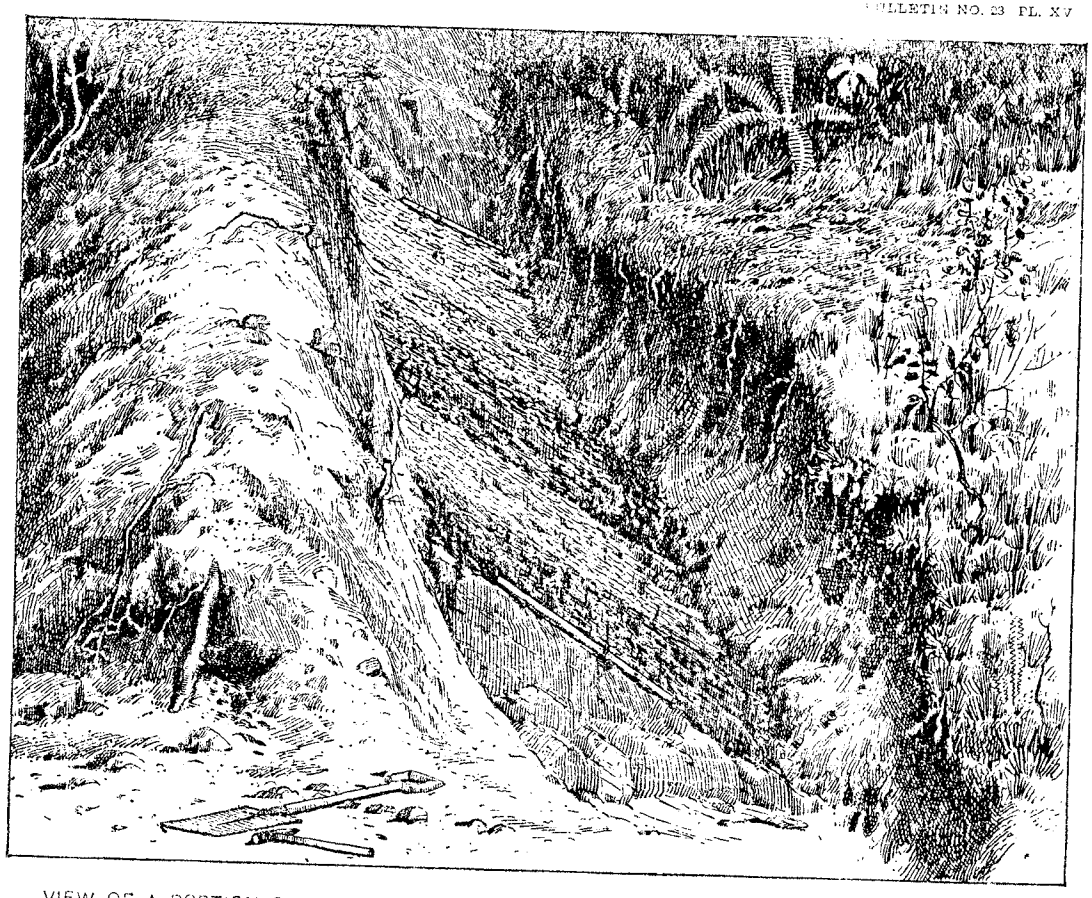


VIEW OF A PORTION OF TRENCH AT THE JUNCTION OF THE EASTERN SANDSTONE AND THE KEWEENAW SERIES ON HUNGARIAN RIVER.

the fine matrices of the basic and acid eruptives of the Keweenaw Series, to which source we are also inclined to refer the feldspar fragments. In some sections a silicious induration of the usual kind is seen to affect the rock. In other more friable kinds this is absent, and the only cementing material is a mingling of oxide of iron and clayey matter. In none of this sandstone were any pebbles seen. We appear here to be quite above the pebble-bearing horizon. A view of this sandstone cliff, drawn from a photograph, is given in Plate XVII.

As the sandstone cliff is followed up-stream toward the junction with the trap it becomes more interrupted, and finally only detached exposures of the sandstone present themselves. These, however, are seen on close examination to retain still the essentially horizontal posi-

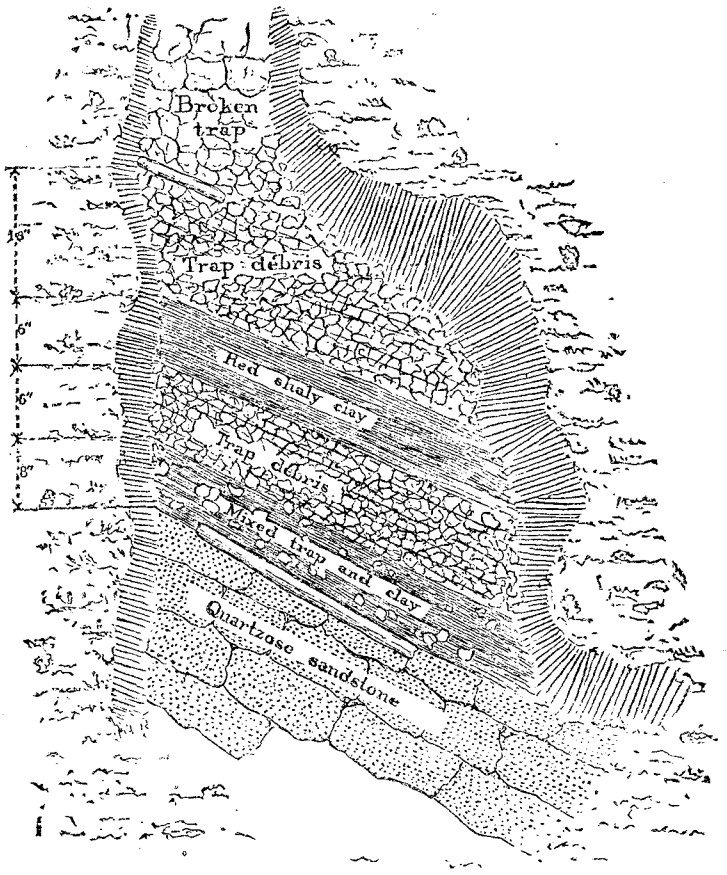


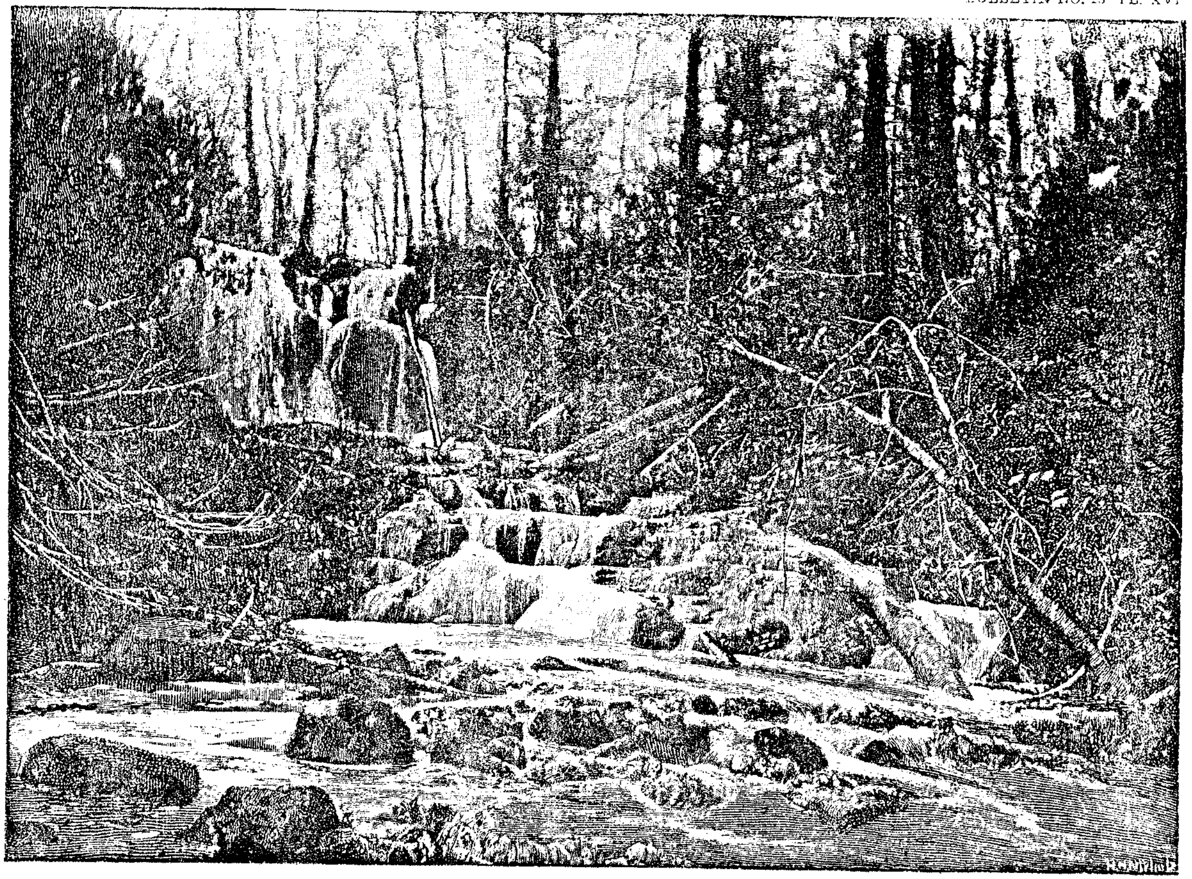
FIG. 10.—Section exposed in trench on Hungarian River, Keweenaw Point.

tion. The last one of these exposures (B of Figure 1, Plate XIV) is within a distance, measured horizontally along the bank, of fifteen feet from the first naturally exposed crumbling mass of trap. In the intervening

space, then, supposing the trappean masses mentioned to be essentially in place, as we subsequently satisfied ourselves that they are, must lie the junction between the two formations. Here our miners were set to work and three trenches were dug, as shown on Figures 1 and 2 of Plate XIV. The trench farthest up the stream (No. 1) was dug about twenty feet down-stream from an eight-foot fall over trap and amygdaloid. It started at a point two-thirds the way up the bank and extended down the slope to within about two feet of the level of the stream. Plate XV is from a photographic view of the lower part of this trench, and Figure 10 shows the relative positions of the various materials uncovered by this part of the trench. Starting from the top of the trench, *i. e.*, some feet above that portion shown in Plate XV, the following is the section laid bare:

	Ft.	in.
1. *Broken trap*, essentially in place	10	0
2. *Trap débris:* This follows the other without any definite demarkation or discernible amygdaloid. It seemed to be formed of disintegrated trap rubbed into a lumpy clay and roughly laminated. It inclines northwesterly at an angle of about 35°, and shows in that portion of the trench immediately below the uppermost of the two poles seen in the photograph of Plate XV	1	6
3. *Red shaly clay:* This is a fine-textured clay, much resembling what is known as joint clay. It is marked with light grayish-green spots, and has some sandy seams, with occasional lumps of trap. It is only in these latter particulars that it differs from a true joint clay		6
4. *Trap débris*, similar to that above described, except that it is more mingled with non-trappean (shaly) material. It is dark colored and so contrasts with the adjoining red clay		6
5. *Mixed shaly trap debris and red clay*, with a minor element of sand; the whole of a reddish cast		8
6. *Light reddish tinted quartzose sandstone*, exposed about	2	0

The sandstone at the bottom of the trench is of the usual quartzose Eastern type, with all of the characters that we have several times noted as belonging to the sandstones of the true Eastern Series; *i. e.*, is composed, as seen in the thin section, chiefly of quartz fragments, mingled with a minor quantity of feldspar fragments and débris of the matrices of basic and acid Keweenawan eruptives, the latter occurring only sparsely scattered through a section. There is also present a small amount of interstitial oxide of iron. This sandstone is not notably hard; indeed, on its face, it is quite friable. In its body it has about the medium hardness of the ordinary Paleozoic unaltered sandstones, being far less indurated than much of the Potsdam Sandstone of Central Wisconsin. There is no evidence of unusual induration either in the hand specimen or in the thin section. On the immediate face of this sandstone, at its junction with the trap débris above it, the structure planes—which may or may not be the deposition planes, so far as we were able to determine—correspond in the main to the oblique contact face. Away from this immediate face, however, planes, in this case more evidently those of deposition, seem to dip about 10° towards the stream, or northeastward.



UPPER FALLS OF HUNGARIAN RIVER, MICHIGAN
[From a photograph.]

In the bed of the stream, just opposite to the foot of the trench thus described, reddish sandstone is seen to cover a considerable area. The exposure C of Figure 1, Plate XIV, is partly covered by stream-drifted bowlders and pebbles, but enough of it shows to enable one to see that it lies in a nearly horizontal position. Quarrying it out, it is found to split easily along surfaces inclining perhaps 4° or 5° or less towards the axis of the stream, or down stream; *i. e.*, southeast. The flat-lying sandstone extends also to the northeast bank of the stream where (D of Figure 1, Plate XIV) it may be seen very plainly dipping eastward, at an angle of 10°. This flat sandstone, while reddish, is of the usual quartzose character, and we should say that it was unmistakably in place. At the point E, however, between this sandstone and the foot of the lower fall, on the north edge of the stream, there are little patches of a reddish sandstone of a wholly different character. This latter sandstone, which is only very doubtfully in place, is alluded to below.

In the second one of the three trenches, which lies eighteen feet southeastward of the first, as measured along the bank, we found essentially the same succession of materials as that above described to obtain in the first trench. The principal difference between the two trenches consists in their position with regard to the line of junction between sandstone and trap, the second trench covering less of the trap and extending farther into the sandstone. At the top of this trench there is broken trap as before. Below this comes dark-colored shaly trap débris about three feet in thickness, or less than in the first trench. At the base of this is about six inches of the fine-textured joint-like red clay, in which are embraced thin sheets of yellow quartzose sand. The rest of the trench displays light-colored reddish or yellowish quartzose sandstone, which, as before, is without notable induration. Next to the contact, as in the case of the other trench, this sandstone seems to dip with the plane of junction, but immediately below is seen to correspond in position with the adjacent main mass of sandstone; *i. e.*, lies within 10° of the horizontal, the inclination just here being towards the northeast.

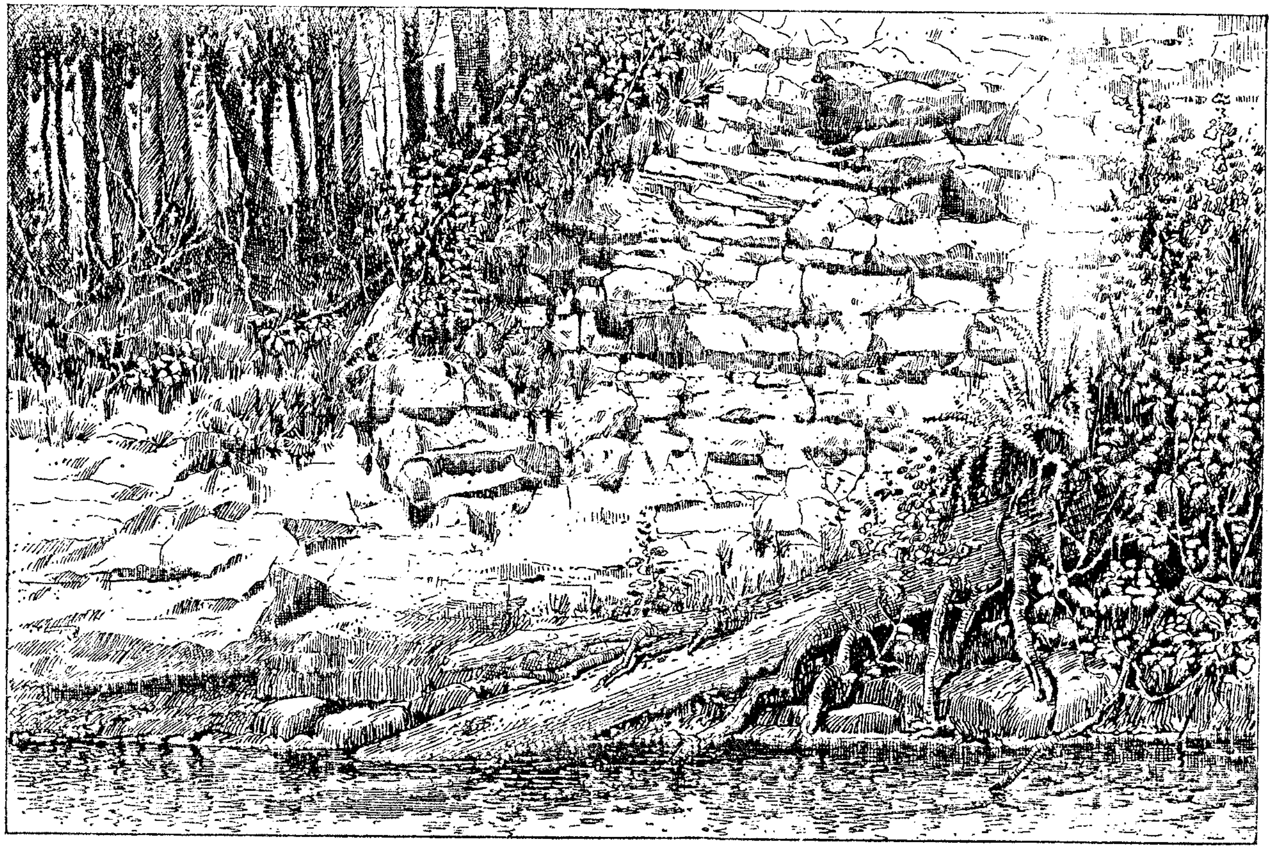
The third trench showed a part of the trap débris at top, but did not reach the trap proper, which may perhaps lie here concealed by the drift, or possibly does not extend so far. The red clayey layer was also seen here as before. The rest of the trench was here carried down nearly to the level of the stream, chiefly for the purpose of developing the structure of the sandstone. The results were entirely in accord with those obtained in the second trench.

Up-stream from the trenches to the second fall the exposures are altogether of diabase and diabase-amygdaloid. These rocks are finely exposed at the lower leap of the falls and show more or less satisfactorily on the sides and bottom of the stream above. The upper or principal leap is over a typical Keweenawan conglomerate, which rock also shows above the upper fall on the south bank of the stream. A few steps still further up-stream, on the same bank, another diabase belt

makes exposure. The relation of the two diabase layers with the porphyry-conglomerate are perfectly plain, the conglomerate being interleaved between the two diabases and the three layers dipping at an angle of between 25° and 30° to the NW. The conglomerate is of the typical Keweenawan kind, its pebbles being in the main composed as usual of some of the Keweenawan acid eruptives. A few basic pebbles may occur near the base of the layer, an occurrence which would be in accordance with what is occasionally true with the Keweenawan conglomerates in other places. On the ground, however, we failed to detect any fragments of this kind. Of twenty-four pebbles broken at random we identified twelve as quartz-porphyry and twelve as close-textured felsite. The whole appearance of this conglomerate is very strikingly in contrast with the "mud and shingle" conglomerates of the Eastern Sandstone.

A number of photographs were taken of the exposures and trenches on the Hungarian River, some of which are here reproduced, with the object of putting the actual conditions before the reader as fully as possible. Of these Plate XVI is a view of the two falls taken from a point at about the eastern edge of the sandstone area C, shown in the bed of the stream on Figure 1 of Plate XIV. The observer is facing in a direction between west and northwest. In the bed of the stream in the immediate foreground are bowlders lying upon flat sandstone (C of Figure 1, Plate XIV). The falls just above are over diabase, which continues to the second leap of the fall, which is over conglomerate. Trench number 1, above described, lies about five feet to the left of the left edge of the view. In the water to the right of the middle foreground, and immediately at the foot of the leaning dead tree, is the peculiar sandstone already mentioned as occurring at E of Figure 1, Plate XIV. Plates XV and XVII have already been explained.

In Figure 2 of Plate XIV the relations of the exposures thus described, as also the positions of our trenches, are indicated. These exposures, together with the information obtained in the trenches, seem to us plainly to indicate the following conditions: (1) A general horizontal position for the sandstone southeast of the junction with the traps, this horizontal position continuing in places to within five to ten feet of the junction and having subordinate to it sudden bowings and bendings in different directions. As the actual junction is approached the edges of the sandstone layers appear to be crushed down so as to lie, in a general way, parallel to the junction. At and near the junction there is no undue induration. (2) Lying immediately against this crushed sandstone and inclining northwestward at an angle of about 35°, a thin seam of mingled soft red clay and trappean fragments, the whole presenting the appearance of having been rubbed together, *i. e.*, of having been the result of faulting motion. (3) Lying over this seam of junction débris, a zone of shattered trappean material whose total thickness is



VIEW OF SANDSTONE CLIFF ON THE RIGHT BANK OF HUNGARIAN RIVER, NEAR JUNCTION WITH KEWEENAW SERIES.

[From a photograph.]

perhaps eight or ten feet; to this thickness, however, it is difficult to give any definite figure, since this zone grades into the débris below and into the less shattered trappean material above. (4) A succession of three layers, viz, diabase, porphyry-conglomerate, and diabase, of a wholly Keweenawan type, dipping northwestward at an angle of 30°, or something less than the inclination of the junction with the Eastern Sandstone.

These conditions seem to us to indicate a sliding motion of the Keweenawan rocks against and upon the sandstone, to which motion the inferior position of sandstone to trap and the broken edges of the sandstone at the immediate contact, as well as its general bowed condition, are to be attributed.

We have still to allude to the sandstone masses in the bed of the river, near the south bank, at the point E of Figure 1, Plate XIV. Here, at a point about twelve feet below the foot of the fall, projecting a few inches from the water, and from underneath the bank, is an irregular edge of a reddish sandstone of quite different appearance and character from the rest of the sandstone of the vicinity; for instance, that not more than ten feet away at C. It is a reddish, compact sandstone, much fissured, the fissures being filled by whitish seams apparently of carbonate of lime, which mineral also manifestly permeates the rock and gives it a very considerable degree of induration. Although we examined this place quite carefully, and on two different days, on one of which the water was considerably lower than indicated in the views herewith given, we were unable to convince ourselves as to whether this peculiar rock is *in situ* or is merely a drifted mass carried down by the stream from above, as have been the much larger and more numerous masses of porphyry-conglomerate which lie in the stream all about and upon the sandstone C. (See also Plate XVI.) This evidently was the view held by Mr. Chauvenet at the time of his examination. In the north bank, vertically above this peculiar rock, crumbling diabase masses, probably essentially *in situ*, occur. But we are unable to find trappean material nearer to this sandstone than several feet. A careful study of the specimens of this rock brought away showed the body of the rock to be of a brick-red color and nearly aphanitic texture, in which compact matrix are numerous small rounded fragments of a

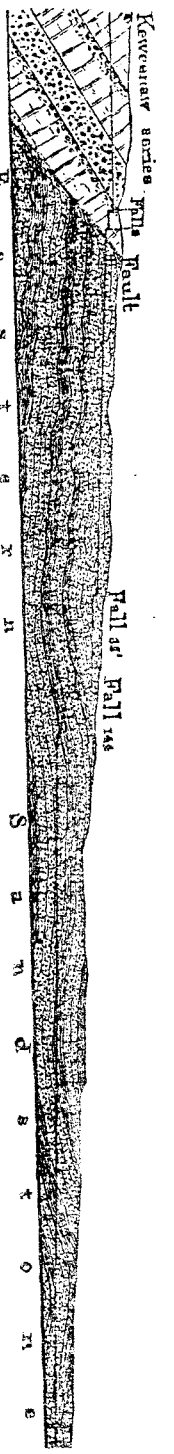


FIG. 11.—General section of the Hungarian Ravine, Keewenaw Point, Michigan. True scale, 700 feet to the inch.

dark-brownish to black color, the whole of the specimen being intersected by numerous white seams of dolomite. In the thin section the rock is seen to have the characters of one of the typical Keweenawan sandstones, *i. e.*, is made up in the main of felsitic débris, in larger or finer particles, mingled with which is some diabasic débris, a little quartz, a good deal of brownish ferrite, and some fine amorphous material. In addition to all of this, there is a large quantity of lime carbonate, which occurs both through the mass of the rock and in the intersecting seams in such a manner as to show that all was introduced at the same time. The lime carbonate in this case proved on analysis, contrary to expectation, to be very highly magnesian, and hence must be taken as dolomite rather than calcite. To it the induration of the rock is entirely due.

The complete difference between this rock and any of the rest of the sandstone of the vicinity, or indeed of the Eastern Sandstone formation anywhere in its entire extent, and its close similarity to the ordinary Keweenawan sandstones, leave us no choice but to regard it as either a drifted mass from the Keweenawan rocks farther west or as the projecting portion of a Keweenawan sandstone layer belonging next beneath the diabase of the lower leap of the falls. If the latter reference be correct, there is no difficulty at all in explaining the presence of a Keweenawan sandstone just here between the Eastern Sandstone and the diabase, which come together without any such intervening sandstone in the trenches on the south bank of the stream. The junction between the two formations being an irregular one, and not exactly parallel to the bedding of the Keweenaw Series, this is quite what we might expect to occur. In the ideal section of Figure 3, Plate XIV, we have suggested the latter view with regard to this indurated sandstone. The induration, on this view, is to be regarded as due to the downward filtration of lime-bearing solutions form the overhanging trap. This is of course a not very uncommon occurrence in the Keweenaw Series at the contacts of sandstones with overlying traps, and is not, to our minds, the result of contact with a heated rock, but is a mere accident of position beneath a rock capable of yielding calcareous solutions. There is nothing in the induration of this rock, then, which deters us from regarding it as part of the Eastern Sandstone, since such calcitic indurations of the sandstone might easily occur on such a junction as we have here; it is the other characters of the rock that compel us to look upon it as Keweenawan.

We have next to compare the statements of previous observers with the results of our own observations as above given.

Mr. Wadsworth's principal points with regard to the occurrences on this ravine appear to be: (1) a northwestern dip to the sandstone, which, while occasionally giving place to reverse dips, in the main shows an increase from 10° at the mouth of the ravine to 21° at the

junction; (2) the passing then
the Keweenawan beds, this bei
sandstone vertically beneath tr
duration of the sandstone next
having been seen. An increasi
of the ravine to the junction i
servations. As we have shown
shows dips in different directions
nations are often seen, a general
marked in the immediate vicinit
of sandstone to trap in place at
to be a fact. Before these trend
ference only. But this inferio
prove to be a result of sliding
sandstone does not pass conform
sandstone mentioned by Wads
the junction flowed over the
doubtless the peculiar red lim
described as occurring, doubtf
Plate XIV. This sandstone
as certainly in place; Mr. Cha
we ourselves rather incline to
from any other Eastern Sand
where else, suffices to show th
next layer beneath the trap at
extraordinary indeed if a sa
quartzose should, by heat ar
of felsitic débris. The dolom
have already indicated, does
ing that it is due to contact w
well occur in the Eastern Sa
the relation of the two forma
between it and the Eastern S
indurated sandstone with tha
pend upon this very doubtful
absence of induration at this
well displayed, and there occu
sandstone.

Mr. Chauvenet's descripti
they go, essentially with ou
resulting from the somewhat
nations, and particularly fro
new information by excavati

Dr. Rominger's description
responds essentially with ou

junction; (2) the passing then of the sandstone conformably beneath the Keweenawan beds, this being proved (*a*) by the position of the sandstone vertically beneath trap at the junction and (*b*) by the induration of the sandstone next the junction, the exact junction not having been seen. An increasing northwestward dip from the mouth of the ravine to the junction is not in accordance with our own observations. As we have shown, the sandstone is often horizontal or shows dips in different directions. Moreover, while northwesterly inclinations are often seen, a general horizontal position is particularly well marked in the immediate vicinity of the junction. An inferior position of sandstone to trap in place at the junction our trenches demonstrated to be a fact. Before these trenches were dug it could have been an inference only. But this inferior position we think our observations prove to be a result of sliding motion, as they certainly prove that the sandstone does not pass conformably beneath the trap. The indurated sandstone mentioned by Wadsworth as proving that the first trap at the junction flowed over the Eastern Sandstone and indurated it is doubtless the peculiar red lime-saturated sandstone which we have described as occurring, doubtfully *in situ*, at the point E of Figure 1, Plate XIV. This sandstone Mr. Wadsworth evidently considered as certainly in place; Mr. Chauvenet thought not; but, if it is so, as we ourselves rather incline to think, its entire lithological distinctness from any other Eastern Sandstone of the immediate vicinity, or anywhere else, suffices to show that it is Keweenawan, and therefore the next layer beneath the trap at the falls just above. It would be very extraordinary indeed if a sandstone everywhere almost completely quartzose should, by heat and induration, change to one composed of felsitic débris. The dolomitic induration of this sandstone, as we have already indicated, does not present to us any reason for believing that it is due to contact with heated lava. This induration might well occur in the Eastern Sandstone at this junction, on our view of the relation of the two formations, and but for the manifest difference between it and the Eastern Sandstone generally, we should place this indurated sandstone with that formation. But we do not need to depend upon this very doubtful sandstone for proof as to the presence or absence of induration at this junction. In our trenches the junction is well displayed, and there occurs in them no such induration and no such sandstone.

Mr. Chauvenet's descriptions, it will be seen, correspond, as far as they go, essentially with our own, the only differences worth noting resulting from the somewhat more detailed character of our own examinations, and particularly from the fact that we obtained a good deal of new information by excavating.

Dr. Rominger's description is of a more general character, but corresponds essentially with our own.

THE CONTACT AT OTHER POINTS.

Quite a considerable number of streams in addition to those followed by us cross the line of junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point. Many of these make ravines of some size, and on several we know of the occurrence of sandstones, but none of them have been examined in any detail by ourselves or others. The exposures of Keweenawan rocks on the north side of Lac la Belle, and certain conglomeratic layers in the low ground near by, indicate plainly that we are here close to the contact. When one of us examined this place in 1880, the opportunities for study were not nearly so favorable as now. The clearings for the new stamp-mill of the Conglomerate Mining Company and the numerous cuttings for the new Lac la Belle and Calumet Railroad offer tempting opportunities for study, of which we were unfortunately unable to avail ourselves. Farther west, in the vicinity of Gratiot Lake, are points exposing sandstone near the contact, as we learn from brief references in the older reports, *e. g.*, at the falls of Tobacco River, Sec. 12, T. 57, R. 31, as stated in the report of Dr. C. T. Jackson (Sen. Docs., 31st Cong., 1st sess., Vol. III, pp. 510–511). There are also similar brief references to the close proximity of sandstone and trap in Sec. 15, T. 57, R. 31 W., and on the upper part of Torch River, southeast of the Allouez mine, in Jackson's report, but in no case is there anything of sufficient importance to be worth quoting in the present connection.

One very important occurrence of a contact between the Eastern Sandstone and the traps, however, has been figured and briefly referred to by Pumpelly as obtaining in the immediate vicinity of Houghton. The accompanying figure is copied from the southeastern end of "Cross

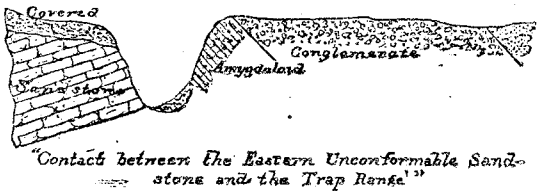


FIG. 12.—Reproduced from Atlas to the Geological Survey of Michigan. Scale, 90 feet to the inch.

Section I" of the Atlas of the Geological Survey of Michigan. The exact locality of this occurrence is on the Isle Royale Mining Company's property, in the southeast quarter of the northwest quarter, Sec. 6, T. 54, R. 33 W. With regard to this place we make also the following quotations from Dr. C. Rominger, confirming Pumpelly's observation:

C. Rominger. (Geological Survey of Michigan, Vol. I, Part III, p. 96, 1873.) "The inconformable abutment of the Lake Superior sandstones against the trappean series, is in several places near Houghton plainly to be observed. One place is on the property of the Isle Royale Company, in Town 54, Range west 33, Section 6, where the top

of a ravine is formed by mighty cong
nature, besides fragments of a shal
trap; they dip under a high angle to
line, on which the company, for the
ploring ditches at close distances, to
strata within this interval. Immedi
projecting conglomerate beds, the ho
much lighter color than the sandsto
abutting in the bed of the small cree

* * *

"A large patch of horizontal sands
top of the hills near Houghton, on th
bia property. I am not absolutely c
there as a huge drift mass or wheth
deposits which were there in their o
am inclined to the last opinion (p. 9

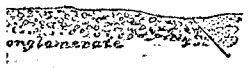
Contacts similar to that at Bê
to occur at several points on th
trap range in the vicinity of the
One of these was examined in
venet in 1880. Unfortunately
taining his quite detailed desc
extant. An abbreviated accou
was given by one of us in th
quoted, along with a reduced
venet's general section. The f
scription:

R. D. Irving. (Copper-Bearing Ro
Monographs United States Geologic
359–369, 1883.) "The above section
M. Chauvenet along the course of th
tions 23 and 24, T. 50, R. 39 W. The
the usual saccharoidal quartzose kind
and at times mingled and streaked w
ish material. It carries frequent p
but none of the Keweenawan diabase
One mile south, in section 27, the san
a horizontal attitude, and in the S.
in large exposures at the falls of
Here it dips southward at an angle
lowed northward some 200 yards this
20°. A short distance farther north
bluff of Keweenawan diabase. It sh
south dips are not wavering and u
served on the Douglass Houghton R
and pronounced, affecting many hu
while the exposures are to be liken
nation to those seen on Bête Grise B

The exact contact of the traj
were not seen by Mr. Chauve
feet of each other and he descr

OTHER POINTS.

eams in addition to those followed
en the Eastern Sandstone and the
t. Many of these make ravines of
the occurrence of sandstones, but
any detail by ourselves or others.
on the north side of Lac la Belle,
the low ground near by, indicate
contact. When one of us exam-
ties for study were not nearly so
the new stamp-mill of the Con-
numerous cuttings for the new
offer tempting opportunities for
tely unable to avail ourselves.
t Lake, are points exposing sand-
rom brief references in the older
iver, Sec. 12, T. 57, R. 31, as stated
Sen. Docs., 31st Cong., 1st sess.,
o similar brief references to the
) in Sec. 15, T. 57, R. 31 W., and
outheast of the Allouez mine, in
ere ...thing of sufficient impor-
nt ...ection.
a contact between the Eastern
been figured and briefly referred
mmediate vicinity of Houghton.
a the southeastern end of "Cross



n Unconformable Sand-
Trap Range'"

rvey of Michigan. Scale, 90 feet to the inch.

l Survey of Michigan. The exact
Isle Royale Mining Company's
he northwest quarter, Sec. 6, T.
ice we make also the following
irming Pumpelly's observation:

n, Vol. I, Part III, p. 96, 1873.) "The
andstones against the trappean series,
e observed. One place is on the prop-
Lange west 33, Section 6, where the top

of a ravine is formed by mighty conglomerate beds, inclosing pebbles of a porphyritic nature, besides fragments of a shaly, well stratified sandrock, and of amygdaloid trap; they dip under a high angle to the northwest, and form the terminal point of a line, on which the company, for the length of a mile, systematically had opened exploring ditches at close distances, to get accurate information of the succession of strata within this interval. Immediately against the faces of the westward inclined projecting conglomerate beds, the horizontal ledges of Lake Superior sandstone of much lighter color than the sandstones connected with the conglomerates are seen abutting in the bed of the small creek which runs through the ravine.

* * * * * * *

"A large patch of horizontal sandstones overlies unconformably the trap rocks on top of the hills near Houghton, on the Sheldon and Columbia property. I am not absolutely certain whether it came there as a huge drift mass or whether it is the remnant of deposits which were there in their original position, but I am inclined to the last opinion (p. 96).

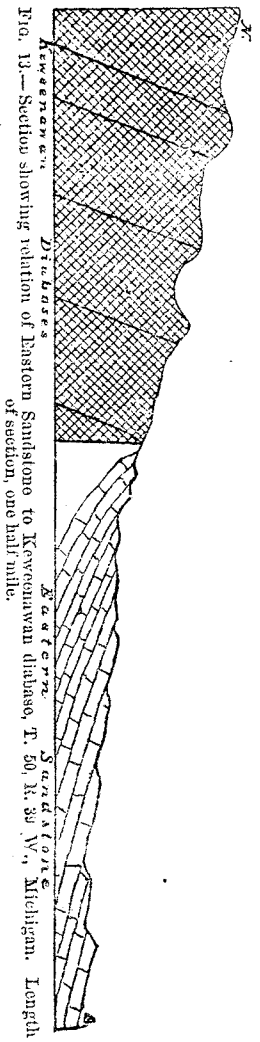


FIG. 13.—Section showing relation of Eastern Sandstone to Keweenawan diabase, T. 50, R. 39 W., Michigan. Length of section, one half mile.

Contacts similar to that at Bête Grise are known to occur at several points on the south edge of the trap range in the vicinity of the Ontonagon River. One of these was examined in detail by Mr. Chauvenet in 1880. Unfortunately the note-book containing his quite detailed description is no longer extant. An abbreviated account of this occurrence was given by one of us in the work heretofore quoted, along with a reduced copy of Mr. Chauvenet's general section. The following is this description:

R. D. Irving. (Copper-Bearing Rocks of Lake Superior, Monographs United States Geological Survey, Vol. V, pp. 359–360, 1883.) "The above section was taken by Mr. W. M. Chauvenet along the course of the small stream in Sections 23 and 24, T. 50, R. 39 W. The sandstone seen here is the usual saccharoidal quartzose kind, often perfectly white, and at times mingled and streaked with more or less brownish material. It carries frequent pebbles of white quartz, but none of the Keweenawan diabase against which it rests. One mile south, in section 27, the sandstone was observed in a horizontal attitude, and in the S.W. ¼, Sec. 28, was seen in large exposures at the falls of the Ontonagon River. Here it dips southward at an angle of 15°, but as it is followed northward some 200 yards this dip changes to 18° and 20°. A short distance farther north is a bold south-facing bluff of Keweenawan diabase. It should be said that these south dips are not wavering and uncertain, like those observed on the Douglass Houghton River, but are persistent and pronounced, affecting many hundred feet in thickness, while the exposures are to be likened in extent and inclination to those seen on Bête Grise Bay."

The exact contact of the trap and the sandstone were not seen by Mr. Chauvenet, but the two were found within a few feet of each other and he describes the whole occurrence as most marked

and unmistakable. It is to be noted that the Eastern Sandstone preserves here its usual quartzose character and that it is just here without included red shale or conglomerate.

In the same connection reference should be made to the very interesting and peculiar occurrences which have been described by Mr. E. T. Sweet as obtaining along the contact of the south-dipping traps and the "Western" horizontal sandstone in the northern part of Douglas County, Wisconsin, which two formations are the equivalents respectively of the north-dipping traps and "Eastern" horizontal sandstones of Keweenaw Point.[1] The similarity between the occurrences described by Mr. Sweet and those of the Douglass Houghton and other ravines on Keweenaw Point was noted by one of us some years since.[2] Our recent examinations have impressed this similarity upon us yet more strongly, and we can have little doubt that they are due to entirely similar and not improbably contemporaneous causes.

[1] Geology of Wisconsin, Vol. III, Part V, pp. 340-349; also Copper-bearing Rocks of Lake Superior, Monographs United States Geological Survey, Vol. V. pp. 252, 258.
[2] Ante, p. 56.

II.—DISCUSSION OF

In this part we give, in chronol
who have advocated them, the v
vanced with regard to the relatio
trappean series, with some comm
of these hypotheses we call after
proposed it. We then close with

THE JA

C. T. Jackson. (Senate documents,
Vol. III, pp. 398, 399.) "The red sand
point existed there anterior to the elev
the deposition of fine sand and pebbl
such as granite, gneiss, or mica slate.
debris, but it is doubtful whether it is
semifusion of the finer materials of san
of the pebbles of the conglomerate, th
shape by long attrition under water or
rounded, and are of various magnitu
man's head. They originated from so
present location by drift agencies—th
have been derived from, in place. If th
more recent drift, they would seem to i
the coal era—an opinion difficult to est
of that epoch.

"There is no reason to believe that
origin of the pebbles of the conglomer
been rounded by the action of water.
borders the trappean rocks it is supp
along that line, or that, during the up
the sandstone were indurated into ma
away the fine sand into deeper water
is certain that the finer sandstone is m
is, and that it is less uplifted and incli
and near the junction of the two rock
it the sandstone strata are horizontal
tainly deposited in water, for the ripp
in an absolute manner, for we at once
sand. By pressure and heat the mate
into solid sandstone, the layers of sa
whole must have been in horizontal o
deposits mechanical sediment in this
be on the shores, where a very moder
than we find it to be where the strata
caused the elevation of the sandstone

iat the Eastern Sandstone pre-
er and that it is just here with-

ıld be made to the very inter-
have been described by Mr. E.
of the south-dipping traps and
the northern part of Douglas
ns are the equivalents respect-
stern" horizontal sandstones of
een the occurrences described
is Houghton and other ravines
of us some years since.[2] Our
is similarity upon us yet more
iat they are due to entirely sim-
is causes.

340–349; also Copper-bearing Rocks
ological Survey, Vol. V. pp. 252, 258.

II.—DISCUSSION OF VIEWS; CONCLUSIONS.

In this part we give, in chronological order, and in the words of those who have advocated them, the various hypotheses that have been advanced with regard to the relations of the Eastern Sandstone and the trappean series, with some comments of our own in each case. Each of these hypotheses we call after the geologist who seems first to have proposed it. We then close with our own views upon this question.

THE JACKSON VIEW.

C. T. Jackson. (Senate documents, Thirty-first Congress, first session, 1849–'50, Vol. III, pp. 398, 399.) "The red sandstone and conglomerate rocks of Keweenaw point existed there anterior to the elevation of the trap rocks, and were produced by the deposition of fine sand and pebbles derived from pre-existent primary rocks—such as granite, gneiss, or mica slate. Porphyry furnished a large proportion of the debris, but it is doubtful whether it is not a metamorphic rock, resulting from the semifusion of the finer materials of sandstone. It is evident at once, from inspection of the pebbles of the conglomerate, that they have been ground into their present shape by long attrition under water or upon some ancient shore. They are oval and rounded, and are of various magnitudes, from that of a buckshot to the size of a man's head. They originated from some nether rock or were transported to their present location by drift agencies—this locality not exhibiting any rock they could have been derived from, in place. If they were transported bowlders, like those of the more recent drift, they would seem to indicate the existence of ice immediately after the coal era—an opinion difficult to establish, it being counter-indicated by the fossils of that epoch.

"There is no reason to believe that igneous agencies had anything to do with the origin of the pebbles of the conglomerate, for they bear ample proofs of their having been rounded by the action of water. From the circumstance that the conglomerate borders the trappean rocks it is supposed that an ancient shore may have existed along that line, or that, during the upheaval of the trap and before the materials of the sandstone were indurated into masses, the reflux of the water may have carried away the fine sand into deeper water and left the pebbles near the uprising trap. It is certain that the finer sandstone is more remote from the trap than the conglomerate is, and that it is less uplifted and inclined as it recedes from the trap band. Thus, at and near the junction of the two rocks, the strata dip 25° or 30°, while remote from it the sandstone strata are horizontal, or only slightly waved. Sandstone was certainly deposited in water, for the ripple marks are well preserved and record this fact in an absolute manner, for we at once recognize the well-known action of water on sand. By pressure and heat the materials of a loose shifting sand became converted into solid sandstone, the layers of sand forming the different strata. At first the whole must have been in horizontal or nearly horizontal layers; for water necessarily deposits mechanical sediment in this manner, and the only slopes of deposition would be on the shores, where a very moderate inclination would take place, but much less than we find it to be where the strata have been disturbed by the trap rocks which caused the elevation of the sandstone along the line of its disruption."

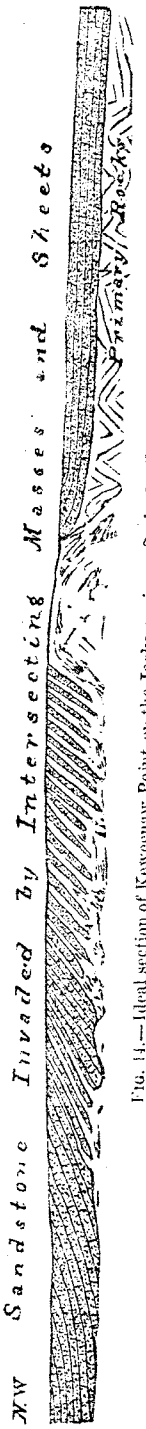


FIG. 14.—Ideal section of Keweenaw Point, on the Jackson view. Scale, 2 miles to the inch.

C. T. Jackson. (Final Report on the Geology, Topography, and Mineralogy of Lands around Lake Superior, Senate documents, Thirty-second Congress, first session, 1851, p. 328, Vol. XI, No. 112.) "At Lac la Belle and at Mt. Houghton the trap rocks occur, and ride over the sandstone strata after passing between their layers; and at Mt. Houghton the igneous agency of this trap rock has changed the fine sandstone into a kind of jasper.

As we understand them, Jackson's views were as indicated in the following summary: (1) The Eastern Sandstone and the conglomerates and sandstones of the copper-bearing series are one and the same formation, and were once spread out continuously in a horizontal position; (2) the traps of the copper-bearing series are all of them intrusive, having invaded the supposed sandstone formation in part as irregular intersecting masses and in part in the shape of sheets which forced their way between the sandstone layers; (3) the conglomerates of the copper-bearing series derived their material by the ordinary aqueous agencies from some subjacent formation, which possibly may have formed an old shore line in the immediate vicinity of Keweenaw Point. More probably, however, the pebbles of the conglomerate have been sorted out, as it were, from the previously existing sand beds by the violent currents set in motion at the time of the trappean intrusions; (4) the inclination *southeastward* in the Eastern Sandstone at the junction with the traps, and that to the *northwestward* of the sandstone and conglomerates of the copper-bearing series, are due to the intruding trap.

The contemporaneous or lava-flow origin of the traps of the copper-bearing series having been since so repeatedly and abundantly demonstrated, there is no reason that we should attempt any further refutation of Jackson's position as to their intrusive character. We can conceive of the Eastern Sandstone passing conformably beneath the copper series, or of its having once been continuous with the uppermost member of the series from which it is now faulted away; but the lava-flow origin of the trap being once admitted, it is sufficiently evident that on no possible structural hypothesis can the Eastern Sandstone and the Keweenawan sandstones and conglomerates be regarded as having once formed a continuous series. There are, of course, abundant other reasons why Jackson's hypotheses cannot be accepted, among which we need now only allude to the entire contrast between the Eastern Sandstone and the Keweenawan detrital rocks, both as to lithological characters and relative thicknesses.

In the accompanying diagram we have attempted to

illustrate—on a cross-section of Ke
and indicating the true widths of t
per bearing rocks—the views main
possible that we may in some respe
him.

THE FOSTER ANI

J. W. Foster and J. D. Whitney. (Repor
tion of the Lake Superior Land District
Thirty-first Congress, first session, 1849–5
ing to the head of Keweenaw Point, we fi
ern boundary of the valley of the Little
line nearly parallel with the northern ch
and differs from the northern both in li
occurrence. While the former, before
trap, in the main of the amygdaloid and
detrital rocks, the southern range consist
clinal axis, flanked on the north by the
south by conglomerate and sandstone.

"The contour of the unbedded trap is
trap. We nowhere recognize the stair-
dome-shaped or rounded.

"The protrusion of so vast a mass of
gree the associated sedimentary rocks,
Thus, on section 30, township 58, rang
phosed sandstone resembling jasper. Its
assumes a vesicular appearance, while ot
composition chlorite and feldspar. In s
can be recognized. The mass is about
bands of porphyry and a chlorite rock
as a volcanic ash. These veins attain
along the southern coast of Keweenaw
station (section 35) we again observe t
jutting points of the bay; but here it a
been subjected to a heat more intense a
tion have disappeared, and the rock
jasper, breaking with a conchoidal fra
planes. Where it comes in contact wi
texture. All traces of its mechanical
termine where the igneous rock ceases

* * *

"The following section, from Copper
contours of the country but the relat
bedded and unbedded trap:

"The Bohemian range, as before ren
ded trap and conglomerate on the nor
south. The conglomerate north of the
clination than 45°, but on the south
an angle of 78°. This is beautifully ex

[1] Probably a misprint for 26, sinc

eport on the Geology, Topography, and Min-
Lake Superior, Senate documents, Thirty-
on, 1851, p. 328, Vol. XI, No. 112.) "At Lac
ton the trap rocks occur, and ride over the
ng between their layers; and at Mt. Hough-
this trap rock has changed the fine sand-

them, Jackson's views were as in-
g summary: (1) The Eastern Sand-
nerates and sandstones of the cop-
one and the same formation, and
ntinuously in a horizontal position;
per-bearing series are all of them
led the supposed sandstone forma-
r intersecting masses and in part
hich forced their way between the
the conglomerates of the copper-
their material by the ordinary
some subjacent formation, which
ed an old shore line in the imme-
naw Point. More probably, how-
e conglomerate have been sorted
previously existing sand beds by
in motion at the time of the trap-
e incli ation *southeastward* in the
e ju n with the traps, and that
the sandstone and conglomerates
ies, are due to the intruding trap.
or lava-flow origin of the traps
ries having been since so repeat-
monstrated, there is no reason
ny further refutation of Jackson's
ive character. We can conceive
passing conformably beneath the
aving once been continuous with
f the series from which it is now
va-flow origin of the trap being
ciently evident that on no pos-
s can the Eastern Sandstone and
ones and conglomerates be re-
med a continuous series. There
ther reasons why Jackson's hy-
ted, among which we need now
contrast between the Eastern
nawan detrital rocks, both as to
relative thicknesses.
iagram we have attempted to

illustrate — on a cross-section of Keweenaw Point, drawn to a true scale, and indicating the true widths of the Eastern Sandstone and the copper bearing rocks — the views maintained by Jackson. It is, of course, possible that we may in some respects misunderstand and misrepresent him.

THE FOSTER AND WHITNEY VIEW.

J. W. Foster and J. D. Whitney. (Report on the Geology and Topography of a Portion of the Lake Superior Land District, Part I, Copper Lands. House Document, Thirty-first Congress, first session, 1849–'50, No. 69.) "*Southern trap range.* Returning to the head of Keweenaw Point, we find another range of trap, forming the southern boundary of the valley of the Little Montreal river and stretching westerly in a line nearly parallel with the northern chain. This is known as the Bohemian range, and differs from the northern both in lithological character and in the mode of its occurrence. While the former, before described, is composed of numerous beds of trap, in the main of the amygdaloid and granular varieties, interstratified with the detrital rocks, the southern range consists of a vast crystalline mass, forming an anticlinal axis, flanked on the north by the bedded trap and conglomerate and on the south by conglomerate and sandstone.

"The contour of the unbedded trap is also very different from that of the bedded trap. We nowhere recognize the stair-like structure in the hills; they are either dome-shaped or rounded.

"The protrusion of so vast a mass of heated matter has changed in a marked degree the associated sedimentary rocks, causing them to resemble igneous products. Thus, on section 30, township 58, range 27, by the lake shore, is seen a metamorphosed sandstone resembling jasper. Its general bearing is east and west. In places it assumes a vesicular appearance, while other portions are brecciated and take into their composition chlorite and feldspar. In some hard specimens the lines of stratification can be recognized. The mass is about 100 feet thick, and surmounted by alternating bands of porphyry and a chlorite rock known as rotten trap, which may be regarded as a volcanic ash. These veins attain a thickness of only a few feet. Proceeding along the southern coast of Keweenaw Point in a westerly direction, at the old fish station (section 35) we again observe this metamorphosed rock forming one of the jutting points of the bay; but here it assumes a different character, as though it had been subjected to a heat more intense and longer continued. All traces of stratification have disappeared, and the rock has become transformed into a red, compact jasper, breaking with a conchoidal fracture and traversed by numerous divisional planes. Where it comes in contact with the trap below it presents a homogeneous texture. All traces of its mechanical origin are obliterated, and it is difficult to determine where the igneous rock ceases and the aqueous begins (pp. 64–65).

* * * * * * *

"The following section, from Copper Harbor to Lac la Belle, exhibits not only the contours of the country but the relative association of the detrital rocks and the bedded and unbedded trap:

"The Bohemian range, as before remarked, forms the line of upheaval of the bedded trap and conglomerate on the north and the conglomerate and sandstone on the south. The conglomerate north of the axis of elevation rarely attains a greater inclination than 45°, but on the southern slope the sandstone is observed dipping at an angle of 78°. This is beautifully exhibited by the lake shore, on section 36,[1] town-

[1] Probably a misprint for 26, since there is no section 36 in this township.

ship 58, range 29. The sandstone is seen in the bottom of the bay, composed of alternating bands of white and red, sweeping round in curves, conformable to the course of the trappean rocks. As we recede a few miles to the south, the strata are observed

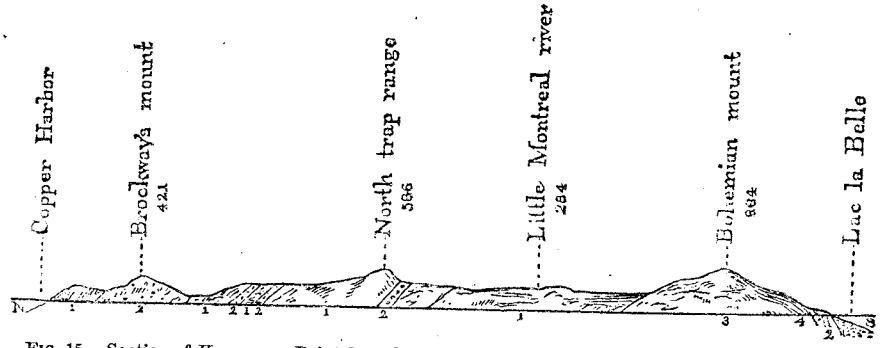


FIG. 15.—Section of Keweenaw Point from Copper Harbor to Lac la Belle. (Reproduced from Foster and Whitney.)

1. Brown granular trap, occasionally crystalline; 2. conglomerate; 3. Labrador and chlorite rock; 4. chlorite (fissile).

to be nearly horizontal. In the two adjoining townships west this range preserves its distinctive character, but beyond it sinks down into sloping hills 200 or 300 feet in height (p. 66).

* * * * * * *

"In the region of Portage lake, the shock by which the bedded trap and conglomerate were elevated, does not appear to have been attended with the protrusion of vast crystalline masses forming a long range, like the Bohemian mountains, or rounded groups, as in the vicinity of the Ontonagon, but simply to have caused a vertical dislocation, lifting up the beds on one side of the fissure while the corresponding beds on the opposite side remained comparatively undisturbed. There can be no doubt that there existed a deeply seated and powerful fissure extending from the head of Keweenaw Point to the western limits of the district, along the line of which the volcanic forces were, at different times, powerfully exerted—similar in character to those in Guatemala, Peru, and Java—the seats of modern volcanic action.

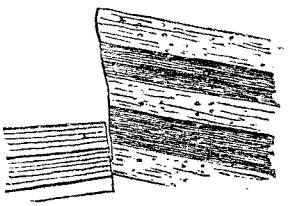


FIG. 16.—Junction of Eastern Sandstone and trappean series. (Reproduced from Foster and Whitney.)

"The only instance observed in this part of the district, of trap occurring remote from the line of the fissure is in the northeast corner of township 49, range 36, 14 miles southwest of the head of Keweenaw bay. It is known as Silver mountain, (*lucus a non lucendo,*) which rises up isolated and dome-shaped to the height of a thousand feet, and occupies an area equal to three sections (p. 68).

* * * * * * *

"*Sandstone.*—It is not our purpose in this sandstone, much less to describe its charact pre-existing rocks. These descriptions will paleozoic rocks of this district. We propo nexion with the cupriferous rocks before d may be better understood, we introduce the

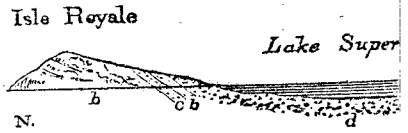


FIG. 17.—Section from Isle Royale to Keweenaw P
a a, crystalline trap; *b b*, bedded trap

"We have seen that, during the deposit trap were ejected and flowed like lava-stre products were so intermingled as to presen from a common origin; and that subsequent parallel fissures, lifting up the sandstones causing the whole mass to dip at high angl Superior is due to these two lines of upheav performs an immense curve, portions of wh formed by the surface of the water. The the outer reefs of Siskawit bay (pp. 109, 11

* * * *

"Passing over the trappean ranges we slope and bearing the same relation to the tion, that the intervening masses of conglo

J. W. Foster and J. D. Whitney. (In a p Superior, with a Description of the Phenom Proceedings American Association for the ing, 1851, pp. 22-38.) "In the vicinity of find the sandstone developed to a great th conglomerate; we find it becoming impre matter and intersected by numerous vein native copper and its ores; we find it in numerous alternations, which beds have s again covered by sedimentary material; v sandstone and bedded trap, lifted up at an proach the central igneous mass and from

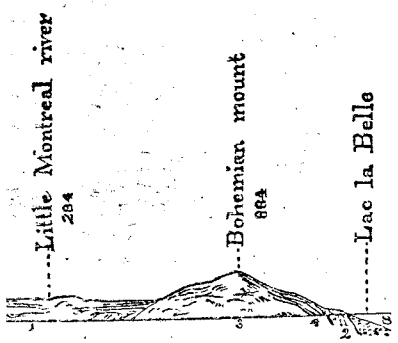
* * *

"Returning to the head of Keweenaw P the southern boundary of the valley of westerly in a line nearly parallel with th the other, both in its lithological charac the northern range, as before described, is main, of the amygdaloidal and granular rocks, the southern range consists of a va axis, and flanked, on the north, by the south by the sandstone and conglomerate

* * *

"The conglomerates of Keweenaw Poi bles and masses of trap, almost invaria probably, from contemporaneous lavas, which may have been a metamorphosed

bottom of the bay, composed of alter-
in curves, conformable to the course
s to the south, the strata are observed



oor to Lac la Belle. (Reproduced from Foster
r.)
onglomerate; 3. Labrador and chlorite rock;
ile).

; townships west this range preserves
down into sloping hills 200 or 300 feet

* * *

y wh[illegible]e bedded trap and conglom-
e been attended with the protrusion of
ge, like the Bohemian mountains, or
nagon, but simply to have caused a ver-
le of the fissure while the corresponding
atively undisturbed. There can be no
d powerful fissure extending from the
of the district, along the line of which
werfully exerted—similar in character
eats of modern volcanic action.

pean series. (Reproduced from Foster and
.)

of the district, of trap occurring remote
corner of township 49, range 36, 14 miles
t is known as Silver mountain, (*lucus a*
me-shaped to the height of a thousand
ions (p. 68).

* * *

"*Sandstone.*—It is not our purpose in this report to set forth the boundaries of the sandstone, much less to describe its characters, where it comes in contact with the pre-existing rocks. These descriptions will be reserved for the general report on the paleozoic rocks of this district. We propose simply at this time to show its connexion with the cupriferous rocks before described. In order that this connexion may be better understood, we introduce the following diagram:

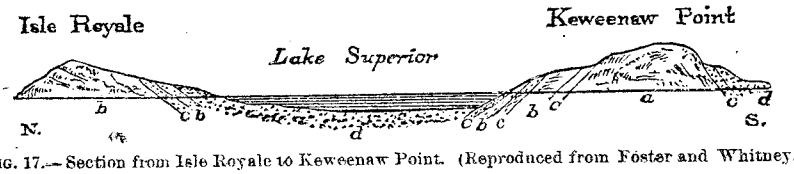


FIG. 17.—Section from Isle Royale to Keweenaw Point. (Reproduced from Foster and Whitney.)
a a, crystalline trap; *b b*, bedded trap; *c c*, conglomerate; *d d*, sandstone.

"We have seen that, during the deposition of the sandstone, numerous sheets of trap were ejected and flowed like lava-streams; and that the igneous and aqueous products were so intermingled as to present the appearance of having been derived from a common origin; and that subsequently the unbedded trap broke through these parallel fissures, lifting up the sandstones, conglomerates, and bedded traps, and causing the whole mass to dip at high angles. Thus, this portion of the bed of Lake Superior is due to these two lines of upheaval. The sandstone between the two lines performs an immense curve, portions of which are at least 800 feet below the chord formed by the surface of the water. The sandstone is seen on Isle Royale, forming the outer reefs of Siskawit bay (pp. 109, 110).

* * * * * * *

"Passing over the trappean ranges we find the sandstone occupying the southern slope and bearing the same relation to the trap as the northern belt, with this exception, that the intervening masses of conglomerate are in the main wanting" (p. 112.)

J. W. Foster and J. D. Whitney. (In a paper on the Age of the Sandstone of Lake Superior, with a Description of the Phenomena of the Association of Igneous Rocks. Proceedings American Association for the Advancement of Science, Cincinnati meeting, 1851, pp. 22–38.) "In the vicinity of the trappean rocks, on the other hand, we find the sandstone developed to a great thickness and accompanied by wide belts of conglomerate; we find it becoming impregnated with oxide of iron and calcareous matter and intersected by numerous veins of calc-spar and baryta, and containing native copper and its ores; we find it interstratified with beds of igneous rock, in numerous alternations, which beds have successively flowed over its surface and been again covered by sedimentary material; we find the whole system of conglomerate, sandstone and bedded trap, lifted up at an angle which gradually increases as we approach the central igneous mass and from which it dips on each side (pp. 29–30.)

* * * * * * *

"Returning to the head of Keweenaw Point, we find another range of trap, forming the southern boundary of the valley of the Little Montreal River and stretching westerly in a line nearly parallel with the northern chain. This range differs from the other, both in its lithological character and in its mode of occurrence. While the northern range, as before described, is made up of numerous beds of trap, in the main, of the amygdaloidal and granular varieties, interstratified with the detrital rocks, the southern range consists of a vast crystalline mass, forming an anticlinal axis, and flanked, on the north, by the bedded trap and conglomerate, and on the south by the sandstone and conglomerate (p. 31).

* * * * * * *

"The conglomerates of Keweenaw Point, and Isle Royale, consist of rounded pebbles and masses of trap, almost invariably of the amygdaloidal variety, derived, probably, from contemporaneous lavas, and rounded fragments of a jaspery rock, which may have been a metamorphosed sandstone; the whole cemented together by

a dark red ferruginous sand. This cement may be regarded as a mixture of a volcanic ash and arenaceous particles; the latter having been derived from the sandstone then in the progress of accumulation. It is not unusual to meet with strata composed entirely of arenaceous particles associated with the conglomerate beds, and when these expand to a considerable thickness, the associated sandstone appears in alternating bands of red and white, and exhibits few traces of metamorphism: but when the belts of sedimentary rock are thin, and come in contact with the trappean rocks, the sandstone is converted into jasper, and becomes traversed by divisional planes.

"We are strongly inclined to the belief that the origin of the conglomerate is not due, solely, to the action of waves and currents which have broken up and rounded and polished, the trappean and jaspery masses of which it is composed: on the contrary, we believe that the greater portion of these immense deposits are the result of an igneous, rather than an aqueous force. The rounded masses, in the conglomerate, often attain a magnitude of 18 inches in diameter, and their surfaces do not always present that smooth and polished appearance which results from the attrition of water. In fact, a close observer can, in most cases, readily distinguish between those pebbles which have been recently detached from the rock, and those which have been, for a time, exposed to the action of the surf. The conglomerate seems to have been formed too rapidly to allow of the supposition that their origin was purely aqueous; for while the contemporaneous sandstone, remote from the line of volcanic action, does not exceed 300 or 400 feet in thickness, the united thickness of the conglomerate bands, in the vicinity of the trap of Keweenaw Point, exceeds 5,000 feet. As we recede, for a few miles, from the igneous rocks, the conglomerates disappear, entirely, as separate members of the formation, and are only found in very thin and insignificant patches, amidst the sandstone.

"We have little hesitation, therefore, in adopting the views of Von Buch, as to the origin of such masses of rounded materials in the vicinity of igneous rocks, and consider them as the result of the friction and mechanical action caused by the volcanic action along the line of fissure. We can hardly conceive of the displacement of such enormous masses of igneous matter as have, during a long period, been flowing over the depositing beds of sedimentary matter, without supposing violent dislocation and crushing of the previously deposited strata. Immense quantities of material would be loosened, and torn off, along the line of volcanic outburst, and would gradually become rounded by friction against each other. Those pebbles which have a vesicular structure may have been ejected as scoriæ, while in a semi-fluid state, and have received their rounded form while falling through the air, like volcanic bombs. Whether it be allowed, or not, that such conglomerates could have been produced, solely, by igneous or volcanic action, it must be evident to every one that in this way materials would be heaped together, and broken up so that under the action of strong currents of water they would soon assume a rounded form. In fact, these very currents must have been caused, or increased vastly in intensity, by the same volcanic action which produced the igneous rocks (pp. 32, 33).

* * * * * * *

"Where the Bohemian range breaks through the incumbent rocks at Lake La Belle, a thin band of conglomerate is observed, not exceeding 30 feet in thickness, and which has been traced at intervals for two or three miles. The inclination is 80° to the south and south-east. The whole mode of action of the dynamic forces on the north and south side of the trap range, seems to have been different. On the north side, we not only find the bedded trap, and immense deposits of conglomerate above described, which rarely occur on the south; but we have a material difference in the character of the dip of the sandstone in the two slopes. On the north, the sandstone and conglomerate dip at angles rarely exceeding 40° in the immediate proximity of the trap, and this dip gradually diminishes as we recede from the center of elevation, so that a gently descending slope is formed, which extends regularly from the highest point

of the igneous rocks to the lake shore. T
west of the Ontonagon, where the desc
lake, is so gradual and regular as to be h
trappean ranges are almost without exc
the sandstone on that side elevated at a
times, just at the junction of the two form
immediately becoming horizontal again.
broken and elevated just at the souther
short distance from it, in that direction,
deposition. To account for this phen
igneous activity was along the northern
ward, during the protrusion of the mor
Bohemian Mt. or Keweenaw Pt. for ins
principally to the region on the north
bedded trap and conglomerate was goin
responding depression was taking place
these circumstances was taking place in
trough, or basin, of Lake Superior was th
and depression (p. 35)."

J. D. Whitney. (In The Metallic Wea
"The sandstone of Lake Superior, in reg
was formerly some disagreement, has now
Silurian age, and probably the equivalen
iferous rock recognized in this country.
point between Sault Ste. Marie and the
the Silurian system cropping out in succe
portion of the Lake the sandstone lies ne
grains of quartzose sand but slightly c
and the whole thickness does not seem t
contact with the older azoic rocks, as
Chocolate Rivers, it is seen resting unco
nearly horizontally on their upturned ed
acter is entirely changed; it has increase
erable angle, and is associated with very

* * *

"The rocks of which the trap range is
eralogical character but they belong mo
from their mode of formation and positio
of the earth, at the time the deposition
of fissures which extended along the li
tion. In the more elevated and central
dominate, containing intercalated beds
ness, between heavy masses of trappean
action in either direction, we find that t
erate predominates, but gradually disap
its normal character. Thus the appear
with and subordinate to that of the ig
result of the combined action of the tw
sandstone were formed. The whole sys
masses of conglomerate is developed on
ing a thickness of several thousand feet

* * *

"Thus in the Bohemian or Southern
have been protruded at a late epoch,
tilted up the system of the bedded tra
to the north, the veins bear only sulphu

may be regarded as a mixture of a vol-
ter having been derived from the sand-
It is not unusual to meet with strata
associated with the conglomerate beds,
clcness, the associated sandstone appears
exhibits few traces of metamorphism:
hin, and come in contact with the trap-
jasper, and becomes traversed by divis-

at the origin of the conglomerate is not
ents which have broken up and rounded
ses of which it is composed: on the con-
f these immense deposits are the result
e. The rounded masses, in the conglom-
s in diameter, and their surfaces do not
pearance which results from the attrition
most cases, readily distinguish between
ched from the rock, and those which have
e surf. The conglomerate seems to have
upposition that their origin was purely
ndstone, remote from the line of volcanic
ickness, the united thickness of the con-
of Keweenaw Point, exceeds 5,000 feet.
eous rocks, the conglomerates disappear,
tion, and are only found in very thin and

dopting the views of Von Buch, as to the
in th[illegible]inity of igneous rocks, and con-
mech[illegible]al action caused by the volcanic
rdly conceive of the displacement of such
, during a long period, been flowing over
without supposing violent dislocation and
. Immense quantities of material would
volcanic outburst, and would gradually
her. Those pebbles which have a vesicu-
iæ, while in a semi-fluid state, and have
g through the air, like volcanic bombs.
conglomerates could have been produced,
t be evident to every one that in this way
oken up so that under the action of strong
a rounded form. In fact, these very cur-
l vastly in intensity, by the same volcanic
pp. 32, 33).

* * * *

ugh the incumbent rocks at Lake La Belle,
ot exceeding 30 feet in thickness, and which
three miles. The inclination is 80° to the
action of the dynamic forces on the north
have been different. On the north side, we
deposits of conglomerate above described,
ave a material difference in the character
es. On the north, the sandstone and con-
0° in the immediate proximity of the trap,
ecede from the center of elevation, so that
extends regularly from the highest point

50)

of the igneous rocks to the lake shore. This is particularly the case to the east and west of the Ontonagon, where the descent of 400 or 500 feet from the trap to the lake, is so gradual and regular as to be hardly perceptible. The mural faces of the trappean ranges are almost without exception turned toward the south, and we find the sandstone on that side elevated at a high angle, dipping almost vertically sometimes, just at the junction of the two formations, but as we proceed southward, almost immediately becoming horizontal again. The appearance is as if the strata had been broken and elevated just at the southern edge of the igneous mass; while but at a short distance from it, in that direction, no disturbing force was acting during their deposition. To account for this phenomenon we must suppose that the line of igneous activity was along the northern edge of the trappean range, and that afterward, during the protrusion of the more southern portion of the trap, that of the Bohemian Mt. or Keweenaw Pt. for instance, the up-heaving action was confined principally to the region on the north. Thus, while a gradual elevation of the bedded trap and conglomerate was going on just north of the central fissure, a corresponding depression was taking place still farther north, and the reverse of all these circumstances was taking place in the line of Isle Royale. The great synclinal trough, or basin, of Lake Superior was the result of this combined action of elevation and depression (p. 35)."

J. D. Whitney. (In The Metallic Wealth of the United States, 1854, pp. 251, 252.) "The sandstone of Lake Superior, in regard to the geological position of which there was formerly some disagreement, has now been satisfactorily determined to be of Lower Silurian age, and probably the equivalent of the Potsdam Sandstone, the lowest fossiliferous rock recognized in this country. Above it, as we proceed southward from any point between Sault Ste. Marie and the Pictured Rocks, we find the upper members of the Silurian system cropping out in succession, with a slight southerly dip. Along this portion of the Lake the sandstone lies nearly horizontally, and is made up of rounded grains of quartzose sand but slightly colored by iron and having little coherence, and the whole thickness does not seem to exceed 300 or 400 feet. Where it comes in contact with the older azoic rocks, as may be observed in the vicinity of Carp and Chocolate Rivers, it is seen resting unconformably upon them, having been deposited nearly horizontally on their upturned edges. On Keweenaw Point, however, its character is entirely changed; it has increased greatly in thickness, is tilted up at a considerable angle, and is associated with very heavy beds of conglomerate and trappean rock.

* * * * * * *

"The rocks of which the trap range is made up are somewhat varied in their mineralogical character but they belong mostly to the igneous class, and it is apparent, from their mode of formation and position, that they were poured out from the interior of the earth, at the time the deposition of the sandstone was going on, from a series of fissures which extended along the line now occupied by the metalliferous formation. In the more elevated and central portion of the range, the igneous rocks predominate, containing intercalated beds of conglomerate, of very inconsiderable thickness, between heavy masses of trappean rock. As we recede from the line of igneous action in either direction, we find that the belts of trap become thinner, the conglomerate predominates, but gradually disappears, and is succeeded by the sandstone with its normal character. Thus the appearance of the conglomerate is seen to be allied with and subordinate to that of the igneous masses, and it appears to have been a result of the combined action of the two classes of agencies by which the trap and sandstone were formed. The whole system of the bedded trap and the interstratified masses of conglomerate is developed on a grand scale, some of the single beds acquiring a thickness of several thousand feet.

* * * * * * *

"Thus in the Bohemian or Southern range of Keweenaw Point, which appears to have been protruded at a late epoch, and under different conditions, and to have tilted up the system of the bedded trap and interstratified conglomerate which lies to the north, the veins bear only sulphuret of copper" (pp. 254–255).

After carefully re-examining the various extracts above given from Messrs. Foster and Whitney, we feel less confident than formerly that we thoroughly understand their theoretical position. As nearly as we are able to gather their meaning, however, it is about as follows: (1) The Eastern Sandstone and the Keweenawan detrital rocks are one and the same formation. (2) The associated igneous rocks are of two classes as to time and mode of eruption: (*a*) those traps which are interleaved with the detrital rocks were formed at the surface during the accumulation of those rocks, *i. e.*, are of lava overflow origin; (*b*) the traps of the Bohemian Range, which are held to lack the bedded structure, were intruded in great masses at a time entirely subsequent to the formation of all of the sandstones, Eastern as well as Keweenawan, and of all of the interleaved trappean flows. (3) To the eruption of the supposed unbedded trap of the Bohemian Range is to be attributed the northward inclination of the Keweenawan rocks on the north of this range and the southward inclination of the Eastern Sandstone on the south of it. To this intrusion also is to be attributed the formation from the previously existing sandstone of "jasper" masses, such as that of Mount Houghton and the Bare Hills on the north side of Bête Grise Bay. (4) The conglomerates of the trappean series are in large part of igneous origin, the rounding of the pebbles being due not to water action, but to "friction of the elevated rock against the walls of the fissures." These conglomerates are composed chiefly of rounded pebbles of trap and subordinately of a jaspery rock. If not directly due to igneous causes, the rounding of the conglomerate pebbles may have been partly produced by the violent currents caused by the igneous outflows. To the production of these conglomerates by eruptive agencies is to be attributed the immensely increased thickness of the detrital portion of the formation in the region of Keweenaw Point as contrasted with its thickness farther to the eastward on the south shore of Lake Superior. (5) The various bedded eruptives of Keweenaw Point reached the surface through a series of fissures along the course of the Point. (6) The massive trap of the Bohemian Range, however, was extruded along an immense fissure formed subsequently to and to the south of those through which the bedded traps reached the surface. This immense fissure extended, however, far to the westward of the Bohemian Range intrusion, along what is now the southern edge of the trappean formation and the northern edge of the Eastern Sandstone, reaching as far as the neighborhood of Lake Gogebic. To the southwest and west of Torch River on Keweenaw Point and until the vicinity of the Ontonagon is reached, the production of this fissure was unaccompanied by any igneous outflow. Along this portion of the fissure the bedded traps and interstratified detrital rocks, dipping to the northward, come directly against the horizontal beds of the Eastern Sandstone.

In addition to the conclusions above enumerated, it seems, although

we do not find such a view exactly stated in their works, that Messrs. Foster and Whitney must have believed also in a former continuity of the Eastern Sandstone with the uppermost sandstones of the copper-bearing series on Keweenaw Point, from which it was faulted away during the production of the fissure above alluded to. It would seem that they must also have considered that, before this fissuring, the bedded traps and conglomerates had an approximately horizontal position.

We have already given three sectional diagrams copied directly from Messrs. Foster and Whitney's reports illustrative of their views. These diagrams are, of course, not drawn to any definite scale. Herewith we give two cross-sections of Keweenaw Point, drawn to a true scale, in which we have embodied their views as to the structure here obtaining as well as we are able.

As confirmatory of a former continuity between the Eastern Sandstone and the uppermost sandstones of the copper-bearing series, there has of late years been cited a lithological similarity, the remaining sandstones of the Keweenaw Series being quite strongly contrasted lithologically with the quartzose Eastern Sandstone. A somewhat more careful examination of this alleged similarity, however, shows us that it depends almost entirely upon certain sandstones which occur in

arious extracts above given from
less confident than formerly that
retical position. As nearly as we
wever, it is about as follows: (1)
eenawan detrital rocks are one and
ted igneous rocks are of two classes
those traps which are interleaved
at the surface during the accumu-
a overflow origin; (*b*) the traps of
ld to lack the bedded structure,
a time entirely subsequent to the
Eastern as well as Keweenawan,
ean flows. (3) To the eruption of
ohemian Range is to be attributed
eweenawan rocks on the north of
ination of the Eastern Sandstone
n also is to be attributed the for-
g sandstone of "jasper" masses,
and the Bare Hills on the north
nglomerates of the trappean series
, th unding of the pebbles be-
to "friction of the elevated rock
These conglomerates are composed
d subordinately of a jaspery rock.
es, the rounding of the conglom-
produced by the violent currents
the production of these conglom-
be attributed the immensely in-
tion of the formation in the region
ith its thickness farther to the east-
Superior. (5) The various bedded
ed the surface through a series of
oint. (6) The massive trap of the
truded along an immense fissure
south of those through which the
This immense fissure extended,
Bohemian Range intrusion, along
e trappean formation and the north-
reaching as far as the neighborhood
and west of Torch River on Kewee-
the Ontonagon is reached, the pro-
mpanied by any igneous outflow.
e bedded traps and interstratified
ard, come directly against the hori-
e.
ve enumerated, it seems, although
52)

we do not find such a view exactly stated in their works, that Messrs. Foster and Whitney must have believed also in a former continuity of the Eastern Sandstone with the uppermost sandstones of the copper-bearing series on Keweenaw Point, from which it was faulted away during the production of the fissure above alluded to. It would seem that they must also have considered that, before this fissuring, the bedded traps and conglomerates had an approximately horizontal position.

We have already given three sectional diagrams copied directly from Messrs. Foster and Whitney's reports illustrative of their views. These diagrams are, of course, not drawn to any definite scale. Herewith we give two cross-sections of Keweenaw Point, drawn to a true scale, in which we have embodied their views as to the structure here obtaining as well as we are able.

As confirmatory of a former continuity between the Eastern Sandstone and the uppermost sandstones of the copper-bearing series, there has of late years been cited a lithological similarity, the remaining sandstones of the Keweenaw Series being quite strongly contrasted lithologically with the quartzose Eastern Sandstone. A somewhat more careful examination of this alleged similarity, however, shows us that it depends almost entirely upon certain sandstones which occur in

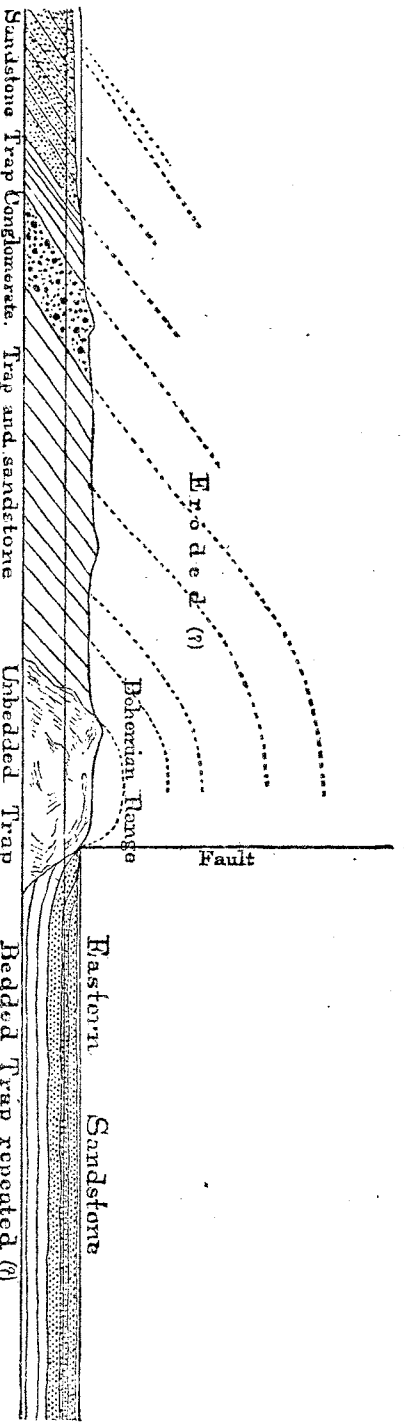


Fig. 18.—Section of the eastern part of Keweenaw Point, on the Foster and Whitney view. Scale, 2 miles to the inch.