Reviews.

SUMMARIES OF PRE-CAMBRIAN LITERATURE FOR 1902–1903. II.

[*Continued from p. 62.*]

C. K. Leith.

A. P. Coleman and A. B. Willmott. "The Michipicoten Iron Ranges." "Geological Series," *University of Toronto Studies*, 1902, pp. 39–83. See also *Report of the Bureau of Mines*, Ontario, 1902, pp. 128–51.

Coleman and Willmott describe and map the Michipicoten iron ranges. The rocks are classified as follows:

Archæan	Laurentian	Gneisses and granites
	Upper Huronian	Basic eruptives
		Acid eruptives
		Doré conglomerate
	Lower Huronian	Eleanor slates
		Helen iron formation
		Wawa tuffs
		Gros Cap greenstones

The Gros Cap greenstones are basic eruptives with ellipsoidal structure corresponding in position and character to the Ely greenstones of the basement complex of the Vermilion district of Minnesota. They are in part basal to the other rocks of the district, but in part also they are interbedded with the rocks of the Helen iron formation. The Wawa tuffs are acid schists having the composition of quartz-porphyry or felsite, usually in the form of tuff, ash, or breccia, and sometimes show stratification, taken to indicate deposition by water.

Slates of distinctly sedimentary origin, occurring in thin bands near Eleanor Lake and called the Eleanor slates, are referred to the Lower Huronian. Their relations to the Helen iron formation are not known.

The Helen iron formation, 500 feet thick, comprises banded granular silica with more or less iron ore, black slate, siderite with varying amounts of silica, and grünerite schist. All are found well developed at the Helen mine, and all but the grünerite schist have been found in the Lake Eleanor iron range also, while granular silica and siderite occur in large quantities in every important part of the range, though small outcrops sometimes show the silica alone. All of the rocks of the iron formation contain considerable amounts of iron pyrites. The grained silica and the granular silica is similar in certain respects to the jaspers and ferruginous cherts of the United States, and their origin is believed to be the same. They differ in being often soft, pulverulent, and brecciated. The black, graphitic slate, forming a thin sheet just under the iron range proper west of the Helen mine and at other points in the region, seems closely related to the granular silica, being composed of the same material with a large admixture of carbon which smears the fingers.

Iron ore is mined in the Helen mine, and this mine is described in detail. The

ore body is located at the east end of the deep Sayers Lake basin, partly above and partly below the old water level. The lake has now been drained, and the ores appear in a great amphitheater opening out to the west. The rocks immediately associated with the hematite are siliceous ore, ferruginous cherts, or grained silica rocks. These are mapped as immediately surrounding the iron ore, and also as forming for the most part the north wall of the amphitheater. The east wall of the amphitheater is composed of iron carbonate which shows gradations into siliceous ore and into hematite ore. The south wall is composed of Wawa tuffs.

The ores are believed to have resulted from the secondary alteration of an original iron formation consisting mainly of iron carbonate, grained silica, and limestone, in part interbedded with the Wawa tuffs, but mainly deposited above them. The iron formation and the tuffs were folded up together, with the result that the tuffs were formed into a trough underlying the iron formation, and the iron formation within this trough was folded and brecciated. Percolating waters then altered the iron carbonates. Probably the chief solvent of the carbonates was acid ferric sulphate or sulphuric acid resulting from the oxidation of the iron pyrites, which are found in considerable quantity throughout the iron formation. The ore body has resulted directly from the alteration of iron carbonate, the oxidation of the iron sulphide having yielded but little ore. The oxidation of the iron took place where solutions of iron carbonate came into contact with waters bearing oxygen.

The principal areas of iron formation possibly bearing iron ore at Gros Cap, Sayers, and Boyer Lakes, just east of the Helen mine, around Brooks Lake, south of Long Lake, just east of Goetz Lake, in Parks Lake, and between Parks and Kimball Lakes.

The Upper Huronian rocks are represented principally by the Doré conglomerate, occurring typically at the mouth of the Doré River and thence eastward beyond Michipicoten Harbor, and to a less extent in other parts of the district. This conglomerate is unconformably above the Lower Huronian rocks of the district. It contains pebbles of granite, felsite, conglomerate, granular silica of the iron formation and breccia.

The Doré conglomerate is cut by acid intrusives in dikes and bosses. These are the latest rocks of the region.

The Laurentian granites and gneisses have not been studied in detail in the Michipicoten district, but their associations with both Lower and Upper Huronian prove them to be post-Huronian eruptive masses.

Comment.— As noted in the above paper, there is very close similarity in lithology and succession between the rocks of the Michipicoten district and the rocks of the Vermilion iron-bearing district of Minnesota, although described under different names. The rocks above called Lower Huronian and Upper Huronian are called respectively Archæan and Lower Huronian by the United States geologists.

There is substantial agreement in the matter of the origin of the ores in the two districts.[1] The Wawa tuffs are also similar to the Palmer gneiss of the Archæan of the Marquette district. The granites and gneisses described as Laurentian for the Michipicoten district are similar in character and relations to granites in United States districts referred to the Lower Huronian.

[1] J. MORGAN CLEMENTS, "The Vermilion Iron-Bearing District of Minnesota, *Monograph XLVI, U. S. Geological Survey*, 1903; C. R. VAN HISE, "The Iron-Ore Deposits of the Lake Superior Region," *Twenty-first Annual Report of the U. S. Geological Survey*, Part III, pp. 305–434.

A. P. COLEMAN. "Rock Basins of Helen Mine, Michipicoten, Canada." *Bulletin of the Geological Society of America*, Vol. XLIII (1902), pp. 293–304.

Coleman discusses the origin of the rock basins of Boyer and Sayer's Lakes of the Michipicoten district of Canada, the former containing the Helen iron-ore body. He holds the lake basins to have resulted from the solution of the iron-bearing rocks long before glacial time.

A. B. WILLMOTT. "The Nomenclature of the Lake Superior Formations." JOURNAL OF GEOLOGY, Vol. X (1902), pp. 67–76.

Willmott discusses the nomenclature of the Lake Superior formations, this being practically a consideration of Van Hise's "Iron-Ore Deposits of the Lake Superior Region."[1] He argues principally against the correlation of the Animikie series with the Upper Huronian of the original Huronian area. He states that there can be no doubt that Logan in 1863 included within his Huronian two series — the one typically represented by the banded jaspers, the other by the slate conglomerate and the jasper conglomerate. This has been uniformly followed from that time forward by all Canadian geologists, and by many American, the vertical green schists and their interbedded banded jaspers being considered Lower Huronian. Professor Willmott doubts the advisability of attempting the separation of the green volcanics and sediments, except in limited areas of economic value. Here each would be given formational names, just as Van Hise has done with the Ely greenstone and the Soudan iron formation. In other places the volcanics and eruptives will take the name of the sediment with which they are associated. The lowest sedimentary series of the Lake Superior region is the Lower Huronian. These sediments were included in the areas mapped as Huronian by Logan in 1863, and, although not actually found in place by him, were recognized from their fragments, and to him should be given the credit. As so used, the term "Lower Huronian" is nearly equivalent to the term "Archæan" as used by Van Hise, and the term "Upper Huronian" is equivalent to Van Hise's "Lower Huronian." Accordingly, the Animikie, or the Upper Huronian of Van Hise, is younger than the original Huronian series. That the Animikie is later than the true Upper Huronian or original Huronian may be shown in the following ways:

1. Stratigraphically it is the third series of sediments upwards from the bottom of the geological column in the Lake Superior region; the Upper Huronian is the second.

2. Lithologically, the two series are quite different, and so presumably are of different age. There is very little conglomerate at the base of the Animikie; in the Huronian the quartzites, slate conglomerates, and jasper conglomerates are of great thickness. The oolitic jaspers found in the Animikie are quite absent from the Huronian. The shales, so important in the Animikie, are almost unknown in the Huronian. The laccolitic sills of the Animikie are lacking in the Original Huronian.

3. Structurally, the two series are usually said to be alike in that both lie flat and undisturbed. While this is quite true of the Animikie, it is only partially true of the Huronian north of the Georgian Bay, and is untrue of the Upper Huronian about Batchawana and Michipicoten. Coleman[2] and Murray[3] have described cases of

[1] C. R. VAN HISE, "The Iron Ore Deposits of the Lake Superior Region," *Twenty-first Annual Report of the U. S. Geological Survey*, Part III, pp. 305–434.

[2] *Bureau of Mines, Ontario*, 1901, p. 189.

[3] *Geological Survey of Canada*, 1858, p. 95.

vertical dip within the so-called Original Huronian, and others have been observed by myself. These seem to occur around the outer portion of the Huronian basin, and more gentle dips obtain in the central part. Evidently the Huronian has been subjected to forces which the later Animikie has escaped.

4. Assuming that the large areas of eruptive granite-geisses in the Lake Superior region are of the same age, we find that the Upper Huronian has in many cases been pierced by them, but that the Animikie always overlies them.

A. P. COLEMAN. "The Huronian Question." *American Geologist*, Vol. XXIX (1902), pp. 325–34.

Coleman discusses the Huronian question, his argument being mainly against the correlation of the Animikie series of the Lake Superior region with the Upper Huronian series. Evidence that the Animikie is unconformable above his Upper Huronian series is summarized, and emphasis is placed on the points that both the Upper Huronian and the Lower Huronian differ lithologically from the Animikie; they are metamorphosed and schistose as compared with the Animikie; and they are much folded aad highly tilted, in marked contrast to the Animikie.

Comment.—For the most part the terms "Upper Huronian" and "Lower Huronian," as applied by Professors Willmott and Coleman to rocks *outside* of the part of the Original Huronian area of Logan on the north shore of Lake Huron, are to be correlated respectively with the "Archæan" and "Lower Huronian" of the United States geologists, and thus Van Hise's "Upper Huronian" or "Animikie" comes above their "Upper Huronian." For such areas, therefore, there is no marked difference of opinion as to the number and succession of series, but only difference in names. However, when it comes to the correlations of these series with the rocks of the Huronian series on the north shore of Lake Huron the difference is fundamental. Coleman and Willmott, in common with other Canadian geologists, apply the term "Upper Huronian" to the entire series north of Lake Huron mapped as "Huronian" by Logan, and apply the term "Lower Huronian" to underlying greenstones, green schists, and jaspers (as typically developed in the Michipicoten district). This Lower Huronian series, with the addition of certain "Laurentian" granites, corresponds approximately to what Van Hise, following the terminology of the U. S. Geological Survey, has called the "Archæan" in this and other parts of the Lake Superior region. But the sediments which Logan mapped as "Huronian," and which are classed as "Upper Huronian" by Willmott and Coleman, have been divided on the north shore of Lake Huron by Van Hise and Pumpelly, following Alexander Winchell, into the "Lower Huronian" and "Upper Huronian" series, the break being placed at the base of the Upper slate conglomerate, It is with these divisions of the Original Huronian series that the correlation of the Upper Huronian and the Lower Huronian series of the rest of the Lake Superior region has been made by Van Hise. Field work done on the north shore of Lake Huron during 1902 by Professors Van Hise, Seaman, and the writer presents further evidence of the correctness of this correlation. A full discussion of the evidence is not possible here, but it will be presented shortly in a general monograph on Lake Superior geology now in preparation.

ANDREW C. LAWSON. "The Eparchean Interval: A Criticism of the Use of the Term Algonkian." *Bulletin of the Department of Geology*, University of California, Vol. III, pp. 61–52.

Lawson criticises the use of the term "Algonkian." He emphasizes the importance of the interval, which he calls the Eparchæan interval, between the "Huronian'

and Animikie series, that is, between the Lower Huronian and Upper Huronian, of the United States Geological Survey, and argues that no one term such as "Algonkian" should include a break of this importance. It is proposed to restrict "Algonkian" to the Animikie and Keweenawan rocks, and to retain Dana's term "Archæan" for all rocks below the Animikie, *i.e.*, below the Eparchæan interval, and also to retain the terms "Laurentian" and "Huronian," as subdivisions of the Archæan, with the significance originally given them by Logan. The correlations of the Animikie with the Keewatin of Minnesota and with the Upper Huronian of Lake Huron is regarded as an error, because of dissimilarity in lithology, stratigraphy, and in relations to intrusives. Following Willmott and others, it is believed that the Animikie is younger than the (Upper) Huronian series of Lake Huron, and thus later than the Eparchæan interval. Emphasis is placed on the marked lithological similarity in the sedimentary series below the Eparchæan break in the Lake Superior and Lake Huron region, and the probable correlation of these rocks with the Original Huronian series. Summarized in tabular form, the correlation proposed is as follows:

Paleozoic.		Cambrian (Upper division or Potsdam only).
		Unconformity.
	Algonkian.	Keweenawan.
		Unconformity.
		Animikie = Penokee = Upper Marquette.
Eparchæan Interval.		
Archæan		Huronian = Upper Keewatin = Lower Marquette, etc.
		Unconformity.
		Laurentian, so called, granite gneisses, etc. (intrusive in the Ontarian) and the Carlton anorthosites.
	Ontarian	Keewatin = Lower Huronian = Crystalline schists of south shore invaded by granite gneisses.
		Unconformity.
		Coutchiching.

Comment.—Concerning the correlation of the Animikie with the Upper Huronian the comment on Professors Willmott and Coleman's articles, summarized on a preceding page, is pertinent. Dr. Lawson implies that the Animikie has been correlated by the U. S. Geological Survey with the entire sedimentary Huronian series of the north shore of Lake Huron, while it has been correlated only with the portion of this series above the limestone; and against such a correlation his argument loses some of its force. If the Keweenawan and Animikie series are not Cambrian, as they are held to be by Lawson, but are pre-Cambrian, as held by the U. S. Geological Survey, then Lawson's objection to the term "Algonkian," as replacing in part the old term "Archæan," would prevent its application even to the Animikie and Keweenawan rocks to which he restricts it. As already noted, the nomenclature of Lake Superior and Lake Huron series is being fully discussed in a general monograph on Lake Superior geology now in preparation. Arguments for the adoption and retention of the term "Algonkian" will be summarized, together with new arguments developed in recent field work.

C. R. VAN HISE. "Geological Work in the Lake Superior Region." *Proceedings of the Lake Superior Mining Institute*, Vol. VII (1902), pp. 62–69.

Van Hise briefly sketches the history of geological mapping in the Lake Superior region, calling attention to the difficulty of preparing accurate maps, and concludes that the maps which have been published from time to time since the earliest map of Foster

and Whitney represent reasonably close approximations to the facts as then known, and that, notwithstanding their many imperfections, they have been of service at the time of publication.

J. E. SPURR. "The Original Source of the Lake Superior Iron Ores." *American Geologist*, Vol. XXIX (1902), pp. 335–49.

Spurr discusses the origin of the pre-Cambrian iron ores of the Lake Superior regions. He repeats his conclusion that the Mesabi ores have resulted from the alteration of a green ferrous silicate of the class of glauconite, and further states that his conclusion in reference to the Mesabi iron formation may be "probably applied to most of the other Lake Superior iron ores."

Comment. — This paper is practically a reply to a brief abstract published in the *Engineering and Mining Journal* of an informal talk given by the writer before the Geological Society of Washington. While fully agreeing with Mr. Spurr's major conclusion that the Mesabi ores have resulted from the alteration of ferrous silicate granules, the writer has emphasized certain facts which seem to prevent the application of the name "glauconite" to this silicate.[1]

As to the statement that conclusions applicable to the Mesabi ores apply to most of the other Lake Superior iron ores, presumably this is based on certain similarities in granules and concretionary forms to be observed in the iron-bearing rocks of the Mesabi and Gogebic districts. This similarity the writer has discussed elsewhere,[2] and believes it will afford no support for Dr. Spurr's somewhat sweeping statement.

C. K. LEITH. "A Comparison of the Origin and Development of the Iron Ores of the Mesabi and Gogebic Iron Ranges." *Proceedings of the Lake Superior Mining Institute*, Vol. VII (1902), pp. 75–81.

Leith compares the origin and development of the Gogebic and Mesabi iron ores. The ores of the two districts occur in the same geological horizon; they result from the alteration, under weathering conditions, of a ferrous compound of iron, through the agency of percolating waters, and are localized in channels of vigorous circulation of water. But the differences in the development of the ores of the two districts are important. The original ferrous compound of iron is mainly iron silicate in the Mesabi district, and iron carbonate in the Gogebic district, although both substances appear in each district. The localization of the ores in the Gogebic district during their concentration has been within clear-cut pitching troughs with definite shapes, while in the Mesabi district the very gentle folding of the iron formation, its fracturing, and the absence of intrusives combine to make the channels of vigorous flow within the iron formation most devious, resulting in the curious and exceedingly irregular shapes now to be observed in the Mesabi ore deposits.

The original ferrous silicate from which the ores develop in the Mesabi district is in minute homogenous granules, the form of which remains even after the substance is changed. Associated with these granules are undoubted concretions of iron oxide and chert with concentric structure. In the Gogebic district there appear numerous

[1] C. K. LEITH, "The Mesabi Iron-Bearing District of Minnesota," *Monograph XLIII, U. S. Geological Survey*, 1903.

[2] C. K. LEITH, "A Comparison of the Origin and Development of the Iron Ores of the Mesabi and Gogebic Iron Ranges." *Proceedings of the Lake Superior Mining Institute*, 1902, pp. 75–81. (See summary below.)

concretions with concentric structure, which Van Hise has shown to develop during the alteration of iron carbonate; and associated with these are rare granules of iron oxide and chert in varying proportions, which may represent altered ferrous silicate granules similar to those of the Mesabi district. Evidences of the existence of original ferrous silicate granules in the Gogebic district are not sufficiently numerous to warrant modification of Van Hise's conclusion that the ores have developed from the alteration of iron carbonate.

C. K. LEITH. "The Mesabi Iron-Bearing District of Minnesota." Monograph XLIII, U. S. Geological Survey, 1903.

Leith describes and maps the geology of the Mesabi district of Minnesota. The district is two to ten miles in width, extending from near Grand Rapids on the Mississippi River to Birch Lake, a distance of approximately one hundred miles. The main topographic feature is a ridge known as the Giant's (or Mesabi) Range, which extends the length of the district. The geologic formations represented in the district belong, in ascending succession to the Archæan, Lower Huronian, Upper Huronian Keweenawan, Cretaceous, and Pleistocene. They are all separated by unconformities. The core of the Giant's Range is formed by Archæan and Lower Huronian rocks, except for the portion in ranges 12 and 13, where Keweenawan granite forms the core. On the south flank rest the Upper Huronian rocks, containing the iron-bearing formation, with gentle southerly dips. The Keweenawan gabbro lies diagonally across the east end of the district.

The Archæan rocks consist principally of green rocks of great variety, including dolerites, metadolerites, basalts, metabasalts, diorites, and hornblendic, micaceous, and chloritic schists. The more massive rocks frequently have an ellipsoidal structure, which is characteristic of the green igneous rocks of other parts of the Lake Superior region. In addition to the green basic rocks, there are present small areas of granite and porphyritic rhyolite.

The Lower Huronian series consists of sediments and granite. The sediments are graywackes, slates, and conglomerates, all metamorphosed, with bedding and schistosity practically vertical. They may be as thick as 10,000 feet, but it is thought more probable that the thickness does not exceed 5,000 feet. The Lower Huronian sediments rest unconformably upon the Archæan rocks, as shown by basal conglomerates containing fragments of all the varieties of rocks found in the Archæan. The Lower Huronian granite forms the main mass of the Giant's Range westward from a point near the east line of Range 14 W. It is intrusive into both the Archæan rocks and the Lower Huronian sediments, and has produced strong exomorphic effects in both.

The Upper Huronian or Animikie consists of three formations — the Pokegama quartzite at the base, above this the Biwabik formation (iron-bearing), and above this the Virginia slate.

The Pokegama quartzite comprises vitreous quartzite, micaceous quartz-slate, and conglomerate. The thickness ranges from 0 to 500 feet, averaging about 200 feet. The conglomerate at the base indicates unconformable relations of the Pokegama formation to the Archæan and Lower Huronian rocks.

The Biwabik formation, the iron-bearing formation, comprises ferruginous, amphibolitic, sideritic, and calcareous cherts, siliceous, ferruginous, and amphibolitic slates, paint rocks, "greenalite" rocks, sideritic and calcareous rocks, conglomerates and quartzites, and iron ores. Cherts make up the bulk of the formation. The

original rock of the formation is shown to consist largely of minute granules of green ferrous silicate, thus confirming Spurr's conclusion. The material was called "glauconite" by Spurr, but is here determined to be a hydrous ferrous silicate entirely lacking potash, and thus not glauconite. It is named "greenalite" for convenience in discussion. The cherts and iron ores are shown to develop mainly from the alteration of the greenalite granules. The slates are in thin layers interbedded with the other phases of the iron formation. The paint rocks result from the alteration of the slates. The conglomerates and quartzites form a thin layer from a few inches to perhaps 15 feet or more in thickness at the base of the formation. They pass upward into ferruginous cherts of the iron formation rather abruptly, though usually at the contact the chert and quartzite are interleaved for a few feet. The conglomerate of the iron formation rests upon Pokegama quartzite, indicating a slight erosion interval between the Biwabik and Pokegama formations, although the interval is not shown by discordance in bedding, which is parallel in both. Heretofore the quartzite and conglomerate in the iron formation have not been discriminated from the rocks of the Pokegama formation. In the eastern portion of the range the iron formation is in contact with the Keweenawan gabbro and granite, and near this contact has suffered profound metamorphism. The characteristic rocks of this area are amphibole-magnetite-cherts. The thickness of the formation may vary from 200 to 2,000 feet. The average may be 1,000 feet.

The Virginia slate is essentially a soft slate or shale formation, but it contains graywacke phases, near its base a little limestone, and near its contact with the gabbro is metamorphosed into a cordierite-hornfels. The normal slate phases of the formation may be distinguished with difficulty in isolated occurrences from the slate layers in the Biwabik formation. The separation of the two is of importance to the explorer, and hence an attempt is made to determine criteria for their discrimination. The thickness of the Virginia formation cannot be measured within the district, but from analogy with the Penokee-Gogebic district and the extent of the low, flat-lying area south of the Mesabi range supposed to be occupied by the slate, the formation is believed to have a very considerable thickness. The slate grades, both vertically and laterally, into the Biwabik formation.

The entire Upper Huronian series is well bedded, conformable in structure (although having a thin conglomerate between the Biwabik and Pokegama formations), and dips in southerly directions at angles varying from 5° to 20°, and exceptionally at higher or lower angles. The series is gently cross-folded, and the axes of the cross-folds pitch in southerly directions. Accompanying the folding is considerable jointing, especially in the brittle Pokegama and Biwabik formations. Indeed, in these two formations the folding is brought about mainly through relatively minute displacements along joints, while in the Virginia formation the folding has taken place mainly by the actual bending of the strata.

The thickness of the Upper Huronian series within the limits of the district mapped may average about 1,500 feet; but if the total thickness of the slate formation outside the limits of the district be taken into account, the total thickness of the Upper Huronian series is probably several times this figure.

The relations of the Upper Huronian series to the subjacent formations are those of unconformity, as evidenced by basal conglomerates, discordance in dip, difference in amount of deformation and metamorphism, distribution of the series, and relations to intrusives.

The Keweenawan rocks consist of gabbro, diabase, and granite, all of which are intrusive into the rocks with which they come into contact. The north edge of the gabbro runs diagonally across the east end of the district from southwest to northeast, resting upon the edges of each of the members of the Upper Huronian series, and at Birch Lake against the Lower Huronian granite. North of the gabbro margin, in Range 12, are isolated exposures of diabase which may represent sills associated with gabbro intrusion. The granite forms the crest of the Giant's Range through Ranges 12 and 13. This granite has not heretofore been discriminated from the Lower Huronian granite. The exomorphic effect of the gabbro and the granite upon the Upper Huronian series has been profound.

J. MORGAN CLEMENTS. "The Vermilion Iron-Bearing District of Minnesota." *Monograph XLV, U. S. Geological Survey*, 1903.

Clements describes the geology of the Vermilion iron-bearing district of Minnesota. Elaborate general and detailed maps, accompanying this report, are based on field work by Clements, Van Hise, Bayley, Merriam, and Leith.

The district ranges from two to eighteen miles in width, and extends from a little west of Lake Vermilion in a direction a little north of east to Gunflint Lake on the international boundary, a distance of about one hundred miles.

The rocks of the district are described under the headings "Archæan," "Lower Huronian," and "Upper Huronian," representing series separated by marked unconformities.

The Archæan of the Vermilion district is divided into three formations, as follows, given from the base up: the Ely greenstone, the iron-bearing Soudan formation, and the granites of Vermilion, Trout, Burntside, Basswood, and Saganaga Lakes.

The Ely greenstones consist of basic and intermediate igneous rocks widely distributed in anticlinal areas, as shown by the distribution of the overlying sediments. They were originally rocks corresponding in character to intermediate andesites and basic basalts. They have been extremely altered, but retain in many cases in striking perfection the original structures, such as ellipsoidal parting, and spherulitic and amygdaloidal structures. A study of their various textures and structures shows that these greenstones are unquestionably of igneous origin, and are largely of volcanic character. Many of them have been rendered schistose by pressure. The greenstones have also been strongly affected by the contact metamorphism due to the intrusion of great granite masses. As a result of this intrusion, there have been produced from the greenstones amphibole-schists, which form a marginal facies of the greenstones, lying between them and the adjacent granites. The greenstones have also been metamorphosed by the Duluth gabbro of Keweenawan age, and granular rocks have thus been produced which in most cases show the original textures of the greenstones, but contain also a development of fresh biotite, hypersthene, brown-green hornblende, and magnetite.

The Soudan iron formation is widely distributed in the western part of the district, but is practically wanting in the eastern half. It is found mostly in narrow belts, which consist largely of greenstone so intimately associated with the iron formation that it has been impossible to separate them on the map. The formation consists of (1) a very subordinate fragmental portion made up of some conglomerate, clearly recognizable as having been derived from the underlying greenstones, grading up into sediments of finer character; and (2) lying above this fragmental portion, the iron-

bearing formation proper, which consists of siliceous rocks, largely white cherts — though varying in color from white, green, yellow, and purplish to black — with red jasper and carbonate-bearing chert, grünerite-magnetite-schist, hematite, magnetite, and small quantities of pyrite. These iron-bearing rocks are clearly of sedimentary origin. They do not now present their original characters, but are presumed to have been derived from rocks that were largely carbonate-bearing, ferruginous cherts. The relation of the iron formation to the adjacent greenstones is clearly that of a sedimentary overlying an igneous series. The few basal conglomerates of the iron formation that have been found consist of pebbles derived from the underlying greenstone, showing conclusively their relationship. This relationship is obscured, however, in most places, by the absence of the conglomerates, and by the fact that the iron formation has been very closely infolded in the greenstone. In consequence of the extreme folding and of the impossibility of determining different horizons in the iron formation, it has been impracticable to ascertain its thickness. The iron-ore deposits of the Vermilion district show a striking analogy with those of the Marquette district. Like them, they may occur in two positions with respect to the iron-bearing formation. They are found, first, at the bottom of this formation, and, second, within it, the ores in both cases being the same in character. The Ely deposits are typical of the deposits occurring at the base of the formation. They are found at the bottom of a closely compressed syncline of the iron formation where it lies in the relatively impervious greenstone. The source of the iron was, in the first instance, the Ely greenstone. From this it was removed through the action of water and collected in the Archæan sea to form the sedimentary deposits of the Soudan formation. After the folding of the formation this disseminated iron was carried by downward percolating waters into places favorable for its accumulation, such as the bottom of this synclinal trough, where it was precipitated by oxygen-bearing waters coming more directly from the surface. *Pari passu* with this precipitation silica was removed, affording space for the accumulation of the iron to form the ore deposits as now known. The Tower and Soudan deposits differ only in detail from the Ely deposit.

Granites, intrusive into the Archæan, occupy a wide area, and are named from the topographic features with which they are conspicuously associated. That these intrusives are older than the Ogishke conglomerate (Lower Huronian), which succeeds in age the Soudan formation, is shown conclusively by the fact that pebbles derived from them occur in this conglomerate. The general period of intrusion of all of these acid igneous rocks is placed between the time of the deposition of the latest sediments of the Archæan and that of the deposition of the earliest sediments of the Lower Huronian series.

The Lower Huronian occurs in two detached areas, one of which, known as the Vermilion Lake area, extends from the western limit of the area mapped, in the vicinity of Tower, to within about eleven miles of Ely on the east, and the second of which, known as the Knife Lake area, begins about seven miles west of Ely, and extends eastward to the eastern limit of the area mapped. At the base of the series there lies a great conglomerate, known as the Ogishke conglomerate, containing pebbles and finer detritus from all of the rocks of the Archæan. Above this conglomerate, in the eastern portion of the district, there are found in a few localities small masses of the iron-bearing Agawa formation. This formation is petrographically the same as the Soudan formation. In it, however, there is in places a development of the carbonate-bearing facies. No iron ores have been found in it. Overlying the Ogishke conglomerate, in the

western portion of the district, and the intervening iron-bearing Agawa formation where present in the eastern portion of the district, there occurs a thick series of slates of varying character, to which the name "Knife Lake slates" has been given. These slates have been very closely folded, and have been more metamorphosed where intruded by granites of Giant's Range, Snowbank Lake, and Cacaquabic Lake, and by the Duluth gabbro. These igneous rocks occupy a considerable area, and their intrusive relation to the Lower Huronian are unquestionable. The Lower Huronian sediments now stand nearly vertical.

The Upper Huronian or Animikie series is found in the extreme eastern portion of the district, where it is continuous with the Animikie of the Mesabi district to the west and Thunder Bay to the east. At the bottom of the series occurs an iron-bearing formation known as the Gunflint formation. Above this occurs a great slate-graywacke formation, to which the name "Rove slate" has been given. The Gunflint formation is correlated with the Biwabik formation of the Mesabi district. It has a very limited development in the Vermilion district, and its most interesting phases are especially well developed in the vicinity of Akeley Lake. In general the formation has a monoclinal dip to the south-southeast at a low angle. It has been extremely metamorphosed by the Duluth gabbro, and where most metamorphosed the rocks are composed of coarsely crystalline bands of quartz, of varying width, alternating with coarsely crystalline bands of magnetite ore reported to vary from one inch up to ten or twelve feet in thickness, and of bands of dark-green, brown, or black rocks that consist of combinations of quartz, augite, hypersthene, hornblende, olivine, and magnetite as the principal minerals, but associated occasionally with some ferruginous carbonate, actinolite and grünerite.

The Duluth gabbro and the Logan sills, referred to the Keweenawan, occur in the eastern portion of the district. The gabbro is found to metamorphose all of the sediments already enumerated, and is thus shown to be one of the youngest rocks of the district. It is also found to be intrusive in the Keweenawan volcanics. A number of facts are enumerated to show that the gabbro and the Logan sills are of essentially the same petrographic character, although they exhibit minor differences that are readily explicable when one considers the relative amounts of the two rocks. After a consideration of these facts, and of the stratigraphic relationship of the rocks, the conclusion is reached that the gabbro and the sills are of essentially the same composition and age, having been derived from the same parent mass of magma. In certain localities in the Duluth gabbro there are found masses of titaniferous magnetite of varying but small size with some associated minerals. These masses grade into the surrounding gabbro, and were formed as the result of processes of segregation.

Cutting the Duluth gabbro are acid dikes and dikes of basalt and diorite.

The entire district has been much folded and metamorphosed, resulting in a marked north of east and south of west trend of the Archæan and Lower Huronian formations, marked principally by schistosity.

Comment on the Vermilion and Mesabi Reports.—Detailed work in these districts has developed a number of points bearing on the general stratigraphy and correlation of the rocks of the Lake Superior and Lake Huron districts.

In the Vermilion district the rocks now called Lower Huronian had previously been referred to the Upper Huronian by the U. S. Geological Survey, and the sedimentary Soudan iron formation, now mapped as Archæan, had previously been called Lower Huronian, and separated from the greenstones and granites supposed alone to

represent the Archæan. The Lower Huronian and Archæan of the present report correspond approximately with the Upper and Lower Keewatin of the Minnesota Survey, although there are minor differences in the reference of the several geological units to these divisions.

In the Mesabi district the rocks underlying the Animikie of the Upper Huronian had previously been lumped together as Archæan by the U. S. Geological Survey. They are now shown to be divisible into (1) a sedimentary formation, referred, with its associated intrusives, to the lower Huronian, showing remarkable similarity in lithology and structure to the Lower Huronian of the Vermilion district; and (2) an igneous series, referred to the Archæan, with marked similarity to the igneous rocks of the Archæan of the Vermilion district. The Lower Huronian and Archæan thus correspond roughly to the Upper and Lower Keewatin of the Minnesota Survey. This division of the Keewatin was not made in the Mesabi district by the Minnesota Geological Survey, although Dr. Grant noted the occurrence of rocks characteristic of the two divisions, and suggested the possibility of their separation.

The correlation of the Animikie series of the Vermilion and Mesabi districts with the Upper Huronian series of the north shore of Lake Huron is the same as in previous reports of the U. S. Geological Survey, and is the feature of the correlation which has been severely criticised by Canadian and other geologists, including Coleman, Willmott, Winchell, and Lawson, who hold the Animikie to be unconformably above the original Huronian series of the north shore of Lake Huron, from which the term "Huronian" comes. Comments on their arguments are made in connection with summaries of their articles on a preceding page.

The reference of the sedimentary Soudan iron formation to the Archæan, instead of including it in the Huronian and thus making a threefold division of the Huronian, as is now possible in the Marquette district, has also been criticised. The defense of such a use of the term "Archæan" involves a discussion of the principles of pre-Cambrian nomenclature not here warranted. Such a discussion will be made in a final monograph on Lake Superior geology now in preparation by the U. S. Geological Survey.

N. H. WINCHELL. Some Results of the Late Minnesota Geological Survey. *American Geologist*, Vol. XXXII (1903), pp. 246–53.

Winchell summarizes some results of the work of the late Minnesota Geological Survey. Those referring to the pre-Cambrian are as follows (the numbers are Professor Winchell's):

5. The discrimination of two iron-bearing formations in northern Minnesota, thus separating the Mesabi range stratigraphically from the Vermilion. This observation was continued into Wisconsin and Michigan by a visit to those states, and the same dualty was pointed out in the iron regions of those states, and was announced for the first time in the Minnesota report for 1888. It has since been discovered that there is still a third iron horizon in northeastern Minnesota, not mentioning the titanic iron ore of the gabbro. It is the upper Keewatin, the others being in the Lower Keewatin and the Taconic.

6. The separation of the Archæan of Minnesota into two non-conformable parts, viz., the Upper and Lower Keewatin, with a great basal conglomerate between them.

7. The determination of the oldest known rock of the Lake Superior region, a greenstone called Kawishiwin, the bottom rock of the Keewatin, the supposed earliest crust of the globe.

8. The great quartzite formation, which cuts quite a figure in the geology ot Wisconsin and Minnesota, is nonconformable upon the Animikie, and is a member of the fragmented beds of the Keweenawan. This has been named "Sioux quartzite," "Baraboo quartzite," and "New Ulm quartzite." It is that which contains the red pipestone (catlinite) in southwestern Minnesota. It is the western representative of the Potsdam sandstone, of Potsdam, N. Y. This quartzite seems to be the representative of the Middle Cambrian, as the Beckmantown is of the upper Cambrian.

9. The origin of the Mesabi iron ore is referred to a greensand, which has been altered, affording iron ore by concentration of the iron in certain favorable positions. Cotemporary with this alteration was a concentration of silica, and this was increased by oceanic precipitation. The original greensand was found to become pebbles, and to increase into angular masses that were neither sand nor pebbles, but rather breccia. These breccia masses have at first an amorphous crystalline texture and grade into a form of the iron-bearing rock which was named "taconyte," and the whole was referred to volcanic action, being different forms of suddenly cooled volcanic glass and rhyolite, broken and distributed by beach action. While this volcanic débris was undergoing this transformation, great quantities of silicia were set free from the glass; but this silicia immediatly saturated the débris, producing spotted jasperoid, taconyte, and sedimentary jaspilyte.

Having reached this result on the Mesabi Range, it opened the door to the understanding of the iron ores of the Vermilion Range, and at once the rhyolitic forms and all the igneous associations of those ares with basic igneous rocks were elucidated, thus confirming Wadsworth's idea of the igneous origin of the jaspilytes of the Marquette region — rather the igneous origin of the rock which later was changed into jaspilyte.

10 and 11. After prolonged field examination, the Minnesota Survey reached the conclusion that the granites of the Archæan grade into gneiss, the gneiss into micaceous gneiss and mica schist, and finally into less and less metamorphic rocks that show a plain fragmental structure and sedimentary origin. There was found no exception among the Archæan granites. The granites are of two dates of formation — one at the close of the Lower Keewatin, and one at the close, or after the close, of the Upper Keewatin. A later granite, associated with the gabbro, and grading into it, is of the Keweenawan, and another did not spring from a deep source, but is a surface product of metamorphism carried to the extreme of fusion, on clastic materials that were later than the basal greenstones. Adventitiously they form intrusions in some of the later (and especially into the clastic) greenstones, but they are not known to penetrate the oldest greenstones. Tentatively the alkaline and the acid siliceous elements in these early sediments were supposed to have been derived from the atmosphere, as the basal crust could not have afforded them.

In the same manner the gabbro, which becomes acid and grades into syenite, was derivdd from the metamorphism and fusion of the greenstone with their clastic variations. Diabase was found to pass insensibly into gabbro; but, on the other hand, it is also certain that it was the original form of all igneous greenstones, and that it must have had, and still has, a deep-seated source.

These belts of intensest metamorphism, whether productive of granite or of gabbro, have a parallelism with each other, and with the northwestern rim of the great synclinorium of the basin of Lake Superior, marking successive continental folds, in harmony with a system which continued through Archæan and Taconic time, and even into the Upper Cambrian.

Comment.—Conclusions 5 and 6 are essentially in accord with conclusions reached by United States geologists who have worked in this area, although differing in nomenclature and minor points. The same may be said of Conclusion 7 in the matter of a greenstone being the oldest rock in the state, although Professor Winchell is alone in calling it the earliest crust of the globe. From Conclusions 8, 9, 10, and 11 the United States geologists dissent *in toto*. Adequate discussion of these conclusions would involve covering the entire range of Minnesota geology. The reader is referred to *Monographs XLIII*,[1] and *XLV*,[2] and to pp. 305–434[3] of Part III of the *Twenty-first Annual Report of the U. S. Geological Survey* for such a discussion.

N. H. WINCHELL. "Sketch of the Iron Ores of Minnesota," *American Geologist*, Vol. XXIX, pp. 154–62.

Winchell briefly describes the iron ores of Minnesota, and incidentally sketches their geological relations. No new points are added to those previously presented.

ROBERT BELL. "Report on the Geology of the Basin of Nottaway River." *Annual Report of the Geological Survey of Canada for 1900*, Vol. XIII, Part K, 1902.

Bell describes and maps the geology of the basin of the Nottaway River. Granites and gneisses referred to the Laurentian occupy the larger portion of the area. They are for the most part intrusive into the crystalline schists referred to the Huronian. Huronian rocks occur principally in a large area that is near the center of the region, and in small areas north of the center of the region and south of Lake Mistassini in the eastern part. The large tract of Huronian rocks forms a part of the great belt of Huronian rocks extending continuously from the eastern side of Lake Superior to Lake Mistassini, a distance of seven hundred miles. The Huronian may be grouped in three classes, namely: (1) crystalline schists, together with some other rocks forming a comparatively small proportion of the same series; (2) massive greenstones; and (3) granites. The schists embrace a considerable variety, but the greater part of them are dark green and hornblendic or dioritic, and they often pass into more or less massive greenstones, so that it becomes difficult to map the two varieties separately. Dolomite, quartzite, arkose, conglomerate, and agglomerate are exceptional occurrences.

J. BURR TYRRELL AND D. B. DOWLING. "Reports on the Northeastern Portion of the District of Saskatchewan and Adjacent parts of the Districts of Athabasca and Keewatin," *Annual Report of the Geological Survey of Canada for 1900*, Vol. XIII, Parts F and FF, 1902. With map.

Tyrrell and Dowling report on the northeastern portion of the district of Saskatchewan, and adjacent parts of the districts of Athabasca and Keewatin, comprising an area adjacent to the north end of Lake Winnipeg. The east, northeast, and northern

[1] C. K. LEITH, "The Mesabi Iron-Bearing District of Minnesota," *Monograph XLIII, U. S. Geological Survey*, 1903.

[2] J. MORGAN CLEMENTS, "The Vermilion Iron-Bearing District of Minnesota," *Monograph XLV, U. S. Geological Survey*, 1903.

[3] C. R. VAN HISE, The Iron Ore Deposits of the Lake Superior Region, *Twenty-first Annual Report of the U. S. Geological Survey*, Part III, pp. 305–434.

portions of the area mapped are occupied by Laurentian and Huronian rocks, of which the Laurentian rocks are in the larger areas. They consist of granites and gneisses, some of which are intrusive into the Huronian, and some of which are probably basal to it. Huronian rocks are found in small areas at Cross Lake, at Pipe Lake, and in the large area extending from Wekusko Lake to Athapapuskow Lake. They consist of conglomerates, quartzites, basic eruptives, and greenstones, and altered schists, similar to rocks of Lawson's Keewatin and Couchiching series.

A. P. Low. "Report on the Geology and Physical Character of the Nastapoka Islands, Hudson Bay," *Annual Report of the Geological Survey of Canada for 1900*, Vol. XIII, Part DD, 1903.

Low describes the geology of the Nastapoka Islands, Hudson Bay. The rocks forming the islands are in descending order as follows:

	Feet
1. Rusty-weathering, dark gray siliceous rock containing ankerite (carbonate of iron and magnesia, and magnetite	20–100
2. Dark gray siliceous rock containing magnetite, with small quantities of ankerite	50–250
3. Red jaspilyte rich in hematite ore	10-100
4. Red jaspilyte poor in hematite ore	5–20
5. Purple, or greenish-weathering, dark green, graywacke shales	10–70
6. Red jaspilyte poor in hematite ore	0–5
7. Light greenish-gray sandstone and shale	10–300
8. Fine-grained dolomite	0–50

There is a general dip toward the westward, or toward the sea, of from 5° to 15°. There are north-and-south faults, the upthrow being almost on the west side, with the result that the rocks appear in north-and-south ridges. The displacement is small and rarely exceeds one hundred feet. Another system of faults lies transverse to the first system.

Large areas of similar unaltered sedimentary rocks occur throughout the peninsula of Labrador, and are probably the equivalents of certain of the iron-bearing series about Lake Superior and of those to the westward of Hudson Bay, hand specimens from these localities being undistinguishable. On former maps of portions of the peninsula of Labrador, the areas of rocks belonging to this formation have been colored as belonging to the Cambrian formation, and in the earlier reports on this region the rocks were thought to be a part of that system, owing to their unaltered condition, in contrast with all the other rocks of that vast area that were either crystalline granites and other irrupted rocks, or crystalline schists and gneisses, so completely metamorphosed as to have lost all trace of their original sedimentary nature, if any were sediments. These highly crystalline rocks were classed as Laurentian or Huronian, and were considered to be much older than the unaltered rocks of the so-called Cambrian areas. More extended and closer study of both the unaltered and crystalline rocks, and of their relations to one another, has changed the views of the writer; and he now considers the unaltered, so-called Cambrian rocks to be the equivalents of many of the gneisses and schists classed as Laurentian (Grenville series), and the Huronian areas of the Labrador peninsula to represent a portion of the unaltered rocks and their associated basic eruptives (traps, trap-ash, etc.), altered by the irruption of granite and rendered schistose by pressure The granites which have been classed as typical Laurentian, always cut and alter the bedded rocks wherever seen in direct contact with them, and are consequently newer than the latter.

During the past season very thin layers of carbon with some resemblance to organic forms were found in the sandstones of Cotter Island; these have the appearance of lowly organized plant life, lower than the known fossils from the lowest beds of the Cambrian; and consequently this formation is older than the Cambrian. It is proposed, therefore to class these so-called Cambrian unaltered rocks as Laurentian, as they represent the oldest known sedimentary rocks in the northeast of America, and probably in the world.

West Virginia Geological Survey. Vol. I, Oil and Gas; Vol. II, Coal; and map showing the occurrence of coal, oil, and gas in West Virginia, By I. C. WHITE, State Geologist.

PROFESSOR I. C. WHITE, state geologist of West Virginia, has just issued a map showing the distribution of coal, oil, and gas areas in that state. The base of the map is topographic, with contours of 1,000 feet, and is, all in all, the most accurate map of the state which has ever been published. The map shows both the coal areas and the coal mines of the state. Of the former, the Pittsburg, the Allegheny-Kanawha, and the New River-Pocahontas are differentiated. In the aggregate, the coal areas cover nearly one-half of the state. The areas of natural gas and oil, though more restricted, are still extensive.

The map, just published, is a welcome supplement to the excellent volumes on Oil and Gas (Vol. I, issued in 1899), and Coal (Vol. II, issued in 1903). No state geological survey has issued economic reports of greater worth. While in the case of both volumes the treatment is primarily economic, the general structural relations of the Mississippian, Pennsylvanian, and Permian series, as developed in West Virginia, are clearly set forth.

R. D. S.

Geographic Influences in American History. By ALBERT PERRY BRIGHAM. The Chautauqua Press, 1903. Pp. x+366; 61 illustrations.

American History and its Geographic Conditions. By ELLEN CHURCHILL SEMPLE. Boston: Houghton, Mifflin & Co., 1903. Pp. 466; 16 maps.

THE above books are pioneers in a most interesting and important field, too long neglected. American history has been profoundly influenced by geological and geographical conditions. To ignore these controls is to make history very largely empirical. To recognize them is to go a long way toward making history a rational science. To