bedded sandstones with 2 feet 3 inches of ferruginous shale and weathered hematite. Ore obtained from a prospect drift was firm and dense, but many fossils were present throughout the bed. The fossils obtained are: (?) *Dalmanella elegantula*, *Leptaena rhomboidalis*, *Camarotoechia*, sp. undet., *Homoeospira* (well developed form), *Meristina* n. sp. very large near *M. oblata*, *Cornulites proprius* (?) or *flexuosus* (?) *Tentaculites*. Of these the *Camarotoechia* resembles *C. neglecta* as found in the McAdam formation much more closely than *C. obtusiplicata* or *C. equiradiata* of the lower zones. The *Cornulites* and *Tentaculites* resemble species found in the McAdam zones. Altogether on the fossil evidence, backed by stratigraphic position, the iron-ore zone appears to belong to the base of the McAdam formation, representing beds that were cut out of the section on the shore by the fault between divisions II and III.

Zone 6 (including Twenhofel's zones 13–21) consists of grey, greenish-grey, and blue-grey argillaceous and arenaceous limestones interbedded with shales. The latter vary from splintery and micaceous-arenaceous shales, to crumbling shales, shales splitting into dagger-like fragments, and at the top soft papery carbonaceous shales. The thickness of this zone as determined by Twenhofel is 574 feet. The fossils present are: *Pholidops implicata*, *Orbiculoidea tenuilamellata*, *Dalmanella elegantula*, *Dalmanella* n. sp. (intermediate between *polygramma* (Sow.) var. *pentlandica* (Dav.), and *subcarinata*), *Leptaena rhomboidalis*, *Chonetes tenuistriatus*, *Camarotoechia neglecta*, *C.* cf. *obtusiplicata*, *Atrypa reticularis*, *Tentaculites*, *Bucanella trilobata*, *Homalonotus dawsoni* ?.

Zone 8 (including Twenhofel's zones 22–27) consists of 446 feet of dark mostly soft carbonaceous shales containing lenses and concretions of sandstone, which are succeeded by 71 feet of greenish-grey argillaceous and arenaceous limestones. The zone is marked by the presence of *Spirifer crispus*. The fossils present are: *Dalmanella elegantula*, *Leptaena rhomboidalis*, *Chonetes tenuistriatus*, *Camarotoechia neglecta*, *C. obtusiplicata*, *Atrypa reticularis*, *Grammysia* (small form), *Bucanella trilobata*, *Calymene tuberculata*.

DIVISION IV, MOYDART FORMATION.

The strata of the Moydart formation consist in ascending order of 250 feet of greenish-grey impure limestones alternating with bluish to greenish grey shales, and succeeded by 32 feet of brick red shale known as the "Red Stratum;" the total thickness thus being, according to Twenhofel, 282 feet.

The formation has been best recognized in the section on the shore between the top of division III and the top of the Red Stratum. The dip here is nearly south varying from 30°–37°. In the gorge of Arisaig brook the formation is also exposed and the Red Stratum may be with difficulty located. The strata here dip to the north at high angles. Along the Old road east of Arisaig brook, the Red Stratum is quite clearly exposed, dipping to the northwest about 75°. There is either a faulted syncline or else an overturn to the north of these north dips. The thicknesses of strata favour the first hypothesis and, therefore, it is thought strata belonging to the Moydart formation also outcrop north of those of division V lower down in the stream valley.

The Moydart formation includes the upper part of Honeyman's division C which he correlated with the Aymestry limestone, and also the Red Stratum which Honeyman did not clearly include in either division C or D. The formation probably includes the upper part of Dawson's Lower Arisaig division, and the top of Fletcher's Niagara along with the Red Stratum which Fletcher placed at the base of the Lower Helderberg. It is thought to include the lower portion of Ami's Moydart, which extended both above and below the "Red Stratum," and coincides with Twenhofel's division IVa, or Moydart formation.

Division IV is not faunally distinct from either division III or division V, and is retained as a separate formation as a matter of convenience in description. However, the unfossiliferous "Red Stratum" forms a suitable upper member. *Chonetes novascotica* first appears where the base of the Moydart is here drawn and extends, with ever increasing size, into division V, finally becoming 1 inch wide on the hinge line. "*Spirifer crispus* of Division III is succeeded in IV by *S. subsulcatus* and this gives rise to *S. rugaecosta* that attains to typical development and large size in Division V" (Twenhofel). The guide fossils to the Moydart formation are *Chonetes novascoticas*, *Wilsonia wilsoni;* "a rhynchonelloid suggestion *Eatonia medialis*, but has a lamellose instead of a striate surface;" *Camarotoechia* cf. *borealis* or *formosa; Spirifer subsulcatus;* large *Spirifer crispus; Homoeospira acadiae; Orthoceras* suggesting the Ludlow *O. striatum; Homalonotus dawsoni* and *Calymene tuberculata.* The age of the formation is thought to be middle Niagaran; or about the time of the Waldron and Louisville faunas of America. It corresponds most closely to the Wenlock of Norway.

Twenhofel has divided this formation into four zones, but for the present description only two subdivisions will be made, the first including all the fossiliferous strata and the second the "Red Stratum."

Zone 9 (including zones 28, 30, and 31 of Twenhofel, who does not describe 29) consists of 250 feet of strata including greenish-grey arenaceous-argillaceous limestones with small thicknesses of bluish to greenish-grey shales. Towards the top the limestones are heavy-bedded and some beds are nearly pure. The fossils of this zone are: *Dalmanella elegantula; Chonetes novascotica; Camarotoechia* cf. *formosa* or *borealis; Homoeospira* cf. *acadiae, H.* cf. *evax; Spirifer subsulcatus; Serpulites* cf. *dissolutus; Pterinea emacerata; Grammysia acadica; Cornulites proprius; Diaphorostoma* cf. *niagarensis; Calymene tuberculata; Homalonotus dawsoni.*

Zone 10 or the "Red Stratum" of previous writers consists of 32 feet of shale described by Twenhofel as follows:—

"A brick-red shale of which the upper thirty feet is prismatic and locally nodular. Shows little evidence of stratification except near its base. It is rather sharply differentiated from the overlying green shales, but grades into the subjacent zone. Twenty feet below the top is a nodular band ten inches thick. The nodules are bright green to greenish-white in color and have their longer axes transverse to the bedding. The same color shows along the fracture lines. At the base are included twenty-seven inches of thin beds of ferruginous limestone and shale which form the transition to Zone 31" (1909, p. 156).

DIVISION V, STONEHOUSE FORMATION.

The Stonehouse formation consists of arenaceous and argillaceous limestones interbedded with arenaceous shales. In the lower part of the formation the sediments are of a bluish-green or greenish-grey colour, but near the top the colour is grey and red with bright-green patches. The green strata are often ripple-marked. The total thickness of this formation measured by Twenhofel is 1,075 feet.

The Stonehouse formation is exposed in the section along the shore from the Red Stratum to the intrusive trap sheets just east of the mouth of McAras brook. This is probably all of the formation that is preserved as above the trap Mississippian strata occur. The Stonehouse strata exposed in Arisaig brook probably represent much less than the original thickness, due to loss by faulting, as they probably form the centre of a faulted syncline. The strata on the shore dip nearly south at angles of 35°–40°.

This formation coincides with Honeyman's division D which he correlated with the Upper Ludlow; probably includes most of Dawson's Upper Arisaig division which he correlated with the Lower Helderberg or Ludlow; corresponds to Fletcher's Lower Helderberg above the "Red Stratum" and includes part of Ami's Moydart and all of his Stonehouse formation. Division V, or the Stonehouse formation, is the same as Twenhofel's division IVb, or Stonehouse formation.

As already stated division V represents in fauna a further development of that of division IV. The guide fossils are: *Pholidops implicata: Rhynchonella nucula, Spirifer subsulcatus, S. rugaecosta, Schuchertella subplana, Cornulites flexuosus, Grammysia acadia, G. rustica, Goniophora transiens, Pteronitella venusta, P. curta, Bucanella trilobata, Beyrichia pustulosa, B. aequilatera, Acaste logani, Calymene tuberculata*, and *Homalonotus dawsoni.* By means of the above fossils the Stonehouse formation is correlated with the Ludlow, and is thought to have its nearest time equivalent in the Guelph of interior America.

Twenhofel subdivided the Stonehouse formation into eight zones. In the present work only two divisions will be made. The dividing line is drawn where the trilobite fauna first becomes common.

Zone 11 (including zones 33–36 of Twenhofel) consists of 665 feet of limestone with some shale. The limestone is grey to bluish-green in colour, is arenaceous-argillaceous in character and is frequently ripple-marked. The shale which is mostly in the lower part of the zone is deep-green in colour and contains some thin lenses of limestone.

The fossils of zone 11 are: *Leptaena rhomboidalis, Chonetes novascotica, Atrypa reticularis, Spirifer subsulcatus* (large), *S. rugaecosta, Homoespira* cf. *evax. Grammysia acadica, Pteronitella venusta.*

Zone 12 (including zones 37–40 of Twenhofel) consists of 410 feet of interbedded shales and limestones. The lower beds are greenish-grey in colour, the upper are mostly red with some greyish-green and greyish-blue strata. Among the upper beds the "trilobite bed" is found. Throughout the zone trilobites are numerous.

The fossils of zone 12 are: *Pholidops implicata, Schuchertella subplana, Chonetes novascotica, Camarotoechia* cf. *borealis, C.* cf. *nucula, Spirifer rugaecosta, S. subsulcatus, Pteronitella venusta, Cornulites proprius* (?), *Grammysia, Goniophora transiens, Orthonota angulifera* (?), *Bucanella trilobata, Beyrichia aequilatera, B. pustulosa, Acaste logani, Calymene tuberculata, Homalonotus dawsoni, Eurypterus* or *Pterygotus* fragment.

KNOYDART FORMATION.

The strata of the Knoydart formation underlie an area about 7 miles long by an average of 1½ miles wide, extending southwest from the Arisaig series which they overlie with a marked erosional unconformity. From the Browns Mountain group on the south this formation is separated by the great fault located along the Hollow. Westward the Knoydart strata are overlain unconformably by the Mississippian formations. Fletcher measured 683 feet of outcrops of the Knoydart formation without recognizing either base or summit. The true thickness is probably much greater, possibly reaching 1,000 feet. The present usage of the formation name is that defined by Ami (1901, pp. 301–312).

From the evidence of the red sediments and the contained fossils, which although considered as representing fresh water forms, may have been derived in some cases from marine sources, the deposition of the Knoydart formation is thought to have been on the flood-plains of a Devonian river, probably along the estuary and on the delta. The climate of the time was probably one of seasonal rainfall, which would give rise to a periodic fluctuation in the level of the river's surface. The interbedded grey impure sandstone probably represents deposits which were carried to seaward beyond the reach of the atmosphere or else deposits laid down in lakes of temporary existence. Lacustrine origin for the whole formation was suggested by Ami, who followed in this the opinion of R. Murchison. The latter believed that the Old Red and the Devonian rocks proper differed because of different geographical conditions during the same period. Ami cited evidence of volcanic activity at the time of sedimentation expressed in volcanic ash found in the sandstone. This corresponded to conditions such as he found in the Devonian of Chaleur bay and he postulated two lakes, Pictou and Chaleur, to allow for the necessary conditions of sedimentation. Thus Ami considered all the deposits of lacustrine origin. As seen below, the writer finds no evidence to support the supposition that ash deposits were mixed with the sediments.

The strata consist mainly of fine grained arenaceous slates of a bright brick-red colour (described as argillaceous shale by Fletcher). They are soft but firm and often considerably cleaved, so that bedding is hard to detect. These slates form the basal member seen in McAras brook not far from the Arisaig contact and again near the contact in McAdam brook. No fossils have been reported from them.

The firm grey sandstones make up a minor part of the Knoydart formation. They are of a dirty grey colour and consist of a mixture of materials. Under the microscope the composition is seen to be that of a greywacke, the components being fairly well rounded quartzes about 0·1 mm. across, surrounded by fine fragments of quartz 0·02 mm. across, mica, and undefined material. The specimen examined was taken from an exposure about 4 or 5 rods north of the strata at McAras Brook bridge from which the fossils mentioned below were obtained.

Ami (1906, p. 310) has published a note by Barlow giving the result of a microscopic examination of the so-called "ash bed" (from locality 6, No. 44 of Fletcher's section) in which the fossils were embedded. In part the note is as follows:—

"Rock of McAras brook * * greywacke. * * * It is composed for the most part of angular, subangular and rounded grains of quartz and feldspar embedded in a matrix of the same material but in a finer state of division. * * * The rock is probably of tufaceous origin."

It will be seen that other than the feldspathic character of the deposit there is no clear evidence cited to show that the rock is made up of ash or tuff. Glass shards are not mentioned and Barlow himself qualified his statement by "probably." The writer has found no evidence of igneous activity during the Devonian period (see page 134), and wishes to call attention to the fact that the case as stated by previous writers is not proved so far as the locality under discussion is concerned. That such activity may have occurred is supported by the opinion of Dr. Barlow, a geologist and petrographer of recognized merit.

The fossils from the Knoydart formation as mentioned by Ami were collected from the grey sandstone or greywacke (described by him as an ash bed) outcropping to the south of the shore road along the west bank of McAras brook. As identified by A. Smith Woodward and Henry Woodward, both of the British Museum, the species were: (1) ***Pterygotus*** sp.; (2) ***Onchus murchisoni*** Agassiz; (3) ***Pteraspis*** sp. cf. ***P. crouchii;*** (4) ***Psammosteus*** sp. cf. ***P. anglicus*** Traquair; (5) ***Cephalaspis*** n. sp. ?; (6) ***Ichthyoidichnites acadiensis***, impressions made by a pair of sharp pointed organs or spines, probably those of a fish.

In his report Smith Woodward wrote: "On the whole, I should place the McAras brook beds on the same horizon as the Lower Old Red Sandstones-Cornstones of the Hereford district of England above the passage beds."

Because of its continental origin, Ami compared the Knoydart formation with the European Old Red Sandstone rather than with the marine Devonian of America, and from a faunal list given by Prestwich he correlated this formation with the strata near Ledbury, in Herefordshire, belonging to the Lower Old Red Sandstone.

Fletcher (1886, p. 49 P) considered the Devonian rocks of McAras brook as representing the highest member of a series which extend in a broad belt "from the Strait of Canso to Lochaber—thence keeping south of the East river of Pictou to strike the Intercolonial railway near Glengarry, form the high land south of Truro, and pass unconformably beneath the Carboniferous of Stewiacke river." The correlation of the Knoydart formation with the Devonian strata of Chaleur bay by Ami has already been cited.

McARAS BROOK FORMATION.

The red conglomerates and sandstones of the McAras Brook formation occupy a small area west of McAras brook, a narrow belt along the Intercolonial railway in the south, and a broad area in the central and eastern part of the district. Everywhere these strata rest with a marked angular unconformity upon the older rocks, and are overlain, conformably so far as evidence obtained from this district shows, by the Ardness formation.

The colour and cross-bedding of these strata suggest continental or littoral sedimentation which gave place to marine conditions as is shown by the presence of the overlying limestones. Limy conditions appear to have been common throughout the deposition, as shown by the lime present in the sediments. The conglomerates contain fragments from the nearby formations, and often from the rocks which they directly overlie. For the most part these fragments are well rounded, but where the material is of local origin, as along the James River granite stock, it is decidedly angular. The finer materials are covered with iron oxide as are many of the coarser fragments. In places the older rocks beneath the formation have also been stained red.

At Pleasant valley and in the vicinity of Maryvale and east of the border of the district of study, viz., at Big marsh, this formation contains beds of oil-shale. According to Ells (1910), who quotes How's "Mineralogy of Nova Scotia," the shales "underlie the Lower Carboniferous limestone at Big Marsh" and may be divided into a lower group "70–80 feet thick including 20 feet of good oil-shale, 5 feet of which are curly cannel, rich in oil;" and an upper group "150 feet thick in immediate contact with the limestone and containing a large percentage of oil." These shales are associated with light grey micaceous shale containing fragments of plants.

The McAras Brook formation was called the Carboniferous Conglomerate by Fletcher (1886, p. 69 P), who stated that it lay unconformably beneath the "Carboniferous limestone," backing his conclusion by the statement that "the great difference of thickness in so many places in adjoining areas cannot, in absence of faults, be explained otherwise than by unconformity." For the district now being described neither great variations in thickness nor other evidence of unconformity were found by the writer. The bedding planes of the two formations at the many contacts examined corresponded in attitude, and if any la, e of time is here represented it is marked by a disconformity rather than an unconformity. It is admitted that this area may represent local conditions which do not correspond to those of the broader field from which Fletcher drew his conclusions.

From the apparent conformability of the McAras Brook formation with the overlying limestones of undoubted Windsor age, from the limy condition of much of the formation, and its close resemblance to the strata succeeding the limestones, the writer has concluded that the age of the McAras Brook formation is essentially that of the Windsor rocks; that is, these strata were deposited in the Mississippian period a short time before the Windsor series.

ARDNESS FORMATION.

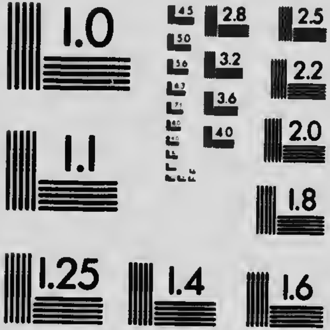
The Ardness strata underlie a narrow belt of land extending southwest from a point near the northwest corner of the Arisaig-Antigonish district. On the south the formation extends from a short distance north of the railway southward far beyond the bounds of the district.

On the shore of Northumberland strait the Ardness limestone overlies, apparently conformably, the McAras Brook conglomerate and is in turn overlain, with apparent conformability, by the Listmore formation. The thickness here represented is about 2,045 feet. On the south the limestone holds the same relations to the underlying formation, but is succeeded by red sandstone and grits and higher up by a thick bed of gypsum, followed again by red sandstone and shale. The total thickness is not definitely known.

The basal limestone containing marine fossils indicates that the deposition took place beneath the sea. Red sand and grit deposits suggest a return to subaërial conditions of sedimentation, or to the deposition of previously oxidized land waste along a littoral zone, and the gypsum beds are evidence of shallow water pans or lagoons which had periodic connexions with the sea during a time of intense evaporation, probably due to a hot dry climate.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



The limestones at the base of the formation are thin-bedded near the top and the bottom, but are massive at the centre. The thickness seen on the shore is about 20 feet. At the base are dark grey beds about 1 inch thick, some of which contain numerous brachiopods and ostracods. The massive limestone near the middle is dark grey and compact, and does not appear to be fossiliferous. Near the top light brown resistant layers occur and in these brachiopods have been found.

In the section observed along the shore west of McAras brook, the remainder of the formation (2,024 feet as measured by Fletcher) consists of thin-bedded sandstone, marl, and shale. For a few feet above the limestone, grey and green are the prevailing colours, but higher up red is predominant. Ripple-marking is common except in the lower beds, and near the top, plant remains, associated with copper carbonate, are found in green concretionary beds. In the south, 200 feet of red sandstone and shale are estimated to overlie the limestone and these are succeeded by about 200 feet (estimated from outcrops, etc.) of gypsum deposits. The gypsum as seen in the cliffs along the railway near Brierly brook is white to greyish-white and shows very little evidence of bedding. Dawson (1847) described a section observed by him at Ogdens point, Antigonish, as consisting in ascending order of white gypsum (containing some carbonate of lime) and reddish foliated gypsum, more than 100 feet thick; succeeded by alternations of thin beds of gypsum and grey earthy limestone; overlain by a thick bed of grey brecciated limestone and reddish sandstones and shales.

The age of the Ardness formation was determined by a study of the fossils obtained by the writer from the limestone west of McAras brook. These were identified by Professor Schuchert as follows: "*Beecheria davidsoni* Hall and Clarke (*Terebratula sacculus* Davidson), *Martinia glabra* (Martin), both of which are characteristic and common species at Windsor. *Pugnax*, sp. undet., is rare, while *Productus* cf. *doubleti* Beede is very common. *Productus dawsoni* Beede, one of the *P. cora* group, is also present." All these forms occur either in the dolomite at Windsor in close association with this well known gypsum horizon of Nova Scotia, or in the Windsor series of the Magdalen islands (see

Beede and Clarke report). The evidence is, therefore, decidedly in favour of correlating the Ardness formation directly with the limestone and gypsum outcropping at Windsor. Thus this formation represents for Antigonish county at least part of the Windsor series of limestones, gypsum, and shales occurring elsewhere in Nova Scotia.

LISTMORE FORMATION.

The Listmore strata extend westward from a point on the shore of Northumberland strait about one-half mile within the west boundary of the Arisaig-Antigonish district. So far as evidence from the contact observed goes, there is no apparent unconformity between this and the Ardness formation. The sandstones are greyer in colour and contain more plant remains than those of the Ardness formation, but in other respects show similar characters. As measured by Fletcher, this formation is 982 feet thick.

The plant remains, cross-bedding, and frequency of red beds in this formation suggest strongly that the deposits are of continental origin.

The plant remains are probably *Stigmaria* (as reported by Fletcher) and *Calamites*. Other than that these represent Carboniferous time, no direct correlation value can be attached to them. The Listmore formation was called the Millstone Grit by Fletcher (1886) and if these strata are the same in age as the Millstone Grit formation of other parts of Nova Scotia and New Brunswick, they probably belong to the Pennsylvanian system, as the Millstone Grit underlies the Coal Measures. Fletcher described the Millstone Grit as having an unconformable relation to the "Carboniferous Limestone" strata, but Ami failed to find any evidence of this in the Cumberland basin (1900).

QUATERNARY DEPOSITS.

PLEISTOCENE.

Deposits of Pleistocene or Glacial age cover the lowlands of the Arisaig-Antigonish district to a greater or less depth, and occur in considerable thicknesses over parts of the plateau underlain by Browns Mountain rocks.

These deposits of clay and clay-gravel bear evidence of glacial origin in their unsorted character and sub-angular and occasionally scratched pebbles.

The oldest of the deposits thought to be of Pleistocene age are firm red, marly clays seen in McNeils brook between the road and the shore. They lie in a nearly horizontal position and are overlain by brownish-red unstratified sandy clay. Such clay was observed about one-half mile up McNeils brook, in the small brook to the east, and again in Vameys brook. The thickness of the red marly clay was not determined as the base was only seen far up the stream where it rested on James River strata. The brownish-red clay, however, attains a thickness of about 12 feet in McNeils brook.

Unconformably overlying the brownish-red clay are unsorted clay and gravel deposits of a reddish-brown colour, which reach a thickness in McNeils brook of about 40 feet. Near the top the gravel is roughly sorted. Such deposits are common along the shore of Northumberland strait, and are probably of the same glacial origin as the many gravel knolls seen at Arisaig, Maryvale, James river, and elsewhere. Sub-angular pebbles are everywhere present and scratched pebbles were obtained from a number of localities. The debris is for the most part of local derivation, but occasionally "travelled fragments" may be recognized.

Generally only the upper part of the till shows sorting and bedding such as results from water action, but occasionally bedded gravels occur of several feet in thickness. Such a deposit may be seen on a western tributary of James river about 620 feet above sea-level.

RECENT.

Flood-plain deposits of stream-worn gravels have accumulated in the graded portions of the brook channels. The thickest observed deposits were those of Knoydart brook. Here about 15 feet or more of deposits had accumulated in a broad flood-plain, before the stream cut down to its present level where it is forming a narrower flood-plain.

Near the town of Antigonish the streams which have come to grade several miles higher up their courses, have deposited silt and other fine materials, making rich bottom lands known as "intervales." These deposits have received additions of organic material resulting from the decay of vegetation growing on them.

The soils of the district are of considerable depth, but although largely consisting of glacial material show a decided relation to the underlying formations, as may be observed in their relative productivity. The Carboniferous lowlands have by far the deepest and most fertile soils.

CHAPTER VI.

GENERAL AND STRUCTURAL GEOLOGY.

INTRODUCTION.

Northeastern Nova Scotia, lying between the Gold-bearing series of the Atlantic shore and Northumberland strait and George bay, is underlain by rocks ranging in age from lower Ordovician to Permian. The lower Ordovician rocks underlie plateau-like areas, but the younger formations of Silurian, Devonian, and Carboniferous age are confined almost without exception to the lowlands. These later sedimentary rocks occupy great depressions in the formations of the uplands, depressions probably originated by erosion and supplemented by crustal warping and faulting.

The oldest rocks generally included in the "Cobequid series" and called the "Cambro-Silurian" formations by previous writers, are exposed in many places over the highlands of the region. They consist of metamorphic rocks, including quartzites, silicified slates, indurated sandstones, conglomerates, etc. Folding and faulting are features of these formations, but because of the lack of consecutive exposures little detailed work has been done on their structure. Igneous rocks of various kinds and ages have cut the metamorphic sedimentaries, and were included by Dawson in his Cobequid series. Rocks of undoubted Ordovician age have not before been recognized in Nova Scotia, but it has been thought by previous workers that portions of the "Cambro-Silurian" strata would prove to be "Lower Silurian" or Ordovician.

The Silurian formations, or the Arisaig series, occupy a number of small areas in the region about Arisaig. These rocks consist of shales, sandstones, and impure limestones, which unconformably overlie the lower Ordovician formations. The age of the Arisaig series has been determined from the numerous fossils which it contains, as representing nearly the whole of Silurian time. However, the fossil species are much more nearly related to the Silurian faunas of Europe than they are to those of the rest of America, and the formations cannot be directly correlated with those that are typically American.

The lower Devonian series of conglomerate, sandstone, and red slate occupy upland areas of considerable extent between the Strait of Canso and the town of Truro. These rocks overlie the older formations unconformably.

The formations of Carboniferous age (Mississippian and Pennsylvanian), include the Union and Riversdale formations, the Windsor series, the Millstone Grit (of Nova Scotia and New Brunswick), and the Coal Measures of former writers, and occupy by far the greater part of northeastern Nova Scotia. The different formations consist of conglomerates, limestones and gypsum, sandstone, grits, and beds of coal, and represent a long cycle of sedimentation which continued during varying relations of the land to the sea, and during varying climatic conditions.

Above the Coal Measures are the Permo-Carboniferous or Permian formations, which occupy considerable areas in the northern part of Pictou county and to the westward. These strata consist of a basal conglomerate, and grits and sandstones "containing plants of Permian aspect."[1] They are the youngest rocks known in northern Nova Scotia.

Of Quaternary deposits, stratified clay containing marine shells, unstratified boulder clay, gravel containing scratched stones, and stratified sands and gravels have been recognized.

Within the Arisaig-Antigonish district of northeastern Nova Scotia, the formations of the region are represented probably as high as the "Millstone Grit" (Listmore of present nomenclature). It is the purpose of this chapter to deal primarily with the general relations and structure of the formations present, the detailed lithologic characters, palæontology, mode of origin, age, and correlation having been treated in the chapter on "Stratigraphy."

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[1] Fletcher, Hugh. Geol. Surv., Canada, Ann. Rept., 1886, Vol. II, p. 94 P, 1887.

BROWNS MOUNTAIN GROUP (LOWER ORDOVICIAN).

EXTENT.

The metamorphic rocks belonging to the James River and Baxters Brook formations of the Browns Mountain group underlie the great central plateau of the district and the smaller plateau in the southeast corner. The greywacke and indurated, banded slates of the James River formation occupy the whole metamorphic area except the region in the vicinity of the igneous rocks south of Malignant cove. Here the greywacke and grey slate are interbedded with red slate and finally give place along the axis of a syncline to the red slates, sandstone, and sandy schist of the Baxters Brook formation.

IGNEOUS INTRUSIONS IN BROWNS MOUNTAIN GROUP.

The James River formation is intruded by a granite stock at James river. Both members of the Browns Mountain group are cut by small rhyolite dykes and diabase dykes of much later date. The Baxters Brook formation is intruded also by quartz porphyry and rhyolite necks and irregular basaltic bodies.

STRUCTURE.

Because of the lack of exposures of the rocks of the Browns Mountain group and the complexities arising from igneous intrusions, the complete structure of the formations has not been deciphered.

The best recognized fold of the region is the great syncline whose axis extends from near the headwaters of Vameys brook in the west, eastward to the headwaters of a small stream emptying into Malignant brook about 2 miles north of Maryvale. From the recorded attitude of the strata the syncline appears to be regular along its central part. To the east the slates of the Baxters Brook formation are held in a structural trough, which does not correspond in direction to the great syncline but extends in a crescentic northwest and then west direction. In this region of numerous intrusions regional structure has given place to confused warpings related no doubt to the igneous activity.

An anticlinal axis begins in the west of the district about 1 mile south of Browns Mountain settlement and about 2½ miles south of the probable axis of the great syncline. This extends eastward to the border of the lowlands about 1 mile north of Brierly Brook station. Folds with north and south axes occupy the V-shaped space between the axis of the anticline on the south and that of the syncline on the north. The strata exposed along the South Branch of Rights river stand at high angles and probably represent more than one compressed and truncated anticline and syncline. Farther east the folds are more open. A succession of three synclines and two anticlines probably comprise the structure of the Browns Mountain rocks, from a point 1 mile east of the forks on the South Branch of Rights river eastward below the McAras Brook conglomerates and across the uplands as far as the Sugar Loaf hill of Antigonish. About this diabase centre, the structure is confused.

Much faulting on a small scale is common where the iron ore of Doctors brook has been investigated, but because of the lack of opportunity for detailed investigation it has not been determined whether or not faulting is a regional feature of the metamorphic rocks. The great fault separating these rocks from the younger formations to the north will be discussed under a separate heading.

The trend of the greater folds and the major fault of the Browns Mountain rocks corresponds to the general directions the axes of the anticlines and synclines of the gold-bearing ks of southern Nova Scotia, which may be of Lower Cambrian but are probably older. Thus it is seen that the regional olding extended to the north coast of Nova Scotia.

RELATION TO OLDER FORMATIONS.

What the relations are between the gold-bearing series and the Browns Mountain formations is largely a matter of conjecture. The two groups of metamorphic formations are separated surficially by many miles of younger formations. The nature of the relations is. therefore, in doubt.

The two groups of rocks have many similarities in character of sediments and in degree of silicification. On the other hand the slates of the Gold-bearing series are much more fissile than those of the Browns Mountain rocks, indicating a greater degree of dynamic metamorphism. The rocks of the Gulf of St. Lawrence definitely recognized as Lower Cambrian do not appear to have suffered severe metamorphism, and for this and other reasons the rocks of the Gold-bearing series have been considered of Pre-Cambrian age. In view of the relative shallowness of the depressions holding the younger formations, it does not seem probable that any undiscovered group of rocks can lie between the Gold-bearing series and the Browns Mountain formations, and, therefore, so far as the evidence goes, the Gold-bearing series may be Cambrian.

METAMORPHISM.

Jointing is everywhere common in the Browns Mountain greywacke and slates. The number of measurements taken was not more than twenty but these are sufficient to show that the joint planes all dip at angles greater than 45° with the horizontal, more than two-thirds of those examined dipping at angles greater than 60°. The strike direction of the joint systems fall into northwest-southeast and northeast-southwest groups, most of the dips being northerly rather than southerly. Such jointing must have originated deep down in the zone of fracture.

The James River rocks include greywacke, or impure quartzite and flinty slate. Under the microscope the greywacke may be seen to consist of grains of quartz and feldspar (andesine and orthoclase were determined in one section), about 0·2 mm. across and angular in shape. Secondary silica has filled in the pore-spaces. The slate is fine grained and very siliceous, resembling navaculite in megascopic characters. Such regional silicification is probably to be ascribed to the readjustment of the silica of quartz and the silicates, which is favoured by conditions of great pressure and high temperature, such as exist some thousands of feet below the surface of the earth. The silicification probably took place before the joint planes of the region were established, as these planes cut across the grain of the rock and do not show quartz accumulations on their surfaces, as might be expected had they existed previous to the chemical readjustments among the minerals of the formations.

MALIGNANT COVE FORMATION.

EXTENT AND CHARACTERS.

Along Malignant brook for the last 1½ miles of its course, and on the east side of Malignant pond, fine silicified red grit and (at the pond) coarse, cross-bedded, silicified conglomerate overlie the James River rocks. At the pond the formation may be seen to lie upon cleavage surfaces of grey slate, portions of which are contained in the conglomerate, among fragments of quartz, purple rhyolite, sand, and fine gravel. Cross-bedding is very marked, a coarse bed of conglomerate with cobbles 6 inches in diameter, overlying finer conglomerate containing pockets of coarser pebbles. Up the brook the conglomerates are replaced by fine silicified grits of a dark red colour, resembling igneous rocks very closely in appearance.

Under the microscope the conglomerate is seen to be composed of partially rounded fragments of rhyolite, tuff, quartz, greywacke, micropegmatite, and feldspar. Many fragments show evidence of subsequent crushing and shearing. Secondary products are iron oxide, chlorite, calcite, sericite, and silica. The silica has filled in the pore-spaces of the rock, making it hard and resistant in character.

PROBABLE STRUCTURAL RELATIONS.

The [illegible] proximity of the Malignant Cove conglomerate to the Arisaig series, makes it seem probable that it may elsewhere underlie these rocks and so belong to the interval between the deposition of the Browns Mountain formations and the laying down of the Silurian strata. It contains, however, fragments of rhyolite that have the characteristics of the aporhyolite at the base of the Arisaig series. Here arises a difficulty. The conglomerate is evidently younger than the aporhyolite flow, but the latter is overlain by the Arisaig series, with apparently no great unconformity so far as local evidence goes. Turning to similar formations elsewhere, we find that Fletcher[1] described conglomerate near Georgeville overlying "the slates from which it is largely derived. * * * This conglomerate is the same as that of Malignant cove and probably not higher in the series than the Baxters Brook group." Later Fletcher thought that these strata might be correlated with the Bears Brook conglomerate. According to his description of the Baxters Brook group as "soft reddish and olivaceous slates" and his interpretations elsewhere, the Malignant Cove conglomerate cannot be correlated with that group.

Fletcher's description of the relations of the Bears Brook conglomerate, sandstone, etc., is not very clear and for that reason and because he was not certain in his correlation of the formation under discussion, a new name has been applied to the conglomerate at Malignant cove. Dawson[2] mentioned conglomerate discovered near Pictou which he thought formed the base of the Silurian.

PROBABLE AGE.

The petrographic evidence that the Malignant Cove conglomerate is younger than the aporhyolite flow seems pretty secure. The flow is not known elsewhere in the district and was probably a remnant of a much larger sheet. The Arisaig basal rocks contain fragments of aporhyolite, showing that there was an erosion interval between the volcanic activity and the sedimentation of Silurian time, and owing to the hardness of the volcanics this interval may have been much longer than the evidence at the contacts would suggest. It is to this period of erosion and local sedimentation that the Malignant Cove conglomerate probably belongs. The silicified character of the conglomerate correlates it much more nearly with the Browns Mountain meta-

[1] Fletcher, Hugh. Geol. Surv., Can., Ann. Rept., 1886, Vol. II, p. 19 P, 1887.

[2] Dawson, J. Can. Nat., Vol. IX, p. 338, 1881.

morphic rocks than with later sediments. For the reasons given, the age of this formation is thought to be Ordovician, with a probability that it dates back to the middle part of the period.

ARISAIG SERIES.

EXTENT AND GENERAL RELATIONS.

Within the Arisaig-Antigonish district the formations making up the Arisaig series are confined to an area between the Hollow and the shore, and extending from Malignant cove about 6 miles southwest to McAras brook. The age of the rocks is Silurian, ranging in American equivalents from lower Clinton to Guelph. They occupy a down-faulted position in relation to the lower Ordovician formations to the south, and rest upon a flow of aporhyolite at their base.

The relations of the sedimentaries to the lava may be studied at the exposures west of Frenchman's Barn or in Doctors brook. At the former locality the rhyolite has had portions of its surface removed along planes of flowage. The beds of shale here are flexed and have probably suffered from later movement which destroyed the original conditions. In Doctors brook no angular unconformity was noted, but conglomerate composed for the most part of volcanic material forms the base of the sedimentary series. The irregularities in the underlying surface and the basal conglomerate are interpreted as evidence of an unconformity which for reasons given in the description of the Malignant Cove formation (page 87) is thought to represent a long time interval.

STRUCTURE.

The Arisaig series has been divided into five formations which are described in the chapter on "Stratigraphy" (page 51). The divisions are important because in mapping their areal extent much structure was deciphered.

It was recognized by the early workers in the district that the Arisaig rocks lay in an asymmetric syncline pitching southwest.

Fletcher[1] also recognized that there was an upthrown block between "Smith brook and a point east of the Trunk road." The previous interpretation is true so far as it goes. When an attempt is made, however, to unite the boundaries of the divisions recognized definitely along the shore, on Arisaig brook, Doctors brook, and elsewhere, it is found to be an impossibility without doing violence to known thicknesses and relations of beds, or else introducing a series of displacements. Thus, the boundaries of the formations recognized along Arisaig brook are so far south and strike and dip in such a way that they cannot be continuous with those on the shore. Eastward a similar discontinuity is recognized by an offset in hard strata and an iron-ore bed. In this manner the upthrust block mentioned by Fletcher is established. In locating the bounding faults, the line of offsets on the west had to be followed and this line passed directly through the break in the aporhyolite flow at Arisaig point. The offset here, however, is too great to be accounted for by the one fault, and for this reason and because of the location of observed discontinuity in the strike of strata, the fault on the west is thought to meet that along the east, on the shore, making the upthrust block triangular. Fossils found in the iron ore along Arisaig brook show it to belong to strata between the top of the Ross brook and the base of the McAdam formations as seen on the shore, and the displacement there observed is consequently extended inland to allow for a down faulting of the McAdam sufficient to eliminate its lower beds. Insufficiency in the thicknesses of formations along Arisaig brook has to be accounted for by faults similar to one observed at the iron ore, which follows the strike of the beds but is vertical, thus differing a few degrees from the dip of the strata. Hence three fault blocks have been set off, being successfully down-faulted to the north except in the case of the last which was upthrust relatively to the adjoining block.

At a sharp bend to the north in Doctors brook, fossils were obtained which belong to the lowest part of the Beechhill Cove formation. The age of the strata to the south and west is not

[1] Fletcher, Hugh. Loc. Cit., p. 41 P.

certain, but from Honeyman's interpretations and from lithological characters, they appear to belong to the Ross Brook formation. It will thus be seen that a fault with down-throw to the south has to be postulated to explain the relations. When the divisions from the east are projected to meet those from the west they fail to harmonize and the location of a fault, with down-throw to the east, passing through the gap in the outcrops on the beach seems very probable. There is a decided offset in the aporhyolite to the east of the mouth of Doctors brook, and the evidence of faulting is clear in the truncation of the rock outcrops. This displacement with down-throw to the east is thought to extend inland as represented. At McNeils brook the rhyolite breccia outcrops along the west of the brook only and a fault here with down-throw to the east seems probable.

The information at hand makes it clear that some such system of faulting as the above is necessary. That much crushing and complicated faulting not represented has taken place is most probable. This opinion is supported by the evidence of small faults and flexures occurring at many places along the shore. Where the great down-faulting of the area took place, the soft shales and thin arenaceous limestones were unable to withstand the great stresses set up and much minor readjustment necessarily followed.

UPPER CONTACT.

The question as to the amount of the unconformity represented where the Arisaig series is overlain by the Knoydart formation on the west, is of considerablc importance. Ami[1] contended on fossil evidence that it was not great. Both series of strata are much deformed, but the upper is found to rest on different underlying Arisaig formations.

A study of the attitude of the beds outcropping along McAdams brook shows the degree of dip not only to be reversed on crossing the contact (which might be explained by the existence of an anticline), but the strata of the Knoydart formation to be

[1] See Ami under "Previous Work."

much more disturbed than is the case with the Arisaig rocks. Fortunately other evidence is available. At the mouth of McAras brook, the Stonehouse formation is overlain by the Knoydart. At McAdams brook the Moydart is probably the basal formation. The presence of the Moydart formation along the upper part of McAdams brook is based mainly upon structural evidence, taking into account the attitude of the strata and the thickness of the Stonehouse formation. Thus there is a probable unconformity ranging through several hundred feet of strata within a mile of horizontal measurement.

The McAras Brook conglomerate is separated from the Upper Arisaig rocks by an intrusive diabase sheet which confuses the contact relations. Evidence here is not needed, however, as the attitude of the strata of the two formations indicates an angular unconformity of more than 45°, and only a short distance up the stream the McAras Brook rocks overlie the Knoydart formation. On the East Branch of Doctors brook, the Ardness limestone, underlain perhaps by some McAras Brook conglomerate, forms a small outlier above what are probably Ross Brook strata.

KNOYDART FORMATION.

EXTENT AND GENERAL CHARACTERS.

The lower Devonian strata of McAras brook, overlying the Arisaig series on the east and disappearing below Mississippian rocks about 2 miles west of the area studied, were named the Knoydart formation by Ami. As measured by Fletcher, the thickness of exposed beds was 683 feet, but its total thickness is evidently much more. This formation is cut by numerous small diabase dykes.

STRUCTURE.

Exposures of Knoydart strata are not numerous except along the lower parts of the brooks, but enough measurements have been taken to indicate that the structure of the formation is that of an asymmetric and probably faulted syncline which pitches to the southwest. As in the case of the Arisaig series, it originated during the movement along the great fault at the Hollow.

To the westward, the Knoydart formation is overlain unconformably by the McAras Brook, and farther west by the Ardness formation.

POST LOWER DEVONIAN, PRE-MISSISSIPPIAN FAULT.

GENERAL DESCRIPTION.

A great fault extends to the southwest from Malignant cove, in line with the shore from Cape George. Its location is marked by a steep scarp several hundred feet in height, forming the south side of a U-shaped valley. The scarp and valley extend across the front of the Arisaig-Antigonish district and appear as an important topographic feature for a number of miles beyond. On the south are the highlands underlain by the metamorphic rocks of lower Ordovician age; on the north, from east to west, are the lowlands and rolling uplands of the Silurian, Devonian, and Mississippian (Lower Carboniferous) areas.

AGE.

The fault originated in pre-Mississippian time, as shown by the fact that the Mississippian rocks are but little disturbed and have evidently been deposited against the fault scarp, which they overlap in some cases to the westward, as appears from the work of Fletcher. The lower Devonian formations are downfaulted and thus the age of the fault is most probably later Devonian (See also "Historical Geology").

CHARACTER.

It will be seen that the faulting was normal and to the northwest along a fault plane dipping at a steep angle. Taking into account the tenacity of the metamorphic slates and greywacke and the friction incident upon such faulting, the dip of the fault plane or fault zone is estimated to be about 70° from the horizontal.

The throw of the fault appears to have been least in the east and greatest in the west. At Malignant cove it is probable that the lowest beds of the Arisaig series lie next the fault zone. What lay directly below the lava flow at the base of these rocks we do not know, and it seems probable that the Malignant Cove conglomerate was elsewhere beneath the Arisaig series and above the Browns Mountain group.

The conglomerate at Malignant pond is exposed about 20 feet above the level of the sea, and here rests upon James River slate. Thus the eroded surface of the James River rocks and the base of the Arisaig series are at the same level, and from the evidence at hand the throw of the fault is to be measured by an unknown quantity, the thickness of the strata once lying between these two formations. The fault scarp is clearly defined 1 mile to the west but is not so well marked here. From the evidence it is possible that Malignant cove is situated at a node in the fault where the throw was considerable (for the shore to the east is very straight and doubtless dependent upon faulting), but not nearly so great as farther west.

The rocks of the Arisaig series, consisting of soft shales and thin limestones, suffered much secondary faulting during the general disturbance and their throw is not readily determined. As the Knoydart formation to the west overlies the Arisaig rocks and suffered little complex faulting, the throw of the great fault may be best studied in relation to it. Although at Malignant cove the base of the younger rocks appears to have been near the present sea-level, as is the case with the Malignant Cove formation, and so may have originally been low compared to the plateau level, there is no evidence that such relations held for the Knoydart formation. Younger and older formations are separated by a clean straight fault scarp and structural valley, the top of the Knoydart formation lying probably 300 feet below the level of the Cretaceous peneplain underlain by metamorphic rocks. Twenhofel has measured 3,465 feet of Arisaig strata, and to this must be added the thickness of the iron-ore zone, probably 100 feet ±. Fletcher measured 683 feet of Knoydart beds without recognizing either the top or the bottom of the formation. From structural evidence it is probable that this is much less than the true thickness.

The Knoydart formation overlies the Arisaig series unconformably, resting upon the Stonehouse and Moydart at places little more than 1 mile apart. The value of the unconformity may be conservatively considered as equal to half the thickness of the Stonehouse formation. Assuming the base of the Arisaig series to have been at least as high as the plateau level whose rocks it may have overlain and neglecting the attitude of the formations to each other, the throw of the fault along the Knoydart formation may be estimated as follows: the thickness of the Arisaig series, plus the thickness of the Knoydart formation, plus the height of the plateau above the Knoydart formation, less the value of the unconformity between the Arisaig series and the Knoydart formation. The result is, in round numbers, 4,000 feet.

To arrive at the minimum estimate of the throw it may be assumed that the base of the Arisaig series was never so high as the plateau top but lay near the present level of the sea. In this case, the throw would be reduced by the height of the plateau, or about 1,000 feet, leaving a result of 3,000 feet. That faulting of this order of magnitude has taken place is evident to the casual observer of the physiographic and geologic relations along the Hollow.

McARAS BROOK FORMATION.

EXTENT AND AREA.

The McAras Brook conglomerate and grits of Mississippian age, occupy a small area northwest of the Knoydart formation. As measured by Fletcher along the shore they are 1,145 feet thick. The same strata occupy the eastern and central part of the Arisaig-Antigonish district and also a narrow belt along the south. With the exception of the intrusive diabase sheets at McAras brook and some irregular diabase and basalt ? at the outlier of Doctors brook, the relations of which are in doubt, no igneous rocks cut the McAras Brook formation within the district.

STRUCTURE AND RELATIONS.

Everywhere these rocks overlie unconformably the older formations, containing much debris derived from them. In the case of the Browns Mountain formations the contacts are sinuous and usually dip very steeply, commonly at 40-50° from the horizontal. The contact surface of the metamorphic rocks usually rises as a scarp with high inclination to the plateau level. The conglomerate beds for some distance from the older formations dip at angles depending upon the contacts. Where independent of border relations, the dips are low, with exceptions occurring in limited areas.

From the above evidence it appears that the McAras Brook conglomerate was deposited by current action in old erosion valleys. These valleys were probably dependent on the structure, but probably were not wholly controlled by it. They were broad and may have been within reach of the influence of the tides. Cross-bedding is a common feature of the conglomerates and marine conditions followed their deposition as will be seen when the next formation is considered. Some time after the deposition of the conglomerates, regional compression probably took place and down-flexing was doubtless influenced by the initial dips at the edges of the basins of sedimentation. As a result the dips at the contacts were increased and the beds were flexed into gentle synclinal structures. Shrinkage in the thickness of beds, due to solidification, may have also accentuated these basin structures. Elevation has caused the erosion of the deposits so that we are now near the bottom of the basins. This may be seen in Rights river about , mile southeast of North Grant. Here a flat erosion surface on James River quartzite is exposed for a few square feet by the stripping away of the overlying conglomerate.

ARDNESS FORMATION.

EXTENT AND GENERAL CHARACTERS.

The Ardness limestone, gypsum, sandy shale, sandstone, etc., are of Mississippian age, being equivalent to at least a part of the Windsor group. The formation extends westward 1 mile along the shore from the top of the McAras Brook formation, and occupies the southern border of the district. Fletcher found the formation to have a thickness of 2,110 feet along the shore. In this he included the thickness of the limestone and underlying beds of marl three times. These are now known to be one bed faulted twice, and as a result 65 feet must be subtracted from 2,110, leaving the real thickness 2,045 feet. No gypsum is present in this section and the total thickness of the southern section including the gypsum is not known. The formation contains no intrusive rocks.

STRUCTURE AND RELATIONS.

The Ardness formation has at its base a limestone member 20 feet or more in thickness, which, wherever observed, overlies the McAras Brook formation conformably. The upper beds of the conglomerate are very even and for a few inches below the limestone are very calcareous. At the base of the overlying formation are thin-bedded limestones containing pebbles from the conglomerate, and these are overlain by the massive limestone. Then after an estimated thickness of 200 feet of red sandstone and shale, the gypsum beds occur. They are probably about 200 feet thick and are overlain by red sandstone and shale.

The Ardness formation overlies the Knoydart along its western extent, and holds a similar relation to the James River quartzites at the southeastern corner of the district.

The Ardness strata dip gently away from their boundaries and show very few evidences of disturbance.

LISTMORE FORMATION.

EXTENT AND GENERAL CHARACTERS.

The Listmore formation was recognized by Fletcher as overlying the Ardness near the mouth of Knoydart brook. From here it extends westward a number of miles beyond the boundaries of the district with which we are concerned. If it is to be correlated with the "Millstone Grit" formation of Nova Scotia and New Brunswick, it is probably of Pennsylvania (Upper Carboniferous) age.

STRUCTURE.

There is no marked change in the characters of the sediments of this formation from those of the formation directly below. A small fault with down-throw to the southwest occurs at the lower contact seen on the shore, but the zone of faulting is narrow, the strata on both sides have the same strike and dip, and no unconformity has been observed. The dip of the Listmore formation, like that of the Ardness below it, is about 30° to the northwest.

RECENT DEPOSITS.

Red marly clay underlies thick deposits of clay and till at the mouth of McNeils brook and elsewhere. This material is several feet thick, appears to be flat-lying, and grades upward into softer clay which is overlain unconformably by unsorted clay and gravel deposits. Near Malignant cove the till is 50 feet thick and shows some rough sorting near the top.

West of Knoydart point well sorted beds are occasionally observed above the till, and these also occur along James river and the Intercolonial railway. The debris is usually of local origin, although some travelled pebbles are found. The shape is generally subangular, and scratching may be occasionally observed. Hog-back ridges and knolls are common in the vicinity of Maryvale and Arisaig and exist to a less extent over the whole district. Three instances of glacial striæ were noted on the plateau, having an average direction of S. 34° E. true bearing. One was situated north of James river and two were southeast of Arisaig. The extreme measurements were only 5° apart. Two other observations, however, were made on the lower lands to the north; one on the Arsiaig rocks of the Old road had a bearing S. 55° W., and another taken on the north side of the Sugar Loaf hill of Malignant cove had a bearing S. 73° W.

STREAM GRAVELS.

The deposits along the lower graded portions of the streams have already been mentioned under "Physiography"; they reach considerable thicknesses in some instances, as in Vameys brook. They are, however, generally local in extent. The rich deposits of the "intervales" or bottom lands about Antigonish may be correlated with the stream gravel deposits. In the case of the "intervales," the streams are long and have deposited their coarser debris far back, carrying only the finer material to their lower courses.

CHAPTER VII.

IGNEOUS GEOLOGY.

GENERAL STATEMENT.

A glance at the geologic map of the Arisaig-Antigonish district will be sufficient to show that while igneous rocks occupy only a small fraction of the area, they are of wide-spread occurrence in all except the Mississippian (Lower Carboniferous) formations and are of various kinds.

The order followed in describing these rocks will be: (1) deep seated intrusions, (a) granite, (b) monzonite; (2) acid intrusions and extrusions, beginning with aporhyolite because of its previous interest to geologists, and then taking up rhyolite and quartz-porphyry necks, etc., and finally rhyolite dykes, breccias, tuffs, etc.; (3) diabase intrusions, (a) necks, (b) dykes; (4) basaltic rocks and a dyke of breccia character.

Table of Igneous Rocks.
(Descending Order).

Post-McAras Brook, pre-Ardness...	Diabase necks, dykes, and intrusive sheets. Basaltic (?) intrusions and red dyke of breccia character.
Post-Baxters Brook, pre-Malignant Cove...........................	Rhyolite intrusions. Quartz porphyry. Rhyolite dykes. Altered tuffs (?)
Post-James River (probably of age of above group....................	Granite. Monzonite.
Pre-Beechhill Cove (probably of age of above group)................	Aporhyolite flow. Flow breccia, etc.

JAMES RIVER GRANITE.

LOCATION AND EXTENT.

The James River granite area is situated about one-half mile north of James River station on the Intercolonial railway, and extends probably 3 miles east and west with an average width of about 1 mile.

The granite is best seen along James river and its branching tributary from the west. The only observed contact with the country rock is situated near the headwaters of a small brook flowing south across the railway about one-half mile east of James River station. Eastward and westward the granite boundaries are obscured by drift.

PETROLOGIC CHARACTERS.

The specimen chosen as the type of the James River granite was taken only 20 feet away from the contact already mentioned. The grain of the rock in this sample is fully as coarse as that of specimens taken from the centre of the igneous area.

The granite is of a bright, flesh-red colour, is tough, and fractures in an irregular to sub-conchoidal manner, depending doubtless in these physical characters upon the texture which is dense but visibly granular. Feldspar is present both as bright red and as flesh-coloured crystals. Quartz occurs in irregular grains, generally under 2 mm. in diameter, and is clear or milky in appearance. Numerous irregular green patches of chlorite are scattered through the rock, indicating considerable weathering.

Alkalic feldspar and quartz are the essential minerals, and from a comparison of several slides they are estimated to occur in the approximate proportions of 2 of feldspar to 1 of quartz. The accessory minerals are biotite (altered to chlorite), epidote, and plagioclase.

The alkalic feldspar consists of the intimate intergrowth of orthoclase and albite forming microperthite, which may be recognized by its flecked appearance when seen between crossed nicols. Quartz is anhedral, occurring in irregular grains and masses. The plagioclase feldspar, as determined by Michel Levy's method, is andesine, varying in proportion of the albite and anorthite molecules from a composition of Ab_7An_3 to Ab_5An_3. The andesine is present in considerable quantity. Chlorite preserving the structure of biotite, indicates the original presence of that mineral. It occurs in small amount.

In texture the rock is granitoid with a strong tendency towards pegmatitic intergrowths of quartz and feldspar. Quartz crystals frequently extinguish together over considerable areas. Even in the normal specimens graphic intergrowths of quartz and feldspar are sometimes seen, while contact specimens show beautiful micrographic structure, as is described below. In general, the texture corresponds to that of a rock which is not far from a contact, and indicates the presence of plenty of water vapour during crystallization.

CONTACTS OF THE GRANITE.

At the observed contact with the country rock no diminution from the normal size of the granite grain could be detected. However, at a contact between two masses of granite, exposed on James river, finer grain in the rock was observed and a microscopic examination of a specimen taken 2 or 3 feet away shows beautifully developed micrographic intergrowths of quartz and feldspar. The quartz takes the form of hollow triangles, hooks, etc., up to 0·04 mm. across and rods up to 0·6 mm. in length with a breadth of 0·04 mm.

Small veinlets of quartz cut the country rock near the north contact of the granite. As seen in thin section under the microscope, these consist of quartz seams carrying a small amount of feldspar. They penetrate a shattered wall rock consisting of hornstone or greywacke. The larger quartz units show wavy extinction and very complete granulation.

STRUCTURAL RELATIONS.

The granite has intruded the James River (lower Ordovician) formation. The one contact examined was nearly vertical and that this is the general relation of the stock to the country rock may be inferred from the absence of other than insignificant dykes or offshoots from the parent mass. If the granite projected beneath a cover of sedimentary rock it might reasonably be expected that numerous acid dykes would be found extending considerable distances from the surface boundaries of the stock. Such intrusives are rare. South of the granite and west of the map boundary, an outcrop of pink intrusive rhyolite about 30 yards across occurs. Eastward about 2½ miles, a few small dykes of similar character are exposed in a stream bed. No other feldspathic intrusives were noted in the vicinity excepting the small dykelets to the north already described.

The debris scattered over the granite consists for the most part of glacial gravels, the surface of which corresponds in elevation and topography to the table-land to the north. Still a tendency towards radial drainage as expressed by the streams shows clearly that the top of the granite stock is slightly dome-shaped. This may have arisen in one of two ways; either we may have here what is practically the dome-shaped top of the stock from which little more than the roof with certain irregularities in the surface of the granite has been stripped; or the doming may be due to the greater resistance offered to erosion by the central part of the granite mass than would be offered by the somewhat shattered contact zone.

The lack of anything approaching channels cut into the granite; the small amount of granite debris either above the igneous rock or mixed with the glacial materials to the south; and more particularly the dense contact character of the granite itself, favour the first explanation.

On the other hand, at the granite contacts with the McAras Brook formation, the oldest of the Mississippian system found in the district, granite fragments ranging from angular to rounded pebbles are packed into the basal conglomerate. This establishes the erosion of the granite as far back as Mississippian time. However, as the contacts noted are along steep declivities which were probably shore-lines, the erosion was most probably due to wave and current action and may not have affected the top of the stock. The long period during which the granite has been exposed to erosion, and the probable steep character of its contacts, make it seem probable that the domed surface is due to the differential erosion during the progress of peneplanation and the later glacial abrasion. Still the texture of the granite favours the conclusion that no great thickness of the upper part of the mass has been removed.

The observations made on the jointing of the granite, when plotted, suggest two joint systems, one dipping to the north and northeast, the other to the south and southeast. The angles of dip vary between 66° and 90° from the horizontal. Corresponding jointing was observed in the country rock showing the systems to be regional. Numerous small diabase dykes have wedged into the granite along its joint planes.

MODE OF ORIGIN.

Little evidence is at hand relating to the method of the intrusion of the granite magma. Sheeting was observed in the granite from 1 to 1½ feet from the contact. This is commonly found where igneous material has been injected into cold rock. Again the regional system of joint planes, frequently meeting at approximately right angles and making high angles with the horizontal, would indicate that this structure was developed hundreds of feet deep in the zone of fracture. The complete jointing of that zone would be expressed along four planes at right angles to each other and making angles of 45° with the direction of maximum force. More commonly two planes are set up instead of four, and the angles vary with the values of the different forces acting.

Inferring that the granite was deep seated when the joint planes were formed, we may conclude that the intrusives took place at considerable depth in the earth, whence the granite was uplifted and exposed at the surface by erosion.

AGE.

Other than the James River granite, no granite is known in the area studied, with the exception of an obscure exposure in a small stream flowing into Malignant cove east of McNeils brook. Here, caught between irregular acid intrusives is a badly crushed and altered granite, penetrated by calcite. This appears to have been a small intrusion into the Baxters Brook formation.

Thus we have the intrusion of the granite positively fixed as younger than the James River slates and quartzites and older than the lowest of the Mississippian formations, which contains granite debris. No other formations have given us any relationships unless it be the Malignant Cove conglomerate, of probable middle Ordovician age. Upon microscopic examination this rock has been found to contain micropegmatite similar to that observed in the granite of James river. The localities are 12 miles apart, but a previous drainage system may have carried granite debris from its source to the location of the conglomerate beds. No other micropegmatite capable of producing such fragments is known in the district, although similar rocks may be found among the varied intrusions occurring eastward toward Cape George.

If the fragments are part of the granite, the intrusion took place after James River and before Malignant Cove time or about the close of lower Ordovician time. This would correspond to the probable time of intrusion and extrusion of the acid rocks south of Malignant cove, which, as explained where they are discussed, may be related in a general way to the granitic intrusion.

MONZONITE INTRUSIVES.

LOCATION AND EXTENT.

Commencing on the seashore about one-half mile east of the pier at Malignant cove, and extending to the eastward are a number of exposures of dioritic rock cut by irregular intrusives of diabase. Inland a few deeply weathered outcrops indicate that the intrusion is probably in the form of a stock extending southward about 1½ miles.

No contacts with the enclosing rock were observed. The surface, for the most part mantled by drift, is rounded and conforms to the general topography of the lower Ordovician rocks as seen east of Malignant cove.

PETROLOGIC CHARACTERS.

The type specimen was taken from an exposure on the seashore about one-half mile east of Malignant cove. The rock is medium granular and of a mottled green and white colour, depending mainly on the presence of green hornblende and white feldspar. Light and dark minerals are present in about equal amounts. The feldspar, which occurs in masses up to 5 mm. across, assumes a delicate pink colour on weathered surfaces, especially where these are wave-worn. Considerable chlorite is present.

The essential minerals of the rock are: hornblende, plagioclase and orthoclase feldspars, and biotite. The accessory minerals are: iron ore, apatite, zircon, and quartz.

The hornblende is a dark green variety. It is commonly euhedral in more or less perfect prisms, but here and there conforms to the shape of the plagioclase. Occasional cores are present which are non-pleochroic and from their high extinction angle appear to be augite. The hornblende is thus probably present as a secondary mineral after augite. The plagioclase, determined by Michel Levy's method, varies in composition from Ab_7An_2 to Ab_2An_3 and so is an andesine. Here and there this mineral tends to be euhedral, controlling the shape of the hornblende, and thus there is an approach to ophitic texture. Orthoclase, recognized by lack of twinning and small extinction angle from the cleavage on the 010 face, is an important constituent of the rock. Biotite occurs in rather irregular masses and is common. It is of a rich brown colour, strongly resembling brown hornblende. Magnetite is present as scattered irregular or rounded grains, included in hornblende. A few apatite prisms are included in hornblende and feldspar. Zircon is rare, occurring as more or less rounded prisms.

A thin section representing a boulder lying above the igneous mass, shows the rock to be made up of labradorite (Ab_1An_1) and basaltic hornblende, with considerable secondary actinolite. In veinlets a mineral occurs which from its optical properties appears to be phrenite. The specimen as represented in thin section consists of the following approximate mineral composition: plagioclase and orthoclase each 25 per cent, hornblende 30 per cent, biotite 15 per cent, and small percentages of apatite, zircon, and quartz. Thus in classification it falls between syenite on the one hand with predominant orthoclase feldspar, and diorite on the other hand with a predominance of plagioclase. The intermediate name monzonite is thus most suitable. It differs from the type, however, in the substitution of hornblende for augite and so may be called hornblende monzonite.

AGE AND CORRELATION.

As the monzonite lies off the area mapped, only little attention was given it in the field other than to determine its character and possible extent within the area. An examination of the exposures extending eastward along the shore towards Cape George might yield information bearing upon the general relations of this intrusion. It is cut by diabase similar to that seen elsewhere in the region. Feldspar fragments similar in character to the plagioclase of the monzonite occur in the conglomerate of Malignant cove. This evidence, so far as it goes, favours the supposition that the monzonite intrusion may have belonged to the general igneous activity at the close of the lower Ordovician.

APORHYOLITE FLOW AT THE BASE OF THE SILURIAN SECTION.

DISTRIBUTION AND GENERAL CHARACTERS.

The upturned edge of a rhyolite flow which has been of great interest to former writers extends eastward, with two interruptions, from Arisaig pier to McNeils brook, a distance of about 3 miles. The first break occurs a short distance east of

Arisaig point where for a little more than a quarter of a mile no volcanic rocks outcrop; again at Beechhill cove for a half mile the sea sweeps without interruption against the lower beds of the Silurian system, which overlie the rhyolite.

The aporhyolite forms a low ridge with nearly vertical contacts and reaches its greatest physiographic expression in Frenchman's Barn, an irregular rock rising about 60 feet above the sea, with a base measuring about 150 yards east and west by 40 yards north and south. The lower part of the sheet varies in colour from pink to green to brown, and shows well developed flow structure. As is best seen in the quarry along the road extending to Arisaig pier, the rhyolite passes by gradations into a flow breccia. At Frenchman's Barn breccia of finer nature is overlain by the coarse breccia. Adding further interest to these striking lithologic characters, younger intrusives consisting of dark green diabase and a red tufaceous dyke have penetrated the volcanic rocks along the whole extent of their visible outcrops.

PETROLOGIC CHARACTERS.

The type specimen was taken from the quarry near Arisaig point. It has a decided platy parting, which coincides with rusty-red bands in the otherwise flesh-coloured rock. These bands are on an average 2 mm. apart. The material between the bands is of felsitic texture and may be seen, even with the unaided eye, to consist of rounded masses like small shot, closely packed and more or less welded together. On parting surfaces these little bodies project, giving an irregular oolite-like appearance. By means of the microscope the rounded masses prove to be spherulites with characteristic radial structure. The dark parting planes are situated along cracks filled in with secondary quartz and iron oxide. As seen in the hand specimen these fine bands or layers have been determined by flow structure, and have no relation to sedimentary origin, which they were formerly thought to indicate.

In general characters the rhyolite corresponds to modern acid lavas from the Lipari islands and the Yellowstone park as seen on a comparison of hand specimens. Iddings states in his work on the geology of the Yellowstone park[1] that lamination in the case of the lithidite at Obsidian cliff depends upon the different amounts of water vapour in the layers, which cause different degrees of crystallization or the formation of bands full of gas cavities. In the lava under discussion the secondary minerals along the parting planes have masked the original texture, but in favourable places narrow bands of finer spherulites may be observed, as described by Twenhofel.[2] The finest material appears micro-felsitic in character. The parting takes place along the cracks originated during crystallization and filled with the secondary minerals mentioned above. No structure that could indicate the former presence of gas cavities has been observed.

Where the aporhyolite does, however, decidedly differ from the recent lavas mentioned, is in its complete felsitic texture, although all the structures point to its once having been partly glassy. Layers of spherulites averaging about 0·5 mm. across, compose nearly the whole rock mass, while the small amounts of glass once present have been devitrified. A similar occurrence is described by Professor F. Bascom in her publication on "The Structure, Origin, and Nomenclature of the Acid Volcanic Rocks of South Mountain, Pennsylvania."[3] Following her suggestion of the name *aporhyolite* as being most suitable for a devitrified acid lava, the name has been adopted as best designating the rhyolite under discussion.

Some specimens representing certain bands of the rhyolite lava flow are fine-grained, flinty looking felsites of light green or pink colour. They possess conchoidal fracture.

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[1] Iddings, J. S. U. S. Geol. Surv., Mono. XXXII, Pt. II, pp. 424–5, 1899.

[2] Twenhofel, W. H. Amer. Jour. Sci. (4), XXVIII, p. 159, 1909.

[3] Bascom, F. Jour. Geol., I, pp. 813–832, 1893.
See also:
Weidman, Samuel. Wisconsin Geol. Nat. Hist. Surv., Bull. III, Sci. Ser. No. 2, pp. 1–63, 1898.
Clements, J. M. Jour. Geol., III, pp. 800–822, 1895.
Hobbs, W. H. and Leith, C. K. Univ. Wisconsin, Bull. 158, Sci. Ser. No. 6, pp. 247–279, 1907.

The flow breccia forming the upper portion of the rhyolite sheet contains rounded fragments of rhyolite and has a grit-like texture. In general it is light grey-green in colour.

The essential minerals of the rock, represented by the spherulites, are quartz and alkalic feldspar. Secondary quartz and iron oxide are prominent along the parting planes.

The texture, in general spherulitic, varies to microgranitic. In one slide representing a bomb taken from a fine-grained red-brown breccia at Frenchman's Barn, a microfelsitic groundmass is very general, showing spherulites only under very high magnification. Sericite is abundant and is probably the cause of simultaneous extinction, or approach to extinction, over oval or pentagonal areas when the section is studied between crossed nicols. These areas are seen in the hand specimen to be sections through small facetted grains into which the rock has become divided. The development of sericite is probably responsible for the separation, which may be described as a perlitic parting.

Sections of the rhyolite obtained by Twenhofel show, as described by him, a flow structure expressed in different sizes of microlites. He says of the minerals in the less dense bands: "These consist of quartz and alkalic feldspar, the quartz acting as a sort of sponge for the feldspar and giving what is known as micropoikilitic structure."[1] An examination ot the slides confirms this statement. (His chemical analyses also confirm our classification).

STRUCTURAL RELATIONS.

Rough columnar jointing with axes about perpendicular to the contacts is common in both rhyolite and breccia. Sheeting is present in many cases where the rhyolite and breccia merge, being more noticeable in the breccia. The sheets vary in thickness from 6 inches to 2 feet.

The rhyolite sheet lies below the Beechhill Cove formation, the lowest of the Silurian system. Debris from the volcanics

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[1] Twenhofel, W. H. Loc. Cit., p. 159.

is included in the basal sedimentaries, as may be seen at the contact exposed in Doctors brook. At Beechhill cove storms have recently exposed a contact where the sedimentary beds are flexed around an irregularity in the rhyolite. Near by small dykes deeply weathered and of uncertain character, cut the sediments. The relations point clearly to the latter having been deposited over an uneven surface, in this case where a lava bed has been partly removed. Later movement was most concentrated at the contact of hard and soft rocks and flexed beds resulted in the shales. The dykes are doubtless representatives of the soft weathering basaltic (?) intrusives everywhere abundant along the rhyolitic exposures, and are connected with the contact only in that the latter afforded a zone of weakness where intrusion was relatively easy.

In Doctors brook the overlying shales are finely jointed and micaceous near the contact; no other changes were noted.

Diabase nearly always occurs with the rhyolite, cutting into it mostly from the seaward or under side. Here and there it penetrates the lava along joint planes.

Besides the dark green diabase, a brown, fissile, irregular, red dyke is present almost everywhere with the rhyolite and cuts both it and the diabase.[1]

MODE OF ORIGIN.

The aporhyolite was originally described as an altered sedimentary but as Twenhofel has pointed out, its characters and relations show that it is without doubt a lava flow which was poured out upon a surface existing before the Beechhill Cove formation was deposited. At first the flow was homogeneous, but as thickness increased, cooling lowered the fluidity of the material and all gradations resulted between lava with flow structure, and flow breccia consisting of lava blocks surrounded by a fine cryptocrystalline[2] rock mass.

[1] For the above intrusives see "Diabase and Basaltic Intrusives."

[2] The microscope shows quartz crystals usually less than 1 mm. across, having wavy or rolling extinction and frequently broken more than once.

That the pouring out of the lava was accompanied by some explosive action and the deposition of fragmental rocks may be inferred from the character of the breccia seen at Frenchman's Barn. In the opinion of the writer, however, this is also a flow breccia. A part of the flow breccia may also consist of tuff or bomb deposits, but the field evidence does not strongly favour this supposition.

AGE AND CORRELATION.

The rhyolite flow is at least older than the Beechhill Cove formation as exposed on the shore. On the other hand, the Malignant Cove conglomerate contains fragments of rhyolite similar to that under discussion. This would make the aporhyolite of pre-Malignant Cove age.

While it cannot be conclusively shown that the extrusion of the aporhyolite belonged to the same period of acitvity as the intrusion of the quartz porphyry, rhyolite dykes and purple rhyolite of the Sugar Loaf area south of Malignant cove, still from similar characters and close association these various rocks appear related. If this could be proven, then the extrusion of aporhyolite would be limited to the time intervening between the deposition of the Baxters Brook slates and the Malignant Cove conglomerate, or to what was probably the close of the lower Ordovician period.

VOLCANIC (?) BRECCIA OF FRENCHMAN'S BARN.

LOCATION AND GENERAL CHARACTERS.

Just west of the prominent rock known as Frenchman's Barn, a dark red bed of fissile material (discussed under basalt) overlies the flow rhyolite. It is about 10 feet thick and is succeeded to the south by a dense red rock which contains some blocks of rhyolite as large as 1 foot across, but which apparently consists mainly of fine felsitic groundmass with angular red fragments 1 mm. and less in size. Above lies a thick bed of dark green rock showing lighter bands. This may be traced for a considerable distance eastward and has been described by Twenhofel as a volcanic breccia.

PETROLOGIC CHARACTERS.

Seen in the hand specimen, this rock is dense, has a felsitic texture, and is of a chocolate brown colour, with purplish variations. The fracture is conchoidal. Scattered through the mass are a few, small angular brick-red fragments, and greenish coloration seems to indicate other fragments.

Microscopic examination of the dense red breccia shows it to consist of a fine-grained groundmass containing angular fragments of quartz about 2 mm. across, and under very high magnification the groundmass appears to have an exceedingly fine micro-granitic texture. Low magnification brings out an arrangement of the groundmass suggesting either flow or irregular bedding. No shards of glass or other material are present.

MODE OF ORIGIN.

The characters and relationships of the breccia beds would indicate that they formed one phase of the volcanic activity during which the aporhyolite was poured out. While the upper beds of rhyolite at Arisaig point were coming to rest as flow breccia, similar action was taking place near Frenchman's Barn, but here, in the case of the lower beds, finer fragments appear to have resulted, while the upper beds differ but little from the breccia farther west. The inconclusive character of the dense red breccia leaves some doubt whether after all, at this eastern locality, the rock is not made up of true volcanic tuff and breccia.

ACID INTRUSIVES.

DISTRIBUTION.

The picturesque Sugar Loaf hill of Malignant cove is a centre from which extends dark coloured rhyolite breaking through the slate cover, quartz porphyry protruding here and there, and small light coloured rhyolite (felsite) dykes penetrating the country rock in very irregular fashion. Only the dykes extend to any considerable distance and they are for the most part included within the southwest quadrant of a circle of 3½ miles radius, with centre at the Sugar Loaf. At the so-called marble quarry of Browns mountain, at a place about three-fourths of a mile northwest from Browns Mountain post-office, and at two or three isolated areas near the James River granite stock, and also, in one instance, within the granite itself, rhyolite dykes occur.

PETROLOGIC CHARACTERS OF THE ACID INTRUSIVES.

The rhyolite forming the neck of the conical hill known as the Sugar Loaf, and many irregular intrusions about it, all of which belong to the zone of transition between flow and intrusion, is a dense dark purple rock so weathered as to be unidentifiable in the field. To the westward it is replaced by quartz porphyry, which has been observed to grade directly into it. Across the transition zone the groundmass of the porphyry becomes successively darker, the feldspar phenocrysts decrease in number, and finally the dense purple rhyolite shows only an occasional oval quartz to indicate its relationship to the porphyry. The quartz disappears also within a short distance.

At one or two localities rhyolite flow-breccia is present. In general it has the purple colour and dense texture of the intrusive variety, but contains angular fragments, usually less than 1 cm. across, of grey-weathering material. Flow lines are well brought out on weathered surfaces.

The quartz porphyry when fresh consists of a purple grey groundmass rather thickly set with large oval phenocrysts of flesh-red feldspar, and occasional round or oval patches of quartz. The feldspar phenocrysts may be as much as 1·5 cm. long, while the quartz is usually less than half that size. The fracture of the rock is uneven and hackly. The rhyolite of the dykes is of a light flesh colour, and usually shows small irregular patches of chlorite. It is of very dense, felsitic texture and has a conchoidal to hackly fracture. Very much altered and often ferruginous dykelets occurring in a small brook northwest of Maryvale, and again along the northern part of the Old road of Maple ridge and elsewhere, are probably weathered dykes of this group.

A slide from the rhyolite of the Sugar Loaf shows under the microscope a micro-felsitic groundmass, containing feldspathic rods. These are probably orthoclase for the most part, but a little plagioclase is present as is shown by distinct albite twinning. As no Carlsbad twins could be found the nature of the plagioclase is uncertain. Serpentine and calcite are common alteration products.

A specimen taken from near the slate contact with the rhyolite of the neck shows much fragmental material consisting of broken laths of feldspar and rounded fragments and shards of quartz. Bunches of material are separated and appear to have been rolled together. Some fragments show small oval amygdules filled with an isotropic mineral having radial lines and what was originally a cavity in the centre. Shards of isotropic material as well as those of quartz are present, but can frequently be traced to their apparent source in material of similar characters showing remnants of a vesicular nature. A fine groundmass surrounds the fragments, and so far as can be seen is microgranitic in texture. Small euhedral, or hollow squares of magnetite are common. Kaolin and fine iron oxide obscure the original structures.

A specimen of quartz porphyry taken from an outcrop a short distance southwest of the Sugar Loaf, proves upon microscopic examination to consist of a microfelsitic groundmass of quartz and feldspar containing a number of large phenocrysts of orthoclase with some plagioclase and a few large rounded quartz masses. The latter fade off at the margins into the groundmass. Alteration to kaolin and chlorite is common.

The type specimen from the rhyolite dykes was taken from an exposure in the bed of a small brook about three-quarters of a mile south of the Sugar Loaf. Microscopic examination shows the rocks to be made up of quartz, orthoclase, and plagioclase feldspar, in about the proportion common in granite. The texture is microgranitic. The grain is equidimensional and of an average diameter of 0·1 mm. With high magnification plagioclase laths were observed about 0·09 mm. across. The extinction angles were about 13°–18° from the albite twinning plane. One feldspar also showed Carlsbad twinning by means of which it was determined as andesine. The extinction angles given above would bear out this determination. Specimens from the dykes in the James River granite show characters similar to those just described. A slide representing a dyke cutting the granite, contains a little scattered magnetite in grains about 0·02 mm. across, and has a microgranitic texture. Some well developed quartz and orthoclase and plagioclase feldspars are present.

A sample of rhyolite dyke-rock from northwest of Browns Mountain post-office, consists of a groundmass exhibiting spherulitic texture, and phenocrysts of orthoclase and plagioclase feldspar. The latter has large angles of extinction, and as determined in one case, by Michel Levy's method, is labradorite. Flow structure is clearly present as shown by broken quartz crystals, broken pieces of feldspar, and by a general flow arrangement of the groundmass about the phenocrysts.

The pink colour of the rock is largely due to strings and shreds of iron oxide which are scattered through the groundmass.

STRUCTURAL RELATIONS.

The acid intrusives, with the exception of the dykes cutting the James River granite, cut either James River or Baxters Brook formations of lower Ordovician age.

The rhyolite of the Sugar Loaf forms a nearly vertical, but irregular neck standing high at its east and west extremities. Against the sides and nearly overlapping the central portion are twisted and more or less stretched red slates. The same rhyolite outcrops in many mounds to the westward, often little more than breaking through the slate, which overlies it generally at a low angle of dip.

The quartz porphyry bears in general the same relations to the enclosing rocks as does the purple rhyolite and forms an irregular neck outcropping in McNeil's mountain, one of the highest eminences in the area. The porphyry appears to represent an intrusion more deeply cut than the rhyolite and has, so far as indications go, steep contacts.

The rhyolite dykes are usually small and cut the country rock along lines of weakness such as bedding and joint planes. In one case they were observed to flow around quartz porphyry. The dykes near James river have the same general characters as those just discussed, while the intrusions of Browns mountain are somewhat irregular though probably of the nature of dykes.

MODE OF ORIGIN.

The fine-grained texture of these rocks and their manner of breaking through the older formations indicate that they were intruded near the surface. The occurrence of flow breccia and tuff shows that they had extrusive phases, which have scarcely been removed by erosion. In one exposure a triangular block of slate 3 feet by 4 feet has settled into the rhyolite. This would indicate that overhead stoping had played a part at least in the irruptive processes.

AGE AND CORRELATION.

That the purple rhyolite and the quartz porphyry are merely phases of the same intrusion seems to rest upon safe evidence in the case of the observed gradation of the one into the other. The rhyolite dykes are evidently younger as they are known to curve about the quartz porphyry. However, their close petrographic resemblances point to their common origin and seem to indicate that the difference in the ages is not great. The rhyolite dykes of Browns Mountain and the James River granite area are probably a little younger than the granite, but appear to be of the same magmatic origin. Their close petrologic resemblance to the acid intrusives of Malignant cove and their presence in the same sedimentary formation, favour the theory that all these intrusives are really of one general age. If we include also the aporhyolite flow at the base of the Silurian formations, which is closely allied in petrologic characters, we may seek for an epoch of activity agreeing with the accumulated data derived from the separate study of these various rocks. Such an epoch is found between the deposition of the Baxters Brook slates and the Malignant Cove conglomerate, probably corresponding in time to the close of the lower Ordovician. All the acid intrusives have been shown to be younger than the James River formation, while the Sugar Loaf intrusions cut the Baxters Brook slates and so are younger than these. These intrusives do not cut the Malignant Cove conglomerate; and fragments of rhyolite of microgranitic texture are found in this formation. The aporhyolite is certainly older than the basal Silurian and most probably older than the Malignant Cove conglomerate which contains fragments of similar material. There seems no good reason for placing its age farther back in time than the lower Ordovician to which belong the oldest formations known in the district. The weight of evidence thus favours one general period of intrusive and extrusive activity for the acid irruptives; and this being granted, the time of activity must have been previous to the deposition of the Malignant Cove conglomerate but after the Baxters Brook slates and sandstones were deposited. A time interval is here represented by an unconformity between the formations named which probably marked the close of lower Ordovician sedimentation. If the Malignant Cove conglomerate is of Ordovician age the igneous activity may be considered as belonging to the close of the lower Ordovician.

VOLCANIC TUFF AND BRECCIA OF SUGAR LOAF AREA.

GENERAL LOCATION AND EXTENT.

In several localities within the igneous area of the Sugar Loaf hill south of Malignant cove, soft purple schist or light green breccia rocks were observed. For the most part, outcrops are of insignificant size, extensions being masked.

PETROLOGIC CHARACTERS.

A specimen of soft green rock weathering so as to show a breccia nature was obtained from an outcrop near hematite prospects north of the Little Hollow. Megascopically it is clearly very calcareous. Other specimens of similar rock differ in being fine grained and of a purple colour. Those tested effervesce freely with acid.

Under the microscope iron oxide is seen to be rather freely scattered through the calcite, which makes up the greater part of the rock. In the arrangement of the oxide and in the peculiar globules of calcite present a former tufaceous structure is thought to have been recognized. The purple schist seen under the microscope shows similar characters.

AGE.

As already indicated, there is some uncertainty as to the real character and relation of these tufaceous rocks, because of their great alteration. The specimen described represents the south wall-rock of a bed of iron ore, and Woodman states (1909, p. 194) that "tuff-agglomerate" has also been observed to form the south wall of an iron ore bed at Iron brook and elsewhere.

If this be tuff and be really interbedded with the James River strata, as it appears to be, it becomes the earliest evidence of igneous activity that has been found in the district. The necessary conclusion would be that extrusive volcanic eruptions occurred during that part of lower Ordovician time represented by the deposition of the James River greywacke and slate.

DIABASE INTRUSIVES.

DISTRIBUTION.

Series of diabase dykes are of common occurrence cutting rocks of all ages from the lower Ordovician to the Mississippian. In almost every stream, excepting those flowing through the upper divisions of the Carboniferous rocks, upright projections of diabase mark the intersection of these dykes by the water course. They are in many cases so weathered as to be with difficulty distinguished from the enclosing rocks.

For the most part the dykes are small, being less than 15 feet in width. Quite a number, however, are of fair size, some reaching a thickness of 40 or more yards. In general they conform to the main direction of faulting and folding in the region, and extend in a northeasterly and southwesterly direction, with a tendency in the Devonian area to swing more nearly north and south. The dip usually varies but a few degrees from the vertical, but there are exceptions as in the case of the amygdaloidal diabase at the mouth of McAras brook. Here the intrusive sheets dip to the north of west at from 40° to 49°. In the metamorphic area of lower Ordovician rocks the regional jointing for the most part controls the form and direction of the dykes.

Numerous small dykes have also wedged into the James River granite along the jointing. In one instance four dykes varying from 1 to 20 feet in width and separated by similar widths of granite, are exposed in parallel arrangement across the bed of the western branch of James river.

Generally longitudinal extensions of the dykes are obscured and dyke terminations occurring in the stream beds would indicate that there are frequent interruptions along their length. However, extending eastward from Arisaig point, diabase may be observed in connexion with the aporhyolite flow for about 3 miles along the shore. This appears to be a continuous intrusion, although outcrops are occasionally lacking. The diabase occurs as an irregular dyke partly following the bedding of the flow, partly breaking across it, and nearly always lying at the base of the lava sheet whence it extends into the ocean forming numerous reefs several rods from shore.

Besides the dykes there are a few irregular intrusions of diabase. One of the best examples of these occurs as a neck in the Sugar Loaf hill about 1¾ miles nearly due north of the town of Antigonish. This prominent physiographic feature is an oval knob about one-fourth of a mile north and south, measured along its major axis. Its top, according to Fletcher's map, reaches an elevation of 760 feet above sea-level.

On its summit, weathered diabase outcrops in the form of an oval with a narrow projection to the south. On the north a precipice of 25 feet marks the contact of the James River rocks with the diabase from which the slate has fallen away. Elsewhere the slopes are more gentle, although still steep down to the plateau level. The slate at the contact is very hard and is frequently jointed into small blocks.

The diabase forms the core of the hill and is the cause of its preservation, both the diabase and the metamorphosed slates about it being very resistant to erosive agencies. Within a circle of 1 mile small diabase dykes are of commom occurrence.

PETROLOGIC CHARACTERS.

Certain of the diabase intrusions, notably the sheets cutting the McAras Brook formation (Mississippian), are decidedly amygdaloidal for several feet both from the upper and lower contacts. Fillings of calcite have been observed that measured an inch in diameter. Similar diabase occurs along the shore east of Arisaig point and amygdaloidal character has been noted elsewhere. Other than this physical difference no natural division of the diabase intrusions has been found and they will be described together.

The type specimen was taken from an irregular dyke exposed along the Old Road about 2½ miles south of Arisaig point. The rock is visibly granular, but dense. Its colour is dark green-grey with lighter spots due to more or less distinct, small, light-green laths of waxy-looking plagioclase feldspar. Scattered through the mass are numerous irregular patches of iron pyrites. Jointing is well developed and much chlorite is present along the joint planes.

Some specimens are so dense that no grain can be seen, while others approach pegmatitic structure and show well developed feldspar crystals of a pink-brown colour. The latter characters may be observed at the forks of the upper branches of the South Branch of Rights river.

As seen under the microscope the essential minerals are augite and plagioclase feldspar; the accessory ones being magnetite and pyrite. The texture is characteristically ophitic.

The magnetite occurs in idiomorphic crystals about 0·27 mm. across, while pyrite is present in irregular grains. The plagioclase feldspar has crystallized in laths about 0·2 mm. wide and 2 mm. long. By means of the Michel Levy method these laths were found to vary in composition from Ab_3An_7 to Ab_1An_4, and so belong to the labradorite-bytownite series. Augite has developed partly before but mostly after the plagioclase, commonly appearing as laths more or less parallel with the feldspar, and more rarely forming irregular masses. Actinolite, chlorite, and epidote have replaced much of the augite.

The rock composition is approximately augite one-third, plagioclase one-half, and magnetite one-tenth, while the remainder is made up of alteration products. The composition and texture of the rock determine it as diabase.

The more feldspathic specimens show some quartz to be present. A sample taken from the intrusion on Rights river, already mentioned, contains considerable quartz, while the feldspar belongs to the andesine-labradorite group. A specimen from a small stream north of James River station shows in thin section considerable quartz and also a tendency towards micrographic structure.

STRUCTURAL RELATIONS.

In many cases the diabase dykes show systems of jointing. Sheeting parallel to the contacts extends into the body of the dyke for a short distance and is replaced by rough columnal jointing with axes perpendicular to the contact planes. The two systems may be observed at the mouth of McAras brook. The columnal jointing here has prism faces from 1 to 2 feet in width. In the case of the smaller dykes, only little jointing is present. No sheeting has taken place at the contacts with the country rock, but it is found that here the grain of the diabase is finer than at the centre of the dykes.

As the diabase sheets at the base of the McAras Brook (Mississippian) formation have been described by Dawson as extrusive flows laid down in water during the deposition of the conglomerate, a rather full description will be given of the character of these intrusives and their relations to the sedimentary formations. The author did not find any evidence of fragments of diabase in the conglomerate as described by Dawson.

The diabase is for the most part intruded either along contact or bedding planes. The lowest sheet occurs at the top of the Silurian section and flexes the shale beds, forming a local syncline. For 5 feet below the "trap" all bedding is destroyed. Tongues of diabase containing fragments of shale penetrate across the direction of bedding for 8 feet or more. For 12 feet beneath the lower igneous contact the shales have become uniform iron-red in colour, and in places assume a submetallic lustre.

A trap sheet passes very near the contact of the Mississippian conglomerate with the Devonian shales, leaving but little conglomerate below it.

In all cases the lower contacts of the diabase sheets with the McAras Brook conglomerate show, in the sedimentaries, discoloration, baking or hardening, and fissility parallel to the contacts. The upper contacts show practically the same characters. In one exposure the trap has an uneven surface; 3 inches of gouge overlies this; the conglomerate is hard for about 3 inches and is finely jointed for about 3 feet more before it becomes normal. In another case the intrusive rock uplifts the conglomerate beds and breaks across their strata as much as 2 feet. At one upper contact shale fragments are contained in the diabase for 6 feet down, one a foot from the contact being 3 feet long. The diabase is amygdaloidal for considerable distances from both the top and bottom. This amygdaloidal nature suggests intrusion near the surface, an inference supported by the observation that the intrusives do not cut the formation above and hence probably came to place before the Ardness sediments were deposited.

In the older formations the intrusives affect the wall rock but little. In the Devonian rocks sheeting has been observed parallel to the contact.

Where the diabase cuts the aporhyolite east of Arisaig point the dyke material flows around and into the joints and fractures of the lava in a very irregular way. In some cases blocks of rhyolite are dislodged and contained in the diabase. Little contact effect upon the wall rock could be observed, but the "trap" is always very dense. In the case of the James River granite where the diabase is intruded along joint planes, discoloration of the granite is often marked at the contacts.

METHOD OF INTRUSION.

As already mentioned the wide-spread regional structure consisting of jointing, faulting, etc., has for the most part controlled the mode and directions of the diabase intrusions. Usually joint planes have been the passageways for the molten material, but bedding planes have also been followed as in the case of the Mississippian formations and the rhyolite flows. A few small irregular masses appear to be more or less independent of structure and were probably related to minor centres of disturbance. This seems to be true in the case of the Sugar Loaf, near the town of Antigonish, with its set of dykes on the south and west.

AGE.

No good reason has been found for considering the diabase dykes to be of more than one period of intrusion. In not a single instance was diabase observed to cut diabase. On the other hand diabase is known to cut representatives of all the other intrusive rocks.

As already noted the sheets of diabase cut the McAras Brook conglomerate but do not cut the Ardness, the overlying formation. They were then, in all probability, intruded during early Mississippian period after the deposition of the McAras Brook formation, but before the laying down of the Ardness limestones, sandstones, etc. For the reasons given it seems probable that the other diabase intrusions of the region also belong to the early part of the Lower Carboniferous or Mississippian period.

BASALT, BRECCIA DYKE, ETC.

LOCATION AND EXTENT.

A number of the irregular basic intrusives scattered over the area are of basaltic rather than of diabase character. Examples of this class are to be found associated with the purple rhyolite south of Malignant cove. Of such a chara .er are the purple intrusives along the Gulf road for the first mile south of the shore and also the amygdaloidal rocks north of Rogers brook, a tributary of Rights river. An altered intrusive in the Silurian rocks of Doctors brook and soft clayey dykes near the small Carboniferous area on the east branch of this brook, are probably basalt.

The long red dyke mentioned in connexion with the intrusives east of Arisaig point, is so friable as to be with difficulty determined. It appears to be a very fine breccia in nature, but amygdaloid associated with it is basaltic. With the exception of breaks common to all the rocks along the shore, this dyke has been traced for nearly 3 miles.

At Arisaig point to the east of the Lighthouse, diabase penetrates the aporhyolite in the form of irregular dykes of small size. Near one of these, brown fissile to powdery material cuts into the rhyolite as small dykes with rounded terminations, and in one case as an almost circular pipe of about 1 foot diameter. This soft-weathering intrusive has a fissility parallel with the contacts, while vesicular nature was present in one case. The rhyolite was faulted previous to intrusion as the diabase follows the fault line. The acid lava also shows a pitchstone character and fine sheeting parallel to the fault line. West of the base of the rock known as Frenchman's Barn, a 10-foot sheet of red fissile rock separates rhyolite-breccia on the south from rhyolite showing flow structure on the north. This sheet is directly in line with the red dyke to the eastward which leaves the aporhyolite and cuts into the diabase. At Frenchman's Barn rounded masses of red material are contained in the mass of the sheet, while rhyolite blocks are enclosed farther east. In places the red material is amygdaloidal. Eastward the red dyke cuts across the sheeting of the volcanic breccia and still farther to the east it is found entirely within the diabase, in places throwing off branches for several feet along the joint planes of the older intrusive. Due to its soft nature, long tide-washed lanes are here and there left with a floor of dyke material and high walls of diabase. West of Doctors brook two small red dykes are present part of the way, while in some places no dyke can be seen. However, to the end of the exposures of diabase east of Doctors brook evidences of the dyke are present.

PETROLOGIC CHARACTERS.

Four specimens have been selected for special description.

The first was taken from an area south of the Hollow and north of Iron brook. It is very dense, of a purple colour, and has a conchoidal to uneven fracture.

The second to be considered is a sample of the red shaly rock occurring west of Frenchman's Barn. This is of a bright iron red colour, with irregular white patches scattered through it. These look at first like sheared amygdules. The texture is fine and the rock is fissile and slaty in appearance. Rounded nodules of the same material cause the fissility to pass around them; some fragments of aporhyolite are present.

The third specimen is taken from the irregular red dyke as exposed east of Beechhill cove. In general only crumbly debris can be obtained, but the specimen is of slaty texture, dark red colour, and fine, even grain. A cleavage parallel with the contacts is very marked.

The fourth rock sample was taken from an amygdaloidal dyke penetrated by the fissile red material last described. It is purplish red in colour, and has light green amygdules about 3 mm. across. These are considerably flattened out and sheared.

Under the microscope, the first rock, although very much altered, from secondary products and remains of crystal forms, may be shown to have contained olivine and feldspar as the best developed minerals. The feldspar had the form of laths twinned according to the albite law and where best preserved these show nearly parallel extinction. These characters determine the feldspar to have been oligoclase. The olivine has altered almost completely to serpentine and iron oxide. It is by the marginal arrangement of the oxide that the original character of the mineral may be determined. Glass and undifferentiated augite were probably present. Secondary quartz is common. A slide from the intrusives along the Gulf road shows considerable augite to be still present as irregular grains, and crystals penetrated by feldspar laths. Secondary chlorite, iron oxide, calcite, and chalcedony are present. Flow structure is marked. In spite of alteration typical pilotaxitic texture is well preserved. It was originally expressed in the crowding together of microscopic laths of feldspar, with olivine, augite, and probably some glass between.

A microscopic examination of a specimen of red material west of Frenchman's Barn clearly shows it to be made up of a fine groundmass containing irregular fragments of rhyolite measuring on an average 0·1 mm. by 1 mm. Some quartz fragments are also present. The rock is filled with iron oxide and little can be said of the original character of the groundmass. It appears to have been made up of fine fragments of some kind.

Twenhofel considered this rock in all probability to be of sedimentary origin, basing his opinion upon his unpublished chemical analyses which show the average content of alkalis to be Na_2O, 2·54 per cent, and K_2O, 2·92 per cent. It is evident that these percentages are greater than would be the case if the rock were of normal sedimentary origin. On the other hand, they correspond to the average percentages found in igneous rocks of intermediate feldspathic character. As the specimens studied show almost complete setting free of the combined iron so that it now fills the rock as iron oxide, it is reasonable to expect that the alkalis have to a large measure been leached out.

The third specimen, which is from the red dyke, is difficult to determine under the microscope. It consists mainly of finely divided iron oxide, with small grains of quartz and some magnetite. The average grain of the rock is about 0·02 mm. in diameter. Some unquestionable shards of quartz are present, and the original rock was clearly made up of fine clastic components.

The last specimen, representing the purple amygdaloid, is almost completely changed from its original mineral composition, yet pseudomorphs of feldspar laths still exhibit albite twinning and show that the original mineral was plagioclase. Magnetite was also a primary constituent, as shown by the development of feldspars around it. In the place of the earlier minerals, chlorite, iron oxide, kaolin, opal, and chalcedony now make up the bulk of the rock, the chalcedony forming the amygdules. Pilotaxitic structure is, however, well preserved. The feldspar laths were on an average 0·15 mm. across, and were closely packed together.

MANNER OF INTRUSION AND RELATIONS.

The basalt of Rogers brook, the igneous area south of Malignant cove and elsewhere, appears to have been merely a surface phase of the diabase intrusions, and may have been in part extrusive.

The red dyke along the shore cuts the diabase and the aporhyolite and so is the youngest igneous rock known in the district. In some cases it appears as pipes and small dykes cutting through the diabase. At other places it includes large blocks of diabase. At Frenchman's Barn it has the characters of a sheet intruded between the homogeneous aporhyolite flow and the breccia above. As might be expected, fragments of the enclosing rock are contained in the intrusive. It is well to note here that at this one locality the sheet might almost equally well be interpreted as a normal tuff overlain by breccia. It is because of the apparent continuity and alignment with the red dyke that the first interpretation is thought to be correct. Eastward from Frenchman's Barn there is no question as to the dyke nature of the fissile red rock. It passes entirely into the diabase, branches and splits, includes rhyolite, diabase, and basalt as only a dyke possibly can. That such dykes occur elsewhere is shown by observations made by various geologists.[1]

[1] In the Quarterly Journal of the Geological Society of London, Volume 57, 1901, pages 479–489, James Robinson Kilroe and Alexander McHenry, M. R. I. A., have described as dykes rocks occurring in Waterford and Wex-

Some evidence bearing upon the origin of the red dyke is afforded by the character of the purple amygdaloidal dyke associated with it. The amygdaloid is entirely distinct from the diabase and occurs along the same line of intrusion as does the red dyke. It is somewhat older as the red material flows into it and around portions of it. The suggestion seems to be that the amygdaloid represents the first pulse of intrusion, and the brecciated material later pulsations. The conditions must essentially have been those close to the surface. As the activity was confined to the vicinity of the diabase, it may well have been an after phase of the diabase intrusion.

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ford counties, Ireland, that had previously been considered volcanic tuffs and breccias. They find them cutting sedimentaries and containing many fragments of the country rocks. Thus slate of Llandeilo age and Bala limestone are intruded. Even the dykelets retain tufaceous character. In form the intrusions are either sills or dykes. An instance was noted where granite grades into felsite and this into breccia, and finally intrusive tuff is found.

The explanation offered is that fracturing occurred in connexion with continued intrusion after portions of the invading magma had solidified in smaller veins. Pumice is explained by the sudden opening out of fissures, etc.

CHAPTER VIII.

HISTORICAL GEOLOGY.

GENERAL STATEMENT.

From lower Ordovician to Pennsylvanian time, the geological history of the Arisaig-Antigonish region is imperfectly written in the sedimentary records, but there are also important chapters dealing with igneous intrusions, lava flows, and erosion intervals.

From Pennsylvanian to Quaternary time, there probably was little or no sedimentary record, the interval being apparently one of long and continuous erosion. The erosion cycles are clearly indicated but are limited in number and not readily placed in the chronology except by analogy with other physiographic provinces. Quaternary time is meagrely represented in sedimentary records.

LOWER ORDOVICIAN PERIOD.

The history of the region opens in lower Ordovician time with a long period of sedimentation. Whether or not these sediments were laid down upon the Gold-bearing series, often stated to be of Cambrian age and sometimes thought to belong to Pre-Cambrian time, we do not know.

The thick deposits of greywacke or impure quartzite inter-bedded with banded slate imply the existence of a shallow transgressing sea during the deposition of the *James River formation*, the older of the two formations here constituting the lower Ordovician record. The minor variations, such as those seen in the banding of the slate, may represent cyclic climatic changes. When the upper part of the James River formation was being laid down, there existed conditions favourable for the deposition of iron, such as a shallow sea rich in iron solutions. Between beds of impure sand, oolitic iron oxide was deposited in beds none of which exceeded 20 feet in thickness. In the muddy ferruginous waters of this time a few linguloid brachiopods were able to live, and they are our only guides for the age determination of these deposits.

The red slates and thin sandstones of the *Baxters Brook formation*, which constitute here the higher beds of the lower Ordovician, commence only a short distance above the iron ore beds and probably represent shallow water conditions of wide extent during which oxidized sediments were washed in from the land along with some clean sands.

Following the solidification of the Baxters Brook strata there was a negative movement of the strand-line, and probably about the same time the *Browns Mountain formations* were folded and the shales were transformed into cleavable slates. According to the present interpretation, great igneous activity occurred at this time. Granite and monzonite stocks and rhyolite and quartz-porphyry necks intruded the Browns Mountain formations and a rhyolite flow more than 200 feet thick was poured out on the land surface as it then existed. As a result of the relative uplift of the land, erosion agencies started vigorously to work removing in places the whole of the Baxters Brook formation. The igneous intrusions were truncated and the rhyolite flow was probably considerably reduced in thickness and extent. With this erosion period lower Ordovician time probably closed.

MIDDLE ORDOVICIAN PERIOD.

After the erosion interval which closed the preceding period was well advanced, sedimentation, probably of middle Ordovician time, commenced with the coarse, cross-bedded conglomerates and overlying grits of the *Malignant Cove formation*. The heterogeneous character and oxidized condition of these sediments suggest that they were of subaërial origin and were probably deposited by strong current action. However, the remnants of the deposits are of such limited extent that little of the history of the region can be read from them. Rejuvenation of the land and erosion doubtless closed the Ordovician period in Nova Scotia, to which the disturbances of the Taconic revolution must certainly have extended.

SILURIAN PERIOD.

The sedimentation of Silurian time is represented by strata of the *Arisaig series*, having a combined thickness of more than 3,500 feet. These were doubtless the deposits of a shallow invading sea, laid down in depressions in the Ordovician rocks over an old rhyolite flow and remnants of conglomerate deposits.

The sandstones, impure limestones, and thin beds of shale of the *Beechhill Cove formation*, with their rather meagre marine life of linguloids, Dalmanellas, worm tubes, and cup corals, are indicative of the advancement of the sea, with but slightly increasing depth of water during Clinton or Lower Llandovery time.

The dark shales, thin sandstones, and green shales of the *Ross Brook formation*, with their entombed brachiopods (*Chonetes*, *Anabaia*, *Anoplotheca*), trilobites, graptolites, eurypterids, and other fossils of Silurian type, were in all probability also the deposits of a shallow invading sea steadily deriving land waste from the surface over which it advanced. The time of these deposits is that of the Clinton of eastern New York and the Lower and possibly part of the Upper Llandovery of Norway.

The iron ore horizon, probably belonging to the lower part of the *McAdam formation*, represents temporary conditions during which the sea was surcharged with ferruginous material. In this habitat a characteristic biota developed, consisting of *Cornulites*, *Tentaculites*, crinoids, and several genera of brachiopods among which a large *Meristina* of a new species is especially striking.

The impure limestones and dark shales of the McAdam formation as seen along the shore of Northumberland strait represent temporary clear water, limy conditions, followed by a return to shallow muddy waters, as is clearly shown by the character of the shales and the ripple-marks at the top of the formation. The marine life of the time was represented by brachiopods (*Camarotoechia*, *Dalmanella*, *Chonetes*, *Spirifer*, *Atrypa*), graptolites, many species of pelecypods, etc. This formation of about 1,100 feet of iron ore, limestones, and shale is correlated with the Rochester of America and the Upper Llandovery of Europe (probably also including the Lower Wenlock) and represents a long period of undisturbed marine conditions.

The argillaceous limestones and red shales of the *Moydart formation* represent a continuation of the conditions prevalent during the previous stage, but with a return to clearer water sedimentation. Large *Chonetes* and various *Spirifers* are among the representative life of this time. There were present also other brachiopods (*Wilsonia, Eatonia, Camarotoechia, Homoeospira*), and *Orthoceras, Homalonotus, Calymene*, etc. The red stratum at the top of the formation was preceded by the deposition of arenaceous strata and thin bedded limestone, and above it repose deep-green shales. The logical explanation of the oxidized concretion-bearing red stratum seems to be that the sediments were deposited during temporary subaërial conditions perhaps due to the rapid advance of a river delta. An alternative explanation is that the climate of the time was favourable to the oxidation of land waste before it was carried into the sea and deposited. Such conditions exist to-day in tropical countries, as may be seen in the case of the Amazon river, which is charged with red sediments. The time represented by this formation is the middle Niagaran of America and the Wenlock of north Europe.

The argillaceous limestones, grey and red shales, and limestones of the *Stonehouse formation* represent a continuation of sedimentary conditions very similar to those of the Moydart formation. Abundance of brachiopods (*Chonetes, Pholidops, Spirifer, Schuchertella, Rhynchonella*), *Cornulites, Bucanella*, pelecypods (*Goniophora, Pteronitella*), *Beyrichia*, and trilobites (*Acaste, Calymene, Homalonotus*) appear during this time. Shallow water conditions prevailed, as is recorded in the prevalent sandy character of the sediments and in ripple-marked beds. Lime, however, was abundant in the water and mixed with all the deposits. Red and green shales, probably from oxidized land waste, were interbedded with the upper sediments. These show bright green patches indicating their probable reduction by organic matter contained in them. Among the red shales and sandstones the "trilobite bed" is found.

The time represented is Ludlow of Europe or Guelph of America, and with this age our Silurian chapter closes. The continuous sedimentation of probably more than 3,500 feet of mostly marine deposits was brought to an end by a negative movement of the strand-line, followed perforce by an erosion interval.

LOWER DEVONIAN PERIOD.

During the disturbances following the deposition of the Arisaig series, their strata were tilted and probably flexed. The succeeding period of erosion probably stripped all of the Stonehouse formation away from part of the area, thus removing more than 1,000 feet of sediments in certain localities.

When sedimentation began again, as recorded in the ***Knoydart formation***, brick-red sandy shales and impure grey sandstones were deposited under subaërial and probably estuarine conditions. In the mouth of the Devonian river lived Ostracoderm fishes similar to those of the lower part of the Old Red Sandstone of Europe. *Cephalaspis* may have passed up into the fresh waters, *Pteraspis* apparently chose the estuary where brackish waters prevailed, while *Pterygotus* may have wandered from its marine habitat into the estuary.

The lower red sediments of the formation were probably deposited along a stream course during a climate marked by seasonal rainfall. During wet seasons much material was washed down and deposited along the river and on its delta. During dry seasons air penetrated deeply into the loose sediments, oxidizing their iron content and giving them eventually a bright red colour. The grey impure sandstones, containing much fine muscovite, mica, and other material, probably represent periods of sedimentation in local bodies of water, so that conditions were unfavourable to the oxidation of the sediments.

The Knoydart formation represents the Old Red Sandstone of Europe of lower Devonian age. Its sedimentary record probably includes more than 1,000 feet of strata, as 683 feet of outcrops were measured along McAras brook by Fletcher without the top or bottom being recognized.

MIDDLE AND UPPER DEVONIAN TIME.

Middle and upper Devonian time in northeastern Nova Scotia is recorded, not in the work of the sea but in the evidence of orogenic disturbance which was prevalent throughout the whole northern Appalachian region at this time. The clearest record for the Arisaig-Antigonish district is the down-faulting of the Arisaig series and Knoydart formation along the fault scarp of the Hollow. This was the greatest structural break recorded in the history of the region and was probably completed near the close of Devonian time.

MISSISSIPPIAN (LOWER CARBONIFEROUS) PERIOD.

During the deposition of the *McAras Brook formation* the land stood high and erosion progressed vigorously. Coarse fragments derived from the older formations were rolled along by the streams and with finer material were laid down possibly as delta deposits that in places were under the influence of the sea. Along the steep contacts with the Browns Mountain rocks disintegration exceeded transportation, and talus breccia of quartzite, slate, and granite was little more than swept into rough bedding by the currents flowing along the foot of the slopes.

Cross-bedding and imperfect sorting were everywhere the natural outcome of the manner of deposition. The larger pebbles of the conglomerates are readily recognized as coming from the Browns Mountain, Arisaig, and Knoydart rocks, but the finer material, especially of the lower beds, is universally of a red colour, due to the presence of iron oxide.

We may infer from the oxidized condition of the sediments that either the climate was warm so that land waste was oxidized before it was deposited, or else the rainfall was seasonal, so that periodically the deposits were exposed to the effects of an oxidizing atmosphere.

In favourable localities, as at Pleasant valley and Big marsh, swamps filled with plant growth occurred leaving as their record considerable beds of oil-shale containing impressions of fern-like leaves and plant stems. Higher up in the formation grey and green bands are found evidently indicating the encroachment of the sea, as the deposition of marine limestone followed, marking the base of the next formation.

Igneous activity occurred probably during the later part of the McAras Brook deposition, and diabase intrusions in the form of necks, small dykes, and intrusive sheets penetrated all the formations of the region. Some phases of the activity were probably represented by basaltic dykes and flows, while others appear to have been of more explosive violence, forming breccia dykes and possibly tuff deposits. Along the base of the Arisaig series, a basaltic dyke came to rest, probably with pulsating injections, and assumed a breccia or tufaceous character.

Within the Arisaig-Antigonish district no break in sedimentation was detected between the McAras Brook conglomerate and the *Ardness limestone*. Submergence and marine conditions followed subaërial and possibly estuarine conditions. In a sea of clear water, high in lime content, organisms secreting calcareous shells, such as ostracods and brachiopods, lived, and on dying contributed to the limy deposits on the sea-bottom. These conditions, however, did not last long. The waste brought in from the land probably pushed the sea back, at all events shallow water conditions followed during which red and grey sands, red marl, and later ripple-marked sands were deposited. At some localities lagoons and shallow water-pans were partially shut off from the sea, and in them upwards of 200 feet of gypsum was precipitated as a result of evaporation and occasional inflow of salt water. The characters and colours of the other sediments are those suggesting subaërial conditions and this conclusion is borne out by the plant remains present in the upper beds. At times, swamps existed in which flourished thickets of *Calamites* and other Carboniferous plants.

Finally, continental conditions again prevailed and marked the passing of Ardness sedimentation which represents the closing stage of Windsor time in this district.

PENNSYLVANIAN (UPPER CARBONIFEROUS) PERIOD.

The continental conditions that set in near the close of the last formation continued without interruption into the time represented by the *Listmore formation*. Considerable sorting was accomplished by the streams of the time and the deposits consist mostly of fine to coarse, grey or white sandstone with some red shaly sandstone near the base.

The remains of *Stigmaria* and *Calamites* indicate that conditions were at least locally favourable to plant growth. The sea was probably wholly excluded and fresh water was the transporting agent for the sediments. Its work is recorded in false-bedding and round concretionary forms similar to deposits filling river pot-holes to-day. With the advent of fresh-water sedimentation, an emergence began which probably was a part of the closing Palæozoic uplift known as the *Appalachian revolution*.

If the Listmore formation is equivalent to the Millstone Grit, it represents an unconformable relation with the Ardness formation, but no such relation has been detected by the writer. In other places the unconformity is said to be marked between the Windsor series and the Millstone Grit, although Ami failed to find it in the Cumberland basin.

CRETACEOUS PERIOD.

Although Permian and Triassic time are represented in some parts of Nova Scotia by continental deposits, the geological history of the Arisaig-Antigonish district during the remainder of Palæozoic and all of Mesozoic and Tertiary time, is written in the negative terms of erosion.

These negative terms may, however, have very definite values and such is the case in the result of Cretaceous erosion. Long continued denudation must have swept away vast quantities of rock debris of varying resistance and left finally a plain of very gentle relief, traversed by rivers meandering over the flat flood-plains. From analogy with other districts, the flat top of the Cobequid mountains is thought to have gained its older surface features during a peneplanation cycle completed in the Cretaceous period.

TERTIARY ERA.

In Tertiary time the land stood high and the erosive agents started to unmake the products of their long activity. Naturally the softer formations suffered most and were gradually etched out below the upland surface. During the Tertiary era a secondary base-level was formed on the Carboniferous rocks and the elevation of the surfaces of the Silurian and Devonian rocks was much reduced. But on the metamorphic and igneous rocks erosion did little more than entrench the stream channels.

The age of this base-level is fixed by analogy with regions elsewhere and there is some evidence at hand from this district. Glacial striæ have been recognized upon the Arisaig rocks and upon the Baxters Brook slate of the Sugar Loaf hill south of Malignant cove. The locations are situated approximately 500 and 400 feet below the plateau level, and show that the ice met in the plateau scarp a barrier that caused it to swing to the southwest. The amount of erosion implied is far too great to be explained by glaciation and the alternative view is that Tertiary erosion was effective in reducing greatly even such hard rocks as the upper slates and limestones of the Arisaig series and the metamorphic slate of the Sugar Loaf. If this were true, the softer rocks would be much more reduced, even assuming a surface of low relief.

QUATERNARY ERA.

Pleistocene or Glacial Time.

By the time the "ice age" took possession of the region, the surface rocks had apparently become much decayed and disintegrated, forming a regolith over the surface of the land. The continental ice sheet passed over the district in an average direction of 10° east of south, and redistributed the land waste, sweeping the plateau bare of all thick deposits and laying down red marly clay and unsorted clay-gravel-boulder deposits in the valleys of streams and as moraines along the margins of the lowlands. During the retreat of the ice the glacial deposits took on their characteristic forms and may at the same time have been modified near their surfaces by outwash from the melting ice, so that bedded gravels resulted. At James river, near the Intercolonial railway, such bedded deposits occur at an elevation of about 180 feet above the sea. Near the headwaters of the western branch of James river bedded gravels dipping 13° to the eastward occur about 670 feet above the sea.

Recent Events.

Since the Glacial period, terraces have been formed along the coast probably during a decided negative movement of the strand-line. Three well-preserved terraces occur, the highest being at an elevation of more than 120 feet. Each probably marks a major halt in the movement of the strand-line.

Recently thin deposits of stream gravels have been formed and it is thought that movement is still taking place, causing the streams to cut down.

CHAPTER IX.

ECONOMIC GEOLOGY.

INTRODUCTORY REMARKS.

The economic mineral resources of the Antigonish district are neither of great variety nor have they proven so far of great commercial value. Most important are the iron-ore deposits which were first prospected many years ago. Next in importance are the gypsum deposits which as white cliffs form a noticeable landscape feature along the Intercolonial railway. Oil-shales have been found in limited quantities and signs of copper occur at a number of localities. Indications of silver have been previously reported, but no evidence of its presence has been recently found. Limestone, formerly quarried to some extent for the manufacture of quicklime, is present in considerable quantity, and stream gravels suitable for concrete work form local deposits along the streams.

The economic deposits will be dealt with in the following order: copper, silver, iron, oil-shale, gypsum, limestone, and gravel.

COPPER.

DISTRIBUTION AND EXTENT.

At a number of localities signs of copper occur in the Mississippian formations. These consist of green stains in the conglomerate and sandstone, and wherever observed were intimately connected with plant remains. Although considerable prospecting has been done no workable deposits of copper ore have been found.

PROSPECTING.

Some insignificant digging has been done along the seashore and in the brooks where the formations bearing the copper stains outcrop, but the only underground work is that at Brierly brook, less than one-quarter mile north of the Intercolonial railway and nearly 1 mile southwest from Brierly Brook station. Here in the McAras Brook conglomerate two shafts have been sunk and a tunnel has been driven. The workings were filled with water when the vicinity was visited, but the shafts were said to be about 30 feet deep and the tunnel about 60 feet long. It was from the eastern shaft that copper ore was said to have been obtained, but the dump showed only scanty traces of copper stain.

SIMILAR COPPER OCCURRENCES ELSEWHERE.

Deposits of copper sulphides in sedimentary formations, having characters similar to those supposed to be present in this district, occur at many places. Lindgren[1] has described the occurrences of such ores in the Permian, Jurassic, and Triassic of Europe, Asia, North and South America, and Africa. They are usually found in fractured or brecciated beds or in proximity to plant fossils, and are characterized by blue and green colours due to the presence of azurite and malachite. In North America copper deposits such as the above occur in the Red Beds of southwest Texas, Oklahoma, New Mexico, Arizona, Colorado, Utah, and Idaho, but they are most successfully exploited in New Mexico. The containing strata are probably of Upper Carboniferous, Permian, Triassic, and Jurassic age, and are thought to have been accumulated in shallow seas or as land deposits as the result of a process of rapid degradation of the adjacent land areas of the Rocky Mountain region.

In New Mexico production has been achieved from picked ore at Naciminto. The copper is nearly all found in the basal 25 feet of strata consisting of reddish-white sandstone rich in fossil wood which is largely chalcocitized. One tree trunk 60 feet long by 2½ feet in diameter is said to be almost wholly converted into copper glance. Malachite, azurite, and chrysocolla are also present. The underlying beds are Pre-Cambrian granitic rocks which contain much older copper deposits.

[1] Lindgren, W. Econ. Geol. Vol. VI, pp. 568–581, 1911.

Lindgren considers that the copper has probably been a concentration of the scattered particles of copper ore contained in the sediments. Atmospheric water containing sodium chloride or sodium sulphate would readily dissolve the disseminated ores and carry them into contact with the plants, where they would be reduced to the sulphides, etc. Later, weathering would produce malachite and azurite stains.

PROBABLE ORIGIN.

The occurrences of copper stain in the Arisaig-Antigonish district represent, on a small scale, the conditions described above, excepting that the older rocks have not been found to contain copper ores. Consequently the possible explanation of the copper stains is that small quantities of copper sulphate, generally present in both sea and river water, were reduced to the sulphides during the deposition of the sediments, by the action of decaying vegetable matter. Later these small sulphide deposits were changed to the carbonates by the weathering action of surface water and have given the insignificant stains already noted.

CONCLUSIONS AS TO FUTURE POSSIBILITIES.

Workable deposits of such an origin are not to be expected, especially where plant remains are small and scarce, as is the case in the Mississippian formations of this district.

SILVER.

Although silver has been indicated on previous maps of the district, no traces of it were found at the locations marked or elsewhere.

IRON.

INTRODUCTORY REMARKS.

The iron ores in the vicinity of Arisaig were carefully described in detail by J. E. Woodman,[1] in 1909. However, the field work

[1] See bibliography.

of 1910 has added new information relating to the age and extent of the ore bodies and has also included one occurrence not previously described. Therefore, this report will deal mainly with the geological problems relating to the ore, its age and origin, and will only describe in a general way the prospects, individual outcrops, ore analyses, etc., all of which may be found in the report already referred to.

DISTRIBUTION, EXTENT, AND DEVELOPMENT.

Iron-ore beds have long been known to exist in both the metamorphic rocks of the plateau (now known to be of lower Ordovician age), south of Doctors brook, and in the rocks of Silurian age south of Arisaig. More recently iron has been discovered on the plateau at Browns mountain. Prospecting has been done in many places and some ore was formerly shipped, more especially from the Doctors Brook area, but work was discontinued probably because of the low grade and siliceous character of the ore. Recent development has been carried on under the management of Mr. George E. Corbitt, in the hope that mining might once more be undertaken.

The development work in the iron-ore areas has been in nearly every case in the form of surface stripping, and trenching. One or more shafts were sunk in the earlier work. In the summer of 1910, Mr. Corbitt drove a tunnel 70 feet into the north-sloping hillside a short distance east of the western brook flowing out of the Little hollow. A small outcropping of ore south of the tunnel was the surface indication depended upon. When last word was received no ore was met with and attention is called to the fact that the ore zone here is cut off by the slope of the hill, and the ore seen is probably a remnant of the southernmost bed. Tunnel development to be successful must be started farther east. At Arisaig and Ross brooks, tunnels were run in on the vertical ore beds for short distances.

COMPOSITION.

In the better samples from the lower Ordovician horizons, the ore consists of oolitic hematite having a fine grain resembling flaxseed; in other samples the grain is comparatively coarse. The finer ore occasionally contains fossils. The poorer varieties consist of a coarse grit impregnated with hematite. Frequently secondary quartz forming masses of considerable size may be detected with the naked eye. According to Woodman the assays of the better class of ore run on an average 46-48 per cent metallic iron.

From the above description it will be seen that the ore closely resembles the Clinton ores and this is confirmed by comparison of samples. However, the silicification due to secondary solution is not found in the Clinton ores of the Appalachian region.

The ore from the Silurian bed south of Arisaig is loose and earthy where it is exposed to the weather. Certain bands of ore are full of fossils and readily crumble down. Farther from the surface the ore is compact hematite, showing a fine-grained oolitic character. According to Woodman (page 183) a sample of a shipment of ore sent to the Dominion Iron and Steel Company, gave the following analysis: Fe = 52·930 per cent, SiO_2 = 11·620 per cent, Al_2O_3 = 7·460 per cent, P = 0·495 per cent.

This ore very closely resembles the Clinton ores and has not suffered secondary silicification.

RELATIONS TO ENCLOSING ROCKS.

Wherever observed the "beds" of hematite are interstratified with the enclosing rocks. The contacts of the denser ore are sharper than is the case with the impregnated grits. In the latter the contacts are often very poorly defined, the iron being present in decreasing quantity for the last foot or more of the ore zone. No cases were noted where the ore penetrated the wall rock as veins, but in the Doctors Brook area the "beds" occasionally split into two thinner "beds."

DESCRIPTION OF INDIVIDUAL LOCALITIES.

Iron Ore of Browns Mountain.

In an area about 1 mile northeast of Browns Mountain post-office, ore has been exposed by prospect trenches at points about five-eighths of a mile apart. In the western prospect an ore zone more than 20 feet across has been uncovered. The "bed" dips nearly south at about 60° and the contained ore consists of coarse grit impregnated with hematite. In the walls the grit is finer than in the ore. In the eastern exposure the "bed" strikes nearly north and south and is only about 5 feet across, and the ore is more compact and of higher grade. Possibly two "beds" are present here. Specimens are said to have assayed as high as 30 per cent metallic iron. The iron ore of this vicinity appears to belong to a lower horizon in the James River formation (the lower formation of the Browns Mountain group) than that which contains the ore beds of Doctors brook.

Iron Ore of Doctors Brook.

The most important ore belt of the district extends southwesterly for nearly 4 miles from a point about three-quarters of a mile southwest of Malignant cove. Many igneous intrusions have interrupted the ore leads in their northeastern extent, but between the East Branch of Doctors brook and the western brook flowing north from the Little hollow, few intrusions are present.

Numerous trenches and prospect pits have been dug and the ore zone more extensively disclosed in this locality than elsewhere. However, the trenches for the most part cross the ore "leads" and the relations of ore to wall rock are frequently obscured. Three ore "beds" have been recognized with widths from 2 to 8 feet. From place to place the widths of individual leads vary and many small faults have been discovered which offset the ore 1, 2, or more feet. The "beds" strike in a northeast direction and are approximately vertical in dip.

The following table gives a summary of the chief characters of the ore leads according to Woodman.

Lead.	Average thickness at Iron brook west.	Character of ore.	Assay, % of metallic iron.		
			Locality.		
			1	2	3
Tunnel.........	5 feet	Compact oolitic ore in part resembling pebbles.	48·174%	46·213%	47·302%
Intermediate....	4 feet	Fine-grained ore......	45·94%	41·177%	43·558%
Coarse.........	10 feet	Grit impregnated with hematite.	35·167%		

AVERAGE OF ALL OBTAINABLE ANALYSES.

	Insoluble matter.	Metallic iron.
Mines Branch..........	20·884%	38·186%
All others..............	28·655%	42·514%

According to Woodman's carefully wrought-out summary (page 202), "The ore is uniformly free from sulphur * * * but it is high in phosphorus. Silica and general insoluble matter stand unfortunately high, the average of all Mines Branch analyses being 20·884, and all the others obtainable at present, 28·655%. In iron the general quality is low, the average of Mines Branch analyses being 38·186, that of all others obtainable, 42·514%."

The exposures of the contacts are not always clear, but the wall rock appears to be generally quartzite. Where this is the case no difference has been noted in the north and south contacts. A breccia was found to form the south wall of a "bed" near Iron brook, and although there is some uncertainty as to the identification of the altered rocks along the extent of what is probably the same "bed," the indications are that the association of ore and breccia may be continuous for nearly their whole extent.

The breccia has been so changed to calcite and in places discoloured by iron stain that little can be said about its origin other than that it may be volcanic. Grey slate has also been noted in contact with one "bed." A short distance south of the ore zone, red slate occurs marking the lower boundary of the Baxters Brook formation. The iron-ore zone appears to hold a definite relation to the base of this formation, which apparently lies in a closed syncline. No iron is found on the south of this syncline, but whether this is due to lack of systematic prospecting, to the thinning out of the ore beds, or to faulting has not been determined.

As already stated the surface extension of the ore beds is quite definitely known. Woodman has stated (page 203) that although the ore "beds" have not been identified as being identical from one end of the property to the other, certain beds have been followed for long distances. "The greatest distance over which any single ore 'bed' has been found is 6,750 feet." This was his Tunnel lead and he says, "the coarse lead is probably continuous for at least as great a distance." On the east, intrusion has interrupted the continuity of the ore, and on the west it is off-set by faults. The displacements appear to be along vertical planes, but it is not clearly established that horizontal breaks may not also occur. Because of the close folding which probably exists, the same vertical attitude of the beds probably holds downwards for several hundred feet. From the distribution of the igneous rocks it is not probable that serious disturbances will be met with, due to their presence, in the area between the East Branch of Doctors brook and the small western brook flowing out of the Little hollow. Small dykes do occur but they are not apt to do more than sever the ore bed.

Ore of Arisaig and Ross Brooks.

In Arisaig and Ross brooks a bed of hematite between 2 and 3 feet thick outcrops. Two exposures occur on Ross brook, but there is evidence of faulting in the vicinity and the bed has probably been off-set along a fault zone. Wherever seen the strata stand nearly vertical. The wall rocks consist of shales and thin-bedded, arenaceous limestones and in places the surface of the wall rock is chloritized. It is probable that the ore bed is continuous or nearly so between Arisaig brook and Ross brook, but beyond these limits, particularly to the westward, the probability of disturbance is great. A fault zone, about 20 yards north of the iron ore in Arisaig brook, parallels the ore bed and by a slight change of dip this may cut the ore off in depth. The thicknesses of the formations to the south are thought to have been diminished by similar faults.

GENESIS OF IRON-ORE DEPOSITS.

The ore beds of the lower Ordovician and Silurian formations are, in general, similar and their origins will be discussed together.

The ore leads of the lower Ordovician for the most part follow the rock stratification. Woodman speaks of them as being "broadly of the bedded type although departing from the rock stratification in a few places, sometimes through irregular replacement, sometimes proceeding for a very short distance along fissures." So far as the observations made by the writer go, they do not clearly depart from the stratification although the contacts are irregular in places. In one or two instances the bed branches, but whether this is due to an interfingering of sedimentary layers, or to other causes was not clearly determined. It is clear, however, that the outcrops of ore extend in general alignment for long distances, and represent a definite number of leads. The horizon followed by the ore is constant, but whether there is a migration from layer to layer could not be definitely told.

In the Silurian strata the iron ore is exposed at only two places, but is of nearly constant width and appears to hold a definite horizon. It is fossiliferous and at Arisaig brook where fossils were collected, contains a fauna related to that of the enclosing sediments, but of very distinct development.

The metamorphic rocks of lower Ordovician age are nearly unfossiliferous, but the iron ore, and a schist associated with it contain linguloids. Thus it seems fairly clear that the iron-ore strata differed during the time of their deposition from the preceding or succeeding sediments. The indications are, too, that the iron ore of the lower Ordovician rocks was deposited before the rocks were disturbed either by intrusion or faulting, and if the interpretations given in this report be correct, the earliest intrusions took place at about the close of lower Ordovician time.

In age, the Silurian iron-bearing sediments are probably early Rochester or a little later than upper Clinton, correlating, however, with some of the "Clinton ores" of the Appalachian region, which are now considered by the best authorities to be of sedimentary origin (See under "Stratigraphy," page 68). The iron ore of Doctors brook contains linguloids (see page 55), which not only fix the age of the formation as lower Ordovician, but correlate the ore horizon directly with that of the deposits of Belle isle, Newfoundland, generally considered to be of sedimentary origin.

In the case of the Silurian iron ore there is little doubt that it is of sedimentary origin, and was formed as were any of the other strata, but under conditions favourable to the deposition of iron oxide.

The same statement may be made with less assurance, in the case of the lower Ordovician iron ores, for the writer wishes to admit the difficulty of explaining the filling of fissures as described by Woodman, by a sedimentary deposit. Then, too, the gradual diminution of iron from the ore to the ferruginous enclosing rocks is what might be expected if the ore were of secondary origin. There is no reason, however, why iron deposited as a sediment should not mix to some extent with the sediments above and below it. The varying thickness of the ore beds is only what might be expected in the case of any strata, and is of common occurrence in sedimentary beds of sandstone, shale, etc.

Although all the information required for a complete discussion of these ore deposits is not available, much is definitely known. Their great extent along a more or less definitely recognized horizon; their independence of igneous intrusions;

their distinctive faunal character; their oolitic character and resemblance to the "Clinton ores"; and their metamorphosed condition corresponding to that of the enclosing rocks, all make the conclusion very probable that they are of sedimentary origin and hence are of the same age as the rocks in which they occur. However, in a formation where metamorphism is a characteristic feature, it is not impossible that some secondary concentration or transfer of iron oxide has taken place at the borders of the iron ore beds.

OIL-SHALE.

GENERAL CHARACTER AND DISTRIBUTION.

A short distance east of Maryvale, and outside of the Arisaig-Antigonish district, drilling and mining have proven the existence of considerable beds of oil-shale. Ells in his report of 1910 describes these and quotes an older authority (How's "Mineralogy of Nova Scotia," 1868) for the statement that the shales are found in two groups, "The lower 70-80 feet in thickness, including 20 feet of good oil-shale, 5 feet of which are curly cannel, rich in oil; the upper 150 feet thick, in immediate contact with the limestone, and containing a large percentage of oil. Of the 5 foot seam of curly cannel, he (How) states that it will yield at least 40 gallons of crude per ton, and 15 feet of the remainder will yield at least 20 gallons."

In the vicinity of Maryvale and Pleasant valley, oil-shale has been exposed in a number of pits and prospecting is said to have been carried on by a core drill.

The formation at Maryvale and Pleasant valley is the Ardness, the same as that containing the oil-shale at Big Marsh, and is probably of Mississippian age; but the upper part of the formation and probably the upper oil-shale zone has been stripped away by erosion. At Pleasant valley and south of Maryvale the strata appear to lie at low angles and the oil-shale is probably not deeply buried. North of Maryvale near the contact with the metamorphic rocks, considerable disturbance in the Ardness formation may be expected, as is indicated by the high dip and the varying strike of the strata where observations have been made.

GYPSUM.

DISTRIBUTION AND EXTENT.

Across the south of the Arisaig-Antigonish district along the Intercolonial railway, pond holes, sink-holes, or gypsum cliffs are scarcely ever absent. The gypsum belt here represented is more than 10 miles long and one-eighth to one-quarter mile wide. The exposed cliffs of gypsum occupy less than half of the total length of the belt, occurring mainly at Brierly brook, a point on the railway more than 1 mile west of Antigonish, and in the vicinity of Antigonish harbour.

CHARACTER.

The gypsum is generally of a crumbly nature as exposed at the surface, and is gradually undergoing solution. A short distance from the surface the gypsum is firm and compact, is of a white to grey-white colour, and appears to contain only a small amount of impurities. As described by previous investigators, considerable of the gypsum may have originally been anhydrite, but weathering has left little of this mineral in the upper parts of the deposits. At Ogdens point in Antigonish harbour, Dawson[1] observed more than 100 feet of white and reddish gypsum, containing some calcite, overlain by alternating beds of gypsum and impure limestone, which were succeeded by reddish sandstones and shales. From the breadth of the gypsum belt represented by ponds and sink-holes, the total thickness of the gypsum horizon is thought to be nearly 200 feet.

Considerable sand overlies the gypsum in most places. Occasionally the gypsum cliffs are uncovered and have assumed

[1] Dawson, J. W. Proc. Acad. Nat. Sci., Phila., Vol. III, pp. 271–274, 1847.

a peculiar honey-comb surface aspect due to water solution. Much sand falls into the channels made by the water and thus the deposits have become more or less mixed with sand and earthy materials. However, much nearly pure gypsum is to be found.

DEVELOPMENT AND FUTURE POSSIBILITIES.

Quarrying is carried on to a very small extent at Brierly brook. The proximity of the railway and the ease with which the gypsum is quarried should make this region the location of a large gypsum industry so soon as the demand for the raw product is sufficiently great.

LIMESTONE.

DISTRIBUTION AND FORMER DEVELOPMENT.

Along the limestone horizon generally about one-quarter mile north of the Intercolonial railway, a number of old lime kilns and lime quarries mark the existence of a former industry. The lime burnt in this vicinity is said to have been of good quality.

RELATIONS AND GENERAL CHARACTER.

The limestone forms the basal stratum of the Ardness formation and is under 20 feet in thickness. Only one bed occurs; the second outcrop of limestone north of the town of Antigonish being due to a local syncline which has brought the limestone to the surface along its south limb. Limestone also occurs on the shore of Northumberland strait and in an isolated outcrop on Doctors brook. In both these instances the age of the limestone is the same as of that already described. Limestone of Silurian age has not been burnt because of its impure character.

FUTURE DEVELOPMENT.

The limestone bed usually dips at an angle of about 30° and is not exposed at the surface except at a few places, generally in the creek valleys. Here, however, quarrying might be readily carried on by following the strike of the beds. Plenty of wood for fuel is near at hand and should demand warrant it, a lime industry of considerable importance could be started along the railway.

GRAVEL.

Deposits of water worn gravel are found in many of the stream courses. For road-metal and concrete work this gravel is well adapted.

CHAPTER X.

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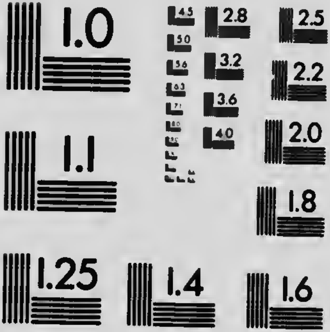
MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers, and, therefore, the following list has been prepared to prevent any misconceptions arising on this account. The titles of all other important publications of the Geological Survey are incorporated in this list.

Memoirs and Reports Published During 1910.

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

Summary Report for the calendar year 19[illegible]. No. 1120.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario—by Alfred W. G. Wilson.

MEMOIR 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley mining district, British Columbia—by Charles Camsell.

MEMOIR 3. *No. 3, Geological Series.* Palæoniscoid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

MEMOIR 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory—by D. D. Cairnes.

MEMOIR 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred E. Barlow.

MEMOIR 7. *No. 6, Geological series.* Geology of St. Bruno mountain, Province of Quebec—by John A. Dresser.

MEMOIRS—TOPOGRAPHICAL SERIES.

MEMOIR 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

Memoirs and Reports Published During 1911.

REPORTS.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902—by Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers—by W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of Lake Timiskaming—by Morley E. Wilson. No. 1064.

Summary Report for the calendar year 1910. No. 1170.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec—by W. J. Wilson.

MEMOIR 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta—by D. B. Dowling.

MEMOIR 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

MEMOIR 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait.

MEMOIR 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906—by Anton Handlirsch.

MEMOIR 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario—by Frank Springer.

MEMOIR 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries, assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES.

MEMOIR 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

Memoirs and Reports Published During 1912.

REPORTS.

Summary Report for the calendar year 1911. No. 1218.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.

MEMOIR 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia—by O. E. LeRoy.

MEMOIR 24. *No. 16 Geological Series.* Preliminary report on the clay and shale deposits of the western provinces—by Heinrich Ries and Joseph Keele.

MEMOIR 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.

MEMOIR 28. *No. 18, Geological Series.* The geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

Memoirs and Reports Published During 1913.

REPORTS, ETC.

Museum Bulletin No. 1: contains articles Nos. 1 to 12 of the Geological Series of Museum Bulletins, articles Nos. 1 to 3 of the Biological Series of Museum Bulletins, and article No. 1 of the Anthropological Series of Museum Bulletins.

Guide Book No. 1. Excursions in eastern Quebec and the Maritime Provinces, parts 1 and 2.

Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa.

Guide Book No. 4. Excursions in southwestern Ontario.

Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island.

Guide Book No. 8. Toronto to Victoria and return *via* Canadian Pacific and Canadian Northern railways: parts 1, 2, and 3.

Guide Book No. 9. Toronto to Victoria and return *via* Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways.

Guide Book No. 10. Excursions in Northern British Columbia and Yukon Territory and along the north Pacific coast.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 17. *No. 28, Geological Series.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que.—by Morley E. Wilson.

MEMOIR 18. *No. 19, Geological Series.* Bathurst district, New Brunswick—by G. A. Young.

MEMOIR 26. *No. 34, Geological Series.* Geology and mineral deposits of the Tulameen district, B.C.—by C. Camsell.

MEMOIR 29. *No. 32, Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.

MEMOIR 31. *No. 20, Geological Series.* Wheaton district, Yukon Territory—by D. D. Cairnes.

MEMOIR 33. *No. 30, Geological Series.* The geology of Gowganda Mining Division—by W. H. Collins.

MEMOIR 35. *No. 29, Geological Series.* Reconnaissance along the National Transcontinental railway in southern Quebec—by John A. Dresser.

MEMOIR 37. *No. 22, Geological Series.* Portions of Atlin district, B.C.—by D. D. Cairnes.

MEMOIR 38. *No. 31, Geological Series.* Geology of the North American Cordillera at the forty-ninth parallel, Parts I and II—by Reginald Aldworth Daly.

Memoirs and Reports Published During 1914.

REPORTS, ETC.

Summary Report for the calendar year 1912. No. 1305.

Museum Bulletin No. 2: contains articles Nos. 13 to 18 of the Geological Series of Museum Bulletins, and article No. 2 of the Anthropological Series of Museum Bulletins.

Prospector's Handbook No. 1: Notes on radium-bearing minerals—by Wyatt Malcolm.

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The archæological collection from the southern interior of British Columbia—by Harlan I. Smith. No. 1290.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 23. *No. 23, Geological Series.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C.—by J. Austen Bancroft.

MEMOIR 25. *No 21, Geological Series.* Report on the clay and shale deposits of the western provinces (Part III)—by Heinrich Ries and Joseph Keele.

MEMOIR 30. *No. 40, Geological Series.* The basins of Nelson and Churchill rivers—by William McInnes.

MEMOIR 20. *No. 41, Geological Series.* Gold fields of Nova Scotia—by W. Malcolm.

MEMOIR 36. *No. 33, Geological Series.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C.—by C. H. Clapp.

MEMOIR 52. *No. 42, Geological Series.* Geological notes to accompany map of Sheep River gas and oil field, Alberta—by D. B. Dowling.

MEMOIR 43. *No. 36, Geological Series.* St. Hilaire (Beloeil) and Rougemont mountains, Quebec—by J. J. O'Neil.

MEMOIR 44. *No. 37, Geological Series.* Clay and shale deposits of New Brunswick—by J. Keele.

MEMOIR 22. *No 27, Geological Series.* Preliminary report on the serpentines and associated rocks, in southern Quebec—by J. A. Dresser.

MEMOIR 32. *No. 25, Geological Series.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C.—by R. G. McConnell.

MEMOIR 47. *No. 39, Geological Series.* Clay and shale deposits of the western provinces, Part III—by Heinrich Ries.

MEMOIR 40. *No. 24, Geological Series.* The Archæan geology of Rainy lake—by Andrew C. Lawson.

MEMOIR 19. *No. 26, Geological Series.* Geology of Mother Lode and Sunset mines, Boundary district, B.C.—by O. E. LeRoy.

MEMOIR 39. *No. 35, Geological Series.* Kewagama Lake map-area, Quebec—by M. E. Wilson.

MEMOIRS—ANTHROPOLOGICAL SERIES.

MEMOIR 48. *No. 2, Anthropological Series.* Some myths and tales of the Ojibwa of southeastern Ontario—collected by Paul Radin.

MEMOIR 45. *No. 3, Anthropological Series.* The inviting-in feast of the Alaska Eskimo—by E. W. Hawkes.

MEMOIR 49. *No. 4, Anthropological Series.* Malecite tales—by W. H. Mechling.

Memoirs and Reports in Press, September 10, 1914.

MEMOIR 41. *No. 38, Geological Series.* The "Fern Ledges" Carboniferous flora of St. John, New Brunswick—by Marie C. Stopes.

MEMOIR 51. *No. 43, Geological Series.* Geology of the Nanaimo map-area—by C. H. Clapp.

MEMOIR 53. *No. 44, Geological Series.* Coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia (revised edition)—by D. B. Dowling.

MEMOIR 61. *No. 45, Geological Series.* Moose Mountain district, southern Alberta (second edition)—by D. D. Cairnes.

MEMOIR 55. *No. 46, Geological Series.* Geology of Field map-area, British Columbia and Alberta—by John A. Allan.

MEMOIR 58. *No. 48, Geological Series.* Texada island—by R. G. McConnell.

MEMOIR 60. *No. 47, Geological Series.* Arisaig-Antigonish district—by M. Y. Williams.

MEMOIR 50. *No. , Geological Series.* Upper White River district, Yukon—by D. D. Cairnes.

MEMOIR 56. *No. , Geological Series.* Geology of Franklin Mining camp, B.C.—by Chas. W. Drysdale.

MEMOIR 42. *No. 1, Anthropological Series.* The double-curve motive in northeastern Algonkian art—by Frank G. Speck.

MEMOIR 62. *No. 5, Anthropological Series.* Abnormal types of speech in Nootka—by E. Sapir.

MEMOIR 63. *No. 6, Anthropological Series.* Noun reduplication in Comox, a Salish language of Vancouver island—by E. Sapir.

MEMOIR 46. *No. 7, Anthropological Series.* Classification of Iroquoian radicals with subjective pronominal prefixes—by C. M. Barbeau.

MEMOIR 54. *No. 2, Biological Series.* Annotated list of flowering plants and ferns of Point Pelee, Ont., and neighbouring districts—by C. K. Dodge.

Summary Report for the calendar year 1913.

LEGEND

CARBONIFEROUS

PENNSYLVANIAN(?)

- **C3** — Listmore (red and grey sandstone and sandy shale)
- Ardness (basal limestone, red sandstone and sandy shale)

MISSISSIPPIAN

- **b** — Basalt, diabase (diabase and basalt dykes and stocks; red "breccia" dyke along the shore)
- McAras Brook (red conglomerate, sandstone and sandy shale, with grey sandstone and oil shale in east)

DEVONIAN

- **D** — Knoydart (red sandy shale and grey arkose sandstone)

SILURIAN

- Stonehouse (red and grey shale and arenaceous limestone)
- **S4** — Moydart (red shale, argillaceous limestone and shale)
- McAdam (black shale and argillaceous limestone; 3½ foot bed of iron ore)
- **S2** — Ross Brook (... shale, thin sandstone, dark fossile slate)
- Beechhill Cove (sandstone, limestone and shale)

ORDOVICIAN

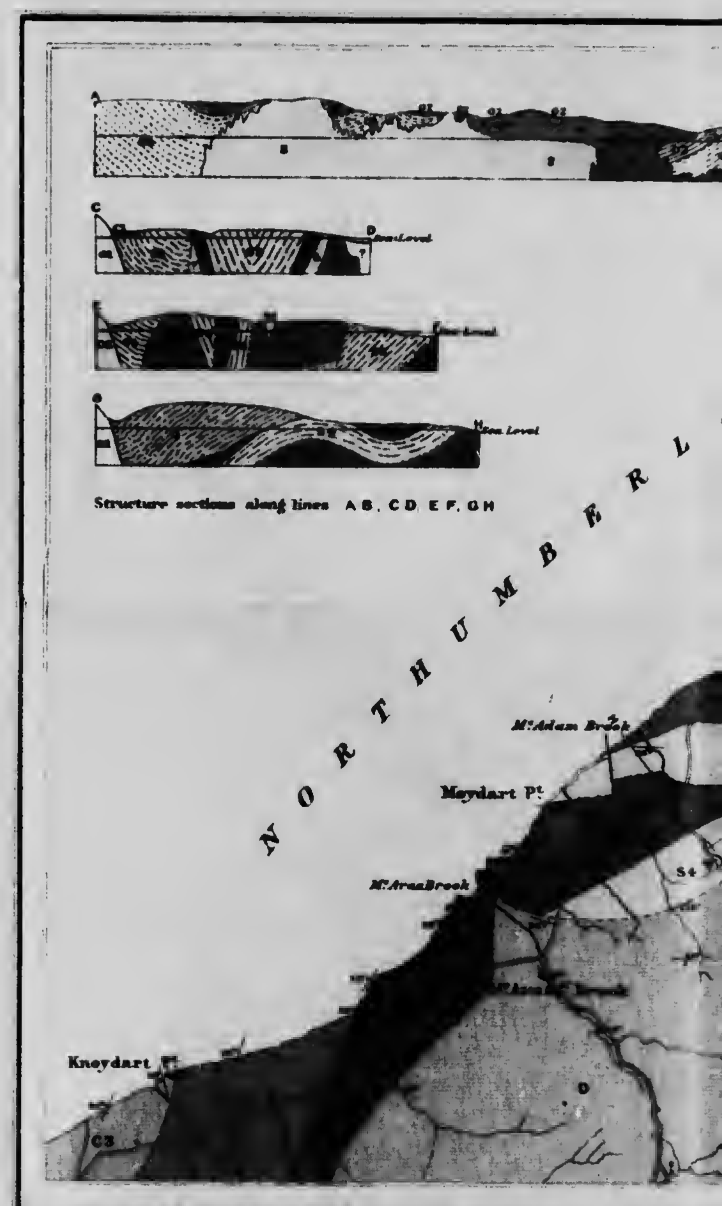
- **O3** — Malignant Cove (cross-bedded silicified conglomerate and grit)
- Aporhyolite (flow of rhyolite and rhyolite breccia at base of Silurian)
- **3** — Rhyolite (stocks and dykes, grades into porphyritic rhyolite)

ORDOVICIAN

- **2** — Porphyritic rhyolite (stocks and dykes)
- Monzonite (irregular stock)
- **O2** — Baxters Brook (red and grey sandstone and schist; red and grey slates)
- **O1** — James River (flinty greywacke and grit, silicified banded slate)

Symbols

- Dip and strike
- Vertical strata
- Glacial striae
- Geological boundary (located)
- Geological boundary (position inferred)
- Fault (located)
- Fault (position inferred)
- Limestone bed
- Iron ore
- Oil shale



C.O. Senécal, Geographer and Chief Draughtsman.

A

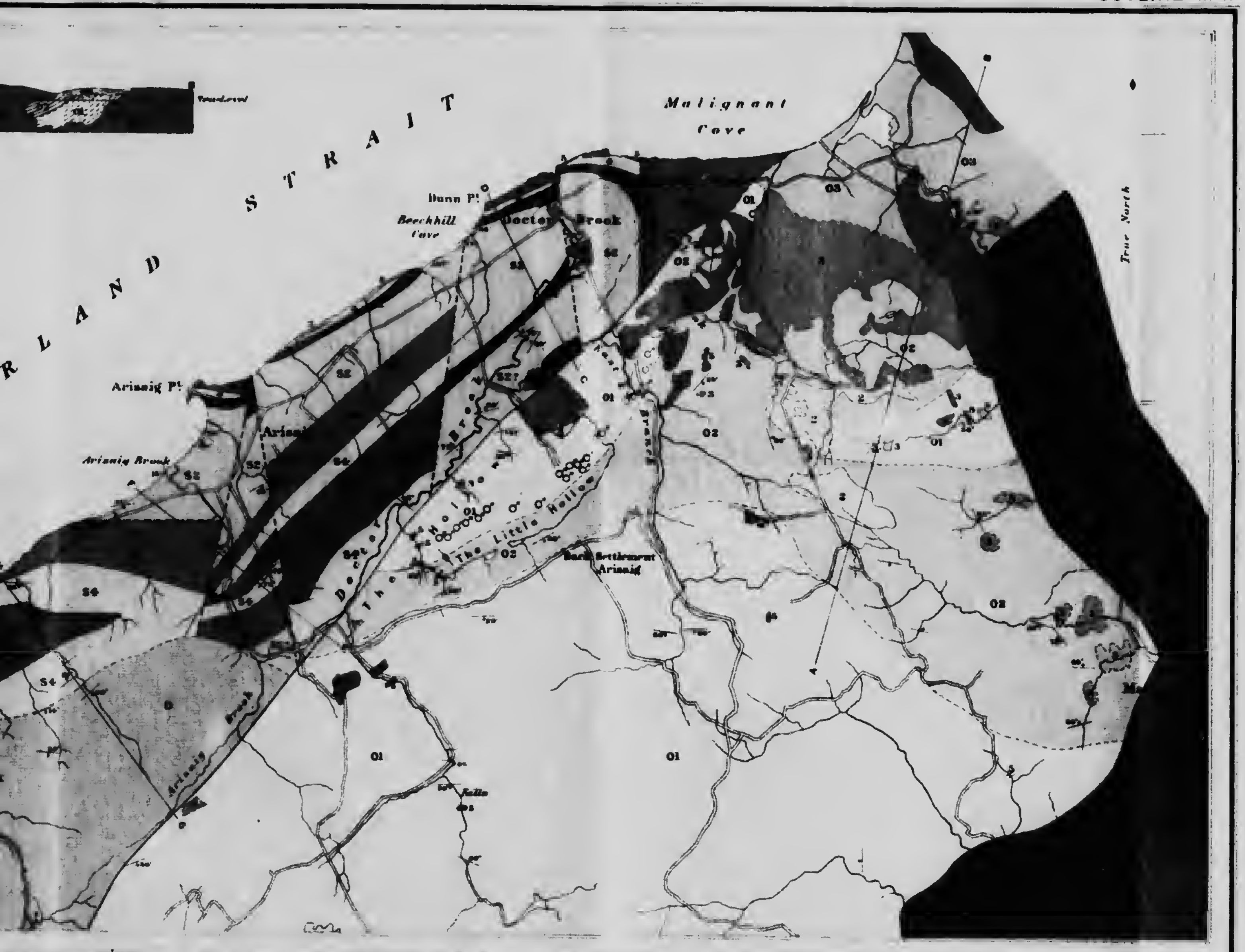
To accompany Memoir by M.Y. Williams

Canada
Department of Mines

HON. L. CODERRE, MINISTER. R. G. McCONNELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

OUTLINE MAP



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MAP 137 A
(Issued 1915)

ARISAIG, ANTIGONISH COUNTY, NOVA SCOTIA

Scale of Miles

LEGEND

CARBONIFEROUS

PENNSYLVANIAN

C3 Listmore (red and grey sandstone and sandy shale)

MISSISSIPPIAN

Ardness (basal limestone, red sandstone and sandy shale, with gypsum in south)

Basalt, diabase (diabase and basalt dykes, necks and stocks)

M'Aras Brook

DEVONIAN

D Knoydart

SILURIAN

Arisaig series (red, grey, black and green shale, argillaceous limestone and thin sandstone)

ORDOVICIAN

O3 Malignant Cove

3 Rhyolite

2 Granite (fine grained, pink granite)

Monzonite

ORDOVICIAN

O2 Baxters Brook (red and grey sandstone and schist, red and grey slate)

O1 James River (grey slate, greywacke and red and grey slate)

Symbols

Dip and strike

Vertical strata

Glacial striæ

Boundary (located)

Boundary (position inferred)

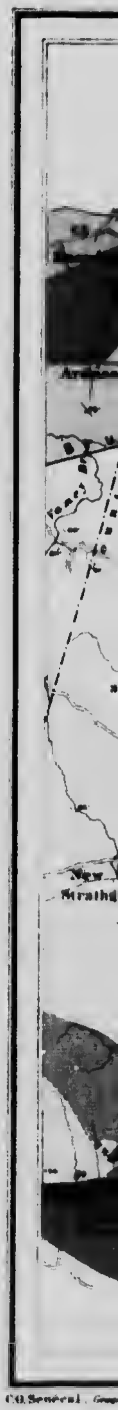
Fault (located)

Fault (position inferred)

♂ Iron ore

◆ Oil shale

Gypsum



AR

Canada
Department of Mines
HON L. CODERRE MINISTER, R. G. McCONNELL DEPUTY MINISTER

GEOLOGICAL SURVEY

OUTLINE MAP

Senécal, Geographer and Chief Draughtsman

MAP 136A
Issued 1915

ARISAIG-ANTIGONISH, ANTIGONISH COUNTY, NOVA SCOTIA

Scale of Miles