GEOLOGICAL SURVEY OF MICHIGAN.

UPPER PENINSULA
1869-1873
ACCOMPANIED BY AN
ATLAS OF MAPS.

VOL. I.
PART II.
COPPER DISTRICT

BY
RAPHAEL PUMPELLY

ASSISTANTS: A. R. MARVINE, M.E., L. G. EMERSON, C.E., and S. B. LADD.

PUBLISHED BY AUTHORITY OF THE LEGISLATURE OF MICHIGAN.
UNDER THE DIRECTION OF THE
BOARD OF GEOLOGICAL SURVEY.

NEW YORK
JULIUS BIEN
1873

TABLE OF CONTENTS.

TO THE HONORABLE BOARD OF GEOLOGICAL SURVEY OF THE STATE OF MICHIGAN:

GENTLEMEN:—I have the honor to submit herewith a Report on the work done by the Geological Survey of the Copper District of the State, during the seasons of 1870 and 1872,

Yours very respectfully,

RAPHAEL PUMPELLY,

NEW YORK, *May* 1, 1873,

PREFACE.

THE work of the Geological Survey of the Copper District in 1870 and 1872 was confined chiefly to the construction of as perfect a series of cross-sections as circumstances would permit, in the Portage Lake, Calumet, and Eagle River districts. This seemed to be the most desirable method of expending the very limited annual appropriation of two thousand dollars. Any attempt to cover a wider field would have resulted in a simple reconnoissance of the district, without adding essentially to the previously existing information. To obtain the cross-sections which accompany this report, it was necessary to make an accurate triangulation of the country examined, without which it would have been impossible to represent in their relative positions, in a very uneven country, the outcroppings of the very numerous thin beds of nearly similar rocks, possessing varying thicknesses, an almost constantly changing course, and a high and varying degree of inclination. During 1870, the work was confined to the Portage Lake district, the survey of which was platted on a large working-map to the scale of 300 feet to one inch = $^{1}/_{3600}$. The cross-sections are on the scale of 90 feet to one inch. This scale appeared to be necessary in order to represent many beds of from two to six feet only in thickness, and especially to admit of adopting the same scale for both vertical and horizontal distances, without which it would not be possible to correlate the different sections as they are now exhibited. The cross-sections are accompanied by an accurate copy of the large working-map reduced to the scale of $^{1}/_{12,000}$, on which the various cross-section lines are delineated. This map represents only the work of the Geological Survey during the summers of 1870 and 1872, except the line of the northern shore of Portage Lake, which was taken from the United States Lake Survey Charts, and some results compiled from railroad surveys.

Both the maps and the cross-sections represent, with a few rare exceptions, only actual observations of rocks *in situ*. The Survey is Indebted to Mr. A. B. Wood, Mr. R. J. Wood, and Mr. Mabbs (Agent of the Isle Royale Mine), for notes of measurements made by them in trenches dug under their supervision. These old explorations have been remeasured by the Survey, and where the rocks were not covered by the fallen *débris* they are described in the accompanying text. In the work of 1870 I was ably assisted by Mr. A. R. Marvine, M.E., and Mr. L. G. Emerson, C.E.

During the early part of the summer of 1872, Mr. Marvine was employed, In connection with Mr. Emerson, in completing some unfinished geological work on the north side of Portage Lake.

During the rest of the season, Mr. Marvine, assisted by Mr. S. B. Ladd, was engaged in making a cross-section in the Eagle River district. The results of this survey are embodied in the map and sheets of cross-section of the Eagle River district, which, like those of the Portage Lake district, are founded upon a careful trigonometrical survey, in which every pains was taken to insure extreme accuracy.

For comparison with the southern part of the Eagle River section I made a detailed geological section underground in the Central Mine.

Careful measurements were made by Mr. Marvine between the conglomerate beds at various points along the Range, in order to correlate stratigraphically the rocks of Portage Lake with those of Keweenaw County. The results of these measurements are given on the plate of "Grouped Sections," together with reduced sections of the Portage Lake and Eagle River districts, in order that the geological relation's between the various sections may be more readily compared. The subject, which presents many difficulties, is ably discussed by Mr. Marvine in a separate chapter.

The chief aim of this report is to present to owners of mining properties a number of accurately determined geological landmarks, as guides in exploring for any given bed, and to establish an accurate base from which the Geological Survey may be prosecuted in Houghton and Keweenaw Counties on the one side, and toward Ontonagon on the other.

The chief portion of the present report is, therefore, to be found in the plates in the Atlas. I had intended to confine the text simply to the limits of the description of the cross-sections; but as many interesting observations were made which throw light on the age of the copper-bearing rocks, and on the distribution and manner of occurrence of the copper, I have thought they might very properly be added to the text.

The Survey is indebted to Mr. Pietrie, agent of the Central Mine, Mr. J. Chassells, Mr. Bolton, C.E., and Col. J. H. Foster, in many ways for aiding in its progress.

R. P.

CHAPTER I. ON THE AGE OF THE COPPER-BEARING ROCKS.

KEWEENAW POINT, from its beginning at the Montreal River to where its extreme point is beaten by the storms at the middle of the Great Lake, is formed by two, stratigraphically, and (for the greater part) lithologically, distinct formations. These are separated by a line dividing the peninsula longitudinally. On the eastern side of this line are beds of sandstone, sloping gently to the *south-east;* on the western side is an immense development of alternating “trappean" rocks and conglomerates, dipping to the north-west at an angle of 55° to 60° at Portage Lake, and of 23° to 33° at other points.

As the question of the relative age of these two formations has given rise to considerable discussion, I will give, as briefly as possible, the principal facts in the case, and certain observations made by Major T. B. Brooks and myself, which bear directly upon the subject. Both formations have been referred by Foster and Whitney to the Potsdam, by Sir William Logan to the Chazy, while Mr. Bell, of the Canadian Corps, considers the Cupriferous series to be Triassic, agreeing herein with Jackson and with the view afterwards abandoned by Owen.

The principal facts on the south shore of Lake Superior are as follows: A series of red sandstone and shales, lying everywhere nearly horizontally, borders the Michigan shore between the Sault St. Mary and Bête Gris Bay on Keweenaw Point. From the former place to west of Grand Island, this sandstone is overlaid on the south by other Silurian rocks, and between Grand Island and Marquette the whole series sweeps around to the south-west, on its way to form the western, as it had hitherto formed the northern rim of the great Michigan basin. Where this south-westerly bend begins, the outcrop-line of the sandstone divides, and from Marquette westward we find, with short interruptions, the sandstone beds flanking the northern foot of the Huron Mountains, and dipping gently, 5° to 15°, toward the trough of Lake Superior.

In this part of its course, where it may be said to belong to the Lake Superior basin proper, it forms a marginal band along the lake shore, varying in breadth from a few rods to one or two miles. But west of the Huron Islands it widens with the south-westerly curving of the topographical axis of the Huron mountains, and fills with its horizontal strata the broad trough lying between these hills and the range of copper-bearing rocks of Keweenaw Point. In this depression there still remain one or two hills formed by remnants of the younger Trenton limestone. The trough, partly occupied by the waters of Keweenaw Bay, has for its western slope the beds of this Lower Silurian sandstone, which rise, at what seems to be the original angle of deposition, from the waters of the bay, to form the broad belt of nearly level sandstone country, which makes up the eastern half of Keweenaw Point.

At the western edge of this belt, its nearly horizontal strata abut against the steep face of a wall formed by the upturned edges of beds of the Cupriferous series of melaphyr and conglomerate, which dip away from the sandstone, at angles of 40° to 60°, according to geographical position. This sharply defined and often nearly vertical plane of contact, having been seen by the earlier geologists at several points along a distance of many miles, and having been found to be often occupied by a thick bed of chloride fluccan, which was looked upon as the product of faulting motion, was considered as a dislocation.

This idea seemed to gain corroboration in the fact that, on the western side of Keweenaw Point, sandstones bearing considerable resemblance to those of the eastern horizontal beds occur, apparently conformably overlying the Cupriferous series.* Both sandstones came to be considered as identical in age, and as forming the upper member of the group.

There are many circumstances which make it difficult for us to accept this conclusion. One obstacle lies in the enormous amount of dislocation required, for instance, at Portage Lake, where the strata of the Cupriferous series, with an actual thickness of several miles, dip away from the supposed *longitudinal* fault at an angle of about 60°.

*It is not yet known whether these sandstones on the west side of Keweenaw Point are upper members of the Cupriferous series or belong to the Lower Silurian.

Again, there are at least two patches of sandstone lying on the upturned melaphyr beds near Houghton, though it was not easy to prove that they were not brought thither by glacial action. Mr. Alexander Agassiz informed me that he has found in the horizontal sandstones near this so-called "fault," abundant pebbles of the melaphyr and conglomerate of the Cupriferous series, a fact which I found abundantly confirmed on the spot.

Sir William Logan hints at a similar doubt as to the proximate equivalence in age of these two series of rocks.* But the most decided facts were gathered by Major Brooks and myself, during a reconnoissance of the country between Bad River in Wisconsin, and the middle branch of the Ontonagon, east of Lake Gogebic† in Michigan. Our route was chiefly confined to the surface of the upper member of the Michigan Azoic, which we have provisionally considered to be the equivalent of the Huronian.

From Penokie Gap, on Bad River, to near Lake Gogebic—a distance of nearly sixty miles—the quartzites and schists of this formation are tilted at high angles, and form a belt one-fourth to one-half mile in width, bordered on the south by Laurentian gneiss and schists. On the north it is everywhere overlaid by the bedded melaphyr (containing interstratified sandstones) of the Cupriferous series. These form ridges and peaks which rise 200 to 300 feet above the surface of the Huronian belt.

These ridges, forming the "South Mineral Range," unite at their western end with the Mineral Range proper, which forms really through its whole length the back-bone of the tongue of land known as Keweenaw Point. Between these two ranges lies the south-western part of the Silurian trough, which has been mentioned before as extending inland from Keweenaw Bay.

*Geol. of Canada, page 85. And again in Geol. Survey of Canada. Rep. of Progr., 1866-69, pp. 472-475. In the last-mentioned place, he protests strongly against the idea that the copper-bearing rocks of Lake Superior are Triassic.

†Wrongly written Agogebic on many maps.

Here, as there, it is filled with the horizontally stratified Silurian sandstone, forming a generally level country. For a distance of nearly thirty miles, between the Montreal River in Town 47 and Lake Gogebic, we found the Cupriferous series apparently conforming in strike and dip with the Huronian schists, and both uniformly dipping to the north at angles of 50° to 70°.* But in approaching Lake Gogebic from the west, we find that erosion of Silurian or pre-Silurian age has made a deep indentation entirely across the Cupriferous series and the Huronian, and into the Laurentian, so that at a short distance west of the lake these rocks end in steep and high declivities, at the base of which lies the level country of the Silurian sandstone, in which is cut the basin of the lake. From this point eastward, this ancient erosion had made great inroads upon the continuity of the Cupriferous and older rocks before the deposition of the Silurian sandstone. The melaphyr ridges are broken into knobs, or are wanting, and no Huronian was found as far as the Ontonagon River, seven miles away, and the limit of our observations.

On this river, in the centre of the north-west quarter of Sec. 13, Town 46, Range 41, the Silurian sandstone was found exposed in cliffs 50 to 60 feet high. The strata are horizontal, or at most have a barely perceptible tendency to a northerly dip. About 150 steps from the base of this cliff, there are outcrops of Laurentian schists whose bedding trends north-east toward the cliff of horizontal sandstone, and dips 45° to 60° south-east. The nearest observed outcrop of the Cupriferous series is in the south-east corner of Sec. 5, about four miles distant. It is a characteristic amygdaloidal melaphyr, whose bedding planes strike nearly east and west, and dip 50° to north. In general terms, the conclusions we are drawn to are these:

I. The Cupriferous series was formed before the tilting of the Huronian beds upon which it rests conformably, and consequently before the elevation of the great Azoic area,† whose existence during the Potsdam period predetermined the Silurian basins of Michigan and Lake Superior.

*We observed several dips in the Huronian of 25° to 40°, while in the overlying Cupriferous series none lower than 50° were found. While this may point toward non-conformability, the greater dip of the overlying beds would make it probable that the lower dips were of a local character and due to minor undulations in the Huronian.

†Islands of Laurentian gneiss, etc., existed in the Huronian sea over parts of this area.

II. After the elevation of these rocks, and after they had assumed their essential lithological characteristics, came the deposition of the sandstone, and its accompanying shales, as products of the erosion of these older rocks, and containing fossils which show them to belong to the Lower Silurian, though it is still uncertain whether they should be referred to the Potsdam, Calciferous or Chazy. The question would still seem to be an open one. whether the Cupriferous series is not more nearly related in point of time to the Huronian than to the Silurian.

Our observations have detected a lack of conformability between the Laurentian and Huronian, at several points on the Upper Peninsula. On the other hand, in the region we have been discussing, which is the only one where the Huronian and Cupriferous are seen in contact, there seems to be a well-marked concordance between these two. There is abundant evidence on the Upper Peninsula, that the Silurian sandstone was not deposited until after the Huronian beds had assumed both their present structural position and lithological characteristics, and after they had undergone an enormous amount of erosion.

Some of the most salient topographical features of the Upper Menominee had been sculptured to the depth of two hundred feet or more before that time, and were afterward buried and wholly obliterated by the Lower Silurian deposits, and have been partially restored by the subsequent erosion to which that valley now owes its features. We now find ridges, consisting of the nearly vertical beds of Huronian quartzite and iron ores, capped with the horizontal sandstone, of which last, patches still remain in place on the end and side declivities. Where the sandstone was deposited at the base of these cliffs, we find it consisting largely of a breccia of the debris of quartzite and iron ore, identical in character with these substances in the unbroken ledge. It would probably be perfectly safe to apply the same remark to the Cupriferous series. Its members were formed, as we have seen in the previous pages, before the elevation of the Huronian rocks. The deposition of the Silurian rocks bordering on Lake Superior, should seem to have taken place during the progress of a gradual depression, which caused the coast line of that part of the Silurian sea to be represented by the bold cliffs of the interior of the Azoic land. In the eastern declivity of the mineral range of Keweenaw Point, we may see, then, one of these shore cliffs instead of the exposed side of a gigantic fault.

It is probably to this process of deposition of the Silurian sandstone over an area, which, after having undergone an enormous amount of erosion, was being gradually submerged, that we owe the absence of outcrops of the Cupriferous series beneath the sandstone at so many points on the south shore. It would be difficult indeed to account for their total absence at L'Anse, for instance, by supposing them to have thinned out, when at a distance of eighteen miles they have a thickness measured by miles, a thickness they exhibit wherever they are known, at points hundreds of miles apart on the north and south shores.

CHAPTER II. ON THE LITHOLOGY OF THE COPPER-BEARING ROCKS OF THE PORTAGE LAKE DISTRICT.

In the immediate neighborhood of Portage Lake, the strata composing the "Mineral Range" have a uniform trend of north 35° east, and a nearly equally regular dip of 55° to 60° to west-north-west.

The series consists of beds of melaphyr, varying in thickness from twenty feet to more than one hundred feet, the demarkation being frequently defined by the amygdaloidal or epidotic character of the upper portion of each bed.

At intervals, varying from a few yards to several thousand feet, beds of conglomerate occur intercalated in the series.

This is the general character of the country near Portage Lake for a distance of about three miles, measured west-north-west across the formation.

Still farther west-north-west the rocks are little known, but seem to consist chiefly of sandstones and conglomerates.

The trappean rocks of Portage Lake occur uniformly in beds varying from a few feet to one hundred feet, or more, in thickness. Frequently an appearance of subordinate bedding is observable, arising, perhaps, from the existence of joints lying parallel to the plane of stratification, which divide the rock into plates a few inches to several feet thick.

The texture of the many varieties varies from compact and sometimes porphyritic, through fine-grained subcrystalline or earthy, to coarse-grained and distinctly crystalline. In individual beds, the texture is usually found to undergo a more or less gradual change from compact or granular at the bottom, to a vesicular or amygdaloidal condition, in the neighborhood of the hanging wall.

Green, of various shades, is the dominating color, and next to this brown and dirty red. Light and dark green, mottled or speckled with brown; dirty brownish-green; reddish-gray; and dark green, almost black, are the usual colors.

Even in the fresh state these rocks may be easily scratched with a knife, but they are exceedingly tough under the hammer, and the force which crushes a fragment often leaves the powder very firmly compacted.

The fracture is generally uneven, or hackly, to imperfectly conchoidal, but in the freshest, and especially in the compact varieties, it is often highly conchoidal. They have an earthy odor often even without having been breathed upon.

Some varieties yield a thick beard of a magnetic iron ore to the magnet, while others contain very little of this mineral.

The ingredients which are visible under the glass, and which seem to be common to all varieties, are a light *green triclinic feldspar*, apparently labradorite and chloride mineral of different shades of green, while the magnet reveals a very variable percentage of a magnetic iron; and in some of the coarser-grained varieties small jet black crystals, apparently of augite or hornblende, are occasionally visible. The accessory minerals observed, many or all of which are probably products of the alteration of the above constituents, are:

A brick-red foliaceous mineral resembling rubellan, occurring as very minute specks in some fine-grained varieties; it lends a soft rusty-brown appearance to the weathered surface, and speckles the interior with red.
Specular-iron in minute flakes, seemingly more frequent in the coarser-grained varieties.
Calcite in seams, and more frequently in grains and amygdules, especially in the amygdaloidal portion of the beds.
Epidote rarely crystallized; most common in the amygdaloidal varieties, but frequently in seams and impregnations, and nearly always associated with quartz.
Quartz which occurs in amygdules and seams, and also as an indurating medium near the hanging; wall of many beds.
Prehnite in amygdules and seams, mostly confined to the amygdaloidal portion of the beds.
A chlorite-like mineral, soft, compact, amorphous, greenish-black, sometimes altered to brick-red, occurring in grains from pin-head to walnut size.
A yellowish-green soft earthy mineral, probably a green earth.
Laumontite and leonhardite in seams and amygdules.
Analcite in amygdules.
Orthoclase in small crystals and massive; in amygdaloidal cavities.
Native copper sometimes in fine impregnations in the fine-grained rock, also in thin sheets in jointing cracks, but chiefly in the amygdules, masses, sheets and impregnations which form the metalliferous deposits in the amygdaloids, where it is occasionally associated with native silver.
Native silver.
Datholite massive in the amygdaloidal portion of some beds, and also in small aggregations of microscopical crystals in the same positions.

We have fortunately several recent analyses of different and typical varieties of these rocks, made by Mr. Thomas Macfarlane.*

Of one of the coarser-grained varieties which forms very thick beds several hundred feet west of the Quincy "vein," Mr. Macfarlane says: "It is distinctly of a compound nature, but all its constituent minerals are not large enough to be accurately determined. Conspicuous among them is a dark green chloride mineral, the grains of which vary from the smallest size to one-fourth of an inch in diameter. In the latter case they are irregularly shaped, with rounded angles, but they are never quite round or amygdaloidal [?]. They frequently consist in the centre of dark green laminæ. The mineral is very soft, and has a light greenish-gray streak. It fuses readily before the blowpipe to a black magnetic glass, and it would seem to be the preponderating element in the rock. The other constituents are in very fine grains, and consist of a reddish gray feldspathic mineral, with distinct cleavage planes, and another closely resembling it, in light greenish-gray particles, but whether of a feldspathic, pyroxenic or hornblendic nature could not be determined.

*Canadian Geological Survey, Report of Progress, 1863-1866, p. 149.

"The prevailing color of the rock is dark grayish-green. Hydrochloric acid produces no effervescence with it, even when in the state of fine powder. Its specific gravity is 2.83, and the magnet attracts a very small quantity of magnetite from its powder. The color of the powder when fine is light greenish-gray.

"When ignited it loses 3.09 per cent, of its weight, and changes to a light brown color. When digested with nitric acid, and afterwards with a weak solution of caustic potash (to remove free silica), it experiences, including the loss by ignition, a loss of 46.36 per cent. This consists of

Silica	14.73
Alumina	7.17
Peroxide of iron	14.87
Lime	4.47
Magnesia	2.03
Water	3.09
	46.36

"In the undecomposed residue light-red and dark-colored particles are discernible. On digesting it with hydrochloric acid, and subsequently with a weak solution of potash, it sustains a further loss of 10.6 per cent., which consists of

Silica	3.48
Alumina	3.03
Peroxide of iron	1.98
Lime	1.76
Magnesia	.35
	10.60

"The undecomposed residue was still found to consist of a light-red and a dark-colored constituent. The latter was the heavier, and an approximate separation was accomplished by washing. The dark-colored particles, which could not, however, be freed wholly from the light-colored feldspathic constituent, fused readily to a dark-brown glass. To judge from its gravity and fusibility, it would not appear unreasonable to regard it as either pyroxene or hornblende. In quantity it did not, however, exceed one-eighth of the feldspar. The latter fused easily before the blowpipe to a colorless glass, tinging the flame strongly yellow. It would therefore seem to be of the nature of labradorite, although it is only slightly decomposed by hydrochloric acid. Since, according to Girard, neither labradorite, pyroxene nor magnetite are decomposable by nitric acid, it may reasonably be concluded that the constituents removed by the nitric acid are those of the chloritic mineral. On treating the rock previous to ignition, much of the iron is removed as protoxide.

"Although some peroxide is also possibly present, I have calculated the whole of the iron as protoxide, and have, moreover, added the difference of the weight between it and the iron estimated as peroxide to the loss sustained by ignition, and put it down as water. In this way the composition of the chloritic mineral, calculated to 100 parts, would be

Silica	31.78
Alumina	15.47
Protoxide of iron	28.87
Lime	9.64
Magnesia	4.37
Water	9.87
	100.00

"In these figures the quantity of iron is much greater and that of magnesia much less than in ordinary chlorite. In its composition, and in being easily decomposed by acids, the mineral most closely resembles the ferruginous chlorite of Delesse (the delessite of Naumann), but differs from it in containing a considerable amount of lime, and in being readily fused before the blowpipe. Assuming, nevertheless, that the chloritic constituent is delessite, and that one-half of the iron removed by hydrochloric acid belongs to the magnetite, then the rock would be composed mineralogically of

Delessite	46.36
Labradorite	47.43
Pyroxene or hornblende	5.26
Magnetite	0.95
	100.00"

By the same method of analysis, Mr. Macfarlane found the rock underlying the copper-bearing bed of the Quincy mine to consist of

Delessite in amygdules and grains	38.00
Labradorite	62.00
	100.00

This rock is distinctly amygdaloidal. "The matrix is fine-grained, but it is crystalline, and is seen to consist of different constituents. Its color is dark reddish-gray." Its cavities, rarely the size of a pea, are filled with what seems to be the same chloritic mineral which occurs as a constituent of the rock above described.

Mr. Macfarlane also examined the rock which overlies the Albany and Boston conglomerate at the Albany and Boston mine. "It is a fine-grained mixture of dark-green delessite, greenish-gray feldspar, and reddish-brown mica, some of the laminæ of the latter showing ruby-red reflections. Its specific gravity is 2.81, and the smallest trace only of its powder is attracted by the magnet." He considers the mineralogical composition of this rock to be

Delessite	40.00
Mica	20.00
Labradorite	40.00
	100.00

The rocks to which the above given analyses refer are representatives of the three predominating types of the melaphyr of Portage Lake. Mr. Macfarlane's results agree very closely with my own observations on several hundred specimens, aided by the blowpipe and examination of external characteristics.

Everything goes to show that the normal, essential constituents of these rocks are, in their present condition, a triclinic feldspar, probably labradorite, and a ferruginous chlorite closely allied to delessite. This composition places these rocks among the typical melaphyrs, the greater specific gravity of the Portage Lake varieties being accounted for by the fact that the sp. gr. of delessite is 2.89, while that of ordinary chlorite ranges from 2.65 to 2.78.

Although the name melaphyr is an unfortunate one, having been first used to designate an entirely different rock, and having been successively applied to others of very various characters, it is now the only distinctive name for the class we have under consideration. All the trap rocks and associated amygdaloids of Portage Lake are varieties of melaphyr.

But I do not doubt that any one who will carefully study the melaphyrs of Portage Lake, and compare them with their equivalents in Keweenaw County, will feel convinced that the melaphyr owes its distinctive character to a process of metamorphism, in which the chlorite resulted, largely or wholly, from the alteration of hornblende or pyroxene. In the more distinctly crystallized traps of Keweenaw County, the pseudomorphic occurrence of chlorite after the hornblende or pyroxene constituent of the trap, may be traced through all the stages to a complete replacement of the latter by chlorite.

The principal varieties of melaphyr on Portage Lake are:—

1. *Coarse-grained;* in which the crystals of feldspar and grains of delessite are more or less distinct. The color is greenish-gray. It contains generally grains of magnetite and small tabular crystals of specular iron.

2. *Fine-grained;* the constituents, light-green or reddish triclinic feldspar and dark-green delessite, are sometimes distinguishable, but more generally they are not so. The usual color is grayish-green, but it sometimes is speckled with brown, through the presence of small flakes of rubellan; or mixed green and brown, from the oxide of iron produced in the decomposition of some of the constituents. As a rule, the greater the amount of rubellan the less there seems to be of magnetite. In some instances, especially in some of the beds east of the Isle Royale copper-bearing bed, the rock is fine-grained and subcrystalline, brilliant black-green, sometimes purplish; slightly shimmering; easily scratched with the knife; contains considerable magnetite, small pieces of rock adhering to the magnet. It weathers rusty gray.

3. *Melaphyr-porphyry;* dark-green, often nearly black; compact, with perfect conchoidal fracture; very hard; contains minute crystals of triclinic feldspar.

AMYGDALOIDS.

The amygdaloids are merely varieties of the melaphyr. On Portage Lake they always form the upper or hanging-wall portion of beds of trap, into which they pass by a more or less gradual transition.

It is rare that one finds a bed of trap which does not contain, here and there, scattered segregations of secondary minerals, especially delessite, but often calcite, laumontite, quartz, or chalcedony, or prehnite, occupying cavities which are often well defined and spherical or ovoidal, but sometimes wholly irregular in shape, and without definite walls. These enclosures usually become more frequent in ascending from the foot-wall of a bed toward the hanging wall. The plane of demarkation between the amygdaloidal upper portion of a bed and the overlying rock is always well defined. Where they are sufficiently numerous to impress a distinctive character upon the rock, while at the same time the matrix retains the essential features, in regard to color and texture of the parent trap, I have designated the variety

AMYGDALOIDAL MELAPHYR.

All the varieties of melaphyr on Portage Lake are subject to this modification, but there is a considerable variation among different beds in regard to the nature of the minerals in the amygdaloidal cavities. In all the varieties, amygdules of delessite, or calcite, or quartz coated with delessite, or again spots of epidote, occur here and there in the body of the rock. In some beds the rock is characterized throughout by the presence of laumontite in small amygdules and minute seams.

In the belt occupying 1,000 feet or more on either side of the Isle Royale copper-bearing bed, many of the beds assume towards the top amygdules of delessite and of a green flinty mineral, resembling chrysoprase, coated with delessite. These are gradually succeeded nearer the top by ovoidal, lenticular, or irregular amygdules, from the size of a bean to several inches in diameter, of prehnite, greenish-white, or tinged with pink generally amorphous, but often with a radiating structure, and sometimes slightly impregnated with native copper.

The portion of the bed nearest the hanging wall is often highly amygdaloidal, while the matrix has at the same time a different degree of hardness, texture and color, and often a different mineralogical constitution from the parent trap. These varieties form the

AMYGDALOIDS PROPER.

The amygdaloids are the most highly altered form of the melaphyr, and present themselves under a variety of characters in different beds and in different parts of the same bed. The colors of the matrix are different shades of brown or red, and of green, or of these mixed; its texture varies from fine-grained or sometimes subcrystalline to compact; and its hardness ranges from that of limestone to that of quartz.

Two quite different kinds of amygdaloid occur on Portage Lake, both separately, and intimately associated in the same bed, and are easily distinguished by their different colors, the one being brown and the other green.

The brown, which exhibits the amygdaloidal character in its highest development, has a chocolate-brown to dirty red matrix, which generally is easily scratched with the knife, but is sometimes indurated and hard; it has a fine-grained to subcrystalline texture, and now and then contains minute reddish crystals of feldspar, and fuses easily to a dark-green and somewhat magnetic glass.

The amygdules in this variety are more generally spherical, but often somewhat irregular and connected, and more rarely long-cylindrical, and then usually perpendicular to the plane of bedding. The contents of these cavities, for they are very rarely empty, are laumontite, leonhardite, calcite, quartz, a soft green mineral, apparently green-earth, delessite (more rarely), native copper, epidote, prehnite, analcite, orthoclase. In places one, in others another, of these predominates; generally several are associated.

The green variety is a very fine-grained to compact light grayish-green rock. It is generally very hard, striking fire under the steel. Its constituents are very largely free silica, and a green mineral which has been generally taken for epidote, but which is so .minutely disseminated as to render it difficult of determination. Small pieces of the rock fuse easily on the edges to a dark enamel which gelatinizes with acids. These beds are called epidote “veins," and they are probably, in many instances, at least, an intimate mixture of quartz and epidote, though in otherwise nearly similar beds the green mineral is soft, and is probably either a green-earth or a chlorite. The cavities in this variety are often less regularly defined in shape than in the brown amygdaloid. The enclosed minerals are quartz, epidote, calcite, delessite, prehnite, laumontite, green-earth, analcite, native copper, orthoclase. These two varieties of amygdaloids often occur together without any well defined lines of separation, the bed being made up of irregular masses of the two rocks. In places, however, the brown amygdaloid forms a band one to two feet thick on the hanging wall, with a rather abrupt transition into the green amygdaloid underlying it; I have never observed the reverse.

Some beds have an exceedingly mixed character; the amygdaloidal portions are associated with massive segregations of calcite, quartz and epidote, and are traversed by seams and irregular veins of these minerals; this structure is especially noticeable in the beds worked for copper. A somewhat similar structure occurs in other beds on a smaller scale, giving to them a brecciated or even a conglomerate-like appearance, which seems, however, to be due to purely metamorphic action; the best example of this is in the "Ancient Pit" bed, on the Shelden and Columbian property.

CONGLOMERATES.

The conglomerates of Portage Lake differ from each other but little, if at all, in lithological characteristics. The pebbles vary from the size of a pea to one foot or more in diameter, being coarser in some beds than in others. The different beds vary in thickness from mere seams to several hundred feet, and the same bed often varies greatly in width.

The pebbles, in most of the beds on Portage Lake, consist almost exclusively of varieties of non-quartziferous felsitic porphyry; two kinds predominate; one of these has a chocolate-brown to liver-brown, subcrystalline to compact almost vitreous matrix containing very scattered minute crystals of triclinic feldspar of the same color as the base. The other and rarer variety, also non-quartziferous, has a chocolate-brown, compact to minutely crystalline matrix, in which lie crystals, 1/8 to 1/2 inch long, of a flesh-colored triclinic feldspar.

In some beds there appear pebbles of a flesh-red rock, composed almost entirely of granular feldspar, containing small specks of a black undetermined mineral. In some instances the feldspar is wholly triclinic, in others the twin-striation is frequently absent. This variety of pebble is altogether absent in some beds, at least where they are opened, while in others they predominate, as in the Albany and Boston Conglomerate. Pebbles of compact melaphyr, and of melaphyr amygdaloid also occur, but are quite subordinate in number to those already enumerated.

The normal form of cement is a fine-grained sandstone, composed apparently of the same material as the pebbles. Often the cement is very subordinate in volume, the pebbles touching each other. Frequently, however, the reverse is the case, and often, the sandstone forms layers from less than an inch to many feet in thickness.

The original character of the cement is often entirely lost; the interstices between the pebbles are sometimes, though rarely, empty; in places, the sand is associated with oxide of iron, chlorite, a white talc-like mineral, and carbonate of lime, or it is entirely replaced by calcite, chlorite, epidote or even native copper.

It is a remarkable fact that while all the conglomerate beds near Portage Lake are free from pebbles of quartz-porphyry, those in the neighborhood of Calumet are characterized by pebbles rich in grains of quartz. This abrupt change takes place about six miles northeast from the lake.

Different horizons of the Portage Lake series of rocks are marked by certain distinguishing lithological characteristics, which, without in any instance being peculiar to a given horizon, still serve to mark decidedly those parts of the series where they are, respectively, most frequent.

Thus, to begin toward the eastern part of the field, from the neighborhood of "Mabbs' vein" to within, say, 1,000 feet east of the Isle Royale "vein," there is a tendency, among the different traps, to a compact or fine-grained texture with a dark-green, almost black color, sometimes slightly mottled, especially on the weathered surface. The fracture is brilliant, and the trap contains enough magnetite to cause small bits of the rock to adhere to the magnet.

From this region till 1,500 feet or more west of the Isle Royale copper-bearing bed, the upper portions of very many of the beds have the amygdaloidal cavities filled with a light-greenish white or pale pink prehnite, which sometimes, for a width of 2 to 6 feet, form from 10 to 40 per cent, of the rock, and lend it a very characteristic spotted appearance.

During the next 2,000 feet or more, the traps have frequent seams 3 to 20 inches thick, consisting of distinctly individualized triclinic feldspar, delessite, prehnite and specular iron; these occur both parallel to the plane of bedding and oblique to it. The traps through a portion of this distance are frequently impregnated with epidote, as is also the cement of the conglomerate beds.

On the "Dacotah" property we come to a belt of the formation in which many beds have a tendency to a coarse-grained, crystalline texture, and in some, the character is highly developed, giving the rock, at a distance, almost the appearance of a chloride granite. Still farther west, on the "Southside" property, the brown amygdaloids often present a scoriaceous appearance which is quite characteristic.

Some, at least, of these features are traceable for miles in the longitudinal extension of the zones in which they occur. Thus, the prehnite amygdaloid of the Isle Royale series is found in the northeast extension of this zone, near where the road to Eagle River crosses the line between Townships 55 and 56 north, or about 7 miles from Portage Lake.

The coarse-grained melaphyr of the "Dacotah" is found extensively developed in the extension of the same zone on the South-Pewabic, Quincy and St. Mary's properties. The brown amygdaloids of the "Southside" reappear with their peculiar scoriaceous structure in the South-Pewabic and Hancock beds, and in the trenches on the St, Mary's, and are unquestionably the equivalents of the "Ash-bed" rocks of Keweenaw County, which they resemble.

CHAPTER III.
PARAGENESIS OF THE MINERALS ASSOCIATED WITH COPPER.

(*With a Comparative Table.*)

NO. 1. CAPEN VEIN.—This is apparently a true fissure vein. It occurs in a compact and very tough melaphyr, which is exceedingly chloritic near the vein. All the joints within a distance of several yards from the vein are covered with a coating $^{1}/_{10}$ to 1/2 inch thick, of dark-green and bluish-green chlorite, having a combined fibrous and foliated structure oblique to the joint surfaces. The melaphyr is rich in magnetite. Sheet copper was found in mining, but not in paying quantity.

1. *Laumontite*, in thin seams.

2. *Prehnite*, in seams which cut through those of laumontite, also between symmetrically arranged bands of laumontite.

3. *Chlorite*, as destroyer and replacer of prehnite, and as lining of cavities in the latter.

4. *Analcite*, in clear crystals on the prehnite and chlorite.

5. *Calcite*.

NO. 2. HURON MINE.—1. *Laumontite*, in thin crystalline bands on the sides of a cavity; the free ends of the opposed crystals nearly meet.

2. *Prehnite*, filling the space between the bands of laumontite.

NO. 3.* COPPER FALLS MINE.—Fissure vein. 1. (?) *Natrolite*. 2. *Laumontite*. 3. *Analcite*.

*Taken from a list given by Hilary Bauerman, Quart. Journ. Geol. Society, Nov., 1866.

NO. 4. PHŒNIX MINE.—(Fissure vein.)

1. *Datholite*, on rock.—2. *Calcite*, scalenohedrons on the datholite.—3. *Feldspar*, crystals on both the datholite and calcite.—4. *Apophyllite*, in very clear crystals on datholite, calcite, and feldspar.

NO. 5.* BAY STATE MINE.—1. *Prehnite*. 2. *Quartz*. 3. *Copper*. 4. (?) *Laumontite*.

NO. 6. * PHŒNIX MINE.—Fissure vein. 1. *Laumontite*. 2. *Quartz*. 3. *"Green-Earth"*

NO. 7.* BAY STATE MINE.—Fissure vein. 1. *Quartz*. 2. *Apophyllite*. 3. *Calcite*.

NO. 8.* BOHEMIAN MINE.—1. *Analcite*. 2. *Copper*. 3. *Orthoclase*.

NO. 9. AMYGDALOID MINE.—Fissure vein. 1. *Prehnite*, in its characteristic reniform shape.

2. *Quartz*, in small crystals on the prehnite.

3. *Analcite* crystals, covering the quartz.

4. *Orthoclase* crystals, on the analcite and quartz.

NO. 10. BAY STATE MINE.—Fissure veins. On the soft brown gangue: 1. *Analcite*, lining part of a vugg. The crystals are 1/4 inch in diameter, often white and transparent, but very much fractured. Near the contact with the rock they are often reddened internally and much altered, and then surmounted by the next member.

2. *Orthoclase*, in the usual minute crystals, some of which are scattered over the altered analcites.

NO. 11. AMYGDALOID MINE.—Fissure vein. 1. *Prehnite*, in the characteristic reniform shape, forming the body of the specimen; fresh-looking on the free surface, but on the under broken side somewhat porous, with earthy fracture, and then rather intimately associated with datolite and a soft green (chloritic?) mineral.

2. *Copper*, in films traversing the prehnite, and moulded to the reniform surface. While the under surface of the copper bears the impression of the prehnite, the upper surface, now free, bears that of some mineral that is gone ; threads of copper rising from this free surface ¼ inch are crystallized at the tips, where they stood above the mineral that has disappeared.

3. Minute grains of a hard yellowish-white mineral, sprinkled like meal over the prehnite and copper ; under the microscope appear to consist of sheaf-like clusters of minute rhomboidal plates; fuses with difficulty.

4. *Datolite*, in microscopic crystals on No. 3; others, one line in diameter, rosy, with suspended flakes of copper, lie upon the prehnite.

NO. 12. AMYGDALOID MINE.—(Fissure vein.) On the gangue—here chloritic—lie, 1. *Calcite*, imbedded between the gangue and No. 2.

2. *Prehnite*, forming the greater part of the specimen, and having a tolerably fresh lustre.

3. *Copper*, in grains, flakes and threads conforming to the radiating cleavage planes of the prehnite.

4. *Datolite;* compact amorphous, white, translucent mass, covering the prehnite with a layer of which ¾ inch thickness still remains. The copper threads do not penetrate it.

NO. 13. PEWABIC COPPER-BEARING BED.—This specimen—about 21/2 inches by 31/2 by ¾—is evidently from the interior of a druse, to whose wall it was attached by only a small part of its surface. The body of the specimen is copper, very cavernous, much of it pseudomorphous after laumontite. The copper is very thickly bestrewn with small green crystals of quartz—prisms terminated at both ends—which are, however, *older* than the copper. On the sides and around the edges of the specimen there are beautifully modified scalenohedrons of calcite. The successions are:

1. *The rock or mineral* to which the laumontite was originally attached, and which has disappeared.

2. *Laumontite* or leonhardite; has also disappeared; the prisms were 1/8 to ½ inch long, terminated at one end with a hemidome.

3. *A mineral*, now gone, which must have been present to sup-port the quartz crystals (see Quartz). It may perhaps have been the alteration-product of the laumontite or an enclosing mineral."*

4. *Quartz*, in prisms $^1/_{20}$ to $/_5$ inch long, often terminated at both ends. They occur on parts of nearly every one of the pseudomorphs after laumontite; the copper is moulded to them, giving casts even of the striæ on the prisms, and they frequently pass entirely through the pseudomorphs after laumontite, so that the two ends of a quartz prism frequently just appear on opposite sides of the pseudomorph and transmit light. In some instances, the quartz crystals are so numerous as to touch each other, but they are often wholly isolated, and supported only by the copper which is younger.

The quartz crystals contain minute, brilliant particles of copper, wholly isolated, in the interior.

*Laumontite crystals often occur enveloped in younger calcite, except at the base.

5. *Copper*, in the form of laumontite, preserving often the sharpness of the angles and smoothness of the faces of the original mineral, when seen by the naked eye; under the glass the surface is less even. The pseudomorphs are not solid copper, as will appear in describing other specimens.

6. *Chlorite?* a soft, light-green mineral in minute hemispherical forms, with radiating structure, scattered over the quartz and copper. Wherever this mineral lies upon the quartz crystals, these are more or less penetrated by it, and some of them are eaten through and through to such an extent that the crystalline form is no longer recognizable.

7. *2d Copper and Calcite;* Calcite crystals—scalenohedrons—1/8 to ¾ of an inch long, lie on the sides and around the edges of the specimen. These crystals, in forming, adapted themselves with partially entering faces to the rough surface of the preexisting quartz and copper. Some of the calcite crystals contain brilliant isolated films of copper, which must have been formed at least after the calcite had begun to crystallize, and is therefore younger than the copper previously mentioned.

8. *Datolite*, in exceedingly minute crystals, lying on both the chlorite and calcite; they are less than $^1/_{200}$ inch in diameter, but the datolite form is distinctly visible under the microscope; they fuse easily with the characteristic green flame.

NO. 14. PEWABIC COPPER-BEARING BED.—1. *The rock* or mineral to which the laumontite was originally attached, which has disappeared, copper now forming the support of all the members.

2. *Laumontite*, of which only the form now remains.

3. *A mineral*, now gone, which seems necessarily to have been present to support the isolated crystals of quartz.

4. *Quartz*, in minute prisms, containing brilliant particles of copper.

5. *? Calcite*, represented only by impressions in the copper. This calcite may, perhaps, be older than some of the foregoing members.

6. *Copper*, now forming the body of the specimen. It is very cavernous, and besides forming in places pseudomorphs after laumontite, it is the support of every member of the series. That it is younger than the quartz crystals is shown by the fact that on removing these, perfect casts of them are visible in the copper. The copper also contains impressions of calcite crystals (see above).

7. *Chlorite?* the same mineral as the 6th member of No. 13, and occurring in the same manner.

8. *Calcite;* a few small scalenohedrons planted on the copper in the impressions of the older calcite - 5th above.

NO. 14 (*a*). *Copper after laumontite*, from the PEWABIC COPPER-BEARING BED.

The upper face of this specimen is part of a partially filled cavity in a cupriferous and highly altered amygdaloid; the lower or broken face is a portion of the altered amygdaloid itself. The general appearance of the specimen at first glance is that of a drusy cavity, nearly filled, except in the middle, with broken crystals of calcite, whose interiors contain many thin plates and threads of native copper.

The amygdaloid is a soft compact brown and green rock with earthy fracture—an altered amygdaloidal melaphyr. The small amygdules near the wall of the larger cavity are of calcite.

The pseudomorphs of copper after laumontite are prisms 1/8 to 1/2 inch long and about 1/8 of an inch square, and are terminated with a hemidome; they are each attached by one end to the wall of the cavity and project out toward the interior. The angles are often sharp, though in some instances the junction of two faces of a prism presents something of the appearance of a copper cast made in a mould whose two halves fit only imperfectly together. Sometimes, under a strong glass, the joining is clearly imperfect, and the pseudomorph has the effect of a prism built with four badly-soldered plates of metal.

Minute prisms of quartz (colored green by the chlorite-like mineral mentioned in specimens No. 13 and 14) project from the interior of the pseudomorphs, through the copper, to $^1/_{100}$ of an inch above the surface.

In one place I cut to the depth of $^1/_{12}$ of an inch in solid copper; but a cross fracture in another prism showed that the copper was, there, a mere superficial film, while the interior was occupied by a confused and rather porous mass of quartz prisms, copper, and the green chlorite-like mineral mentioned above. It is these quartz crystals whose ends just pierce the copper coating. In some instances, a prism of quartz terminated at both ends passes entirely through the pseudomorph and appears on both sides, and allows the light to pass through. After removing a quartz crystal from the copper, a perfect cast, even to the horizontal prism-striæ, is found in the copper.

The copper-surface of the pseudomorphs seems nearly smooth to the naked eye, but under a strong glass it appears not only often perforated with holes, but it often shows flakes of copper rising on edge to a height of $^1/_{100}$ of an inch above the face.

These pseudomorphs before the breaking of the specimen were imbedded in the interior of scalenohedrons of calcite, except at the attached ends of the prisms. At the contact planes between the calcite and the pseudomorphs, the former seems to adapt itself fully to all the irregularities of surface of the latter.

On the bottom of the specimen the calcite amygdules exhibit marked signs of change to datolite. The transparent crystals become gradually opaque, with a pearly lustre on the cleavage planes, and a little farther away this condition merges almost insensibly into a lustreless white mass composed of an aggregation of exceedingly minute crystals, which exhibit the datolite form under the microscope, and fuse easily with the characteristic green flame before the blowpipe. The same change is visible, in places, on the crystals of calcite enveloping the pseudomorphs after laumontite.

The relative ages here appear to be, 1, *The amygdaloid*, though probably not in its present condition; 2, *Laumontite;* 3, *Quartz;* 4, *Copper, chlorite-like mineral;* 5, *Calcite;* 6, *Datolite*.

NO. 14 (*b*). *Another specimen* from the same locality exhibits—besides pseudomorphs of copper after laumontite—pseudomorphs of quartz after laumontite. In these last, the ends of the pseudomorphs are broken off, leaving only the prism. The faces are formed by a tolerably even mass of quartz, on the outer surface of which a crystalline form appears here and there under the glass. The interior of the prism is not a compact mass of quartz, but is merely filled with quartz prisms projecting from all sides toward the middle, and containing minute brilliant and isolated particles of copper.

Near these are the copper pseudomorphs; they are mere hollow shells, scarcely as thick as paper; the angles are sharp and the faces tolerably smooth, but often pierced with holes. The hemidome of one of these is studded with the ends of minute quartz prisms, which occupy the interior of that part of the pseudomorph and project through the copper shell.

In this specimen, also, some of the pseudomorphs are imbedded in scalenohedrons of calcite, which sparkle with brilliant particles of copper swimming in the transparent crystals.

In these remarkable pseudomorphs, the quartz is undoubtedly the oldest existing intruder, while the copper, which far more generally preserves the crystalline form of the laumontite, seems to be pseudomorphous in, at least, the second degree of removal. Yet in nearly all instances the older quartz is present, occupying a part of the space originally belonging to the laumontite crystal; and very often these quartz crystals are wholly separate from each other and supported only by the younger copper. Something which is now gone must have existed to perform this office of support before the copper was deposited.

NO. 15. "RAGGED AMYGDALOID," ALBANY AND BOSTON M.—On the rock lie: 1, *Prehnite*—2, *Orthoclase*, in minute crystals on the prehnite.

NO. 16. "EPIDOTE LODE," ST. MARY'S.—In a cavity in the quartz-epidote rock, which forms a frequent feature of this bed, lie: 1, *Prehnite* crystals, disposed as a reniform lining of the cavity—2, *Quartz*, in transparent prisms on the prehnite—3, *Analcite*, crystal 1/2 inch in diameter, slightly opaque and somewhat cavernous internally, planted on the quartz—4, *Orthoclase* crystals planted on the prehnite, quartz, and analcite.

The prehnite is partially altered, containing cavities lined or filled with a soft green mineral, chlorite or green-earth. There is also a greenish-yellow chlorite-like mineral which incrusts and has eaten away the surface of the quartz crystals.

NO. 17. AMYGDALOID ON THE KEARSARGE LOCATION.—On the rock lie: 1, *Prehnite*—2, *Quartz* on the prehnite.

NO. 18. HURON MINE.—On the rock lie: 1, *Analcite*, in a continuous band 1/2 inch thick, crystallized on the inner face; it is reddish and perhaps much altered, though still hard—2, *Calcite* incrusting the analcite crystals, and occupying cavities in their interior.

NO. 19. ALBANY AND BOSTON AMYGDALOID.—The rock of this bed is a wholly irregular mixture of hard light-green amygdaloid, and soft-brown amygdaloid, in which the vesicular form is frequently lost, from the fact that the cavities containing secondary minerals have extended and become merged together, forming a confused patch-and-vein structure: 1, *Prehnite*, amorphous and altered to a slightly cavernous appearance on the surface—2, *Quartz* in prisms—3, *Orthoclase* in minute crystals chiefly on the altered prehnite, with which its formation is probably connected, and also on the quartz.

NO. 20. SAME BED.—On the amygdaloid, which contains quartz amygdules, lie: 1, *Prehnite* penetrated with strings and films of copper—2, *Quartz* in prisms; *Chlorite-like mineral* in hemispherical forms, with radiating structure; *Orthoclase* in minute crystals; all these lie separately on the prehnite—3, *Calcite* covering all the above-mentioned members.

NO. 21. SAME BED.—1, *Quartz* in prisms—2, *Chlorite-like mineral* in hemispherical forms, with radiating structure; wherever it is in contact with the quartz it has pitted it and eaten into it—3, *Calcite*.

NO. 22. SAME BED.—On the amygdaloid lie: 1, *Prehnite* crystals in reniforn masses—2, *Quartz*, in prisms on the prehnite crystals—3, *Orthoclase; Calcite;* the orthoclase is in minute crystals on the prehnite and quartz.

NO. 23. SAME BED—The amygdaloid on which the following succession occurs consists of quartz and chlorite, and is wholly altered, so much so that the quartz which now composes a large part of it is evidently of the same age as that which follows the prehnite: 1, *Prehnite*, in crystalline reniform masses—2, *Quartz* prisms—3, *Copper* in cubes, with octahedral modifications, planted on, and moulded to, the quartz crystals.

NO. 24. SAME BED.—1, *Prehnite*—2, *Quartz*—3, *Calcite*.

NO. 25. SAME BED.—*Analcite* in pellucid crystals—2, *Calcite; Orthoclase;* in this specimen the analcite appears to have incrusted some mineral which has disappeared, and the feldspar crystals occur in the cavity thus formed as well as on the outer surface of the analcite.

NO. 26. SAME BED.—1, *Prehnite*—2, *Quartz*—3, *Copper*, in threads often moulded to the quartz—4, *Orthoclase* in minute crystals planted on the prehnite, quartz and copper.

NO. 27. SAME BED.—1, *Prehnite*, penetrated with copper threads—2, *Quartz* in prisms—3, *Chlorite-like mineral* mentioned in Nos. 20 and 21; here also it has eaten into the faces of the quartz crystals—4, *Analcite* crystals, much fractured and eaten away, and sometimes quite hollow.

NO. 28. SAME BED.—1, *Prehnite* in places cavernous—2, *Quartz* in prisms in the cavities in the altered prehnite—3, *Orthoclase* crystals planted on the quartz.

NO. 29. SAME BED.—1, *Prehnite*—2, *Copper* traversing the prehnite in the form of threads, etc., ending in crystals which adapt themselves to the crystalline surface of the prehnite.

NO. 30. SAME BED.—1, *Prehnite*—2, *Analcite*—3, *Copper* in flakes on the analcite—4, *Orthoclase; chlorite-like mineral*.

NO. 31. SAME BED.—*Quartz* in prisms—2, *Orthoclase* crystals, planted on the quartz.

NO. 32. SAME BED.—1, *Prehnite*—2, *Copper* in crystals whose under surfaces are moulded to the crystalline surface of the prehnite.

NO. 33. HURON MINE.—On the amygdaloid containing smaller amygdules of delessite and quartz, lie: 1, *Laumontite*, a crystalline layer with projecting crystals—2, *Calcite* crystallized upon and wholly enveloping the laumontite crystals.

NO. 34. WESTERNMOST ADIT ON THE "SOUTHSIDE."—1, *Analcite*, in opaque crystals 1/8 to 1/2 inch in diameter—2, *Orthoclase* crystals planted on the analcite. (The rock containing this is chocolate-brown, and filled with small amygdules of 1st, Laumontite, 2d, Calcite).

NO. 35. "RAGGED AMYGDALOID." ST. MARY'S.—This is a soft brown amygdaloid with brown streak, in which the cavities have assumed the most irregular shapes, and merge into each other in a manner which gives to the rock a highly brecciated appearance. The cavities are generally partially open at their wider points; and the minerals occupying them are chiefly the following, often accompanied by a white clay: On the rock lie, 1, *Analcite*—2, *Orthoclase* crystals on the analcite—3, *Calcite* over both the foregoing members.

NO. 36. SAME BED.—On the rock lies *Calcite*. *Orthoclase* crystals on the calcite.

NO. 37. SAME BED. On the rock are scattered: 1, *Analcite* crystals—2, *Calcite* on the analcite.

NO. 38. SAME BED.—1, *Analcite* in large crystals; much altered—2, *Orthoclase* crystals planted upon the outer surface of (and in cavities in) the analcite.

NO. 39. PEWABIC COPPER-BEARING BED.—On the amygdaloidal rock lie: 1, *Calcite; Copper*—2, *Datolite* in a granular mass incrusting the calcite crystals.

NO. 40. SAME BED?—1, *Calcite* in scalenohedrons—2, *Datolite*, a granular mass of microscopical crystals. Here the datolite has partially displaced the calcite; only the points of the crystals of the latter were exposed, all the rest being imbedded in the younger datolite. These free-standing points remain perfect in glance and form, while wherever the calcite crystals are in contact with the datolite, their surfaces are roughened and perceptibly eaten into. The calcite crystals rest upon a granular mass of the same variety of datolite, which is perhaps the result of a displacement of calcite.

NO. 41. "EVERGREEN BLUFF."—1, *Quartz* prism—2, *Orthoclase* in minute crystals—3, *Calcite* in simple and twin scalenohedrons.

NO. 42. "AMYGDALOID" MINE.—(Fissure vein), 1, *Copper*—2, *Compact datolite.*

NO. 43. SAME VEIN.—1, *Prehnite* in its characteristic form—2, *Copper* conforming to the radiating cleavage-structure of the prehnite—3, *Datolite*, compact.

NO. 44. LOCALITY UNKNOWN.—1, *Prehnite* in its characteristic form—2, *Quartz* in prisms on the prehnite—3, *Analcite* crystals on the quartz—4, *Orthoclase* crystals on the analcite.

NO. 45. WESTERNMOST ADIT. "SOUTHSIDE."—Small amygdules consist of: 1, *Laumontite*—2, *Quartz* surrounded by the laumontite.

NO. 46. MICHIGAN MINE.—(Fissure vein). On the veinstone, which is here a greenish-gray, hardened clay-like material with flakes of chlorite and copper, and which becomes brown and soft near the contact with No. 1, lies: 1, *Datolite* in a uniformly distributed layer $^{1}/_{10}$ of a line to 2 lines thick, with the free surface highly crystallized. The crystals are transparent and rose-colored from the presence of minute particles of copper. The datolite appears quite fresh, and the copper seems to be confined to it—2, *Calcite*, four small slightly yellowish semi-transparent rhombohedrons, modified with steeper scalenohedron faces, lie upon the datolite—3, *Orthoclase*, yellowish crystals, $^{1}/_{20}$ of an inch long, are scattered over the surface of the specimen, some lying upon the calcite and some upon the datolite.

NO. 47. MANY LOCALITIES.—1, *Prehnite*—2, *Delessite*. The prehnite which occurs as the solid filling of amygdaloidal cavities in the upper part of many beds, is subject to alteration to chlorite. It is very common to see the prehnite soft and green to a slight depth from the outer surface of the amygdule, without any line of separation between this portion and the hard centre; and in the interior the prehnite often passes gradually into spots and flakes of chlorite. In these amygdules the prehnite is characterized by a radiating structure starting from a single centre. It is along these planes of radiation that the change begins. Every possible gradation is observable. The resulting product is sometimes a mass of foliated chlorite, but more generally, it is an amygdule of compact chlorite, exhibiting in its fracture the same radiating structure as the prehnite.

NO. 48. SHELDEN AND COLUMBIAN LOCATION.—1, *Prehnite*, which is the general filling of the cavities in the upper part of the amygdaloid of this locality—2, *Feldspar*, red. It is quite an exceptional occurrence in this neighborhood, and it is intimately associated with the prehnite in a manner that makes it seem to be pseudomorphous after it.

Crystals of epidote and of quartz occur on this feldspar, but the specimen gives no insight into their relation, as regards age, either to each other, or to the feldspar, as a secondary product.

NO. 49. SOUTH PEWABIC MINE.—In this bed, a frequent form of the rock is a compact amygdaloid, of which 50 or 60 per cent, of the volume consists of amygdules from the size of a pin-head to 1/3 inch in diameter. The matrix in a specimen before me is brown, and too hard to be scratched with a knife. The amygdules are sometimes of calcite, but more generally contain, 1, *Quartz*, clear and filling the cavity—2, *Chlorite; copper*. The chlorite (apparently delessite) appears to displace the quartz; in some amygdules, it merely penetrates the fissures of the quartz, giving to this a green color; in others, nothing remains but a cavernous mass of quartz and chlorite usually well charged with copper; indeed the copper occurs here only with this chlorite.

The series to which this bed belongs is represented on the "Southside," and again on the St. Mary's, by arnygdaloids which resemble this one in all essential particulars, except that the amygdules are there filled chiefly with laumontite, and are free from copper and nearly free from chlorite.

NO. 50. "OSSIPEE AMYGDALOID."—The rock is compact, spotted green and brown, and contains small *separate* amygdules of prehnite, quartz, epidote, calcite, chlorite. The chlorite appears as a destroyer of prehnite, quartz and calcite. A larger cavity shows the following succession: 1, *Prehnite;* a lining 1/8 to 1/3 inch thick, much altered and in places changed to chlorite—2, *Orthoclase*, minute crystal—3, *Epidote* on the feldspar.

NO. 51. HURON MINE.—In places, the Isle Royale copper-bearing bed consists largely of a light grayish-green, fine-grained rock of epidote and chlorite indurated with quartz; small, irregular cavities in this contain; 1, *Epidote;* crystalline lining 1/4 inch thick—2, *Quartz* filling the interior.

NO. 52. SHELDEN AND COLUMBIAN MINE.—In cavities, in a brown and green amygdaloid, lie: 1, *Quartz* in well-shaped prisms—2, *Calcite; Quartz.* This second quartz is in small and very much distorted crystals, which are often partially imbedded in the calcite, and are also often planted on the older quartz, from which they can be easily removed without fracture.

NO. 53. HURON MINE.—1, *Quartz* with more or less crystalline structure—2, *Copper* moulded on the quartz and filling cracks and interstices in it.

NO. 54. RAGGED AMYGDALOID. ST. MARY'S.—In the rock (see No. 35), some of the smaller cavities contain: 1, *Orthoclase* as a thin crystalline lining—2, *Calcite* filling the interior—3, *Chlorite-like mineral* penetrating and apparently replacing the calcite.

In a larger cavity occur the following:

NO. 55.—1, *Analcite* crystals 1/4 inch to 2 inches in diameter, much reddened—2, *Orthoclase;* small crystals on the analcite—

3. *Clay?* a soft white mineral, apparently the result of continued decomposition of the analcite under conditions unfavorable for the formation of new silicates as feldspar.

NO. 56. "ANCIENT PIT" BED. DOUGLASS LOCATION.—1, *Epidote* forming a crystalline lining of a cavity—2, *Quartz* filling the interior.

NO. 57. SULPHURET VEIN (Fissure vein). HURON LOCATION.—The vein (6 to 8 inches wide) consists of the following: 1, *Ankerite?* (crystalline, massive, white on fresh surface, but rusty brown on exposed fractures) forming the member nearest the wall on each side—2, *Quartz*, in two symmetrical comby bands on the dolomite, and in thin seams in the dolomite connected by cross-seams with the quartz-comb—3, *Chalcocite*, black—bluish-black *with distinct cleavage*. It resembles the pseudomorphous chalcocite of the Lac la Belle mine. Bornite occurs sprinkled through the chalcocite in minute specks; in places it predominates, sometimes to the exclusion of the latter.

These sulphurets form the central member, and bunches of them are often surrounded by the older members, giving the "cockade" structure to the vein.

NO. 58. UNKNOWN.—A specimen (in Mr. W. H. Stevens' collection at Copper Harbor) consisting chiefly of prehnite and containing beautiful cast-impressions of calcite.

1st. *Calcite* scalenohedrons 11/2 inches long, represented now only by perfect casts.

2d. *Prehnite* massive and botryoidal containing the casts of calcite.

3d. *Quartz* upon the upper surface of the prehnite.

NO. 59. SCHOOLCRAFT MINE.—(See cut on next page). Small amygdules in the brown amygdaloid immediately overlying the conglomerate bed. This rock is very rich in copper surrounding amygdules and filling their cracks.

1st. *Copper* forming outer shell of amygdule.

2d. *Delessite*.

NO. 60. IBID.—(See cut on next page). In same specimen with No. 59.

1st. *Copper* forming the outer shell of a large amygdule.

2d. *Red feldspar*, forming the next inner layer.

3d. Calcite filling the interior.

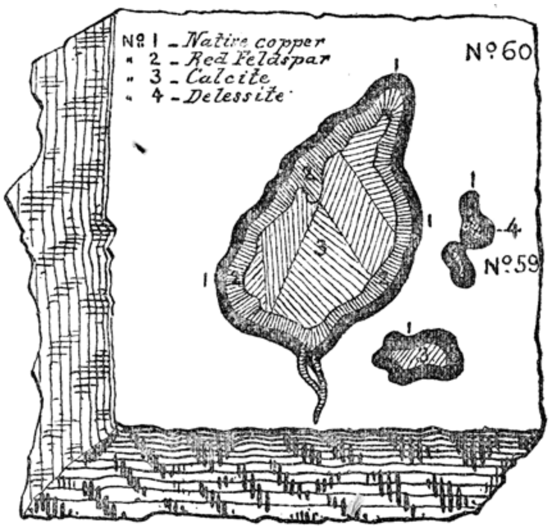
NO. 61. PHŒNIX MINE.—(Fissure vein). A specimen of purple and green vein rock, 5 inches by 4 inches, is covered on one side by

1st. *Datholite ?* crystals closely studded over the whole surface.

NOTE.—It is in another portion of this vein that the arseniurets, whitneyite and domeykite are found.

2d. *Green-earth or chlorite ?* forming a thin film over much of the datholite.

3d. *Analcite* in numerous 1/3 inch semi-limpid crystals, often very cavernous.



4th. *Feldspar* in small limpid crystals scattered profusely over the datholite and green-earth, but rarely sitting on the analcite.

5th. *Calcite* in scalenohedrons sitting on the green-earth and feldspar.

6th. *Apophyllite* in countless $^{1}/_{16}$ inch crystals perfectly transparent, and sitting on 2, 3, 4 and 5; where it occurs on calcite the crystals are pure and colorless ; elsewhere they are colored red, possibly through particles of oxide of copper.

I have attempted to bring the foregoing observations into the following tabular form for greater convenience of comparison. The table is unavoidably imperfect, owing to the necessary difficulties which arise in attempting to compare the successions of different localities. The detailed observations, however, will serve for a check upon the imperfections of the schedule.

COMPARATIVE TABLE.

Capen Vein	1	Laumontite		Prehnite				Chlorite				Analcite	Calcite				
Huron Mine	2	Laumontite		Prehnite													
Copper Falls Mine	3	Laumontite										Analcite					
Phœnix Mine	4								Calcite		Datolite						Apophyllite
Bay State Mine	5			Prehnite	Quartz		Copper										
Phœnix Mine	6	Laumontite			Quartz			Green-earth									
Bay State Mine	7				Quartz							Apophyllite	Calcite				
Bohemian Mine	8											Analcite		Copper	Orthoclase		
Amygdaloid Mine	9			Prehnite	Quartz							Analcite			Orthoclase		
Bay State Mine	10											Analcite			Orthoclase		
Amygdaloid Mine	11			Prehnite, Cu *							Datolite						
" "	12		Calcite	Prehnite, Cu							Datolite						
Pewabic Lode	13	Laumontite			Quartz		Copper	Chlorite or Green-earth	Calcite / Copper		Datolite						
" "	14	Laumontite			Quartz	Calcite	Copper	Chlorite or Green-earth					Calcite		Orthoclase		
Alb. & Bost. "Ragged Amygd."	15			Prehnite											Orthoclase		
"Epidote Lode," St. Mary's	16			Prehnite	Quartz			Chlorite or Green-earth				Analcite					
Amygd. Kearsarge	17			Prehnite	Quartz												
Huron Mine	18											Analcite	Calcite				
Alb. & Bost. Amygd	19			Prehnite	Quartz										Orthoclase		
" "	20			Prehnite	Quartz			Chlorite or Green-earth							Orthoclase	Calcite	
" "	21				Quartz			Chlorite or Green-earth								Calcite	
" "	22			Prehnite	Quartz										Orthoclase		
" "	23			Prehnite	Quartz, Cu												
" "	24			Prehnite	Quartz											Calcite	
" "	25											Analcite			Calcite / Orthoclase		
" "	26			Prehnite	Quartz, Cu										Orthoclase		
" "	27			Prehnite	Quartz			Chlorite or Green-earth				Analcite					
" "	28			Prehnite	Quartz										Orthoclase		
" "	29			Prehnite, Cu													
" "	30			Prehnite								Analcite		Copper	Green-earth or Chlorite / Orthoclase		
" "	31				Quartz										Orthoclase		
" "	32			Prehnite, Cu													
Huron Mine	33	Laumontite	Calcite														
"Southside"	34											Analcite			Orthoclase		
"	"	Laumontite	Calcite														
"Ragged Amygdaloid"	35											Analcite			Orthoclase	Calcite	
" "	36												Calcite		Orthoclase		
" "	37											Analcite	Calcite				
" "	38											Analcite			Orthoclase		
Pewabic Bed	39								Calcite	Copper	Datolite						
" "	40								Calcite		Datolite						
Evergreen Bluff	41				Quartz										Orthoclase	Calcite	
Amygdaloid Mine	42									Copper	Datolite						
" "	43			Prehnite						Copper	Datolite						
Unknown locality	44			Prehnite	Quartz							Analcite			Orthoclase		
"Southside"	45	Laumontite			Quartz												
Michigan Mine	46										Datolite		Calcite		Orthoclase		
Many localities	47			Prehnite	Delessite												
Shelden & Columbian	48			Prehnite											Feldspar		
South Pewabic Mine	49				Quartz			Chlorite or Green-earth / Copper									
Ossipee Amygdaloid	50			Prehnite											Orthoclase	Epidote	
Huron Mine	51		Epidote		Quartz												
Shelden & Columbian	52				Quartz	Calcite / Quartz											
Huron Mine	53				Quartz		Copper										
Ragged Amygdaloid	54														Orthoclase	Calcite / Chlorite	
" "	55											Analcite				Clay	
"Ancient Pit" Bed, Douglass	56		Epidote		Quartz										Orthoclase		
"Sulphuret Vein," Huron	57		Ankerite ?		Quartz		Bornite / Chalcocite										
Unknown	58		Calcite	Prehnite	Quartz												
Schoolcraft Mine	59						Copper	Delessite								Calcite	
" "	60						Copper								Feldspar	Calcite	
Phœnix Mine	61										Datolite / Gr.-earth	Analcite			Feldspar	Calcite	Apophyllite

* The symbol Cu occurring in the same column with another mineral indicates merely that the copper is younger than the prehnite or quartz and older than the datolite or orthoclase.

COPPER AND CALCITE.—In many of the instances in which calcite crystals are found enclosing copper, it is difficult and often impossible to distinguish as to the relative ages of the two. But specimens in my collection offer conclusive proof that each of the following cases occur:

I.—*The copper was present before the calcite began to form, and became enclosed in the growing crystal.*

In this case the copper and its associated minerals generally form the basis on which the calcite rests, and the crystals of the latter exhibit entering faces wherever the surface of the crystal is in contact with the copper; it should seem to indicate an effort at those points to crystallize free from the foreign substance, by forming separate individuals. But on the finished crystal the traces of this tendency are visible, generally, only in the comparatively very small entering faces at the contact with the copper.

In this way calcite crystals, formed in a cavernous mass of copper, are intersected internally by a perfect network of thin plates of the metal, and yet preserve their cleavage unaffected; but wherever the copper comes in contact with the surface of the crystal, the small entering faces are present.

II.—*The crystal of calcite was partly formed, then became incrust-ed with copper, and was finished by a new growth of calcite over the metallic film.*

A most remarkable instance of this case is that of a crystal about 2 inches long—a steep scalenohedron—with a basal termination of about I square inch surface. At this stage of its growth it was covered, over nearly the whole surface, with a thin coating of copper. The basal termination on scalenohedrons of calcite is as rare on Lake Superior as elsewhere, and in the few instances where I have seen it, it lacks the polish which indicates perfect growth. The tendency to complete the point of the scalenohedron is well shown on this specimen; over the partially copper-coated basal plane there are scattered a large number of perfectly pointed scalenohedrons—two or three of these are 1/3 to 1/2 inch high—and others are scattered over the side-faces. All of these younger crystals are arranged in perfect uniformity with the plan of the underlying, older individual.

Those portions of the surface on which the copper-coating is perfect have no younger calcite crystals; these occur where the metallic film is thinnest and more or less perforated.

The copper is not confined absolutely to the surface of the crystal on which it lies; it penetrates to a slight distance along the cleavage-planes, and the result is an exceedingly delicate reticulation on its under surface. The calcites which are planted on the copper contain brilliant particles of the metals swimming, if one may use the word, in the interior of the crystals; and these are so disposed as to lead to the idea that, throughout the growth of the younger crystals, they had to contend with the continued deposition of the metal. Thus one of the new scalenohedrons, after growing to the height of ¼ inch, was, like the underlying one, also ended with a basal termination, on which again smaller new and well-pointed individuals were built up.

III.—*The copper has entered the calcite crystal since its growth was finished.*

A specimen, in my collection, illustrates this remarkably well. It is a cleavage-rhombohedron of opaque calcite, traversed by intersecting sheets of copper, which are wholly independent of the cleavage planes. On detaching the copper from the calcite, the surface of the latter appears rough; it is a fracture oblique to the cleavage, and the face of the fracture is formed by countless corners, or solid angles, of minute cleavage-rhombohedrons, as is fully proved by the reflection of the light. The copper-sheets, which are about $^1/_{40}$ inch thick, reproduce this very completely.

Another very remarkable specimen is from the cement of the Albany and Boston conglomerate. It is about 1 inch in diameter, and consists of opaque white calcite. The continuity of the cleavage shows it to be a single individual, though it passes on the edges without any sharp demarkation into the common cement of the conglomerate. This calcite is traversed by continuous sheets of copper $^1/_{200}$ to $^1/_{40}$ inch thick, which are perfectly straight. These sheets are parallel to several planes (nearly all of which are independent of the cleavage), and intersect each other. In each of the sets thus formed the sheets are perfectly parallel, and are separated by plates of calcite, which are, in places, as thin as the copper itself. Where three such sets intersect each other, the resulting solid appears composed of concentrically arranged laminæ of copper and calcite. In some parts of the specimen, the copper predominated over the calcite. Wherever the faces of the copper laminæ are exposed, they are marked with a delicate, reticulated tracery, indicating the lines of intersection of the sheet with the cleavage planes of the crystal. The cement in the vicinity of the calcite is impregnated with copper; in places it is almost wholly replaced by the metal in the fine granular condition called "brick copper," and into this the laminæ of metal extend, without break, from the calcite. This specimen is really a pseudomorph of copper after calcite.

Copper and Silver.—It is a well-known fact that these two metals occur in the metallic state, in the Lake Superior deposits, in the most intimate contact with each other, and yet without being mutually alloyed. Even at the contact they are not absolutely joined together, for after rolling out a piece of copper containing spots of silver, the two metals become more or less separated, and may often be readily detached from each other.

In all the instances that have come under my observation the silver appears to be younger than the associated copper, and seems to have been directly precipitated by copper, and to have replaced the latter.

Chalcocite, Bornite, Whitneyite, Domeykite.—Two fissure-veins are known in the neighborhood of Portage Lake which carry these ores. They have been examined only very superficially; but it is a remarkable fact that the amygdaloids traversed by these veins contain only native copper. One of the fissure-veins, bearing both sulphides and arsenides of copper, enters the Grand Portage cupriferous amygdaloid bed, which bears only native copper, and remains in it with a changed direction for a short distance. The gangue of these veins is quartz, calcite, and a carbonate of lime containing some iron and magnesia—ankerite?

The only other instance I have observed of the occurrence of copper in combination with sulphur, is in the fissure-vein of the Mendota property, near Lac la Belle. This vein appears to traverse the entire trappean series from Agate Harbor on the north to Lac la Belle.

Wherever this vein has been opened or uncovered, along the greater part of its course, north of the Mendota property, only *native* copper has been found ; but when it enters a bed of conglomerate on the north flank of Mt. Bohemia, the little copper it contains is combined with sulphur in a very pure chalcocite. Where the vein passes from the conglomerate into the underlying amygdaloid, a fine deposit of chalcocite with calcite was found to have been formed, for a short distance, on both sides of the vein, between the two beds.

Still farther south the vein enters a mass of syenite, consisting of a pink triclinic feldspar, some hornblende and much chlorite, as an alteration-product of hornblende, and containing frequent impregnations of chalcopyrite, bornite, and, more rarely, chalcocite. In this syenite the vein and its many feeders carry bornite and considerable quantities of a bluish sulphuret of copper, in sheets 1/3 to 3/4 inch thick, which has a very crystalline structure and exhibits octahedral cleavage.*

Near the contact between the syenite and trap, the latter rock is impregnated with magnetite, specular iron, chalcopyrite, and bornite. Excepting the syenite, wherever copper is found in the traps and amygdaloids on the Mendota property, it is in the metallic state. The occurrence of the sulphides and arsenides of copper in this isolated manner and in fissure-veins traversing rocks more or less impregnated with metallic copper, seems to show a diversity of origin for the sulphur and arsenic on the one hand, and the copper on the other. It does not seem unreasonable to suppose the copper to have entered the vein-fissure from the adjoining rocks in solution, as carbonate, sulphate, or silicate, and to have been then precipitated by sulphuretted hydrogen and arseniuretted hydrogen respectively. Or the copper may have been deposited in these as in other veins, in the metallic state, and have been subsequently changed by the same gases. In the case of the pseudomorphous chalcocite, where the Mendota vein traverses syenite, cuprite must have been formed by the oxidation of chalcocite or of native copper, and the oxide must have been subsequently decomposed by sulphuretted hydrogen. The Huronian formation, which probably underlies all this region, contains in its upper members large amounts of carbonaceous matter in the form of graphite; the gases may have originated in a reduction of sulphates and arseniates by the carbon of these beds.

*Prof. Cooke, after a casual examination of this mineral, suggests that it is probably a pseudomorph of chalcocite after cuprite.

REPLACEMENT OF PORPHYRY MATRIX BY CHLORITE AND COPPER.

Among the pebbles in the Calumet conglomerate there is a variety of quartz porphyry, with a brown, compact, almost jaspery matrix, which only glazes slightly before the blowpipe. In this paste there are numerous grains of dark quartz $^{1}/_{20}$ to $/_{4}$ inch in diameter, and often more frequent crystals of flesh-red feldspar, apparently orthoclase,—$^{1}/_{10}$ to $^{7}/_{10}$ inch in length.

It not rarely happens, that in these flesh-red crystals there appear dirty green portions exhibiting the twin-striation of a triclinic variety. The feldspar is hard and brilliant, but is nevertheless no longer intact; under the glass the crystals appear cavernous, 10 per cent, or more of the substance being gone. This is the character of this porphyry in the freshest pebbles.

I have before me a pebble 4 inches in diameter, broken through the middle. It was the same variety of porphyry I have just described—the same brown matrix, with the same grains of quartz, and the same large crystals of orthoclase, often enclosing crystals of triclinic feldspar. But this pebble carries on its face the history of an extreme change. In the interior, where it is freshest, the matrix, still of the same brown color, has become so soft as to be easily scratched with the point of a needle. The quartz grains are highly fissured, and the surfaces of the fissures are covered with a soft, light-green magnesian mineral. The feldspar, although it still resists the point of the steel needle, has generally lost its glance, and has an almost earthy fracture; it is lighter colored, and tends to spotted dirty-red and white. In places, specks of chlorite are visible in the holes in the altered feldspar, and the cleavage planes often glisten with flakes of copper. As we go farther from the middle of the specimen toward the original surface of the pebble, the matrix becomes much softer, though still with brown color and brown streak, and then changes to a soft, green, chloride mineral, which whitens before the blowpipe, and fuses on the edges to a gray glass. A little farther from the centre there is no longer a trace of the porphyry matrix: it is altered wholly to chlorite. The feldspar crystals are somewhat more altered here than they are in the middle of the pebble, but the quartz grains seem to have been in part replaced by chlorite. The change to chlorite is accompanied throughout by the presence of a large amount of copper. While in the interior of the pebble, the flakes of copper are confined to the cleavage planes of the feldspar, and the porphyry matrix exhibits scarcely a trace of the metal, the chlorite which has replaced the matrix contains in different parts of the specimen from 10 to 60 per cent., by weight, of copper.

In another pebble of the same porphyry, not only is the original matrix gone, but the usurping chlorite has been almost, if not wholly, replaced by copper; and we have as the remarkable result a quartz-porphyry, whose crystals of feldspar and grains of quartz lie in a matrix of metallic copper. There is still a very small amount of chlorite present, but it seems to have come from the change of the feldspar crystals and quartz grains.

In other pebbles of the same quartz-porphyry, containing, perhaps, less quartz, the alteration seems to have taken a somewhat different direction, or at least the result before us is different. In the interior of the pebble, the matrix is of a darker and dirtier brown than in the previous cases, which may be due to the presence of manganese in the alteration-product. Going from the middle, the brown color changes rather abruptly to a dirty greenish-gray; the material also becomes softer, but it is earthy, with an earthy odor, and gritty to the touch. The change seems here to be in the direction of kaolinization.

The entire pebble is permeated with minute shining threads and plates of carbonate of lime. The lighter-colored portion contains considerable copper, while nearer the surface of the pebble it is largely replaced by that metal. Pebbles showing the various alterations described above are by no means rare. Many of them, from 1 inch to 1 foot in diameter, are found every day.

A very interesting occurrence of copper and silver is visible in specimens, in my collection, from the abandoned Suffolk mine in the "South Range," south of Eagle River.

There is here an extensive development of feldspathic porphyry (without visible free quartz). In this rock a vein carrying sulphuret of copper was once worked. The specimens referred to were found loose in a gorge near the vein, but are porphyry. They have a dark purplish brown compact matrix, with uneven to semi-conchoidal fracture, and contain numerous amber-colored to flesh-colored crystals of triclinic feldspar, averaging ¼ inch in diameter by ½ inch thick, and occupying about $^{1}/_{5}$ of the surface area of fracture.

The rock contains, disseminated through the matrix, small particles of black sulphuret of copper. The feldspar crystals often contain minute flakes of native copper, and in some instances flakes of native silver occur in the same manner in the cleavage planes of the feldspar. The chain of changes was, perhaps, initiated by the forming of chloritic substance in the feldspar crystals, the ferrous oxide then reduced the copper from solution, and the copper precipitated the silver.

CONCLUSIONS.

We may be permitted to draw a few conclusions from the facts brought out in the observations thrown together in the foregoing pages.

I. The *Chlorite* of the melaphyr, and consequently the distinctive character of that rock, is due to the alteration of hornblende or pyroxene. This seems to have been the first step toward the production of melaphyr proper. *Laumontite*, which we find alike in the beds containing the least and in those containing the most chlorite, and occurring both diffused and concentrated in seams, appears to have been formed either contemporaneously with the chlorite, or as the next step in the process.

In the fissure-veins of Keweenaw County, laumontite is most abundant near and under the "Greenstone," as in the north end of the Central Mine. Here the great body of overlying rock is one in which the hornblende has undergone but little change.

The next step appears to have been the individualization, in amygdaloidal cavities, of *non-alkaline silicates*, viz., *laumontite, prehnite, epidote* respectively, according as the conditions favored the formation of one or the other of these.

In the fissure-veins of Keweenaw County, prehnite is the most abundant silicate found in depth, *i.e.,* below the 80 or 90 fathom level. The alkaline silicates are found chiefly in the upper levels.

Following the non-alkaline silicates came the individualization of *quartz* in these cavities.

Perhaps we may be warranted in considering these minerals, together with the lime of the calcite that more rarely occurs in this portion of the series, as chiefly due to the decomposition of the pyroxenic ingredient of the rock.

So far as we may infer from the tabulated results, the concentration of *copper* in the amygdaloidal cavities does not appear to have begun till after the formation of the quartz.

In this part of the series falls also the formation of a chloritic or green-earth mineral, which in some manner has displaced prehnite, quartz, calcite, and with which copper, when present, appears to stand in intimate relation. Subsequently to this came the individualization of the alkaline silicates, viz., analcite, apophyllite, orthoclase. Here also seems to belong the formation of datolite.

The alkaline silicates represent the period of decomposition of the labradorite ingredient of the original rock, and when they occur in the mass of the rock (as distinguished from veins), it is only where the alteration of the rock has proceeded so far that the amygdaloidal form has merged into the brecciated through the enlargement and union of the cavities.

In the fissure-veins of Keweenaw County, the alkaline silicates, as before stated, abound in the upper levels, and are rare in depth; in other words, they are abundant in that zone of the veins which lies between walls of those portions of the beds of melaphyr in which we should look for the most advanced stages of alteration in the components of the melaphyr, supposing such alteration to be due to the action of *descending* solutions.

The fact that calcite occurs at almost every step in the paragenetic series, and forms one of the most common of the secondary minerals, is proof that carbonic acid was very generally present throughout the whole period of metamorphism; it was probably the chief mediating agent in the processes, without being sufficiently abundant to prevent the formation of silicates.

II. The change of pyroxene to chlorite, as illustrated on an immense scale in the formation of the melaphyr, and the displacement of feldspar and quartz—quartz-porphyry—by chlorite, as exhibited in pebbles of the conglomerate, point to an extremely important line of investigation for the chemical geologist. The alteration of the pebbles appears to have followed two different directions according to the ruling conditions, viz., either toward chlorite or toward kaolinization; and as the result of the latter process is impregnated with calcite, while the result of the former is free from carbonates, it would seem that the direction was determined by the presence or relative freedom from free carbonic acid. The deposition of calcite, if formed from the acid carbonate, would set free sufficient carbonic acid to prevent the formation of silicates of iron and magnesia.

III. *Copper*, wherever we can detect it with the eye, has already gone through a partial concentration. The presence of this metal in minute quantity in the sandstones of Lake Superior, is made evident by the stains of carbonate which form on the cliffs of the "Pictured Rocks."

It has also been found in the form of thin sheets of native copper occupying thin vertical fissures in the cliffs of Lower Silurian sandstone on the lake shore north of the Huron mountains. It is found here and there in the less amygdaloidal melaphyr in minute specks and impregnations, or even in a more concentrated form, as thin sheets occupying the joint-cracks.

These occurrences increase in frequency in proportion as the rock is more amygdaloidal; in other words, the copper is more concentrated in those portions of the beds where the chemical change has been greatest. Where the rock has not passed beyond the strictly amygdaloidal stage, the copper occurs in the amygdules, traversing these in flakes, or coating them in a film of greater or less thickness, to such an extent as to form from ¼ per cent, to 3 per cent., by weight, of the rock over considerable areas. Finally, in those beds where the metamorphism has proceeded to such an extent as to wholly replace large portions of the amygdaloid by secondary minerals, epidote, calcite, quartz, chlorite, laumontite, etc., there the copper occurs in masses of many pounds, and sometimes of several tons weight, and in forms equalled in their irregularity only by those of the masses of secondary minerals accompanying the metal.

In each and all of these positions we find that the deposition of the copper took place subsequently to the decomposition and removal of a portion of the rocks, and subsequently to the deposition of laumontite, epidote, prehnite, and quartz, where these accompany it.

In all this we have direct evidence of the movement of some salt of copper in wet solution, and the concentration of the metal by accumulating deposition in places where the precipitating agent existed.

In the fissure-veins of Keweenaw County, the widening of the vein is frequently due to " splicing," *i.e.*, a portion of the wall rock became detached and split by countless small cracks having a general parallelism to the main vein. Thus, instead of forming a solid "horse of ground," it consists of myriads of small and large lenses of often wholly decomposed rock, surrounded by films and seams of chlorite, laumontite, calcite, and clay. These places are often the home of large "masses" of copper, which then also have a spliced structure. Where the masses occur in a gangue of calcite, they are not spliced, but have a solid texture and the most irregular shapes. These facts point, perhaps, toward the formation of "masses" by replacement.

According to Mr. Pietrie, the superintendent of the Central mine (fissure-vein), where a "horse" occurs in the vein, the regular vein filling follows the foot-wall side of the "horse," and the younger fissure on the hanging-wall side is filled with calcspar and mass-copper. The foot-wall branch contains (like the regular filling elsewhere) prehnite, one of the earlier-formed minerals.

Except in the melaphyrs of Lake Superior, the copper so widely diffused in the Palaeozoic and older stratified rocks, exists either in the various sulphurets, or as oxidation products of these. Indeed, we cannot well suppose the copper to have been deposited in submarine formations in any other condition than as sulphuret. Nor can we suppose it to have taken any other form permanently, so long as unoxidized organic matter remained in the beds. An oxidation of the sulphuret would be followed by reduction of the resulting sulphate to new sulphurets around the organic remains. In this way we may suppose the simplest and most common form of concentrated deposits—the impregnations—to have originated, as well as the farther enrichment of particular beds or zones—*fahlbands*—which may represent strata which were originally richer in organic substances, or which may have retained these longer than the other beds.

The trappean series of Keweenaw Point differ from all the other cupriferous rocks of the Northwest in lithological constitution, and in having the copper in the metallic state. It is still an open question whether the trap which formed the parent rock of the melaphyr was an eruptive or a purely metamorphic rock. If it was eruptive, it was spread over the bottom of the sea in beds of great regularity, and with intervals which were occupied by the deposition of the beds of conglomerate and sandstones.

It should seem probable that the copper in the melaphyrs was derived by concentration from the whole thickness of the sedimentary members of the group, including the thousands of feet of sandstones, conglomerates, and shales which overlie the melaphyrs, and including melaphyrs also—and especially, if these are purely metamorphic.

Among the most interesting questions connected with the occurrence of the copper are those touching its condition previous to concentration during the amygdaloidal stage of metamorphism, the chemical combination by which this concentration was effected, and the character of the precipitating agent.

The great persistency of metallic sulphurets through the usual processes of metamorphism, and the almost universal association of sulphur with copper in crystalline rocks, renders it perhaps probable that this was here also the combination in which the metal was diffused, or rather, very partially concentrated. Traces of sulphur detected by Mr. Hochstetter in the melaphyr contiguous to the Hecla conglomerate point also in this direction, considering that the only acids generally present in the melaphyrs are silicic and carbonic acids, and if we add sulphuric acid as an oxidation product of the sulphurets, our choice of the form of solution, by which the final concentration was effected, should seem to be limited to silicates, carbonates, and sulphates of copper. Probably all of these combinations took part in the process, but while we may consider the translocation of the copper to have been initiated by the sulphate, this salt must have been so soon decomposed by the abundant acid carbonate of lime,* as well as by the alkaline silicates, that we cannot readily suppose the sulphate† to have generally effected the final concentration of large deposits. It is more probable that this was accomplished by the more permanent solutions of carbonate and silicate of copper respectively, as the circumstances favored. The position of the metallic copper in the paragenetic series, shows it to have been deposited after the non-alkaline silicates, and before the formation of the alkaline silicates, *i.e.*, after those minerals which resulted from the decomposition of the pyroxenic constituent of the rock, and before those which were formed by the destruction of the feldspar. Now this is what we should expect if we suppose the pyroxenic rock to have been altered to its present condition under the co-operation of water carrying carbonic acid and some free oxygen, because the oxygen must have been employed in oxidizing the carbonate of iron resulting from the decomposition of the pyroxene;** the oxidation of the sulphuret of copper could not, therefore, take place until the pyroxene had so far disappeared as to leave a relative excess of oxygen as compared with the amount of ferrous salts exposed to, a higher oxidation.

Throughout its deposits the copper exhibits a decidedly intimate connection with delessite, epidote, and green-earth silicates, containing a considerable percentage of peroxide of iron as a more or less essential constituent; while among the other silicates, viz., analcite, laumontite, datolite, prehnite, only the last named, which alone seems subject to a considerable replacement of its alumina by ferric oxide, is especially favored by copper. This association is so invariable and so intimate that one is forced to the conclusion that there exists a ck se genetic relation between the metallic state of the copper and the ferric condition of the iron oxide in the associated silicates; that the higher oxidation of the iron was effected through the reduction of the oxide of copper and at the expense of the oxygen of the latter.

*A coating of gypsum covering very thin sheets of copper from the jointing-cracks of the melaphyr contiguous to the Hecla conglomerate, may be due to this decomposition, followed by the reduction of the copper.

†Compare Bischof, Chem. u. Phys. Geol., I., p. 52, and III., p. 716.

**The result of this oxidation is seen in the brick-red color of the amygdaloids and in the brown color and spots of many of the melaphyr beds.

As regards the green-earth and that variety of chlorite or delessite which is intimately associated with the copper, they either immediately follow the copper in point of age or are contemporaneous with it, and they may be looked upon as having been formed under the influence of this reduction. Where copper is associated with prehnite it is invariably younger than the latter, a fact which would seem at the first glance to oppose the supposition that there is any relation between the peroxide of iron in the zeolite and the deposition of the copper. But we have seen that prehnite undergoes a change to delessite; we find these pseudomorphs in every stage of the process from the first green discoloration on the cleavage planes to the amygdule of delessite with prehnite structure. Now, may we not consider the presence of iron in prehnite generally to be due to a beginning change, and the deposition of native copper in the Lake Superior prehnites to be partially or wholly correlated with the higher oxidation of the iron?

In at least very many instances, if not in all, the deposition of the copper has been a result of a process of displacement of preexisting minerals. In some rare instances the metal retains the form of its more or less remote predecessor, as in the pseudomorphs after some mineral (clay?) after laumontite.

Nowhere is this displacement more apparent than in the cupriferous conglomerates. In these, the cement is the home of the metal, and in some places, as in portions of the Hecla and Calumet mines, it is wholly replaced by it; copper forming 20 to 50 per cent., by weight, of the rock. In these instances, either chlorite or epidote is associated with the copper as minerals formed since the deposition of the conglomerate, while calcite very frequently replaces the cement in barren portions of the bed.

The cement of the conglomerates is of the same materials as the pebbles in a more comminuted form. The displacement of the whole mass of quartz porphyry in large pebbles by chlorite and copper described above, is probably an illustration of the manner in which the cement was displaced on a more extended scale.

The absence of the ores of the baser metals—lead, zinc, nickel, etc., from the deposits of the trappean series, while they are present in the less metamorphosed rocks of the Quebec group in other localities—may be due to the greater intensity of the chemical action to which the melaphyrs have been subjected; an intensity which may be measured by the extent to which the process of concentration has been carried. Concentration is a process of removal, relatively speaking, and concentrated deposits are accumulated masses of material arrested in the drainage channels of rock masses by the action of competent forces; if the arresting cause is absent from a given region, the removal will continue to another where it is present. If causes exist which are able to arrest one class of the substances in the passing solution, and are powerless as regards another class, then a separation will occur between the two classes.

Now, copper and silver belong to a class distinct from the baser metals, in that, by reason of their smaller affinity for oxygen, they are more readily reduced to the metallic state, the condition of greatest permanence in presence of the usual reagents to which they are exposed. If the arresting cause of these metals was, as we have supposed, their reduction by protoxide of iron, it is a cause which would have been powerless as regards the salts of the baser metals, and we may suppose these to have continued in solution till they reached some region where they were arrested by the presence of organic matter, or of sulphuretted hydrogen, etc.

CHAPTER IV. CORRELATION OF THE ROCKS OF HOUGHTON AND KEWEENAW COUNTIES.

BY A. R. MARVINE.

(See table at the end of this chapter.)

UPON the Plate of Grouped Sections are gathered the various sections that have been made by the Geological Survey in the years 1870 and 1872, that their relations may be more readily studied. They are placed down the Plate in the order in which they occur, going from south to north. All the sections but I. and II. are taken very nearly across the formation. I. and II. of the Portage Lake District, however, contain many points scattered along the formation, as well as across it, as may be seen by reference to the map; the two being connected by the Roman numerals.

In Section I., the exposures have been projected upon the plane of section from the various points at which they occur along such lines of strike, as near as may be, that the formation has at them. In Section II. (which stands in a relation to Section I. to be hereafter explained) the "Albany and Boston " conglomerate, No. 15, has been assumed as a straight line between the Pewabic and Rhode Island mines, and the remaining beds plotted off from it at right angles, at the distances which they were found to have at those points where they happened to be exposed. Under these circumstances, both in Sections I. and II., points exposed directly across the formation from one another, would appear upon the sections as having the same geological relations to one another that they have along the line at which they actually occur. Exposures not lying directly across the formation from one another would also carry with them to the section their true relations, provided that the intervening beds had neither thickened nor thinned in going along the formation from one point to the other. But if thickening or thinning has taken place, two points so exposed would be projected upon the section, either farther apart or nearer together than they would if either point had been exposed directly across the formation from the other; while they might or might not appear as they would, supposing the beds prolonged till they actually intersected the plane of section.

Thus Sections I. and II. show the relations the beds have at the various points along the range at which they happen to be exposed. Were it an object to form a true section across the range at some one point, the rates of thickening or thinning of the beds would have to be first ascertained and a correction—depending on those rates and the distances of the exposures from the section—applied to the various beds, as shown upon the printed sections, thus reducing them to their proper places upon the ideal section.*

The differences in dip which occur along the mineral range are apt to lead to very deceptive results in comparing the distances between beds as shown upon the surface. Two beds, whose dip angle is growing less as we follow them along the formation, will appear to gradually separate from one another, while the actual distance between them, measured perpendicular to the plane of bedding, remains the same or may even diminish. Thus, the horizontal distance between the Allouez and first conglomerate, south at the Central mine, is more than four times the horizontal distance between the Albany and Boston and Houghton conglomerates as exposed on the Mesnard property. The dip at the former, however, is twice as flat as at the latter, thus accounting for most of the difference in distance; while if allowance be made for the rate at which we know the intervening beds to be actually widening at the Mesnard, the remaining discrepancy is entirely accounted for.

*It is with the object of avoiding the publication of a number of such sections, while at the same time affording data for forming them when necessary, that the table which is to follow has been prepared. Having some known bed to measure from, this table, in connection with the accompanying sections, enables the positions of beds, covered upon the property in question, but known elsewhere, to be ascertained with considerable accuracy.

In order, then, to impartially compare different portions of the mineral range, the perpendicular distances between the beds only must be regarded.*

The number and lithological similarity of the amygdaloids, together with the fact that they are prone to wholly disappear, as may be readily seen from the sections, render them unfit for the purpose of tracing the formation. The great similarity among the melaphyrs renders them also doubtful guides; though in both amygdaloids and melaphyrs there are certain broad features obtaining over more or less wide belts, which are serviceable in correlating, in a general way, different parts of the range. Such are the coarse-grained melaphyr belt of the Dacotah, and the belt containing scoriaceous beds to the west.

The relative infrequency of the conglomerates, notwithstanding their lithological similarity, renders them, therefore, the only reliable stratigraphical guides of the formation.

*The perpendicular distance between two beds equals their horizontal distance multiplied by the sine of the dip angle. A measurement made between two beds that are exposed at different heights does not give the horizontal distance between them. With strata dipping to the north-west, if the north-west point is the higher the measurement will be shorter than it should be,—if lower, longer than it should be. The correction to be added or subtracted, as the case may be, to a measurement itself reduced to the horizontal, in order to give the horizontal distance between the beds, equals the difference in height of the observed points divided by the tangent of the clip angle. The following table gives the natural sines and tangents of the dips of the principal mining locations:—

Dip angle.	56°	55	54	53½	53	52¾	52	45	43	39¼	31	30	26
Sine......	.82904	.81915	.80902	.80386	.79864	.79600	.78801	.70711	.68200	.63271	.51504	.50000	.43837
Tangent..	1.48256	1.42815	1.37638	1.35142	1.32704	1.31507	1.27994	1.00000	.93252	.81703	.60086	.57735	.48773

The measurements between the conglomerates, to which the survey paid much attention, have therefore been discussed, and the results gathered into the accompanying table, (opposite page 66) a description of which follows:—

The right-hand column contains the names of the various properties along the range on or opposite to which the various measurements were made. These, in going down the page, read from south to north. The strip across the paper opposite each is supposed to represent a narrow strip running directly across the formation. Column two contains the dip of the formation, as near as could be ascertained, on the property it is opposite. Column three contains the approximate distances, in feet, along the formation of the various strips from the southernmost one; and subtraction of the numbers opposite any two measurements enables one to obtain the distance along the formation between them. The conglomerates are numbered uniformly with the grouped sections. The names of several near Portage Lake are placed along the top of the table, of several in Keweenaw County, along the bottom.

The Albany and Boston and the Allouez conglomerates being represented by a straight line (No. 15), the various other conglomerates are plotted off from it, and from one another, to a scale of 1,600 feet to one inch, the distances from foot-wall to foot-wall* perpendicular to the formation being taken. This part of the table, then, may be taken to represent the appearance the outcrops of the conglomerates would present, on the supposition that the mineral range, instead of being tilted into its present position, had been tipped up, without faulting, until the strata at all points stood vertical, and then straightened out until the Albany and Boston and the Allouez conglomerates formed one straight line.†

*Except No. 14, in which the hanging-wall is taken, the foot-wall not being observed.

†The distances across the table being drawn to scale, it may be cut in two, just above the Kearsarge, when, by moving the lower part back or forth upon the upper, any other apposition of the conglomerates than that here adopted may be made.

The horizontal measurements between the conglomerates are placed opposite the points in column 1, at which they were made, and between the lines representing the conglomerates, their direction and limits being indicated by the fine dotted lines. Under each of these, in a parenthesis, is placed the resulting perpendicular distance between the beds. It is those numbers which are drawn to a scale of 1,600 feet to an inch. Numbers in parentheses which stand alone are not derived from horizontal measurements, but are obtained indirectly either by subtracting adjacent parenthetical numbers, or by applying a correction to direct or diagonal measurements on account of thickening or thinning of the formation. Placed between those numbers in parentheses, which represent the perpendicular distances between the same two conglomerates at different points of the range, are numbers in brackets. These represent the number of feet of thickening or thinning, per each thousand feet along the formation between the measurements, that has taken place in the beds lying between the conglomerates in question. They are obtained by subtracting the perpendicular distances between two conglomerates at different points, and dividing the difference by the number of thousand feet lying between the points, as obtained from column 3. Thus, take conglomerates 14 and 15, between the Mesnard and Albany and Boston, when measurements between them were made. At the former place the two are 411 feet apart, and having a dip of about 53°, the perpendicular distance between them would be (328) feet. At the latter, these distances are 460 and (362) feet respectively. The total thickening is, therefore, 34 feet, which has taken place in a distance along the range (column 3) of 12,800 feet, or at the rate of [2.7] feet per thousand. Thickening toward the north is indicated by the simple rate; thinning toward the north, by the minus sign,—thus [-1.6].

Rates that are derived from measurements made directly across the formation are the most reliable. Having these we may correct diagonal measurements, or calculate the distances between the same beds at other points, and from these obtain rates of thickening of beds not directly measured. Thus, at the Pewabic we have a measurement (3,166) between 9 and 15, but no direct one elsewhere. At the Montezuma, however, we have from 9 to 12, and at the Dacotah from 12-14 (1467), which, corrected for the rate [3] to the Montezuma, becomes 1,480. Reducing the distance between 14-15 at the Mesnard for the rate [2.7] gives (297) feet at the Montezuma, or, in all, from 9 to 15 at the Montezuma (3,151) feet. Comparing this with (3,166) at the Pewabic, gives a rate of widening, per 1,000 feet, of [2.8] feet for the total space between conglomerates 9 and 15. If we add the rates of widening given in the table for the spaces included between 10 and 15, we have for this whole space [-1.8] feet which would leave [4.6] for the space 9-10. It will be observed that between the Montezuma and the Kearsarge, a rate of [4.1] was obtained for this same space. It may be objected that in the above calculation the rate [2.7] which 14-15 has between the Albany and Boston and the Mesnard was assumed to continue to the Montezuma.

The projected distance in Sec. 1. between 14 and 15, corrected, for a reason not readily explained, for the rate [6.4] between 15 and 17 gives [285] at the Montezuma, and this number, compared with the distance at the Mesnard, gives the same rate of widening as from there to the Albany and Boston, or, indeed, from the latter point to the central. But be this as it may, the assumption may be avoided by regarding the region between 9 and 14 only, and considering that the rate [2.7] holds good only so far as the Pewabic. Here 14 and 15 would therefore be (310) feet apart, leaving (2,856) feet between 14 and 9. Proceeding as before, we find that between the Montezuma and the Pewabic the zone 9-14 is widening at the rate of [0.3] per thousand, leaving [4.8] for the zone 9-10, or [0.2] larger than before. These examples, taken at random, serve to show the manner of obtaining rates not entered in the table, for the purpose of ascertaining the approximate positions of unexposed conglomerates, and, with the help of the sections, of intermediate beds, should there be reason to suppose them continuous. It must be observed that numbers thus derived from the table are *thicknesses*, or distances perpendicular to the plane of bedding. To reduce them to the horizontal, they must be divided by the sine of the dip on the property on which a bed is sought (p. 3), and this number should be increased if the ground slopes downward to the west, or decreased to the east.

General Conclusions.—Regarding, first, the region lying between the South Pewabic and the Albany and Boston, we see that there is a very general thickening of the beds in going north along the formation.* In only one zone does the reverse take place, viz., between conglomerates 11 and 12. The large rate here obtained [-10] may be somewhat in excess owing to some error. It could not be varied much, however, and shows that there is a very decided narrowing going on in this belt. Eastward of No. 9 the thickening toward the north is small throughout, while west of it, excepting the narrowing zone, it is much greater, being especially marked west of 14. The rate [5-9] between 15 and 16, derived from a measurement probably not reduced to the horizontal, must be inaccurate; but it serves to show that most of the total thickening [6.4] between 15 and 16 is taking place in the zone 15-16.

*Upon the table, a sudden bend or widening in the lines representing the conglomerates does not indicate a similar change in the formation, for distances up and down the page are not drawn to any scale, so that some parts of the Range are much crowded together compared with others. Two lines that are separating indicate a thickening, the actual amount of which, however, must be obtained from the numbers between them.

Identity of the Allouez and Albany and Boston Conglomerates.—It will be observed that in the table the Albany and Boston conglomerate has been assumed to be the same as the Allouez. We may seek the proof of this in three separate groups of facts—geographical, stratigraphical, and lithological.

1. *Geographical*.—The extension of the line between the Albany and Boston and Rhode Island shafts northward would intersect the line of the Calumet conglomerate near the line between the Calumet and Hecla properties, at an angle of about 53/4 degrees, and it has been supposed that by curving in a peculiar way they might be the same bed. The extension of the Calumet base, however, passes over 2,400 feet east of the Rhode Island, and not far from where the North Star conglomerate (No. 12) should be; while the extension of the line of strike of the Allouez conglomerate from the Allouez mine would intersect the Albany and Boston conglomerate not far from the Rhode Island. Might not a curving throw either of these two together?* The Albany and Boston conglomerate, between the Pewabic and Albany and Boston mines, is bending eastward toward the Calumet, partly in virtue of the flattening of the clip

which is here taking place. This effect is much exaggerated upon the map by the depression of the Albany and Boston Creek, which throws the outcrop here too far to the westward. Reduced to Lake Livet, the line of the bed still shows considerable eastward curvature, which, however, notably diminishes at the Albany and Boston, and is hardly apparent at the Rhode Island, where there seems to be almost a slight reversal of the curve. It is a line bearing eastward of this which fails to intersect the Calumet till reaching that mine. A bend at the Rhode Island, similar to that which takes place between the South Pewabic and Portage Lake, or at the Pewabic mine, would throw the Albany and Boston conglomerate west even of the Allouez. The Calumet conglomerate, in going south, also swings westward toward the Albany and Boston. Here, fortunately, we have data which give an approximate idea of the amount of curving. Explorations on the Ossipee and Sawabic show that at about one-fourth of the distance toward the Rhode Island, the Calumet has swerved 60 feet westward from the extended Calumet Base Line, not taking difference in height into account, which might or might not increase this distance. Supposing that this rate continued, not directly as the distance from Calumet, which would give a departure from the extended line at the Rhode Island of 300 feet, but as the *square* of the distance, a most liberal estimate, and which would give a departure of 960 feet, still leaving the bed over 1,400 feet east of the Albany and Boston. Upon previous considerations, it has been seen to be between 1,600 and 1,700 feet east of the Albany and Boston. So far as curvature goes, these two cannot be identical, while placing the Calumet where curvature would probably carry it, leaves the Allouez the same as the Albany and Boston.

*The Calumet base line was extended by Mr. L. G. Emerson southward to the Rhode Island. Mr. A. B. Wood prolonged the Albany and Boston strike, as a picket line, northward toward the Calumet, while the Allouez was prolonged, as a transit line, from the Allouez mine to Calumet by Mr. Harry Beaseley, formerly county surveyor. A line nearly parallel with, but about 900 feet west of, the latter was afterwards run by Mr. L. G. Emerson, southward, I believe, to the Rhode Island.

At the Calumet mine, the dip, according to Mr. G. D. Bolton, is 39° 15'. Both toward the north and south it is increasing, becoming, according to Mr. E. J. Hulburt, 52° at the Albany and Boston, and, according to Mr. G. D. Bolton, 46° at the Allouez, while the survey obtained 43° in several observations on the Kearsarge. It is partly in virtue of this steepening in the dip that the Calumet curves toward the Albany and Boston as we have seen. But if this curvature is small, smaller than is due to the mere steepening of the dip, it shows a bending in the opposite direction of the whole formation, in which case the widening upon the surface between outcrops, also due to decreasing dip, would increase the curvature of beds to the east, while it would diminish it to the west, and at a point far enough off in this direction actually reversing it. This is what takes place. The Allouez conglomerate, as exposed at Calumet, notwithstanding the flattening dip and difference in height between the two, is exposed 120 feet west of the extended Allouez base. If, with a flattening dip, this bed has swerved from the line, with a steepening dip it would again approach it, and, with the thinning of the strata, at the Rhode Island could not be far from the Albany and Boston conglomerate. The Pewabic West conglomerate (No. 16) is too far west to be it, and between the latter and the Albany and Boston the explorations on the St. Mary's show that no conglomerate exists. It must either be the Albany and Boston, or have vanished. It is hardly possible that a dislocation of the strata could have affected this reasoning. The glacial, or preceding eroding agencies, which have so strongly modified the surface of this region, have selected those weak points formed by all known faults of any magnitude upon which to leave their deepest impress. No such surface evidence of any fault exists between Calumet and the Rhode Island.

2d. *Stratigraphical*.—*a*. Number of beds. It will be seen from the table that, considering the Albany and Boston the same as the Allouez, only four, out of fifteen conglomerates considered, are not found in both districts, and these would all pass, supposing them persistent beds, through regions as yet not uncovered from the "drift," unless it be the Calumet. This could easily escape notice on the south shore of Portage Lake under the covered portions of the Dacotah and Huron Properties;* but on the north shore of the lake, certain now-filled-up explorations on the Pewabic should have passed near it. The Survey has been unable to obtain any definite information of these, except that the deep "drift" upon the surface was not always penetrated, and the bed may have been thus not uncovered.

*Fragments of a conglomerate resembling the Calumet have been seen near the road following up the valley of "Huron Creek."

b. Thickening of beds. It is unfortunate that more exposures of the various beds are not known in Keweenaw County, in order that rates of thickening could here be obtained to compare with those of the Portage Lake District. Between Calumet and Kearsarge thickening continues, and also between the Central and the Delaware, though the latter is approximate. The rates of thickening, however, obtained in the Portage Lake District are singularly in harmony with those obtained by comparing Portage Lake distances with those north, and which are placed in the table between the Albany and Boston and Calumet properties. We have already referred to the widening in the zone 14-15 between the Albany and Boston and Central as being the same as that from the Albany and Boston southward, and also to the similarity of rates between 9 and 10. The rate [3-3] between Nos. 7 and 10 is small when the thickness between these beds is considered,—though larger than the rate that exists between these beds from the Huron to the Douglass (which may be obtained by taking the rate before derived [4.6] between 9 and 10 and deriving the distance 6-9 at the Huron, to compare with (2,756) at the Douglass). The distance between 6 and 9 on the Kearsarge is probably also somewhat in error, being scaled from a small map made from measurements by Capt. Newcomb.

Though No. 12 has not been opened to the north, the narrowing zone between it and 11 still continues through. The absence of 12 makes it impossible to directly ascertain the amount of narrowing, but we may approximate to it. Regarding the zone 11-14, we may obtain the rate of widening in it in two ways: first, 14 not being exposed on the Kearsarge, we may calculate its distance from 15 by the rate [2.7] between the two. This gives (462) leaving (2,034) between 14 and 11, which may be compared with the distance between them at the Montezuma;—or, second, we may obtain the rate in the zone 11-15 between the Montezuma and the Kearsarge, and subtract the rate due to the zone 14-15 [2.7]. These two methods give [-1.6] and [-1.7] feet per thousand, respectively, as the rate of narrowing that has taken place between 14 and 11 from the Montezuma to the Kearsarge. This is made up of a widening between 12 and 14, and a narrowing between 11 and 12. At the Kearsarge the rate between 13 and 14 would be about [3.8]—[2.7] or [1.1], leaving [-2.7] between 11 and 14. Supposing the [3] between 12 and 14 to the south continues through, it would leave [1.9] for the zone 12-13 or [-4.6] for the zone 11-12, giving, as at the south, a very decided narrowing going on in this one belt. In the Eagle River District, the "slide" lying some sixty feet above the so-called "Ash-bed," has unmistakable patches of sandstone in it, and is the only bed corresponding with No. 17 in the Portage Lake District. It gives a rate of [7.2] between Eagle River and St. Mary's,—the rate from St. Mary's to the South Pewabic being [6.4]. No. 16 would be represented at Eagle River =by two thin sandstone seams, giving a rate of [4.7] between 15 and 16 from St. Mary's to Eagle River. These seams widen to true sandstones at Copper Falls, six miles farther north-east.

It appears, then, that this particular apposition of the conglomerates, gives rates of widening from the Portage Lake District northward differing but very little from those obtained from actual measurements between known beds in that district,—so little, in fact, that it seems absolutely impossible that it could be owing to mere chance.

3. *Lithological*.—I am unprepared to enter into a detailed correlation of the lithological characters of individual beds, and can only speak of broader distinctions extending over wider areas. Among the conglomerates themselves too much similarity prevails on any one line across the formation to give any conclusive evidence. At Portage Lake, all are much alike. At Calumet, all have gained in addition to their components at Portage Lake, a greater or less percent, of pebbles, of grains of quartz in the pebbles. The representative of the "greenstone" series of Keweenaw County would be the "coarse-grained melaphyrs" occurring between the Albany and Boston and Pewabic west conglomerates in the Portage Lake District. In some beds of the latter, as for instance a belt exposed in a ravine just east of the Hancock Mine, hornblende crystals are abundant, and they closely resemble some of the upper strata of the greenstone series as exposed near Eagle River. There is a decided dissimilarity, however, between the beds lying immediately above conglomerate 15, in Sections II. and V. This can be no argument against the correlation, however, as the change has taken place before the space to be spanned is reached. At the Allouez mine, the lower greenstone beds have lost much of their character, while at the Kearsarge and at Calumet the beds just above No. 15 are more like the beds above it at the St. Mary's than at the Allouez. West of 16, however, the accordance in the general characters of the formations north and south is very striking.

The lithology of the formation lying at any distance south of the greenstone in Keweenaw County, is too little known to compare with equivalents in Houghton County.

Thus, three separate lines of evidence converge to establish the fact that the Albany and Boston and the Allouez conglomerates are one and the same bed.

1. Geographically, they are either identical or else one disappears toward the south, the other probably to the north.

2. Stratigraphically, 11 out of 15 conglomerates have equivalents in both regions, and in such a way that the rates of thickening observed in the Portage Lake District are so nearly reproduced as to render it most improbable that it can be due to chance.

If the alternative of reason 1 is accepted, but few beds would have equivalents, and there would be no general harmony in rates of thickening.

3. Lithologically, conditions, so far as known, are satisfied.

It will be observed, that under these circumstances, the "ash- bed" of Keweenaw County becomes the equivalent of the Hancock, or South Pewabic bed of Houghton County, a correlation that has been suggested by several, and arising, no doubt, from their general lithological resemblance. It is an exception to the general rule, however, of non-persistence of individual amygdaloid beds, and is not a proof of the general reliability of the correlation of individual beds based on individual lithological characters. The family resemblance, as it were, often existing between the beds of certain zones, while it may enable one to say that a distant bed belongs to the zone in question, renders it impossible for any one to prove, on mere lithological evidence, that it is the equivalent of any one certain bed of that zone. In its minerals and peculiar structure, as well as in the accompanying trap, the South Pewabic amygdaloid and the "ash-bed" are much alike. Yet these facts, judging from the interchange of characters sometimes occurring between neighboring beds in other parts of the range, as well as the thinning out of beds and replacement by others, would not prove them to be identical; a fact, the probability of which is made much greater by their occupying the same horizon beneath the same conglomerate.

The Pewabic Lode, which, judged by lithological characters, has been found by different persons at such a variety of points in Keweenaw County, probably does not pass far beyond the Kearsarge; while the bed on which the Concord and Douglass mines are situated, is some distance east of either the Isle Royale or Grand Portage beds. The amygdaloid over conglomerate 9 on the Kearsarge, which is opened on the Huel Vivien, and which is thought by some to resemble the Douglass or Isle Royale bed, must be some 3,000 feet west of them.

The Calumet conglomerate furnishes an instance of a, bed, of which there is perhaps a more general desire in the Copper region to trace than any other bed. While, as will appear in the sequel, there is reason to suppose that it is persistent, there is a possibility that it may continue as a mere seam, and no reason to suppose that it should carry with it the remarkable richness which it has at the Calumet and Hecla mines. The short distance which it has been traced renders prediction as to its place probably more uncertain than of almost any other bed. The only two measurements to it are near together, so that any error in either would strongly affect the rate of widening, and there are no minor facts which can serve to indicate in which way the rate may err. However, its place upon various properties has been calculated, with such data as the table gives, with the following results, which are probably correct within 50 to 150 feet, either one way or the other, depending on the distance of the point from Calumet.

At South Pewabic, 1,390 feet east of conglomerate No. 15 (Albany and Boston) or 3,070 feet (about) east of the South Pewabic amygdaloid.

Huron and Montezuma, between 750 and 850 feet west of No. 12.

On the Huron, 12 is exposed near the Slaughter House, and is the third conglomerate west of Huron Finishing Mills.

On the Montezuma, 12 is exposed on the Lake Side Road, west of Houghton. (See map.)

Pewabic, 1,500 feet east of the Albany and Boston conglomerate.

Mesnard, 1,560 “ ” ” ”

St. Mary's, 1,590 “ “ “ “

Albany and Boston, 1,640 “ “ “

Phœnix Mine, 3,290 (about) south of the "slide" under the "greenstone."

Central (dip 26?) 2,245 (about) south of second conglomerate south of the greenstone.

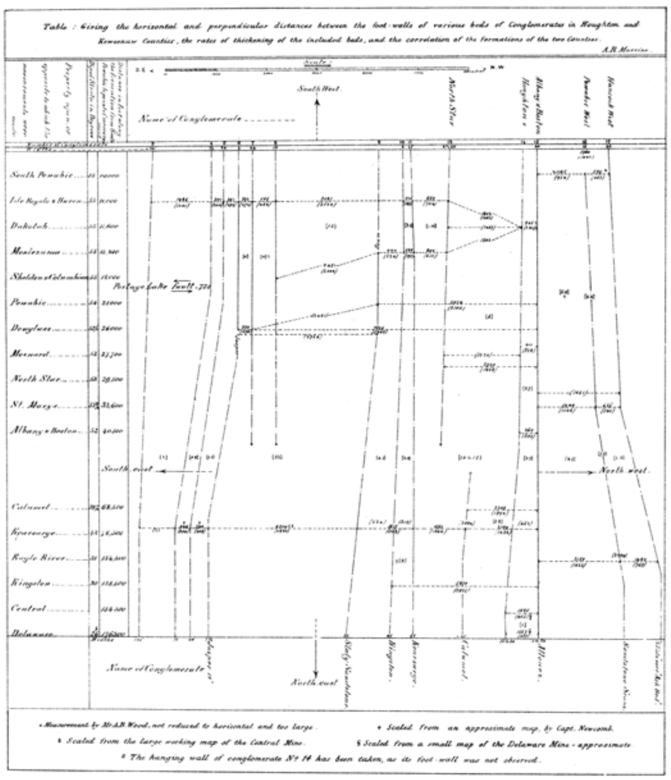
These are approximately the horizontal distances between the beds, and, with a flat dip and much difference in height, should be amended accordingly.

General Conclusions.—There are certain general conclusions which result from the facts presented in the table, and which may be of interest, concerning the original structure of the range. The very uniform thinning of the zones included between the conglomerates toward the south-west, excepting always the zone 11-12, shows that when first laid down in a nearly horizontal position, whatever may have been their mode of origin, the *source* from which the material forming them came, was toward the north-east. I believe that near the extremity of Keweenaw Point the formation is said to be again thinning. If so, it would place this source somewhere abreast of the centre of the Point, and probably to the south or south-east, rather than north of it.

The conglomerates do not seem subject to the general thinning toward the south characteristic of the intermediate beds. In fact, their thickness seems to follow no well-defined law, but to be wholly irregular, some seeming to thin or thicken in one direction as well as another. This fact, together with a pretty general uniform coarseness, would seem to show that the direction of the source from which they were derived was different from that of the melaphyrs, and that the source must have been a shore line not far from parallel to what is now Keweenaw Point. Upon this shore, opposite and north of Calumet, a quartz-porphyry must have predominated among the rocks, and which did not exist further south. This shore line, however, was variable. Conglomerate 9, on the Pewabic, is of the normal Portage Lake type, while at the Kearsarge it is 50 feet wide, and is composed of two parts, a lower of dark gray, more or less fine shaly sandstone, some layers approaching slate in character, an upper of a red, exceedingly fine arenaceous non-shaly sandstone. This portion of the bed must have been further from the shore than that near Portage Lake. The reverse takes place in the first broad conglomerate skirting the north-west border of the range—a heavy conglomerate all along the upper point, near Portage Lake it is composed of sandstones and fine arenaceous shales, which must have been a deep-water deposit compared with the conglomerate.

The conglomerate beds of Keweenaw Point have been generally considered as mere local deposits, rapidly fading out in either direction. The table would seem to show, on the contrary, that for conglomerates they are unusually persistent, and that while a bed may thin out and lose its character as a conglomerate, it may still exist even as a mere seam. Thus the Allouez conglomerate has a thickness of from 15 to 20 feet at the Central and Allouez mines, while near the Phœnix mine, between them, it does not appear, being replaced by what is locally known as the "slide," a layer of soft red clay 2 to 6 inches thick. We gather from those facts that when the beds composing the trappean range were being originally formed, the agencies, whatever they were, which formed what are now the melaphyrs, ceased to act not only over limited but over extended areas, in once instance at least over fifty (50) miles, and for periods of time long enough to allow of the accumulation of beds of conglomerate from a few to over 75 feet—in one instance over half a mile—in thickness.

In the Portage Lake District, commencing upon the eastern limit, so far as known of the range, the trappean zones have considerable thickness, which are separated by three beds of conglomerate about 50 feet thick. Then follows a zone of about 1,300 feet thick, in which there are five conglomerates from 2 to 20 feet thick. Twenty-five hundred feet of melaphyrs and amygdaloids then follow, with no known conglomerate, and then, for 5,000 feet in thickness, nine conglomerates from 200 to 1,000 feet apart, and from almost 0 to 30 feet thick occur. West of these, conglomerates and sandstones frequently occur, in aggregate thickness probably equalling that of the interstratified melaphyrs, until the wide conglomerate (slates and sandstones) is reached.



Fault in Portage Lake: Section II. stands in the relation to Section I. that it would have, supposing the Albany and Boston conglomerate were accurately projected from the Pewabic mine, with the line of strike it then has, until it intersected Section I., and then plotted off from the point so obtained, and moved down into its present position. If the Albany and Boston conglomerate were exposed upon the south shore, there would be shown a fault in this conglomerate of about 710 feet horizontal. Applying corrections for widening to the apparent faults in other conglomerates, gives from 705 to 720 feet, excepting the extreme east and west ones, which give nearly 740 feet. The discrepancies are due to the bending of the formation in crossing the lake, a source of error not easily eliminated. The numbers serve to show, however, that the actual amount of faulting is probably not far from 720 feet, the north shore having been raised or the south shore depressed, giving the effect of the north shore having been moved westward upon the southern one. If the fact that the north shore is generally over a hundred feet higher than the south shore is not wholly due to erosion, it may be in part due to this fault. The dislocation is probably made up of many lines of fracture, as several pass through the Hancock property.

CHAPTER V. DESCRIPTIVE CROSS-SECTIONS AT PORTAGE LAKE.

N.B.—The numbers refer to the *absolute* thickness of the beds in full feet, and the sequence is from older to younger.

Cross-section I.

THIS cross-section is taken, without re-measurement, from the sketch of the exploration-trenches made by the Isle Royale Mining Co., under the superintendence of Mr. Mabbs. These explorations were filled with dirt and water when visited by the members of the Survey.

THE EASTERN SANDSTONE unconformable with the trap series, and dipping gently to the East.

- ? **Amygdaloid;** soft.
- 14. **Amygdaloid;** hard.
- 97. **Conglomerate.**
- 329. **Covered** by swampy ground.
- 43. **Amygdaloid;** light-colored.
- 40. **Amygdaloid;** light-colored.
- 82. **Melaphyr;** dark and rough.
- 82. **Melaphyr;** dark and rough.
- 82. **Melaphyr;** dark and rough.
- 82. **Melaphyr;** gray.
- 82. **Melaphyr;** dark and bluish; carries some fine copper.
- 82. **Melaphyr;** dark and bluish; carries some fine copper.
- 82. **Melaphyr;** gray.
- 46. **Melaphyr;** red.
- 34. **Amygdaloid.**
- 81. **Melaphyr;** red.
- 20. **Amygdaloid.**
- 64. **Melaphyr;** red.
- 64. **Amygdaloid;** red.
- 94. **Melaphyr;** black.
- 42. **Melaphyr;** red.
- 41. **Amygdaloid;** red.
- 83. **Melaphyr;** gray.
- 56. **Conglomerate.**

Cross-section II.

(Determined by triangulation and levelling by the Geological Survey, except where otherwise accredited.)

Hanging-wall of first conglomerate east of the "Mabbs' vein," determined by the Geological Survey.

21. **"Amygdaloid."** From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

77. **"Melaphyr;** gray." " " " "

82. **"Melaphyr;** dark." " " " "

82. **"Melaphyr."** " " " "

2-6. **"Mabbs' vein."** On the foot-wall barrel and mass copper in quartz and calcite. One mass weighed 2,200 lbs. The rest of the vein is stamp-work. Position determined by the Geological Survey.

62. **"Melaphyr."**

111. **"Melaphyr;"** soft, jointed. From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

147. **"Covered."** From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

20. **"Amygdaloid;** epidotic." From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

31. **"Melaphyr;** dark, rough." From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

39. **"Amygdaloid."** From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

148. **"Melaphyr;** dark." Float copper on the surface. From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

148. **"Melaphyr;** bluish." From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

152. **"Melaphyr and Amygdaloid."** Float copper on the surface. From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

23. **"Melaphyr;** dark and rough." From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

17. **"Amygdaloid."** From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

12. Conglomerate. Position determined by the Geological Survey.

53. **"Melaphyr;** bluish." From Mr. Mabbs' map of the Isle Royale Co.'s explorations.
"New Vein." Fissure vein of quartz, prehnite, calcite, copper. Position determined by the Geological Survey.

47. **"Melaphyr;** red, fine-grained." From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

37. **"Amygdaloid."** From Mr. Mabbs' map of the Isle Royale Co.'s explorations.

26. **"Melaphyr;** dark." " " " "

358. **"Covered."** " " " "

1½. "Conglomerate." According to Mr. J. H. Foster, this bed is only ½ an inch thick on the north part of the Shelden and Columbian location.

Covered.

40.+ **Melaphyre.**
Covered

30.+ **Melaphyr;** dark-green, mottled with purple; fine-grained to compact; slightly shimmering.

713. **Covered.**

4. **Amygdaloid;** chocolate-colored, with amygdules of delessite, of quartz, epidote, and prehnite.

16. **Melaphyr;** greenish-brown, fine-grained; contains grains of delessite. Towards the top it contains abundant amygdules of a light-green mineral resembling chrysoprase and passes into

4. **Amygdaloidal Melaphyr;** filled with amygdules of radiating prehnite. This rock passes rather abruptly into

1. **Amygdaloid;** with a dark-brown matrix. (This bed is very persistent in its character, being visible east of the Isle Royale copper-bearing bed on the "Shelden and Columbian," "Grand Portage," "Isle Royale," and "Huron" properties.)

69. **Melaphyr;** brown; fine-grained. Above the middle of the bed the trap contains round masses somewhat resembling boulders 4-8 inches in diameter, which are very amygdaloidal and have the cavities filled with prehnite. These masses increase in number towards the top of the bed. They are much harder than the melaphyr, and stand out an inch or more above the glaciated surface of the rock. Glacial furrows are sometimes forked at these harder points and continue separately beyond them. This bed passes into

15-50. **Amygdaloid;** (" Isle Royale lode;") a mixed green and brown amygdaloid; in places very epidotic with extensive segregations of quartz, calcite, prehnite, and is then richest in copper; in others, brown, with amygdules and seams of laumontite, calcite, etc., and is then poorest in copper.

18. **Melaphyr;** green; medium-grained and crystalline; contains much magnetite and a black, infusible mineral, and near the foot-wall some specks of copper. The weathered surface is dirty white and black, and exhibits magnetite and the infusible black mineral. This plane of contact is in places marked by a thin seam of epidote, which often branches out in irregular seams, and branches into the *underlying* rock.

81. **Melaphyr;** brown-green; fine-grained, contains abundant small flakes of red mica. The weathered surface is fine-grained, gray and rusty-brown from the mica.

277. **Covered.**
Fissure-vein; 6 inches to several feet; quartz and ankerite; carries considerable chalcocite and bornite. It has been struck in the"Shelden and Columbian" mine between the "Bloodgood" and "Skip"-shafts, and on both the "Grand Portage" and "Huron" properties.

38. **Melaphyr;** passing into

12. **Amygdaloid;** with amygdules of prehnite and quartz,

and containing some copper.

31. **Melaphyr;** hard; fine-grained.

128. **Covered.**

? **Melaphyr;** coarse-grained and crystalline; resembles the coarse-grained crystalline melaphyr on the Dacotah location. See Cross-section IX.

Cross-section II. a.

80+ **Conglomerate;** either not present in II. or not observed by Mr. Mabbs.

Cross-section II. b.

(Determined by triangulation and levelling by the Geological Survey, except where otherwise accredited.)

Along the exploration, trenches on the Huron (formerly the Howard) property.

? **Melaphyr;** brown and green; fine-grained; the weathered surface is mottled gray green and dark red.

97. **Covered.**

? **Amygdaloid?** a brown and gray fine-grained rock, which, in places, has brown, porous portions surrounded by a yellow sandy material.
Covered.
Fissure-vein; prehnite and quartz.

47. **Melaphyr;** brown, hard, and compact, with scattered amygdules of delessite.

? **Amygdaloid?** a rock strongly resembling a conglomerate or breccia, of altered trap pebbles; the matrix contains prehnite and quartz.

216. **Covered.**

24. **Conglomerate;** in places the cement of this conglomerate is very hard, and filled with small round amygdules of calcite and laumontite. Sometimes these minerals have disappeared, and the cement then presents the appearance of a scoria. There is a thick flucan on the hanging-wall.

? **Melaphyr;** light green, with spots of dark-green delessite; soft; fine-grained.
Covered.

? **Amygdaloid;** green, compact, very hard and silicious matrix, with amygdules and segregations of quartz, epidote, and calcite; a pit was sunk on this bed.

157. **Covered.**

3.? **Conglomerate;** small pebbles of brown non-quartziferous porphyry lying in a fine-grained cement of very calcareous sandstone containing more or less epidote.

260. **Covered.**

24. **Conglomerate;** with a band of sandstone on the upper side.

255. **Covered.**

? **Amygdaloid;** ("Foster Mass vein.") ("Ancient Pit vein.")

85. **Covered.** From the notes of Mr. A. B. Wood.

5. **Amygdaloid.** From the notes of Mr. A. B. Wood.

85. **Covered.**

10.+ **Conglomerate;** small pebbles of brown non-quartziferous porphyry, in a highly calcareous cement of comminuted porphyry; rich in magnetite. Carries some sheet-copper near the hanging-wall.

355. **Covered.**

7. **Amygdaloid;** light green, and filled with amygdules of quartz, chlorite, and some epidote.

150. **Covered.**
"Isle Royale" cupriferous bed.

Cross-section II. c.

(Determined by triangulation and levelling by the Geological Survey.)

(On the south part of the "Shelden and Columbian" location.)

? **Amygdaloid;** brown; soft; with irregular streaks of a compact brown material resembling hardened clay.

? **Melaphyr;** hard; fine-grained.

1. **Fissure-vein;** quartz, prehnite, and calcite.

35. **Melaphyr and Covered.**

? **Conglomerate?** grayish green rock with occasional pebbles.

Cross-section II. d.

(Determined by triangulation and levelling by the Geological Survey.)

? **Conglomerate.**

Cross-section II. e.

(Determined by triangulation and levelling by the Geological Survey.)

? **Melaphyr;** dark brownish green; fine-grained; contains considerable magnetite and fuses not very easily to a black and very magnetic globule. Towards the top of the bed it contains quartz amygdules, and then without any sharp line of separation becomes mixed with, and passes into

3-6. **Amygdaloid;** yellowish green, matrix of epidot and quartz, with quartz amygdules; this passes rather abruptly into

1. **Amygdaloid;** dark-brown, semi-vitreous matrix, with amygdules of quartz and chlorite, and seams of calcite; the weathered surface is green and brown; contains some copper.

50. **Covered.**

? **Melaphyr;** red and green; soft; contains little or no magnetite, scattered amygdules of calcite, also of quartz, sometimes carrying copper; fuses to black magnetic enamel. This bed frequently contains large and small masses of quartz and epidote, having amygdules of quartz.

? **Amygdaloid;** light green to bluish and brown green; silicious matrix, containing amygdules of quartz, with chlorite and seams of brown jasper.

Cross-section II. f.

(Determined by triangulation and levelling by the Geological Survey.)

? **Amygdaloid;** the lower half of the bed is greenish brown, hard, with amygdules of calcite, prehnite, and green-earth. The upper half is dark brown, and filled with minute amygdules of laumontite and prehnite.

58. **Covered.**

9. **Amygdaloid;** purple brown, compact and hard, with abundant amygdules of quartz; the matrix fuses with difficulty to a magnetic glass.
Covered.

? **Melaphyr;** mottled light and dark green; fine-grained.
Covered.

? **Melaphyr;** brown; very fine-grained, with some spots and seams of delessite, and occasional small amygdules of calcite.

Cross-section II. g.

(Determined by triangulation and levelling by the Geological Survey.)

? **Amygdaloid;** green; very fine-grained, and not very hard rock, fusible on the edges to black magnetic glass; probably a silicious chloritic rock.
Covered.
Amygdaloid; of varying character; in places brownish green, compact and hard, quartz epidote rock, with small amygdules of calcite; other portions are dark brown and soft, with amygdules of calcite, or calcite and green-earth.
This bed shows stains of carbonate of copper.
Covered.
Melaphyr; dark green, semi-crystalline, and slightly shimmering; contains considerable magnetite, and weathers rusty gray.
Covered.
Melaphyr; dark, almost black; compact and slightly shimmering, and tolerably soft. Near the "Capen vein" it is spotted with foliated delessite, and carries minute particles of copper; small pieces of the rock adhere to the magnet.
"Capen vein" (apparently a fissure vein). Seams of calcite, prehnite, laumontite, and fibrous chlorite, with copper in flakes and sheets. Several tons of copper were extracted from this pit.

Cross-section II. h.

(Determined by triangulation and levelling by the Geological Survey.)

On the north part of the "Shelden and Columbian" location.

? **Melaphyr;** dark green; hard, semi-crystalline, compact, near the "Capen vein" it becomes highly chloritic, and the joints are covered with smooth asbestiform delessite.

½—3. **"Capen vein"** (see description in Cross-section II. g). An adit was driven here and some sheet-copper found.

102. **Covered.**

17.+ **"Ancient Pit" Amygdaloid.** (So called from the fact that a number of ancient workings were discovered on the "back" of this bed.) Portions of this bed are almost a homogeneous melaphyr, but the greater part bears a striking resemblance to a breccia, owing to the segregation of quartz, prehnite, and calcite in countless fine cracks, enclosing irregular fragments of the rock from the size of a pea to several inches in diameter. In some places the rock becomes epidotic, retaining the same structure and segregations. Some copper was found here.

168. **Covered.**

12. **Conglomerate.** (1st conglomerate east of the Isle Royale copper-bearing bed.) Some small pieces of copper were taken out of this bed.

Cross-section II. i.

(Determined by triangulation and levelling by the Geological Survey.)

"Ancient Pit" Amygdaloid; same character as in II. h.

Cross-section II. j.

(Determined by triangulation and levelling by the Geological Survey.)

? **Melaphyr.**

25. **Covered.**

? **Amygdaloidal Melaphyr;** dark green; hard; containing amygdules of prehnite impregnated with native copper.

Cross-section II. k.

(Determined by triangulation and levelling by the Geological Survey.)

14. **Amygdaloid;** bed irregularly occupied by bright green epidotic rock, abounding in grains of clear quartz, and a dark brown amygdaloid with amygdules of epidote and calcite, and of porous delessite or green-earth.

20. **Melaphyr;** green brown, fine-grained; towards the top it becomes

8. **Amygdaloidal Melaphyr;** with amygdules of delessite, and of delessite and green and rose-colored prehnite.

7. **Amygdaloid;** green brown, compact, with, amygdules of quartz and chlorite, and larger amygdules and seams of green and rose-colored prehnite.

73. **Covered.**
Fissure-vein; direction north-west. Comby strings of quartz with calcite arsenurites of copper, chalcocite, and native copper.

12. **Covered.**

9.+ **Amygdaloid;** this bed has been opened here by an adit, under the erroneous supposition that it forms the continuation of the Isle Royale copper-bearing bed, which really lies to the westward.

55. **Melaphyr;** brown, slightly mottled with dark green; fine-grained; it becomes green higher up and more distinctly crystalline, and near the top assumes abundant spots and grains of delessite.

5. **Amygdaloid** (probable continuation of the Isle Royale cupriferous bed); grayish green, compact, epidotic matrix, with semi-conchoidal fracture; filled with amygdules of prehnite. The upper portion of the bed, to the extent of 1 foot in thickness, is a well-defined band of dark brown amygdaloid with spike-shaped amygdules, standing at right angles to the plane of stratification, and filled with prehnite, which is frequently replaced by porous delessite.

20. **Melaphyr;** brown, fine-grained and hard; weathers dirty gray; towards the top it becomes

3. **Amygdaloidal Melaphyr;** with irregular grains of delessite, sometimes containing epidote, and amygdules of prehnite.

4. **Amygdaloid;** greenish gray, with amygdules of delessite, quartz, and laumontite. The upper portion of the bed is compact gray-green epidote, with tabular fracture filled with amygdules of quartz.

37. **Melaphyr;** passing into

6. **Amygdaloidal Melaphyr;** containing amygdules of prehnite. This passes into

1. **Amygdaloid;** brown, compact, with amygdules, and irregular masses of delessite, red feldspar, prehnite, quartz, and epidote. (Observed succession—1, delessite; 2, red feldspar; 3, quartz, epidote.)

9. **Melaphyr;** dark brown, fine-grained, weathers dirty brown gray.

20. **Melaphyr;** green brown, fine-grained, with many irregular grains of delessite, the weathered surface is brown white, pitted with rust-colored holes from the decomposition of the delessite grains. Towards the hanging-wall it becomes

7. **Amygdaloidal Melaphyr;** containing irregular small segregations of red feldspar (orthoclase ?), prehnite, and quartz. The feldspar contains casts of rhombohedrons of calcite.

3. **Amygdaloid.**

50. **Covered.**
Grand Portage Cupriferous Amygdaloid.

Cross-sections II. l; *II.* m; *II.* n.

(Determined by triangulation and levelling by the Geological Survey.)

Shafts on the Grand Portage Amygdaloid on the Shelden and Columbian, and Grand Portage locations.

Cross-section II. o.

(Determined by triangulation and levelling by the Geological Survey.)

? **Amygdaloidal Melaphyr;** dark, fine-grained matrix, with numerous amygdules of prehnite. Farther north and south this bed appears more amygdaloidal and somewhat cupriferous, and forms the so-called "Frue lode."

? **Melaphyr.**

Cross-section III.

(Determined by triangulation and levelling, etc., by the Geological Survey, except where otherwise accredited.)

? **Melaphyr.**

9. **Amygdaloid.**

8. **Amygdaloid;** with amygdules of prehnite.

8. **Amygdaloid;** (Frue "lode") bears copper.

10. **Melaphyr.**

11. **Amygdaloid;** green and hard, with amygdules of quartz.

12. **Melaphyr.**

8. **Amygdaloid;** green and hard, with amygdules of quartz.

10.† **Melaphyr.**

279. **Covered.**

? **Melaphyr.**

14. **Amygdaloidal Melaphyr;** purplish gray, fine-grained matrix, with uneven fracture, carrying grains of delessite, and large amygdules of prehnite; it contains bunches of epidote and on the hanging-wall a seam of epidote with amygdules of prehnite.

60. **Melaphyr;** gray green, hard, fine-grained, and indistinctly crystalline.

35. **Amygdaloidal Melaphyr;** gray green, and fine-grained; contains amygdules of prehnite. In some instances large amygdules of delessite show a tendency to the radiating structure of the prehnite, and in some cases the prehnite amygdules are entirely changed in the interior to delessite, the outer portion being partially intact. This bed contains many bunches of compact epidote, with amygdules of prehnite, and in the upper portion crystals of epidote are visible in the matrix.

40. **Melaphyr;** green, compact, with semi-conchoidal fracture; contains lamellæ of a red mica which resist the weathering.
Melaphyr Seam; indistinctly crystalline, containing prehnite in amygdules and impregnations.

32. **Melaphyr;** same as that below the seam.

15. **Melaphyr;** gray-green rock, with numerous red spots of mica; contains ¼ inch amygdules or grains of compact and radiating delessite. Near the hanging-wall it carries amygdules of prehnite and bunches of compact green rock, with amygdules of prehnite, epidote, and delessite. Still nearer the top it becomes

12. **Amygdaloidal Melaphyr,** with many small amygdules of prehnite.

37. **Melaphyr;** similar to the next underlying.

21. **Melaphyr;** dirty green, compact, and containing less red mica than the underlying varieties.

10. **Amygdaloidal Melaphyr;** green and hard, with amygdules of prehnite.

11. **Amygdaloid;** very hard epidotic matrix, with amygdules of prehnite and calcite.

129. **Covered.**

? **Amygdaloid.** (Position given by Mr. R. Shelden.)

79. **Covered.**

? **Amygdaloid.** (Position given by Mr. R. Shelden.)

17. **Covered.**

? **Amygdaloid,** bearing copper. (Position given by Mr. R. Shelden.)
Covered.

Cross-section III. a.

(Taken from notes furnished by Mr. A. B. Wood.)

Cross-section III. b.

(Determined by triangulation and levelling, etc., by the Geological Survey.)

32. **Amygdaloid.**

63. **Melaphyr;** gray brown, fine-grained and hard; contains scattering amygdules of delessite and much red mica.

24. **Melaphyr;** green, compact, speckled with red mica; contains some amygdules of prehnite.
Seam.

10. **Melaphyr.**

7. **Melaphyr;** same as the next underlying. Near the hanging-wall it carries abundant amygdules of prehnite.

? **Melaphyr.**

56. **Covered.**

? **Melaphyr;** green, compact and hard, with specks of red mica.
Melaphyr Seam; coarsely crystalline, greenish gray.

50. **Melaphyr;** same as next underlying the seam; weathers dirty gray; passes into

? **Amygdaloidal Melaphyr;** containing numerous small amygdules of delessite, and larger ones of prehnite, some of which last are partially changed into foliated and amorphous delessite.

10.* **Amygdaloid;** brown and green; contains a little copper.

? **Melaphyr.**

Cross-section III. c.

(From notes furnished by Mr. A. B. Wood.)

Cross-section IV.

(Determined by triangulation and levelling, etc., by the Geological Survey.)

? **Melaphyr;** gray green, hard, fine-grained, and speckled with ruby-red mica.

43. **Covered.**
Melaphyr Seam; coarse-grained and crystalline, and containing apparently feldspar, chlorite, hornblende or pyroxene, mica, and specular iron.

10. **Melaphyr;** green brown and fine-grained, with red mica and grains of delessite.
Epidote Seam.

12. **Melaphyr;** same as next underlying.

2. **Melaphyr Seam;** coarse-grained and crystalline.

8. **Melaphyr;** brown green, compact and hard, with some red mica, and weathering dirty white. Near the top it contains amygdules of prehnite and delessite.
Seam.

4. **Amygdaloid;** with epidotic matrix.
Seam.
Covered.

Cross-section V.

(Determined by triangulation and levelling, etc., by the Geological Survey.)

36. **Amygdaloid;** very epidotic, and containing ½ inch amygdules of prehnite.

36. **Jasper;** apparently stratified, and more or less epidotic. In places, highly siliceous, with amygdules of quartz; in others a soft brown amygdaloid.

? **Melaphyr;** gray green, passing into

Amygdaloidal Melaphyr; with amygdules of prehnite and of epidote.

190. **Covered.**

? **Melaphyr.**

233. **Covered.**

5. **Conglomerate.**

170. **Covered.**

? **Melaphyr;** brown, with amygdules of delessite.

6. **Conglomerate.**

24. **Melaphyr;** with much epidote.

9. **Conglomerate.**

115.+ **Melaphyr;** fine-grained; brown, spotted green and red.

168. **Covered.**

Amygdaloidal Melaphyr.

? **Melaphyr;** fine-grained.

70. **Covered.**

60. **Amygdaloid;** the lower part of the bed is a confused mass of epidote-quartz rock and brown amygdaloid; while the upper and larger part of the bed is a brown amygdaloid, in which amygdaloidal masses are enveloped in a brown, hardened, clay-like material, resembling portions of the South Pewabic and Hancock beds.

133. **Melaphyr;** fine-grained.

1. **Seams** of coarsely crystalline melaphyr, containing crystals of green triclinic feldspar, delessite, and specular iron.

56. **Melaphyr.**

3. **Conglomerate;** contains rare pebbles of quartz porphyry, similar to that of the Calumet conglomerate; also traces of copper.

8. **Covered.**

10. **Amygdaloid;** green; contains segregations and amygdules of quartz, prehnite and calcite, and some copper.

114. **Covered.**

3. **Amygdaloid;** green; contains amygdules of prehnite, quartz, and calcite.

62. **Covered.**

10.? **Amygdaloid;** ("Montezuma lode.") Brown and green siliceous matrix, with amygdules of prehnite, and quartz and some copper.

102. **Melaphyr** and **Covered.**

5. **Amygdaloid;** brown amygdaloidal matrix, with large and small irregular segregations of quartz with prehnite.

99. **Covered.**

62. **Amygdaloid;** the *lower* portion of the bed, for a thickness of several yards, is a green and more or less epidotic and siliceous amygdaloid; the *upper*, and much thicker portion of the beds, is a soft brown amygdaloid, containing amygdules of red laumontite, and irregular seams and spots of a soft white mineral (Kaolin ?)—perhaps a decomposition product of a zeolite.

127. **Melaphyr.**

? **Amygdaloidal Melaphyr.**

60. **Covered.**

? **Melaphyr.**

60. **Covered.**

? **Melaphyr.**

Cross-section V. a.

(North ½ of Sect. 2, Town. 54, Range 34.)

(Taken in part from the notes of Mr. A. B. Wood, and in part by triangulation and levelling by the Geological Survey.)

Cross-section V. b.

(Determined by triangulation and levelling, etc., by the Geological Survey.)

Amygdaloid.

Cross-section V. c.

From notes furnished by Mr. R. Shelden.

Cross-section V. d.

(Determined by triangulation and levelling, etc., by the Geological Survey.)

Amygdaloid; epidotic.

Cross-section VI.

(Determined by triangulation and levelling, etc., by the Geological Survey.)

Along part of the road from Portage Lake to the Huron Stamp Mill.

? **Melaphyr;** hard.

44. **Amygdaloid;** the lower portion of the bed is epidotic and hard; the upper portion is a soft brown rock, abounding in laumontite, and containing patches of epidote and quartz.

37. **Melaphyr;** hard.

33. **Covered.**

28. **Melaphyr;** hard.

17. **Amygdaloid;** soft brown, and abounding in laumontite.

? **Melaphyr;** hard.

Cross-section VII.

(Determined by triangulation and levelling, etc., by the Geological Survey.)

Along the banks of Dacotah Creek.

? **Amygdaloid;** soft; brown, and abounding in laumontite.

35. **Melaphyr;** grayish brown; fine-grained; earthy fracture; soft; contains much red mica.

21. **Amygdaloid;** a very irregular mixture of bright-green epidotic rock, containing grains of quartz, with a soft chocolate-colored rock containing amygdules of delessite and calcite, and larger bunches of calcite with radiating crystals of leonhardite. The epidotic portions of the bed are impregnated with copper.

? **Melaphyr;** grayish brown; soft; fine-grained; contains much red mica.

Cross-section VIII.

Position indicated by the Hon. S. W. Hill.

1½-2 ft. **Conglomerate;** considered by Mr. Hill to be the "Houghton" conglomerate. The trench in which it was formerly exposed was filled with rubbish when visited by the Geological Survey. According to Mr. Hill, it was well filled with copper.

Cross-section IX.

(Determined by transit survey, chiefly underground, by the Geological Survey.)

? **Amygdaloid;** portions of the bed fine-grained, greenish-gray to bluish-green, siliceous matrix; very hard (strikes fire with steel), and filled with amygdules of white quartz, more rarely of calcite; portions of the bed consist of soft, chocolate-colored material, with amygdules of calcite and of green-earth. Struck in bottom of a shaft; width not seen.

? **Melaphyr;** soft; greenish brown; fine-grained with spots of delessite, and thin filmy seams of laumontite. Struck in the end of an adit. No walls seen.

120. **Concealed** on south side of Portage Lake.

11. **Amygdaloid;** fine-grained, soft green-brown matrix, with irregular amygdules of delessite and green-earth, and of delessite and quartz. The upper portion of the bed is chiefly green-brown amygdaloid, with compact siliceous matrix and amygdules of more or less crystalline quartz, of quartz and epidote, and of calcite. Forms the east end of the adit.

19. **Melaphyr;** green; fine-grained; somewhat crystalline; tolerably hard; contains minute acicular crystals of triclinic feldspar and much magnetite.

7. **Amygdaloid;** towards foot-wall, soft brown-green matrix with earthy fracture; contains amygdules of quartz coated with delessite, and of quartz and epidote. It carries fine copper. The upper portion of the bed has a compact, gray-green, and very siliceous matrix, with amygdules of quartz and of calcite.

76. **Melaphyr;** the lower portion of the bed is green and fine-grained, the upper portion contains seams of laumontite.

5. **Amygdaloid;** light green; soft, with earthy fracture; contains amygdules of quartz, of delessite, and of quartz and epidote.

6. **Amygdaloidal Melaphyr;** green brown, soft, with earthy fracture; contains spots of delessite and amygdules of green-earth and of laumontite.

8. **Amygdaloid;** soft, almost earthy, green rock in the lower part of the bed, with brown streaks; contains flakes of delessite. The upper portion is more amygdaloidal, with amygdules of quartz and epidote, and forms, in places, a very hard and compact brown and green rock, with semi-conchoidal fracture. Some copper was found in the bed, and some rich boulders of exactly similar rock, in driving the adit through, the sand near by. It has been supposed to be the continuation of the Pewabic copper-bearing bed.

? **Melaphyr;** very disintegrated, and containing laumontite. Thickness not known.

106. **This ground** is said to have been cut in the next adit westward, but as this was driven below the lake level, and full of water, it was inaccessible to the Survey.

? **Melaphyr;** mottled, grayish green and dark green; contains abundant spots of delessite, and minute indistinct crystals of green feldspar. Forms the eastern end of the adit on the south side of the lake-shore road.

7. **Amygdaloid;** very hard, siliceous, compact matrix, with conchoidal fracture; brown, speckled with green; contains amygdules of quartz, of calcite, and of laumontite.

13. **Melaphyr;** soft, with considerable laumontite.

15. **Amygdaloid;** brown, shaded with green; very hard, compact, siliceous matrix, with conchoidal fracture; contains abundant amygdules of quartz, more rarely of green-earth, of calcite, or of epidote and quartz.

29. **Amygdaloidal Melaphyr;** green, fine-grained, semi-crystalline rock, mottled with dark green delessite, and containing minute crystals of green triclinic feldspar, and amygdules of quartz and delessite.

22. **Amygdaloid;** brown, semi-crystalline matrix, with earthy fracture, containing minute crystals of triclinic feldspar, and filled with irregular spots of dirty green chlorite, and amygdules of calcite and laumontite. The upper portion of the bed is siliceous and compact, with better defined amygdules of quartz and delessite, and of quartz and epidote, and in places is highly siliceous and contains seams of quartz and amygdules of quartz and of prehnite.

60*. **Melaphyr;** coarse-grained and crystalline; consists of light green triclinic feldspar, and black green delessite, in apparently nearly equal proportions. It contains considerable magnetite. It closely resembles a similar rock, west of the Pewabic copper-bearing bed, on the Quincy and St. Mary's locations.

122. **Not exposed** on the south side of Portage Lake, but very possibly the same crystalline melaphyr, since this bed is between 200 and 300 feet thick on the St. Mary's.

12. **Amygdaloid;** green, and tolerably compact, hard matrix, with amygdules of quartz and of laumontite; the upper portion of the bed has a brownish-green and rather siliceous matrix, with abundant amygdules of laumontite.

25. **Not exposed** on the south side of Portage Lake.

3. **Amygdaloid;** light green, soft matrix, with earthy fracture, containing amygdules of delessite and of quartz.

25. **Not exposed** on the south side of Portage Lake.

? **Amygdaloid;** green matrix, with amygdules of quartz, laumontite, and calcite, in places highly siliceous; often the matrix is changed to a red jasper near the amygdules.

323. **Not exposed** on the south side of Portage Lake.

Cross-section IX. a.

(Included in IX.)

Cross-section IX. b.

(Determined by the measurements of the Geological Survey.)

In the trenches east of the South Pewabic Mine.

33.? **Conglomerate;** porphyry pebbles, with grayish-red cement. The cement effervesces somewhat in muriatic acid, and fuses partially B. B. to white highly magnetic glass with black specks.

22. **Covered.**

? **Amygdaloid;** green brown; compact, and abundantly filled with amygdules of a soft pink zeolite. The matrix is very hard, and fuses on the edges of splinters to a highly magnetic glass. It contains films of magnetic iron.

25. **Covered.**

? **Melaphyr;** gray green, fine-grained, and soft, with scattered amygdules of quartz. Is quite soft, probably very chloritic. Contains magnetite; fuses with intumescence to a dark magnetic glass.

200. **Covered.**

? **Melaphyr;** gray green; amorphous, or crypto-crystalline matrix, porphyritic, through numerous long, flat crystals of green triclinic feldspar, and grains (pin-head to pea size) of almost black delessite. Contains irregular amygdules of a soft pink zeolite (laumontite), and considerable magnetite. Mixed with the fragments of this trap are those of a more even-grained and darker variety.

65. **Covered.**

10? **Amygdaloid;** matrix the same as in next rock to west; the irregular cavities either empty or coated with delessite, or crystals of quartz. Perhaps part of next bed west.

22? **Amygdaloid;** blue green; hard, round, and sometimes connected amygdules of calcite or quartz, or again of a flesh-colored, soft zeolite (leonhardite?). The cavities are often bordered on one side by a dark-red jaspery substance. This red substance may be simply the result of oxidation of protoxide of iron in the bluish-green matrix, without further decomposition of the rock. It is accompanied in the debris on the side of the trench by a fine-grained, green, slightly amygdaloidal trap, with amygdules of quartz, and filled with minute green-white points.

400. **Covered.**

100.?* **Melaphyr;** green; crystalline; light-green triclinic feldspar, and delessite in irregular grains, in apparently nearly equal amount. Contains grains of magnetite, also apparently some tabular crystals of specular iron ore. Closely resembles the bed 200-300 feet thick, in about the same position on the St. Mary's, and a similar bed on the Dacotah. Thickness not observed, but seems to be more than 100 feet. Neither wall seen.

470. **Covered.**

? **Melaphyr.**

8-12. **South Pewabic Amygdaloid;** almost uniformly chocolate brown. It is characterized by the very general presence of a fine-grained or compact, brown material with conchoidal fracture, varying in hardness from quite soft to harder than steel; this substance effervesces in muriatic acid, owing to the presence of minutely associated calcite. The smallest splinters fuse on the edge, and become magnetic. This red material is so distributed as to resemble the cement of a conglomerate in which the more amygdaloidal portions resemble the pebbles, but this is merely a resemblance. The amygdaloidal portions are darker brown, often tinged with green; they are usually a few inches in diameter, and are filled with spherical amygdules of shot sizes, chiefly of quartz, calcite, delessite, green-earth, and copper; the matrix fuses to a black magnetic glass. The copper is disseminated as a coating of the amygdules, and in thin films in the cracks.

53. **Covered.**

21. **Conglomerate** ("Hancock West" conglomerate).

? **Amygdaloid.**

Cross-section X.

(Determined by underground compass survey by the Geological Survey.)

? **Melaphyr;** fine-grained green rock, with minute crystals of green triclinic feldspar, and spots of dark-green delessite and seams of chalcedony. It forms the eastern end of the easternmost adit on the "South-side" location.

22. **Amygdaloidal Melaphyr;** soft green rock, with earthy fracture, containing much delessite; it is traversed by minute threads of calcite, and filled with amygdules of laumontite.

4. **Melaphyr;** dark green, fine-grained, and hard, with minute crystals of green triclinic feldspar, and spots of dark-green delessite.

4. **Amygdaloid;** light green, rather hard and siliceous matrix, with semi-conchoidal fracture; contains amygdules of quartz and laumontite.

9. **Melaphyr;** contains laumontite.

2. **Amygdaloid;** light green, hard and siliceous, with amygdules of laumontite and quartz.

2. **Melaphyr.**

2. **Amygdaloid;** brown, speckled with green, very siliceous, with conchoidal fracture; contains amygdules of quartz and chlorite.

5. **Melaphyr;** with amygdules of laumontite near the hanging-wall.

4. **Amygdaloid;** brown and green, very siliceous, with conchoidal fracture; contains amygdules of quartz and some laumontite.

4. **Melaphyr;** dark green, fine-grained, and hard.

? **Amygdaloid;** dirty green, with earthy fracture, contains amygdules of leonhardite and of delessite, and minute specks of a soft flesh-colored zeolite. Parts of the bed are a very siliceous brown and green amygdaloid, with conchoidal fracture containing amygdules of quartz.

Cross-section XI.

(The eastern adit was surveyed by compass; the western adit by transit, by the Geological Survey; the remaining beds are given from the notes of Mr. A. B. Wood.)

On the "South-side" location.

5. **Amygdaloid;** grayish green, siliceous, filled with amygdules of laumontite.

23. **Melaphyr;** green and chloride, becomes amygdaloidal towards the top of the bed, assuming amygdules of delessite and passing into the overlying bed.

4. **Amygdaloid;** green and hard; the cavities are either empty or filled with laumontite.

40. **Melaphyr;** dirty green, very fine-grained, with perfect conchoidal fracture, and containing much diffused magnetite. Near the hanging-wall becomes very amygdaloidal, the cavities being either empty or filled with delessite, or with quartz coated with delessite.

25. **Amygdaloid;** the matrix consists largely of a brown crystalline mineral, and contains abundant round and oval amygdules of quartz surrounded with laumontite. This rock resembles in places that of the South Pewabic copper-bearing bed, being then traversed by a chocolate-colored, very fine-grained material, which has an even earthy fracture, is easily scratched, and fuses readily to a dark-green, somewhat magnetic glass. This reel material also contains irregular amygdules of laumontite enclosing quartz, and smaller fiat ones of laumontite alone, so arranged as sometimes to give to the rock a laminated appearance.

? **Melaphyr;** dark gray green, and very fine-grained, with imperfect conchoidal fracture; it contains specks and threads of delessite, minute threads of laumontite and magnetite both diffused and in distinct grains.

82. **Covered.**

32.? **Conglomerate;** (" Hancock West.")
From the notes of Mr. A. B. Wood.

38. **Melaphyr.** " "

Epidote Seam. " "

135. **Melaphyr.** " "

20. **Amygdaloid;** the lower portion of the bed is a fine-grained, soft rock, speckled brown and yellowish green, containing amygdules and specks of a soft, greasy white mineral, and of delessite with calcite, and more rarely of laumontite. The rest of the bed is chiefly a dark chocolate-brown rock, filled with amygdules of calcite, or of laumontite, or of laumontite enclosing calcite. Druses occur containing crystals of analcite ⅛ to ½ inch in diameter, with super-imposed crystals of orthoclase.

47. **Melaphyr.**

5. **Amygdaloid;** dark purple brown, with large irregular vesicles which are either empty except a lining of red laumontite (?), or filled within this coating with calcite or with green-earth. This bed carries some

copper.

27. **Amygdaloidal Melaphyr;** soft, and containing many large and small amygdules of laumontite and calcite.

5. **Melaphyr.**

10. **Amygdaloidal Melaphyr;** soft, with amygdules of laumontite and calcite.

44. **Melaphyr;** very dark colored, hard and compact, with conchoidal fracture, and containing minute crystals of green triclinic feldspar, and very little visible delessite, some diffused magnetite, and grains of a hard, black, infusible mineral.

9. **Amygdaloid;** dark green, soft, and consisting largely of amygdules of calcite and chlorite.

155? **Conglomerate;** forms the west end of the westernmost adit on the "South-side" location.

94. **Melaphyr.** From the notes of Mr. A. B. Wood.

13. **Sandstone.** " "

100. **Melaphyr;** coarse-grained. " "

19. **Sandstone and Conglomerate.** " "

51. **Amygdaloid.** " "

15. **Sandstone.** " "

66. **Melaphyr;** compact, gray. " "

? **Conglomerate;** width unknown, but very thick. " "

Cross-section XII.

(From the measurement of Mr. Graveldinger.)

On the Douglass location.

? **Amygdaloid;** epidotic matrix.

138. **Covered.**

? **Amygdaloid.**

13. **Melaphyr.**

? **Amygdaloid.**

46. **Melaphyr.**

? **Amygdaloid.**

12. **Melaphyr.**

? **Amygdaloid;** epidotic.

60. **Melaphyr.**

? **Amygdaloid.**

195. **Covered.**

? **Amygdaloid;** "soft."

11. **Melaphyr.**

? **Amygdaloid.**

61. **Covered.**

? **Amygdaloid;** "epidotic."

45. **Melaphyr.**

? **Amygdaloid;** light green; soft; contains amygdules of delessite and copper.

? **Jasper;** banded brown and green.

17. **Melaphyr.**

? **"Capen vein." "Mass vein."**

10. **Melaphyr.**

63. **Covered.**

? **Amygdaloid;** "Ancient Pit" bed; resembles the same bed on the Shelden and Columbian location.

168. **Covered.**

? **Conglomerate.**

525. **Covered.**

? **Amygdaloid,** in which is the Douglass mine.

Cross-section XIII.

(Determined by the measurements of the Geological Survey.)

On the North-star location.

31. **North-star Conglomerate.**

188. **Covered.**

6.? **Amygdaloid,** resembling that of the Montezuma mine.

Cross-section XIV.

(Determined by the Geological Survey.)

At the Albany and Boston Mine.

? **Houghton Conglomerate;** rounded pebbles of medium size, of brown porphyry (non-quartziferous). The cement is, in places, calcite and laumontite (?) altered to red clay; in places, a very chloritic sand.

10. **Covered.**

38. **Melaphyr;** fine-grained, green, soft; abounds in delessite; crystals of green triclinic feldspar are visible.

9. **Amygdaloidal Melaphyr;** green brown, fine-grained, in places resembling the crystalline seams in trap west of the Isle Royale group, and carrying amygdules of delessite and others of prehnite undergoing change to delessite.

8. **Amygdaloid;** chocolate brown, finely crystalline to amorphous matrix; amygdules of prehnite changing to delessite; also of calcite.

12. **Melaphyr;** brown green, very fine-grained, soft.

Covered.

Melaphyr; greenish gray; finely crystalline.

Covered.

Amygdaloidal Melaphyr.

Melaphyr; very crystalline; contains flat thin crystals of brown and white triclinic feldspar and grains of delessite or chlorite.

Cross-section XIV. a.

(Determined by the measurements of the Geological Survey.)

East of the Mesnard Mine.

? **Houghton Conglomerate.**

Cross-section XV.

In the open trenches on the St. Mary's location.

The positions of the conglomerates, and of the rocks lithologically described in this section, were determined by the Geological Survey; the remainder is from the notes of Mr. A. B. Wood.

Covered.

15. **Melaphyr.**

8. **Melaphyr.**

31. **Melaphyr.**

9. **Amygdaloid.**

63. **Melaphyr.**

40. **Amygdaloid.**

35. **Albany and Boston Conglomerate.**

40. **Melaphyr.**

38. **Melaphyr.**

17. **Melaphyr.**

10. **Amygdaloid.**

20. **Melaphyr.**

31. **Melaphyr.**

7. **Amygdaloid.** ("Albany and Boston Amygdaloid.")

29. **Melaphyr.**

6. **Amygdaloid.**

90. **Melaphyr.**

12. **Amygdaloid.**

10. **Amygdaloid.**

9. **Amygdaloid.**

32. **Melaphyr.**

81. **Melaphyr.**

11. **Amygdaloid.** (Supposed Pewabic cupriferous bed.)

25. **Melaphyr.**

9. **Amygdaloid.**

78. **Melaphyr.**

10. **Amygdaloid.**

42. **Melaphyr.**

6. **Amygdaloid.**

65. **Melaphyr.**

4. **Amygdaloid.**

11. **Melaphyr.**

4. **Amygdaloid.**

14. **Melaphyr.**

4. **Amygdaloid.**

226. **Melaphyr;** crystalline, granular; contains light-green triclinic feldspar; mottled with dark green spots and grains of delessite.

6. **Amygdaloid.**

112. **Melaphyr;** fine-grained brown rock, spotted with dark-green amygdules of delessite, sometimes enclosing quartz.

8. **Amygdaloid;** brown matrix; amygdules filled with greenish-white, soft, decomposition product; others lined with red-stained crystals of feldspar.

40. **Melaphyr;** greenish brown; fine-grained, hard; conchoidal fracture; contains many spots of bluish-green compact delessite; also of calcite.

52. **Amygdaloid,** very fine-grained, green-brown matrix, with large amygdules of delessite enclosing quartz; others of only foliaceous delessite; smaller bird's-eye amygdules of—1st, compact delessite; and within this, 2d, a thin ring of light green chlorite (?); 3d, the centre filled with foliaceous delessite. In places, the amygdules contain more quartz, sometimes red, or, again, filled with metallic copper. Often the matrix becomes quite siliceous, the cavities being filled with small crystals of quartz, on which rest scattered crystals of white feldspar. In places, the matrix adjoining the amygdules (generally on the under side) is changed to a red jaspery substance; in such cases, many of the amygdules contain a soft, white, decomposition product.

11. **Conglomerate** (Pewabic West); reddish, somewhat calcareous cement of sandstone; containing pebbles (generally under two inches diameter) of brown non-quartziferous porphyry, which in some instances show the beginning of amygdaloidal action. Contains numerous stains of carbonate of copper.

12. **Melaphyr;** ("with orthoclase." A. B. Wood.)=

Amygdaloid, the only rock identifiable on the side of the trench, is a brown, almost black, subcrystalline amygdaloid; the cavities run into each other, and are filled, some with calcite, but mostly with a soft, white clay,—a product of decomposition of some previous mineral.

8. **Amygdaloid.**

8. **Amygdaloidal Melaphyr;** grayish green-brown; medium grain, with numerous large and small spots and amygdules of dark-green delessite.

15. **Amygdaloid;** brown; tolerably compact and hard amygdaloid, with amygdules of calcite, of a flesh-red zeolite (?), and others of chlorite.

15. **Melaphyr.**

24. **Amygdaloid.**

16. **Melaphyr.**

10. **Melaphyr.**

27. **Melaphyr.**

23. **Amygdaloid.**

21. **Melaphyr.**

9. **Melaphyr;** grayish green and black green; medium-grained; contains green triclinic feldspar, and dark green chlorite.

5. **Amygdaloid.**

17. **Melaphyr.**

23. **Melaphyr.**

4. **Amygdaloid.**

54. **Melaphyr.**

5. **Amygdaloid.**

22. **Melaphyr;** the exposed rock is much affected by weather; granular; contains gray altered feldspar, delessite, and small crystals of a resinous-looking mineral resembling nepheline.

17. **Amygdaloid;** green, with branching amygdules of light pink laumontite.

7. **Melaphyr.**

12. **Amygdaloid.**

19. **Amygdaloidal Melaphyr;** very fine-grained, brown rock; hard, with conchoidal fracture; spotted dark green with amygdules of delessite; contains small spots of calcite.

43. **Melaphyr;** dirty black-green, very hard, with perfect conchoidal fracture, contains minute crystals of triclinic feldspar; also scattered spherical amygdules of chalcedony, surrounded with delessite.

13. **Melaphyr;** compact; dark.

8. **Amygdaloid** ("Hancock-vein," A. B. Wood); chocolate-brown matrix, filled with large and small amygdules of flesh-colored zeolite (laumontite ?), rarely calcite.

23. **Melaphyr;** very fine-grained; green; hard; conchoidal fracture; small crystals of green and flesh-colored triclinic feldspar.

11. **Amygdaloid;** closely resembling the South Pewabic type in form. Amygdules form a large part of the rock, and are almost wholly of laumontite.

27. **Melaphyr;** fine-grained; green; amygdules of delessite or laumontite; more rarely quartz and delessite.

32. **Hancock West Conglomerate.** At or near the bottom there is sandstone, which splits in thin layers; contains much carbonate of lime and some magnetite. There is also a finer sediment, apparently very fine arenaceous clay. Pebbles (not generally more than 1 inch diam.) are chiefly of brown non-quartziferous porphyry, with compact matrix in which are small crystals of reddish feldspar. The cement of the conglomerate is very calcareous.

14. **Melaphyr.**

5. **Melaphyr.**

16. **Melaphyr.**

43. **Melaphyr.**

8. **Melaphyr.**

24. **Amygdaloid.**

Cross-section XV. a.

(Determined by the measurements of the Geological Survey.)

Being the exposures in the eastern part of the covered drain at the St. Mary's Mine.

? **Melaphyr;** hard; dark green, speckled with red.

35. **Covered.**

6.+ **Amygdaloid** ("Ragged Amygdaloid"); chocolate-brown matrix, with large cavities of irregular shape, tending to give a brecciated appearance to the rock. The cavities are partially filled in the given sequence with, 1st, analcite; 2d, calcite; 3d, orthoclase; 4th, calcite.

25. **Melaphyr;** dark greenish-gray; fine-grained; hard; exhibits beginning alteration in the form of small greenish, soft, white spots; it becomes brown and less distinctly crystalline towards the hanging-wall, and assumes veins and amygdules of delessite.

18. **Melaphyr;** brown, speckled green. Towards the hanging-wall this bed carries more grains of delessite and some amygdules of prehnite.

? **Amygdaloidal Melaphyr.**

10. **Covered.**

? **Amygdaloidal Melaphyr;** brown; fine-grained, and hard; contains scattered small amygdules of calcite and delessite.

4. **Amygdaloid;** chocolate brown; soft; contains amygdules of calcite and delessite.

? **Melaphyr;** dark gray brown; fine-grained, hard; conchoidal fracture, with minute red specks of altered delessite? At a few feet from the foot-wall the rock becomes lighter in color, and, without losing in hardness, shows decided signs of change, becoming porous near the joints. In the centre of a polygonal block the delessite is fresh; towards the joints it is changed to a blood-red, soft mineral; nearer the joints the delessite has disappeared wholly, leaving only the empty cavities.

44. **Covered.**

? **Amygdaloidal Melaphyr;** resembling the last-mentioned, but containing amygdules of calcite.

? **Melaphyr;** greenish-brown, fine-grained; hard, conchoidal fracture; contains scattered spots of calcite, and grains of delessite which show minute red specks. Higher up it contains numerous amygdules of delessite.

? **Amygdaloid;** dirty-brown, fine-grained matrix, with small amygdules of calcite and orthoclase ?

Covered.

? **Melaphyr;** speckled green and pink; fine-grained and hard. Higher up it is very decomposed, and contains many amygdules of delessite and laumontite.

18. **Covered.**

? **Amygdaloid.**

35.? **Conglomerate.** ("Albany and Boston.")

25. **Covered.**

4. **Amygdaloid** ("20-foot amygdaloid"); hard, light-green matrix, with empty round cavities and round amygdules of quartz.

? **Amygdaloidal Melaphyr;** dark green; contains amygdules of delessite and minute flesh-colored acicular crystals.

15. Covered.

6.? **Amygdaloid.** ("**Epidote** lode.") Brown and green compact matrix, with amygdules of calcite, delessite, green-earth and quartz; often very siliceous; carries some copper.

? **Melaphyr;** dark green; fine-grained, soft; carries much delessite.

20. **Covered.**

? **Melaphyr;** brown green-gray; granular; hard; contains small spots of prehnite.

7. **Amygdaloidal Melaphyr;** gray-green; fine-grained, rich in delessite; carries amygdules of rosy and white prehnite.

? **Melaphyr;** brown green, spotted dark green with amygdules of delessite; fine-grained.

26. **Covered.**

? **Melaphyr;** similar to the last described.

4. **Amygdaloid;** chocolate brown; contains amygdules of green-earth and calcite.

8. **Melaphyr;** brown, with spots of delessite; fine-grained.

7. **Amygdaloid** (probably the "Albany and Boston amygdaloid"); violet and green; irregular hardness; contains amygdules of green-earth, quartz, and epidote.

10. **Melaphyr;** brown green; fine-grained; soft; contains many spots of delessite.

10. **Amygdaloidal Melaphyr;** green-gray; soft; the cavities are partially filled with minute pink and white acicular crystals of a zeolite.

8. **Melaphyr;** gray green; much altered; contains amygdules of delessite.

9. **Amygdaloid;** brown and green; hard matrix, containing amygdules of prehnite and quartz and some copper.

? **Melaphyr;** brown; granular; hard, with imperfect conchoidal fracture. Higher up it is gray and softer, and much altered.

27. **Covered.**

? **Melaphyr;** light gray-green, spotted with dark-green delessite; rather coarse-grained, and marking proximately the eastern limit of the coarse-grained crystalline melaphyrs.

22. **Covered.**

? **Amygdaloidal Melaphyr;** light-brown green, with spots and amygdules of delessite and quartz, and containing porphyritic crystals of a triclinic feldspar.

Cross-section XV. b.

(Determined by the measurements of the Geological Survey.)

On the "Mesnard" location.

10. ? **Amygdaloid;** resembling the "Ragged Amygdaloid." (See *Section XV*. a.)

70. **Covered.**

? **Amygdaloid.**

25. **Covered.**

30. † **Albany and Boston Conglomerate.**

Cross-section XV. c.

(Determined by the measurements of the Geological Survey.)

Near the “Powder-house," at the Albany and Boston Mine.

Cross-section XV. d.

(Chiefly from the printed report of the Pewabic Mining Company for 1865.)

In the cross-cut from the "Albany and Boston Conglomerate" westward to the 70-fathom level of the Pewabic Mine.

32. **"Albany and Boston Conglomerate."** Boulders and pebbles, ½ inch to 2 feet or more in diameter, in a tolerably fine-grained cement of green and red sand. The cement is very subordinate in quantity as compared with the pebbles; it is free from magnetite.

The predominating pebbles are of a red crystalline rock, of medium grain, of the granite family, chiefly of triclinic feldspar and quartz, with little or no mica, and some chlorite. Next in point of frequence are pebbles of a chocolate-brown porphyry, free from quartz, with a very compact matrix, in which lie numerous minute crystals of a triclinic feldspar of the same color as the matrix. This rock is the most common among the pebbles in the other conglomerates of Portage Lake.

Another characteristic variety of pebble is a dark-brown porphyry, free from quartz, with a very fine-grained base, containing crystals ⅛-½ inch long, of flesh-colored triclinic feldspar, which have generally begun to change chemically.

The conglomerate carries copper, though, so far as tested, not in paying quantity.

20. **Melaphyr.**

23. **Amygdaloid** (supposed continuation of the "Epidote" amygdaloid).

41. **Melaphyr.**

8. **Amygdaloid** (supposed continuation of the "Albany and Boston" amygdaloid). Carries copper.

80. **Melaphyr.**

16. **Amygdaloid.** ("Green Amygdaloid.") Carries copper.

69. **Melaphyr.**

29. **Amygdaloid.** ("Old Pewabic" Amygdaloid.) Carries copper.

104. **Melaphyr.**

10. **Amygdaloid.** (Pewabic—Franklin—Quincy copper-bearing bed.)

? **Melaphyr.**

Cross-section XV. e.

(From the measurements of the Geological Survey.)

In the Quincy "Hill-side Adit."

East end covered; large conglomerate boulders were found in the "drift," just before meeting with rock.

32. **Melaphyr;** rather fine-grained; dirty dark and light green, with rusty brown specks; hard; tough; fracture irregular; changes into

28. **Amygdaloidal Melaphyr;** fine-grained, dirty green color; numerous dark-green delessite spots; loosely textured.

12. **Amygdaloid;** mixed green and brown; some hard amygdules in places mostly of quartz and green-earth, in others of calcite and green-earth; epidote is present, and some laumontite: some amygdaloidal melaphyr occurs near the centre.

37. **Melaphyr;** fine-grained; dark brown, mottled dirty green; hard. The lower one foot is amygdaloidal. Above, it slowly changes to

31. **Amygdaloidal Melaphyr;** coarse; dirty green, spotted with dark green deles-site; fracture very uneven.

1. **Amygdaloid;** narrow, poorly developed, hanging-wall not well defined; green; hard; amygdules of quartz and delessite, some laumontite.

73. **Melaphyr;** rather coarse, not closely textured; color, dirty green of different shades; fracture irregular; inclining toward amygdaloidal melaphyr in places. Toward the base it is dull brown and rather compact, with conchoidal fracture, while at 15 feet from the top it changes irregularly into a very compact rock; the color here is dull purple, indefinitely inclining toward, and mottled with, dull green; very hard; conchoidal fracture. Thirty-four feet horizontally from the foot-wall are two parallel seams, three feet apart; the upper one is 4 inches wide; strike about north; dip 40° east.

18. **Amygdaloid;** green; compact; hard; amygdules mostly quartz in green-earth or epidote; also calcite.

12. **Melaphyr;** very compact; color green, purplish; rather hard; elastic; highly conchoidal fracture; occasionally flesh-red triclinic feldspar crystals porphyritically imbedded; changes to

48. **Amygdaloidal Melaphyr;** in part with dirty greenish-gray base, sprinkled with small porphyritically imbedded flesh-red feldspar crystals, and numerous green delessite spots, and in part light green, with scattering brown specks, and deles-site amygdules; tough; fracture uneven.

4. **Amygdaloid;** mixed green and brown; the green is hard, and usually with quartz and epidote; the green is generally softer, with calcite and delessite. Drifts of 15 feet either way near hanging-wall.

6. **Amygdaloidal Melaphyr;** base dirty greenish-gray, sprinkled with flesh-red feldspar crystals, and numerous green delessite spots; tough; fracture uneven.

5. **Seam** of laumontite, narrow.

8. **Melaphyr;** coarse-grained, rather crystalline; dark purplish-green; hard; brittle, yet tough, changes gradually into

14. **Amygdaloidal-Melaphyr;** base purplish-brown; rather fine-grained, growing coarser toward the bottom, where small flesh-red feldspar crystals are imbedded; amygdules of delessite at the bottom, of laumontite and green-earth, or delessite, near the top.

Cross-section XV. e.

(From the measurements of the Geological Survey.)

In the western half of the Quincy "Hill-side Adit."

10. **Melaphyr;** dirty brown, fine-grained, mottled with very dark delessite.

4. **Amygdaloid;** brown; hard; conchoidal fracture; siliceous amygdules of green-earth and quartz, and green-earth and calcite, and of green-earth alone. Contains some copper. Shaft sunk.

18. **Amygdaloidal Melaphyr;** green; fine-grained; crystals of green triclinic feldspar; numerous amygdules of very dark delessite; others of delessite enclosing quartz.

4. **Amygdaloid;** light green; siliceous; amygdules of quartz and calcite; some copper.

17. **Amygdaloidal Melaphyr;** very fine-grained; in places amygdules of laumontite; in others, of green-earth and quartz.

8. **Amygdaloid;** brown matrix; small amygdules of green-earth, and large ones of green-earth and calcite.

34. **Melaphyr;** brown green; fine-grained; brown triclinic feldspar and dark-green delessite.

6. **Amygdaloid;** light-green and brown; hard conchoidal fracture; very siliceous; amygdules of quartz, calcite, epidote, copper.

72. **Melaphyr;** fine-grained; green, through predominance of delessite. Some crystals of brown

triclinic feldspar. Below this the rock is mottled dark and light green, and under the glass seems to consist of compact delessite, with amygdules of gray-green chlorite or green-earth, with a little quartz. It has the appearance of a feldspar-delessite trap in which the feldspar had disappeared, leaving cavities now occupied by secondary minerals. Towards the foot-wall, the rock is medium-grained, crystalline, brown, mottled with the usual dark-green delessite, and with light-green spots. It consists of crystals of brown triclinic feldspar, which are partially changed to a soft, light-green clay. Still nearer to the foot-wall the rock appears fresh; a medium-grained, dark-greenish gray mixture of gray to light-green triclinic feldspar, and dark-green delessite. Contains minute hexagonal crystals of specular iron. Resembles the coarse-grained trap west of the Pewabic lode, and on the St. Mary's.

13. **Amygdaloid;** bearing copper; shaft sunk.

46. **Melaphyr;** fine-grained, crystalline; consisting of brown triclinic feldspar and diffused delessite; contains amygdules of delessite and of green-earth.

4. **Amygdaloid;** compact and hard; green-brown matrix, with abundant small brown crystals of triclinic feldspar, and numerous amygdules of calcite, green-earth, and quartz.

31. **Melaphyr;** fine-grained; crystalline; conchoidal fracture; consists of brown triclinic feldspar and diffused delessite, with abundant amygdules (mostly spherical) of delessite.

Narrow Amygdaloidal Seam.

25. **Melaphyr;** to the eye a fine-grained crystalline rock with uneven fracture, and consisting of reddish triclinic feldspar, with delessite both diffused and in flakes and grains; general color brown, mottled and veined with dark green. Contains some magnetite. Passes towards the hanging-wall into the overlying amygdaloid.

7. **Amygdaloid;** brown, with light-green amygdules of green-earth and quartz and calcite, containing copper. Matrix contains crystals of triclinic feldspar.

24. **Amygdaloidal Melaphyr;** abounding in amygdules of delessite. In the body of this bed, there occur portions of regular amygdaloid, with amygdules of quartz and calcite with green-earth. Small cavities in the amygdaloidal trap are lined with delessite, and this with clear, slightly pink crystals of feldspar; at the hanging-wall this passes into

6. **Amygdaloid;** compact and hard; brown, mottled green, with amygdules of green-earth and quartz.

85. **Melaphyr;** fine-grained towards the foot-wall; middle of the bed medium-grained crystalline trap; crystals of green and brown triclinic feldspar; delessite near the hanging-wall, almost foliaceous from the abundance of delessite.

8. **Amygdaloid;** green brown, with amygdules of green-earth, and cavities lined with minute crystals of feldspar. Carries considerable copper.

CHAPTER VI.
UNDERGROUND CROSS-SECTION AT THE CENTRAL MINE.

Beginning south of the "Greenstone" and proceeding from younger to older.

	C*		
	1	50 ft.	**Melaphyr:** dirty green; fine-grained and soft, with almost earthy fracture; ¼ to ⅓ delessite [essential], the rest chiefly triclinic feldspar much altered; contains impregnations of calcite and specks of a copper-colored micaceous mineral with a red streak. Little or no magnetite.
In Adit...	2	18 ft.	**Amygdaloid:** chocolate brown; matrix predominant; micro-crystalline, hard; semi-conchoidal fracture; contains amygdules of *prehnite*; often colored red in centre by disseminated copper; also amygdules of calcite with prehnite. This bed passes into the underlying melaphyr (C 3).
	3	45 ft.	**Melaphyr:** dark red near the top ; fine-grained ; uneven fracture; has scattered amygdules of delessite and of a whitish steatitic mineral; lower down this rock be comes brownish green, very fine grained and hard, with conchoidal fracture, and contains scattered irregular particles of delessite, and in places amygdules of prehnite and calcite; large *bunches* of amygdaloid occur in this rock, with brown matrix containing round amygdules of calcite and green-earth; at the bottom of the bed the rock is mottled, brown and green, the green portions being mostly delessite, while the brown are similar to the lighter spots in the greenstone, consisting of triclinic feldspar, very much fractured; the rock here contains considerable magnetite and impregnated calcite. In small veins occurs the following series: 1. Laumontite. 2. Analcite.

*The numbers in the first column refer to Pl. XXIII. of Atlas, where the corresponding figures indicate the points from which the specimens were taken.

	C		
90 fathom level...	4	16 ft.	**Amygdaloid:** brown; fine-grained, compact, in places hard; contains bunches of prehnite with copper, also amygdules with calcite, veins of laumontite, and very irregular cavities coated with crystals of feldspar. This passes below into C 5.
90 fathom level...	5	55 ft.	**Melaphyr,** similar to C 1, very fine-grained, speckled brown and green; under the glass three ingredients appear about equally divided, viz., dark green delessite, a glistening white mineral, apparently altered feldspar, and a porous, red substance, possibly an altered product of delessite; the joints are glazed with delessite.
90 fathom level...	6	15 ft.	**Amygdaloid:** brown matrix, containing amygdules of calcite and delessite.
90 fathom level...	7	40 ft.	**Melaphyr,** similar to C 5; towards the middle and bottom of the bed it becomes hard, with conchoidal fracture, and brown color predominating through comparative absence of chlorite.
Adit level...	10	15 ft.	**Amygdaloid;** brown, compact matrix, filled with numerous amygdules, and seams of a light bluish green, soft, alteration product; the same bed has similar character at the 90 fathom level.
Adit level ...	11		
90 fathom level...	12 and 13	60 ft.	**Melaphyr,** identical with C 5. This very thick bed is remarkably uniform in character, and presents the same appearance in every respect at the 90 fathom level and the adit.
90 fathom level...	14	15 ft.	**Brown Amygdaloid,** with scattered amygdules of prehnite containing copper, and others consisting of a more or less porous light-green, chlorite-like mineral, perhaps an alteration product; the vein made mass copper in this bed.
90 fathom level...	15	37 ft.	**Melaphyr,** similar to C 5; small mass here in the vein.
90 fathom level...	16	17 ft.	**Amygdaloid:** very hard, compact, brown matrix, with amygdules of prehnite and others of calcite, with green-earth.
90 fathom level...	17	45 ft.	**Melaphyr,** resembling C 5, but with perfect conchoidal fracture; vein made a mass in this bed.
	C		
90 fathom level...	18	22 ft.	**Amygdaloid:** matrix brown, in places hard; in the uppermost softer portions of the bed frequent amygdules of a white and green mineral with radiated structure, probably altered prehnite; in the harder portions frequent veins of prehnite and delessite carrying copper, also, in places, epidote, and cavities lined with feldspar.
90 fathom level...	19	5 ft.	**Melaphyr,** similar to C 5, with isolated small amygdules of delessite.
90 fathom level...	20	5 ft.	**Amygdaloid:** compact, brown matrix, with amygdules of epidote and others of red feldspar and delessite.
90 fathom level...	21	5 ft.	**Melaphyr,** similar to C 5.
90 fathom level...	22	12 ft.	**Amygdaloid:** matrix brown, containing irregular amygdules of prehnite, more or less altered, with calcite, green-earth, and copper; passes below into amygdaloidal melaphyr, containing irregular amygdules of prehnite.
90 fathom level…	23		**Amygdaloid,** in irregular bunches of prehnite with copper, the prehnite apparently undergoing change to delessite. In this bed the feeders of the vein consist of coarsely crystallized calcite, having irregularly distributed feldspar and delessite.

90 fathom level...	24		**Amygdaloid,** with amygdules of altered prehnite and feldspar and delessite.
90 fathom level...	25	10 ft.	**Melaphyr,** resembling 5, with less delessite.
90 fathom level...	26 to 34	10 ft. 10 ft.	**Porphyry Conglomerate,** with epidote cement containing disseminated copper in both pebbles and cement. Vein in this conglomerate carries large crystals o calcite.
90 fathom level...	35	16 ft.	**Amygdaloid:** South Pewabic and Ash-bed type; amygdules are almost wholly calcite.
90 fathom level…	36		
90 fathom level…	37 38 39	45 ft.	**Melaphyr:** very fine-grained; in the upper portion purplish brown matrix, thoroughly impregnated with minute irregularly shaped particles of a soft white mineral containing small isolated impregnations of calcite. The middle portion of the bed is a dark gray micro-crystalline rock. Under the glass it is seen to be somewhat impregnated with delessite, and to contain, in scattered particles, a copper-colored micaceous mineral, which gives a dark red streak. The lower portion of the bed is minutely mottled, gray and green, is fine-grained, and contains a considerable amount of the red mineral above mentioned.
	C		
90 fathom level... At No. 4 Shaft...	40	15 ft.	**Amygdaloid:** brown matrix filled with very small amygdules of green-earth, of green-earth and calcite, and of a very red feldspar; it carries finely disseminated copper. Feeders of the vein observed in this rock consist of prehnite with younger sheet-copper and calcite.
90 fathom level...	42	68 ft.	**Melaphyr:** chocolate brown, very fine-grained, with even fracture, containing small crystals of triclinic feldspar in the matrix, and disseminated particles of the copper-colored micaceous mineral above referred to; and also isolated small amygdules of delessite at the 90 fathom level. This bed is intersected by a cross course, immediately beneath which there was found a large mass of copper.
90 fathom level...	43	20 ft.	**Amygdaloid:** green and brown matrix, with amygdules of green-earth, calcite, copper, and analcite.
90 fathom level...	44		**Melaphyr:** fine-grained, gray-green matrix, speckled red with the copper-colored micaceous mineral above referred to, and containing considerable magnetite; the joints of this rock are coated with laumontite.
90 fathom level...	45		**Amygdaloid.**
90 fathom level...	47	34 ft.	**Melaphyr:** fine-grained greenish-gray matrix, speckled red with the copper-colored micaceous mineral. Feeders of the vein as observed in this rock consist of red feldspar and calcite, with a green, talc-like mineral.
90 fathom level...	48		**Melaphyr,** resembles C 5, but harder and with perfect conchoidal fracture.
90 fathom level...	49	16 ft.	**Amygdaloid:** brown matrix, filled with amygdules of prehnite more or less altered, and of calcite with green-earth. Feeders of the vein as observed in this bed consist of prehnite filled with native copper.
90 fathom level...	51	43 ft.	**Amygdaloidal Melaphyr:** very hard, brown, fine grained matrix, showing numerous minute crystals of triclinic feldspar, and containing isolated amygdules from ½ to ¾ inch diameter of prehnite, apparently undergoing a change to delessite; below this passes into C

			52.
90 fathom level...	52		**Melaphyr,** similar to C 5; on the 90 fathom level the vein in the members of this bed was exceedingly rich in mass copper, while at the 120 fathom level the vein was reduced in the same bed to a narrow brecciated mass, consisting of small pieces of wall rock surrounded and sustained by thin seams of laumontite.
	C		
90 fathom level… At No. 2 shaft.	53	28 ft.	**Amygdaloid:** soft, brown matrix, filled with round amygdules of calcite and altered prehnite.
		68 ft.	**Melaphyr.**
		25 ft.	**Amygdaloid.**
		45 ft.	**Melaphyr.**
120 fathom level.. 200 ft. N. No. 2 shaft.	54		**Amygdaloid:** matrix purple brown, in places very soft, almost uniformly filled with amygdules of prehnite.
120 fathom level...	56		**Melaphyr:** very hard, uniformly dark greenish gray, very fine-grained, with conchoidal fracture; exhibits under the glass scattered particles of a copper-colored micaceous mineral.
120 fathom level...	57	50 ft	**Amygdaloid:** brown matrix with isolated amygdules of prehnite with delessite; approaches an amygdaloidal melaphyr; probably not a persistent bed.
120 fathom level...	58		**Amygdaloidal Melaphyr:** hard brown matrix, isolated amygdules of prehnite, delessite, calcite, and native copper.
120 fathom level… At No. 2 Shaft...	59 and 60	68 ft.	**Melaphyr,** same type as C 5, though harder, with perfect conchoidal fracture.
130 fathom level... 75 ft. N. No. 2 shaft.	61	9 ft.	**Amygdaloid:** soft brown matrix with irregular-shaped amygdules, with prehnite, analcite, and native copper.
	62	30 ft.	**Melaphyr:** dark green, very fine-grained matrix, apparently rich in delessite.
		9 ft.	**Amygdaloid.**
	63	30 ft.*	**Melaphyr,** same type as C 5.

*This is geologically the lowest point reached.

CHAPTER VII. GENERAL STRUCTURE AND LITHOLOGY OF THE EAGLE RIVER SECTION.

BY A. R. MARVINE.

THE width of the "Trap Range" of Keweenaw Point, measuring from Lake Superior at the mouth of Eagle River across to the unconformable sandstones forming the south-eastern border of the Point, is about six miles. Topographically it here consists of two ranges of hills, which conform in direction with the general trend of the strata and of the Point, and while rising gently on their northern, fall more steeply upon their southern slopes. Locally, these are known as the North, or Greenstone, and the South Ranges.

The former, at an average distance of two miles from the lake shore, attains a height of from 400 to 700 feet, when it falls abruptly, even precipitously, to the longitudinal valley separating the two ranges. The South Range occupies the remainder of the trappean series, and while rising to a height of 600 to 800 feet above lake level, has a more gently moulded contour than the North Range.

The drainage waters of the intermediate valley accumulate in the branches of Eagle River, and flowing east and west at the southern base of the North Range, unite at the Phœnix mine, where, turning, they pass through a break in the Range and flow northward across the formation to Lake Superior.

Except in scattered exposures, the South Range lies buried under glacial and modified drift, while the frequent exposures of the North Range, together with the channel of Eagle River, offer excellent opportunities for a geological section.

The accompanying section, in two plates, exhibits in detail the section of the rocks of the North Range taken at this point, while the geographical relations of the exposures correlated in the section are shown in the accompanying map.

The sections are numbered in Roman numerals, and their limits —with the corresponding numerals— indicated on the map. The map and sections may be still further connected by means of the lettered survey stations and the numbers of beds, commencing at the northern end, placed on each.

General Geological Structure of the Section.—In the immediate vicinity of a line drawn from the Phœnix mine to the mouth of Eagle River, the rocks are very regularly bedded, the strata having a trend of slightly more than sixty-two degrees east of north, and dipping toward the Lake, or north north-west, at an average angle of about thirty-one degrees, being somewhat steeper at the north, and less steep toward the south. Upon either side of this line, the strata, participating in the general bending of the Point, swing slowly around, until, in a mile or more, their strike differs by two or three degrees from that of the main line of section. Moreover, in leaving the section toward the east, a flattening of the strata takes place, the dip decreasing about a degree in a mile. It probably increases slightly toward the west. Besides the geographical widening of the formation toward the north, owing to this flattening of the strata, there is also a widening from the actual thickening of some beds, or from the wedging in of new ones. Even within the limits of the map the formation thickens considerably in going eastward.

This system of rocks may be divided into three groups: sandstones or conglomerates; melaphyrs, including amygdaloids; and diorites.

The latter stand alone, occurring in a single belt of 2,400 feet in width. Being much harder and more massive than the adjoining rocks, they form the highest and southern portion of the North Range. Locally, the term "greenstone" is applied to the finer varieties of the diorites, and "feldspathic trap" to some of the coarser varieties, thus distinguishing them from the melaphyrs or "traps."

Both above and below the belt of diorites, and perfectly conformable with it, are the melaphyrs. To the south, excepting occasionally intercalated narrow beds of conglomerate, they are said to extend to the limit of the range. Northward they extend to a distance of nearly 5,800 feet, or to within a quarter of a mile of Lake Superior. For the first 3,500 feet of this distance they are comparatively free from any true sandstone strata, only four sandstone seams occurring. From this point northward, however, a series of sandstones occur, interbedded with the melaphyrs and amygdaloids. These, in their aggregate thickness, amount to over one-third of that of the including melaphyrs, but, as a rule, increasing in thickness toward the north, they there dominate over them.

Resting on this interstratified series of melaphyrs, amygdaloids, and sandstones is a wide belt of coarse conglomerate extending to and under the Lake. Some miles eastward of the main line of section, this conglomerate has a width of about a mile,* a trappean belt of about two-thirds the width resting upon it, which is in turn overlaid by another wide conglomerate. The United States Lake Survey chart represents a reef about 3,400 feet off the mouth of Eagle River, which at one point rises to within six feet of the water's surface, and as it is stated to be of “trap rock," it probably belongs to the outer trappean belt. This would make the conglomerate at Eagle River from 4,000 to 4,500 feet wide.

The diorites, as before stated, form a massive group of rocks about 2,400 feet wide, or 1,200 feet thick. They are heavily bedded in strata of from 20 to 150 or more feet in thickness, and without the interpolation, so far as known, of any amygdaloidal bands. Excepting a very massive bed at the base, and a thinner one upon the top, all the interior two-thirds of the series have a coarse-grained texture, especially so as compared with the adjoining melaphyrs. This texture varies from nearly that of the coarsest melaphyrs to beds in which the component crystals average one-eighth of an inch or more square, while the specific gravities are generally greater than those of the melaphyrs, and range from 2.89 to 3.03.

*See Foster and Whitney's Report on the Geology of the Lake Superior Land District, Part I., Map. Washington, 1851.

These beds are composed essentially of nearly opaque, lustrous, black to greenish-black, sometimes inclined to translucent resinous-brown, *hornblende*, and *triclinic feldspar*. Two kinds may be observed: the first, in which the feldspar is white, inclining to grayish-green, and sometimes red; fuses rather readily before the blow-pipe in coarse splinters; has a specific gravity, in one bed, of 2.73; weathers less easily than the hornblende; and is probably *Oligoclase*, or Albite. Its presence gives rise to handsome gray or greenish-gray, and sometimes mottled rocks, which may be designated as the "lighter type." In the second variety of diorite the feldspar is very brittle, hard, colorless, or inclined to green, and sometimes to resinous brown, and is transparent; fuses before the blow-pipe only in very fine splinters; weathers more readily than the hornblende; and is probably *Anorthite*. Its presence, owing chiefly to the fact that the hornblende shows through it, gives rise to dark-colored, and generally dirty, resinous-hued strata, which may be designated as the "dark type." In both types a dark green chlorite, probably delessite, occurs to a greater or less extent, occasionally nearly wholly replacing the hornblende, from which it seems to be derived, thus transforming the bed into a coarse, loosely textured melaphyr, not especially like the typical melaphyrs above and below the diorites. Segregations are quite frequent, especially in the dark-type beds. In these the feldspar generally occurs in large crystals, but irregularly, and white and opaque, like that of the lighter type, and usually imbedded in hornblende, and intersected by it. Indurated green spots of quartz and epidote also occur, and occasionally prehnite and a bronze-colored mica. In the dark type also, larger crystals of the glassy feldspar often occur. These generally contain scattered particles of the usual ingredients of the rock, often to such an extent that the crystals themselves cannot be recognized except by the reflection of the light. This tendency to a larger crystallization in the mass is not so apparent with the hornblende, except when brought out upon the weathered surface of the rock, where the feldspar crystals have been removed, while the projecting hornblende crystals, often over an area of one or two inches square, all catch and reflect the light simultaneously.

The strata of the dark type predominate in the group, especially toward the bottom, form the more massive beds, and have, as a whole, the finer texture, never reaching the coarsest. The lighter type, on the contrary, occurs in thinner beds, which generally have a coarser texture, reaching the coarsest. Other things being equal, the latter are the more enduring of the two, but their comparative thinness and coarseness of texture generally reverses this character. The beds of the lighter type generally weather rather evenly, but with a rough surface, the color being a handsome gray, sometimes mottled, and speckled with projecting black hornblende crystals. The beds of the dark type sometimes also weather evenly and rough, with projecting crystals, but generally the weathering is rugose, often very exaggerated, the depressions being rusty brown in color, smooth and free from crystals, while the projecting knobs, often an inch high, are whiter, but sprinkled with projecting black hornblende crystals, those on each knob generally all reflecting the light at once to the eye.

In one bed (No. 107) the two types are banded together in strata of from 5 or 6 inches to 5 or 6 feet in thickness, with no perfectly sharp lines of demarcation separating them. The lighter type layers were here exceedingly coarse, and their granular components could be separated quite well from one another.

The hornblende grains often showed very lustrous cleavage planes, some of which could be measured. In one of these, measured on the reflecting goniometer, the cleavage angle of Pyroxene (Augite), viz., 87° 5', was obtained. Several gave the undoubted angle of hornblende, 124° 30'; while, in general, those which were not sufficiently perfect to measure accurately were not far from the latter angle. An analysis of this material was made which, though not wholly successful, showed conclusively that the mineral was hornblende,—the amount of lime in it not exceeding 10 per cent. Its specific gravity was 3.39,—that of the feldspar 2.73, and of the rock 3.02, showing that about 57 per cent. of the latter was feldspar and 43 per cent. hornblende.

Commencing several hundred feet from the base, there is a coarse-grained, hard, dark, resinous-hued bed. From here clown-ward a gradual change occurs, the texture growing finer and finer, the feldspar element seeming to increase, giving a gradually increasing crystalline character to the bed, until the components finally become undistinguishable, and there is formed at the base 200 or 300 feet of an exceedingly brittle, elastic, hard, compactly crystalline aphanite, having a conchoidal fracture, and handsome clear green color, sometimes mottled vaguely with purple, and with occasional large, flat, transparent crystals of glassy feldspar imbedded in the mass. When mottled, the weathering is of a uniform rugose character, the silver-gray projections being composed of grains of glassy feldspar, sunk in which are minute crystals of hornblende, all of which on each knob, as on the larger, coarser knobs, before described, reflect the light simultaneously at the same incident angle. This shows that the rock is still of the diorite type, and that, though changed in its physical character, it has not changed materially in its chemical. The specific gravity of the homogeneous aphanite is 2.95. For 15 feet above the foot-wall of the "greenstone" its eminently crystalline character is lost, the rock looking much like some fine-grained and compactly textured melaphyrs; the specific gravity, however, still being 2.92. The lower 3 or 4 feet are broken and fissile, and are followed by the red-clay seam called the slide, separating it from the melaphyrs and amygdaloids of the Phœnix mine, or those lying below the diorites.

Commencing at the base of the uppermost bed of the diorites (No. 91), the rock is precisely similar to the purple-mottled aphanitic greenstone, and has the same specific gravity, 2.95.

It gradually changes, however, becoming at first somewhat coarser-grained, and resinous in lustre, with specific gravity 3.01, and finally a fine-grained, brownish, homogeneous rock, in all respects like some melaphyrs, and with a specific gravity of 2.89. This is separated by a distinct plane from a fine-grained, dark-bluish, semi-columnar rock, which forms the base of the melaphyrs lying north of the diorites.*

* A much more complete knowledge of these diorites may be had by referring to the detail descriptions of the typical and peculiar beds of the series in Chap. VIII., as appended. Dark type, No. 92, p. 133 ; light type, No. 96, p. 134; coarse, inclined to melaphyr, with large red feldspar crystals at base, No. 94, p. 134; coarse, light and dark types banded, No. 107, p. 135; dark type, changing to aphanitic, No. 108, p. 1365 aphanitic, changing to melaphyr-like form, No. 91, p. 133.

Melaphyrs and Amygdaloids.—The limits and position of the melaphyr group upon the section have already been indicated. In general characters these melaphyrs are precisely similar to those in the Portage Lake District; and the results given in the description of that district as to their general lithological characters, chemical or mineralogical composition, accompanying minerals and their paragenesis, etc., are equally applicable, in a general way, to the melaphyrs of this district. In fact, the region lying north of the diorite group is in the same horizon as the western end of the Portage Lake section, and there is not only a strong resemblance, but, so far as traced, a general accordance between them; many beds in the two being lithologically, probably stratigraphically, identical.

The melaphyrs lying above or north of the diorites do not separate themselves into any apparent natural groups, but for convenience .of reference they may be divided into three series :—(*a*), Those extending from the diorites north to the bed next below the Ash-bed, or No. 66; (*b*), from No. 66 to the Upper Falls, or through No. 45; (*c*), the remainder of the melaphyrs northward to the wide conglomerate, and containing ten intercalated sandstones. The respective widths and thickness of these three series are—(*a*), 1840 (±925)* feet; (*b*), 1,200 (618) feet; (*c*), 2,700 (1,417) feet, with sandstones aggregating above 860 feet.

(*a*.) The most characteristic and prominent beds of series (*a*)— mostly confined to its northern 580 feet—are composed of rather coarse and not closely textured melaphyrs; tough, but not brittle, and breaking with a rough fracture. The colors are dirty light green, strongly mottled with quite well-defined spots of dark green, causing them to approach amygdaloidal melaphyrs in structure, while they have a medium specific gravity of about 2.87. Their capping amygdaloids are not very strongly developed. South of these beds finer-grained, darker, and more evenly colored beds seem to prevail, but the covering of soil renders this the least known of any part of the section. Near the base a wide bed (No. 87, 350 feet wide), similar to those at the top, occurs, below which, and at the base, is a wide (175 feet), hard, homogeneous, fine-grained, clear bluish-black melaphyr, which has a quite well-defined and striking semi-columnar structure.

The middle division (*b*) of the northern melaphyrs has at both its base and summit a porphyritic bed, composed of small semitransparent crystals of greenish-white triclinic feldspar, generally without definite form, profusely sprinkled in a very fine-grained base of purplish—or purple lightly mottled green—color, and containing considerable magnetic iron. It is a hard, elastic, brittle rock, with rather smooth and semi-conchoidal fracture.

These are the only two marked porphyritic beds among the melaphyrs of the section, and are also somewhat more brittle and elastic than any others, approaching in these two qualities the aphanitic diorites. They also have a high specific gravity, 2.93 and 2.91, respectively. Each has a scoriaceous amygdaloid upon its summit, separated from the main bed by rather a sharp line of demarcation. Situated between these two extremes are a variety of beds, mostly abnormal in composition. Commencing at the base there is the compact dark-bluish melaphyr, with the associated scoriaceous amygdaloids called the "Ash-bed;" then a semi-columnar trap with wide, coarse amygdaloid above; then a width of curious, coarse, easily decomposing beds of very irregular structure, followed by many very thin, but perfectly bedded amygdaloids with narrow intermediate amygdaloidal melaphyrs.

*Numbers in parentheses indicate generally thicknesses, or distances measured perpendicular to the bedding.

The northern series (*c*), extending north to the wide conglomerate, and containing sandstones aggregating probably 860 feet in width, has, for its predominant type of melaphyr, a rather fine-grained and compactly textured rock, breaking with an irregular to semi-conchoidal fracture, and somewhat brittle and elastic. The color is generally a dark but dull green vaguely mottled purple, the latter often predominating, having in it a mottling of green, and occasionally all is green, a darker shade mottling a lighter background. Though the purple element enters largely into the colors of these rocks they are inclined to dark shades, being darker than the normal green rocks of series (*a*), while the mottling, though striking, is not so well defined or spotted, nor of such dark green color. They are also finer grained, more brittle, not so tough, nor with so rough a fracture, and show a closer texture. The quantity of magnetite in this series seems quite small, and much less than in (*a*), while the specific gravity may average lower—2.71, 2.76 to 2.89.

As exceptions to this general nature we have one light green (No. 1) and two grayish beds (Nos. 9, 10), while No. 39 is of quite exceptional character.

In amygdaloidal melaphyrs delessite is nearly always the mineral that first occupies the amygdules, the matrix or base generally remaining much the same as the accompanying melaphyr. Laumontite generally follows closely after, but north of the diorites it occurs far less than in the Portage Lake District, series (*a*) being nearly free from it, (*c*) having but little more, though considerable occurs in (*b*). Calcite and prehnite occupy the position next most important to delessite in the amygdaloidal melaphyrs. In their most developed stages in series (*a*) calcite occurs in the delessite amygdules, nearly to the exclusion of prehnite, but in (*c*), especially all through its middle parts, prehnite occurs in the amygdaloidal melaphyrs in most characteristic pink- and salmon colored radiated amygdules, to the exclusion not only of calcite, but almost entirely of even delessite.

In the amygdaloids throughout, calcite largely predominates, but is often closely followed by prehnite (the latter generally enclosing the former), which is generally light green, semi-transparent, and botryoidal, and almost always accompanied by small amounts of copper.

Quartz follows next in importance, and those amygdaloids containing it in larger quantities are generally more or less indurated. The matrix of amygdaloids is seldom similar to the underlying melaphyr, being almost always very fine grained to compact, sometimes inclined to earthy, sometimes indurated and hard, and generally reddish-brown in color, with sometimes red crystals of feldspar porphyritically imbedded in it, while in the harder amygdaloids, the base is often green in color.

South of the diorites a few hundred feet of rock are exposed in the Phœnix mine. In the upper part of this series the melaphyrs, which all approach amygdaloidal melaphyrs, are of a rather coarse-grained, inclined to loose, texture, being rather soft and tough, and having a very uneven fracture. The feldspar is greenish-white, and occurs in elongated crystals, which are sometimes twins, and in the coarser varieties, appear spread like a network upon a background of dark-green delessite and pinkish feldspar, the delessite being separated into frequent and rather well-defined spots, while magnetic and specular iron are present in quite large quantities.

In the finer-grained beds brownish-red largely prevails, with dirty white in the base, the colors, though dull, as in nearly all rocks, being well marked and in strong contrasts. At one or two points, the whole rock becomes a nearly uniform, decided, brownish-red color, and as no magnetic iron then seemed present, the color may be due to the decomposition of the iron ingredients of the original rock. In looseness of texture, and consequent rough and uneven fracture, these rocks somewhat resemble the typical melaphyrs of series (*a*), but in colors they are decidedly dissimilar. The amygdaloids are but little more than exaggerated forms of the amygdaloidal melaphyrs, the matrix not being compact but fine-grained, and of a dull brownish-red color, with but little calcite or prehnite with the delessite amygdules. Toward the south the melaphyrs become finer grained and more compactly built, harder, more brittle and elastic, and with more even and conchoidal fracture, while the color darkens, a dark green predominating, indefinitely mottled with dark dull purple. There is but little or no magnetite. The mottling spots may be .3-inch diameter, though their limits are variable and indefinite, and they may merge into one another. In part of one bed (No. 120) they reflect to the eye, when the fractured face is held at the proper angle, a glistening or sheen, which causes them to strongly resemble a similar modification which sometimes occurs near the lower part of the aphanitic diorites. The latter, however, is harder, and in texture inclines to compact crystalline rather than to fine granular, while the color is a clearer green.* The specific gravity of the former is 2.84-2.87, of latter 2.92-2.95. The amygdaloids of this part of the mine are much better developed than those at the northern end, calcite predominating in some, prehnite in others, and delessite and laumontite in the amygdaloidal melaphyrs.

One amygdaloid (No. 111), lying about between these two series, is pretty well developed, and where examined contained much copper. The prehnite of the amygdaloids, especially in this part of the mine, seems to be readily attacked by the decomposing agencies at work, changing to a soft, white, amorphous chalk or kaolin-like material, the larger amygdules sometimes having a partly unchanged prehnitic nucleus and exterior.

Certain changes which have been suggested in the preceding pages as occurring in the melaphyrs may be of sufficient interest to warrant a more detailed description.

Being of the same general nature in all, it may be convenient, in examining them, to select those features presented by the characteristic rocks of series (*a*), the coarser character of which enables their components to be more readily detected and their changes examined, referring, when occasion requires, to other beds which may differ from those under consideration.

*At the Allouez mine these distinctions are nearly lost, and the "greenstone" is so changed that, were it not known to be the equivalent of the "greenstones" farther northeast, it would certainly be considered as a melaphyr.

Upon breaking the rock at various points, a rather rough fracture is obtained, indicative of a rather coarse and not very closely compacted texture, while the color is decidedly a green, generally a dirty light shade, mottled or even spotted with a dark shade.

The normal form, however, seems to tend toward a uniform shade lying between the two, though the mottling is even here hardly lost. This normal form does not necessarily lie at, nor next to, the bottom of a bed, for variations from it are somewhat irregular, though generally arranged parallel with the plane of bedding; but it seems never to occur near the top and adjacent to the overlying amygdaloid.

Taking the most uniformly colored rock, the glass discloses it to be composed of small crystalline grains of light green feldspar, thickly scattered in, or rather mixed with, a dark green, soft, amorphous, generally earthy, sometimes shining mineral, which is undoubtedly a chlorite, and which, according to Macfarlane's analyses, would seem to be delessite.

Here and there, but wholly subordinated to these two principal ingredients, are shining flakes, sometimes set in a dull reddish spot, which have a brown streak and iron reaction, and which probably are specular iron, while grains of magnetite occasionally appear. Still more sparingly, small black crystals, as if of hornblende, occur in the delessite, and sometimes flakes of rubellan (?).

The feldspar sometimes assumes a pinkish hue, which, with the green, produces a subdued but decided purplish shade. This change is seldom uniform, but confined to irregular spots, giving a rude purple mottling upon the green base, an extension of which produces a purplish base with a green mottling.

This tendency, however, is almost *nil* in the coarser (*a*) rocks, though always present in the typical (*c*) rocks; in fine-grained rocks a suggestion of it is almost always present, which sometimes, by going through almost imperceptible changes, may have a dull, uniform, purplish-brown rock.

Returning to the rocks of the (*a*) series, which to the eye approach a uniform texture and color, there is found, a few feet farther on, generally above, a tendency in the delessite to segregate into spots to the exclusion of the feldspar. These spots at first are of decidedly indefinite and irregular boundary, and tend to produce the effect of mottling; but farther on they are more definite and less irregular in shape, though seldom perfectly round, till, finally, the well but not sharply defined spot of earthy-looking, dark green delessite stands on a background of nearly uniform shade or uniform mottling of shades. This background in these rocks is of a dirty light or grayish-green, and is composed mostly of feldspar, though much delessite still remains. In the change, however, the feldspar is apt to assume a pinkish shade.

It is through some such changes as these that the rock always passes in approaching the form of the amygdaloidal melaphyr, into which is an easy transition;

the delessite spots becoming more definite amygdules, generally accompanied by the entrance into them of some laumontite, calcite, or prehnite.

The matrix generally re-mains much the same as the melaphyr below, though the feldspar is apt to become pink or red, and often porphyritically imbedded in a fine-grained mixture of feldspar and delessite, very occasionally in delessite alone. If laumontite and other minerals are present together in the amygdule, the former is always the oldest, following the delessite (see paragenetic series). The entrance of these minerals seems to be by a replacement of the delessite.

From a bed in the southern part of the Phœnix mine, containing generally delessite amygdules, many amygdules could be easily broken out intact. Some of these amygdules averaged an inch in diameter, somewhat irregular in shape, and outwardly of shining green delessite.

Upon breaking them open, however, they showed a variety of structures. One seemed to be wholly composed of what appeared like a crystalline granular mixture of white calcite and pink laumontite in a light green base. Much of this base is of dark green, as if of the original delessite filling, some of which still coats the amygdule, while the lighter green seems to contain prehnite. Laumontite crystals sometimes enclose dark delessite, while calcite sometimes encloses, in a thin coating, laumontite. The cleavage faces of the calcite particles throughout the amygdule all reflect the light at the same incident angle, showing a uniform tendency to crystallization throughout it.

In another amygdule much of the periphery was like the above, but, instead of filling the amygdule, it rapidly changed into pink prehnite, which in time became green in the interior, some spots of delessite still remaining and particles of copper being present. In a third case, the outside was much like the first, except that the light green matrix was nearly all prehnite;—this changed into a prehnitic interior like the second. Again, a portion of the periphery was composed of very small grains of delessite and laumontite, changing along an irregular boundary into a radiated laumontite core. In the accompanying fine-grained rock may be seen incipient delessite amygdules of various sizes and stages of development, some having the usual laumontite core.

The gradual development of a delessite amygdule in a melaphyr seems undoubted. From the above facts it would seem that the genesis of the laumontite was also a true metamorphic change, and took place, not by the filling of a cavity, but by direct replacement of delessite; while the incoming of prehnite and calcite would seem also to belong to the same class of changes, probably by the replacement of laumontite.

In the characteristic amygdaloidal melaphyrs of the (*c*) rocks, it has been already noticed that while a purple green mottling is nearly always present upon the rather fine-grained and closely textured rock, it seldom seems to develop, as in certain beds of the (*a*) series, into delessite amygdules. The amygdules, instead, contain a salmon-colored radiated prehnite, in appearance strongly suggestive of radiated laumontite, but which shows, in many instances, a gradual transition through vitreous pink to transparent green, non-radiated prehnite. Though there is no direct proof of the genesis of this prehnite, the facts noticed above, together with the occurrence of laumontite associated with it in a few beds (Nos. 18 and 30) would indicate that it was all derived by replacement of laumontite, which, in turn, replaced delessite. Perhaps the very resemblance of the radiated prehnite to radiated laumontite may indicate a step in this change. It seems strange, if such transition has taken place, especially when its large extent is considered, that it should not have left an easily discovered record of the intermediate steps. The beds having this character, however, contain numerous sandstones, which would readily allow of the penetration of metamorphosing agents.

Some one of the transitions from melaphyr to amygdaloidal melaphyr, as have been described, almost always occupies a more or less wide zone between a melaphyr and its overlying amygdaloid. It also often occurs within a melaphyr, though generally in a zone parallel with the plane of bedding. But besides these cases, it is also found *cutting directly across* the bedding, in which case it accompanies a vein, joint, or fissure, from which it may extend several feet either side, the intensity of the action being greatest near the vein. The change here is just the same in kind, and often in degree, which takes place beneath an amygdaloid, amygdules of delessite and laumontite being common, sometimes with prehnite and calcite, though generally not well developed. These facts, especially the latter, point to the conclusion that the transitions from melaphyr to amygdaloidal-melaphyr are of a truly *metamorphic* character, that they were impressed upon an approximately homogeneous rock by chemical action long after it was first formed, and that the amygdules which mark this change were thus slowly developed, and are not the mere fillings of pre-existing cavities.

In passing to the consideration of the amygdaloids, it becomes more difficult to clearly distinguish between that part of their structure which existed in the original rock and that which is due to subsequent metamorphism. From what we have seen, it seems almost possible that metamorphism, by carrying the process a step beyond the formation of an amygdaloidal melaphyr, might produce an amygdaloid. The differences between the two have already been sufficiently pointed out. After the number, irregularity, contents, or general development of the amygdules in an amygdaloid, their next most noticeable characteristic, and one much less easily accounted for by metamorphism, is the almost invariably fine-grained, compact, or even earthy nature of the base, no matter how coarse the underlying melaphyr maybe. But the strongest proof would seem to be in the structure of the so-called scoriaceous amygdaloids. In these, patches or balls of amygdaloidal material are associated, even surrounded by, an imperfectly stratified material, which is un-distinguishable from the true fine-grained sandstones.* This association is such that it seems as if it could in nowise be accounted for by metamorphism acting on sedimentary beds, but only by supposing a peculiar mixture of the materials at the time of deposition, which mixture is not such as sediments assume. In these amygdaloids, also, there is sometimes a well-marked plane of demarcation between the amygdaloidal melaphyr—or the amygdaloid, perhaps—and the scoriaceous amygdaloid which rests upon it. The fact that in sandstones which are intercalated between two trap beds the upper parts, for several inches from the hanging wall, are often changed as if by heat, while at the bottom contact there is no such change, cannot be offered as an objection to the metamorphic theory, for it would be in just such regions that metamorphism would naturally occur. But the fact that sandstone material seems to have entered amygdules near the upper part of beds covered by sandstones; that it may fill a well-defined crack extending down into an underlying melaphyr (see p. 113 and p. 119), or that melaphyr may nearly surround pebbles apparently caught up from an underlying conglomerate (p. 119); these facts, as does the peculiar structure of the scoriaceous amygdaloids above noticed, seem to point to a very different origin for the melaphyrs than a sedimentary one.

*The nature of this material is set forth in speaking of the sandstones, p. 113, as well as the association mentioned, which is also more especially noticed in detail descriptions of beds No. 45, p. 125, and No. 65, p. 129.

It would seem, then, that the fine-grained nature of the amygdaloids, together with amygdaloidal cavities, probably originated with the bed, though both must have been strongly affected by that metamorphism which has produced the more prominent features of the amygdaloidal melaphyrs. The amygdules must, in many cases, have been much changed, in size and shape, and subsequently filled, by this agency, while the small feldspar crystals often found porphyritically imbedded in the amygdaloidal matrix may also be due to this cause. Whenever well exposed, the melaphyrs generally exhibit, from a few inches to a foot or more from their foot-walls, a modification similar to the amygdaloidal melaphyr of the same bed, with sometimes a true amygdaloid at the very bottom. These three often shade gradually the one into the other, and, as at the top, it is impossible to accurately draw the line between what is original structure and what due to metamorphism.

As a whole, then, the *structural* features of these beds remarkably resemble those of true lavas. They have been affected, however, and to a very great extent, by metamorphism, and this metamorphism has taken place in such a manner, has so heightened and carried on the original structure, as it were, that the ordinary proof of their igneous origin, such as contact changes in adjacent sandstones, presence of amygdules, etc., fail, and it seems natural to consider this metamorphism as a *vera causa* for the whole structure. Certain extraordinary features, however, as noticed above, seem wholly incompatible with this idea, and when considered as true igneous rocks in which great and peculiar metamorphism has taken place, all the phenomena presented seem to be satisfactorily and naturally accounted for.

The general structural features of these beds long ago gave rise to the belief that they were of igneous origin, a belief now almost universal in the mining regions; while the metamorphic changes which have taken place in them since their formation are not generally recognized, if indeed suspected. These changes, however, have been both very many and very great; so great, in fact, that, as seen above, when once examined they seem almost sufficient to have developed all the peculiarities of the beds from sedimentary deposits.

The practical importance of the recognition of this metamorphism, and of a proper understanding of its methods and effects, will be apparent when it is recollected that to it is due all the economical value that the beds possess. The beds as originally formed probably contained the elements of its minerals, together with its copper and silver, more or less disseminated through their mass, as much so remains till the present day, or else they were so contained—at least in part—in overlying rocks, and in this form they could have been of no economic value; nor could any process taking place at that time have concentrated the minerals in the manner in which they now occur.

One hears of the melted copper being squeezed from the adjacent heated rock into the veins, and run into amygdules as bullets into a mould, the facts being ignored that—supposing the hydraulics of the case possible—these rocks, at the temperature of melted copper, would no longer be what they now are; and also that, at such a temperature and under a moderate pressure, a fissure, supposing it once formed, would be immediately welded solid again; while in amygdules copper is seldom, if ever, the only occupant, but occurs in them in company with minerals which are readily changed by heat, but which never show such change. The fact that chemically pure silver and copper constantly occur intimately united, but never in the least degree alloyed with one another, proves that they could never have been so placed by the action of heat, for it is well known that in melting they would have alloyed instantly. Suppose that, in an amygdaloidal cavity or vein, transparent crystals of quartz stand upon crystals or masses of green prehnite, fitting into their irregularities and touching nothing else, and that no replacement has taken place, it is clear that in such a case the quartz must have been placed upon and adapted to the form of the prehnite after the latter had been placed in its position and had assumed definite form. Prehnite, however, will almost melt in the flame of a common candle, while quartz is one of the most infusible of substances, and could not possibly have been placed upon the prehnite by the agency of heat alone without the fusion of the prehnite and the destruction of its form, to say nothing of the various other chemical effects that would be induced. Moreover, the quartz, after melting, is found to have a different specific gravity than when crystallized.

This is but one of many cases. In fact the whole manner of occurrence of, and general relations between, the many refractory and easily fusible minerals which occur in a similar way in these rocks shows that great heat has had absolutely nothing to do with arranging them as they now are. The result must be looked for in some other cause. Does chemical action supply such a cause?

Many experiments have shown that carbonic acid and oxygen held in solution in water can readily attack alkaline silicates, and that these, or similarly obtained substances, even in apparently insignificant quantities, are powerful agents in changing rock masses, provided sufficient time be allowed for them to act. Water falling upon the earth soon obtains these reagents from the atmosphere, decomposing vegetation, soil and rocks, as proved by the fact that all spring water which has travelled any distance through rock-masses always contains them. In this form, these agents are generally recognized as producing many metamorphic changes, and are known to have produced effects quite antagonistic to those produced by heat.

All the phenomena tend to prove that it is by means of some such chemical actions as these, continued through long periods of time, that the metamorphism of these beds has been effected. It is such metamorphism which has developed the amygdaloidal melaphyrs, formed segregations, modified and filled the veins and amygdules, placing in them their minerals in the present relative positions; and, in the general process, the copper, like the other ingredients, was selected from its disseminated and therefore useless condition, and concentrated in veins, amygdaloids, and conglomerates till it reached a percentage of richness that gives to the deposits an economical importance.

This action has taken place certainly not at a high temperature, and possibly at a temperature no greater than that of the beds at present, while it may have been largely aided by that electric action which chemistry almost always induces, and which is known to be active at the present day. In fact the presence of the latter is proof that chemical action is even yet going on.

This metamorphism, then, being the means by which these ore deposits have been formed, it is evident that a knowledge of its laws and methods should lead to important practical results. It is not necessary for me to say that the studies in Chapter III. go a long way in discovering these laws, and it is hoped that they may be still further developed until wholly known.

SANDSTONES AND CONGLOMERATES.—Interbedded in the northern 2,300 feet of the section are ten sandstones, which aggregate about 860 feet in width, and which, as a rule, may be considered as increasing in thickness and coarseness toward the north.

Commencing with the southernmost one and going north, we have—

Bed No.	Width in feet.	Character.
35	55	Rather coarse.
28	18	Rather coarse; inclined to conglomerate.
26	50	Very fine, shaly.
21	33	Very fine, banded, and shaly.
19	45	Coarse; some conglomerate.
17	120	Medium fine, shaly; some conglomerate.
8	170?	Rather coarse; some conglomerate.
6	280?	Coarse as far as known; much covered.
4	10?	? ?
2	282?	Coarse; considerable conglomerate; much covered.
		Above the Melaphyr occur—
–1	129	Coarse; with considerable conglomerate, coarse and fine.
–2	Over 4,000	Coarse conglomerate.

These are apparently all composed of the same materials.

The predominant pebbles of the conglomerates are of a compact chocolate-colored, felsitic rock, generally with small, lighter-colored crystals of a triclinic feldspar, porphyritically imbedded in it. Next is a coarser-grained, crystalline, hard, reddish, felsitic rock. Pebbles of quartz-porphyry occur sparingly, and occasional pebbles of a rock somewhat resembling some fine-grained melaphyrs.*

The sandstones seem made up of the same ingredients; they are generally of shades approaching brick red. All contain much calcite as an impregnation. This often occurs, filling small lenticular cavities, which may occur grouped together for a few inches parallel to the formation, and may have replaced a constituent of the rock; it also fills veins where they intersect the beds.

Where observed, the hanging-walls of the sandstones were generally smooth and gently undulating, but occasionally quite uneven, while the upper two to twelve inches were somewhat changed, being harder or softer, or lighter or darker-colored than the mass of the bed. In one instance, at the top of Bed No. 2, this change was so great as to render the sandstone difficult to distinguish from the overlying greenish melaphyr, except for the unchanged pebbles enclosed in it. The foot-walls are sometimes smooth and undulating; the surface of the underlying bed, when not an amygdaloid, as was sometimes the case, seeming to have been worn smooth, as if by attrition; or else the sandstone seemed to fill inequalities in the underlying amygdaloid.

The sandstones were not observed to be changed near the foot-wall. In one remarkable instance, a crack or fissure was observed extending down into a melaphyr, which was filled by the overlying sandstone. The conclusion is inevitable, that the melaphyr had formed, hardened, and cracked before the sandstone was deposited.†

Lying south of the sandstones there are several others scattered along the section, but which occur as mere seams of only a few inches in thickness, and generally on the surface of, and intimately associated with, the upper part of the so-called scoriaceous amygdaloids. Though these seams are generally too fine-grained to distinguish the form of their component particles, and no pebbles were observed, yet they undoubtedly are true sandstones. They are of the same color, and in places often, though irregularly, banded or stratified—in one instance breaking shaly, with wavy laminæ. Both contain much calcite as an impregnation, often in small lenticular cavities. Before the blow-pipe they behave like the sandstones, the harder varieties fusing with difficulty, the finer ones more easily, in fine splinters, and without intumescence, to a green-black mass. In some cases, where foreign material seems present, some intumescence occurs, but less than with the melaphyrs. Their specific gravities are the same as those of the sandstones, and lower than those of the melaphyr, ranging from 2.56 to 2.70, reaching in one case 2.80 (compact shaly).

The conglomerate pebbles are probably heavier, one of the chocolate-colored, non-quartziferous, felsitic porphyry having a specific gravity of 3.02.

The red-clay seam, a few inches thick, underlying the "greenstone" at the Phœnix mine, and known as the " slide," is the equivalent of the Allouez conglomerate, which a few miles either way along the formation expands to a thickness of 15 or 20 feet.

The "Kingston conglomerate,"—which was exposed by Mr. A. H. Scott about 500 feet south of the centre of Section 33, Town. 57, Range 31,—lies about 5,870 feet horizontally from the "greenstone," and is about 45 feet wide. This is entirely different from the preceding beds, and belongs to the quartz-porphyry type of conglomerate, as does the Calumet conglomerate. The predominant pebble is of a hard, compact, brownish-red, felsitic rock, containing quite numerous flesh-red to pearly-white crystals of orthoclase feldspar, occasionally over .25 inch in length; and grains of colorless, transparent quartz, 1/8 inch in diameter and under, which appear black from non-transmission of light. It strongly resembles the Kearsarge conglomerate exposed near Calumet, and if the mean dip of the formation between the greenstone and the Kingston conglomerate were about 25°, it would be the same bed as the Kearsarge. The dip, however, is probably steeper, so that it probably lies 600-700 feet east of the Kearsarge.

*See description of Beds Nos. -2 and -1, pages 117 and 118.

†For this and the irregular metamorphosed hanging-wall, see figures on p. 119.

VEINS AND FAULTS.—The system of rocks described in the preceding pages is intersected by numerous veins, in many of which movement or faulting has taken place.

Two principal systems seem to exist: first, in which the trend is about N. 15° W. to N. 25° W., with a nearly vertical dip, but perhaps tending eastward ; second, with trend perhaps averaging N. 16° E., dip also nearly vertical, tending eastward. Besides these, several veins have been noticed trending nearly with the formation, but having a much steeper dip.

Upon the first system more or less faulting has generally occurred, though some of the better defined veins show none. In those cases where opportunity was had to measure the amount of throw, the distance varied from a few inches to about 75 feet, the eastern side always having moved northward. In the large faults of this system, however, which are generally occupied by the larger transverse valleys, or breaks in the range, the detritus in which hides the actual fault and its amount of throw, the throw is obviously in the opposite direction,—the east side moving south,—and it is generally sufficiently great to more than counterbalance those faults which have thrown the strata in the opposite direction. The formation, which is slowly changing its trend—in going east—more and more to the southward, at some of these larger faults makes a sudden bend of a few degrees in the same direction, so that these large faults act both by offsetting and bending, in increasing the general curvature of the formation.

Faulting was not noticed in the second system, and a fault of only a few inches in one case in the third.

But movement has taken place upon the formation along certain planes of bedding separating the strata. The so-called "slide"— lying a few feet above the "Ash-bed"—is a case in point, the rocks above having slid down upon those below probably about 150 feet.

Motion also seems to have taken place upon the "slide" at the base of the Greenstone—the horizon of the Allouez conglomerate, here occupied by a clay seam—but probably to no great extent, it being said that veins are not displaced by it. Movement may have similarly occurred at other points as yet undiscovered.

The veins of the district were of course formed long after the consolidation of the beds, and probably when they were being lifted into their present position. They have subsequently been filled with the various minerals which now occupy them, wholly by infiltration and chemical, probably aided by attendant electric, action, and in a systematic and natural sequence, as shown by the paragenetic table. The more successful mines seem to have been worked in the first system of veins, on one of which the present Phœnix mine is now working. The "old Phœnix" however, on a similar vein, but farther north, was not successful. The work upon the Robbins and Armstrong lodes, both of the second system, was not remunerative in either case.

Besides vein-mining, considerable work was formerly done on the "Ash-bed," but without success. There is no apparent reason, however, why there should not exist beds in this region, either of amygdaloid or conglomerate, as near Portage Lake and elsewhere, which it would be profitable to mine for copper. A better examination of the "amygdaloidal floors" already exposed in the vein-mines might lead to profitable returns.

A system of vein and bed mining could be carried on simultaneously with considerable economy, the one helping the other: the beds generally carrying a low but nearly uniform per cent. of copper, the veins more generally containing larger but more erratic and uncertain "masses."

CHAPTER VIII.
DESCRIPTIVE CROSS-SECTION OF THE EAGLE RIVER DISTRICT.

By A. R. Marvine.

The following chapter gives a detail description of the various beds which compose the Eagle River cross-section. Attention having been called in the preceding chapter to the more prominent features of the section, this chapter is intended only to be of service in prosecuting any mining enterprise, in which it would be useful to know the distances and the nature of the rocks to be passed, or of use in correlating or comparing in detail with any sections which future surveys may make in other parts of the copper region.

The initial point of measurement and numbers is at the foot-wall of the wide northern conglomerate and sandstone, lining the lake shore, or, what is the same thing, the hanging-wall of the northernmost melaphyr of the section, as exposed at the lower fall and dam just above the town of Eagle River. From this point the beds are numbered in regular order going south, while occasional larger numbers upon the left give the total *horizontal* distances of certain points, also measured from this initial point. Common Arabic numerals, also on the left, are used to express the *horizontal* widths of beds in feet, while numbers standing alone in parentheses always express actual *thicknesses* of beds, or parts of beds, measured *perpendicular* to the plane of bedding.

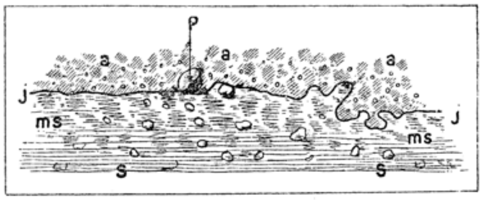
-2. Conglomerate; over 4,000 feet wide; variably bedded thick and thin; large pebbles predominating in some strata, coarse sandstone in others; latter sometimes cross-stratified, sometimes inclining to a shaly structure. Generally coarse, with
+4000 predominant pebbles from 3 to 8 inches diameter, often 1 foot and more, cement being smaller pebbles and coarse sand. No angular fragments, many not perfectly rounded, those rounded affect oval form. Majority composed of (*a*) non-quartziferous porphyry; matrix, predominant color, liver to chocolate brown, compact to subcrystalline; crystals, subordinate, sometimes nearly absent, always scattering; small, generally $^1/_{50}$ to $^1/_{20}$ inch long; generally somewhat lighter colored than the base. Flesh-red crystals .1 to .5 inch long sometimes occur in chocolate-colored matrix. The crystals in these seem to be of triclinic feldspar. Subordinate to these occur (*b*) pebbles of a coarser, but compactly crystalline flesh-red felsitic rock, the light reflecting from the many small cleavage planes of the fractured crystals which form the rough broken surface. Numerous black specks of unknown nature occur (quartz?); exceedingly hard, and hence often in large pebbles. So far as seen these two varieties compose most of the bed. Very occasionally there occur (*c*) pebbles having a dull brick-red, hard, compact inclining to jaspery matrix, in which are pretty thickly scattered crystalline grains of black quartz from .02 to .20 inch diameter, together with flesh-red to pearly crystals of feldspar, probably orthoclase, from .1 to .6 long. The quartz appears black from non- transmission of light, being in reality colorless. It is invariably fractured upon breaking the pebble, and lies about flush with the fractured surface, which is uneven, and generally exhibits a rude hexagonal outline. Pebbles of a rock (*d*) very closely resembling some fine-grained or compact melaphyrs also sparingly occur. The matrix and sandstone layers are apparently composed of the same ingredients as the pebbles, small quartz grains sparingly but pretty generally occurring. Calcite, generally white, opaque, with rhomb cleavage, frequently occurs impregnating the mass, and filling the cavities and the veins where they pass into the bed.*

-1. Sandstone; generally coarse but varying from harder, thicker, coarser beds, generally more or less cross-stratified, to finer, thinner,
129 shalier ones. Bands of pebbles occur, and
(68) much calcite is present; composition same
-o- as above; general color, dull brick red.
Junction, well defined, slightly undulating, quite smooth; no contact change in either bed.

1. Amygdaloid, inclining to amygdaloidal melaphyr; aniygdules not abundant, scattered, containing calcite, sometimes with laumontite and a light green green-earth. Matrix same as underlying accompanying Melaphyr, which has a medium coarse-grained texture and semi-conchoidal inclined
85 to uneven fracture. Prevailing color a light
(48) grayish green, rudely mottled with dull flesh red. The dark green chloritic element is very sub ordinate; glistening black specks of specular iron occur, and much disseminated white calcite. Specific gravity, 2.94. Tendency toward amygdaloidal zones in the bed; lower two feet amygdaloidal.

Junction, very irregular. For two feet the underlying sandstone is changed and indurated, being, in places, hardly distinguishable from the overlying melaphyr, except for enclosed pebbles which are not changed. Some pebbles rest upon the hanging-wall which are quite enclosed in the overlying amygdaloidal melaphyr.

85 - = - (48)



a a—Amygdaloidal melaphyr.
s s—Sandstone with pebbles.
j j—Junction of a and s.
m s—Metamorphosed top of s, with unchanged pebbles.
p—Pebble surrounded by a.

*It is in a vein in this horizon that the impure manganese occurs, at Manganese Lake, near the extremity of Keweenaw Point.

5 (3) **2.** **Sandstone;** coarse, some conglomerate. Same as No. -1.

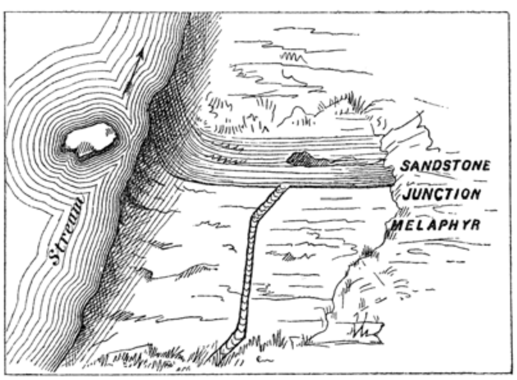
70 (37) *Covered* (probably sandstone).

55 (30) **Conglomerate** and sandstone. Same as No. -1.

148 (78) *Covered* (probably sandstone).

4 (2) **Sandstone;** rather coarse. Same composition as the preceding.

367 -=- (196) *Junction,* slightly undulating. No change or metamorphism in the adjacent beds. Extending from the junction down into the underlying



melaphyr—about eight feet being exposed—is a fissure or crack with sharply defined edges and two abrupt bends, giving widths of two and four inches. This crack is filled with sandstone similar to that above, but somewhat finer and slightly decomposed or softened. There is an appearance of irregular, but rudely curved stratification, about parallel, as a whole, with the formation.

3. **Melaphyr,** inclining to amygdaloidal melaphyr; medium coarse texture. Color dull reddish purple, sprinkled with numerous small green spots; former mostly feldspar, latter delessite. Some amygdaloidal portions have delessite spots of larger size, enclosing radiated laumontite.

50 (26)

10? (5) **4.** **Sandstone.** Same as -1.

40 (21) **5.** **Melaphyr,** inclining to amygdaloidal melaphyr; resembles No. 3, slightly finer,—more purple; occasional calcite amygdules, and small feldspar crystals porphyritically imbedded in the base.

175 (89) *Covered*, probably sandstone.

40 (21) **6.** **Sandstone,** similar to preceding; rather coarse.

160 (83) *Covered*.

7. **Melaphyr,** inclining to amygdaloidal melaphyr, rather irregularly. Upper 15 feet are of dark green decomposing melaphyr. The lower 10 (5) feet are of irregular **Amygdaloid;** decomposing; the harder parts composed of a rather compact dark reddish-green base, containing small scattered flesh-red feldspar crystals, and irregular, generally elongated, amygdules of delessite, containing calcite and sometimes accompanied by small amounts of prehnite and laumontite. Enclosed in this amygdaloid are some irregular patches of fine-grained light gray melaphyr.

25 (13)

867 --=-- (456) *Junction*, well defined, straight; rocks adjacent rather soft, and weathering; slight stains of carbonate of copper.

90 (47) **8.** **Sandstone;** upper few inches somewhat changed by the overlying rock. Same composition as the preceding sandstones. Ten feet quite consistent, followed by ten feet shaly; rest not well exposed; some conglomerate occurs.

88 (45) *Covered*, probably sandstone.

14 (7) **9.** **Melaphyr;** medium to fine grained; color light grayish, from minute light-green and dark-red component spots; fracture uneven, inclined to smooth; rather hard and elastic; many small calcite cleavages glistening; over the fractured face; no magnetite. Lower ten inches are amygdaloidal; calcite with some laumontite amygdules, increasing toward the foot-wall.

1059 - = - (555) *Junction*, well defined.

10. **Amygdaloid;** base reddish-brown; compact, not indurated; amygdules very irregular, from .05 to .50 inch longest diameter, composing about 40 per cent, of the rock and filled with calcite accompanied sometimes by small amounts of green-earth and some prehnite for about ten
20 feet, and then gradually changing through

(10) rather fine-grained.

Amygdaloidal Melaphyr to **Melaphyr** at fifteen feet; general color greenish-purple, composed of light-green feldspar crystals and small red specks; fracture uneven ; occasional calcite amygdules.

26 **11.** **Amygdaloid,** and **Amygdaloidal Melaphyr,**
(14) similar to No. 10, but not well developed.

12. **Amygdaloid,** 15 (8) feet, similar to that of No. 10; 50 per cent, amygdules.

50 **Amygdaloidal Melaphyr,** 30 (16) feet, and
(26) **Melaphyr,** 5 feet; color greenish-gray; finer
grained and harder than No. 10; fracture
somewhat uneven. Lower foot amygdaloidal,
calcite amygdules.

13. **Amygdaloid;** narrow, 5 feet, but well
developed; base fine grained; purple;
amygdules mostly calcite, at top with
considerable green and white prehnite and
scattered specks of copper and some datolite.
40 **Amygdaloidal Melaphyr**; 20 feet; base
(21) somewhat coarser grained; dull dark green,
mottled purple; fracture uneven; amygdules
scattering; laumontite, sometimes surrounding
a green-earth core; some of delessite and
calcite.

Melaphyr; 15 feet; inclining to amygdaloidal, with delessite spots; lower foot quite amygdaloidal.

1195 **14.** **Amygdaloid;** 10 (5) feet; very fine-grained to
==-- earthy, reddish-brown base; amygdules
(626) irregular, not ramifying, reaching .3 inch
diameter, and forming about 30 per cent. of
the rock; some of calcite with delessite lining;
rest partially, some wholly, filled with prehnite,
some of which are further filled with calcite;
30 ramifying seams of prehnite occur, with some
(16) copper.

Amygdaloidal Melaphyr; 20 (11) feet; medium fine grained; mottled dirty green and purple; scattering amygdules of delessite and laumontite.

15. **Amygdaloid;** 4 (2) feet; similar to No. 14, but subordinate; some

87 **Amgdaloidal Melaphyr** and **Melaphyr;** 75 feet;
(45) medium fine-grained; irregularly mottled green
and purple; irregular to hackly fracture; much
like melaphyr of No. 14.

1312 **16.** **Amygdaloid;** 25 (13) feet; mixed soft and hard,
--==-- former predominating; upper part, as usual,
(687) much the best developed; irregularly
associated with and changing to amygdaloidal
melaphyr; the base of the amygdaloid is very
fine-grained to compact; greenish to red
brown; amygdules irregular and ramifying,
43 forming 20 to 40 per cent, of the rock, mostly
(22) of calcite and prehnite, small amounts of
copper generally accompanying the latter.

Melaphyr; 12 feet; medium coarse-grained; intermingled dull-green and purple ingredients, giving a mottled greenish-purple color, relieved by numerous small greenish-white feldspar crystals, which sometimes are .1 inch diameter.

120 **17.** **Sandstone;** medium fine-grained; specific
(63) gravity 2.56; mostly rather heavily bedded,
some thinly bedded and shaly, and some
conglomerate layers; color dull brick red; not
well exposed.

18. **Amygdaloid (?);** narrow; mostly covered; not well observed.

Amygdaloidal Melaphyr; 17 (9) feet; characteristic; base rather fine grained; indefinitely mottled dull green and purple, former sometimes prevailing, giving a dark, dirty, dull-green color, and sometimes the latter, giving a handsome purple hue to the rock; fracture generally un even, sometimes approaching conchoidal, not rough; rather tough and elastic. In this base are sprinkled amygdules reaching .5 inch diameter and averaging about .3 inch. These occur from very occasional to where they are irregularly scattered, but averaging .5 to 1 inch apart, being generally more numerous toward the upper part of the bed. These amygdules are all filled, and almost invariably with prehnite, sometimes having calcite in the interior. Very occasionally the prehnite has its characteristic green hue; but this only occurs near the centre. More often it has a flesh pink color and vitreous lustre and fracture, either radiated or not, in the latter case strongly resembling rose quartz. It is in this form, inclining to green, that it may enclose calcite, and in which it resembles the characteristic prehnite amygdules of the "Isle Royale" series of rocks near Portage Lake. But the most
24 characteristic and predominant form that the
(13) prehnite assumes is one in which the color
has less red in it than, pink, being a whitish salmon color, without a vitreous lustre, while a well-developed radiated structure gives a fracture as if from interrupted cleavage. It much resembles laumontite, but is harder. The radiations diverge from a point on one side, like a palm-leaf fan, or from two, or even three, points, the systems meeting along curved lines. In a flat-sided amygdule, the radiant point will be at the corner, the rays being at first parallel to the flat side. Occasionally, immediately about the radiant point, salmon-colored prehnite occurs, changing into the rose colored variety toward the extremity; and more often a dull, earthy green band runs through the amygdule, concentric with the radiant point. The outer surface has often a thin coating of delessite; but as often the prehnite is in direct contact with the base. This contact is intimate, never perfectly smooth, but always uneven, sometimes very irregular, and. never suggestive of a filled-up cavity, but rather—as in most amygdaloidal melaphyrs—of a segregation. The base but seldom exhibits a changed appearance near the amygdule, though, as a whole, it is apt to differ somewhat

from the underlying melaphyr.

Melaphyr; 4 feet; same as the base of the above; slightly coarser.

(20) 11 *Covered;* possibly occupied by an amygdaloid, etc., like the preceding, probably by melaphyr.

10 (5) **Melaphyr;** like that of No. 18.

±45 (24) **19.** **Sandstone;** rather coarse; some conglomerate layers; mostly covered; neither wall observed; same as the preceding sandstones, and, like them, having carbonate of lime generally present.

70 (37) **20.** **Amygdaloid;** 10 (5) feet; soft, decomposing; mostly covered; calcite predominating. **Amygdaloidal Melaphyr,** followed by some **Melaphyr;** same as No. 18.

±33 (18) **21.** **Sandstone;** mostly covered; very fine; some thinly banded light and dark red; in parts slightly indurated, tending toward jasper; no junction visible.

119 (62) **22.** **Amygdaloid;** 10 (6)? soft; decomposing; mostly covered.

Amygdaloidal Melaphyr; 30 (16); specific gravity, one piece, 2.72; and **Melaphyr;** 79 (40); specific gravity, 2.77; same as No. 18.

14 (7) *Covered;* probably occupied by an amygdaloid (No. 23) and amygdaloidal melaphyr similar to the preceding.

14 (8) **23.** **Amygdaloidal Melaphyr;** 5 feet; and **Melaphyr,** same as No. 18.

17 (9) **24.** **Amygdaloidal Melaphyr;** 5 feet; and **Melaphyr,** 12 feet; same as preceding, inclining to purple.

30 (16) **25.** **Amygdaloid;** 20 (10) feet; some hard; matrix compact, purplish brown, with occasionally whitish-red crystals of triclinic feldspar, sometimes 2 inches long, imbedded in it. Near hanging-wall are irregular bunches of calcite, some prehnite; amygdules often reaching .25 inch diameter, and rather irregular; forming 50 per cent, of the rock near the top; mostly of calcite in thin pellicle of delessite, and sometimes enclosing green prehnite with little copper; amygdules with red lining (feldspar ?) enclosing quartz, and often copper, occur in the harder parts.

Amygdaloidal Melaphyr, inclining to melaphyr, 12 (6) feet; similar to that of No. 18; amygdules small, not well marked.

±50 (26) **26.** **Sandstone;** in part very fine-grained to compact texture, inclined to shaly structure; laminæ ⅛-¼-⅔ inch thick; remainder thicker bedded and coarser; specific gravity, 2.68; composition same as the preceding, having occasional black quartz grains, and the usual calcite impregnation.

1921 --=-- (1008) *Junction;* smooth; slightly undulating; no apparent contact metamorphism.

27. **Amygdaloidal Melaphyr;** 10 (5) feet; poorly exposed; amygdules of delessite and some prehnite in a green base, which beneath becomes

79 (42) **Melaphyr;** 15 (8) feet; rather fine-grained; irregular fracture; of dark and light green components; similar to that of No. 18, but without the purple element of the color. At 25 (13) feet from the hanging-wall it becomes amygdaloidal, with many amygdaloidal-like segregations of delessite, which are somewhat indurated but inclined to earthy; centre light green, circumference dark green, the base being strongly inclined to purple. Amygdules of quartz-like and radiated salmon prehnite also occur occasionally. Without having well-defined walls, two or three more amygdaloidal zones occur parallel with the bedding, with the greener melaphyr between. Lower 10 feet are of the darker, mottled, dirty green **Melaphyr,** somewhat coarser than the rest.

18 (9) **28.** **Sandstone;** rather coarse, inclining toward conglomerate; similar to No. -1; non-quartziferous, chocolate-colored, felsitic rock, with occasional small feldspar crystals, predominating.

2022 -=- (1159) 11 (6) **29.** **Amygdaloid,** inclining toward amygdaloidal melaphyr; 6 (3) feet; matrix dark, purplish brown; fine-grained; amygdules not predominating, mostly of some delessite with calcite and some green prehnite with little copper.

Melaphyr; 5 feet; medium fine-grained; like the purpler varieties of the preceding melaphyrs; foot-wall not well defined.

30. **Amygdaloid;** 4 (2) feet; hard, fine-grained, purplish-brown base; amygdules forming about 25 per cent, of the rock, irregular, but neither large nor ramifying; generally contain calcite enclosing prehnite, often the latter alone or enclosing quartz. The prehnite is usually colorless, inclining to light green, and fills also small veins in the rock. It is nearly always—the quartz sometimes—accompanied by little copper.

53 (27) **Amygdaloidal Melaphyr;** 16 (8) feet; same type as No. 18, base somewhat coarser, though component crystals are still nearly undistinguishable; green predominates over the purple. Amygdules contain radiating prehnite, but salmon color not marked, often colorless, white; sub-fibrous, but lustre vitreous. Unlike No. 18, however, these are generally surrounded by laumontite, and many wholly filled with it.

Melaphyr; 33 (17); same as base above; slightly coarser and greener than No. 18.

29 (15) **31.** **Amygdaloid;** upper foot having from a very fine-grained to compact, inclined to hard, base of dark greenish-brown color, and containing irregular and ramifying amygdules and bunches of calcite. This graduates into 18 (9)

feet of softer and less amygdaloidal material, with coarser and purpler matrix, in which calcite is subordinate, and spots of dark and light green delessite or green-earth, or both, predominate. Laumontite and radiated pink prehnite also occur. This graduates into

Melaphyr; 10 (5) feet; rather fine-grained; handsome purple, irregularly mottled dark green, with uneven and often rough fracture. Same type as No. 18.

24 (13) **32.** **Amygdaloid;** 10 (5); **Amygdaloidal Melaphyr,** 6 (3), and **Melaphyr,** 10 (5) feet, like No. 31.

20 (10) **33.** **Amygdaloid;** well developed, calcite and prehnite, often in bunches for 1-2 feet, then less irregular for 10 feet, followed by

Amygdaloidal Melaphyr; like No. 31, but with more salmon-colored prehnite.

27 (14) **34.** **Amygdaloid,** and **Amygdaloidal Melaphyr,** same as preceding.

55 (28) **35.** **Sandstone;** rather coarse, similar to the others.

41 (21) **36.** **Amygdaloid;** mostly covered, 6 to 8 feet soft, decomposing; red prehnite and delessite, followed by 2 feet of harder amygdaloid. This is inclined toward a scoriaceous character, in which occurs very irregularly banded or thinly stratified material, which is wholly undistinguishable from that in some of the finer sandstones, though somewhat indurated. It often partially encloses irregular bunches or balls of calcitic amygdaloid, while it is impregnated by calcite as is the sandstones. Below this are two feet of soft, blackish green, crumbling delessitic rock, with laumontite scattered through it; crumbling shaly. A normal **Amygdaloid,** inclining to amygdaloidal melaphyr, follows, 28 feet; base dirty light grayish green; delessite, calcite.

Melaphyr; 12 (6) feet; forming base of bed; dirty gray green predominating; occasional delessite spots.

30 (16) **37.** **Amygdaloid;** 4 (2) feet; dark, chocolate-colored particles in light-green base, forming grayish-green colored matrix; amygdules of calcite in pellicle of delessite; occasionally of pink and salmon prehnite.

Melaphyr; same as matrix above.

20 (10) *Covered;* probably occupied by a coarse, soft amygdaloid—No. 38?—like No. 36.

27 (14) **38.** **Melaphyr;** 27 (14) feet; exceptional; quite coarse-grained; fracture somewhat uneven; composed of small, but generally indistinct, crystals of flesh-red triclinic feldspar, and dark-green, to lighter bluish-green amorphous delessite; colors well marked. A soft, dark, chocolate-colored mineral is present in small quantities; no magnetite; particles of metallic copper occasionally appeal through the mass, generally in the feldspar crystals; specific gravity 2.79.

150 (80) **39.** **Melaphyr;** rather fine-grained; uneven fracture; mottled indistinctly and irregularly dark green and dull purple, former mostly predominating and giving rise to a dirty, dark-colored rock.

103 (54) *Covered;* much very amygdaloidal debris.

95 (50) **42** and 43. Space mostly covered; two melaphyrs showing, each probably with an overlying, very amygdaloidal bed. **Melaphyrs** incline to dark color; some being nearly black or greenish black, mottled with very dark, indistinct purple.

44. **Sandstone,** with

45. **Amygdaloid;** 24 (12) feet; forming a "scoriaceous amygdaloid;" composed of irregular bunches or "bomb-like" masses of calcitic amygdaloid, 1.5 feet to .5 inch diameter, filled in with a very fine-grained to compact brick-red material, which often shows fine, but irregular, bands or lines, apparently of stratification. This material increases in amount toward the top of the bed, where it often quite encloses and surrounds the smaller, irregularly round, amygdaloidal balls. The strata-like bands are more evident when the material is in larger amounts, and they often seem to separate or open out to enclose the imbedded balls. In appearance it is undistinguishable from the finer-grained sandstones, though, perhaps, containing more calcite, which is more often collected into small, generally lenticular, cavities, which are sometimes more numerous in rude, narrow bands, parallel with the bedding, than is the case with the sandstones.

154 (86) **Amygdaloid,** or **Amygdaloidal Melaphyr;** 10 (6) feet; very fine-grained; purplish brown; containing small white and red crystals of feldspar; amygdules of green-earth and calcite, when together, latter contains the former; very little copper. Graduates into

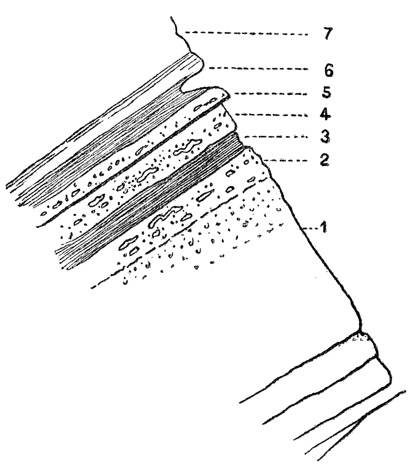
Melaphyr; 120 (68) feet; exceptional; very brittle and elastic, and harder than the average melaphyr, with sub-conchoidal and rather smooth fracture; specific gravity, 2.91; consists of a very fine-grained to compact purplish base, in which are profusely scattered small, semi-transparent, light-green crystals of a triclinic feldspar (labradorite ?), occasionally showing striation, but seldom definite form. Considerable magnetite is present, which, with small flakes of specular iron, occurs scattered here and there, often connected with a small spot of discoloration of the rock to dark brown, as if from hydration. The chloride ingredient is occasionally segregated out in amygdules, in which flakes of copper sometimes occur. Weathered surface smooth, color gray, with feldspar white. Lower 4-6 inches of melaphyr broken, up, rock more compact than above, feldspar crystals red, rock brown. With this, but mostly below it, are 4-5 inches of finely amygdaloidal rock, base compact; purple; red feldspar crystals;

amygdules mostly calcite, some green-earth.

2861 --=-- 1503 *Junction*. The line over the broken-up material is strongly marked, while the real foot-wall of No. 44, though a true plane of separation, is not so apparent.

46.	**Amygdaloid;**	(2) feet;	**Amygdaloidal Melaphyr** and	**Melaphyr**	(27).
47.	"	(1)	"	"	(8) feet.
48.	"	(2)	"	"	(4)
49.	"	(2)	"	"	(8)
50.	"	(1)	"	"	(15)
51.	"	(2)	"	"	(7)
52.	"	(2)	"	"	(4)
53.	"	(4)	"	"	(9)
54.	"	(4)	"	"	(10)
55.	"	(5)	"	"	(10)

3100 --=-- (1630) These ten beds, though thin, are well defined. With some variations they are much alike, and may be described as follows, taking No. 47 for the type: Commencing near the middle of one of the amygdaloidal melaphyrs—No. 1 of the adjoining section—we find a rather soft, but tough, medium fine-grained, but not closely textured rock, breaking with an un even and rough fracture. Upon the purplish-brown base are numerous dark-green, poorly defined, delessite spots. The purple-brown base is composed of the light green or pinkish feldspathic element, and small chocolate colored specks, apparently a decomposition product of an iron mineral, probably specular iron, glistening points of which still remain. Amygdules not numerous, in some beds almost wanting, generally of delessite, occasionally stellated, sometimes of calcite, laumontite, and green-earth. This grows more and more amygdaloidal in ascending, passing into an irregular, somewhat harder belt, having a finer-grained to compact matrix, with an even reddish-brown color, and amygdules of calcite and green-earth and some prehnite. This changes rather abruptly to a band—No. 2—a few inches wide, of the same base, but very



1. Amygdaloidal melaphyr.
2. Very amygdaloidal; calcite, prehnite.
3. Soft, decomposing, delessitic zone.
4. Same as 2, and top of bed.
5. Hard; not as well developed as 2 and 4.
6. Soft, fissile; delessite and laumontite.
7. Amygdaloidal melaphyr, same as 1.

amygdaloidal, green botryoidal prehnite predominating, with calcite; amygdules very irregular, reaching 5 inches long; the larger-ones generally lying parallel with the plane of bedding, and mostly confined to the centre of the narrow belt. No. 3 follows, soft, easily decomposing, dirty brown, containing much delessite; about 6 inches wide; overlain by No. 4, also about 6 inches wide and like No. 2. Its top is the real "hanging-wall" of the bed, having an even, free, plane of stratification separating it from the bed above. The lower two or three inches of this upper bed—No. 5—are rather hard and somewhat like Nos. 2 and 4 below, but not so well developed. It graduates into No. 6, which is very soft, inclining to fissile, and easily decomposing, having in its lower part abundance of radiating laumontite and delessite, the latter prevailing above but decreasing in amount till about a foot or more above the "foot-wall," when a rather sudden change takes place into the melaphyr or amygdaloidal melaphyr above. The prehnite is almost invariably accompanied by small amounts of native copper. This double structure of the amygdaloids occurs in most of the beds, but is absent in some, and some of the amygdaloids are much better developed than others; while the individual distances may be somewhat incorrect.

67 (35) *Covered;* probably containing two or three beds similar to the above.

18 (9) **58.** **Melaphyr.**

58 (30) **59.** **Amygdaloidal Melaphyr,** varying irregularly to amygdaloid or melaphyr, and generally much decomposed.

11 (5) **60.** **Melaphyr.**

185 (95) **61.** **Amygdaloidal Melaphyr,** same as No. 59.

11 (6) **62.** **Melaphyr,** inclined to semi-columnar structure.

These five beds form an exceptional series. No. 58 resembles the melaphyrs of the last-described series, a rather coarse, soft, easily decomposing, uneven fracturing rock of dull reddish-brown color, spotted dark green. No. 60 is finer, harder, uneven but smoother fracture; color greenish, mottled reddish brown, and of more even tint. No. 62 is very fine-grained, elastic, but tough, inclined to semi-columnar structure, and of dark blackish-green color, with occasional crystals of glassy feldspar. These three melaphyrs graduate most irregularly into the two intermediate zones, Nos. 59 and 61, the easily decomposing nature of which, however, renders them difficult of observation. Throughout there is much melaphyr similar to the enclosing beds, but seemingly mixed with it are large amounts of most irregular material, sometimes occurring in vein-like seams, or in wide irregular bands, paralled to the bedding.

Some of these are composed almost wholly of coarse delessitic material, patches of which are filled with ramifying, connecting amygdules of pink laumontite and calcite, which may even become the predominating ingredients of the rock, rather than amygdules. Others, somewhat harder, have but little laumontite and more calcite and prehnite, with a little copper; but these minerals are more confined to cavities and spots, and appear more like accidental than essential ingredients of the rock, as is the case sometimes with the delessite and laumontite. Stellated groups of small quartz crystals occur in vugs. Still various amounts of compact melaphyr are frequent, balls of which may be pried from out the crumbling mass, leaving irregular cavities behind. One or two zones show a material consisting of dark glistening delessite and grains of feldspar, which crumbles away into a sand and encloses balls of harder melaphyr.

3450 --=-- (1810) *Junction, "Slide";* strongly defined, somewhat uneven. The "Old Phœnix workings on the Ash-bed "show the" Armstrong Vein," thrown horizontally along this junction about 260 feet (Merryweather's map). Considering the dip and strike of the vein, and supposing the movement to have taken place directly down the bed, it would appear that the beds above had slid down upon the beds below about 150 feet.

·5 **63.** **Sandstone;** seam, 1-6 inches thick; very fine-grained to compact; reddish-brown to chocolate color; occasional fine lines of stratification; undistinguishable from the fine sandstones, and, like them, melts before the blowpipe flame on their edges, without intumescence, to green-black glass; specific gravity, 2.61. Fills irregularities on the surface of amygdaloid below.

64. **Amygdaloid;** 12 (6) feet; made up of several thin beds; the upper ones very amygdaloidal; 60 per cent, amygdules, calcite, little prehnite, not very irregular, base compact, reddish gray. Near the amygdules, generally on their lower side, often only there, the base is changed, to an indurated, amorphous, chocolate-colored material, resembling the sandstone above, but harder, and intumescing before the blowpipe, like most melaphyrs.

108 (55) **Amygdaloidal Melaphyr;** 40 (20); in several beds; base varying from very compact to rather fine-grained; former even light-green color; latter same, finely mottled darker green; amygdules small, rather numerous, contain laumontite and calcite.

Melaphyr; 50 (26) feet; very fine-grained; elastic, rather brittle; rather smooth, inclined to semi-conchoidal fracture; color, dark, greenish black inclined to brown; decided semi-
fault columnar structure.

—35 **65.** **Amygdaloid;** about 180 (92) feet, variable; scoriaceous; locally called the

—(18) ±280 (143) **"Ash-bed";** upon it, and on the "Old Phœnix Vein" where it inter sects the ash-bed, much mining has been done, but without ultimate practical success.* Debris on the surface and water in the workings mostly hide the bed. It seems to be composed of three or four indefinite zones or "floors," one of which is strongly marked, separated, by, and inter mingled with, compact melaphyr similar to that forming the base of the bed below. These zones often appear to be made up of more or less round and various-sized balls of amygdaloid, often distinctly surrounded by the melaphyr, a pretty well-defined line of demarcation sometimes separating the two, but often very irregular and not well defined. Again they are enclosed in a brownish-red, fine-grained material, similar to the medium and finest grained to compact sandstone. It is in places distinctly but irregularly stratified, but no pebbles have been observed. Specific gravity of the coarser, 2.70; of the finer, 2.66. When the melaphyr surrounds the balls, its dull bluish color sometimes changes to a reddish hue, resembling that of the supposed sandstone material, but, unlike it, containing occasional incipient delessite amygdules, and scattering red feldspar crystals. It fuses, like the parent melaphyr, before the blow pipe rather readily on the edges of large pieces, and with intumescence, while the finer sandstone-like material is not readily fused, with hardly any intumescence, the coarser being almost infusible. In one specimen the fine sandstone material was associated with small layers of ash- colored, porous, tuff-like material. The amygdaloid itself has generally a dark, chocolate-colored base, with amygdules often quite filled with delessite; but generally of calcite and the other minerals, crystallized datolite being common in veins intersecting the bed. Copper is scattered through the bed.

*Merry weather's map of the "Old Phœnix workings on the Ash-bed" gives this bed as about 70 feet wide, but variable. The survey measured 90 feet upon it without seeing either wall. At Copper Falls it is over 150 feet wide.

Melaphyr; 100 (51) feet; lying below the preceding, as well as associated with it. Texture very fine-grained to very compact; fracture smooth, sub-conchoidal; color, at a little distance, a soft, even, neutral, bluish tint, which inspection shows, as with most melaphyrs, to be composed of a delicate mottling of green and purplish red. Throughout, more or less definite green spots appear, sometimes increasing in number and definition, giving an amygdaloidal character to the rock. Small shining particles of copper are quite numerous, and considerable magnetic iron is present. Specific gravity, 2.98; large probably on account of the copper and iron present.

3803 (1990) **66.** **Amygdaloid;** 14 (7) feet; scoriaceous; matrix brown, fine, with flesh-red. feldspar crystals; amygdules small, very numerous, mostly calcite; change abrupt to

Amygdaloidal Melaphyr; 14 (7) feet; very fine
purplish base, composed of green and dark-
red particles, with porphyritically imbedded
numerous small flesh-red crystals of triclinic
feldspar, in which occasionally are flakes of
88 copper. Amygdules are of black-green
(45) delessite, containing green prehnite and
quartz, generally some copper, near the top;
delessite alone near the bottom, earthy on the
exterior of the amygdules, often stellated or
radiated, and shiny within; specific gravity,
one piece, 2.84. Changes to

Melaphyr; (31) feet; hard, brittle, elastic; fracture rather smooth, sub-conchoidal; color even, purplish, or lightly mottled green, with numerous small crystals of whitish-green, inclining to pink triclinic feldspar, porphyritically imbedded; considerable magnetic iron; specific gravity, 2.93. Similar to No. 45. Lower foot is amygdaloidal.

67. **Amygdaloid,** inclined to amygdaloidal melaphyr; 6 (3) feet; composed of three rather distinct layers; base very fine-grained; purplish; porphyritic, with small, flesh-red feldspar crystals; amygdules mostly delessite, some calcite and prehnite, little copper. Changes to

Melaphyr; inclined to amygdaloidal melaphyr.
In descending, the feldspar changes from
flesh-red to dirty white, and then to light green,
composing, in a few feet, with some generally
disseminated delessite, the greater part of a
rather coarse-grained, dirty gray-green matrix,
109 spotted with numerous dark-green, delessite
(56) spots, the porphyritic character no longer
existing, and with but little magnetite and no
observable specular iron. It is tough, non-
elastic; fracture uneven and rough, giving the
impression of a loose texture. Specific
gravity, 2.88. The delessite spots give an
amygdaloidal-melaphyr character to the rock,
which exists through out the bed.

68. **Amygdaloid;** fine-grained, hard; quartz, with other minerals, present.

Amygdaloidal Melaphyr; a mixture of small red feldspar crystals and much delessite, latter mostly collected into frequent spots reaching .2 inch diameter. In descending, as in No. 67, the feldspar loses its depth of shade, becomes light dirty pink and green or white, and semi-transparent, and forms, with apparently about an equal amount of delessite, a more even granular mixture of a dirty pinkish, color, profusely spotted with greenish-black segregations of delessite.

82 **Melaphyr.** In descending still further, about
(42) fifteen feet from the hanging-wall, the feldspar
mostly becomes of a light-green color, giving
to the base a dirty gray-green hue, sometimes
slightly mottled with purple, and a more
compact fine-grained texture, while the dark-
green delessite spots become smaller and
smaller. In the fullest development of the
melaphyr these spots lose their definition,
forming an irregular, undefined, but evenly
distributed mottling of dark green upon a
lighter green background, and even this may
be nearly lost. But little magnetic iron is
present. Specific gravity of finest, 2.87.
Fourteen (7) feet from the foot-wall a distinct
head, parallel to the bedding, occurs. The
lower foot is inclined to amygdaloidal, pink
feldspar, larger delessite spots.

69. **Amygdaloid;** 12 (6) feet; hard ; green and brown mixed; former compact, jaspery, few amygdules; latter very fine-grained; amygdules mostly of prehnite, with little copper; but often of quartz or calcite, generally free from chlorites. Softer, less developed toward bottom. At about 12 (6) feet from the hanging-wall, and along a pretty well defined plane of demarcation, is an abrupt change to

132 **Amygdaloidal Melaphyr;** (5) feet; same as in
(67) No. 68, but with laumontite accompanying the
delessite near the top. Changes to

Melaphyr; same as No. 68; approaching the even-shaded variety toward the base. Thirty feet from hanging-wall is an amygdaloidal melaphyr zone; 25 feet from foot-wall is distinct "head" or joint, parallel with the formation, forming a fall in the river. Lower foot is amygdaloidal melaphyr.

70. **Amygdaloid;** 2(1) feet; base fine-grained,
22 purplish-brown amygdules chlorite or green
(11) prehnite, with calcite and some quartz. Small
orthoclase crystals resting on prehnite.

Amygdaloidal Melaphyr; 18 (9) feet; rather fine-grained; purplish and green speckled; delessite amygdules; texture rather loose; fracture rough.

4236 **71.**
(2211) **Amygdaloid;** (4) inches; same as No. 70, with
30 **Melaphyr** below, same as No. 68.
(15)

47
(24) *Covered;* amygdaloid?

46 **72.** **Melaphyr;** (25) feet; same as No. 68; rather
(24) coarse purplish base, mottled green.

28 *Covered;* amygdaloid in part?
(14)

86 **73.** **Amygdaloidal Melaphyr;** 20(10) feet; base like
(44) No. 68; radiated pink prehnite in amygdules;
followed by **Melaphyr,** like No. 68.

64 *Covered*.
(32)

76. **Amygdaloidal Melaphyr;** 15 (8) feet; mostly covered; greenish; laumontite and calcite.

35 **Melaphyr;** very fine to compact, even bluish-
(18) green tint, like that of No. 65 ("Ash-bed");
debris indicates amygdaloid, probably
scoriaceous.

30 *Covered*.

(15)

78. **Amygdaloidal Melaphyr;** poorly exposed; like No. 76, followed by a

70 **Melaphyr;** very fine grained; blackish green;
(35) elastic.

125 *Covered;* the first sandstone south of the "Ash-
(64) bed" at Copper Falls may pass here.

82. **Amygdaloidal Melaphyr,** and **Melaphyr;** latter
predominating near the base; very fine-
grained; fracture quite smooth, inclined to
conchoidal; similar to the melaphyr of No. 65
("Ash-bed"), except the Purple element of the
color prevails, giving a dull purplish-brown
color. Occasional crystals of salmon-colored
50 feldspar occur, and few dark delessite spots.
(25) These, more particularly the delessite,
increase, but irregularly, toward the summit,
where calcite and quartz occur with it. This
amygdaloidal tendency is not regular; often
confined to irregular areas. Narrow zones of
amygdaloidal action, two to six inches wide,
accompany seams, cross the bed N.W. to
S.E. For 12 to 18 inches from the foot-wall
the bed is very amygdaloidal.

·5 **83.** **Sandstone;** 3-4 inches; irregularly banded; intimately associated with

84. **Amygdaloid;** 10 (5) feet; somewhat scoriaceous; resembling No. 45, but less developed; less developed toward the bottom; occurring in patches in underlying

100 **Melaphyr;** 90 (47) feet; very fine to compact;
(52) bluish green; similar to that of the "Ash-bed."
Near the foot-wall it is dull purplish, with red
feldspar crystals scattered porphyritically, and
spots of dark-green delessite, as in No. 82.

85. **Sandstone;** few inches, or wanting; shaly or laminated, wavy; associated with

32 **86.** **Amygdaloid;** 10 (5); scoriaceous; matrix brown,
(16) compact; amygdules mostly calcite, some
prehnite and quartz, little copper.

Melaphyr; 21 (11); rather fine-grained; dirty dark-green color; uneven fracture; weathers into balls, and with a tendency to semi-columnar structure.

Junction; marked, occupied by thin seam, but very irregular.

87. **Amygdaloid;** 13 (7) feet; pretty well developed near the top; base fine-grained, reddish brown; sometimes indurated; porphyritic with minute flesh-red feldspar crystals; amygdules somewhat irregular; quartz, enclosed in delessite; with very little copper. Graduates into an

302 **Amygdaloidal Melaphyr;** 45 (23) feet;
(154) composed largely of small flesh-red crystals of
feldspar (triclinic) in a rather coarse base of
smaller gray-green feldspar crystals and
delessite, the latter being also collected into
numerous prominent green spots. By the
omission of the flesh-red feldspar, or by its
change of color to light green, and by the
more even distribution of the delessite,
together with a more compact aggregation of
the mass, this gradually changes to

Melaphyr; 244 (124); spotted. Like No. 68, but of somewhat more exaggerated form.

192 *Covered;* in part probably occupied by an
(97) amygdaloid.

172 **90.** **Melaphyr;** 172 (87) feet; exceptional; semi-
(87) columnar in structure; a very fine-grained,
inclining to crystalline, rock; brittle, elastic,
rather hard; fracture uneven to sub-
conchoidal, and rather smooth; clear uniform
bluish-black color, with faintly purple element.
Considerable magnetic iron. Specific gravity,
2.89. Weathers smooth; drab color.

5646 **91.** **Diorite,** *aphanitic;* very fine-grained, changing
--=-- to sub-crystalline; rather brittle, but very tough;
(2927) fracture uneven, quite rough; color greenish
black, but showing through the transparent
feldspar; component gives a dirty brownish
tint, inclined to resinous. Near top of bed
hardly distinguish able from some melaphyrs;
except the tendency to a resinous hue, and
lack of any columnar character, it is much like
melaphyr 69. In descending through the bed,
the resinous character at first increases,
187 occasional crystals of glassy feldspar
(94) occurring; fracture irregular to hackly, and
specific gravity increasing. Near the bottom it
again grows finer, becoming quite compactly
crystalline, the resinous and brown
appearance disappearing, and a clear green
color with purple mottling taking its place;
purplish spots rather large, and reflecting light.
The green is not the dead, nor shiny delessite
green in melaphyrs. Near the bottom the rock
is like the mottled crystalline "greenstone"
near the base of the diorite series. Specific
gravity near the top 2.89, near middle 3.01,
near bottom 2.95.

92. **Diorite;** *dark type;* a fine-grained, glistening,
crystalline aggregate of black or greenish-
black hornblende, and brownish or greenish
transparent feldspar, the shining of the former
through the fractured edges of the latter,
giving a dark dirty-brownish color, and
resinous lustre to the rock. Considerable dark
green chlorite (delessite ?) is present, and
25 some magnetite; tough; fracture irregular and
(13) rough; specific gravity 2.89. The bed contains
irregular patches or segregations of coarser
material, in which the feldspar is white,
opaque, its crystals forming an irregular
network on a black background of hornblende;
latter often of high lustre, and accompanied
by, seemingly changed into, a soft dark green
chloritic mineral (delessite ?). In these
prehnite and a radiated bronze-colored mica
are present.

93? **Diorite;** *dark type;* same as preceding, but
25 coarser. Feldspar sometimes in larger
(13) crystals, or nearly square plates; cleaving,
transparent, glassy, or resinous; melts before

blowpipe only in fine splinters. Weathers in large flattish knobs, which are sprinkled with small protruding shiny black crystals of hornblende, all of which upon the same prominence generally catch and reflect the light at the same incident angle, as from a large but irregularly interrupted cleavage face; color of depressions rusty brown; of prominences, whiter.

96 (48) **94.** **Diorite;** *light-colored type;* inclining to coarse melaphyr; a coarse, crystalline, irregular-textured bed, containing numerous segregations of coarser material composed of prehnite with feldspar, or of green indurated spots of quartz and epidote (?). The bed is composed mostly of white, inclined to red, generally elongated, crystals of feldspar, lustrous hornblende, and a soft dark-green chlorite, probably delessite, which often predominates over the hornblende and is apparently derived from it; loosely textured. In places it strongly resembles the melaphyr of bed No. 87 or No. 68. For several feet near the base (absent near station D_1) the feldspar is red, sometimes pearly, and occurs in long intersecting crystals, often over an inch long, and twinned. Sometimes the surface, and near the composition plane of twins, will be red, and the interior pearly. This feldspar here forms about 40 per cent. of the rock, more than half the remainder being chlorite; specific gravity about 2.94.

40 (20) **95.** **Diorite** (observed at station D_1, absent at D_2); dark type; much like Nos. 92 and 93. Dark colored, resinous; hard, tough; fracture uneven, medium fine-grained, but compactly textured; some chlorite present. Weathers rather evenly and not rugose; rusty brown with protruding hornblende crystals.

72 (36) **96.** **Diorite** (directly beneath No. 94 at station D_2); light-colored type, typical. A rather coarse-grained, but compactly textured, crystalline aggregate of white and greenish-white, opaque, triclinic feldspar, and black, often lustrous, hornblende, with occasionally a little chlorite. Color greenish gray, but the whiter and more opaque feldspar is more or less confined to certain spots, thus giving a large and handsome mottling of grayish white on a greener ground. The hornblende crystals in many of these lighter colored spots, reflect light at the same incident angle. Hard, tough, somewhat brittle; specific gravity 2.90. Weathers rather evenly, color rusty gray, mottled white, with projecting crystals of black hornblende, which are more prominent on the lighter spots.

60 (30) **97.** **Diorite;** much like No. 92. Some chlorite and bronze mica present.

15 (8) **98.** **Diorite;** similar to No. 96, somewhat darker colored, with mottling very indistinct.

90 (45) *Covered.*

170 (85) **99.** **Diorite;** *light type*, much like No. 96; rather fine-grained, color dark greenish-gray, not mottled; feldspar mostly greenish, hornblende not generally lustrous, considerable chlorite; fracture neither very rough nor uneven. Weathers even rusty brown, generally without projecting hornblende crystals. Has frequent hard, compact, indurated, green segregations. Thirty feet covered.

114 (57) **100.** **Diorite;** *dark resinous type*, like No. 92 or 93, or No. 106. Quite resinous. Weathers in large but flat prominences, like No. 93.

25 (13) **101.** **Diorite;** *lighter type*, much like No. 99, somewhat coarser.

168 (84) **102.** **Diorite;** *dark type,* same as No. 100.

53 (26) **103.** **Diorite;** *lighter type,* similar to No. 96, but not mottled, and with a somewhat closer structure; chlorite very subordinate.

125 (62) **104.** **Diorite;** *dark type*, much like No. 100, but less brown and resinous. Much amorphous, and rather hard chlorite is associated with the hornblende. Specific gravity, 2.91. Weathers like No. 100.

± 50 (25) **105.** **Diorite;** *lighter type*, mostly covered; unusually coarse-grained; feldspar white, opaque; hornblende, in part hard, with highly lustrous jet-like cleavage faces, but mostly dull and softer, with some changed into soft amorphous, chlorite; bands of dark diorite also occur. Weathers very roughly, with protruding snow-white decomposing crystals of feldspar; also smoothly, with little hollows, each with hornblende segregation at bottom. Bed much like No. 107.

138 (69) **106.** **Diorite;** *dark type*, with but little chlorite; rather coarse; color very dark, but not very resinous; frequent larger crystals of transparent feldspar; excellent example of the dark type. On the more exposed points this rock weathers in a very exaggerated rugose manner; the depressed portions are rusty brown and comparatively smooth, the numerous rough projecting knobs, often an inch high, and rising quite abruptly and irregularly, are lighter colored, and dotted black with projecting crystals of hornblende, nearly all upon each projection reflecting the light simultaneously. Coarse crystalline segregations, containing larger crystals of white opaque feldspar, are quite numerous.

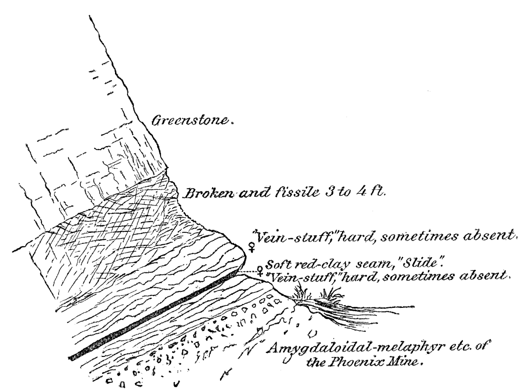
— 7140 — *Junction*, a well-marked plane of separation.

= **107.** **Diorite;** *white* and *dark types*. This bed is composed of both types of diorites in alternate strata of from 5 or 6 inches to 5 or 6 feet in thickness, separated by rather abrupt, but neither sharp nor free, planes of demarcation. The wider and predominant beds of the white type are of an unusually coarse granular character; feldspar white or slightly greenish; hornblende mostly highly lustrous, and some chlorite; specific gravity of the rock 3.03, of the

hornblende 3.39, of the feldspar 2.73. In places, nearly all the hornblende is changed to a dark-green chlorite—delessite— when, if the feldspar crystals arc small, the rock resembles a coarse melaphyr; and if, as at one point, delessite occupies, at the same time, spots formerly occupied by larger hornblende crystals, it may appear like an amygdaloidal melaphyr, as the upper part of melaphyr No. 87, for instance. Again, some of the white bands tend toward a gneissoid structure, the flattish feldspar crystals being arranged approximately parallel with the
83 (41) bedding. In this case the feldspar and hornblende are most compactly gathered together, the former being greenish and forming 54 per cent, of the rock, the latter highly lustrous and forming 46 per cent, of the rock, chlorite being absent; fracture thin, rather smooth; specific gravity 3.02. In this gneissoid-like rock the hornblende is gathered, together in frequent black spots, 4 inches or more in diameter. In weathering, each of these segregations forms a little pit, the rest of the sin-face being even; color, white, speckled black, the feldspar crystals protruding slightly.

The dark type bands are the narrower, being generally .5 to 2 or 3 feet thick; being softer than the whiter bands, they weather in, with smooth, rusty-brown surface. Rather fine-grained, tough; fracture rough; color, dark blackish, resinous. The lower stratum is of the white type, but finer grained than those above, and like No. 96, but not strongly mottled.

108. **Diorite;** *dark type;* coarse, changing to aphanitic ("greenstone"). At, and for a hundred feet from the summit this bed is, for the dark type, quite coarse-grained; color very dark greenish black, inclined to resinous; glistening highly from the large amount of transparent, resinous-hued, glassy feldspar, as well as from the hornblende ingredient, though most of the latter is not lustrous; chlorite is generally present. It is hard, and very brittle, though tough, a hard, quick blow shivering the rock with an uneven and rough fracture. Larger crystals of light resinous-
825 (412) W. of Robbins Lode. hued glassy feldspar quite frequently occur, but they often contain the other ingredients of the rock scattered in them, and often make themselves known only by reflecting light from areas which seem at first to be composed of an ordinary mixture of the ingredients. The hornblende also exhibits this character somewhat, but much less than the feldspar, possibly as not having highly lustrous faces. It is well brought out on the weathered surface, however. This surface weathers in large, flattish, rounded knobs; the depressions being smooth and rusty brown, the knobs lighter colored, with numerous small, projecting, black hornblende crystals. These, often over a space of nearly two inches square, all catch and reflect the light simultaneously. In descending through the remainder of the bed, the rock, with some local reversions, gradually grows finer-grained, though more particularly does it gradually become more crystalline in its texture, and very compactly built, while the feldspar seems to increase in amount, in places apparently impregnating the rock and almost producing a crysto-crystalline structure. The change in fineness is reached in the lower 200 feet. The fracture has become much more even and smoother, the rock is remarkably elastic and brittle, while the black resinous color has gradually changed to a clear, handsome dark green, sometimes vaguely mottled with an indefinite purple, from which mottling a more glistening sheen may reflect than from the adjacent rock. Specific gravity of the homogeneous aphanite 2.95. The weathering also changes; in the middle parts being smoother and whiter but less regular than at the top; the hard, white, irregular feldspar segregations standing slightly out, the small hornblende crystals being slightly sunk and mostly noticeable by reflection. In the more crystalline variety, near the bottom, the weathering is uniform again, having the surface covered with numerous small characteristic knobs, often silver gray in color, composed of grains of glassy feldspar, from which, as at the top of the bed, light reflects from hornblende crystals, but here the latter are very minute, and each is sunk slightly below the surface. The presence of these shows the dioritic character of the aphanite, and that it has not become a melaphyr. For 20 feet above the foot-wall most of the eminently crystalline character is lost, the rock becomes fine-grained to compact, of a duller green color, and resembling some fine compactly textured melaphyrs; specific gravity 2.92. The lower 3 or 4 feet of the "greenstone" is broken up and fissile.



— 8090 — ± (4120) At the Phœnix mine. **The Slide;** a soft red clay seam, one to four inches thick, the equivalent of the Allouez conglomerate. Above and below it may occur several inches of hard vein-like material, red and green, with quartz, calcite, prehnite, and epidote, with some copper pretty generally scattered through it, and sometimes being present in nearly workable quantities. The Waterbury mine was worked upon the slide, but without success.

The following section is from the *Phœnix mine;*

thicknesses of beds approximate.

In the **Shallow Adit.**

109. **Amygdaloid,** narrow and indefinite, and **Amygdaloidal Melaphyr;** character obscured, apparently by the adjacent "slide" and vein. It contains much calcite, often in small veins; and scattering amygdules of delessite, prehnite, and calcite in a base similar to the underlying **Melaphyr;** rather coarse-grained, not closely textured; very irregular fracture. Composed of small but elongated crystals of reddish-white or pale-green feldspar, and very dark-green, shining delessite, which is often aggregated into mottling spots, and sometimes colored red at numerous points, probably from changing magnetic or specular iron, considerable of
85 both being present in parts of the bed. It is
(42) coarsest at a point near the middle of the bed
; whitish and dark green, spotted dark brown, with numerous incipient dark-green, delessite amygdules; colors marked. Specific gravity 2.87. Above, it is somewhat finer and greener, and at one point below nearly all of the delessite seems changed to a quite bright red, probably from change of iron minerals, no magnetite being there present. Near the foot-wall it again assumes its normal composition. Sixteen feet south of the "slide" is a narrow vein strike, with formation dip 45° S., lined with calcite in flat fundamental rhombic crystals on which rest small, pyramidal crystals of apophyllite terminated with the basal plane.

48 **110.** **Amygdaloid,** inclined to *Amygdaloidal*
(24) *Melaphyr;* matrix much as above; color brownish red ; composed of small but elongated (often twinned) dirty white to transparent greenish feldspar crystals, in a reddish-brown, mottled green base; contains scattered amygdules of calcite and decomposing prehnite enclosed in delessite; graduates into **Melaphyr;** like 109, but finer, and with less magnetic iron.

111. **Amygdaloid,** inclined to *Amygdaloidal Melaphyr;* narrow, like no, but finer; changing to **Melaphyr** like **110,** but finer and more compact.

Section in **Sixty Fathom Level,** *Phœnix Mine*, commencing at north end and probably just above the last-described bed, or No. 111. The prehnite occurs in the amygdules like the calcite, often with calcite, en closed in delessite, and is generally changed to a soft, amorphous, kaolin-like material. In larger
165 amygdules, decomposition has often attacked
(82) the outside and inside, leaving unchanged
prehnite between. The process of "winding," as the miners call it, goes on very rapidly in this part of the mine. The white decomposed prehnite does not effervesce with acids, and hardly diners, before the blowpipe, from prehnite. Matrix, as above, medium fine-grained; colors marked; purplish-brown, mottled green; texture not close.

Melaphyr; colors same, mottling fine. Near the centre of the bed is a coarse zone; feldspar in a network of whitish, elongated, often twinned crystals in a red and green base; green delessite also in frequent spots; considerable specular, some magnetic, iron; grows finer, harder, and more compactly textured in descending, becoming darker colored, green, indefinitely mottled indistinct purple. At 23 and 42 feet respectively from the foot-wall is a nearly vertical seam of laumontite.

112. **Amygdaloid;** quite well developed; base compact; reddish brown; amygdules irregular; near the top often united, and for a few inches below tending to form, here and there, zones of increased amygdaloidal action parallel with
62 the bedding. While irregular amygdules often
(31) have their longer axes perpendicular to the
plane of bedding, more often they are parallel with it. They contain prehnite, sometimes enclosing calcite; former often decomposed; in places, much copper occurs. Changes rather abruptly to

Amygdaloidal Melaphyr; 20 (10) feet; base fine; reddish-brown, some green; amygdules delessite, rather numerous; shades insensibly into **Melaphyr;** growing darker and more uniformly colored, being finely mottled red and green at the base, where it is fine, quite dense, and somewhat brittle and elastic.

113. **Amygdaloid;** 4 (2) feet; like No. 112, but not so
48 well developed, and with but little copper.
Changes rather abruptly into

(24) **Amygdaloidal-melaphyr,** and **Melaphyr,** like 112, but rather darker and greener. At 26 feet north of foot-wall is a vein of laumontite 2 inches wide, approximate strike S.E., dip 75° S.W.

114. **Amygdaloid;** 8 (4) feet; inclined to amygdaloidal melaphyr; matrix fine, reddish or purplish; amygdules mostly delessite, but near base mostly radiated laumontite, enclosed in delessite.

30 **Melaphyr;** fine grained, compactly textured;
(15) color dark, dull purple, finely mottled darker
green; becoming more compact toward base. Thin laumontite seam, with narrow accompanying amygdaloidal action, 10 feet from hanging wall.

18 **115.** **Amygdaloid,** nearly *Amygdaloidal Melaphyr*,
(9) narrow with **Melaphyr** below, same as 114.

24 **116.** **Amygdaloid;** 4 (2) feet; better developed than
(12) last; base fine-grained to compact; brown red;
amygdules, mostly calcite in delessite, some prehnite. **Melaphyr** below, like 114.

117. **Amygdaloid;** 8 (4) feet; inclining to amygdaloidal melaphyr, and not well defined; base fine, red brown; amygdules mostly
57 delessite; some radiated laumontite. Below is
(28) a **Melaphyr,** like that of No. 114, having at 34
and 13 feet, respectively, from the foot-wall, a tendency toward an amygdaloidal character.

118. **Amygdaloid;** 12 (6) feet; base compact, brown
red; amygdules of calcite, with delessite
exterior; irregular, inclined to large size and
scattering. **Amygdaloidal Melaphyr;** 8 (4)
40 feet; rather hard, fine, compactly textured;
(20) delessite spots in a dark purplish background.
Melaphyr; much like No. 114; but more
compactly textured, and the purplish ground
being sometimes inclined to a hard metallic
appearance.

119. **Amygdaloid;** 8 (4) feet; not as well developed
as preceding; base greener; amygdules of
calcite and delessite above, of laumontite and
delessite below, changing into

115 **Melaphyr;** like 114; rather hard, brittle, elastic;
(57) fine-grained, close-textured; color of brown
and dark and lighter green particles, with
green delessite spots. More uniform colored
at base, compact, with conchoidal fracture; no
magnetite. Ten feet from foot-wall is a seam;
strike little east of north; clips 75° or 80° to
west; laumontite and chlorite, accompanied by
change of melaphyr to amygdaloidal
melaphyr; amygdules of delessite and some
calcite.

120. **Amygdaloid;** 4 (2) feet; base compact, earthy
looking, but not soft; color reddish or
chocolate; amygdules calcite, prehnite, some
quartz; changes to hard **Amygdaloidal**
36 **Melaphyr;** almost melaphyr, like No. 119. At
(18) 28 feet from hanging-wall is an amygdaloidal
melaphyr zone, better developed than that
below the amygdaloid, which changes to a
Melaphyr like those adjacent; fine, hard,
brittle, rather dark colored.

121. **Amygdaloid;** 8 (4) feet; base very fine; color
dull red brown; amygdules of prehnite, and
with little copper; changing through
Amygdaloidal Melaphyr; 6 (3) feet; to
Melaphyr, a wide bed; near the top inclines to
brown-red color; near the middle it is a fine-
grained and closely textured rock, with
conchoidal fracture. The color is a clear
shade of dark green, mottled purple, the dark
206 purplish areas being larger than usual, though
(103) with indefinite boundaries, about .3 inch
diameter. A spot often reflects light from all its
parts at the same incident angle, causing the
rock in this particular, as well as in other
characters, to strongly resemble the similar
modification which often occurs in the
aphanitic diorite, or greenstone. It contains
but little magnetite, and its specific gravity is
less. Near the foot-wall the color is a nearly
uniform shade of purplish brown. "*Crocker
Shaft*" is about 120 feet north of foot-wall.

122. **Amygdaloid;** 5 (2.5) feet; not well defined;
prehnitic; followed by **Amygdaloidal
Melaphyr;** brown, fine; large, scattering;
delessite amygdules, sometimes containing
laumontite, or prehnite, or calcite, or all;
sometimes in a granular mixture; extends to
south end of sixty-fathom level, or 56 feet.

320 In **twenty fathom** level, “Bay State," a wide
(160) melaphyr, supposed to be 121, has a foot-wall
at about 223 feet south of "Taylor Shaft."
Below is 122. **Armygdaloid;** not well defined,
with wide, chocolate-colored **Amygdaloidal
Melaphyr** below, followed by a wide
Melaphyr, like 121; color generally redder.

123. **Amygdaloid;** like preceding, followed by
Melaphyr; hard, fine-grained, purplish green,
dark, containing but little magnetite; extends
18 feet, reaching southern end of 20 fathom
level.

ATLAS PLATES
REFERRED TO IN PART II

14. Map of Portage Lake (west half).

14a. Map of Portage Lake (east half).

15. Cross-sections near Portage Lake, South Shore, I.

16. “ “ “ II.

17. “ “ “ III.

18. “ “ North Shore.

19. Grouped Sections in Houghton and Keweenaw Counties.

20. Map of Eagle River District.

21. Cross-sections in Eagle River District, I.

22. “ “ “ II.

23. Cross-sections in the Central Mine.