GEOLOGICAL SURVEY OF MICHIGAN

LUCIUS L. HUBBARD, STATE GEOLOGIST

UPPER PENINSULA

1893-1897

VOL. VI

PART I. ISLE ROYALE

ALFRED C. LANE

PART II. KEWEENAW POINT

WITH PARTICULAR REFERENCE TO

THE FELSITES AND THEIR ASSOCIATED ROCKS

LUCIUS L. HUBBARD

THE CRYSTALLIZATION OF THE CALCITE FROM THE COPPER MINES OF LAKE SUPERIOR

CHARLES PALACHE

PUBLISHED BY AUTHORITY OF THE LAWS OF

MICHIGAN

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LANSING

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OFFICE OF THE STATE GEOLOGICAL SURVEY,
Houghton, Michigan, December 15, 1896.

To the Honorable, the Board of Geological Survey of Michigan:

GENTLEMEN—Herewith I transmit Reports, with maps and illustrations, covering work done by the State Geological Survey in the Upper Peninsula, principally during the years 1895 and 1896.

With great respect, I am your obedient servant,

LUCIUS L. HUBBARD,
State Geologist.

GEOLOGICAL SURVEY OF MICHIGAN

VOL. VI

PART I

GEOLOGICAL REPORT

ON

ISLE ROYALE

MICHIGAN

BY

ALFRED C. LANE
Assistant State Geologist

ACCOMPANIED BY SIXTEEN PLATES AND TWENTY-NINE FIGURES
INCLUDING MAP IN COVER

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ERRATA

PART I

Page 5, 19th line from the bottom, for "McCullough" read "McCulloch."

Page 18, the first paragraph of the foot note belongs properly after the first paragraph of the text.

Page 19, 16th line, for "47" read "22."

Page 21, 11th line, for "dicovered" read "discovered."

Page 26, 16th line, for "Stockley" read "Stockly."

Page 41, 4th line, for "fault" read "faults."

Page 42, 3d line, before "mere" insert "a."

Page 74, 16th and 23d lines, for "tufa" read "tuff."

Page 74, 2d line from the bottom, for "Richey" read "Richie."

Page 94, 20th line, for "tufa" read "tuff."

Page 104, 3d line, for "tufa" read "tuff."

Page 105, table, for "Agate River" read "Agate Bay."

Page 105, over the columns headed "Conglomerate numbers" and "Distances" should be inserted "Portage Lake District."

Page 132, 9th line in explanation of figure 17, for "bottom" read "margin."

Page 134, 5th line in explanation of figure 18, for "130" read "124."

Page 149, 2d line from the bottom, for "increases" read "increase."

Page 168, 8th line from the bottom, *dele* "14748."

Page 185, 3d line, for "flow" read "floe."

CHAPTER I

HISTORICAL INTRODUCTION

§ 1. Prehistoric Mining.

The progress of knowledge is like the growth of a coral reef; each generation builds upon that which has been left behind by those who have gone before. It is, therefore, fit that this account of the geology of Isle Royale, a part of Michigan hitherto practically untouched by the State Geological Survey, should begin by a review of the records of what others* have in the past done toward its geological development.

The first mining upon Isle Royale was long before the arrival of the white man. Like other parts of the copper region about Lake Superior, Isle Royale was visited by tribes contemporary with the mound builders, and sheets of native copper were worried out of the rocks in which they were found enclosed. The hammers used in this work were hard pebbles. Specimens of these hammers found upon Isle Royale were not grooved for a withe, which might be twisted around them for a handle. In this respect they differ from those found on the south shore of Lake Superior. Such is the testimony of W. W. Stockly, Jacob Houghton, Dr. Simonson, Capt. Wm. Uren, B. Livermore, S. W. Hill and others, who have spent much time on the island, and their statements

*Jackson, Executive Documents, No. 1, 1849, First Session, Thirty-first Congress, p. 371. Hereafter cited as "J."

Foster and Whitney, Report on the Geology and Topography of a portion of the Lake Superior Land District in the State of Michigan, 1st Sess. 31st Con., Ex. Doc. No. 69, 1850, Pt. I, p. 162. Hereafter cited as "F. & W."

Gillman, Henry, "Ancient Works at Isle Royale, Michigan." Appleton's Journal, Aug. 9th, 1873, X, p. 173, "Mound-Builders and Platycnemism in Michigan." Smithsonian Report, 1873-74, p. 364, 1st Sess. 43rd Con. "The Ancient Man of the Great Lakes," Proceedings of American Association for Advancement of Science, 1875, B., p. 316-330.

Winchell, N. H., 9th Annual Report Minn. Geological Survey, 1880, p. 162; 10th Annual Report Minn. Geological Survey, 1881, pp. 48-54; 14th Annual Report Minn. Geological Survey, 1885, p. 322; Popular Science Monthly, Sept., 1881, XIX, V, p. 601.

Swineford, A. P., Annual Report of Commissioner of Mineral Statistics, Michigan, 1884, p. 8.

Sherzer, Will H., "Platycnemic Man in New York," Report of State Geologist, New York, 1894, p. 663.

are confirmed by my own observation, as far as it goes. Winchell, however, says that occasionally and exceptionally one is found grooved, and figures one found on Isle Royale which belonged to Dr. Gailey. On Isle Royale they must certainly have been most exceptional. Swineford also mentions grooved hammers from Isle Royale.

It is probable, from the abundance of charcoal and half burned sticks that were found near the "Indian pits," that fire setting was practiced by these miners, that is that the rock adjacent to the copper was caused to crumble by dashing cold water on it suddenly, after having heated it very hot. It was then shoveled away or farther pounded with the stone mauls above spoken of. Then the copper in its turn was pounded off and fashioned into various instruments, axes, knives, arrow- and spear-heads, etc. These early workings were exceptionally abundant about the Minong mine and will be farther referred to when we come to the history of that mine (§ 3), but they also occur at the extreme northeast of the island on Blake Point,* and on a little island off Washington Island at the extreme southwest end of the Isle Royale archipelago, for the main island is fringed with more than a hundred and fifty smaller islets, and innumerable minor rocks.

These workings are prehistoric. By this we mean, that while they may well have been contemporary with Greek or Asiatic civilization, they were not being worked by the aborigines when the first hardy Jesuit missionaries penetrated into these regions, but were then already covered with a growth of forest.† Gillman thinks that they may have been abandoned seven or eight hundred years ago, judging from the size of the stumps of decayed trees. The works, however, were, as Winchell says, later than the glacial period, and later than the period of lakes much larger than the present, that immediately followed it, as they come down to within thirty feet of the present water's edge, or, according to Gillman, to within less than eighteen feet of it. Now Isle Royale, from one end to the other, shows evidence of a recent emergence from Lake Superior. This evidence consists in raised beaches, over which barely more than lichens have grown, in cascades falling into the lake, and in other marks. Hence no very great age can be assigned to the

*F. and W., l. c., p. 162.

†Henry Gillman, Smithsonian Report, 1873-1874, p. 386.

end of these workings. Winchell thinks that the miners and mound builders were the aborigines found here by the first discoverers, in other words, the Indians, and quotes a large number of references to the possession of copper by the Indians, and their use of it and knowledge where it occurred. So, also, Foster and Whitney quote from Father Dablon, in a "Relation" for 1669-1670, an account of " Menong," celebrated for its copper, and there is also an account of gathering copper there. Pierre Boucher in 1640 speaks of a mine of copper on an island in Lake Superior (Swineford, *loc. cit.*, p. 8). If we agree with Winchell that the miners were the Indians, we must suppose that the contact with European civilization, and the introduction of iron, made the early and laborious copper mining unprofitable, and that these early copper mines shut down for the same economic reasons which shut down mines at present. A very curious fact is reported, that none of the bones of the ancient miners have been found (Swineford, *loc. cit.*, p. 9), though the fish scales of their noonday lunches, their wooden bowls and implements, and even a bit of knotted rawhide have been preserved. Can we imagine that mining of copper was a prerogative of some class of medicine men who visited the island only at intervals? The possession of copper implements must have been at one time a coveted privilege. The question of the true nature of the earliest copper miners is, however, only a branch of the general question as to the character of the mound builders, which is likely to be settled by researches elsewhere, and is complicated with various considerations, as to the racial value of platycnemism, etc., that would carry us too far from our subject. Therefore, leaving the above references with those who desire to pursue the subject farther, we pass on to the historic epoch.

§ 2. Earliest Historic Explorations, 1844-1855.

With the ending of the copper mining just described Isle Royale seems to have been abandoned, except by occasional trappers and fishermen,* though some report of its mineral wealth is said to have reached Franklin, perhaps through the Jesuit "Relations" and through his French friends, and to have led him in making the treaty with Great Britain which defined the limits of the United States, to curve the boundary line slightly so as to

*The Hudson's Bay Co. had a station on the island, Sec. 24, T. 64, R. 37, and the American Fur Co. one at Sec. 35, T. 64, R. 37; (J. 427), and near Card Point and perhaps on Fish sland, Sec. 35, T. 66, R. 34; Hulbert's map.

take Isle Royale and separate it from the Canadian shore, nearest to which it lies. The earliest explorations for copper were on the other side of the lake, and I have no record of mining or geological exploration on the island until after its cession with other lands, by the Chippewas in 1843.* Soon after this, prospectors appeared on the island, among them, in 1845, the veteran geologist, James Hall, who gave Chippewa Harbor its name and who was nearly caught on the island by the approach of winter, and crossed the lake in a small, open boat.† In 1846 explorations began and by 1847 the island presented perhaps as lively a scene as ever in its history. The U. S. Linear Survey was being pushed by William Ives and his assistants. I cannot let Ives's name go by without especial note as to the fine character of the work he did. Working far from civilization, through an extremely rough and densely wooded country, with an enormous amount of lake meandering, as will be obvious from the map, he turned out work far surpassing that customary on the Linear Survey, which has never been properly appreciated because never properly worked up, the map in this report being the first in which his notes have been computed and platted. This map is the work of Mr. W. W. Stockly. In the same year the U. S. Geological Surveyor, C. T. Jackson, made his first visit to the island with Messrs. Ransom, Peabody, Foster, etc. The margin of the island was then dotted with explorations, which within ten years were all closed. Let us review them briefly, beginning at the southwest end of the island.

On Washington Island (referred to by Foster and Whitney and others, as Phelps Island), the Ohio and Dead River Company had Isaac Hewitt and Mr. Wright, an English miner, at work (J., p. 426) on three veins of only an inch wide, composed of datolite, compact feldspar and prehnite, containing a little native copper. Strike N. 17° E.; dip 75° W. Compare Jackson's map. These were on the north side. By the next year, when Dickenson and McIntyre visited the region, the place seems to have been abandoned (J., p. 506). Foster and Whitney (F. & W., p. 91) also mention veins on the southeast shore (Sec. 10, T. 63, R. 39) containing calcite, prehnite and native copper, and striking S. S. E., 18 inches wide. Farther east was another vein of great power, 30 inches wide and striking

*F. and W., p. 15, and J., p. 1157.

†Private communication.

nearly north (dip 78° N. ? J., p. 770), with quartz, laumonite and prehnite, and disseminated copper, and on the S. E. ¼ of the same section another copper-bearing vein well defined, 7 inches wide.

At Huginnin (J., text, p. 425, Huganon; map, Huganin; F. and W., p. 90, Hugennin) Cove, Sec. 19, T. 64, R. 38, was an exploration of the Isle Royale and Chicago Company, soon abandoned.

Farther along the shore in Sec. 11, of the same township, was the Franklin Company (J. B. Corey, agent), working on some small veins of copper, striking north, and two of them 4 to 6 inches wide. These were also soon abandoned (J., p. 425).

On Sec. 33, T. 65, R. 37, the Siskowit Company had a location in charge of Chas. Whittlesey, the same who had charge of the Siskowit mine.* This was on some small veins and soon abandoned (J., p. 425). Passing over the veins near by, described by Jackson (p. 425), which do not seem to have been worked upon, we come to the Pittsburg and Isle Royale Company's location at Todd Harbor. This was one of the most important openings of the time, and was still worked when Koch visited it in August, 1850, and the traces of the old workings were still very plain when I visited the region in 1893. Foster (J., p. 770) also speaks of McCullough's working at the outer point of Todd Harbor. The works lie near the harbor and are in and near the lower side of that group of rocks that I propose to call the Minong trap, since it underlies the Minong mine, later to be described (p. 16). These rocks are more acid, as is shown by the less development of augite, than the flows above and below (see Chap. III), and answer well to Foster and Whitney's description of "hard greenstone with a conchoidal fracture," the clean fracture being especially characteristic at the bottom. The main location was on Sec. 12, T. 65, R. 36 (F. and W., p. 150). The first working that Jackson examined (J., p. 424) was a stockwerk without any well defined walls, thus resembling the occurrence at the Minong mine. The veinstone he says was an amygdaloid containing laumonite, calcite, datolite, and native copper, the metal occurring in pieces of a pound weight. This copper-bearing rock was 15 feet wide and in general sloped to the north.

Another vein was 7 to 8 inches wide; strike N. E. and dip to N. W. 65°. In a third place was a vein a foot wide, bearing thin sheets of copper. Strike N. 25° E., dip to N. W. 74°. As is often

*See below.

the case, the wall rock "is shivered into a shingle of slaty appearance, and is disintegrated for the width of four or five feet." This last vein is probably also given by Foster and Whitney as the lode with a strike N. 20° E., dip W. 78° (p. 150). Foster and Whitney also seem to allude, on pages 150 and 169, to another vein running north and dipping to the east. They describe two shafts, 63 and 67 feet deep, with the first adit or level 42 feet long, the second 113 feet, the third 18 feet, fifty tons of ten per cent ore raised, and twenty-four men employed. In the following summer, July, 1848, the mine was again visited by Dr. Jackson's agents, who in substance reported (J., pp. 505, 509): There were then nine men employed. Three veins were worked, two a short distance from the one (!) worked last season. After drifting on that vein some 30 feet the copper disappeared. A shaft was then sunk a short distance north of this drift, and in sinking 5 or 6 feet, a blue earth was struck filled with copper in the form of shot. This bed was 5 to 6 feet thick and below this there was a red colored rock filled with spar, but it contained no copper. Then they drifted 60 feet from the edge of the lake on a vein 2½ feet wide, with well defined walls dipping W. 70°. One sheet of copper was exposed, 8 feet long, 4 feet high and 1 to 2 inches thick.

West of this vein (No. 3) a shaft was being sunk on a small spar vein with some copper. There was still another vein east of the agent's house, which ran north (No. 4). The agent sank a shaft on this vein so near the lake that the water compelled him to abandon it, and then he went farther inland and sank a shaft, and also struck a small spar vein running east. James McIntyre (J., p. 509) gives vein No. 3 as striking N. N.E., dipping 70° W., and mentions that they are sinking a shaft from the top of the hill to strike the drift.

In August, 1850, the island was visited by the German mining engineer, Fr. C. L. Koch, who found only the Todd Harbor and the Siskowit works still in operation. He gave to the world the observations that he made on his trip, in Vol. VI, parts 1 and 2, of the "Studien des Goettingischen Vereins Bergmænnischer Freunde," 1852, and I will translate from this rare report that part which refers to Isle Royale. The map accompanying is a copy of that of Foster and Whitney, with the original misprints retained, and others added (Amyghaloid Island for Amygdaloid Island, Loke's Point for Locke's Point, etc.).

"Todd's Harbor,* Pittsburg and Isle Royale Company, on the northerly shore of the island, opposite Canada. The company has undertaken several exploratory openings here, of which one was in operation when I was there (1850), close to the lake, probably only 20 feet above the surface of Lake Superior. The wall rock consists of a close grained, crystalline, dark amygdaloid, which may be considered as a transition to a close grained or compact trap. The vein stands in this, striking from south to north, and as it appears, dips tolerably vertical. So far as the vein is yet known, it is not very wide. The vein-rock is here a compact chloritic mass, with quartz, calcite, and prehnite, which minerals occur in small druses with a tendency to crystalline form and also as complete and beautiful crystals. Beside these I also noticed associated with calcite the reddish yellow feldspathic mineral, and small but very beautiful apophyllite crystals. I also found small copper crystals here.

"The product of good stamp copper appeared to be not inconsiderable and will be made manifest as soon as the stamp mill begins work, which is in process of construction (which will take its water for motive purposes [?] or for jigs, ["Aufschlagwasser,"] from a little stream which forms a beautiful waterfall on the margin of the lake near the mine). Some barrels of the coarser masses of copper, some of them weighing several pounds apiece, were packed for shipment. The mine was manned with only a small force, and it was uncertain whether the vein was to be explored to a greater depth. It would be regrettable if the company should withdraw their capital from this locality; it deserves, at any rate, a still closer investigation." Page 201, trap contains augite and labradorite; p. 202, epidote replaces the augite and quartz the feldspar; p. 205, copper; p. 213, apophyllite at Todd Harbor (with copper crystals and prehnite); p. 217, prehnite at Todd Harbor; p. 219, epidote (thallite).

The first shaft that I saw on my visit in 1893 was nearly vertical and 30 to 40 feet deep. It was in a light green seam with a little copper in a compact, slightly mottled trap. About 100 feet northeast the openings on vein No. 3 are well marked; strike S. 25° E., dip 75° W.; and at the water's edge there is an adit connected with

*Pp. 188, 189.

the opening. This seam, and joints parallel to it, intersect a laumonite seam which is nearly parallel to the formation (strike N. 50° E., dip 54° to S.E.), without displacing it. The seam is about 300 feet from the ten foot fall mentioned by Koch, which does not come in at the lowest point of the shore, and is a significant index of the recent changes of lake level.

Continuing northeast, the next location visited by Jackson (p. 424) was that of Mathewson Miller, (J., p. 770) or, as Ives called it in his field notes, the Amygdaloid and Isle Royale Mining Company, Sec. 23, T. 66, R. 35, where the main vein had a strike to east, dip to north, was 2 feet wide, and had yielded about 30 pounds of copper. Another vein near by had a strike N. 60° E.; dip to north. This is opposite Hawk Island, and just north of the Minong mine.

On Amygdaloid Island (J., p. 423), claimed by Miller and the American Exploring Company, was a vein of little value, dip 48° to N. by E.—epidote with a little copper. Neither of these locations is again mentioned.

Of Duncan's explorations, on Secs. 27, 28, 33 and 34 of T. 67, R. 33, on Duncan Bay, about three-quarters of a mile from Monument Rock, nothing more is written (J., p. 423), unless Foster and Whitney, in their reference to the Duncan vein on Sec. 34, T. 66, R. 34, have made a slip and really refer, as I am inclined to suspect, to T. 67, R. 33 (F. and W., p. 169). They were doubtless soon given up.

Coming to Scovill Point, we find once more comparatively siliceous traps, having passed around Blake Point, which marks one end of the great range of basic lustre-mottled melaphyres, or as Foster and Whitney call them, varioloid greenstones, which form the "backbone" of the island. The more acid beds lying above correspond to those lying around the "Ashbed" on Keweenaw Point, as will be later shown, and like them are much more inclined to a fine grained texture, with basaltic jointing, and a cleaner conchoidal fracture, as mentioned by Foster and Whitney (p. 82-83). Here, on the "forefinger" (J., p. 770) of the island, Scovill Point, Jackson found Scovill (J., pp. 422, 423, 505; F. & W., pp. 83, 169, 171; both spell the name without the final e) on Sec. 35, T. 67, R. 33. The vein on which he was working was from 1 foot 3 inches to 2 feet 6 inches wide, with some lateral string veins or leaders, containing a greenish mixture of calcite, prehnite and trap, and sheets and spicules of native copper. The strike was N. 65° E., dip 68° to N. W. (J., p. 422). By the next year, when Dickenson visited it, there was but one man left, and but little had been done in the interval. Only a shallow pit was opened. A marked ravine and "fossa" are said to indicate a continuation of this vein to the southwest, according to Foster and Whitney, nearly nine miles. This may possibly be so, but the strike of the vein as given is nearly that of the formation, which dips off to the southeast at an angle of about 17°, and from my observations I should say that Scovill Point was made up of two flows of trap (J., p. 770) and that the hollow, running as Jackson says, by solar compass N. 61½° E., var. 6½° E., marked the line of contact of the two beds with associated amygdaloids.

Shaw's or Smithwick's location, the next met, was on Sec. 4 and perhaps also Sec. 3, T. 66, R. 33, directly opposite to Smithwick's Channel, about 100 rods southwest of Scovill's, along the line or vein mentioned above. The deposit there was similar to Scovill's, and contained some specks of silver. In 1848 there were three men there and the shaft was down 90 feet (J., pp. 422, 505). By 1849 (J., p. 605; F. and W., p. 171) it was down 96 feet. For 30 feet the rock was soft, the vein well developed, expanding in places to 4 feet in width, and containing considerable copper. Then a band of columnar trap was struck and penetrated 66 feet. The vein contracted to a foot in width and was nearly worthless. This columnar trap appears, according to Foster, in the point north of Scovill Point, at the water's edge, and continues in a cliff on the north side of the point, 30 to 40 feet high (J., p. 770). Mr. Shaw (F. and W., p. 171) had a similar experience on the main point, Sec. 33, T. 67, R. 33, where he sank 15 feet on a vein composed of quartz, chlorite and calcite with considerable copper (strike N. 50° E.), where on passing from a crystalline trap with feldspar to a darker trap, the vein became worthless.

On Mott Island, Jackson (J., p. 422) saw a small copper vein, 4 inches wide; strike N., 80° E., dip 50° to N. The veinstone is 2 feet 4 inches wide, but is not all metalliferous.

The next location was, we believe, the most enduring of any of those worked in 1847, as well as one of the first opened. Called by Jackson the Union Company, its permanent name was the Siskowit mine. Chas. Whittlesey, a cousin of the prominent writer, Col. Chas. Whittlesey, of Wisconsin, came up in the Julia Palmer (the first steamer on Lake Superior) in October, 1847 (with Mr. John Senter), to take charge of the explorations, and wintered there. Under him was Mr. Jas. Hubbard. The explorations were on Sec. 13, T. 66, R. 34. The vein Jackson (J., p. 421) found to be 5 feet wide, the copper mainly in sheets in contact with the walls of the vein, which is well defined. Veinstone (F. and W., p. 150) was epidote, chlorite and calcite, with copper disseminated and in sheets and masses,—the largest mass (F. and W., p. 143) 350 pounds; strike N. 88½° W., dip N. 82°, or, according to Foster and Whitney, 75°. Jackson also noticed (J., p. 421) three small veins which traversed these rocks. Next year Dickenson found a 40 foot shaft, and a 90 foot drift, with about 40 tons of ore (J., p. 505). In 1849, Foster and Whitney reported two shafts, respectively 40 feet and 35 feet deep, and 115 feet of drifting. As at Shaw's location, just described, 35 feet to 40 feet below the surface the vein passed from an overlying amygdaloidal trap (F. & W., p. 171; p. 150, dark, compact trap) to a columnar bed in which the vein was badly pinched. In August, 1850, Koch visited the mine, and we translate his description:—(*loc. cit.*, p. 185.)

"1. Siskawit Mining Company, Town 66, Range 34, Sec. 13, situated on the south [*sic*] shore of Rock Harbor. The principal strike of the trap ridges of the island is from southwest to northeast. The deposit worked by this company strikes from east to west and dips about 35° to the N. E. It crosses the trap rock, therefore, at an angle of about 45°. The principal rock in which the copper occurs is of a chloritic nature, more or less solid, possibly as there is more or less siliceous matter mixed with it; it assumes an amygdaloidal character near the country rock and finally passes into an amygdaloid, which has, however, a tufaceous ["blattersteinartiges"] appearance, owing to various kinds of crystalline secretions, especially of calcite. I have not been able to perceive distinct selvages, but at many points one can distinguish the chloritic rock-mass from the country rock. This copper lode is about 2½ feet thick, but the copper has penetrated into the foot- and hanging-wall beyond and outside of it. At many points the copper occurs in thin plates, which now and then thicken to larger pieces, up to several pounds in weight. It occurs less often in thick lumps. Not rarely we find in the chloritic mass small druses with crystalline copper, transparent colorless ["hellen weissen"] calcite crystals, and other small crystals of a feldspathic mineral of yellowish and reddish yellow color. Whether another mineral which occurs in indistinct crystals belongs to the zeolite family (perhaps analcite) I shall not venture to decide.

"Since the mine furnishes principally stamp rock, the steam engine just put in place, by which the stamp mill, etc., are to be run, will meet one of the most pressing needs. Considerable of the coarser masses of copper had already been sold, and they figure on a product of about 30 tons up to the close of navigation. The elevation of the point where the mining is at present being pushed, above the lake level, is inconsiderable, perhaps only 30 or 40 feet; if one does not shortly have to fight too much with water, this field may perhaps give favorable results. At that time ten miners were employed, and thirty odd people in surface work."

The deposit seen by Koch seems to have been different from that visited by Foster and Whitney. The former is possibly the one mentioned by Foster and Whitney as 1,800 feet west of Shaft No. 2.

The Siskowit mine continued working until 1855. Capt. W. Tonkin, later of the Atlantic mine, was in charge from 1852 to 1853. He reported to Swineford (p. 10; the account below is based also on personal interviews with Capt. Tonkin and John Senter) that the work was done on two veins, the more easterly of which dipped to the west, thus corresponding to the one above described by Jackson and Foster and Whitney, and at the time Capt. Tonkin left, the shaft upon it was down to the sixth level. Afterward this shaft was sunk 100 feet more, to about 500 feet in all, but the vein was lost. The other, or west vein, was very nearly vertical and the shaft upon it was down to the third level. The mine produced about 150 tons of copper. Each vein carried some copper, and it was Tonkin's expectation that when they came together, as he expected them to do at about 600 feet, a good mine would be found. That depth was never attained. The white chimney of the old mine is still a conspicuous feature of Rock Harbor. My notes of the mine are as follows: The old dump extends to the water's edge; specimen No. 16282 represents the country rock trap, at the surface, while specimen No. 16283, from the dump, doubtless represents the columnar trap spoken of, being fine grained and black. About 100 feet northwest from the shore is the old stack, and immediately adjacent, the foundations of two old buildings are visible. Directly from these to the west are four old test-pits or shafts, extending for 400 feet or more, filled with water, on a vein striking north of east and dipping to the north 73°. About 150 feet farther northwest is another row of five or more pits on a vein apparently parallel to the last mentioned (strike N. 80° E.), and dipping perhaps very slightly to the north. It is obvious that, taking the dips as 90° and 75° (F. and W., p. 150), and the distance between the two veins as 100 feet, we get just the 600 feet which Tonkin spoke of as the distance at which they should meet. The trap ledges seemed to strike N. 49° E., and to dip 17° to the southeast. The elevation of the work was about 25 feet above the lake (see cross-section E-F, Pl. XIII).

On the next section adjacent, to the southwest (Sec. 23), were explorations of the Ohio and Isle Royale Company which seem to have been confused with those of the Siskowit mine just described (Swineford, p. 10; F. and W., pp. 143, 144, 150; J., pp. 418, 419, 505, 796). It is obvious from these references that Swineford is in error in saying that Foster and Whitney's report does not mention the Pittsburg and Isle Royale Company, nor the Siskowit Mining Company. It appears also that C. C. Douglass was the agent for the Ohio and Isle Royale Company, which had very numerous explorations in various parts of the island, and was distinct from the Union Company, afterward Siskowit Mining Company, which had Whittlesey as agent. The description of the location of the first explorations as one mile northeast of the main entrance to Rock Harbor, fits the Ohio and Isle Royale, but hardly the Siskowit mine. Swineford's doubt as to the furnace is also clearly unjustified, and he is also in error in saying that Foster and Whitney make no reference to the ancient diggings (F. and W., p. 162).

The rock is reported like that at the Siskowit mine and on the S. E. ¼ of Sec. 22, at 20 feet they struck the columnar trap again, the vein pinching from 3 feet to a mere seam, and it seems to have been taken as the same vein, which, considering the strike, it could hardly be, though very likely of the same system of veins.

Other similar openings were made by this company, on Sec. 23 and Sec. 27 adjacent, T. 66, R. 34 (F. and W., pp. 144, 171), and the latter section was the site of the town of Ransom, opened by Ransom and Reynolds in 1846, where quite a clearing was made. It is

at the mouth of the stream draining Lake Benson. The explorations here were similar to those at the Siskowit mine, etc. (F. and W., p. 144). In 1847 the company had fifty men at work. After the preliminary work by Leander Ransom, in 1846, J. H. Blake seems to have had charge in 1847. During a large part of the summer of 1848, Mark Matthews, now (February, 1896) residing in Houghton, had charge, but he left the same summer, and soon afterward C. C. Douglass arrived with workmen to finish the copper furnace (priv. comm.; J., p. 505; F. and W., p. 144; Koch, p. 187).

In 1849, Messrs. Douglass, Whittlesey and Shaw were still at work in these regions (J., p. 506), but, as we have already remarked, in 1850 Koch found only the Siskowit mine still manned.

Other explorations of the Ohio and Isle Royale Company were on Sec. 34, or Sec. 35, T. 66, R. 34 (J., p. 428; F. and W., pp. 143, 144, 150, 169; priv. comm. of Mark Matthews, and personal observations). There are some puzzling misprints in Foster and Whitney about what I suppose to be this location. On page 143 they give quite a description of a vein on the S. E. ¼ of Sec. 34, T. 66, R. 34, which they say is about two miles south of Rock Harbor by the lake shore, so that an adit has been started near the water level to intersect a shaft 25 feet deep, a short distance from the shore. The same description is given on page 150, and again on page 169, where the vein is called the Duncan vein. This last name might lead us to think of the section whereon Monument Rock stands, the scene of Duncan's labors, but if so, both the town and range are wrong, and, besides, we have no other indication that the Ohio and Isle Royale worked in that neighborhood; nor is a mine indicated there on any of the maps.

On the other hand, if the town and range are right, the S. E. ¼ of Sec. 34 is more than a third of a mile from the lake in any direction and more than 25 feet above the lake, and has also no indication on the map of having been mined. (Jackson, to be sure, mentions, on p. 428, a vein at Conglomerate Bay, strike E. N.E., dip 85° to N., which might be in Sec. 34.) On Sec. 35, which is just adjacent, Foster and Whitney on their map indicate, by a sign which they use elsewhere only for the other two properties given in their table on page 150, a mine in operation, and Mr. Matthews remembers working in that region. Finally, on lot 5, of Sec. 35, I found traces of works corresponding to Foster and Whitney's descriptions

(Sp. 16318, 16319). There are on this lot a number of ruined shanties and remains of a shaft house in a little cove. Judging from the shaft, the vein might have had a strike of N. 65° E. and a dip of 57° to N. W. There seem to be rhombohedra of dolomite in the vein rock and cavities coated with prehnite on epidote. These works are not very far south of some old works on lot 4, that I suppose to represent the Saginaw mine (but C. LeSage, a boatman who has been off and on the island for many years, said the more southerly work was the younger), which was developed much later in the seventies, in similar rock. Foster and Whitney give strike N. E., dip to N. W. 68°, the country rock a dark gray granular trap capped with greenstone, the length of the adit 40 feet, and the product 10 tons of 9 per cent "ore."

On Sec. 2, T. 65, R. 34, near Lea Cove (J., p. 504) or Lucky Bay (Winchell, *loc. cit.*, 1881, p. 53) a shaft was sunk 40 feet (F. and W., p. 144). At the depth of 10 feet a belt of sandstone was struck which continued as far as the shaft was prosecuted.

On section 35, in the same town and range, another shaft is reported (F. and W., p. 144), 90 feet deep on a vein inclined to the northwest, the formation dipping to the southeast. But this location would be away out in Lake Superior! Should not the reference be to Sec. 35, immediately abutting on Sec. 2, on the north, i. e., in T. 66, and thus to the works already described?

On Sec. 10, T. 65, R. 34, close to the line between sections 9 and 10, where a little pond on Sec. 9 is almost immediately adjacent to the lake shore, are the works known as Epidote, which I have visited (F. and W., pp. 144, 169; J., pp. 418, 770).

This Jackson describes as five miles southwest of Rock Harbor in latitude 48° 2′ 8″ N. "The whole coast is composed of trap rocks, with two beds of epidote rock, the upper of which is full of native copper. The copper-bearing bed is about one foot in thickness, and consists of a yellowish green, granular epidote, filled with angular grains of pure metallic copper very uniformly distributed, and constituting from 8 per cent to 20 per cent of its weight. Under the copper-bearing bed there is another bed of epidote, more compact in structure, and about five or six feet in thickness. This bed contains stellated masses of a mineral which I named chlorastrolite." The lower bed of epidote was hard to drill. The dip of the copper-bearing bed was S. E. by S., 28°. Small true veins of datolite,

calcite and prehnite, containing spicules and sheets of copper, were seen to traverse the trap rocks and cut through the epidote veins. (Dip 60° to N. W. by W.) Foster and Whitney allude to the deposit at Epidote as a bed.

The works are, of course, much overgrown and obscured now. Their location is shown on the map. The elevation is about 50 feet above the lake, and less. The material of the dumps—there are three distinct pits noticeable—is sandstone, often indurated and full of epidote and calcite. It is highly probable that the works are in the same belt of sandstone which was met in Sec. 2, and which also outcrops at Chippewa Harbor from beneath the outer wall of trap. The epidotic zone is its upper contact, where it has been altered through the influence of the overlying traps, as it is for about three feet below the traps at Chippewa Harbor.

The work at Epidote was done in 1846-8. The next location was called Datolite (J., pp. 427, 505; F. and W., p. 88), on Sec. 34, T. 65, R. 35, and was named from the abundance of datolite found there. There were two veins, (1) 2 feet wide, strike N. 60° E., dip 50° to N. W.; (2) a few inches wide, strike N. 35° E., dip to N. W. Native copper in rhombic dodecahedra occurred in them. The Ohio and Isle Royale Company were sinking a shaft in 1848, while the work begun in 1846 had been allowed to lapse in 1847. It is possible that the descriptions of F. & W., pp. 143-144, may refer to this, as they fit pretty well, instead of to Sec. 35 of the township next northeast.

§ 3. The Minong, Island and Saginaw Mines, 1871-1883.

We have thus been around the island and described the numerous openings which marked the period of activity which culminated in 1847-48, and rapidly waned until the closing of the Siskowit mine in 1855. Then the island was a desert once more, with no permanent inhabitants. Thus it remained for many years, so far as any scientific results were concerned, though of course there were visitors. So for example, Prof. A. Litton, of St. Louis, informs me that the eminent geologist, D. D. Owen, with himself visited the island in 1858, on their return from the famous trip preparatory to Owen's report on the geology of Minnesota, Wisconsin and Iowa.

In the meantime, especially during the war period,* the property was gradually becoming consolidated, until the North American

*Swineford, loc. cit., p. 14.

Mineral Land Company came to own most of the island north of the sandstone area.

The revival of activity on Isle Royale may perhaps be dated from the arrival of the engineers of the Lake Survey (John C. Mallory, G. A. Marr, etc.), who were employed making a chart and map from 1867 to 1871. At that time no mining work was going on.* But in 1871, when the U. S. Engineers were almost through, and only three men were left flashing signals from the station back of Rock Harbor, explorers for the North American Mineral Land Company arrived on the island, who were under the general direction of S. W. Hill, among them B. Livermore, yet alive, who had been with Whitney, and had helped him ascend Monument Rock in 1849 and 1850. The explorations of these parties which were carried on very extensively over the island, resulted in two promising mines.

In 1871, in the fall, the old Indian diggings on the Minong range were found, first on a fissure vein crossing the high outcrop of the Minong trap. In 1872, a force of forty men were set exploring, with the result that there was disclosed an enormous amount of prehistoric mining on Sec. 26 and Sec. 27, T. 66, R. 35, between McCargoe Cove and Todd Harbor (Fig. 1.) Here the ungrooved cobbles that were used as hammers, could, it is said, be collected by the cartload. Some of the pits were 20 feet to 30 feet deep, and Capt. Uren tells me that in a stope 30 feet deep and 18 inches to 30 inches wide, boulders had been rolled in and wedged to take the place of timbering. There were drains for these pits, and in one case a drain 60 feet long had been covered by timber, felled and laid across.

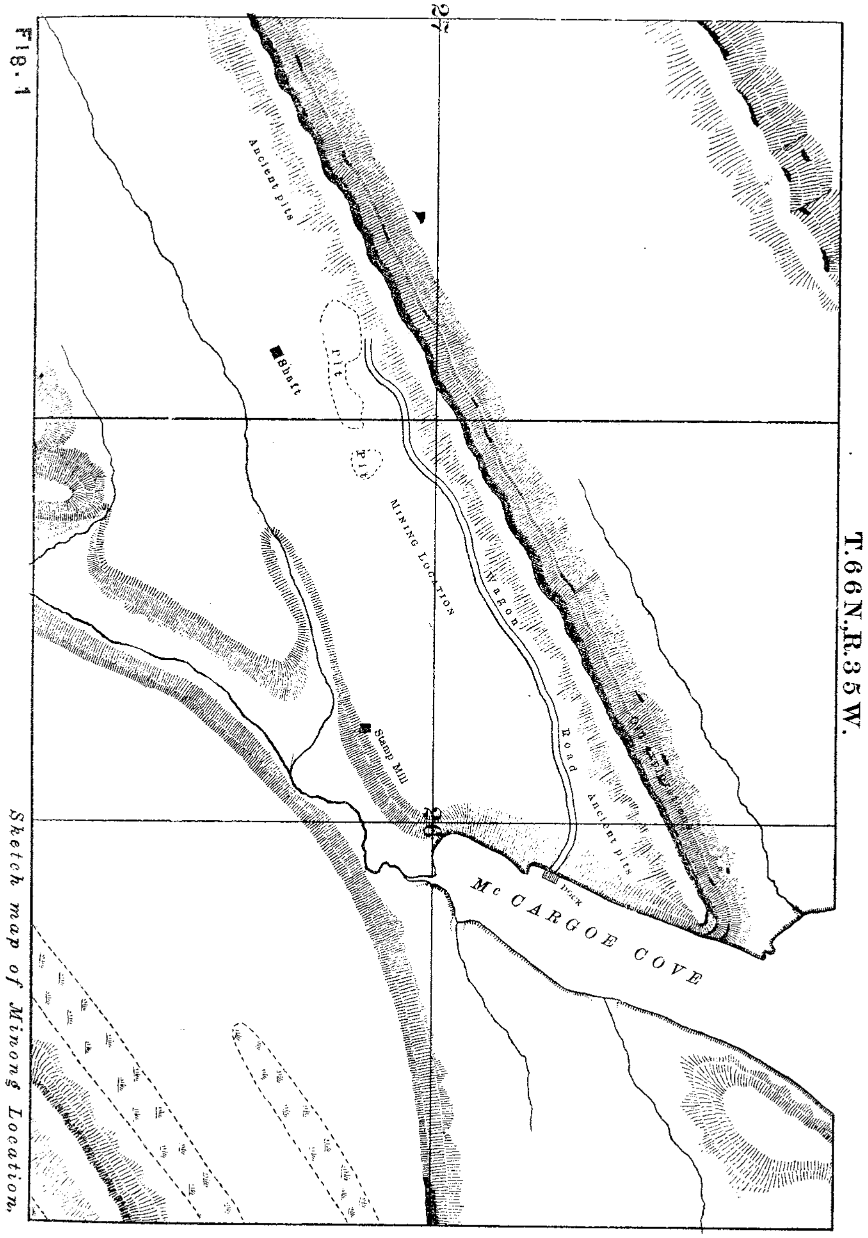
As already mentioned, fire-setting had been employed, and a fragment of a wooden bowl about three feet across, and of a wooden shovel, and also of a rawhide string were discovered.

In May, 1873, the region was visited by Henry Gillman, whose account is referred to on page 2.

In 1874 a company was duly organized to work these old mines once more, under the name of the Minong Mining Company (Minong being the Indian name generically for island and applied specifically to Isle Royale). An area of some 1,445 acres was bought from the parent North American Mineral Land Company, for the purpose, including in T. 66, R. 35, west of McCargoe Cove, the western half of Sections 23, 26 and 35, and the eastern half of

*Priv. comm. from J. C. Mallory.

Fig. 1



Sketch map of Minong Location.

sections 22, 27 and 34. In 1874 a mass of copper weighing 5,720 pounds.*

In 1878 a mass weighing six tons was found, followed, in 1879, by two masses weighing respectively 3,317 and 4,175 pounds. The latter was about nine feet long. These large masses were buried, but there was a depression in the surface over them. In 1879 Winchell visited the island, and his published notes are found in the 10th Annual Report, Minnesota Geological Survey, and in the article above quoted in the Popular Science Monthly.

The first agent for the Minong Mining Company was A. Clayton Davis (Swineford says that he left at the end of the second year); H. Walker, of Detroit, President; E. W. Hudson, Secretary and Treasurer; Wm. Stevens, of Detroit, and John Senter, were prominent stockholders. Capt. Wm. Jacka was mining captain.

In 1876 a stamp mill was built, with a Ball's stamp, and is reported to have yielded, in 1876, 20.25 tons of "mineral" from

(*Winchell, Pop. Sci. Monthly, Sept., 1881, p. 602) which had been worked upon by the miners, was found on the island with poles underneath it, and was exhibited in Detroit and at the Centennial Exhibition of 1876, and afterwards sold.

Letter of S. W. Hill, Dec. 19, 1874:

"Commencing at the harbor in section 26, there is a ridge of bedded diorite having a direction south 60° west; its length in this property is something more than one mile. This ridge is traversed by veins, the greatest number of which bear south 10° to 30° west; there are more than twenty in this property, the greatest number of them have been extensively mined by a pre-historic race.

"The depth of some of these old mines has been found to be sixty feet; where the veins have been uncovered, the excavations in them by the old miners, when cleaned out they have been found well filled with copper; one thousand feet west of the harbor, in Sec. 26, west half, there is a group of several veins; the works of the old miners mark their course more than twelve hundred feet, the veins are united in the north part of the ridge. The evidences are that these mines will pay to mine. They are of good width: other and large veins near this group that have been extensively mined have been found.

"The Witthaus veins in the east half Sec. 27, form another group in which the works of the old miners are as extensive as even the works of this kind in both Minnesota and National mines, on the south side of the lake; these veins are large and well defined, and will, I believe, be found to be of great value when mined."

Letter of A. C. Davis:

"The property has a number of transverse veins that show a large amount of ancient mine work. I cleaned out one of the ancient pits on a vein near the east line of section 27. Its depth was twenty-six feet. I found a vein two feet wide. I put in a blast, and the result was about forty pounds of barrel copper, besides stamp work. I consider this vein a valuable one to mine for copper, and the chances of getting a paying mine I regard as almost certain.

"The property has a sedimentary belt running through it that is highly metalliferous. This belt has also been extensively mined by the ancient miners. I cleaned out three of the ancient pits on this belt, distant one from the other nearly a mile, in all of which I found barrel and stamp copper in quantity to warrant mining. At one point I made a cross cut across this belt, and found it to contain copper for a width of forty feet. It was in this cross cut I found the mass estimated to weigh 6,000 pounds. This mass had been detached from its bed by the ancient miner. I found a number of pieces of copper besides the mass, weighing from an ounce to seventeen pounds. I did not do any blasting in the cross cut, but broke the rock with a pick in many places, and invariably found it well filled with copper."

1,579.50 tons of rock, or about 1 per cent copper. A diamond drill was also employed.

In 1879 there was a reorganization, the Minong Copper Company replacing the Minong Mining Company. Dr. Simonson, at present of the Calumet and Hecla Mine, went there as physician. Among the later agents were S. Brady, and Capt. Hodgson. Finally, in 1883, the mining was suspended, but in the meantime from 1881 to 1883 the mine had been taken on tribute by John F. Johns, Cribeau and others, who worked a while longer and are said to have done pretty well the first summer, finding a six ton mass and a number of smaller masses, making about $800 to $900 apiece.* In the report of the Commissioner of Mineral Statistics, however, the mine disappears as a producer in 1883. The information as to tributing is from memory and therefore unreliable. The statistics of production are given in the table with the Island mine and the Saginaw, page 47.

The extensive location of the Minong is now all gone to wreck and ruin, and has been pretty thoroughly plundered. We find the traces of old explorations, whether prehistoric or not, clustered along the fine-grained trap, the same belt around which McCulloch was working at Todd harbor. Here as there, too, the fine-grained black conchoidal trap is overlain by, and has apparently intrusive contact with a red, more acid rock (felsophyrite specimen No. 16,082 intrusive in 16,081 and 16,080A; Sp. 16,137-16,142, 16,155, illustrate the relations). Above this latter is a sedimentary bed of volcanic breccia.

This same acid rock is, as we shall see later, exposed around Todd harbor but a little way south of here. The acid felsophyrite encloses fragments of the darker rock and is evidently affected in composition by it. Along this contact the copper occurs in a sort of stockwerk, that is, in a number of irregular and ill defined veins running into one another all ways, and the workings have followed them most irregularly. As usual in the Isle Royale ranges the south slope is the gentler, and all over this slope in Secs. 26 and 27, T. 66, R. 35, are found pits and explorations, with a great many of the cobbles that have been used as hammers. The strike of the range from Todd harbor to McCargoe cove is about N. 61½° E., and the

*So I am informed by Godfrey Vaudrey, who worked in the mine from 1880 on, and now spends his summers on the island, fishing.

strike at the mine seems not far from 60°. The dip is about 20° to the south, and one shaft was put down following the dip and, probably in a general way, the contact of the intrusive rock. Some of Vaudrey's recollections of this shaft throw light on the general dip. According to him the diamond drill went down only 50 feet to 60 feet and got stuck, and they abandoned the bit. The drill hole was started about 200 feet from the dryhouse in lower ground, i. e., southeast of it. The inclined shaft ran southeast under the dryhouse and would have struck the drill, it was supposed, within 500 to 600 feet. The shaft went down 300 feet; the ground was stoped from 100' to 300 feet. The slope of the shaft is about 1:4 and the shaft is not 100 feet from the surface at a point under the old blacksmith shop, so that the sound of the sledges could be distinctly heard in the dryhouse. It appears, therefore, that the dip of this shaft harmonizes pretty closely with the general dip of the formation and was following the upper side of the Minong trap, and its contact with the acid rock (felsophyrite). The intimate relations of this acid rock with the underlying trap, which is itself not as basic as are the beds in this part of the series commonly, are hard to describe. They suggest those red rocks which are often associated with basic rocks, apparently, as the result of chemical splitting in the original molten magma, such as Grant's augite granites,* some of the diorite porphyrites of Picnic Rocks near Presque Isle, etc. But in other places the acid rock seems more independent.

The mining began in an old Indian pit which was on a vein that crossed the bluff. From 1 foot the vein widened to 3 feet, when they had sunk 35 to 40 feet, and it contained a good deal of copper—a sheet 3 to 4 inches thick in the middle of the vein.

Beside the above explorations we find on the north side of the bluff a number of others, working along the lower contact of the trap or in the softer underlying amygdaloidal beds. Some of these are very laumonitic, unpromising, broken stuff, but expose a contact and furnish a good opportunity to determine its dip and strike. Strike N. 65° E., dip to S. E. 20°. Another strike observation is N. 55° E. The contact lies only about 30 feet or so below the crest of the ridge, which is about 150 feet high.

*Minn. Geol. Survey, 21st Ann. Rep't, 1894, Pt. II.

The vein above mentioned is probably parallel to a set of prominent joints; strike N. 40° E., dip to N. W. 70°.

The western part of the Minong territory has not been developed, though I have heard that offers were made for it on tribute. The sketch map, Fig. 1, has no pretensions to accuracy, as I have not been able to get any trace of a mine map, but will serve to illustrate the general relations.

But little later than the Minong Mine, and earlier in organization and in running its course, was the Island Mine. The Island Copper Mining Company was formed in 1873 to exploit a copper-bearing conglomerate, which had been dicovered under S. W. Hill the year before, near the head of Siskowit bay, close to the north quarter-post of Sec. 29, T. 64, R. 37. Prominent in its organization were Messrs. Hardy, Devereaux, F. White, Mason and S. W. Hill. Murdoch was mining engineer, Hardy was agent. Two shafts were sunk, respectively 200 feet and 150 feet deep and 350 feet apart, which were connected on two levels, and a third shaft 350 feet farther west is down 50 feet.* In 1875 a stamp mill was built, but burned down almost immediately. The discouraged company leased the mine to the Equal Rights Tribute Company, of which S. E. Cleaves was a prominent stockholder. The name was later changed to the Island Tribute Company, and E. Vivian, now engineer at Calumet, was in charge. The last season of work was in 1877. When Winchell was there in 1879, things were still in good condition, including the courthouse, for this was once the county seat of Isle Royale county. Now the location is pretty well devastated.

The shafts of the Island Mine are in a conglomerate from 14 to 16 feet thick. The two feet near the foot wall, I am informed, were the rich part. At any rate, while very rich blocks of rock may be found, not the whole thickness of the conglomerate shows copper, by any means. Specimens 14746-14749 illustrate the bed and its foot and hanging. The outcrop is about 230 steps south of the north quarter-post, the east shaft dipping 19°, while the west one dipped 25°. Immediately to the south there is a rise of land with exposures of mottled melaphyres, while to the north the grade is steadily up hill over amygdaloids and beds with agates, of a more

*Swineford, p. 12.

acid "ashbed" type. Various facts lead me to identify this conglomerate with bed No. 35 of Marvine's Eagle River section.* It appears to be the first normal conglomerate, with a considerable variety in pebbles, and a generally quartzose or sandy character, that one notices in coming up above the greenstone in each section.

The only other mine that we have to mention that was active during this period, is the Saginaw Mine, on Sec. 35, T. 66, R. 34, near where the Ohio and Isle Royale had worked so many years before. Tim. Nester, of Marquette, was the agent. They began work in 1875, and closed in 1878 or 1879. Their ore was the same as that of the Ohio and Isle Royale, copper finely disseminated in epidote, and hard to stamp. The production of the last three mines above mentioned was:

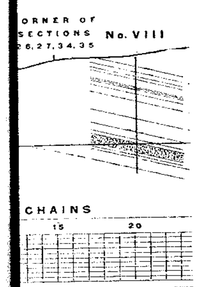
	Minong.		Island.		Saginaw.	
	Tons.	Pounds.	Tons.	Pounds.	Tons.	Pounds.
1875	24	344				
1876	57	537	24	340		
1877	52	892	44	867	0	1,800
1878	45	596				
1879	36	515			24	1,464
1880	13	1,407				
1881	7	1,397				
1882	10	1,380				
1883	1	1,582				

§ 4. Recent explorations, 1889-1896.

With the closing of the Minong Mine in 1883, the island sank into rest once more. The period of activity was somewhat longer than the preceding period of activity, and the period of repose following very much shorter than the preceding period of repose.

In 1889 the Isle Royale Land Corporation, having much of the estate of the North American Mineral Land Corporation, and adding some smaller areas to it, began work once more. Their estate amounted to some 84,000 acres, and the stock was largely held in England, where, also, the office was, although Jacob Houghton, of Detroit, was one of the largest individual stockholders, and the Consulting Engineer as well; Mr. J. H. Thompson was First President, i. e., Chairman; after him G. H. Feldtmann was Chairman; Leslie was Secretary, succeeded by Alex. H. Hay; W. W. Stockly

*Geol. Surv; of Mich., Vol. I, Pt. II, p. 124. For a full discussion see below, Chapter III, §3.



was Engineer, to whom much of the value of this report is due; and S. S. Robinson, Manager.

Work was begun in June, 1889 (Report Com. Min. Stat. for 1889, p. 26). It consisted merely in trenching and costeaning until August, 1890. Work was first begun in the neighborhood of Todd harbor, around what was known as Haytown, on Sec. 11, T. 65, R. 36, and also on the north flank of the Greenstone range, on Sec. 13 and Sec. 12, T. 65, R. 36, and on Sec. 7, T. 65, R. 35 (Pl. XI). Work was also begun about Washington harbor, which was made headquarters of the company, "Ghyllbank," S. 29, T. 64, R. 38. In August, 1890, an auxiliary company, the Wendigo Copper Company, was formed, to which some of the lands around the head of Washington harbor were assigned (Pl. II). This company began a systematic series of diamond drill holes, which gave a practically continuous section across T. 64, R. 38 (I-K, Pl. XIII). Their other tunnels and explorations were not fortunate, and in 1892 almost all work was suspended, though a small party was left to finish drilling two holes on the extreme northwest of the section, close to the water's edge. It was the extreme and unique value of the geological column afforded by these drill cores, which promised to be the key, not merely to the geology of the island, but perhaps to the stratigraphy of the Keweenaw series in general, and even to throw light also on broader questions of the successions of eruptive rocks,—questions of world-wide significance,—which caused the State Geologist to feel that this material must be saved to science at any cost, even though it delayed publication in other directions. Moreover, this cross-section was the last thing finished of the explorations, so that none of the ground shown up by it has been farther tested. It was thus of the highest importance for the future explorations that the record and results of these explorations should be saved. Therefore I spent the time between August 4 and November 10, of 1893, with Chas. LeSage, boatman, and W. W. Stockly, the Engineer of the Wendigo Copper Company, in going over the drill cores, some 9,000 feet, taking notes and samples, and in visiting and taking notes of the explorations in other parts of the island. At that time the secretary of the company, Mr. Hay, was there, and the Isle Royale Land Corporation has kept and is still keeping some one in charge of the property, so that the diamond drills are still there in good order, ready to renew work. The company has also had other plans for the development of the island as a summer resort, and for the exploration of its timber. There are a large number of fishermen that set their nets around the island every summer, and the steamer Hiram R. Dixon stops at the island during the summer season, on her way from Port Arthur to Duluth. The island is also frequently resorted to by camping parties from Duluth, and John F. Johns lets a cottage on an island north of Washington Island to such parties, or they camp in tents or in the deserted lighthouse at Rock harbor and at other points. The picturesque beauty of the island is only faintly indicated by some of the illustrations of this report (Plates VIII, IX, X, XIV, taken from negatives made by Mr. Stockly), and every one who has been there has sung its praises. The scenery is of that fiord type of scenery, which lends such a charm to the coasts of Maine and Norway, and is not unworthy of comparison with them. It is not surprising, therefore, that the company aforesaid planned to make a summer resort on the island. Rock harbor was the place they had fixed on, and a town site has been surveyed, on Sec. 23, T. 66, R. 34, close to the location of the erstwhile Ransom.

Between September 16 and October 12, 1895, I revisited the island with R. T. Mason, assistant, D. C. Forbes and G. Wallace, partly to get farther barometric data, and partly to examine more carefully the region between Rock harbor and Siskowit bay. In the meantime no work had been done there by miners.

The history of these latest explorations (I trust it is not yet finished), must be gathered from the local papers and from private data. Further accounts of these explorations are given in various places in this report, for I have not attempted to summarize them in this historical chapter. The special Regatta Edition of the Duluth Evening Herald in July, 1890, contained under the heads "Lotus Land of the Lake," p. 7, and "A Western Mecca," p. 10, some accounts of the plans of the Isle Royale Land Corporation and its auxiliary companies. In the summer of 1896, Mr. Jacob Houghton continued explorations on the vein running near drill-hole No. 4 or No. 5, but these explorations were suddenly brought to an end by the failure of a Duluth bank.

A word, in closing, on those maps of the island which appear to have incorporated original observations.

The first map of which I know, is that of the Jesuit missionaries in 1670-1671, reprinted by Foster and Whitney.

In 1825 there was a chart of the Canadian shore prepared for the British Admiralty by Capt. Bayfield, which included a delineation of Isle Royale and soundings around it, which were used on Foster and Whitney's map.

Then in Executive Document No. 5, accompanying the Annual Message to the 31st Congress, 1849, there are two maps:

The first, by C. T. Jackson, United States Geologist, shows the locations of the veins, and of the various explorations, and gives the swamps in detail, but is not as accurate in its delineation of the sandstone conglomerate at the southwest point of the island, as the other.

The second was prepared by J. W. Foster and J. D. Whitney, with the assitance of S. W. Hill and S. W. Chlatter (*Sic!* Schlatter). One or two locations are given on this map that are not given on Jackson's, and the sedimentaries are more fully indicated. It is the best geological map of Isle Royale heretofore published.

In their final report, Pt. II, in 1851, Pt. I having been printed the previous year (Senate Special Session, March, 1851, Executive Document, No. 4) was included a general geological map of the Lake Superior Land District, with a small map of Isle Royale. This adds nothing to the large map before mentioned, and is less accurate than that in bringing the conglomerate at the southwest end of the island still farther to the south.

In 1864 was published what is known as the Hulbert map, compiled and drawn by J. C. Booth and E. J. Hulbert, with geological notes from Foster and Whitney, S. W. Hill, W. H. Stevens, N. (*sic!* H. F. Quarre?) d'Aligny and Ed. J. Hulbert. The conglomerate band from Siskowit bay to Rainbow cove is too far south, as on Foster and Whitney's small map, and probably unintentionally the region south of it is colored trap instead of sandstone.

In 1871 S. W. Hill published a map very different from any that had preceded it. The south boundary of the trap range is brought north again to where it was given by Jackson, and a belt sketched nearly parallel to it, running from Scovill point to Huginnin cove, which does not correspond to any geological feature that I have observed. There are a large number of veins noted. If we knew on just what data these were drawn in, and how far they represented the results of Hill's extensive explorations, they might have much more value. But as the map was issued in 1871, the year his explorations began, it has probably more the character of a prospectus.

In 1871 the U. S. lake survey chart of Isle Royale, with detail charts of the more important harbors, was published. The scale of the principal map is 1:120,000. This is beautifully engraved and covers all but a small part of the interior of the island. Much of the island was contoured, and these contours have been the base of the contour map of the island now being issued by the United States Geological Survey.

In 1892, Mr. Stockley compiled a map, using U. S. Linear Survey notes for section lines, township plats of the Land Office for shore lines, and original surveys; this map has had a considerable circulation in blueprint form, and was the base used in our geological researches.

Mr. Stockly, however, discovered that these plats had not been made from a careful platting of the original Government field notes, and consequently he undertook the task of computing the whole matter over again, a herculean task, when one considers the amount of meandering there is in the island. The resultant map is the base used for this report, and we may fairly boast of having the most accurate map hitherto published. The original Land Office notes by Ives have been supplemented so far as needful, from our geological note books, Mr. Stockly's surveys, and the Lake Survey chart. But it should be said that Mr. Ives and his assistants did work of a much higher character than has often been done since his time for the Linear Survey. The errors of closings are small, the work having been done with the solar compass, and magnetic variations, rock-ridges, etc., are carefully and frequently noted. In this brief resumé, only those maps have been noted which are supposed to have incorporated original material, and this rules out such maps as that of Irving, in "Copper-bearing Rocks of Lake Superior" (Pl. XXVII), because none of his parties visited the island.

CHAPTER II

CONSTRUCTION OF CROSS SECTION FROM DRILL RECORDS

§ 1. Deviation of drill holes.

Before we proceed to give an account of the succession of rocks revealed by the Wendigo Company's borings, I have thought it well to give some account of the method of construction of a cross-section. The use of the diamond drill is comparatively new, and but little can yet be found in the literature upon the method of treating such records as the drill may give, and of avoiding the errors to which one is liable in constructing a section from them. This chapter may therefore serve a double purpose,—as a credential for our work, and as a guide to others who have similar work.

In our work we have had to assume that the drill holes were straight, and with one exception vertical, as they were intended to be. This is a good deal of an assumption, for a diamond drill is in this respect very different from a churn drill, where any considerable deviation from the vertical is sure to make trouble. In the diamond drill the drill is being pressed and not dropped into the earth, and however stiff a few feet of the rods by which it is pressed may seem, the discussion at the second annual meeting of the Lake Superior Mining Institute, March, 1894,* showed plainly that they would easily bend as much as 6 feet in 50 feet and the experiments of Mr. Channing, there recorded, show that his inclined holes went very much astray. By using a tube with 20% of hydrofluoric acid to etch the glass, he measured the dip of his holes at various depths.

"The final method of work was as follows: A blank tube was put in the combined bit and core shell from the top end until the lower end rested on the spring. Holding this in position it was laid beside the core barrel so that the length of thread was allowed

* Vol. II, pp 23-32.

for, and a file mark made on the barrel core just even with the top of the glass stopper. A dry wooden plug was made to fit the core barrel and driven in until it just cleared a point corresponding to the file mark. The core barrel was now clamped in a vise in a nearly vertical position.

"The stopper of the tube was held in a tin spoon with a little paraffine over a candle flame and the upper end of the tube warmed. An inch of 20% hydrofluoric acid was carefully poured in the tube, then an inch of water and the stopper taken from the melted spoon of wax, smartly rapped to throw off any excess of paraffine and quickly put in the tube. The acid immediately heated up the tube but no ill effects were felt from this. Wrapping a thread or two of lamp wicking around the neck of the tube, it was put in the core shell and still holding it in an upright position the upper end was introduced into the core barrel and the thread between the shell and the barrel screwed up. Carrying the barrel in an upright position it was put down the hole and no special pains taken in lowering the rods, save to touch the bottom of the hole carefully."

His results were roughly as follows:

Hole No.	1	2	3	4	5	6	7	8	9
Deviation in degrees per hundred feet	4°	5°	3°	12°	12°	8°	8°	8°	4°

The cause of this deviation he attributes to the weight of the core barrel in a slightly larger hole inclining the drill upward.

So far as this cause is concerned, we see that it will not operate so much in a vertical hole. Moreover, in a vertical hole there is no reason to suppose that the deviation will be constantly in one direction, and if the deviation is at random, the drill hole will describe an irregular spiral, and such cases have been known. For instance, Mr. W. W. Stockly reports a case where a shaft 8 feet square, in following a vertical drill hole, found it describing a spiral, and at 500 feet depth it had shifted from the center to the corner of the shaft, and then disappeared for good. We shall need to correct our measurements by multiplying them by the cosine of the angle which the hole makes with the vertical. As long as the deviation from the vertical does not exceed 8°, the consequent correction will not be more than 1 per cent. It is not probable, there-

fore, that in assuming our drill holes vertical we make any considerable error. This is also shown by the way our results check up.

§ 2. Determination of dip and of true thickness of bed.

A certain amount of the softer rock is ground away, but in general the drill cores show us pretty well the vertical width of the several beds along the drill holes. Now, beside this, we must also know the dip, to get the true thickness of the bed. We have the following methods of obtaining the dip:

(1) By the lines of bedding or of flow, which we often observe running across the drill core. Thus, holding the drills vertical, we can measure the dip directly from these lines. Of course, we cannot discriminate small irregularities or cross-bedding in this way.

(2) By field observations of the dip on adjacent outcrops. Unfortunately we have seen no outcrops of sediments close to the drill holes. Observations of contacts of flows are important, but observations based merely on the attitude of the joints of a rock can not be trusted for precise results, though the columnar jointing more or less at right angles to the surface of cooling, and a parting about parallel to the same surface, often give a clear idea of the general dip.

(3) By comparison of the depths at which some bed, so characteristic as to be surely identified, is found in different holes. The strike of the rocks and the relative altitudes of the drill holes being known, this is much the more accurate way of determining the dip, and also enables us with great certainty to piece on to the record of one hole that of another. It requires the drill holes to be near enough or deep enough to overlap. This, unfortunately, is only twice the case in the Isle Royale drill cores, to such an extent that we can identify corresponding beds with absolute certainty. It is a penny-wise pound-foolish policy to let the drill holes only barely overlap, for the sake of saving the cost of a few extra feet, when thereby the uncertainty of the whole section is greatly increased, when, too, the proving of the same bed at diferent points is of interest.

It is obvious that this method of overlap gives us what may be called the average dip between the drill holes, which might be slightly different from the dip at any one drill hole, and if the strike were so different at the two drill holes that it was not permissible to use an average strike, the problem would be much more complex, and new factors would be introduced. Assuming dip and strike as constant between two holes, we have the following simple reckoning. In Fig. 2 let A be the position of the bed in drill hole No. 1 and D the position of the same bed in drill hole No. 2. Let DE be a horizontal line parallel to the strike of the bed. All points of DE will then lie in the bed and be at the same time in a horizontal

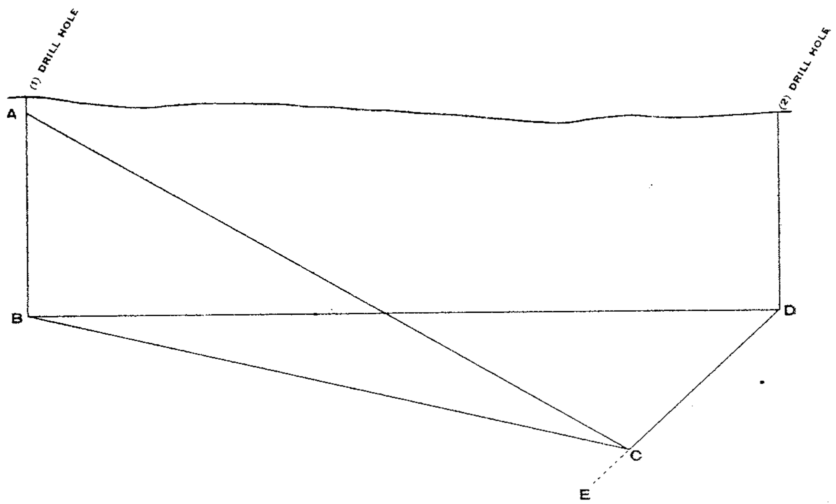


Fig. 2

Illustrates the computation of the dip from observations upon the same bed, at A in drill hole (1) and at D in drill hole (2).

plane. Let AC be a line perpendicular to DE at C through A. It will also lie in the bed and be the direction of dip, since it is perpendicular to the strike. Let B be directly below A on the same level as C and D. Then the tan of the dip, which is $\angle$ ABC, = AB : BC. But AB is equal to the difference in level of A and D. Moreover BC = BD. sin $\angle$ CDB. This angle $\angle$ CDB is the difference of the direction of the strike and of the direction of drill hole No. 1 from drill hole No. 2.

Thus if a^1 be the altitude of the top of drill hole No. 1, and
a^2 be the altitude of the top of drill hole No. 2, and
d^1 be the depth of the bed in drill hole No. 1, and
d^2 be the depth of the bed in drill hole No. 2, and if
s be the strike, and b the bearing of hole No. 1 from hole No. 2, and the distance between the two holes, i. e., BD, be l, then tan

$$\text{dip} = \frac{AB}{BC} = \frac{(a^1 - d^1) - (a^2 - d^2)}{l.\ \sin\ (s-b)} = \frac{(a^1 - a^2) - (d^1 - d^2)}{l.\ \sin\ (s-b)} = \frac{(d^2 - d^1) + (a^1 - a^2)}{l.\ \sin\ (s-b)}$$

If the bearing of drill hole No. 1 is nearly at right angles to the strike, so that (s--b) is near 90°, but the dip is not great, an error in estimating the strike will not produce nearly as great an error in the dip. Such is practically the case before us. Moreover, if we take the distance apart of the drill holes, from their projection on a cross-section perpendicular to the strike we at once obtain the denominator l. sin (s--b). There is another more serious error liable to be encountered, in that a fault may have intervened so that the bed ACD will not be continuous. This is certainly a serious feature of this method of determining the dip. It can be guarded against only by watching to see if either set of drill cores show signs of such a fault, by examination of the surroundings to see if such a fault be geologically likely, and by checking up the results by other methods. A modification of the third method consists in connecting the outcrop of a bed with its position in the drill hole. In such case the outcrop may be considered as though it were at 0 feet depth in another drill hole.

(4) The fourth method of finding the correction for dip is hardly a method by itself, but consists in certain general considerations of analogy and structure, which may serve as a check upon the previous methods. Thus we may argue from the analogy of the Keweenawan series elsewhere that the dip should flatten in going toward the top of the series.

§ 3. Combination of records of different holes.

Having corrected the beds in each drill hole from their vertical width along the drill hole to their true thickness, the next step is to combine the records.

(1) If the drill holes overlap, so that each cuts the same bed or beds, and these are so distinct that we can recognize the same bed in the two holes, then when in constructing our geological column we come to this bed, we can pass from the one hole to the other and continue the record.

(2) If we cannot be sure which are corresponding beds, or if the holes do not overlap, then we can find to what point in that drill hole which is the higher in the series, or in the hypothetical downward continuation of that hole the top of the other drill hole does correspond,—provided we have found the dip in some other way,—by using the formula on page 31 and merely working the problem (3) backward. For in this case placing $d^1 = 0$, we may rewrite the formula given on page 30 in a form from which to find d^2; thus $\tan(\text{dip})\ l.\ \sin(s - b) - (a^1 - a^2) = d^2$. This method should also be used as a check on others. But here, as before, faults may cause us serious error.

§ 4. Effects of faults.

Faults going across the strike are in general steep on Isle Royale, and we shall be warned of their probable existence, if they cut the drill hole, by considerable streaks of vein rock. Faults running with the strike would be much more readily confused with the contact of the two flows, especially if they follow the same as they often do. Let us then consider what the effect on our record would be, of the various classes of faults.

In the first place we can see that a simple slide like the Allouez slide (at Eagle River gap, Keweenaw Point) exactly accordant with the dip and strike, will not disturb the record at all. Faults with a dip flatter than the dip of the beds, and the upper side sliding down, are not likely to occur. Now, for simplicity's sake, suppose our series of beds to dip southerly, as, in fact, they do, and let us first consider faults that practically coincide with the strike of the formation. We lose no generality in assuming that the beds dip south, if we give the faults all possible directions, and the assumption will shorten our expressions. Now, in strike-faults we shall consider first:

A. The south side thrown down. Fig. 3.

If we estimate the dip from a bed in hole No. 2 below the fault, and in hole No. 1 above it, we shall err in making the dip too steep. If we have obtained the dip in some other way, then suppose,—

(1) Hade of fault either way, north or south; fault between two holes, cutting neither. In this case, Fig. 3, we may under-estimate or ignore the gap between them, or, if they ought, according to the distance and gap between them, to overlap, we shall find at depths

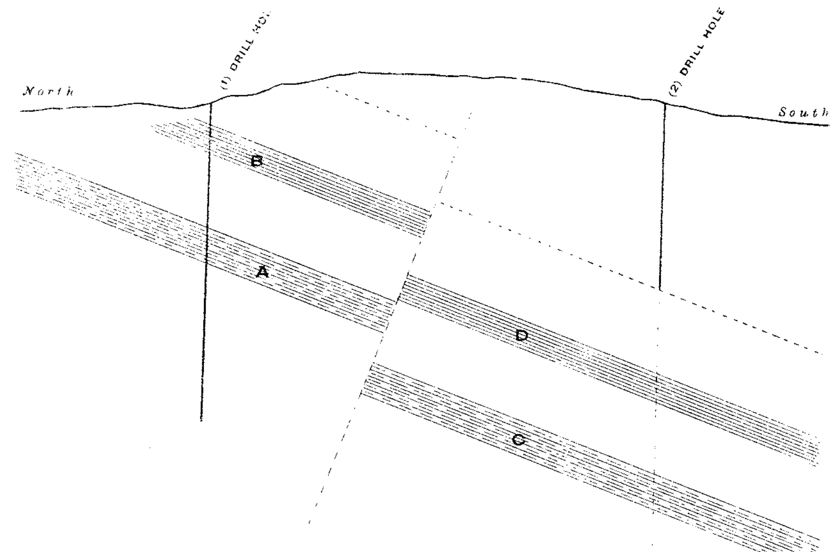


Fig. 3

Illustrates the effect of a fault hading north, which throws the south side down and cuts neither drill hole.

at which certain beds should correspond, beds which did not correspond, and if we could force them into correspondence, assuming for example that bed A of hole No. 1 was equivalent to bed D of hole No. 2, instead of bed C, we should make our geological column shorter than it ought to be.

(2) Hade of fault to north, and the south hole (No. 2) passing through from above the fault to below it, Fig. 4. There will be a repetition of beds in the neighborhood of the fault. We shall be in danger of supposing in case, for example, hole No. 2 stops at bed D, that they fill a part of the column occupied by a gap really unknown. If the holes are so near that without a fault they would

overlap, we shall find that the lower part of hole No. 2 does not correspond to No. 1, as we should expect, and thus probably be warned of the fault. Finally, by correlating C with F we might possibly be led to imagine too steep a dip.

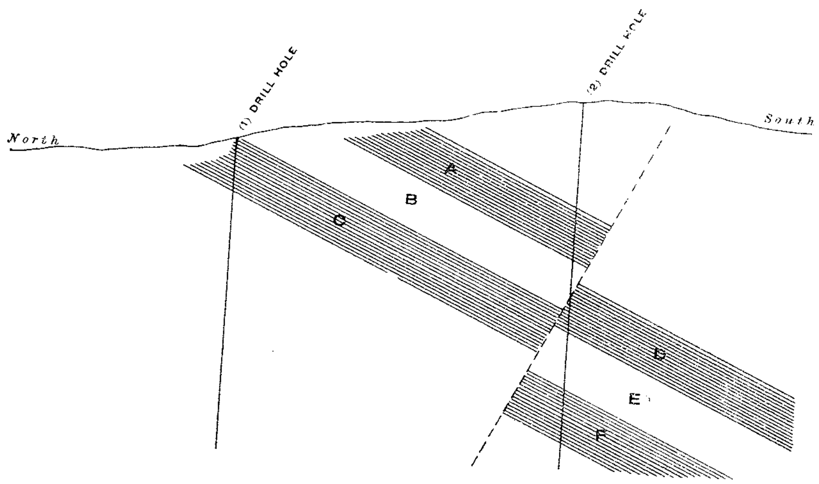


Fig. 4

Illustrates the effect of a fault hading north, which throws the south side down and cuts the south drill hole.

(3) Hade of fault to north, as before, but the north hole (No. 1) is cut by the fault. The effect, so far as correlation is concerned, will in general practically be the same as when the north hole does not go down far enough to reach the fault, case (1), since we should naturally use the top of the north hole (No. 1) to correlate with the bottom of the south hole (No. 2). Below the line of the fault, correlations could be made directly with the south hole, and in the record of the north hole there would be a reduplication of beds.

(4) Hade to south, and north hole cut by fault. There will be no extra difficulty in correlating the beds. The record of the north hole (No. 1) will be deficient by some beds, as is obvious from Fig. 5, unless indeed the fault is one with a very flat dip; flatter than that of the beds, in which case it would be likely to cut both holes.

But such flat faults are not known except as over-thrusts as previously noted. Such a fault would cause reduplication of beds in the record of (1).

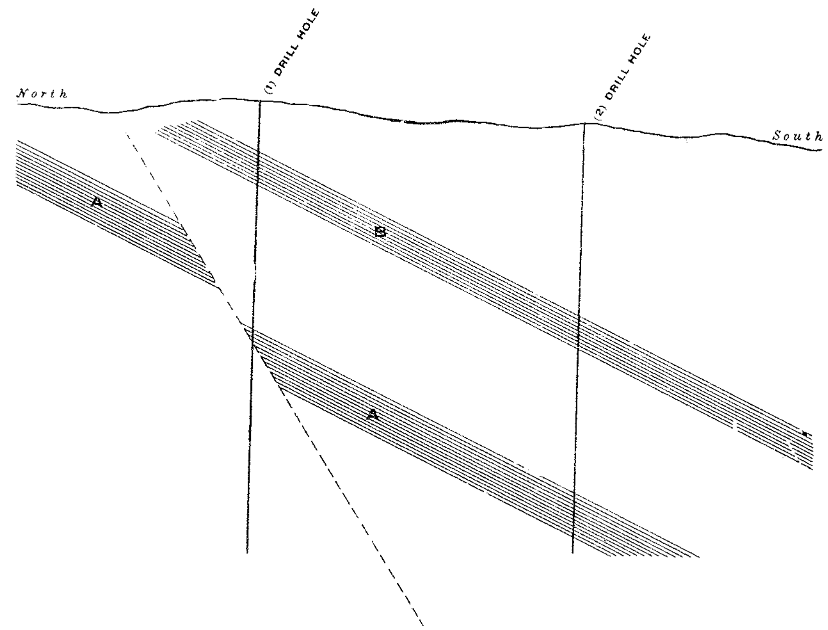


Fig. 5

Illustrates the effect of a fault hading south, which throws the south side down and cuts the north drill hole.

(5) Hade to south, and south hole cut by fault; dip of beds flatter than dip of fault. Fig. 6.

If the north hole is near enough to overlap the bottom of the south hole, true correspondences and dips can be obtained by matching the beds, from the bottom of the south hole up to the fault, i. e., to D, in Fig. 6.

Then there will be a loss of certain beds. If the north hole also contains a bed which can be recognized in the upper part of the south hole, e. g., the bed B, the missing beds will be found in the record of the former; the dip computed from the two occurrences of the bed B will be too steep and the fault will be detected. Compare the correlation of drill holes IX and VIII, in chapter III. In this case (5) there is danger of establishing a false correspondence, for suppose that B and A, Fig. 6, of the south hole are assumed to correspond with B and A of the north hole, when really they are equivalent to B′ and A′, which were not cut by the north hole, while the real A and B have been cut out by the fault. In this case, or if we could not match any beds above the fault, and yet were not aware of the discordance, because the north hole was so far away that its highest bed would come below the fault in the south hole, we might leave beds out of our series unawares.

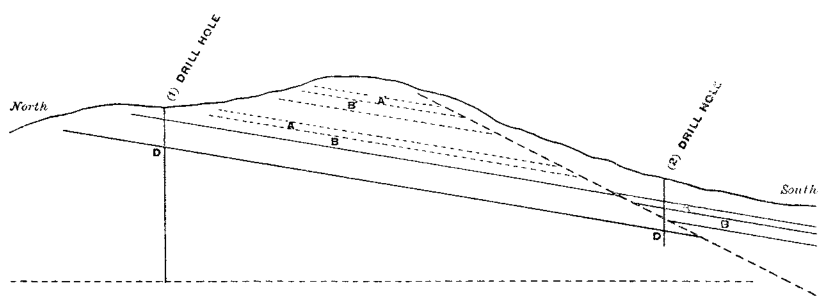


Fig. 6

Illustrates the effect of a fault hading south, which throws the south side down and cuts the south drill hole.

If, then, the holes are so deep and so near together that normally the beds cut by them should overlap somewhat, one case may occur where there is great liability to error,—that is when, with no duplication nor correspondence of beds to warn us, the hade of the fault is to the south and the south hole is cut by the fault so high up as to be out of the way of the matches with the north hole.

B. The south side thrown up; dip of fault if to south, steeper than dip of beds.

(1) If neither hole is cut by the fault, Fig. 7, if we estimate the dip of beds from the holes, we shall make it too flat, or possibly even find it the wrong way. If we get our dip in some other way, we shall be in danger of getting our column too thick by repetition of beds. If then we find the bottom bed B of the south hole (No. 2)

match the top bed A of the north hole (No. 1), we shall see if the dip thus derived (by method (3) on p. 63), agrees with what we should otherwise expect. If it is abnormally flat, we may suspect a fault of this class.

(2) If the north hole is cut by the fault with a south hade, we are not so likely to err in dip or correlation, but there will be a reduplication of the record in that hole, which may again lead us to to get our column too thick.

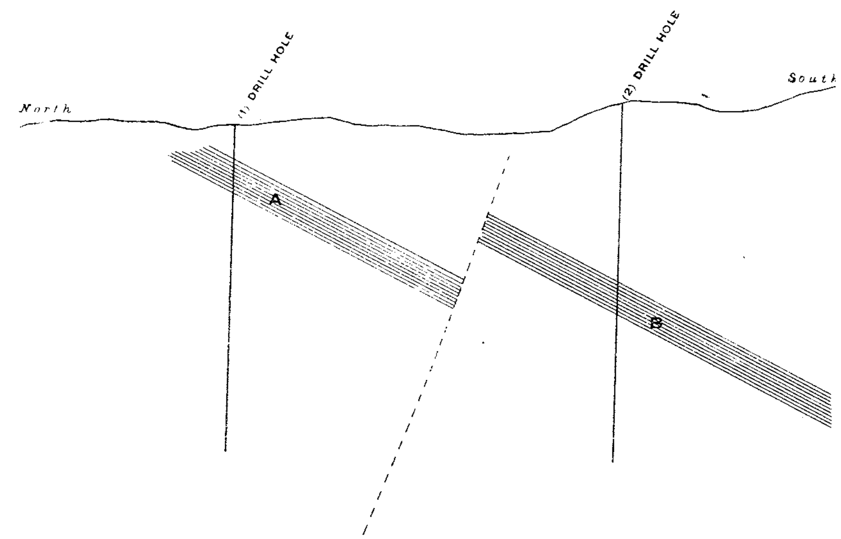


Fig. 7

Illustrates the effect of a fault hading north, which throws the south side up and cuts neither drill hole.

(3) If the south hole is cut by the fault with a south hade, we shall have a reduplication of record as before, and while the correlations, below the fault, of the top of the north with the bottom of the south hole will be all right, those above will give dips too flat.

(4) If the north hole is cut by the fault with a north hade, we have the case shown in Fig. 8, between holes No. 2 and No. 3. This is an especially important case to discuss, as Lawson has suggested that it occurs frequently on the north shore of Lake Superior adjacent to

Isle Royale.* In a case of this kind we shall be unable to correlate the top of the north hole, No. 2, with the bottom of the south hole, No. 3, correctly, and shall be likely to make our geological column too thick, by reduplication of beds. The means of detecting this kind of fault will be by the recurrence of the same beds. For example, the set of beds A will occur again at a higher level south of the fault. Of course, if the throw is very great, they may occur at a considerable distance south beyond the hole next south of the fault, and be found only in some higher hole. We shall have to look over our records to see if there is any such recurrence in the succession of beds as to warrant the idea of such faults.

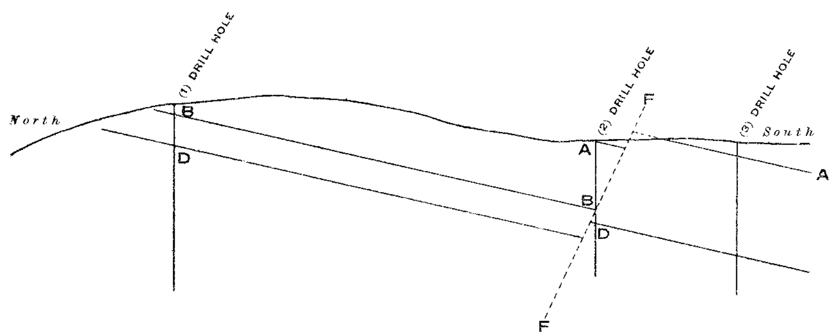


Fig. 8

Illustrates the effect of a fault hading north, which throws the south side up and cuts either drill hole.

(5) If it is the south hole which is cut by the fault with a north hade, Fig. 8, holes No. 1 and No. 2, the difficulties and dangers will be much as in the preceding case. If the holes are so near together that there is an overlap above the fault, then the correlation can be there correctly made, while beds below the fault will give dips too flat.

In any and all of the above cases, if the fault cuts both holes, the relations of the parts of the holes that are on the same side of the fault will be normal, and of the parts on opposite sides of the fault

*20th Annual Report, State Geologist, Minn. p. 192; also Bulletin No. 8, of same survey, pp. 33, 39, 45.

at normal, following the appropriate cases above. In such cases, inasmuch as the hade of the fault is steeper than the dip, the holes must be quite near each other, and with south-hading faults there will almost certainly be at least two corresponding beds, and there should be no difficulty in noticing the fault, unless the beds are extremely uniform and similar. In the north-hading faults, at the bottom of the north hole, we ought to find a bed that will correspond to one in appropriate position in the south hole, while the lack of correspondence in the upper part of the hole would tell the story of the faulting.

There remains to consider:

C. Hade of fault flatter than dip of beds. In this case, as we have said, it is almost invariable that the throw is up, as it is hard to conceive the mechanics that would lead to a down throw on a plane flatter than the dip. But reverse faults, so-called thrust planes, are more to be expected.

(1) Neither hole cut. This would not happen if the holes were planned to overlap at the normal dip, when undisturbed, and hence is an unimportant case. There will be no possibility of correlating correctly.

(a) If the south side is thrown up,—thrust,—the gap in the column will be greater than supposed. The geological column will be made too short.

(b) If the south side has slid down, the gap in the record will be less than supposed. The column will be made too long.

(2) If the south hole alone is cut, below the fault line it may correspond to the north hole. At the fault line,—

(a) If the south side is thrown up,—thrust,—there will be a gap in the geological column unsuspected, at the fault, and the geological column will be made too short.

(b) If the south side has slid down there will be a repetition in the series, and the geological column will be made too long.

(3) North hole cut. In this case the south hole also must be cut, if they are near enough to correspond. Below the fault the two holes may correspond and be correlated, and a correct dip be derived.

There may also be a correlation above the fault line. The series between will not correspond.

(a) If the south side is thrown up, there will be a gap of unknown size in the column, possibly two. We may or may not be able to piece out the record from the four parts of the column given.

(b) If the south side has slid down, there will be a reduplication in the series and we ought to be able to detect the fault and correct the series, if the beds are sufficiently characteristic. It will be noticed that, in a series of drill holes planned to overlap, all faults will tend to produce repetitions of the beds, if the hade is to the north or the direction of downthrow is to the north, except in the case of flat overthrust faults. If corresponding beds can be noted, the abnormal dips that would be derived from them generally give a clue to faults. The only faults that cannot be thus detected, if the holes are properly spaced and there is enough variety in the beds to admit of correlations, are—a normal fault with dip south, greater than that of the beds;—a reverse fault with dip south, less than that of the beds.

In regard to faults that do not coincide in strike with the beds, we need consider only that component of the motion which is up or down, and the angle at which the faults cut the plane of dip, and having found their projection on the cross-section, we shall find that the same rules apply as above, since the drill holes give us information only concerning the vertical position, and will be not at all concerned with the displacement in other directions. We may also look at it in another way. In our cross-section the boundary between that part of the beds which we consider undisturbed by the fault, and that part which we consider moved by it, will be given by the projection of the plane of the fault on the plane of the dip, and the motion of the disturbed part, which is of course parallel to the plane of the fault, may be resolved into two parts, the one along the line of projection and the other horizontal in the direction of the strike, which we need not consider.

In order fully to grasp this case we shall need to use some projection like the stereographic, which I have used for other purposes, and of which a description will be found in Dana's larger mineralogy and also in Bull. Geol. Soc. Am., Vol. II., pp. 365, 368, Pl. 14. We will apply this particularly to the discussion of two classes of faults, which we know occur on Isle Royale, and may be expected to occur in our cross-section. The first class is well exemplified at the

entrance to Chippewa Harbor. These faults are parallel to joints running nearly east and west, more so, at all events, than the strike, and they dip at about 70° to the north. The second class occurs at various points, and fault the Minong trap. One probably comes out near Huginnin Cove. Another lies evidently between drill holes No. XV and No. XVI, which are both close to the northwest shore of the island, throwing No. XV, which is northeast of No. XVI, up about fifty feet, and apparently throwing the outcrop to

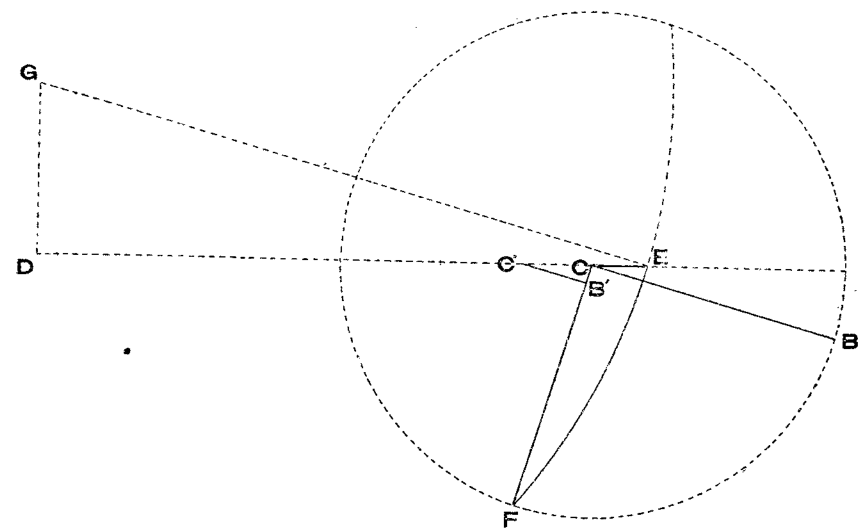


Fig. 9.

Illustrates by a stereographic projection the displacement of the bed C^1B^1CB by a fault, CEF, of the Chippewa Harbor type.

the right or southeast in going northeast. This throw can be seen 25 chains, *i. e.*, 1650 feet, west of the southeast corner of Sec. 19, T. 64, R. 38, and about 500 steps west and 200 steps north of the southeast corner of Sec. 16, T. 64, R. 38.

Let us study to what classes these faults respectively belong, and what effects they would produce. Figure 9 illustrates the Chippewa Harbor type in stereographic projection. To understand it we must imagine ourselves at the horizontal level looking northeasterly in the direction of the strike of the formation, so that a line representing that strike would be foreshortened to mere point at C. Then the dotted circle represents an arc passing through the zenith, and the area within it represents half the universe, and any direction at right angles to the strike will be represented by a radius of that circle r; thus CB may represent the dip of the beds. Any direction not perpendicular to the strike will be foreshortened more or less. Thus CE may represent the direction east, which we will also take as the direction of the strike of the faults. According to the principles of the stereographic projection, then, $\frac{CE}{r}$ is equal to the tangent of half the angle between the strike of the beds and the strike of the fault, which is in the present case about 25°. The angle ECB is, of course, equal to the dip of the beds. To get the dip of the fault in the direction of the dip of the beds, we draw EG, making an angle with the horizontal EC equal to the overhang or hade (the complement of the dip) of the fault. This angle is taken on that side of E toward which the fault dips. Then we also take on the opposite side of C from E a distance CD, equal to the cotangent of the difference in strike of fault and beds—in the case of the Chippewa Harbor fault about 25°—and erect a vertical which cuts the line EG at G. Then G thus found will be the centre of a circle EF, which will cut the dotted circle "primitive" at F. Then by the theory of the stereographic projection, CF will be where the fault will cut the plane of dip, which is the plane of projection, and CEF will represent the fault plane.

Going along the strike of the beds to the northeast, at Chippewa Harbor, we find the outcrop thrown to the left as at C′; thus to the north of the fault the bed CB will be displaced to C′B′. We see then that the fault belongs to the class B 4, with downthrow and hade to the north, and is a normal fault. *It will be noticed too that CF is nearly perpendicular to CB, as if the fault had been influenced somewhat by joints perpendicular to the bedding, which are common in all formations, but especially in igneous rocks.*

Turning now to the second class, represented in Fig. 10, we find the strike of the faults near north, generally a trifle east of north. Then the strike of the beds being foreshortened to the point

C as before, inasmuch as the strike of the beds is near N. 55° E., the strike of the faults will lie to the left and will be represented by the line CN foreshortened somewhat, and proportional to tangent ½ 55° This class of faults is very nearly vertical, sometimes dipping a little to the east, sometimes a little to the west. Of course if such a fault were exactly vertical, a vertical drill hole once in it would never get out of it. Such a fault occurring between two drill holes would produce the same effect whether it had a slight hade one way or the other. We will assume for our drawing a slight hade to the west which is perhaps the more common. Then, just as before, we

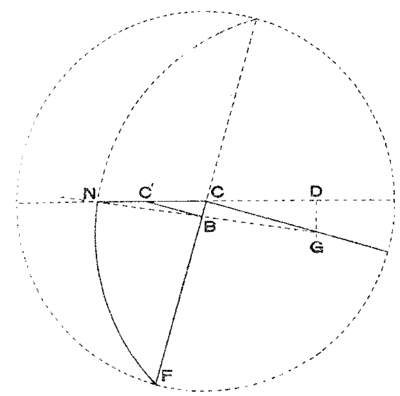


Fig. 10

Illustrates by a stereographic projection the displacement of the bed CG-CB by a fault, NCF, of the Huginnin type.

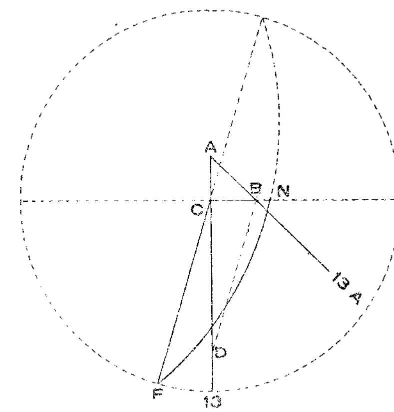


Fig. 11

Illustrates by a stereographic projection the displacement of the fault at drill hole No. XIII.

lay off CD equal to cot 55°, find G, the intersection of the perpendicular at D with a line making an angle with the horizontal equal to the overhang or hade, and about G describe the circle NF. NFC once more represents the fault plane. Going northeast along the strike, that is, in the direction of C, we find the outcrop thrown to the right. Thus, crossing the fault plane NCF we find C′ thrown to C. Thus the east side of the fault is thrown up and the west side down. Thus we see that these field observations on the outcrops harmonize perfectly with what the records of holes Nos. XV and XVI show us. This class of faults, though so different in strike, would then be of the same group as the Chippewa Harbor, northward-hading normal faults, the fault-plane being nearly perpendicular to the plane of dip.

In Chap. III, at the beginning of the description of drill hole No. XIII, there is further study of a fault of this class, which probably affects this drill hole and XIIIA.

§ 5. Description of records and drill holes.

At the bottom of our record we have three drill holes all close to the northwest shore of Isle Royale and not much above Lake Superior. Holes Nos. XII and XV are on Sec. 16, T. 64, R. 38, and No. XVI is just over the line to the west on Sec. 17 adjacent. Of No. XII Mr. Stockly kept track down to 1038 feet which, as we know, was within sixteen feet of the bottom, and although the drill house with boxes, etc., was burned, I was able to get a few scattered samples, especially some which are without doubt from the very bottom of the hole, at 1054 feet, and thus to see that the bed of porphyry had not changed from what it was at the bottom of hole No. XVI. The remainder of these three holes were drilled after Mr. Stockly left the island, and the records may not have been so carefully kept, but they agree so well with each other and with Mr. Stockly's record, that I think we may depend upon them in a general way very well.

A word should be said as to how the samples were kept. Boxes were made the width of a board and about five feet long, divided by strips of wood into partitions the width of a drill core. There were generally five rows, so that if all the core was saved there would be just 25 feet of it in a box. But the amygdaloids and softer beds ground away somewhat into sludge, so that sometimes there would be more than twenty-five feet of strata represented in the box. The depth in feet for every raising was placed alongside the sample, on the partition, in pencil; the number of the hole, and the top and bottom depth represented were marked on each box. Thus, while there is some liability to error in the location of a sample, it is likely to be confined to five feet, and if not to that, at least to the range of the box. The samples in the top of hole No. XIII, from 31 feet to 113 feet, got mixed. The holes are located by survey on the map of the Wendigo property (Pl. III) and the altitudes were obtained by Y level. In the table below, their locations and elevations are given, *Table of Drill Holes of Wendigo Copper Company.*

1. No.	2. Lat.	3. Dep.	4. Sec.	5. T.	6. R.	7. Alt.	8.	9. Distance apart. Chains	10. Distance apart. Feet.
I.	S. 9.55	E. 22.21	¼ S., 20:21	64	38	163.7	XII	-------	-------
II.	S. 19.95	W. 15.51	{ Cor., 21:22 / Cor., 28:27 }	64	38	407.0	XIV.	19.70	1300
III.	N. 4.18	W. 0.37	¼ S., 20:21	64	38	231.0	XIII.	23.00	1518
IV.	S. 0.64	W. 6.02	{ Cor., 21:22 / Cor., 28:27 }	64	38	194.0	III.	26.90	1775
V.	N. 21.09	W. 7.83	{ Cor., 21:22 / Cor., 28:27 }	64	38	56.0	I.	23.00	1518
VI.	S. 45.28	E. 45.23	{ Cor., 21:22 / Cor., 28:27 }	64	38	341.0	V.	31.70	2092
VII.	S. 65.70	E. 65.80	{ Cor., 21:22 / Cor., 28:27 }	64	38	262.6	IV	19.60	1293
VIII.	S. 0.93	E. 8.65	{ Cor., 27:26 / Cor., 34:35 }	64	38	376.3	II.	27.40	1808
IX.	S. 28.16	E. 29.22	{ Cor., 27:26 / Cor., 34:35 }	64	38	232.5*	VI.	36.40	2402
X	S. 50.19	E. 51.13	{ Cor., 27:26 / Cor., 34:35 }	64	38	206.7	VII.	28.00	1848
XI.	S. 0.39	W. 11.54	{ Cor., 35:36 / Cor., 2:1 }	{ 64 / 63 }	38	143.0	VIII	24.00	1584
XII.	N. 9.36	E. 6.31	¼ S., 16:17	64	38	10. ±	IX	33.60	2218
XIII.	S. 2.63	E. 2.24	{ Cor., 17:16 / Cor., 20:21 }	64	38	216. ±	X.	29.90	1973
XIV.	N. 24.00	E. 1.77	{ Cor., 17:16 / Cor., 20:21 }	{ 64 / 64 }	38	198. ±	XI.	33.20	2191
XV.	N. 13. ±	E. 13. ±	¼ S., 16:17 }	64	38				
XVI.	N. 3. ±	W. 2. ±	¼ S., 17:16 }			20 or less	-----	--------	---- --

* Measurements began at rock, *i. e.*, with an altitude 202.5 ft.

The A holes (13A, 4A, 7A) were bored from the same setup at an angle of 45° to the NE. No record of 4A nor of 7A was kept.

In column 1 are the holes in numerical order; in column 2 the distance of the drill hole north; in column 3 its distance east or west in chains from the quarter section post or section corner given in column 4. For XV and XVI the locations are only approximately scaled from note book of A. C. Lane. We have in column 5 the township. The range is always 38. In column 7 is the altitude, close estimates merely for holes XII to XVI; in 8 the holes are arranged in order from NW to SE. Their distance apart in the direction N. 30° W. is given in chains in column 9; in feet in column 10.

and the distances between them projected on a line running N. 30° W., which Stockly took as the direction at right angles to the strike, after careful observations at the holes, as well as at a number of test-pits between the holes. These distances are scaled from a blue print, the original map not being extant, and are liable to an error of 1:120. He found the dip in general to be about 15°, and in particular, from observations on the Minong trap in No. 5 tunnel and in No. 1 drill hole, he determined the dip as 14° 15′. These figures agree fairly with my observations, as recorded on the map of Isle Royale and in the geological column, except that I thought I observed that the dip increased slightly on the N. W., and especially on contact planes near the shore I got some good observations of 18°. On the whole, we cannot pretend for our work a greater accuracy than within 1 per cent. The dips derived from the correlations are given in connection with the geological column.

CHAPTER III.

THE SUCCESSION OF ROCKS.

§ 1. Introduction.

It is my object in this chapter to give an account of the succession of rock beds on Isle Royale revealed by the borings of the Wendigo Company, and by outcrops, and in this connection I shall try to give such an account of the rocks as may be understood by any intelligent mining man or explorer. Many of them are exceedingly fine grained, and their true mineral composition can be found only by examining thin sections under the microscope. The detailed account of microscopic work, however, and other technicalities, will be left to later chapters, or, where such may best be introduced in this chapter, it will be in finer print. I shall at the same time give my correlations with the beds on Keweenaw Point, and my reasons for the same, in so far as they are not too technical.

A. Mineral ingredients.

The rocks of the island are a set of old lava flows, and of sediments apparently derived almost wholly from the lavas or from similar rocks. The mineral ingredients of these lavas are often too fine grained to be recognized with the naked eye, and consequently a fuller description will be left until the petrographical chapter. For the present it will be enough to recognize among the original minerals, *i. e.*, those not produced by alteration:—

Feldspar, light colored, with light reddish or greenish tints due to alteration. Often on the cleavage faces fine parallel lines can be detected, and such feldspars contain less silica. The more siliceous feldspars are generally in shorter rectangles.

Quartz, often secondary, like glass and hard.

Augite, not easy to recognize and often altered, dark-colord. In the coarser basic, *i.e.*, less siliceous rocks augite is the main mass of what surrounds the feldspar. When there is a good deal of it, the feldspars lie in crystalline patches of it which when broken show a cleavage, and reflect the light in patches. This gives the lustre-mottled appearance characteristic of the Greenstone, and such rocks have been called ophites. In such cases, between the augite patches are more easily decomposed substances, and the consequence is that, on weathering, the surface of such a rock will have a peculiar pock-marked, lumpy look, which made Foster and Whitney call the rock "varioloid greenstone." Plate VII shows the general appearance of an exposure of this lustre-mottled rock, and a pocket lens will bring out the pock-marked appearance. The augite was often mistaken by early writers for hornblende. There is practically no hornblende visible in the Isle Royale rocks.

Olivine. Another mineral abundant in the Isle Royale rocks is olivine, which is hard to recognize in its fresh state, in fact hardly occurs fresh, but weathers into red micaceous specks which are easily noticed, and at other times changes into serpentine, a dark green substance. Iron ores may occasionally be recognized as black specks, generally magnetic with a black streak, *i. e.*, magnetite. Hematite gives the red color to many rocks; menaccanite has not been recognized with the naked eye. We must avoid a full description of all the minerals of alteration here, but shall refer to them in the chapter on petrography, Chapter VI., and shall merely remark here that, while the familiar epidote and calcite and chlorite occur everywhere, analcite and datolite seem to be more common in the rocks that are not very augitic.

B. Variations in flows.

The lava flows vary decidedly in chemical character and in structure, not merely as between successive flows, but in different parts of the same flow, and some general account of these variations is necessary. Then, again, the flows are millions of years old, and have been more or less weathered and altered. This introduces a new class of variations.

(*a*) *Variations between different flows.*—As an example of the class of variations which appear on comparing different flows, we find in these lavas a great range in the amount of silica, some of the beds being quite acid, that is to say siliceous, others much less so. In a general way we may say for these rocks that the

less silica a rock has (secondary impregnations not counted), the less likely it is to have white or light red, yellowish or light flesh-colored tints, and the more likely it is to have dark colors—grey, green, red or purplish. The less siliceous it is, the more readily fusible. Experiments show that this is true for the slags corresponding to lavas, and consequently the lavas which are less siliceous will solidify more slowly than the acid, and hence will spread out into more extensive sheets and be coarser grained, for the same thickness of sheet. They are also heavier, and contain more iron, lime and magnesia, and generally less of soda and potash. The bubbles formed by escaping gas, which when later filled with minerals are called amygdules, are likely to be larger and more clearly defined, and less like irregular pores.

Owing to the lack of a lustre-mottled texture and perhaps to their more rapid cooling, the less augitic rocks generally present a finer and more compact appearance, they break more cleanly, and with a smoother conchoidal fracture, and are more smoothly, abundantly and conspicuously jointed. The jointing often divides them into columns. The "ashbed" diabases, for example, indicate their relatively less augite in these ways even to the naked eye.

(*b*) *Variations in the same flow.*—Here we find great differences in texture and composition. Near the margin the flow is finer grained, the contrast being more marked in the basic flows. The crystals which began to form while it was still moving, especially the feldspar and the olivine, are conspicuously in contrast with the rest of the rock, in which the eye can recognize no grain, but which looks like glass or porcelain. These marginal forms might naturally be called fine grained porphyritic trap, to distinguish them from the central forms which are coarser and have not so marked a distinction between the crystals formed before and after the bed came to rest, and might be considered different flows, if one were not careful. Of course a thin flow may have only the marginal form.

Then again at the top of the flow there is usually a belt of rock known as amygdaloid, which was originally full of bubbles of gas. The places of these bubbles have since been filled in with various minerals, as such porous layers allowed freer percolation of water. These amygdaloid layers will naturally be more sharply defined at

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the top than at the bottom and are of such importance as the repositories of copper, that the mining man's record of a boring is generally of an alternation of amygdaloid and trap, with occasional sandstone or conglomerate. This statement applies to the Keweenaw Point records also. But in correlation, such a record is not sufficient, as sometimes small flows will be amygdaloidal throughout, and so a belt of amygdaloid may be merely the top of one flow, or may be several small flows; it is by no means always easy to tell which, even in the drill cores, for a section through the ropy top of a modern lava field would show some puzzling alternations, and, moreover, the amygdaloid beds being soft, are much ground away.

Furthermore a tendency shows itself distinctly, as for instance in the flow which occurs in drill hole No. VIII from 196 feet down, for the lighter feldspar to gather at the top (Ss. 15354 to 15358), and for the augite to be more abundant at the bottom, of the same bed. This tendency cannot show itself at the margins where the cooling is too quick for it, but in the larger flows there is often, about two-thirds of the way from the top, a streak which is quite poikilitic or lustre-mottled, whereas the top is quite feldspathic.

C. Classification. Volcanic rocks.

We may then, for the naked eye, divide the lavas according to their acidity, into

1. *Quartz porphyries*, with distinct hexagonal pyramids of primary quartz, which often give nearly square outlines, in a porcelain-like groundmass which is generally reddish and light colored. The fracture is clean and conchoidal, if there are not too many porphyritic crystals, and the jointing is abundant and smooth, breaking the rocks up into angular fragments.

2. *Felsites*, with groundmass as above, but with no porphyritic quartz, the porphyritic crystals, if any, being of feldspar. Curious rounded forms (spherulites; see Chapter VI) occur in the Minong upper bed (p. 18). The felsites may be divided into felsophyres, and felsophyrites or felsite porphyrites, according as the feldspar is unstriated or striated.

3. *Melaphyre porphyrites*, with much striated feldspar which generally appears more or less porphyritic, usually greenish, more rarely reddish; the flows have a strong tendency to fine grain, smooth fracture and well developed joints, and are dark colored and frequently have conspicuous reddish specks of altered olivine; they tend to have a very scoriaceous upper surface, "ashbed," with red sedimentary fillings of clay, etc.; the amygdaloid pores are smaller and more irregular than in the more basic rocks, and less completely filled, the secondary zeolites which fill them being often analcite and datolite; chalcedony is common. These are the "ash-bed" diabases of Pumpelly and very nearly the diabase porphyrites of Irving, but since I find as a general rule that altered olivine in large distinctly porphyritic crystals, altered to a red micaceous substance, is a pretty constant ingredient in these rocks, I presume Irving called this substance altered augite. This it would be very convenient to do from a systematic point of view, but the original mineral is certainly more often olivine. Moreover, this melaphyre porphyrite may occur in the same flow with more basic types next to be described, and in fact can hardly be distinguished from marginal forms of other, more basic flows, which are probably included among Irving's diabase porphyrites. But the melaphyre porphyrite is not quite so dark, nor so heavy.

4. *Melaphyre ophites.* These are the same as the lustre-mottled melaphyre, varioloid greenstones, and olivinitic melaphyres and diabases of previous writers. But the olivine is a microscopic constituent, even though the rocks are distinctly more basic than those of the preceding group. It was always abundantly present, but is only rarely visible to the naked eye. It is the crowding out of the olivine from the augite patches, which in a bright light often appear irregularly lustrous and make no objections to enclosing the feldspar,—that gives the characteristic mottled texture. The term ophite, in allusion to the resemblance to the mottlings of a snake, is a short and convenient term originally applied by A. Michel Lévy to similar French rocks, which I shall use interchangeably with mottled and lustre-mottled melaphyre.

5. *Melaphyre dolerite.* This is a term which I apply to certain parts of flows, rather than to indicate a certain basicity. Near the center of certain of the thicker flows are streaks of this texture, in which the coarse grained feldspar and augite are both well crystallized, in similar dimensions, and there appear to have been interstices between them which are now filled with chlorite.

D. Sedimentary rocks.

We pass next to the sedimentary rocks of Isle Royale. These vary, according to their grain, from coarse conglomerates, so coarse that we can hardly tell if certain pebbles are not really lava flows, to red shales. The character of the fragments varies, from the angular fragments of the breccia bed, the irregular scoria of the "ashbed," e. g., down in drill hole No. IX, 279-291 feet, and the conchoidal angular fragments of the true volcanic glass ashes (S. 15236), to the rounded pebbles of the conglomerate bed, and the rounded grains of the sandstone. In general there is much more basic material in these beds, i. e., grains of augite and feldspar and pebbles of porphyrite and melaphyre, than we are wont to see in fragmental rocks, but on the other hand the proportion of basic material is less than that of basic lavas among the lava beds. This may be due to the greater durability of the acid rocks, or also it may be due to the fact that the acid lavas having been at the time of their protrusion more viscid than the basic, were more likely to pile themselves up, so as to be more exposed to attack by the waves. A deep red color is characteristic of all the sedimentaries, and as this color is due probably to oxidized iron from the associated igneous rocks, and to the fact that there was no vegetable matter to reduce the iron, it has more than accidental significance.

E. Field names of rocks.

Even in our detailed survey of the geological column as derived from the drill borings, which is planned to be intelligible for those who work only with the naked eye, I cannot deny that in many cases I have received aid from the microscope, but I have made only those distinctions, and used only those names which can, I believe, be used by the field observer, after he has had a little special acquaintance with the rocks. I do not wish to be understood as maintaining that the particular grouping and divisions that I have made here will be found sufficient or even as plain in some other region. There are a large number of rock names, beside those strictly technical ones, which can be applied only after a thorough investigation of a rock —names from which a selection must be made by the worker in the field, to express such important characters as he can observe in the field. As we have already said above, the very same flow may differ in many ways at its margin and at its center, and an ophite may be easily recognized as such in a thick flow, while in a thinner flow the same structure requires a microscope for its recognition, though even then there are often suggestive hints in the character of the decomposition, which may guide the experienced observer. In some other region perhaps, the presence or absence of olivine may be a feature upon which many other features depend, but in our rocks the altered olivine is more conspicuous, if not originally more abundant, in the porphyrites than in the ophites.

The field observer may in some cases be able distinctly to class a rock as ophite or something else, in other cases he cannot do so. In some cases he may be quite certain whether a given rock is a quartz porphyry, a quartzless porphyry, or a porphyrite (with predominant soda-lime feldspars), and in some cases he must fail. There are, indeed, flows which stand on the border lines, where only the most careful and systematic application of an arbitrary definition will put them into one class rather than into the other. For the field observer, therefore, it is necessary to have overlapping names which will cover such cases as these, and the following scheme, I believe, is sufficient for field use.

Felsite ——— Melaphyre

Trap—non-amygdaloidal dark rocks.

Amygdaloid

Porphyry ——— Porphyrite ——— Ophite

If a special term is needed for the coarser forms of basic rocks, dolerite is far preferable to diorite, and a proper gabbro does not appear in place on Isle Royale, so far as I know.

§ 2. Rocks south of the drill holes.

In giving the succession of the rocks, we shall begin at the top or youngest bed, as that is the way Marvine reckoned the Eagle River section on Keweenaw Point with which we wish to compare the Isle Royale section. That is the order, too, in which the beds are met and numbered in drilling, and in sinking shafts like the Tamarack, or in driving adits like the long one at the Copper Falls mine. In numbering and measuring, we shall call 0 the top of drill hole No. XI, where we have the highest trap observed. We may have traps indeed south of this, but probably not, as south of

Cumberland Point no trap has been observed, nor south of Hay Bay, and hole No. XI lies on a line joining these points and considerably southeast of the line of strike of the extensive outcrops of conglomerate on Cumberland Point, between Grace Harbor and Rainbow Cove. According to the correlations here advocated there should at least be the horizon of the Lake Shore traps of Keweenaw Point to the south of hole No. XI, for it must be remembered that the beds farthest north on Keweenaw Point correspond to the beds farthest south on Isle Royale. The occurrence of beds on or near Isle Royale corresponding to the Lake Shore traps cannot be absolutely denied, for they may be under the waters of Lake Superior, or may pass through the drift-covered stretch extending from Rainbow Cove to Siskowit Bay. But the Lake Shore traps are not, as I believe, persistent on Keweenaw Point, rapidly diminishing, and finally disappearing to the southwest, in harmony with a general law. Where they go inland south of Silver Creek, in T. 58, R. 32, they are much narrower than they are farther out on the point, and around Portage Lake no trace of them is found. Consequently we should not, in the absence of any confirmatory evidence, be justified in assuming that they spread to Isle Royale, especially as they represent the last effort of the volcanic activity.

The southeast shore of Isle Royale is lined with conglomerate and sandstone ledges, and is about 24,395 feet from the southeast corner of Sec. 27, T. 64, R. 38, in a direction S. 30° E., or (as drill hole No. VIII is 340 feet S. 30° E. from the same corner) 24,055 feet from No. VIII. Our conclusions as to the rocks that occupy the space between this southeast shore and drill hole No. XI must be largely hypothetical, both as to their thickness and as to their character, but it seems to me there is some reason to believe that a fault runs as indicated on the map, through the low land connecting Rainbow Cove, Lake Feldtmann, and Siskowit Bay. The reasons are as follows:

(1) There is a difference in the attitude of the conglomerate of the two sides of Rainbow Cove that indicates some disturbance between them. The end of the point at the southeast end of Rainbow Cove is made of coarse conglomerate with occasional layers of coarse sandstone, which has a dip of 8° to 9° almost due south. Imbedded pebbles of the traps, melaphyres, amygdaloids, and

especially of a coarse porphyrite with large feldspar crystals in a dark base, are very numerous, continuing along the south side of lot 2, Sec. 30, T. 63, R. 39. Whereas on the other side of the cove, the point between Sec. 14 and Sec. 23, T. 63, R. 39, has a similar conglomerate, with dips; 10° to S. 30° E., 10°-12° to S. 20° E., 15° to S. 25° E., 13° to S. 25° E., 14° to S. 30° E., and the like. This indicates some disturbance between these two conglomerates. I have also thought of an unconformable overlap, or of a fault, the continuation of that coming down from the fault on Huginnin Cove, as the explanation of this.

(2) On the other end of this southernmost shore we have, across Point Houghton, dips averaging 20½° to the S. E., the formation being a rather uniform red sandstone, while a similar sandstone which occurs on Wright Island and on the other islands on the north side of Siskowit Bay, has dips of only 7°, 8°, 9°, etc. Now we find on the south side of Lake Superior suggestively similar relations between the dips,—say of the south trap range of the Ontonagon valley, and of the main range.

(3) The conglomerates of the point south of Rainbow Cove are continued in a ridge which runs south of Lake Feldtmann through Secs. 16 and 15, T. 63, R. 38. It looks very much as if this ridge might be a repetition of the conglomerate belt which outcrops north of Rainbow Cove.

(4) Except by some such fault there is no accounting for the topography. There is nothing exceptionally resistant in the beds of Point Houghton, so far as one can see, which should enable them to withstand the preglacial erosion as a prominent ridge, and elsewhere on the island the rule is that the sandstones run in the valleys or underneath protecting trap. It will also be noticed in the Lake Survey soundings of Siskowit Bay, how quickly the water deepens to the northwest of the Siskowit islands, indicating an old valley there with a steep cliff (fault scarp?) on the southeast.

(5) Finally, such an assumed fault seems to be analogous to other faults of the island, as the one at Chippewa Harbor, p. 41 *et. seq.* We feel justified, therefore, in assuming its existence, though the uncertainty attending it is another good reason for taking our starting point on that side of it which is the more important, as any change in our views as to the fault will produce less change

in our work. If we draw the fault through the low ground, as suggested, it will very nearly divide the territory between drill hole No. VIII and the lake shore into halves (distance taken as 11,860 feet). Then, assuming the dip of 12° 20′, which is the dip found between No. X and No. IX, as the general dip, and it agrees well with the observations on Rainbow Cove and Siskowit Bay, and subtracting 300 feet to allow for the greater altitude of drill hole No. VIII, which is 376 feet above the lake, we shall have (11,860 × $\overline{.219 = \text{tan. } 12° 20′}$ = 2,584 — 300) about 2,300 feet of rock measured vertically above drill hole No. VIII, represented on the island. But, as we shall soon see, drill hole No. XI is 1,202 feet vertically above No. VIII, leaving us 1,098 feet of conglomerate and sandstone above No. XI. Applying a correction to reduce this vertical width to thickness perpendicular to the surface of the beds, we have 1,073 feet (1,098 × $\overline{0.977 = \text{cos } 12° 20′}$), say about 1,100 feet of sandstone on the north side of the fault, and about 2,600 feet of conglomerate and sandstone southeast of it, in each case with conglomerate at the base (12,200 feet × $\overline{\text{sin } 12° 20′ = 0.2136}$ = 2,606 feet).

How much of this section is repeated by the fault we do not know. On the point north of Rainbow Cove there is apparently over 600 feet of conglomerate exposed (3,000 feet × $\overline{\text{sin } 12° 20′ = 0.2136}$ = 641 feet). If this is the same conglomerate as that south of Lake Feldtmann, we may assume:

2,000 feet. Red sandstone of Point Houghton, corresponding to the series found around Portage Lake from the old to the new Atlantic stamp mill (Sec. 34, T. 55, R. 34, to Sec. 20, T. 55, R. 35), and near the Portage Lake Ship Canal.

600 feet. Conglomerate, with the cement often very calcareous, color prevailingly bright red, pebbles of all the range of lavas the melaphyres and porphyrites quite common, agate pebbles like the agate pebbles which occur in the Minong trap, not rare. This I take to represent both the "Outer" and the "Great" conglomerate of Keweenaw Point, the "Lake Shore" trap not appearing.

§ 3. DRILL HOLE RECORD.

DRILL HOLE NO. XI.

Top of No. XI, dip assumed 12° 20′; cos dip=0.9763.

The reasons for the assumption of this dip will be stated when there shall have been enough of the column given to include the part for which a given dip is assumed, at which time the reasons can be given without anticipating facts. (See end of record of this drill hole.) The *vertical* width of the beds, i. e., along the drill holes, is given in feet in the left hand column without parentheses (N. B. not the *horizontal* width which Marvine gives), and under it in parentheses is given the true thickness as found by subtracting a correction equal to (vertical width) × (1–cos dip). In the main body of the text follow, next, numbers that denote the limits, in feet, of the several beds below the tops of their respective drill holes. Then follow, in parentheses, high numbers which refer to the thin-sections of rocks from the respective beds; collection of Michigan Geological Survey.

17+ 0–17; (Ss. 15544–5). **Ophite;** fine grained, massive, with red and white fine grained veins; lustre-mottlings visible. This is near Marvine's bed No. 7, Eagle River section.*

73 (71) 17–90; (Ss. 15546–63). **Conglomerate;** red with calcareous cement and a great variety of pebbles; the acid quartz porphyry predominates, but felsites, porphyrites and melaphyres are also present. Marvine's bed No. 8.

6 90–96; (Ss. 15565–6). **Melaphyre,** thin and amygdaloidal, with chloritic amygdules; slightly ophitic.

7 96–103; (Ss. 15567–8). **Melaphyre,** amygdaloidal. While not coarse enough, that is not thick enough flows to show the characteristic texture to the naked eye, the two small preceding beds appear to belong to the melaphyre ophites, with calcite, quartz and zeolite amygdules.

21 (20) 103–124; (Ss. 15569–72). **Melaphyre,** ophite. The upper 5 feet are amygdaloidal, and make, with the above two small flows, one amygdaloid belt.

0 A very thin **Sediment** with a calcareous cement underlies this bed.

13 124–137; (Ss. 15573–5). **Melaphyre,** amygdaloidal. Marvine's bed No. 16.

9 137–146; (Ss. 15576–9). **Conglomerate;** red, with the usual porphyry and felsite pebbles. Perhaps equivalent to Marvine's bed No. 17.

* Geol. Sur. of Mich., I, Pt. II, p. 120.

8

8 146–154; (Ss. 15582–3). **Porphyrite** (?), amygdaloidal. I think it not impossible that this is merely a boulder in the conglomerate, as we have the conglomerate again interrupted by something similar (S. 15585).

5 154–159; (S. 15584). **Conglomerate,** as above.

2 159–161; (S. 15585). **Porphyrite,** like S. 15583.

37 (36) 61 (59) 161–198; (Ss. 15586–99). **Conglomerate;** continued, growing finer and passing into red sandstone in the last 7 feet. It seems to me quite possible that we have in these last 59 feet only one bed of conglomerate which will correspond about to Marvine's bed No. 17, but his sandstones, Nos. 17, 19 and 21, are separated by single flows, and are more or less conglomeratic, and our conglomerate may represent the whole of them.

11 198–209; (Ss. 15600–4). **Melaphyre,** amygdaloidal.

3 209–212; (Ss. 15604?–5). **Melaphyre,** glassy; in contact with sediment; perhaps a surface coil of the trap next below.

10 212–222; (Ss. 15606–9). **Melaphyre,** ophite; amygdaloidal and feldspathic.

44 (43) 0 222–266; (Ss. 15610–19). **Melaphyre,** ophite; about 17 feet of amygdaloid at top and 9 feet at the bottom. Perhaps they are two minor flows. We have distinct **Sedimentary** matter in the parting at bottom.

9 266–275; (Ss. 15620–1). **Melaphyre,** amygdaloidal; from 272 to 275 the amygdules are not so prominent.

8 275–283; (Ss. 15622–3). **Melaphyre,** amygdaloidal; 2 feet amygdaloidal at top, the rest compact. It is really a fine grained ophite, as most of these beds are, but they are too thin for the structure to develop so as to be visible to the unaided eye.

19.5 18 283–302.5; (Ss. 15624–6). **Melaphyre,** amygdaloidal; the upper 9 feet amygdaloid, with *copper* (at 289 feet), prehnite and quartz.

2.5 (2) 302.5–305; (Ss. 15627–8). **Shale,** red, indurated; in vein-contact with trap. Dip measured on drill cores, 14°.

6 8 305–311; (Ss. 15629–33). **Conglomerate,** with pebbles of melaphyre as well as of felsite; toward the bottom fine-grained and epidotic. Dips measured on the cores, 18° and 14°. This is about the same distance above the bed that we correlate with Marvine's bed No. 35, as Marvine's No. 21 is. The very fine and partly indurated character of Marvine's bed No. 21 matches our two feet of red shale.

16.5 311–327.5; (Ss. 15634–8). **Melaphyre,** ophite; amygdaloidal; is markedly amygdaloidal for about 4 feet, then mildly spotted—somewhat more so at the bottom. The contact with the conglomerate dips 19°. If the overlying bed is the same as Marvine's No. 21, this may represent bed No. 22, which is mentioned by Irving as a typical representative of his ordinary diabases.*

* Copper-Bearing Rocks of Lake Superior, Mon. V, U. S. Geol. Survey, 1883, p. 65.

16.5 (16) 327.5–344; (Ss. 15639–42). **Melaphyre,** ophite; amygdaloidal for the first 7 feet.

5 344–349; (Ss. 15643–4). **Melaphyre,** amygdaloidal.

13 349–362; (Ss. 15644–6). **Melaphyre,** ophite; about 7 feet at the top and 1 foot at the bottom are amygdaloidal.

8 362–370; (Ss. 15647–50). **Melaphyre,** ophite; about 3 feet at the top are amygdaloidal.

14 370–384; (Ss. 15651–5). **Melaphyre,** amygdaloidal; possibly two flows.

5 384–389; (Ss. 15656–7). **Melaphyre,** amygdaloidal.

7 389–396; (Ss. 15658–60). **Melaphyre,** amygdaloidal.

61 (59) 396–457; (Ss. 15661–8). **Melaphyre,** ophite; first 20 feet or more amygdaloidal, then a fine grained black trap, with the lustre-mottling showing somewhat.

1 457–458; (Ss. 15669–71). **Sandstone,** dark, basic; porphyry fragments not marked. This may represent Marvine's bed No. 26.

(24) 458–482; (Ss. 15671–6). **Melaphyre,** ophite; first 6 feet an amygdaloid with datolite, then a fine grained black trap, finally distinctly mottled. At the base there is a **sediment.** Compare Marvine's bed No. 27.

10 482–492; (Ss. 15677–9). **Melaphyre,** ophite; first 5 feet amygdaloidal; below that a fine grained trap, the bottom of the bed apparently gone.

1 492–493; (Ss. 15680–1). Seam of red **clay flucan,** perhaps marking a fault. A fault throwing the south side down, and hading to the south would make a gap which we could not detect (see p. 71, Fig. 5), but we may be reasonably sure that there is no fault which would lead to a repetition farther north of the beds we have already described, for these consist of a number of sandstones and conglomerates with thin basic melaphyres of the ophite type, whose texture is sometimes coarse enough to be recognized, and these we do not again encounter. After two more conglomerates, we come to a series of somewhat less augitic flows, with nonfelsitic conglomerates.

6 493–499; (Ss. 15683–99). **Conglomerate,** with porphyry, felsite, and trap pebbles, and calcareous cement; dip about 13°–14°.

1 499–500. **Clay;** another seam, which may indicate a fault. Thus, as the conglomerate may be bounded by possible fault planes above and below, we cannot be certain of its correlation, and it may be a repetition of some higher or lower conglomerate, but relatively to our general correlation it is nearly in the position of Marvine's No. 28.

7.5 (7) 500–507.5; (Ss. 15690–2). **Melaphyre,** amygdaloidal.

3.5 (3) 507.5–511; (S. 15693). **Amygdaloid;** may belong to the flow above or to that below.

14 511–525; (Ss. 15694–6). **Melaphyre,** ophite: more or less amygdaloidal, especially the first two feet.

Here we will pass for a moment from hole No. XI to hole No. X, to compare the two. Assuming that hole No. XI at 525 feet is equivalent to hole No. X at 113 feet, which will make a difference of 412 feet; adding the excess of altitude of No. X over No. XI (206.7 — 143 = 64 feet), makes 476 feet, and dividing by the distance between them, 2,191 feet, we have 0.218 as tan of dip; i. e., the dip is 12° 20′.

The rest of No. XI we correlate as follows:

Hole No. XI at 532 feet, contact, is equivalent to hole No. X at 123 feet; difference, 409 feet. Hole No. XI at 536 feet, contact, is equivalent to hole No. X at 133 feet: difference, 403 feet, and the characters of the beds assumed to be equivalent harmonize very well.

We are led to this correlation by the fact that we cannot match, in No. X, the conglomerate at 493 feet in No. XI, unless possibly at 469 feet, in No. X, and if we did that the adjacent beds, e. g., at 457 feet, would not correspond. Hence we must find a match for the first beds in No. X, i. e., at 109 feet (for the first 107 feet are in a surface deposit, old lake bottom, fine red sands and clays), below 493 feet in hole No. XI, and we come upon the one given above, which is the best we can find. Moreover, this match gives the same dip for the beds that we shall find later for the correlation from No. X to No. IX,—one that agrees pretty closely with the dips measured on the drill cores. If the correlation is good but the dip really 13°, it would mean that the rock of No. XI had been upthrown about 29 feet, in which case our column would be that much too long. But there is absolutely no indication of any faulting in either direction. If the dip is steeper than we assume and the two
(512) holes do not overlap at all, we have made the column too short.

DRILL HOLE NO. X.

10 113–123; (Ss. 15463–5). **Melaphyre.**

12 123–135; (Ss. 15466–9). **Melaphyre,** amygdaloidal; a trace of sand
0 at lower contact.

13 135–148; (Ss. 15469–72). **Melaphyre,** amygdaloidal; more compact in the lower 4 feet.

21 148–169; (Ss. 15473–8). **Melaphyre,** ophite; upper 9 feet amyg-
(20) daloidal, then more massive.

23 170–193; (Ss. 15478–88). **Conglomerate.**
(22)

(589) This conglomerate contains abundant acid pebbles, of porphyry and felsite, and of melaphyre as well. This bed I take to be the conglomerate opened by the Island mine, as the two have a similar lithological look or character, and lie nearly in line of strike from each other. The Island mine conglomerate runs about 500 feet south of the north quarter post of Sec. 29, T. 64, R. 37, and has a steep dip (from 19° to 25°), considering its position. Again, near Siskowit Lake, 50 steps north of the southwest corner of Sec. 26, T. 65, R. 36, and down to the corner, we find along the same line of strike a conglomerate which I take to be the same bed. So it continues on, being probably the same as that indicated by Foster and Whitney at the southwest corner of the head of Rock Harbor, on Sec. 5, T. 65, R. 34. I think, however, that it does not pass through to Conglomerate Bay, but like other beds in this vicinity veers a little to the north and goes through the trough of Rock Harbor. It is barely conceivable that, if we turn and go in the other direction, by the time we shall have come to Grace Harbor all the overlying traps will have run out, and that this conglomerate will have merged in the general conglomerate of Cumberland Point. This conglomerate in drill hole No. X differs from those above it in that it carries a greater proportion of basic pebbles, especially of the immediately underlying melaphyre porphyrites, but it differs still more decidedly from any conglomerate within the first thousand feet beneath it, in that it still contains a considerable proportion of felsitic debris — more perhaps at the Island mine than at the drill hole. This contrasted relation of the conglomerates above and below this horizon holds good, so far as the meagre facts indicate, for the corresponding beds at the other exposures above mentioned. All these exposures, moreover, lie on the southeast flank of a fairly continuous ridge which is principally made up of the rocks which we have described as melaphyre porphyrites, similar to the "ashbed" type of diabase. Northwest of this porphyrite ridge we find a still more continuous ridge, the "backbone" of the island, which is made up of coarsely lustre-mottled rocks—ophites. It will be noticed, from what we have said, that not only the sedimentaries but the eruptives change their character, above and below the conglomerate horizon which we are studying. Above it we have a series of thin flows, generally largely amygdaloidal, but when coarse enough showing the mottling of the ophites, and interstratified with them numerous beds of siliceous sedimentary rocks. Below it, as we shall see, the beds are in general

thicker and more massive, and less augitic (porphyrites), and the interstratified sediments and amygdaloids resemble those which form the hanging of the Ashbed type.

Now we have on Keweenaw Point at Eagle River and elsewhere a precisely similar series, only with the order from southeast to northwest reversed, but the stratigraphic order the same. I use mainly for comparison Marvine's Eagle River section, as I have been over and revised it and have collected specimens from it expressly for this purpose. Beginning from the uppermost trap bed actually noted (Geol. Sur. of Mich. I, Pt. II, p. 112) Marvine counts ten sandstones in the first 2,300 feet of the section horizontally, (i. e., 1,272 feet thick; *loc. cit.*, p. 124) to bed No. 35. This is the greater part of his series (c) which he however carries down somewhat farther to the first scoriaceous amygdaloid. In this part of the series the beds incline to be ophitic when at all thick, and the character of the formation generally matches the beds above the Island mine conglomerate. It will be noticed that for this part of the section we have on Isle Royale but half the thickness represented at Eagle River, the thickness to the bottom of the Island mine conglomerate being but 589 feet, but on the other hand we have six to eight of the ten conglomerates and sandstones.

Beginning with the flows immediately below Marvine's bed No. 35 and the Island mine conglomerate, we find a distinctly less augitic character in the flows as a whole, while the base of each flow remains somewhat ophitic in texture; we can recognize this change under Marvine's bed No. 35, in the Copper Falls adit, the Tamarack mine and elsewhere. In my re-examination of the Eagle River section I observed that the change really takes place there also at the point indicated. Then in all cases the first sedimentary bed we meet below the Island mine conglomerate, respectively below Marvine's bed No. 35, is distinctly of the Ashbed type, e. g., at 415 feet in No. X, Marvine's bed No. 44. Below this bed the traps are still less augitic, and they, together with their associated scoriaceous conglomerates, have in each case about the same thickness. Under this complex we find also, both on Isle Royale and on Keweenaw Point, the largest flow of the coarsest ophite that occurs anywhere in the series, the Greenstone.

Now I am well aware of the danger of purely lithological correlations, but in view of the fact that beds of the series which we have been studying have been followed for a distance along Keweenaw Point equivalent to that across the lake, in

view of the fact that a basic lava sheet of 200 feet, yes, in some places of 1,000 feet thickness may be expected to spread a great distance, with some uniformity of lithological character, in view of the general parallelism both in sedimentaries and in traps, both above and below, there seems to be no reasonable doubt that the Island mine conglomerate is equivalent to Marvine's bed No. 35, or is, at least, at very nearly the same horizon.

I put in this last clause because if anyone should object that Marvine's No. 35 might have faded out and that another conglomerate might have formed on the Island at nearly the same point in the series, my arguments would not conflict with this hypothesis. As a matter of fact, however, the *indications* are that the bed we have just discussed is identical with Marvine's No. 35.

113 193–306; (Ss. 15489–501). **Melaphyre,** porphyrite. This is a
(110) pseudamygdaloid for the first 20 feet, that is, the amygdules are indistinguishable from decomposition spots. It is different from the ophites above, most markedly in microscopic characters, but also to the naked eye, for the feldspar is much more conspicuous and there is no lustre-mottling, as there would be very plainly in a bed of ophite of equal thickness. In other words the feldspar is large in proportion to the size of the augite. Light greenish seams and spots, and a generally lighter, more grayish green color may be noted on comparison. This would correspond to Marvine's bed No. 36.

It will be noticed in Marvine's description of bed No. 36 that the scoriaceous character of the amygdaloid is mentioned, which is characteristic of the less augitic melaphyres. Farther details as to the change in character must be left to the petrographic chapter. The feldspar is oligoclase instead of labradorite.

16 306–322; (Ss. 15502–5). **Amygdaloid.** This is a fine grained red amygdaloid, apparently the same kind of rock as the bed above, but a thinner flow.

0? Among the drillings at 321 feet were 2 inches; at 322 feet, 4 inches; at 323.3 feet, ½ inch of a basic **sandstone.** The driller's record threw no light on the occurrences, but from the gradually finer grain of the traps above and below them, I am led to believe that they all really belong at 322 feet, and that there is a bed of fine grained dark red basic sandstone there. Dip 14°.

3 322–325; (S. 15506). Perhaps another bed of **Amygdaloid.** At
(718) 325 a narrow seam is noted which may however be a fault.
7 325–332; (Ss. 15506–8). **Amygdaloid;** at 332 feet highly amygdaloidal, brecciated, and mixed with finer grained sediment; quite likely a slip.
6 332–338; (Ss. 15508–12). **Amygdaloid.**
77 338–415; (Ss. 15513–24). **Melaphyre;** of the porphyrite type at
(75) the top, but becoming darker and approaching the ophite type at the bottom. It is somewhat amygdaloidal down as far as 352 feet, beginning as a fine grained red porphyrite with amygdules of chlorite and a few of agate at the top. At 344 feet and 377 feet green rock was cut which would in the field prove, I feel sure, to be either rounded masses or irregular skeins, which are characteristic of this group, and are slightly more likely to be amygdaloidal than the adjacent rock. They are more decomposed, though this decomposition doubtless follows some primary feature, and are permeated with cavities lined with crystals of quartz and chlorite.

As we get toward the bottom the rock, which is firm and compact, and yields long drill cores, becomes darker, and finally somewhat lustre-mottled. *Copper* appears in paper-like sheets in the chlorite seams. This is probably Marvine's bed No. 43.
(806) Analyses of this bed will be found in Chapter IX.
11 415–426; (Ss. 15525–30). **Conglomerate.** This bed is the first of
(817) the scoriaceous conglomerates, otherwise known as ashbeds or scoriaceous amygdaloids. The matrix is very dark, of a deep maroon shade, generally speaking, very fine grained and argillaceous, and the pebbles are irregular masses of amygdaloid, like the beds with which they are associated. The line between the conglomerate and the underlying amygdaloid is extremely difficult to draw. This is the reason why these scoriaceous beds have been considered as extreme forms of amygdaloid, but there is no doubt that in the beds which I am now considering there is a large amount of detrital matter, almost exclusively from basic rocks. They are very calcareous.

This conglomerate corresponds very nicely to Marvine's bed No. 44—as well, indeed, as his bed No. 35 corresponds to the Island mine conglomerate. The underlying rock corresponds to Marvine's bed No. 45, being a melaphyre porphyrite, with a clean conchoidal fracture, as we shall see, and the immediately overlying bed is in each case indistinctly mottled. Marvine allowed eight beds between No. 35 and No. 44, but two numbers were allowed for beds unobserved, and none of the observations showed that Nos. 42 and 43 were separate beds,

and in fact I inferred from the coarseness of grain and other things that in reality from No. 39 down to No. 43 was all one large flow (184 feet) corresponding so closely to our melaphyre in No. X (338–415, i. e., 75 feet thick) as probably to be the same flow. That left four beds in the Eagle River section, between No. 35 and No. 44, to correspond to our six beds, in each case with a thick flow at the base. From the top of Marvine's bed No. 35 to the top of his bed No. 44 is, according to Marvine, 273 feet. The corresponding distance in our column of rocks is (806–567) 239 feet, which is quite as close a correspondence to the general ratios (see table at the close of this chapter) as could be expected, 50 miles away, and eminently satisfactory. The correlation is made much stronger by the study, under the microscope, in Chap. VI, of the comparative coarseness of grain, and the change in the character of the feldspar.

57 426–483; (Ss. 15531–7). **Melaphyre,** porphyrite. This is one of
(56) the most acid of the melaphyres, really of the type of an olivinitic augite andesite. The smoother fracture, generally lighter, green color, abundance of not very large white porphyritic feldspar aggregates, and compact texture are well marked. This is the bed that we seem to find at the top of
(874) drill hole No. IX.

We assume that No. X, 483 feet, is equivalent to No. IX, 49 feet, a difference of 434 feet. Subtracting the excess of altitude of No. X over No. IX (206.7–202.5*), 4.2 feet, we have 430 feet, which divided by the distance between them along the line of cross-section, 1973 feet, gives 0.217, the tan 12° 20′. This is the same as we had before, the two computations confirming each other and strengthening our correlations, which were in the first place purely lithological. In case this correlation is wrong, so that No. X and No. IX do not overlap, the resemblance noted being that of similar successive flows, we should have a steeper dip, or a fault. The correlation with the next hole north will give us a slightly steeper dip, about 13°. But a slight flattening of the dip going south is to be expected, and there is no reason at all to assume a fault. A fault the other way, producing a repetition of beds and leading us to exaggerate our column, is ruled out by the fact that the conglomerate, 415–426 feet in No. X, can be matched even approximately only at about 313–338 feet in No. IX, in which case we should expect to be able to match all of No. X and No.

* The altitude of the surface is 232.5 feet, but the 30 feet of drift material first encountered were omitted in reckoning the drill hole depths.