GEOLOGY OF THE ALSTON DISTRICT
HOUGHTON AND BARAGA COUNTIES, MICHIGAN

Thesis by

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ABSTRACT

The copper-bearing sediments and flows of Keweenawan age which underlie the northwest side of Keweenaw Point form a conformable series which to the southeast has been thrust over the Cambrian Jacobsville sandstone. The stratigraphic correlation of the Freda sandstone, which lies at the top of the copper-bearing series, to the Jacobsville sandstone is uncertain, as are also the definite dating of the periods of deformation and the age of the copper mineralization.

Field work was conducted to the southeast of the main copper-bearing area with the hope of establishing: (1) the date of the native copper mineralization, (2) the relations of the Freda and Jacobsville sandstones, and (3) the dates of deformation.

The existence of a pre-Jacobsville period of mineralization was established, but its correlation with the native copper mineralization to the northwest cannot be definitely established.

The Jacobsville sandstone rests unconformably upon Keweenawan flows; in an adjacent area, the Freda sandstone rests conformably on flows of the same character. Hence the Jacobsville sandstone is thought to be later than and unconformable to the Freda sandstone.

At one locality the Keweenawan flows are tilted and sheared, while the overlying Jacobsville sandstone is not affected, thus proving the existence of a pre-Jacobsville, but post-Keweenawan deformation. Elsewhere, the marked disturbances of Lower Paleozoic strata prove another period of deformation which is definitely later than the Silurian' and probably later than the Devonian.

INTRODUCTION

PURPOSE OF INVESTIGATION

Although the copper-bearing series of rocks in Keweenaw, Houghton, and Ontonagon Counties of Upper Michigan have been extensively studied,[1] several major problems remain unsolved. Among these problems are: (1) the age of the native copper mineralization, (2) the relationship of the Freda or Western Sandstone to the Jacobsville or Eastern Sandstone, and (3) the dating of the several periods of deformation.

Reconnaissance work during 1937 and previous years, in a region a few miles to the east of the copper-bearing series, revealed valuable information concerning these fundamental problems. During the summer of 1939 about two months were spent in the field mapping in more detail a portion of this region to the east of the copper-bearing series.

Even though the major task was to throw light on the above problems, it must be admitted that practice in field mapping was another objective. This being the case, time being limited, and the literature on some aspects of the problem being very extensive, the emphasis in this report has been on interpretations from actual observations, and no attempt has been made to review all the literature on the Lake Superior District which might throw light on some of the subjects discussed.

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[1] Butler, B. S., Burbank, W. S., et al: U.S.G.S. Prof. Paper 144, 1929, pp. 3-14, gives an excellent bibliography of the region.

It is hoped that the new data here presented will not only help to solve some of the problems connected with the region, but will also prove to be of some use in expediting exploitation of the mineral resources to better advantage.

METHOD OF INVESTIGATION

All of the mapping was done by means of a Brunton compass and pacing. The general procedure was to locate outcrops by traversing, and then to map them in as much detail as they seemed to warrant. Since no topographic maps were available, they were constructed, where necessary, by means of pacing and hand-leveling. In many cases the country was so rugged that the degree of accuracy was impaired, and at times the timber and brush was so thick that the sketching in of contours was impossible, as was the sighting of objects for purposes of location. For this last named reason position had constantly to be maintained by pacing and running lines with a compass. A notebook with coordinate paper was used for this purpose, and by plotting the traverse on this paper position was continuously maintained. Coordinate paper had the advantage of permitting 90° and 45° lines to be plotted without the use of a protractor and scale, thus saving much time.

In some places a plane table could have been used advantageously, but since the work was done individually such a procedure was not practical. Likewise, bringing in control by more accurate means would have given more accurate results, but this extra trouble, even if possible, probably would not have been worth while.

ACKNOWLEDGMENTS

The author wishes to acknowledge the supervision given to the field work by Dr. R. M. Dickey. The help of Dr. H. J. Fraser, of California Institute of Technology, in organizing the field data and criticizing the manuscript has been especially valuable. Credit must also go to the hospitable inhabitants of the Alston district whose friendly attitude was a great help.

GEOGRAPHY

LOCATION AND SIZE OF MAPPED AREA

The area investigated is in Houghton and Baraga Counties in the Upper Peninsula of Michigan, and is about 12 miles west of the village of L'Anse. Although the region is about 100 square miles in extent, the area of actual exposures free from glacial till is less than four square miles.

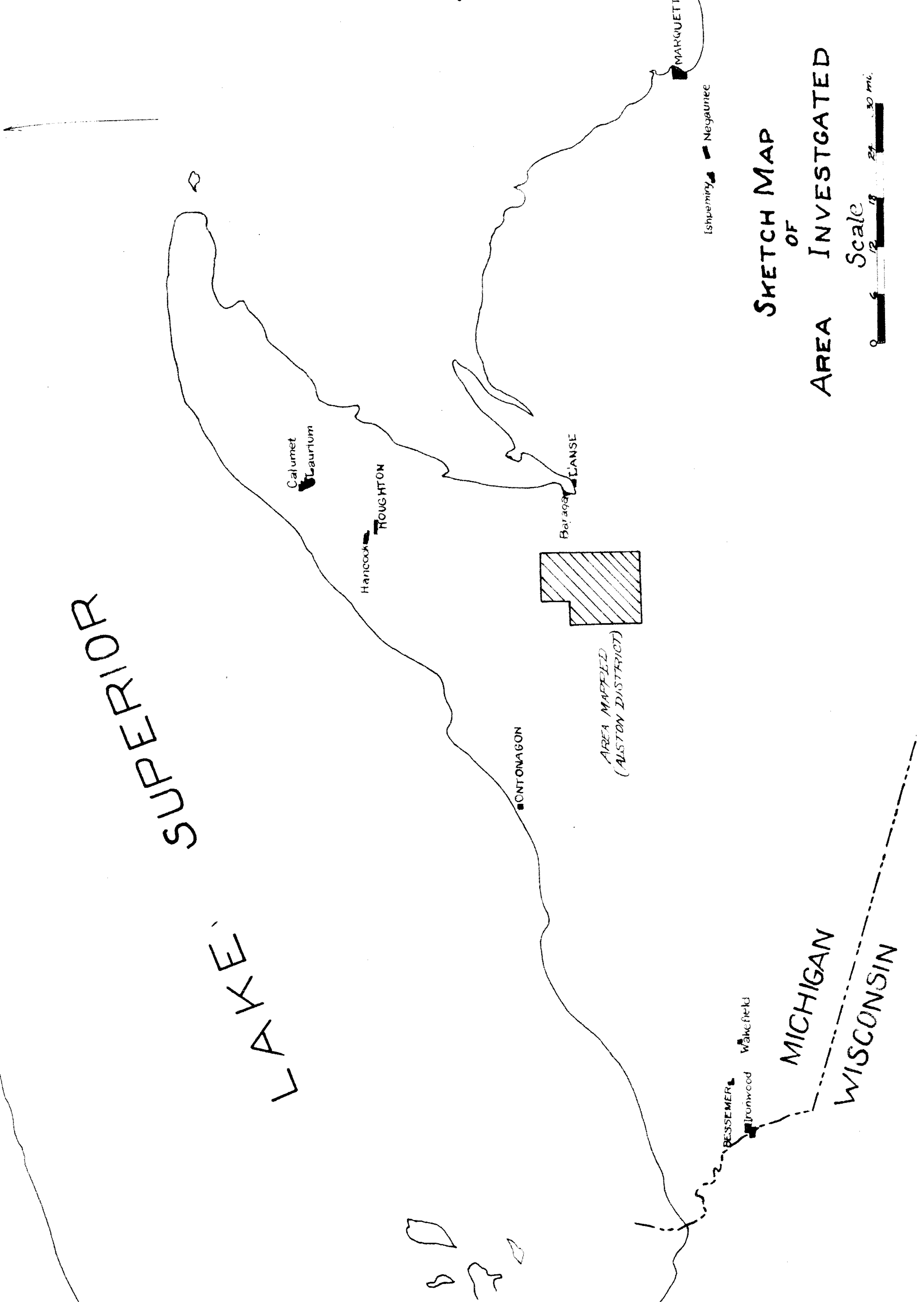
The map on page 6 (No. A) shows the general size and location of the area studied.

RELIEF AND ELEVATIONS

The maximum difference in elevation is about 450 feet. In general, the southern half of the area, to use Davis' nomenclature, is youthful, and the northern half is late mature in the geomorphic cycle.

DRAINAGE

The area is drained by the Sturgeon River and its tributaries, the Little Silver Creek, the Silver River, the West Branch of the Sturgeon River, and the Otter River. See Map No. 1 in pocket. On the whole the region is well drained, but marshes and swamps of considerable size are to be found in a few places.


SKETCH MAP
OF
AREA INVESTGATED
Scale
0 6 12 18 24 30 mi.
MARQUETTE
Negaunee
Ishpeming
L'ANSE
Baraga
Calumet
Laurium
HOUGHTON
Hancock
AREA MAPPED
(ALSTON DISTRICT)
ONTONAGON
LAKE SUPERIOR
MICHIGAN
WISCONSIN
Wakefield
BESSEMER
Ironwood

VEGETATION

Native vegetation is practically all second growth, a considerable portion of this area having been burned by forest fires about 20 years ago; it consists of maple, aspen, etc. A belt of land along the old Mineral Range Railroad right of way is under cultivation, and there are a few small farms south of Alston. See Map No. 1 in pocket.

ROCK EXPOSURES

Exposures are scanty; perhaps four per cent of the area has bed rock outcropping through the cover of glacial deposits, and even these places are often partly obscured by vegetation. Usually the river courses, gullies, high hills, road cuts, and ditches furnish the most outcrops. The best method to locate outcrops without a great loss of time is to talk to local farmers or lumbermen who are well acquainted with the country and have them direct the investigator to the outcrops. The accuracy of the memories of these people in regard to locations is remarkable, but their observations in regard to type of rock, etc. are not to be trusted.

STRATIGRAPHY AND PETROGRAPHY

General

Keweenaw Point is on the south side of the Lake Superior syncline or basin. On the northwest side it is composed of flows and sediments of Keweenawan age which strike northeasterly and dip toward the northwest. On the southeast side it is composed of Cambrian sandstone which in general is flat lying. Between the two series is a fault. The Keweenawan flows, conglomerates, sandstones, etc. are thrust over the Cambrian sandstone in such a manner that the Keweenawan series near the fault is dipping to the northwest at a steep angle. The dips become progressively less away (northwest) from the fault.

The area described in this report lies to the southeast of the Keweenaw fault. The rock types are similar, but differ in amounts and relations; and, in addition, the area contains small patches of Ordovician and Silurian strata. The map on the following page, taken from U.S.G.S. Prof. Paper 144, shows the general geologic features.

The reader is referred to U.S.G.S. Prof. Paper 144 for further details of the general structure and geology of the vicinity.

Uralitized Basalt Flows of Silver Mountain

History of the Subject.

Historically, the first reference of note to Silver Mountain was by Burt,[2] who mentioned the locality and found small amounts of copper sulfides as well as quartz and calcite veins containing "carbonate of steatite."

The Foster and Whitney Expedition[3] described the mountain as being a dome-shaped knob occupying an area equal to three sections and

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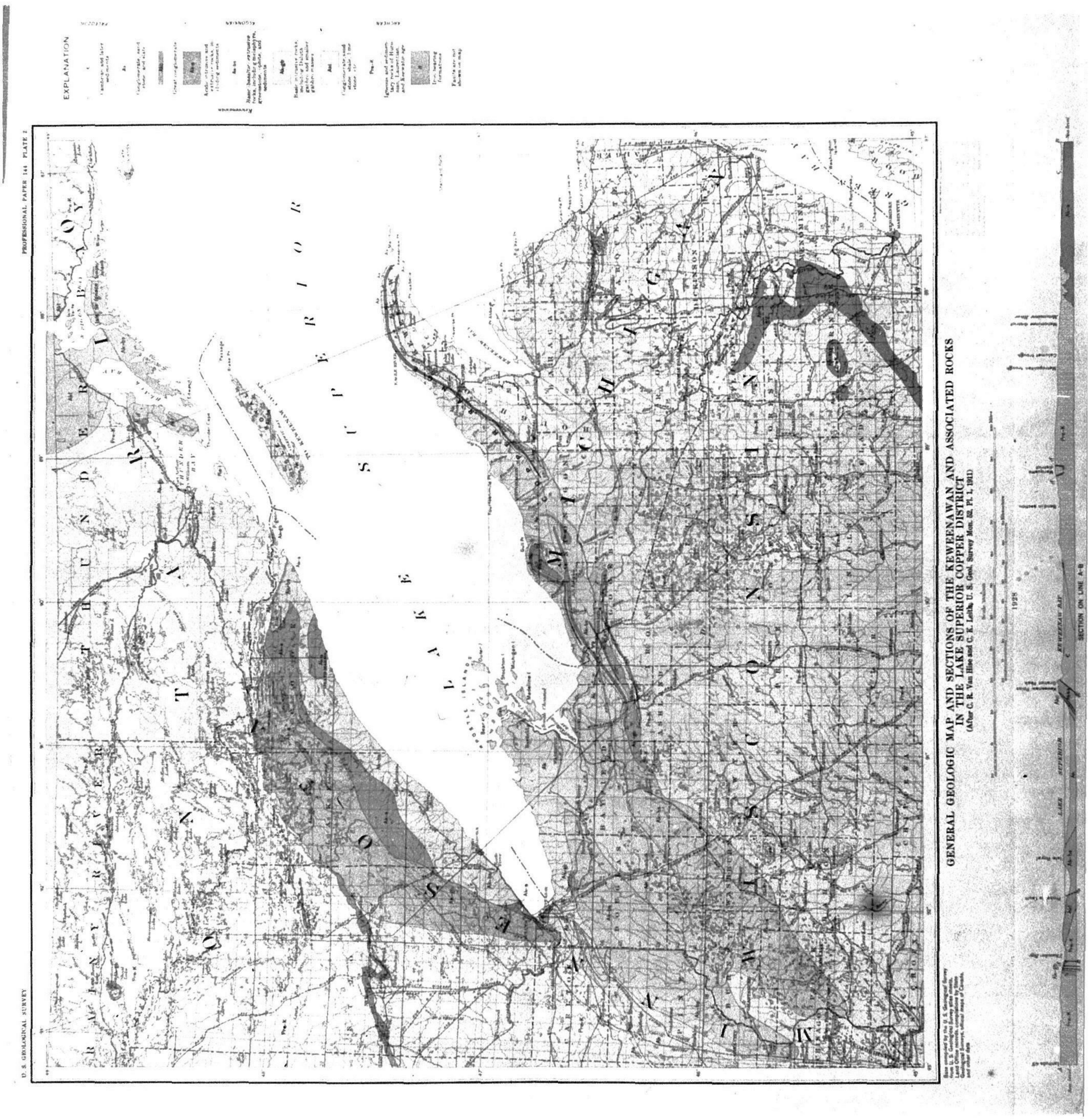
2 Burt, W. A.: Message from the President of the United States to the two Houses of Congress at the Commencement of the First Session of the 31st Congress, December 24, 1849, Pt. III, Geological Report of W. A. Burt on Surveys of Township Lines in 1846, p. 849.

3 Foster, J. W., and Whitney, J. D.: Report on the Geology of the Lake Superior Land District, Pt. II. 32nd Congress, Special Session, Supt. Executive Documents 41, 1851, pp. 68-69.


U. S. GEOLOGICAL SURVEY
PROFESSIONAL PAPER 144 PLATE 2
EXPLANATION
LAKE SUPERIOR
GENERAL GEOLOGIC MAP AND SECTIONS OF THE KEWEENAWAN AND ASSOCIATED ROCKS IN THE LAKE SUPERIOR COPPER DISTRICT
(After C. R. Van Hise and C. K. Leith, U. S. Geol. Survey Mon. 52, Pl. 1, 1911)
SECTION ON LINE A-B

being made up of a labrador and hornblende rock, the labrador being predominant. In addition, nodules of quartz and chalcedony were scattered through the mass.

The National Company had put an adit in for 100 feet along a fissure dipping 63° to the northwest. No metallic mineralization was found in the rock dump. They felt that the adit was along a fault because of the polished walls and broken rock of the fissure. They also mention a dike at the summit which has a zig-zag course.

Foster and Whitney had the conception that the trappean rocks were intruded into the Jacobsville sandstone and thus domed it and deformed it at various places.

M. E. Wadsworth[4] described the results of a party in charge of A. E. Seaman which studied Silver Mountain. It was found to be composed of interbedded lava flows of which at least ten flows were distinguished with more or less certainty. The flows were found to dip northwest at an angle of 10° to 16°.

R. D. Irving[5] described Silver Mountain, and from a microscopic examination of the rocks concluded that the amphibole in the rocks came from augite. Uralite, and in addition augite, titaniferous magnetite, and feldspar were mentioned. He remarked that the flows might be of Huronian age.

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[4] Wadsworth, M. E.: The South Trap Range of the Keweenawan Series, American Journal of Science, Vol. XLII, pp. 417-419, 1881.

[5] Irving, R. D.: Copper Bearing Rocks of Lake Superior. U.S.G.S. Monograph No. V, pp. 201-205, 1883.

Description.

At Silver Mountain (see Map No. 2), which is located on sections 1 and 12 of T49N R36W and section 6 of T49N R35W, uralitized basalt flows occur in the dome-shaped knob comprising Silver Mountain. There seem to be present at least 14 flows, ranging in thickness from a few feet to about 20 feet. The flows are blocky and have irregular contacts, with frequent pipe amygdules at the base of the individual flows. Amygdules of the ordinary spheroidal type are much more abundant and contain the following minerals: quartz, calcite, chert, chlorite, adularia, sericite, hematite, bornite, and chalcopyrite. Quartz, calcite, and chert are the most common, copper sulfides being very rare. The adularia is sometimes in typical crystal form, much altered to sericite, and contains an appreciable amount of hematite which imparts a red color to it. The small amounts of copper sulfides occur in small grains up to about 3 mm. in diameter and are associated with calcite. The borders of these sulfide grains are sometimes slightly altered to malachite. Calcite occurs as irregular replacements of the rock itself, as well as in amygdules. Sericite is often quite coarse, and from the limited thin section work seems to be primarily an alteration of adularia. The paragenesis of the amygdaloidal fillings appears to be quartz, calcite, adularia, sericite.

The flows themselves are of a fine-grained, very tough, dark-green, amygdaloidal extrusive with about the following mineralogical composition:

Minerals: andesine (basic), 40%; hornblende (uralite), 40%; calcite, 10%; chlorite, 4%; and leucoxene, 5%.

Alteration: hornblende is altered from pyroxene, probably from augite. Calcite is usually associated with hornblende and is possibly the result of pyroxene alteration, but may also be due to introduction of material hydrothermally. Some calcite is found on the feldspar which is slightly sericitized. Chlorite is an alteration product of the ferromagnesian minerals. Leucoxene presumably is the result of alteration of magnetite-ilmenite because of occasional remnants of octahedral form.

Texture: the rock is fine-grained and shows the usual size distribution across a given flow. Hornblende occurs in ragged grains, usually elongated in the direction of cleavage. In a few cases the old pyroxene outline may be observed, but little or no pyroxene has escaped alteration. Andesine occurs in typical jackstraw arrangement and formed prior to the hornblende. Chlorite is fine grained and in irregular patches.

Dikes made up of finer-grained material similar to the flows are commonly seen on the weathered surfaces where a zone of weaker material up to a quarter of an inch wide along their borders has been weathered into a brownish groove. These dikes are narrow, of steep but variable dip; they pinch, branch, and zig-zag. Fractures pass through these dikes, causing no displacement. At other places the dikes are obviously offset, and yet there is absolutely no indication of this offset in the adjacent rock. Microscopic examination shows that the borders of the narrow dikes have been chilled. These dikes are interpreted as being due to solidification of the top of a flow to a very viscous consistency, then fracture, and either (1) welling up of molten lava from within the flow, or (2) filling of the fracture by material from an overlying flow, and subsequent plastic flow to give the offsets and zig-zag appearance. Of these two latter possibilities the first seems the more plausible because of amygdules in the dikes, and because plasticity of the flow tops at the time of deposition of a subsequent flow is less likely.

The relations of the flows to underlying rocks are beyond the scope of this investigation. The relations to overlying or interbedded rocks are discussed later.

Basaltic Flows at Sturgeon Falls

Historical.

W. A. Burt[6] mentioned briefly Sturgeon Falls and the basaltic flows which outcrop there. His conception was that the flows were Huronian in age because his work in this locality was an extension of previous work done in the Huronian regions to the east. He also observed the unconformable relations of the sandstone and lava, but his mistaken identity of the age of the flows coupled with the infrequency with which geologists consulted his work prevented the exact nature of the relations and their significance from being recognized.

As far as is known, the only other published description of the geology at Sturgeon Falls is by C. W. Robinson,[7] who, in a series of letters published by D. L. Robinson, recognized that there was

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[6] Opt. Cit., p. 849.

[7] Robinson, C. W.: Early Days in the Copper Country. Edited by D. L. Robinson, Houghton, Michigan.

"trap rock" at the falls proper and that there were sandstone cliffs farther downstream. However, he was primarily a logger and so did not describe the locality from a geological viewpoint.

Ira Klein studied the area in 1938, and the results of his work are available at the Department of Geology of Michigan College of Mining and Technology, Houghton, Michigan. He concluded that the sandstone unconformably overlay trap rock of Keweenawan age and that the trap rock had been subjected to hydrothermal alteration whereas the sandstone had not. This is by far the best account on the locality and it is unfortunate that it is available only in manuscript form.

Description.

This type of basalt outcrops only at the Sturgeon River Falls in the center of section 16 of T49N R35W. (See Map No. 2.)

Observations of amygdaloidal zones suggest that three flows are present at the falls proper. The flows have a poorly developed columnar jointing and a sheet structure developed parallel to the surface of the flows. Megascopically the rock is a fine-grained, black, amygdaloidal basalt.

Numerous veinlets cut the basalt, and amygdules are common. Minerals in these include quartz, chlorite, calcite, epidote, jasper, probably ankorite, and alkali feldspar. The paragenesis of the fillings seems to be chlorite, epidote, quartz, alkali feldspar, ankorite- calcite, and jasper. It must be remembered that there is considerable overlap in this sequence and this conclusion is based on limited evidence. There may be a break in mineralization between deposition of ankerite-calcite and the jasper.

The flows themselves have about the following characteristics:

Minerals: augite, 1 mm., 20%; andesine, 0.2 x 1.5 mm., 45%; chlorite, 3 mm., 25%; magnetite-ilmenite, 0.5 mm., 5%; epidote, fine, 2%; hematite-limonite, 0.3 mm. patches, 2%.

Alteration: feldspar is altered to epidote, and to a lesser extent to kaolin. Augite shows alteration to chlorite. Ilmenite is partially altered to leucoxene. Magnetite and chlorite are slightly altered to hematite-limonite. In the amygdaloidal zones the flows contain much more hematite and are more extensively altered. Calcite and quartz form prominent replacements in these amygdaloidal zones.

Texture: lath-shaped andesine forms a felted mass with only slight linear parallelism. Augite is subhedral to anhedral, and is definitely later than andesine. Chlorite is in irregular patches, sometimes rimmed with epidote. Epidote occurs chiefly as an alteration of the plagioclase.

In determining the relation of the uralitized basalts of Silver Mountain and the basalts of Sturgeon Falls, two main possibilities are to be considered: (1) the uralitization is a deuteric effect connected with the composition and conditions of deposition of the flows, and (2) the uralitization is due to subsequent metamorphism. The first alternative seems less likely, for (a) the flows are thin and volatiles had opportunity to escape, (b) there seems to be no variation of alteration with thickness of flow, and (c) there is no microscopic evidence of deuteric effects, such as wormy intergrowths or reaction rims.

The metamorphism of the Silver Mountain flows may have been due to local intrusion which did not affect the flows at Sturgeon Falls about two miles distant. However, such a possibility is unlikely because the flows at Silver Mountain have a considerable area of outcrop (see Map No. 2), and over this whole area of outcrop the alteration is remarkably uniform. It seems highly improbable that the flows at Sturgeon Falls, only two miles away, could have completely escaped the effects of a process that uniformly uralitized the Silver Mountain flows over a square mile or more of exposed outcrop. On this basis alone, it appears that the flows of Silver Mountain must be older and must have been subjected to conditions differing from those which have affected the Sturgeon Falls flows. In other words, an unconformity or break of some kind seems possible. However, the evidence is far from conclusive, and it may be that the slightly more basic composition of the uralitized flows has made them more amenable to alteration by uralitization and thus explains the differences. More work is necessary to determine definitely the relation between the Silver Mountain flows and the Sturgeon Falls flows.

Although the flows of Silver Mountain are apparently at a higher stratigraphic position than the flows at Sturgeon Falls, either faulting (which is not uncommon in the vicinity), or an unconformity, or both, could easily account for this fact.

The flows at Sturgeon Falls are of the same age as the copper-bearing series of Keweenaw Point, for both are lithologically similar, and no similar flows of different ages are known to exist in the general region.

The typical basic flow of Keweenaw Point is of a dark shade and highly crystalline. The first mineral to form was olivine which is in irregular patches up to about 2 mm. It is often absent. Plagioclase is mostly labradorite in the coarser phases, and oligoclase-andesine in the finer phases. It is typically developed in lath-shaped forms, and is later than the olivine. Magnetite-ilmenite occurs in irregular grains. Augite is later than olivine and plagioclase, and often seems later than magnetite-ilmenite. It often alters to chlorite and small amounts of hematite. Compared with the description on page 14, there is a marked similarity. Certainly there are no lava flows in the district, other than Keweenawan, that approach this type. This is the basis for correlation.

If this is accepted, the general relations of stratigraphy of the copper-bearing series must pertain in the rocks underlying the Jacobsville sandstone east of the Keweenaw fault. In other words, it is believed that since the basic flows, conglomerates, shales, and Freda sandstone of the western part of Keweenaw Point are essentially conformable, they should be repeated beneath the Jacobsville sandstone in the eastern part of the point.

It is absolutely certain that the Jacobsville or Eastern sandstone unconformably overlies the basalts at Sturgeon Falls. The variance in dip between the two formations, the hilly topography of the buried basalt, and the weathering of the old basalt surface all strongly indicate the existence of an unconformity. In addition, the sandstone penetrates cracks in the basalt, and the basalt has been subjected to hydrothermal alteration whereas the sandstone has not. The relations of the Freda and Jacobsville sandstones are discussed elsewhere.

Jacobsville or Eastern Sandstone

This formation is confined to the region southeast of the Keweenaw fault and outcrops at many places in the mapped area and elsewhere. See Map No. 1 for distribution of outcrops in the area.

The thickness of this sandstone is not known. Reports of drill holes near the Keweenaw fault in the vicinity of Lake Linden indicate a thickness of over 1500 feet. A drill hole put down about two miles west of Limestone Mountain is reported[8] to have penetrated the sandstone for over a thousand feet. Geophysical methods near the Baraga-Houghton County line on highway U.S. 41, near the hamlet of Keweenaw Bay, indicated[9] a depth of about two thousand feet; but the method used was a resistivity method and the error may be large. The thickness at Sturgeon Falls is not less than 120 feet.

Megascopically the sandstone is a coarse reddish sandstone, with banding showing alternate red and white liminations. Some massive strata are found, but by far the largest amount of the sandstone (especially toward its base) outcropping within the investigated area shows fine cross bedding of a type developed in shallow waters under turbid conditions. Ripple marks are not uncommon.

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[8] Personal communication by Waisanen Bros., Pelkie, Michigan.

[9] Personal communication by T. C. Sermon, Houghton, Michigan.

Microscopically the rock has about the following characteristics, based on two representative thin sections and many hand specimens taken from Sturgeon Falls.

Minerals: quartz, 50%; microcline, 20%; orthoclase, 10%; muscovite, 10%; magnetite-ilmenite, 5%; plagioclase, 2%; traces of zircon, garnet, green biotite, and hematite.

Alteration: Feldspars are slightly kaolinized. The main portion of rock has a hematite stain (dark brown in thin section and reddish in hand specimen) on the cementing material. Along joints which traverse the bedding are sharply defined white zones about an inch wide. They are probably the result of leaching of the ferruginous material by meteoric waters. The red coloring in the rock is due to hematite in the cement, and in the white zones this hematite has been removed.

Texture: The grain size of the formation varies from conglomeratic zones with one half inch pebbles, to fine sandstone. Most of the sandstone is composed of grains less than one mm. in diameter. The largest grains are composed of quartz, and are of a shape typical of ordinary beach sand. Feldspar grains are a little smaller than the quartz grains, but just about as round. The smaller quartz and feldspar particles become much more angular. Magnetite-ilmenite grains are rounded to about the same degree as the above minerals, but are smaller in size. Mica occurs sparingly as irregular, deformed grains about 0.5 mm. long. Most of the mica is very fine, and forms the matrix of the sandstone.

The source of the sediments is not definitely known, but since the underlying basalt was being actively eroded at the time of deposition, it seems logical to assume that the underlying basalt was the source of the ferruginous material, and perhaps of the mica matrix, through plagioclase alteration. The presence of microcline and orthoclase in appreciable amounts may indicate erosion of pre-Cambrian granites at some unknown point. The absence of plagioclase is probably due not to its lack in the source rocks, but to its rapidity of decomposition.

The deposition of this sandstone must have taken place in shallow waters on a suddenly submerged topography of late mature relief. The knobby nature of the buried topography at the time of deposition of the Eastern sandstone may well explain the irregularity of bedding and cross bedding, for any knobs or ridges in shallow waters would certainly accentuate turbidity.

As previously stated, the Jacobsville sandstone is very definitely unconformable upon the Keweenawan flows.

In regard to the relations of the overlying rocks, all that can be said is that although the contacts cannot be observed, the Jacobsville sandstone, St. Peters(?) sandstone, and the Ordovician-Silurian limestones have strikes and dips that are in approximate agreement so that there is no direct evidence of an unconformity; however, one may exist. Which formation overlies the Jacobsville sandstone is not known. There is a considerable gap between the Jacobsville sandstone outcrop near the quarter post between sections 23 and 14 to the west of Limestone Mountain, and the outcrop of

St. Peters(?) sandstone on the west flank of Limestone Mountain. There may be faulting in this gap, other Paleozoic members may be present, or the Jacobsville sandstone may continue up to the St. Peters(?) sandstone.

The age of the Jacobsville sandstone is Cambrian. A similar sandstone outcropping in the St. Croix River region of Wisconsin[10] has been determined to be Cambrian in age on the basis of contained fossils.

This sandstone unconformably overlies Keweenawan flows. Further, this Cambrian sandstone is found beneath Ordovician sediments to the west of the St. Croix district. Likewise, the Jacobsville sandstone unconformably overlies Keweenawan flows and dips under Ordovician sediments. No reliable fossils have been found in the Jacobsville sandstone.

St. Peters(?) Sandstone

Outcrops of this formation were found only in section 23 on the west side of both Big Limestone and Little Limestone Mountains. See Map No. 5.

Thickness of the formation is not known, but it is at least forty feet. The formation is a massive sandstone with layers of coarser sand arranged parallel to the bedding. Sand grains are up to about 1.5 mm. in diameter, and consist very largely of quartz, but with small amounts of feldspar and traces of magnetite or ilmenite. The

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[10] Chamberlain, T. C.: Geology of the Upper St. Croix District of Wisconsin; Geology of Wisconsin, Vol. 3, pp. 363-428, 1880.

sandstone is white in appearance and remarkably pure. The grains are very well rounded, have frosted surfaces, and are very loosely cemented together.

The source of the sediments is not known; they might have been derived from Huronian quartzites or the underlying Jacobsville sandstone.

As previously set forth, the relation between the St. Peters(?) and the Jacobsville sandstones is not known. Lower Ordovician beds may or may not be present below the St. Peters(?) sandstone, and there may or may not be an unconformity between the two sandstones.

The limestones found above the St. Peters(?) seem to be conformable, and at one point, on the west side of Little Limestone Mountain where a trench was dug to expose the contact, there was no evidence of any important break. One foot below the contact the sandstone is white with green and red stained patches; for five inches above this there is a clay-like layer which contains much calcite (or dolomite) and very fine sand; just above the clay-like layer the limestone is encountered, and for a few inches it carries many well developed manganese dendrites.

The limestone overlying the St. Peters(?) has been found by Case and Robinson[11] to be Upper Black River in age. The reasons for assigning the white sandstone to the St. Peters are: (1) its position below the Black River limestone and above the Cambrian Jacobsville

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[11] Case, E. C., and Robinson, W. I.: Geology of Limestone Mountain and Sherman Hill in Houghton County, Michigan; Michigan Geological Survey Publication 18 (Geological Series 15), pp. 165-181, 1915.

sandstone, and (2) its very characteristic lithology. No fossils have been found in it and the correlation may be incorrect, but it cannot be the Jacobsville sandstone because it is composed of more rounded grains with frosted surfaces, it contains much less iron and feldspar, lacks the characteristic stratification, and is very poorly cemented.

Limestones

Historical.

Limestones outcrop on Big and Little Limestone Mountains and on Sherman Hill. See Maps No. 4 and No. 5.

Limestone Mountain was first mentioned by Foster and Whitney,[12] who mentioned that it was not flat lying and that it was dolomitic in character.

In 1891 M. E. Wadsworth[13] published some results of a party in charge of W. L. Honnold. A sketch map was given, and the structure described as an oblong syncline. A pit was dug at the northwest end of the mountain to expose the base of the sandstone. It is not certain whether the Jacobsville or the Madison sandstone was exposed, and it was admitted that a minor unconformity might exist.

A. C. Lane[14] in 1909 concluded, on the basis of paleontology done by W. F. Cooper, that the Trenton and Niagaran limestones were present.

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12 Opt. Cit., p. 117.

13 Wadsworth, M. E.: The Relations of the Eastern Sandstone of Keweenaw Point to the Silurian Limestone; Amer. Jour. of Science, 3rd series, Vol. 45, pp. 45, 72-73, 1892.

14 Lane, A. C.: The Keweenawan Series of Michigan; Michigan Geological and Biological Survey Publication 6 (Geol. Series, pp. 523-525, 1909.

Case and Robinson[15] in 1915 made a thorough study of the fossil assemblage and found the strata mentioned on page 28. The fault between Big and Little Limestone Mountains was mentioned, as were also the presence of many minor faults. They believed the important fact brought out was the extension of the Paleozoic seas so far north.

Description.

The limestones are dolomitic, with some siliceous layers, and have bedding from about an inch to eight inches thick. A tabulation of analyses which have been made will be found under Economic Aspects. Marine fossils are present, but as a rule are poorly preserved and not abundant. The limestone is at least 400 feet thick on Big Limestone Mountain. Since the outcrops mentioned are erosional remnants due to structural features, and since they are the only remnants of limestone for almost 100 miles, it is obvious that erosion has removed much of the deposited Paleozoic strata in the region. Many younger beds may have been deposited, and subsequently removed by erosion.

The deposition was marine, as is indicated by the fossils. The lack of sand layers above the St. Peters(?) sandstone hints that the source of the St. Peters(?) had been removed either by erosion or by submergence before the time of limestone deposition.

There may be an unconformity between the St. Peters(?) and the Black River member, but no evidence of this fact could be established from dips and strikes, or from observations of the contact in a trench which was excavated on the west side of Little Limestone Mountain.

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[15] Opt. Cit.

Case and Robinson[16] have collected and studied the fossils from the limestones and have found the following horizons in place: Upper Black River, Decorah, Galena, and Lower Richmond. Horizons found but not definitely in place are Upper Richmond, Niagaran, and Mid-Devonian.

Glacial Deposits

The only other formations found are the Pleistocene glacial deposits of clay, sand, and gravel which cover most of the area. Their investigation and description is not within the scope of this paper.

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16 Opt. Cit.

GEOLOGIC STRUCTURE

Introduction

In this discussion, the detailed structure of the individual areas is considered first. These descriptions are based on observation, and have little inferred material. In the discussions on probable geologic structure, these individual areas and some additional information have been used to arrive at a hypothesis of the general structure of the area investigated. At the end of this section a discussion on the relations of the Freda and Jacobsville sandstones is presented because it is thought that certain information obtained from the area has a direct bearing on this problem.

Silver Mountain

The details of the structure of Silver Mountain are shown on Map No. 2. The basalt flows here dip at about 15° to the northwest and strike about N20°E.

There are two sets of shear joints which show rough agreement over the square mile or so of outcrop. These two sets are about N70°E dipping 80° to the south, and N30°W dipping about vertical. Sufficient evidence is not available to permit a stress interpretation of these fractures. However, it is certain that they were not the result of cooling, for they often cut through several flows.

At least two faults are present. One can be observed at the Silver Mountain Adit. It follows up along a small valley to the other side of the mountain with a strike of about S85°W and a dip of about 60° to the north. The movement was appreciable, for the sides of the adit are much slickensided and fault gouge zones up to a foot in width are to be seen in the roof of the adit. Fault breccia consisting of rounded fragments up to eight inches in diameter (coated with talc) are not uncommon in the gouge. Slickensides indicate approximately dip slip movement, but which side moved up is not known.

The other fault can be observed at a prospect pit near the northeast end of the mountain. It also can be traced across the mountain by a small, debris-filled ravine which is a surface manifestation of the fault. It strikes in a N45°W direction and has a dip of about 80° to the north. The fault zone is up to about three feet wide and is similar to the one previously described. The slickensides indicate that the south side moved up and to the west along a line on the fault surface which, when projected to a vertical plane, dips 30° to the east.

There may be a fault in the valley flanking the southeast side of the main part of Silver Mountain, as well as the west side, but no positive evidence of this fact could be found other than geomorphic expression.

A distinct magnetic anomoly on the northwest side of the mountain is interesting, because the mountain itself causes little magnetic deviation. The anomoly causes a deviation up to about 10° and indicates a change in rock type, possibly the occurrence of augitic basalts in which magnetite has not been appreciably altered.

Sturgeon Falls

Map No. 3 shows the details of the structure at the Sturgeon Falls. The most important structural feature is the unconformity between the lava flows and the Jacobsville sandstone. The old erosion surface of the basalt shows a rugged topography; very steep hills well over 40 feet in height are discernible. From lack of outcrops of basalt at lower elevations downstream, it is certain that the order of relief on this old surface was at least 100 feet, and probably much more. The surface of the basalt is weathered for a few feet below the contact with the sandstone. In several places, the sandstone has been deposited in surface cracks of the basalt. Boulders of weathered basalt are occasionally found in the lower parts of the sandstone. The flows dip about 10° to the northwest while the sandstone is horizontal, except for initial dips along the flanks of old basalt hills. The contact indicates rapid erosion followed by fairly sudden submergence, for the ancient basalt surface is rugged.

A deformation period prior to the Jacobsville is indicated at Sturgeon Falls by the unconformity, and also by the presence of shears in the basalt containing several inches of fault gouge. These shears do not cut the sandstone. The magnitude of this deformation cannot be determined.

Filling the shears, and also the fractures and vesicles, are minerals previously described. These fillings are found in the basalt, but not in the sandstone. At the upper surface of the basalt the veins are weathered along with the basalt. Furthermore, the basalt has suffered hydrothermal activity, whereas the sandstone has not. Therefore, a period of hydrothermal activity preceded the deposition of the Jacobsville sandstone. Whether or not the mineralization corresponds to the native copper mineralization to the west is not definitely known.

Sandstone East of Pelkie

Map No. 1 shows the details of the structure near Pelkie. Sandstone about a mile west of Pelkie has steep dips (up to 70°), but the cross bedding proves that it is not overturned. On the south line of section 17 the dips are about 60° and the strike is about N45°E. One third of a mile to the north there is a dip of about 35° to the east with a strike of about N30°W. On the north line of the section a dip of 45° to the west with a strike of about N30°W is to be found.

Whether all of the sandstone at this location is Jacobsville, or whether it is sandstone corresponding to the Freda sandstone of the region several miles to the west is not certain. It is probably Jacobsville because of the proximity of Ordovician limestone at Sherman Hill, and because the lithologic character is identical with the Jacobsville. At any rate, the structures indicate considerable deformation of the rocks at this point.

Sherman Hill

The details of the structure of Sherman Hill are shown on map No. 4. As the section shows, the limestone beds have dips up to about 30°. Whether the synclinal structure is to be regarded as due to faulting or folding is not absolutely known, but faulting is favored because: (1) minor faulting is common in the limestone, and (2) at no place can the beds be observed to bend.

Limestone Mountain

The structural details of Limestone Mountain are shown on Map No. 5. Limestone Mountain is of complicated structure in detail, but in general is a syncline with a northerly strike and a shallow plunge toward the north.

As mentioned earlier, there may be an unconformity between the St. Peters(?) sandstone and the overlying limestones, but this cannot be definitely established.

The largest fault is the one which separates Big Limestone Mountain from Little Limestone Mountain. This fault has an easterly strike, and displaces the sandstone-limestone contact so that a minimum movement of about 150 feet must have taken place, and probably much more. The exact direction of movement is not known. As can be seen on the map, many other faults are visible, and since faults in this area are usually characterized by filled valleys, it is likely that more are present.

Again, it is not possible to be sure whether faulting or folding has been the most important factor in creating the structure, but for the same reasons as at Sherman Hill, faulting seems the more plausible.

Miscellaneous Areas

As shown on Map No. 1, the remaining areas of outcrop consist of Jacobsville sandstone with low angles of dip, except for the dips along the north side of section 27 about two miles west of Limestone Mountain which are up to about 30°, and they strike approximately N45°E.

General Structure

In obtaining the general geologic structure from the individual outcrops in the area, the evidence is so scanty that it is possible to deduce only generalizations.

The general structure is shown on Map No. 1. The structure consists of a series of basalt flows striking northeast and dipping at an angle of about 15° to the northwest. These basalts have been subjected to faulting, and mineralization of indeterminable magnitude, before being eroded and submerged. Upon submergence, sandstone (the Jacobsville) was deposited to a depth of over a thousand feet, and then Ordovician, and later sediments were deposited upon the Jacobsville sandstone. At some later time, after the Devonian, a period of deformation took place which caused faulting and perhaps folding.

During this deformation the areas occupied by Limestone Mountain and Sherman Hill were depressed, and were thus protected from erosion. The area in the vicinity of Silver Mountain and Sturgeon Falls was sufficiently elevated to bring the older lava flows to the surface. Thus it becomes apparent that either a fold or a fault must lie between these two areas. Now in section 17, just to the west of Pelkie, the beds of sandstone have steep, variable dips and are much fractured. In general, they dip to the west, which could be explained either by folding or faulting. However, faulting seems the more reasonable explanation becasue: (1) with rocks like basalts at no great distance beneath, a sharp fold, such as the steep dips west of Pelkie would necessitate, seems unlikely on account of the brittle nature of basalt; (2) the sandstone at most points in the area has flat dips, and this seems unlikely if much folding took place; (3) there is a magnetic anomoly one mile south of Pelkie, and if this is considered as due to the proximity of basalt flows, the folding must have been very sharp; (4) as mentioned, the sandstone west of Pelkie is much fractured and has variable dips; and (5) faulting is known to occur in nearby areas at Limestone Mountain and Sherman Hill.

Therefore it is strongly suspected that a fault lies between the area enclosing Limestone Mountain and Sherman Hill and the area enclosing Sturgeon Falls and Silver Mountain. Further, the displacement must have been considerable, for the thickness of Jacobsville sandstone is over a thousand feet.

The only position for such a fault which is compatible with both the geomorphic and geologic facts is the general position shown on Map No. 1. Not only does it fit the rather striking trend of the rivers and the prominent ridges in the area investigated, but it is also in harmony with similar features for many miles to the north and east. In addition, the position is in agreement with the general trend of the Keweenaw fault. It must be emphasized that this fault is based upon indirect evidence. Its position as shown on the map is, at best, only approximate.

The Problem of the Freda and Jacobsville or Eastern Sandstones

For a comprehensive review of the problem, the work done, and the ideas set forth prior to 1885, the reader is referred to U.S.G.S. Bulletin No. 23 by T. C. Chamberlain and R. D. Irving. Their conclusions are set forth in the figures on page 34 of the present paper.

In 1916 A. C. Lane[17] proposed a somewhat similar though more complicated hypothesis which is summarized by the figures on page 35.

In 1929, U.S.G.S. Prof. Paper No. 144, pp. 50-53, B. S. Butler, W. S. Burbank, et al discussed the problem and set forth two possibilities; the one summarized by the sketches on page 36, and the other summarized by the sketches on page 37. The former one was held unlikely, and the latter one was favored.

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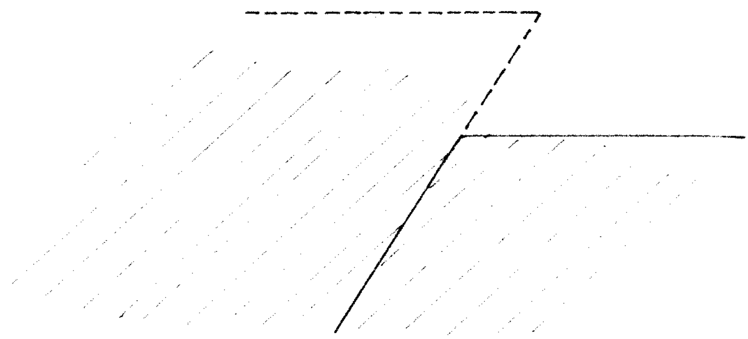
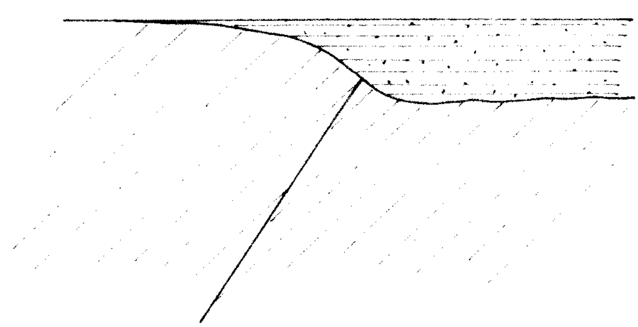
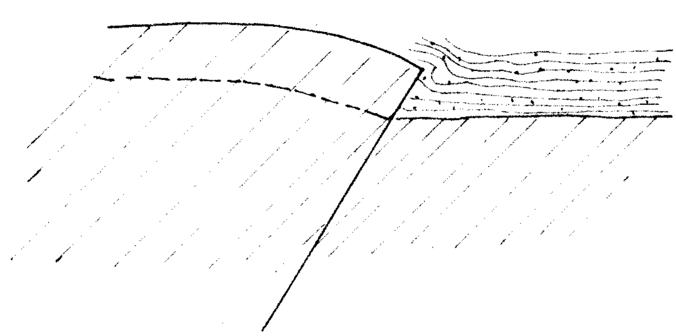
[17] Lane, A. C.: Keweenaw Fault; Geol. Soc. of America Bulletin, Vol. 27, pp. 93-100, 1916.



Primitive Keweenaw fault

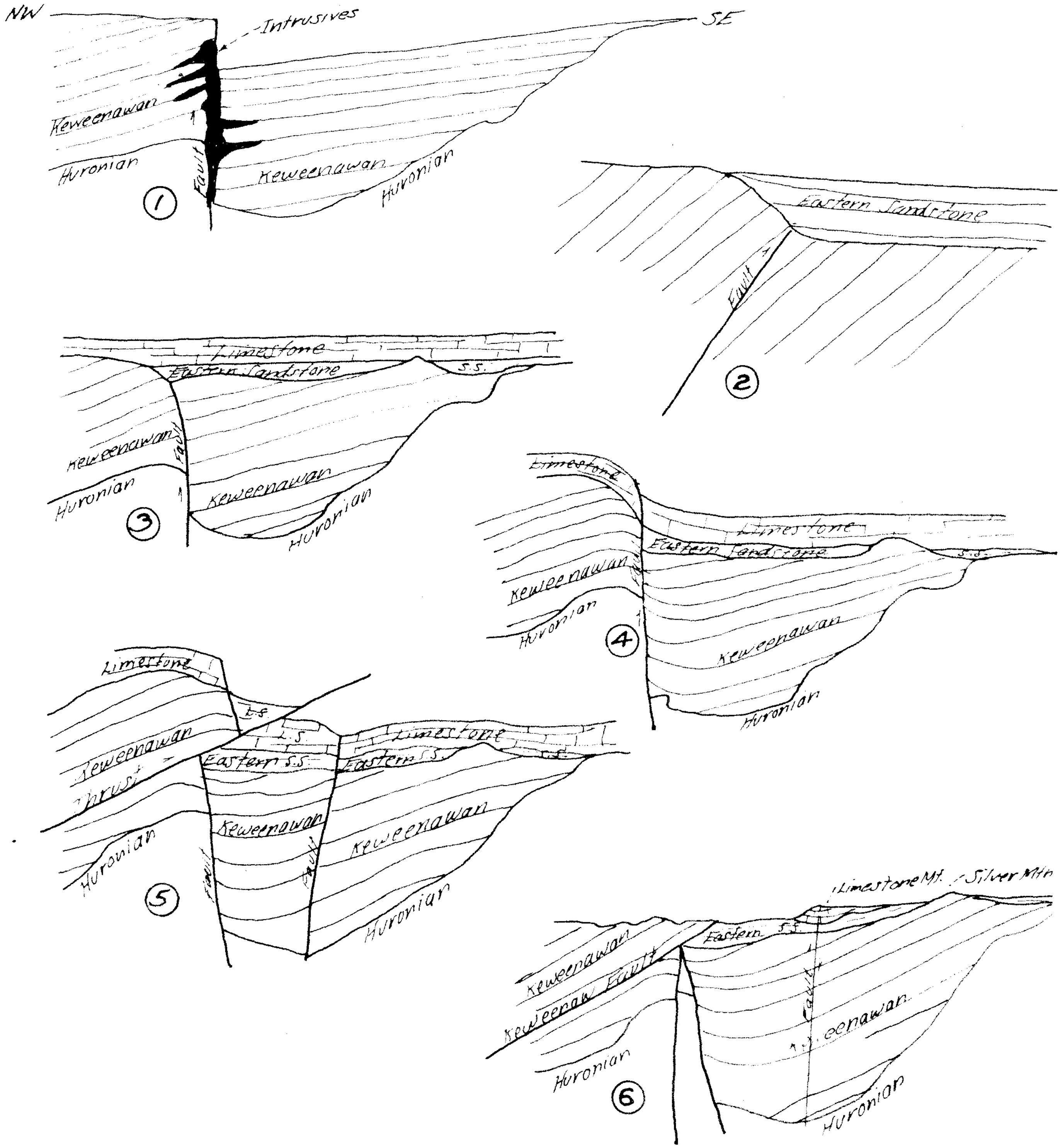


Keweenaw fault after deposition of Eastern Sandstone and before secondary faulting

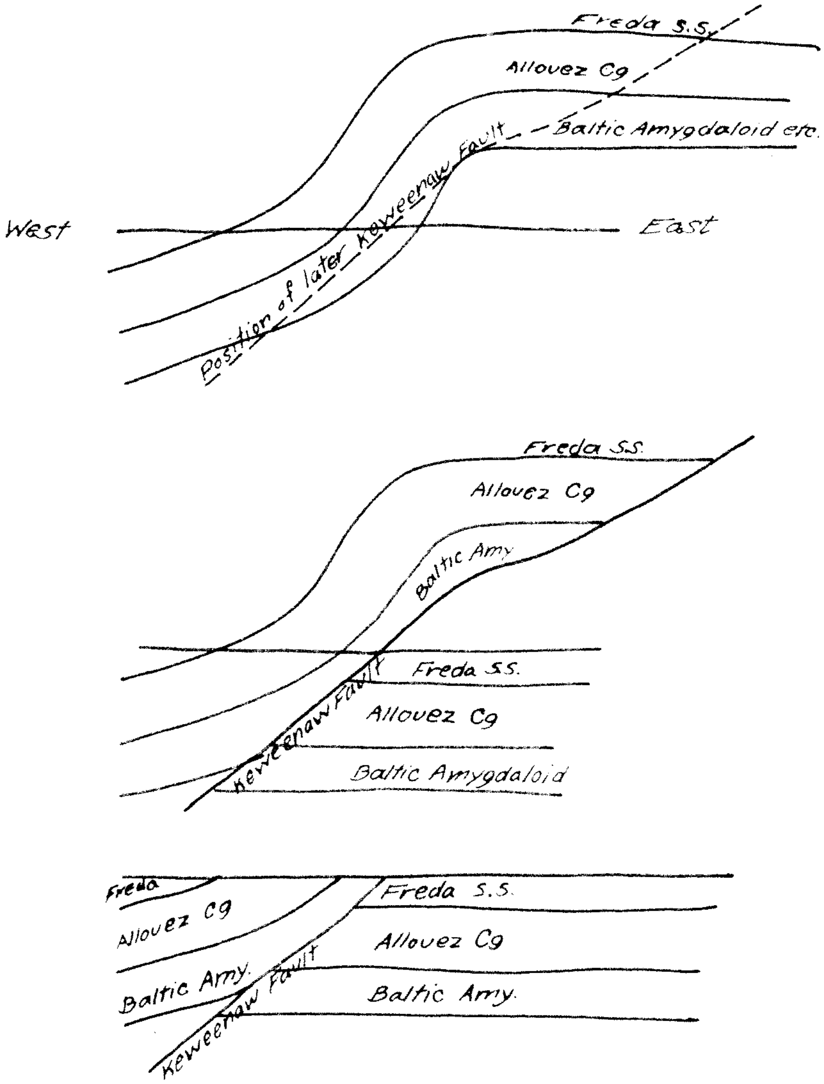


Keweenaw fault after secondary faulting

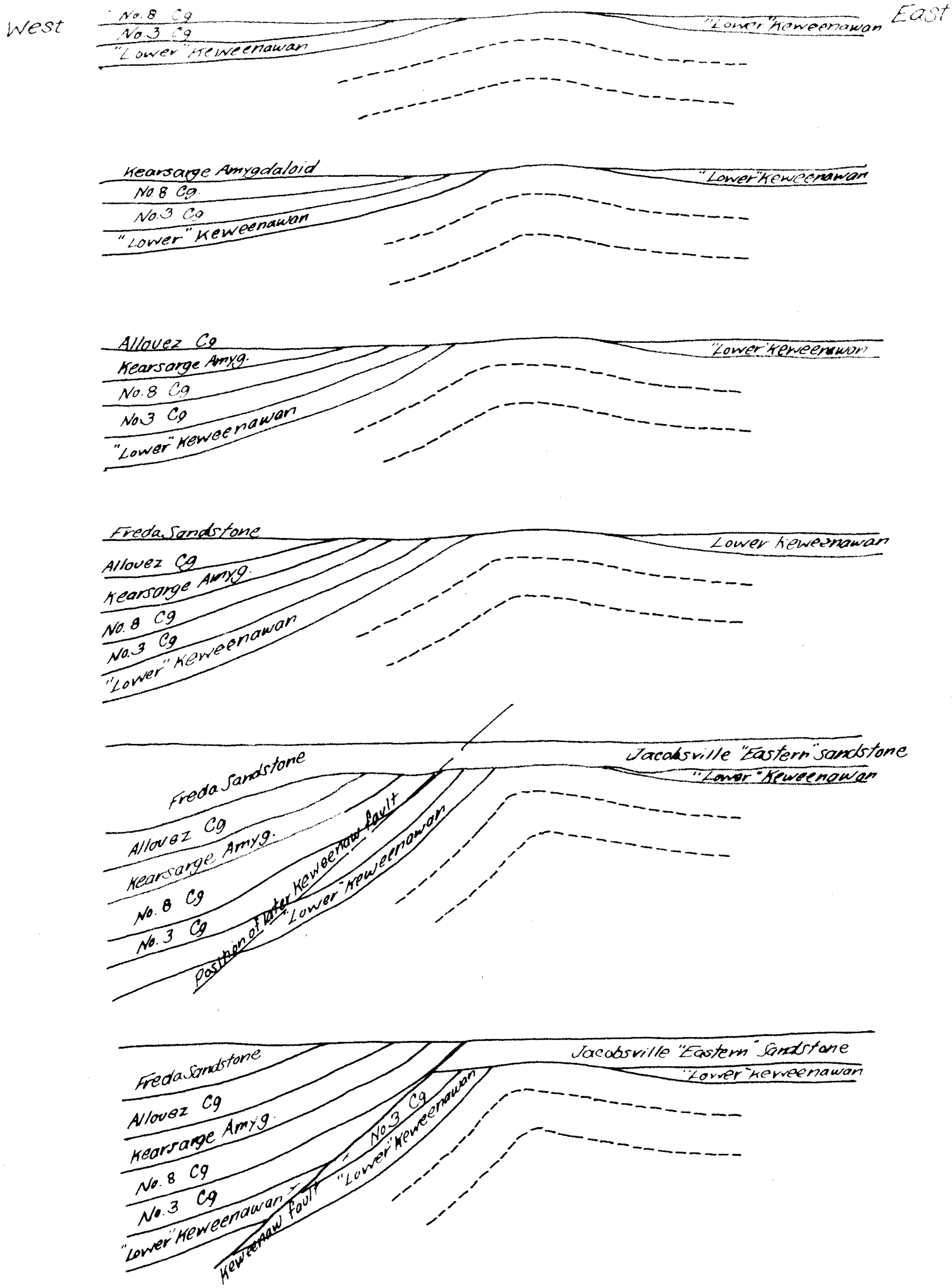
Development of Keweenaw fault and relation of Eastern sandstone after Irving, R.D. and Chamberlain, T.C. in U.S.G.S. Bull. No. 23, 1885



Generalized and simplified northwest - southeast sections after A.C. Lane, The Keweenaw Fault. G.S.A. Bull., vol. 27, p. 93-10 1916. These sections show sequence of events which are a possible explanation of the relations of beds and development of the Keweenaw fault.



West-East, St. Louis section modified after U.S.G.S. Prof. Paper 144 showing possible relations of Freda and Eastern sandstones and development of the Keweenaw Fault. Very much simplified.



West-East section after U.S.G.S. Prof. Paper 144 showing possible development of the Keweenaw fault and relations of beds upon the assumption that folding was earlier than deposition of the Jacobsville sandstone. Much simplified.

There are several basically important facts which must be considered before attempting to arrive at a conclusion of this problem. These are: (1) The Jacobsville sandstone is separated from the basalt flows of the Keweenawan by a regional unconformity. Not only can this unconformity be observed at Sturgeon Falls, but also in the St. Croix River region of Northern Wisconsin.[18] This proves that the unconformity was not of a local nature, but extended for a minimum distance of over 100 miles. (2) The Freda sandstone is, as far as is known, conformable upon the Keweenawan flows, conglomerates, etc. (3) Major deformation took place later than Lower Paleozoic time. (4) The Keweenaw fault is a thrust fault. (5) The Keweenaw fault is traceable for over 100 miles. At the northeast end it is lost beneath Lake Superior, and towards the southwest it is not directly traceable. (6) The Keweenaw fault has a wide zone of disturbance. (7) The thickness of the Keweenawan strata is very great, even if allowance is made for possible duplication by faulting.

On pages 39 and 40 are shown sketches giving a rough idea of what is believed to be the most reasonable answer to the problem.

The evidence for tilting, folding, mineralization, and erosion prior to deposition of the Jacobsville has been dwelt upon previously. The regional extent of the unconformity precludes attempts to explain the problem by having erosion to the east of the present position of the Keweenaw fault, and simultaneous deposition of several thousand feet of Freda sandstone a few miles to the west with conformable relations to the underlying rocks.

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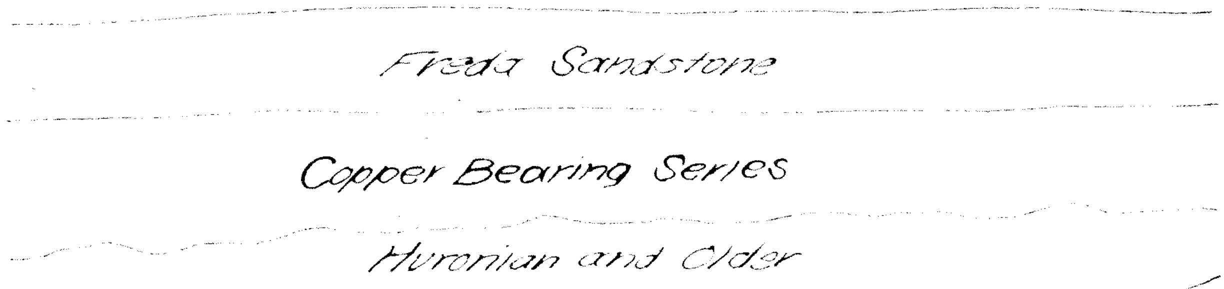
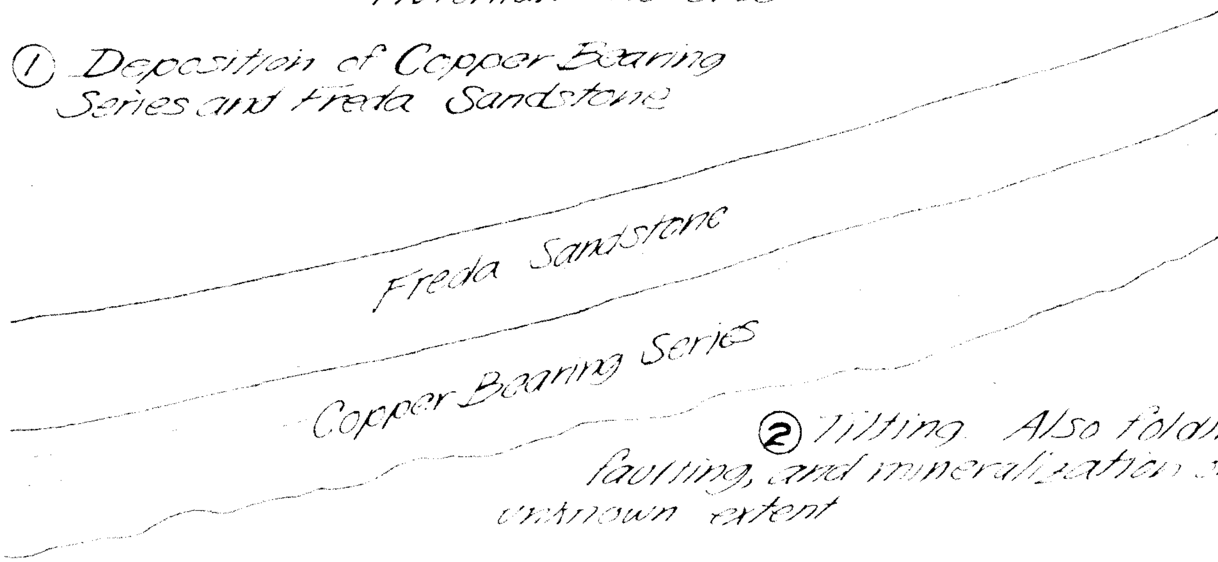
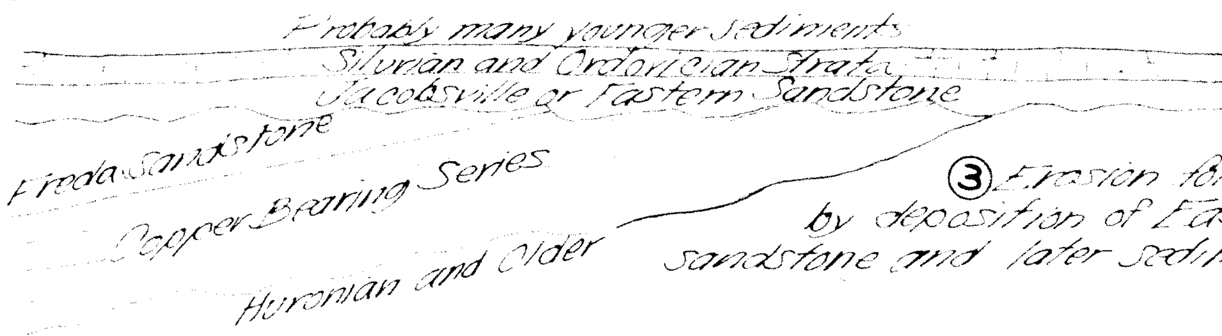
[18] Chamberlain, T. C.: Geology of the Upper St. Croix District; Geology of Wisconsin, Vol. 3, pp. 263-428, 1880.



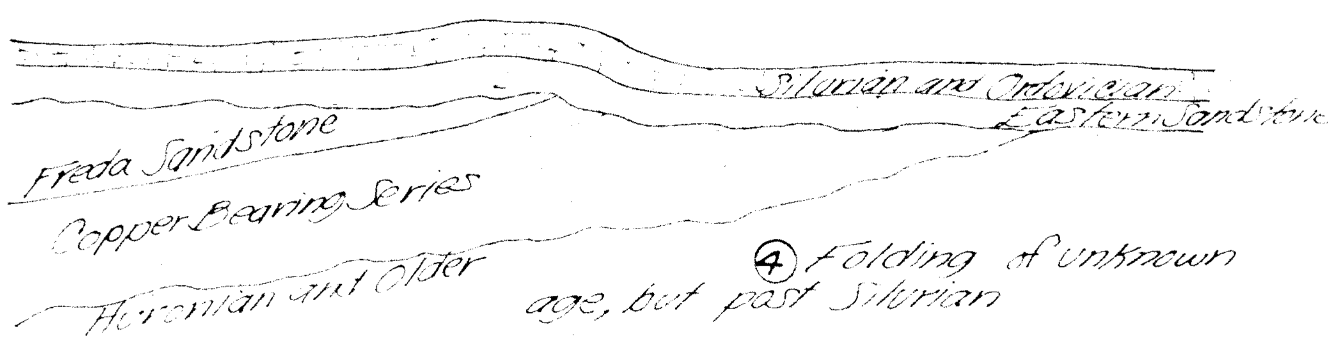
(1) Deposition of Copper Bearing Series and Freda Sandstone



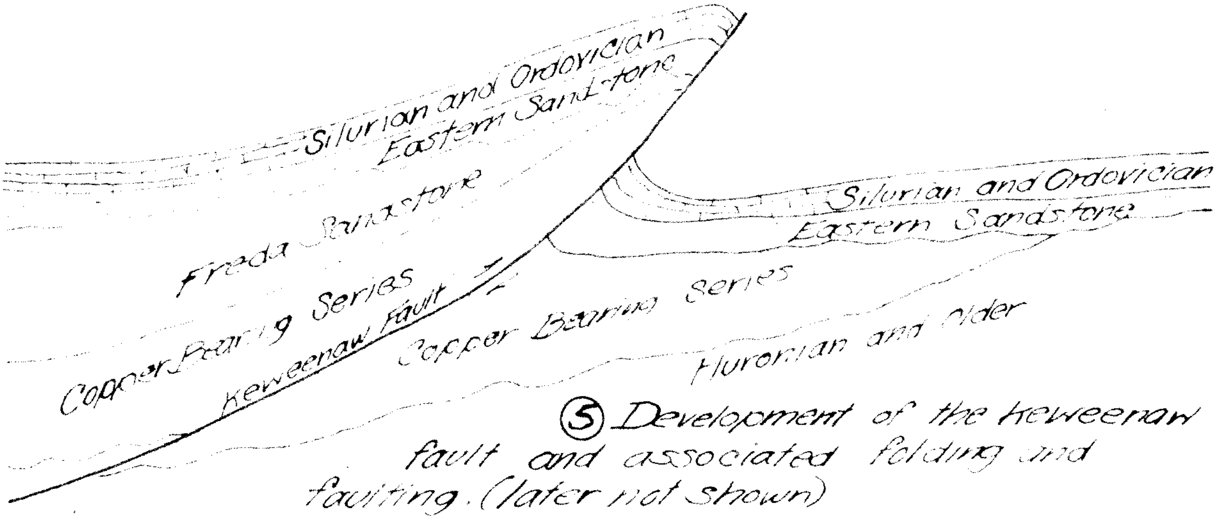
(2) Tilting. Also folding, faulting, and mineralization of unknown extent



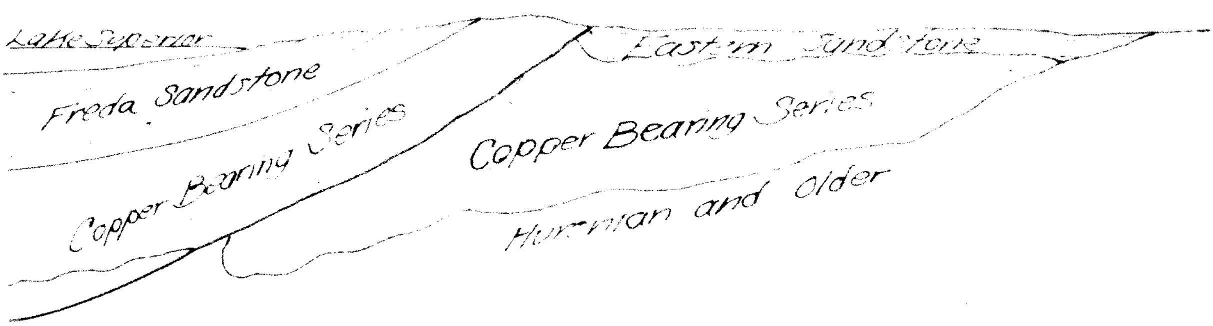
(3) Erosion followed by deposition of Eastern sandstone and later sediments



(4) Folding of unknown age, but past Silurian



(5) Development of the Keweenaw fault and associated folding and faulting. (later not shown)



(6) Erosion

Sketch sections, which are hypothetical and very much simplified, to show possible development of the Keweenaw fault and the relations of the Freda and Eastern Sandstones.

The relatively straight nature of the Keweenaw fault and the lack of change in coarseness of the Jacobsville at different distances from the fault are strong evidence against having the sandstone deposited along a fault scarp. Thus if the sandstone were deposited against a fault scarp, it should be coarser near the fault than in places remote from the fault. This is not found to be true. Also, the material in the sandstone is derived in substantial part from sources other than basalt flows which would have made up such a scarp.

A great many thrust faults began as folds, but the direction of thrust is ordinarily towards the direction in which the axial plane leans. Any attempt to explain the faulting as the result of a monocline which flanked the south edge of the Lake Superior basin must contend with this objection. Thus in the figures on pages 36 and 37 it would be much more reasonable to have a thrust fault develop with opposite dip and direction of thrust than that shown.

The chief objection to the author's conception of the problem is that the movement required would have to be in the order of five miles (assuming no duplication of strata by thrust faulting, which would give a thicker apparent amount of Keweenawan deposits and consequently would necessitate a maximum displacement). However, as previously mentioned, the Keweenaw fault zone is characterized by much deformation; in fact, it is so much shattered that little diamond drilling has been done in it because of the expense involved due to the intense brecciation. A movement of five miles is not extraordinary for thrust faults, and the great distance seems to be a less important objection than the objections encountered by other explanations.

Age of the Keweenaw Fault

As to the age of the Keweenaw fault, it is felt that the evidence points to post Lower Paleozoic age.

There is no evidence of an unconformity between the Jacobsville sandstone and the Lower Paleozoic rocks, and since the fault is certainly later than the Jacobsville, it must likewise be later than Lower Paleozoic. In addition, deformation of the Lower Paleozoic strata is appreciable enough to be the result of the same deformation which caused the Keweenaw fault.

No earthquakes have occurred along the fault, and the scarp can easily be explained as a fault line scarp. A great thickness of material must have been eroded since the beginning of the deformation, which rules out initiation of movement at a recent date. Therefore the fault is not recent.

GEOLOGIC HISTORY

The sketches on pages 39 and 40 summarize the history. After the period of erosion which followed the Huronian, the Copper Bearing Series of flows and sediments were deposited. Then the Freda sandstone was laid down conformably upon these rocks. This was followed by deformation of unknown magnitude, mineralization, and erosion. The Jacobsville sandstone was then deposited upon the old erosion surface, and this was followed by deposition of Ordovician, Silurian, and probably younger sediments. A period of folding and faulting followed at some date later than the Silurian, and probably later than the Devonian. This period of deformation was responsible for the Keweenaw fault, the deformation at Limestone Mountain and Sherman Hill, and the fault near Pelkie. Following this event, erosion continued. In Pleistocene time the country was glaciated. In general, this glaciation removed material from the higher portions of land and deposited material in the lower portions. At present, erosion is active.

ECONOMIC POSSIBILITIES

Metals

The possibilities of finding commercial metal deposits in the area to the southeast of the Keweenaw fault are not within the scope of this thesis.

Non Metals

Agricultural Limestone.

The following analyses are of limestone from Sherman Hill and Limestone Mountain:

Location	Analyst	Composition in Per Cent				
		SiO_2	CaO	$CaCO_3$	MgO	$MgCO_3$
Sherman Hill	M.C.M.&T.[19]	4.15	28.33	50.66	19.3	40.4
Sherman Hill	M.C.M.&T.	2.55	28.9	51.7	19.9	41.6
Big Limestone Mtn.	M.C.M.&T.	2.83	29.4	52.4	20.7	43.4
Big Limestone Mtn.	M.C.M.&T.	4.55	27.43	48.9	18.4	38.6
Little Limestone Mtn.	Tyson[20]			61.5		37.4
Limestone Mtn.	Foster and Whitney[21]					45

19 K. Spiroff in letter to Houghton County Agricultural Agent, 1938.

20 Tyson, J.: Michigan State College Extension Service in a letter to Houghton County Agricultural Agent, 1938.

21 Opt. Cit., p. 117.

The limestone is suitable for agricultural purposes, having a neutralizing equivalent of about 105% based on calcium carbonate.[22] Field tests have been conducted by the Michigan State College Extension Service at the Waisanen farm near Little Limestone Mountain and the results were satisfactory for sweetening the soil.

The problem of utilization is thus an economic one. There are about 500 farms within 15 miles of the limestone which average about 35 acres of cleared, crop land each. Assuming that 20 acres per farm would be limed, the potential acreage is about 10,000. The normal application is three tons of limestone per acre every 15 years. Very little land is now limed, so there is a potential immediate market of about 30,000 tons providing the farmers could be induced to lime their land.

Conditions are good for quarrying the stone. Good roads, ample labor, and electric power are available near the limestone. There is little overburden, and the topography is sufficient to permit gravity feed in a crushing and screening plant. If a contract to supply crushed rock for road metal could be secured in conjunction with the production of agricultural limestone, the possibility of economical utilization would be still better.

Crushed Rock.

The scarcity of good gravels in the Alston district lends importance to the deposits suitable for crushed rock. There are four outcrops in the district containing suitable material. These are located at Silver Mountain, Sturgeon Falls, Limestone Mountain, and Sherman Hill.

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[22] Opt. Cit.

The Silver Mountain rock is of unlimited tonnage and near a fair road; but there is no electric power nearby and the rock is very tough, which would make crushing expensive.

The basalt at Sturgeon Falls is suitable and is not as tough; but the tonnage available by economical mining methods is only about 150,000 tons, there is no electric power for several miles, and it is half a mile over hilly, roadless terrain to a poor road.

The materials at Limestone Mountain and Sherman Hill afford the best sources. Tonnages are practically unlimited, good roads and electric power come within 500 feet, and crushing costs would be lower because of the softer rock. However, the rock is hard enough to make satisfactory road metal. The possibility of the simultaneous quarrying of agricultural lime and of road metal has been discussed previously.

Dimension Stone.

There is no suitable dimension stone in the area except for purposes of local use in rough masonry or for flagstones.

The rock at Silver Mountain braks into large, tough, dense blocks which would be suitable for harbor rip rap for which there is a good local demand. However, such a use is out of the question because of freight charges.

Glass Sand.

The St. Peters(?) sandstone at Limestone Mountain might be suitable for glass sand. It appears to be pure, but no analyses were made. The available tonnage is a minimum of 60,000 tons by open cut methods, with little stripping. Much more is available with moderate stripping. It is a twelve mile truck haul to rail and lake transportation. Under present conditions the sand, even if it is of good quality, could not compete with other sources of glass sand used by present factories.

Oil.

Rumors of oil in the countryside, due to finding oil films resulting from decomposition of organic materials on swamp water, are not uncommon. Because rocks of suitable type and structure are absent, there are no oil possibilities.