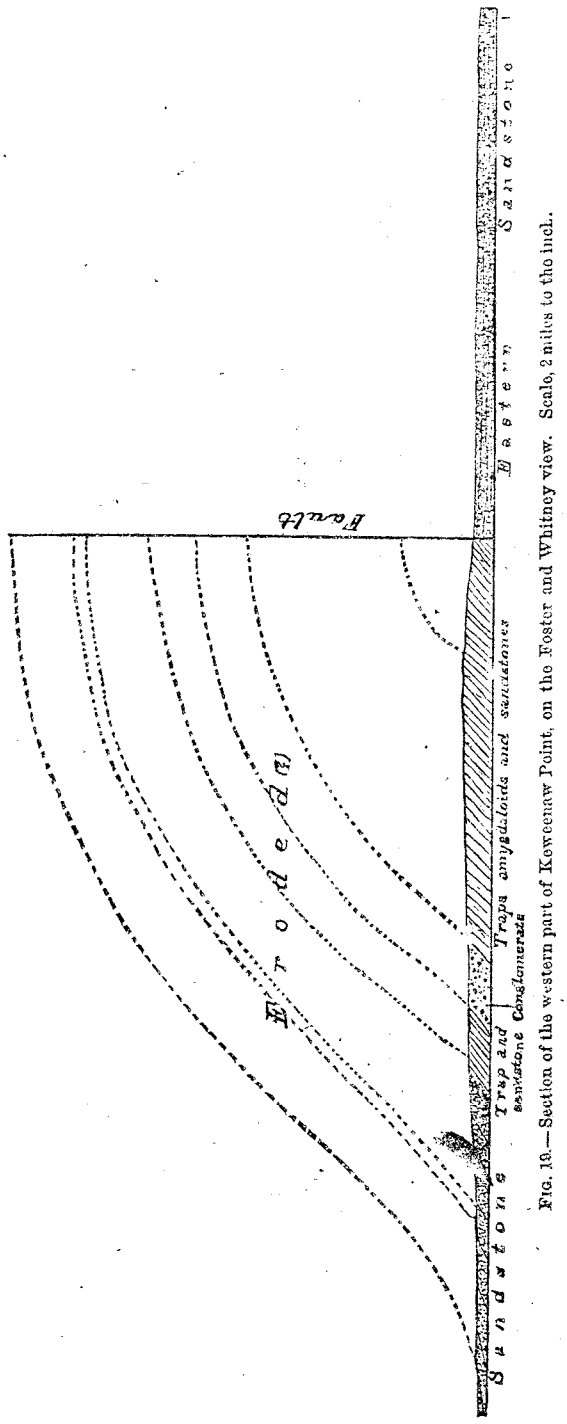



FIG. 19.—Section of the western part of Keweenaw Point, on the Foster and Whitney view. Scale, 2 miles to the inch.





quite flat positions along the shore
age Entry and the Ontonagon River
position it is certainly natural tha
part of the Keweenaw Series, are wit
any that we have yet studied from
series. If we may judge, however
the most quartzose portions of th
Portage Canal, they are never so
Sandstone, from which they differ
cles. Small, rather angular partic
often secondarily enlarged so as
sections of the sandstone near the
ingredients there are fragments of
mainly composed of chloritic and
haps representative of some of the
also a quite plentiful oxide of iro
this sandstone, even on the view
ern Sandstone and the Keneewaw
the former formation as with the
covered space between it and th
relation to them is matter of infe
possible hypothesis that this san
tion of the horizontal sandstone o

On account of the doubt which
these sandstones, we have studied
stones unquestionably from the up
selecting always those localities
The results are as follows: (1)
River, southwest quarter Sec. 19
Mountains, gives a section which i
angular fragments of quartz and
quartz not forming more than on
plex fragments, more or less deco
present, also a considerable port
and oxide of iron cement (slide 63
stone of the Porcupine Mountai
of the Porcupine Mountains, wh
the lowest part of the upper divis
examined a rock obtained at Carp
composed mainly of fragments
porphyry, and of individual felds
angular and very small. A larg
calcite (slide 652). (3) A sandston

[1] See Monographs United States Geolo
[2] Ibid., Plates XIX, XX, and XXI.

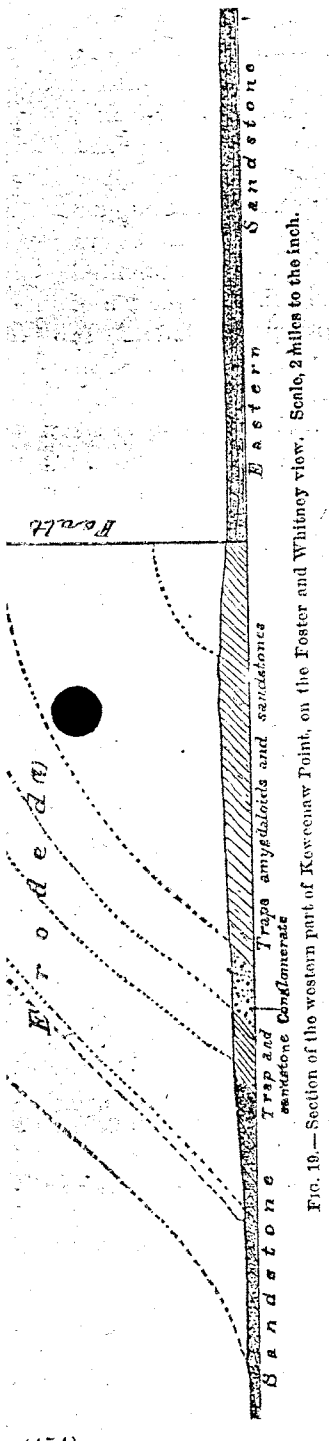



FIG. 19.—Section of the western part of Keweenaw Point, on the Foster and Whitney view. Scale, 2 miles to the inch.





quite flat positions along the shore of Lake Superior, between the Portage Entry and the Ontonagon River. These sandstones, which from their position it is certainly natural that we should regard as the uppermost part of the Keweenaw Series, are without doubt much more quartzose than any that we have yet studied from the remainder of the extent of that series. If we may judge, however, from thin sections recently made of the most quartzose portions of the exposures near the mouth of the Portage Canal, they are never so completely quartzose as the Eastern Sandstone, from which they differ, also, in the angularity of the particles. Small, rather angular particles of quartz and feldspar, the former often secondarily enlarged so as to fit closely, make up most of the sections of the sandstone near the Portage Canal. In addition to these ingredients there are fragments of a complex character, now apparently mainly composed of chloritic and kaolinic material, but which are perhaps representative of some of the Keweenawan basic rocks. There is also a quite plentiful oxide of iron cement. It is to be observed that this sandstone, even on the view of the entire distinctness of the Eastern Sandstone and the Keneewaw Series, might as well be placed with the former formation as with the latter. There being always a wide covered space between it and the undoubted Keweenawan rocks, its relation to them is matter of inference only. It does not seem an impossible hypothesis that this sandstone may be an eastern continuation of the horizontal sandstone of the Apostle Islands.[1]

On account of the doubt which thus hangs over the true position of these sandstones, we have studied in this connection a number of sandstones unquestionably from the upper horizons of the Keweenaw Series, selecting always those localities promising the most quartzose kinds. The results are as follows: (1) The sandstone from the bed of Carp River, southwest quarter Sec. 19, T. 51, R. 42 W., in the Porcupine Mountains, gives a section which is made up chiefly of exceedingly fine angular fragments of quartz and feldspar, the latter predominant, the quartz not forming more than one-third of the section. Various complex fragments, more or less decomposed, of basic and acid rocks are present, also a considerable portion of indurating quartz and calcite, and oxide of iron cement (slide 631). This rock is from the Inner Sandstone of the Porcupine Mountains.[2] (2) From the Outer Sandstone of the Porcupine Mountains, which has been selected by one of us as the lowest part of the upper division of the Keweenaw Series, we have examined a rock obtained at Carp Lake Landing, which gives a section composed mainly of fragments of felsitic porphyry matrix, granitic porphyry, and of individual feldspars and quartzes, the latter sharply angular and very small. A large part of the section is composed of calcite (slide 652). (3) A sandstone from a lower horizon, in the southeast

[1] See Monographs United States Geological Survey, Vol. V, Plates I, and XXIII.
[2] Ibid., Plates XIX, XX, and XXI.

quarter of Sec. 14, T. 50, R. 45 W., is grayish, much indurated, and of fine grain, and gives a section of about the same sort, the proportion of fragmental quartz being very small. Most of the quartz of the specimen is infiltrated or indurating quartz (slide 351). (4) From a higher horizon come certain sandstones at and near the mouth of Carp River. These are dark reddish-brown or yellow, and feebly indurated. The principal constituents are fragments of porphyry matrix, detritus of basic rocks, and sharply angular feldspar and quartz fragments. The quartz does not form more than one-tenth to one-fifth of the section. Quite a large proportion of iron oxide cement is present (slide 2161). (5) Quite closely similar to the last described is the thin section of a rock from a much higher horizon, viz, the main sandstone mass of the upper division of the Keweenaw Series as exposed in the bed of Presque Isle River, northeast quarter Sec. 5, T. 49, R. 45 W. (slide 355). (6) At a still higher horizon—indeed the very highest with which we are acquainted, if we exclude the doubtful sandstone on the lake coast between the Portage Canal and the Ontonagon River—lies the sandstone at the mouth of the Montreal River. Of this sandstone two sections representing different phases were studied. One of these is a dark reddish-brown, coarse-grained, friable rock, containing numerous mica flakes. The main constituents of the rock are quartz and feldspar in sharply angular fragments, fragments of porphyry matrix, and magnetite fragments. Both quartz and feldspar grains have received quite strongly-marked enlargements.[1] Besides the complex particles certainly referable to acidic Keweenawan eruptives, others occur which are as plainly referable to the basic eruptives. Muscovite flakes are somewhat plenty. The quartz fragments of this rock, whose angularity is somewhat striking, are more plentiful than in any other undoubted Keweenawan sandstone examined, but they yet form only a minor portion of the whole section (slide 2193). The other rock from the same vicinity on Montreal River is also very coarse grained, but is light colored, the feldspar fragments being quite noticeable to the naked eye. In the thin section these feldspar fragments are seen to make up fully one-half the mass of the rock. These fragments are at times quite fresh, although commonly they are more or less thoroughly decomposed. They include both orthoclase and plagioclase. Of the remaining portion of the rock, about one-half is made up of complex fragments of basic and acid Keweenawan rocks, with greenish and reddish decomposition-products and iron oxide cement. The balance of the rock, not more than one-fourth of the whole, is composed of quartz fragments, mostly simple, but in a few cases finely complex. The simple grains of quartz have frequently received secondary enlargements, to which cause the slight induration of the rock is plainly due (slide 2190). Precisely similar rocks to the last described, and

[1] See Bulletin United States Geological Survey No. 8.





belonging to an equally high ho
Bad River, Ashland County, Wi
Welton's Dam, on White River
46, R. 4 W. (slides 2191, 2192).[1]

Thus, after selecting the mos
weenawan horizons for comparis
ent from the Eastern Sandstone
in quartz and having as chief co
tives of the Keweenaw Series, i
of these sandstones may well t
larity of these quartz fragment
sally well-rounded fragments o
note. The view that the Eas
from the outermost layers on I
the corroboration that might ha
studies; on the contrary, the re

With regard to the other po
Whitney, we have to say, in the
their division of the trappean
intrusive and contemporaneous
absence of intrusive eruptives o
enough that such should occu
recognize any intrusives other
rocks of the Bohemian Range.
far as we have seen them, ar
we find any proof whatever in
here of intrusives. The Bohe
Messrs. Foster and Whitney sp
having by its intrusion tipped
beds to the north of it and the
ined with some care several ye
along the shore of Bête Grise B
River. What he saw in this e
the Bohemian Range was in g
rocks, being made up of a succ
interstratified conglomerates.
pear somewhat different from
to be seen at similar low horiz
of the Keweenaw formation;
dominating over them are var

[1] Geology of Wisconsin, Vol. III, p
localities, and analyses of the sandst
203. Also, for figures of thin section
of this plate, though not very succe
tween the Keweenawan and later sa

:ayish, much indurated, and of fine
e same sort, the proportion of frag-
st of the quartz of the specimen is
351). (4) From a higher horizon
the mouth of Carp River. These
l feebly indurated. The principal
ry matrix, detritus of basic rocks,
:artz fragments. The quartz does
fifth of the section. Quite a large
present (slide 2161). (5) Quite
s the thin section of a rock from a
sandstone mass of the upper di-
xposed in the bed of Presque Isle
9, R. 45 W. (slide 355). (6) At a
ry highest with which we are ac-
andstone on the lake coast between
1 River—lies the sandstone at the
s sandstone two sections represent-
ne of these is a dark reddish-brown,
ning numerous mica flakes. The
rtz and feldspar in sharply angular
mat[illegible] and magnetite fragments.
ve received quite strongly-marked
x particles certainly referable to
occur which are as plainly refera-
e flakes are somewhat plenty. The
e angularity is somewhat striking,
undoubted Keweenawan sandstone
minor portion of the whole section
same vicinity on Montreal River is
it colored, the feldspar fragments
ye. In the thin section these feld-
fully one-half the mass of the rock.
e fresh, although commonly they
sed. They include both orthoclase
portion of the rock, about one-half
basic and acid Keweenawan rocks,
ion-products and iron oxide cement.
an one-fourth of the whole, is com-
mple, but in a few cases finely com-
have frequently received secondary
ght induration of the rock is plainly
: rocks to the last described, and

: Geological Survey No. 8.

6)



belonging to an equally high horizon, are those (7) of Leiby's Falls, on Bad River, Ashland County, Wisconsin, Sec. 25, T. 47, R. 3 W., and (8) at Welton's Dam, on White River, in the same county, N. E. $\frac{1}{4}$, Sec. 6, T. 46, R. 4 W. (slides 2191, 2192).[1]

Thus, after selecting the most quartzose varieties of the upper Keweenawan horizons for comparison, we find them yet very strikingly different from the Eastern Sandstone itself, they being always greatly leaner in quartz and having as chief constituents the detritus of the acid eruptives of the Keweenaw Series, to which category the quartz fragments of these sandstones may well themselves belong. The striking angularity of these quartz fragments, as compared with the almost universally well-rounded fragments of the Eastern Sandstone, is worthy of note. The view that the Eastern Sandstone has been faulted away from the outermost layers on Keweenaw Point does not, then, receive the corroboration that might have been expected from our microscopic studies; on the contrary, the results are quite against it.

With regard to the other points in the views of Messrs. Foster and Whitney, we have to say, in the first place, that we are unable to accept their division of the trappean rocks into the two prominent classes of intrusive and contemporaneous. We do not mean to assert the entire absence of intrusive eruptives on Keweenaw Point; it would be natural enough that such should occur. We have, however, been unable to recognize any intrusives other than certain reddish granite-like acid rocks of the Bohemian Range. All of the trappean beds of the point, so far as we have seen them, are plainly of lava-flow nature. Nor do we find any proof whatever in the writings of others of the existence here of intrusives. The Bohemian Range of Keweenaw Point (which Messrs. Foster and Whitney speak of as a great intrusive mass and as having by its intrusion tipped up the alternating lava-flows and sand beds to the north of it and the sandstone to the south) one of us examined with some care several years since in the vicinity of Lac la Belle, along the shore of Bête Grise Bay, and again to the southeast of Eagle River. What he saw in this examination served to convince him that the Bohemian Range was in general character like the more northern rocks, being made up of a succession of lava-flows with here and there interstratified conglomerates. Certain rocks of this range, which appear somewhat different from those farther north, are just such as are to be seen at similar low horizons throughout the geographical extent of the Keweenaw formation; while interstratified with these and predominating over them are various traps and detrital rocks in no way

[1] Geology of Wisconsin, Vol. III, pp. 202–203. For descriptions of the two latter localities, and analyses of the sandstones, see Geology of Wisconsin, Vol. III, pp. 202–203. Also, for figures of thin sections, Plate XIX A of the same volume. The figures of this plate, though not very successful, still serve well to mark the difference between the Keweenawan and later sandstones.

different from the more northern rocks of Keweenaw Point. The supposed structural difference between the Bohemian Range and the rest of the point seems to have been suggested partly by the unusual occurrences above alluded to, but largely also by the rounded contours of the range, the latter being taken to indicate an unbedded structure. These rounded contours, however, as one may very quickly learn from the exposures north of Lac la Belle and along the shores of Bête Grise Bay, are plainly due to the very high northern dip which here obtains, the step-like contours of the more northern ranges resulting in turn from a relatively low dip. The Bohemian Range beds, then, form the lowest part of the alternating series of lava-flows and detrital rocks, and are by no means the product of subsequent intrusion. They cannot, therefore, have produced the northward inclination.[1]

It also results that these supposed Bohemian Range intrusions did not produce the southward inclinations in the Eastern Sandstone on the southern contact; a conclusion which is sufficiently indicated by other and independent considerations. In the first place the southerly dips in the Eastern Sandstone are not restricted to that portion of the contact along which the supposed intrusions are indicated by Messrs. Foster and Whitney as having taken place. Quite beyond the western extremity of the Bohemian Range occur the most notable instances of the upturning of the layers of the Eastern Sandstone, as indicated in our foregoing descriptions of the Wall and Saint Louis ravines. Again, the south-dipping Eastern Sandstone along the north shore of Bête Grise Bay is crowded with sharply angular and often large-sized fragments of the Bohemian Range rocks themselves. The angularity and frequent softness of these fragments render it certain that they lie in the immediate vicinity of the rocks from which they were derived, a view which is abundantly confirmed by the lithological identity between the fragments and the trappean rocks against which the sandstones holding them immediately rest.

In declining to accept the existence of the supposed late intrusions of the Bohemian Range, we of course reject also another of their supposed effects, viz, the production, from the sandstone invaded, of such felsitic rocks as that of Mount Houghton. We cannot here take the space to discuss the nature of these so-called jaspers. That they are eruptive felsites and quartziferous porphyries of an entirely similar nature and origin with the rocks of that class throughout the Keweenaw Series seems to us abundantly evident. One of us has already discussed these rocks at some length in another connection.[2] We need merely point out here that they have unquestionably produced the principal part of the pebbles of the conglomerates of the Keweenaw

[1] For a fuller discussion of the structure of the Bohemian Range, see Monographs United States Geological Survey, Vol. V, pp. 179–186.

[2] Monographs United States Geological Survey, Vol. V, pp. 30–32, 95–125.





Series which, on Messrs. Foster
massive intrusions by which the
produced. In the same connection
been done elsewhere at some le
Messrs. Foster and Whitney appe
conglomerates of the Keweenaw
very plainly made of water-worn
that series itself.

With Messrs. Foster and Whi
material which formed the bedded
a series of fissures, we can readi
that these fissures were placed a
naw Point. Had they been so i
not meet somewhere with the d
us preferable to attribute the e
southward of the course of the
Point, where they are buried bene
filled fissures which we know to
the Lake Superior basin.

That an extended fault fissure
range, as held by Foster and W
conceive that this fissure was i
production of the Eastern Sands
or that it gave vent to any erupt

In the production of this fiss
view, it seems necessary to be
faulted away from the uppermos
weenaw Point. We have alread
mation when we come to compar
but there are other very weigh
The faulting would demand a t
mensely great erosion. Moreov
lieving that the northward-di
South Range, east of Lake Gog
Keweenaw Series; and yet the
the valley between the Main an
these beds in an unmistakably u
it seems impossible to believe
the uppermost member of the
ances along the Eastern Sand
wholly against any such view.
contact seems plain to us, bu
there has been no great faulting
Were this contact a fault co
crowded with fragments, often
rests.

ts of Keweenaw Point. The sup-
he Bohemian Range and the rest
ested partly by the unusual occur-
also by the rounded contours of
indicate an unbedded structure.
one may very quickly learn from
nd along the shores of Bête Grise
northern dip which here obtains,
northern ranges resulting in turn
mian Range beds, then, form the
s of lava-flows and detrital rocks,
subsequent intrusion. They can-
rthward inclination.[1]

l Bohemian Range intrusions did
ions in the Eastern Sandstone on
which is sufficiently indicated by
ns. In the first place the south-
are not restricted to that portion
posed intrusions are indicated by
ng taken place. Quite beyond the
n Range occur the most notable
yers of the Eastern Sandstone, as
ions of the Wall and Saint Louis
East Sandstone along the north
ed with sharply angular and often
nian Range rocks themselves. The
f these fragments render it certain
nity of the rocks from which they
lantly confirmed by the lithological
the trappean rocks against which
iately rest.

ce of the supposed late intrusions
rse reject also another of their sup-
rom the sandstone invaded, of such
oughton. We cannot here take the
e so-called jaspers. That they are
s porphyries of an entirely similar
that class throughout the Kewee-
evident. One of us has already dis-
n in another connection.[2] We need
have unquestionably produced the
e conglomerates of the Keweenaw

e of the Bohemian Range, see Monographs
pp. 179–186.
Survey, Vol. V, pp. 30–32, 95–125.





Series which, on Messrs. Foster and Whitney's view, antedate the massive intrusions by which the rocks furnishing the pebbles were produced. In the same connection we may also point out, as has already been done elsewhere at some length, the quite erroneous views that Messrs. Foster and Whitney appear to have had of the nature of the conglomerates of the Keweenaw Series, which, it appears to us, are very plainly made of water-worn fragments of the acid eruptives of that series itself.

With Messrs. Foster and Whitney's view as to the ejection of the material which formed the bedded eruptives of Keweenaw Point through a series of fissures, we can readily coincide, but we find no evidence that these fissures were placed along the course of the present Keweenaw Point. Had they been so it seems inconceivable that we should not meet somewhere with the dikes representing them. It seems to us preferable to attribute the eruptions to fissures lying quite to the southward of the course of the present trap range of the Keweenaw Point, where they are buried beneath a newer formation, or to the dike-filled fissures which we know to intersect the regions about the rim of the Lake Superior basin.

That an extended fault fissure exists along the south side of the trap range, as held by Foster and Whitney, we also think; but we cannot conceive that this fissure was in the main formed subsequent to the production of the Eastern Sandstone, as they seem plainly to maintain, or that it gave vent to any eruptive material.

In the production of this fissure, on Messrs. Foster and Whitney's view, it seems necessary to believe that the Eastern Sandstone was faulted away from the uppermost sandstone on the western side of Keweenaw Point. We have already shown that this view meets no confirmation when we come to compare the two sandstones with one another; but there are other very weighty objections against this conception. The faulting would demand a throw of 35,000 feet or over and an immensely great erosion. Moreover, there is very excellent reason for believing that the northward-dipping trappean beds of the so-called South Range, east of Lake Gogebic, are the lowermost members of the Keweenaw Series; and yet the Eastern Sandstone, when followed across the valley between the Main and South Trap ranges, is found to overlap these beds in an unmistakably unconformable position — a relation which it seems impossible to believe could exist were this sandstone merely the uppermost member of the trappean series. Further, the appearances along the Eastern Sandstone contact on Keweenaw Point are wholly against any such view. That there has been motion along this contact seems plain to us, but it certainly seems equally plain that there has been no great faulting here since the sandstone was laid down. Were this contact a fault contact only, the sandstone would not be crowded with fragments, often angular, of the rocks against which it rests.

## THE AGASSIZ VIEW.

*Alexander Agassiz.* (In a paper On the Position of the Southern Slope of a Portion of Keweenaw Point, Lake Superior. Proceedings Boston Society of Natural History, 1868, Vol. XI). "Foster and Whitney, in their report of the Lake Superior mineral district, represent the sandstone on the south side of the trap range of Keweenaw Point as dipping south and resting conformably upon the beds of trap of the north side of the anticlinal axis of Keweenaw Point. This anticlinal axis formed by the Bohemian Mountain, as asserted by Foster and Whitney, is not found further south as far as I have had occasion to examine. In two of the ravines cut through the sandstone by creeks flowing in an easterly direction from the crest of the range towards Torch River, near the head of Torch Lake, we find good exposures of the sandstone, and in two points, one of which was examined by Foster and Whitney, we find the sandstone resting unconformably upon the trap, which has still the same northern dip as further west, of about 42° (p. 244).

* * * * * * *

"On examining this sandstone more carefully we find that the strata are made up of alternating layers of sandstone of reddish or yellowish grain and of beds of loose sandstone containing boulders, some of the beds of boulders resembling what is common on sea-shores as a mixture of mud and shingle. On breaking open several of the small boulders, taken *in situ* from the beds, we find that they consist mostly of reddish trap, but frequently we come across perfectly well-waterworn boulders of greyish trap containing amygdules, identical with the trap of the copper range a short distance west from these beds of sandstone, plainly showing that the sandstone was deposited upon the shores of the ridge of trap forming Keweenaw Point, and has not been uplifted by it as is stated by Foster and Whitney. The case is totally different with the sandstone north of the range that lies conformably upon the trap, but the sandstone of the southern side of the mineral range in the vicinity of Torch Lake is plainly of a different age, lying as it does unconformably upon the former" (p. 245).

*Raphael Pumpelly.* (Geological Survey of Michigan, Vol. I, Part II, pp. 2-5). "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 chloritic 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°.

"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 m
Brooks and myself, during a reconnoissanc
consin, and the middle branch of the Onto
Our route was chiefly confined to the surf
Azoic, which we have provisionally consid

"From Penokie Gap, on Bad River, to
miles, the quartzites and schists of this fo
a belt one-fourth to one-half mile in wi
gneiss and schists. On the north it is ev
(containing interstratified sandstones) of
and peaks which rise 200 to 300 feet abov

"These ridges, forming the 'South Mine
the Mineral Range proper, which forms re
of the tongue of land known as Keweenaw
south-western part of the Silurian trough
tending inland from Keweenaw Bay.

"Here, as there, it is filled with the hori
ing a generally level country. For a dista
River, in Town 47, and Lake Gogebic, w
conforming in strike and dip with the Hu
to the north at angles of 50° to 70°. I
west, we find that erosion of Silurian or p
entirely across the cupriferous series and
that at a short distance west of the lake th
at the base of which lies the level countr
the basin of the lake. From this point ea
inroads upon the continuity of the cuprif
of the Silurian sandstone. The melaphyr
ing, and no Huronian was found as far a
the limit of our observations.

"On this river, in the center of the
Range 41, the Silurian sandstone was fou
strata are horizontal or at most have a
dip. About 150 steps from the base of
schists whose bedding trends north-east
dips 45° to 60° southeast. The nearest o
in the southeast corner of Sec. 5, abou
amygdaloidal melaphyr, whose bedding
50° to north. In general terms, the conc

"I. The cupriferous series was formed
which it rests conformably, and, consequ
area, whose existence during the Potsdam
Michigan and Lake Superior.

"II. After the elevation of these rocks
lithological characteristics, came the dep
ing shales, as products of the erosion of th
show them to belong to the Lower Silur
should be referred to the Potsdam, Calc
seem to be an open one, whether the cup
point of time to the Huronian than to th

The principal points of the vi
elaborated by Pumpelly appear to
trap range of Keweenaw Point is

SIZ VIEW.

osition of the Southern Slope of a Portion
dings Boston Society of Natural History,
heir report of the Lake Superior mineral
uth side of the trap range of Keweenaw
nably upon the beds of trap of the north
int. This anticlinal axis formed by the
and Whitney, is not found further south
In two of the ravines cut through the
direction from the crest of the range to-
ake, we find good exposures of the sand-
examined by Foster and Whitney, we find
e trap, which has still the same northern

* * *

ully we find that the strata are made up
or yellowish grain and of beds of loose
eds of boulders resembling what is com-
mingle. On breaking open several of the
e find that they consist mostly of reddish
ly well-waterworn boulders of greyish
e trap of the copper range a short dis-
ply showing that the sandstone was de-
forming Keweenaw Point, and has not
Whitney. The case is totally different
es conformably upon the trap, but the
rang[illegible]e vicinity of Torch Lake is
nformably upon the former" (p. 245).
igan, Vol. I, Part II, pp. 2–5). "At the
strata abut against the steep face of a
of the cupriferous series of melaphyr
sandstone at angles of 40° to 60°, ac-
ply defined and often nearly vertical
er geologists at several points along a
to be often occupied by a thick bed of
product of faulting motion, was con-

e fact that, on the western side of Ke-
resemblance to those of the eastern
ly overlying the cupriferous series.
eal in age and as forming the upper

t difficult for us to accept this conclu-
of dislocation required, for instance,
ferous series, with an actual thick-
ed *longitudinal* fault at an angle of

stone lying on the upturned melaphyr
prove that they were not brought
z informed me that he has found in
alt," abundant pebbles of the mela-
a fact which I found abundantly

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 60 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 backbone 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.

"Here, as there, it is filled with the horizontally stratified Silurian sandstone, forming a generally level country. For a distance of nearly 30 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, 7 miles away, and the limit of our observations.

"On this river, in the center 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 towards the cliff of horizontal sandstone and dips 45° to 60° southeast. The nearest observed outcrop of the cupriferous series is in the southeast 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.

"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."

The principal points of the view thus enunciated by Agassiz and elaborated by Pumpelly appear to be these: (1) The south face of the trap range of Keweenaw Point is an ancient shore cliff, having been

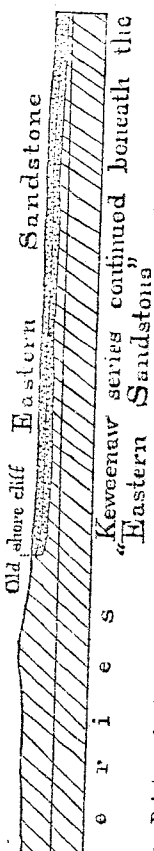



FIG. 20.—Section of Keweenaw Point, on the Agassiz view. Scale, 2 miles to the inch.

produced entirely by the erosion of the waves of that sea in which the Eastern Sandstone was laid down. (2) The Keweenaw Series extends unconformably continuously beneath the Eastern Sandstone to the South Range, the entire trough in which this sandstone lies having been produced by erosion.

To this view we have to object that it demands an almost inconceivably great thickness for the Keweenaw Series and an enormously great erosion prior to the deposition of the sandstone. By supposing the south face of the trap range to have been in the first place the result of faulting, we remove both of these difficulties, and are then able to accept the view of these gentlemen without further reserve, though with some addition.

## THE ROMINGER VIEW.

*C. Rominger.* (Geological Survey of Michigan, Vol. I, Part III, 1873.) "The sandstones lining the eastern shore of Keweenaw Point extend approximating to the center of the Peninsula, retaining their horizontal position and also their lithological characters to such a degree that the different strata can be parallelized without difficulty with those of the more eastern localities. Near the center, the horizontal sandstone ledges are found at once abutting against the uplifted edges of a different rock series—the *Copper-bearing rocks*—which form the most elevated central crest of the Peninsula. The strike of this upheaved rock series is in conformity with the shape of the peninsula, from southwest to northeast. The abrupt edges of the strata look to the southeast and their dip is in the opposite direction, under angles variable from 40 to 70 degrees. Without intending to enter into a closer examination of the structure and composition of the copper-bearing series, I describe it in general terms as composed of mighty conglomerate beds, connected with sandstone ledges, exhibiting perfectly plain ripple-marks, which demonstrate their aqueous sedimentary origin, alternating in often-repeated sequence with powerful seams of crystalline or semi-crystalline rocks, which are comprehended under the collective name of trap but are of a very variable character and composition. The thickness of this formation is very considerable, and I think is rather under-estimated at 10,000 feet. The inconformable abutment of the Lake Superior sandstones against the Trappean series is in several places near Houghton plainly to be observed (pp. 95–96).

* * * * * *

"On the west side of the Trap range, half a mile south of Portage canal entry, large outcrops of only slightly inclined sandstone strata border the lake shore, and continue southwestward as far as the eye can reach. Along the space of about a mile, 200 feet of strata come to the surface. The uppermost are thin-bedded argillaceo-arenaceous layers; below these follow light colored sand rocks in thick ledge, which are quarried for the pur-





pose of filling the cribs built out into
them again more shaly and thin-bedde
are dark, fine grained, hard sandstones,
six feet thickness, which are susceptibl
desired thickness. This rock is also use
be quarried in large, fine blocks, which
very frequently ripple-marked and exhi

"The white and red banded or spotte
east side, is also observed here, and the
far below the eastern deposits. For th
from there all the surface rock is sand
does not allow us to follow across the
a mile west of the South Pewabic sta
fine grain, intermingled with micaceo
Their dip is about 35 degrees to the nor
tinues as we go eastward to the South I
strata having the same strike and dip a

"They are in beds of various thickne
ple-marks. Next below follow conglo
granules not larger than mustard see
abundant zeolithic cement (Laumonite)

"Other conglomerate beds are very
than a man's fist. The pebbles are of
of trappean rocks and pieces of sandst

"Laumonite and calespar crystals li
immediately rest on crystalline trap
several thousand feet, are in conforma
however, is not perfectly demonstrate
ing dip, succeed in a westerly directio
series with the sandstones forming the

The rock character of all the sand
throughout of much darker ferruginou
cementing substance than the rocks of
clusively forming the cement of the fi
bic stamp mills is also, in the much hi
recognizable as an admixture to the
seem to be lower than any stratum of
position it seems highly probable tha
sion; and as the beds near the South
part of the copper-bearing series, see
descending order, an uninterrupted s
bearing deposits and the Lake Super
the strata on the east side of the axi
sloping west side finds its explanatio
heaval of the Trap range, in its subs
western margin from the water, whil
remains submerged. The deposits, w
with undisturbed regularity on the g
abrupt edges facing the east side in d
suggest a following subsidence of thi
to the Trap range, on the east side
found superimposed on the Huronian
the later horizontal strata were formi

Summarized, Dr. Rominger's
The sandstones on the lake sh

ly by the erosion of the waves of that
e Eastern Sandstone was laid down.
aw Series extends unconformably con-
h the Eastern Sandstone to the South
e trough in which this sandstone lies
luced by erosion.

ve have to object that it demands
ivably great thickness for the Kewee-
an enormously great erosion prior to
the sandstone. By supposing the
trap range to have been in the first
f faulting, we remove both of these
re then able to accept the view of
rithout further reserve, though with

E ROMINGER VIEW.

gical Survey of Michigan, Vol. I, Part III,
ies lining the eastern shore of Keweenaw
ating to the center of the Peninsula, retain-
sition and also their lithological characters
he different strata can be parallelized with-
e of the more eastern localities. Near the
andstone ledges are found at once abutting
ges of a different rock series—the *Copper-*
m the most elevated central crest of the
of the upheaved rock series is in con-
of the peninsula, from southwest to north-
s of the strata look to the southeast and
site direction, under angles variable from
out intending to enter into a closer exam-
and composition of the copper-bearing
eneral terms as composed of mighty con-
ed with sandstone ledges, exhibiting per-
s, which demonstrate their aqueous sedi-
ng in often-repeated sequence with pow-
ne or semi-crystalline rocks, which are
collective name of trap but are of a very
composition. The thickness of this for-
le, and I think is rather under-estimated
formable abutment of the Lake Superior
rappean series is in several places near
bserved (pp. 95–96).

* * * *

Trap range, half a mile south of Port-
nterops of only slightly inclined sand-
ke shore, and continue southwestward
h. Along the space of about a mile,
the surface. The uppermost are thin-
ous layers; below these follow light
ledge, which are quarried for the pur-



pose of filling the cribs built out into the lake for protection of the entry; under them again more shaly and thin-bedded layers follow; and the lowest exposed beds are dark, fine grained, hard sandstones, of laminated structure, in beds of five and six feet thickness, which are susceptible of being split into thin, even slabs of any desired thickness. This rock is also used for the above mentioned purpose, but could be quarried in large, fine blocks, which would serve a better purpose. The strata are very frequently ripple-marked and exhibit discordant stratification.

"The white and red banded or spotted appearance, so common in the series of the east side, is also observed here, and the geological horizon of these layers cannot be far below the eastern deposits. For the distance of ten or twelve miles eastward from there all the surface rock is sandstone, but the forest covering of the country does not allow us to follow across the series. A few miles west of Houghton, about a mile west of the South Pewabic stamp mills, dark, blackish brown sandstones, of fine grain, intermingled with micaceous scales, and quite hard, compose the hills. Their dip is about 35 degrees to the northwest, and a succession of such layers continues as we go eastward to the South Pewabic stamp mills, where apparently lower strata having the same strike and dip are largely exposed.

"They are in beds of various thickness and alternate with sandy shales full of ripple-marks. Next below follow conglomerate beds, some of which are composed of granules not larger than mustard seed up to the size of a pea; they have a very abundant zeolithic cement (Laumonite).

"Other conglomerate beds are very coarse, with pebbles, some of which are bigger than a man's fist. The pebbles are of porphyritic character and a good proportion of trappean rocks and pieces of sandstone and shale are intermingled.

"Laumonite and calcspar crystals likewise make part of the conglomerates, which immediately rest on crystalline trap rock. All these beds, which must amount to several thousand feet, are in conformable superposition; and the suggestion, which, however, is not perfectly demonstrated, is, that such strata, with gradually decreasing dip, succeed in a westerly direction, and connect in uninterrupted conformable series with the sandstones forming the western shore line.

The rock character of all the sandstones of the west side of the Trap range is throughout of much darker ferruginous tint and mixed with a greater proportion of cementing substance than the rocks of the east side. The red zeolithic mineral exclusively forming the cement of the finer-grained conglomerates at the South Pewabic stamp mills is also, in the much higher beds near Portage canal entry, distinctly recognizable as an admixture to the sandstones. These upper beds of the west side seem to be lower than any stratum of the east side, but from their almost horizontal position it seems highly probable that they follow the strata in conformable succession; and as the beds near the South Pewabic stamp mills, which undoubtedly make part of the copper-bearing series, seem to be their conformable continuation in the descending order, an uninterrupted serial connection between the trappean copper-bearing deposits and the Lake Superior sandstones is obvious. The discordance of the strata on the east side of the axis of elevation and their conformability on the sloping west side finds its explanation in the hypothesis of a gradual submarine upheaval of the Trap range, in its subsequent rupture, and the final emergence of the western margin from the water, while the eastern portion of the fissured earth's crust remains submerged. The deposits, which on the west side continued to accumulate with undisturbed regularity on the gradually diminishing slope, had to meet with the abrupt edges facing the east side in discordant horizontal position; and if we further suggest a following subsidence of this eastern portion, we can explain why, so close to the Trap range, on the east side of it, none of the lower beds of the series are found superimposed on the Huronian slates. These were submerged at the time that the later horizontal strata were forming (pp. 96–98)."

Summarized, Dr. Rominger's argument appears somewhat as follows: The sandstones on the lake shore at the mouth of the Portage canal

approach the Eastern Sandstone in character so closely that they may be considered as belonging to the same formation, or rather immediately below that portion of the Eastern Sandstone now exposed to view. The Portage canal sandstones *seem* to be the uppermost member of the copper-bearing series, and therefore in them we find beds linking the Eastern Sandstone and the Keweenaw Series; and the latter sandstone must therefore have conformably and horizontally beneath it, the same great trappean series that forms the greater part of Keweenaw Point. The latter series is separated from its equivalent beneath the Eastern Sandstone by a fault, but this fault took place before the deposition of the Eastern Sandstone was completed. Therefore, in being laid down, this sandstone had to meet the trappean beds unconformably on the east side of the range while following them conformably on the west side. On this view, the copper-bearing series is an older formation than the Eastern Sandstone, but is not separated from it by a great unconformity.

Dr. Rominger's conclusions rest largely upon a similarity between the sandstones at the mouth of the Portage Canal and those east of the trap range. We have already shown that this similarity is not nearly so great as has been supposed, and, moreover, that it is not evident that the Portage canal sandstones really belong to the Keweenaw Series, there being between them and the Keweenawan rocks a wide belt without exposures. We have also shown that the uppermost undoubted Keweenawan sandstones always contrast strongly in lithological characters with the Eastern Sandstone itself.

However, we find more cogent reasons for dissent from Rominger's view outside of the special field to which this discussion is limited. In the Saint Croix region we have found the Potsdam Sandstone deposited upon the upturned Keweenaw Series, and inserted in deep valleys and wrapping around considerable hills carved from the Keweenawan rocks in the interval between their upheaval and the deposition of the Potsdam Sandstone. So, also, in the Gogebic region, sandstone is found to lie horizontally in gaps eroded in the upturned Keweenaw Series. So, again, north of the Montreal, the horizontal sandstone is seen to approach within two miles of the upturned Keweenaw Series, which there stands at an angle of 80°. Manifestly, therefore, this upheaval must have taken place before the deposition of the horizontal sandstone on its two sides, and there must have been sufficient interval for the erosion of the upturned series to the depth and extent of the valleys filled by the sandstone. These we regard as specific evidences that the deposition of the horizontal series was separated from the upheaval of the tilted series by a geologically important time-interval.

Again, on Dr. Rominger's view the Eastern Sandstone must have the series of Keweenawan traps conformably beneath it; but, as Pumpelly long since showed, the Eastern Sandstone overlies the Keweenawan traps of the South Range with a most unmistakable unconformity, lying horizontally quite across the steeply inclined Keweenawan belts.





THE CRE

*H. Credner.* (Elemente der Geologie,
die Eruptivgesteine, welche zwischen d
steinen am Südufer des Lake Superior in

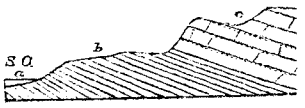



FIG. 21. Profil durch Keweenaw Point im Lake
rische Sandsteine und Conglomerate; c Melaphy
glomeraten.[1]

in Gestalt einer Schichtenreihe von abw
aphyrmandelsteinen mit untergeordnet
nerungsleeren Sandsteinen und Conglome
dung des benachbarten Nebengesteines a

*M. E. Wadsworth.* (Notes on the Geol
Superior. Bulletin of the Museum of C
"The general geological structure of th
follows. Beginning on the southeastern
and conglomerate overlaid by melaphyr.
stones and conglomerates, principally the
base, sandstone, and conglomerate, with
inating, continue across the center of the
western side is approached, the sandstone
aphyr and diabase diminish, until a pure

"All these rocks taken together make
down successively one upon the other
west. These rocks are known to form th
one another. These traps are old lav
surface along a shore line. They have f
under like conditions and retain the sam
modified by the agencies to which they
127).

* * *

"Most of these old basalts are directl
greater or lesser intervals of time; but
glomerates and sandstones. These congl
and water-worn character of their const
deposits. The surface of the underlyin
overlying conglomerate is made up at
from the underlying rock and mixed wi
conglomerates are chiefly composed. T
entirely wanting, as we recede from the

[1] FIG. 21.— Section through Keween
*a*, Lake Superior; *b*, Lower Silurian sa
phyrs, alternating with amygdaloids an

[2] "Considerable interest attaches to
stones on the southern shore of Lake Su
long to the lower Silurian. They appe
melaphyrs and melaphyr-amygdaloids,
tween sandstones and conglomerates de
eruptive rocks and the formation of the
same period."

character so closely that they may
ne formation, or rather immediately
ndstone now exposed to view. The
be the uppermost member of the
in them we find beds linking the
w Series; and the latter sandstone
l horizontally beneath it, the same
greater part of Keweenaw Point.
s equivalent beneath the Eastern
k place before the deposition of the
Therefore, in being laid down, this
eds unconformably on the east side
formably on the west side. On this
older formation than the Eastern
it by a great unconformity.
argely upon a similarity between
ortage Canal and those east of the
that this similarity is not nearly
moreover, that it is not evident
really belong to the Keweenaw
he Keweenawan rocks a wide belt
wn that the uppermost undoubted
rast[illegible]ongly in lithological char-
elf.

sons for dissent from Rominger's
ich this discussion is limited. In
l the Potsdam Sandstone depos-
ries, and inserted in deep valleys
lls carved from the Keweenawan
beaval and the deposition of the
fogebic region, sandstone is found
the upturned Keweenaw Series.
horizontal sandstone is seen to
turned Keweenaw Series, which
nifestly, therefore, this upheaval
position of the horizontal sand-
have been sufficient interval for
e depth and extent of the valleys
ard as specific evidences that the
separated from the upheaval of
rtant time-interval.
astern Sandstone must have the
ly beneath it; but, as Pumpelly
tone overlies the Keweenawan
nmistakable unconformity, lying
clined Keweenawan belts.



## THE CREDNER VIEW.

*H. Credner.* (Elemente der Geologie, 1878, p. 416). "Hohes Interesse besitzen die Eruptivgesteine, welche zwischen den wahrscheinlich untersilurischen Sandsteinen am Südufer des Lake Superior in Nord Amerika eingelagert sind. Sie treten

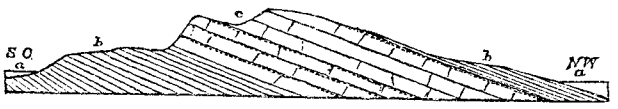



FIG. 21. Profil durch Keweenaw Point im Lake Superior (*H. Crd.*). *a* Lake Superior; *b* Untersilurische Sandsteine und Conglomerate; *c* Melaphyrlager, wechsellagernd mit Mandelsteinen und Conglomeraten.[1]

in Gestalt einer Schichtenreihe von abwechselnden Dioriten, Melaphyren und Melaphyrmandelsteinen mit untergeordneten Conglomeratbänken zwischen versteinerungsleeren Sandsteinen und Conglomeraten auf, so dass ihre Eruption und die Bildung des benachbarten Nebengesteines augenscheinlich in dieselbe Periode fällt."[2]

*M. E. Wadsworth.* (Notes on the Geology of the Iron and Copper Districts of Lake Superior. Bulletin of the Museum of Comparative Zoölogy, Vol. VII, No. I, 1880). "The general geological structure of the region visited by us is, then, in general, as follows. Beginning on the southeastern side of Keweenaw Point we find a sandstone and conglomerate overlaid by melaphyr. This melaphyr is again overlaid by sandstones and conglomerates, principally the latter. The alternations of melaphyr, diabase, sandstone, and conglomerate, with the melaphyr and diabase largely predominating, continue across the center of the Point, forming its backbone. As the northwestern side is approached, the sandstones and conglomerates increase, while the melaphyr and diabase diminish, until a purely sandstone formation is reached.

"All these rocks taken together make one geological formation and have been laid down successively one upon the other in order, going from the east towards the west. These rocks are known to form the same series by their conformably overlying one another. These traps are old lava flows, spread out over the then existing surface along a shore line. They have flowed the same as modern basaltic lavas do under like conditions and retain the same characters, except so far as they have been modified by the agencies to which they have been subjected since their outflow (p. 127).

* * * * * * *

"Most of these old basalts are directly covered by succeeding flows, following after greater or lesser intervals of time; but part, as remarked above, are covered by conglomerates and sandstones. These conglomerates and sandstones show, by the rounded and water-worn character of their constituent pebbles and grains, that they are beach deposits. The surface of the underlying basalt is smoothed as by water action. The overlying conglomerate is made up at its base of basaltic mud and pebbles, derived from the underlying rock and mixed with the felsitic mud and pebbles of which the conglomerates are chiefly composed. The trappean mud and pebbles diminish, or are entirely wanting, as we recede from the underlying trap (p. 128)."

[1] FIG. 21.— Section through Keweenaw Point, on Lake Superior. (H. Credner). *a*, Lake Superior; *b*, Lower Silurian sandstones and conglomerates; *c*, layer of melaphyrs, alternating with amygdaloids and conglomerates.

[2] "Considerable interest attaches to the eruptive rocks lying between the sandstones on the southern shore of Lake Superior, in North America, which probably belong to the lower Silurian. They appear as a series of layers of alternating diorites, melaphyrs and melaphyr-amygdaloids, with subordinate banks of conglomerate, between sandstones and conglomerates destitute of fossils. Thus the protrusion of the eruptive rocks and the formation of the neighboring layers evidently fall within the same period."

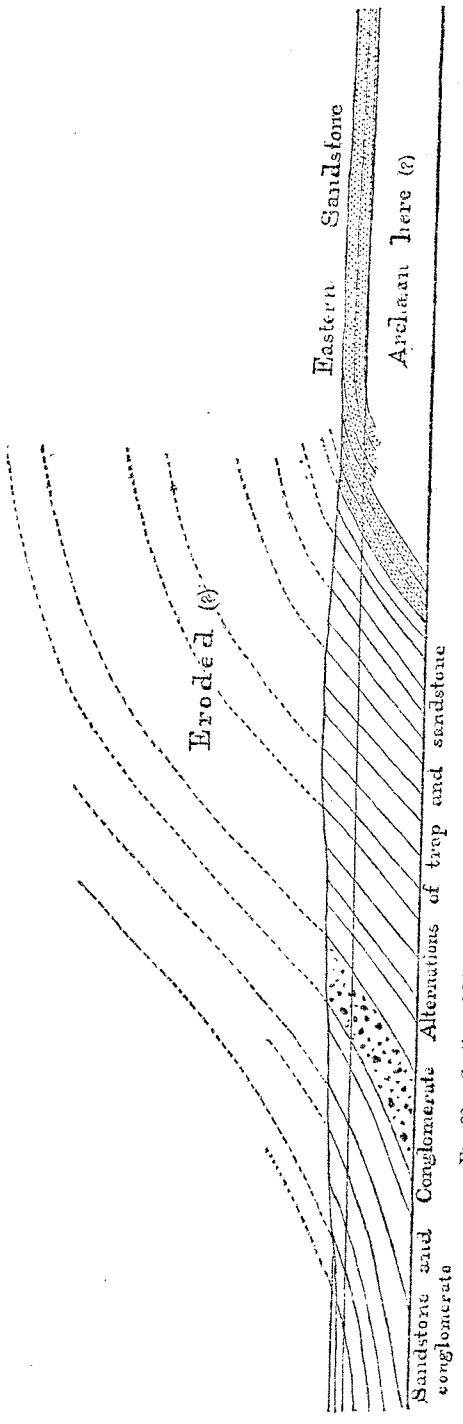



FIG. 22.—Section of Keweenaw Point, on the Credner view. Drawn to a natural scale of 2 miles to the inch.

In advancing this view Credner, as above quoted, gives only a general statement without accompanying proof, nor have we met with any paper by this author in which such proof is adduced.

In Figure 22 we give a cross-section of Keweenaw Point on the view expressed in Credner's sketch (Figure 21). Unlike his figure, we have drawn ours to a natural scale and with due regard to the inclinations of the Keweenawan beds as now determined.

Mr. Wadsworth, in advancing the same view subsequently, appealed for support only to the occurrences at the contacts on the Hungarian and Douglass Houghton Ravines. It does not appear that he advocates all of the conditions that Credner's sketch would imply, but he does not give any sketch illustrative of his views as to the general relations of the Keweenaw Series and the Eastern Sandstone. Nor does he give any sufficiently definite statements from which we can construct a sketch with any certainty that it would express his views. Indeed, we have failed, after many attempts, to reach any definite conception of a structure which would be in accordance with all of his statements.

On the structural view expressed in Credner's sketch it seems to us that it would be necessary to believe in an incredibly great amount of de-





nudation, as we have indicated in
has removed from the flat regio
the continuation in that direction
view such a continuation must ha
not seem possible to conceive that
inclined, for enormous thicknesses,
90° (Montreal River), with their co
sandstone, could have been deposi
occupy. They have evidently bee
lation to some disturbing force by
produced. Except for the moder
ing of the center of the basin duri
sequently explain, we conceive th
spread out in a relatively flat po
ficiently evident from the interlea
deposited, often ripple-marked, s
of the series, in the region of th
sandstones stand now at an angl
indeed, the entire Keweenaw Seri
from the lowest trap to the hi
position; while but a few miles
izontally.[1] It seems manifest, th
basal member of this series, the e
conglomerates, and traps must o
on top of it. Reconstructing th
at this time and before these
position, we find ourselves force
this great thickness stopped sud
of this height or else it once e
present northern limit of the E
tives we must, of course, selec
find ourselves obliged to explai
great series in the sandstone c
this theory offers no satisfactory
linear, often cliffy, southern limi
son, the southern face of the m
sive eruptions along its line.
Rominger, it is the result of faul
is a cliff of erosion, but erosion
Sandstone. The view at present
for this abrupt limit, but it is
must regard it as a cliff of erosio
cliff without recesses or outliers
unharmed a soft and friable san
uation of the rocks composing th

[1] Monographs United States Geological

In advancing this view Credner, as above quoted, gives only a general statement without accompanying proof, nor have we met with any paper by this author in which such proof is adduced.

In Figure 22 we give a cross-section of Keweenaw Point on the view expressed in Credner's sketch (Figure 21). Unlike his figure, we have drawn ours to a natural scale and with due regard to the inclinations of the Keweenawan beds as now determined.

Mr. Wadsworth, in advancing the same view subsequently, appealed for support only to the occurrences at the contacts on the Hungarian and Douglass Houghton Ravines. It does not appear that he advocates all of the conditions that Credner's sketch would imply, but he does not give any sketch illustrative of his views as to the general relations of the Keweenaw Series and the Eastern Sandstone. Nor does he give any sufficiently definite statements from which we can construct a sketch with any certainty that it would express his views. Indeed, we have failed, after many attempts, to reach any definite conception of a structure which would be in accordance with all of his statements.

On the structural view expressed in Credner's sketch it seems to us that it would be necessary to believe in an incredibly great amount of denudation, as we have indicated in Figure 22, and in a denudation which has removed from the flat region to the south of Keweenaw Point the continuation in that direction of the trappean series. That on this view such a continuation must have existed is evident to us. It does not seem possible to conceive that the beds of the trappean series, often inclined, for enormous thicknesses, at an angle of over 45° and even up to 90° (Montreal River), with their conformably overlying enormously thick sandstone, could have been deposited in any such positions as they now occupy. They have evidently been subjected during and since accumulation to some disturbing force by which their inclined position has been produced. Except for the moderate inclinations due to a gradual sinking of the center of the basin during the growth of the series, as we subsequently explain, we conceive that the entire series must have been spread out in a relatively flat position. That this was so seems sufficiently evident from the interleaving throughout the series of water-deposited, often ripple-marked, sediments. Even at the very summit of the series, in the region of the Montreal River, the ripple-marked sandstones stand now at an angle of 80° to 90°. On the river named, indeed, the entire Keweenaw Series, with a thickness of over 45,000 feet from the lowest trap to the highest sandstone, occupies a vertical position; while but a few miles away the Eastern Sandstone lies horizontally.[1] It seems manifest, then, that if the latter sandstone be the basal member of this series, the entire 45,000 feet or more of sandstones, conglomerates, and traps must once have been spread out horizontally on top of it. Reconstructing the conditions that must have obtained at this time and before these rocks were thrown into an inclined position, we find ourselves forced to one of two alternatives: either this great thickness stopped suddenly to the south with a vertical wall of this height or else it once extended far to the southward of the present northern limit of the Eastern Sandstone. Of these alternatives we must, of course, select the latter; when we immediately find ourselves obliged to explain the entire absence of outliers of this great series in the sandstone country to the south. In other words, this theory offers no satisfactory explanation for the singularly abrupt, linear, often cliffy, southern limit of the trappean series. With Jackson, the southern face of the main trap range is the result of intrusive eruptions along its line. With Foster and Whitney, and with Rominger, it is the result of faulting. With Agassiz and Pumpelly, it is a cliff of erosion, but erosion before the deposition of the Eastern Sandstone. The view at present under discussion offers no explanation for this abrupt limit, but it is evident that under this view also we must regard it as a cliff of erosion. But an erosion that leaves a linear cliff without recesses or outliers, and one which yet has in front of it unharmed a soft and friable sandstone, above which once lay a continuation of the rocks composing the cliff, is to us quite incredible.

Fig. 22.—Section of Keweenaw Point, on the [illegible] view. Drawn to a natural scale of 2 miles to the inch.

Sandstone and Conglomerate Alternations of trap and sandstone conglomerate

[1] Monographs United States Geological Survey, Vol. V, pp. 226-230, Plates XXI, XXII.

There are many other considerations of a general character which forbid an acceptance of the Credner hypothesis. We may merely refer to the singular difficulty this view offers us in interposing between the Eastern Sandstone and the overlying Calciferous, the great trappean series of over 45,000 feet thickness, of which over a third is sediment; and this when but a few miles away from Keweenaw Point, eastward from Marquette, the Eastern Sandstone grades upwards imperceptibly into the Calciferous. Still nearer to the south face of the Keweenaw Range is the Trenton Limestone of the hills in Sections 13, 14, 23, and 24 of T. 51, R. 35 W., as described by Rominger and others. Experience with the lower Paleozoic throughout the Northwest would warrant us in believing that underneath these limestones, and between them and the still lower Eastern or Potsdam Sandstone, lies the Calciferous, now hidden by drift. But even if this be not the case, and the Trenton here be placed directly on the Potsdam, it is a heavy strain on our credulity to ask us to place the great Keweenaw Series in this interval.

Turning now our attention to the occurrences along the immediate contact line between the Eastern Sandstone and the trappean series, upon which occurrences at two localities Mr. Wadsworth bases his advocacy of a view essentially the same as that of Credner, we observe that he makes special use of (1) a passage of the Eastern Sandstone conformably beneath the trappean series, (2) an interstratification of the Eastern Sandstone with traps at the junction, (3) an induration of the Eastern Sandstone at the junction by the heat of the overlying trap, and (4) the absence of fragments derived from the trappean series within the Eastern Sandstone below the contact. We have already, in describing the several important localities, shown that the facts, as we read them, do not support Mr. Wadsworth in any of these points.

We need not repeat details here, but as to the conformable passage of the Eastern Sandstone beneath the trappean series may recall that, on Bête Grise Bay, three localities have been described by several different observers, by all of whom it is specifically asserted that the Eastern Sandstone does not pass beneath the Keweenaw Series at all, but overlies it; that in the Wall Ravine, the Eastern Sandstone, instead of dipping beneath the Keweenawan beds, as demanded by this hypothesis, shoots upward toward the zenith; that in the Saint Louis Ravine the beds are likewise turned skyward near the contact and at a short distance away they dip at lower inclinations *away* from the Keweenaw Series; that Pumpelly and Rominger describe the Eastern Sandstone near Houghton as dipping away from the Keweenaw Series at a notably high angle; that in the region back from Ontonagon Chauvenet describes the Eastern Sandstone as likewise dipping away from the Keweenaw Series near the contact; and that in none of these localities is there any approach to a conformity with the hypothesis of Credner and Wadsworth. We may also remind the reader that there is no such conformity at the specific localities from which Mr. Wads-





worth draws his sole support of
is a lower and conformable men
merely been brought to the surf
to present a dip and a general st
the rest of the great series. N
quite remarkable steadiness and
nowhere notably warped, nor do
graphical aspect to another. The
the actual subterranean explorat
insula (reaching down, in two in
the assiduity with which every
furnished us an unsurpassed de
condition and of its stratal unif
diate vicinity of the localities w
of this view, the great Calumet
slope of a thin bed of conglomera
of the mining company have det
cision, and found it to be so ste
as 38½° has been adopted as a w
angle are found so slight that it
to the adopted uniform plane th
inequalities of the dip. The exp
able profile sections of Marvine
Now, it is simply incredible that
rior beds happen to be denuded
lying sandstone, there should h
the strata above described, and
tion in the general character of t
of the series. It is the more s
line, the dip again becomes me
true, the dip of the Eastern San
as that of the Keweenaw Series
eastward it should be gradual a
the rest of the formation. Now,
beds of the Eastern Sandstone, i
the trappean series with a like
in a manner altogether inconsiste
Series. In the Hungarian Ravin
similarly discordant with those
abrupt change in the general cha
at the junction is nowhere know
of this district. There is an e
graphical characteristics of the E
the adjacent Keweenaw Series.
gruity, and were it not for the f
the fact that in the Hungarian

ions of a general character which for-
hypothesis. We may merely refer to
rs us in interposing between the East-
Calciferous, the great trappean series
hich over a third is sediment; and
om Keweenaw Point, eastward from
grades upwards imperceptibly into
e south face of the Keweenaw Range
lls in Sections 13, 14, 23, and 24 of T.
inger and others. Experience with
he Northwest would warrant us in
estones, and between them and the
andstone, lies the Calciferous, now
e not the case, and the Trenton here
it is a heavy strain on our credulity
aw Series in this interval.
e occurrences along the immediate
Sandstone and the trappean series,
dities Mr. Wadsworth bases his ad-
as that of Credner, we observe that
of the Eastern Sandstone conforma-
an interstratification of the Eastern
n, (3) an induration of the Eastern
at o[illegible] overlying trap, and (4) the
he trappean series within the East-
We have already, in describing the
hat the facts, as we read them, do
of these points.
, but as to the conformable pas-
ath the trappean series may recall
ies have been described by several
it is specifically asserted that the
neath the Keweenaw Series at all,
ne, the Eastern Sandstone, instead
beds, as demanded by this hypoth-
ith; that in the Saint Louis Ra-
skyward near the contact and at
lower inclinations *away* from the
d Rominger describe the Eastern
away from the Keweenaw Series
he region back from Ontonagon
ndstone as likewise dipping away
ontact; and that in none of these
conformity with the hypothesis of
lso remind the reader that there
localities from which Mr. Wads-



worth draws his sole support of the theory. If the Eastern Sandstone is a lower and conformable member of the Keweenaw Series, and has merely been brought to the surface by denudation, it should be found to present a dip and a general stratigraphical behavior harmonious with the rest of the great series. Now, the Keweenaw Series possesses a quite remarkable steadiness and uniformity of dip in this district. It is nowhere notably warped, nor does it abruptly change from one stratigraphical aspect to another. The careful studies of Pumpelly and Marvine, the actual subterranean explorations of the numerous mines of the peninsula (reaching down, in two instances, to more than 3,000 feet), and the assiduity with which every portion of it has been prospected, have furnished us an unsurpassed demonstration of its thoroughly bedded condition and of its stratal uniformity and consistency. In the immediate vicinity of the localities which have been appealed to in support of this view, the great Calumet and Hecla mine has followed down the slope of a thin bed of conglomerate more than 3,500 feet. The engineers of the mining company have determined the dip with the greatest precision, and found it to be so steady and uniform that so precise a dip as 38½° has been adopted as a working basis, and variations from this angle are found so slight that it is more economical to cut them down to the adopted uniform plane than to adjust the workings to the slight inequalities of the dip. The experience in other mines and the remarkable profile sections of Marvine testify to the same striking feature. Now, it is simply incredible that just along the line at which the superior beds happen to be denuded away from over the supposed underlying sandstone, there should happen to be the various distortions of the strata above described, and that there should be a sudden transition in the general character of the dip and the stratigraphical behavior of the series. It is the more surprising since, a little away from that line, the dip again becomes measurably uniform. If this view were true, the dip of the Eastern Sandstone should be essentially the same as that of the Keweenaw Series, or if there were a flattening to the eastward it should be gradual and progressive to be in harmony with the rest of the formation. Now, in the Douglass Houghton Ravine the beds of the Eastern Sandstone, instead of passing conformably beneath the trappean series with a like steady dip, are warped and angulated in a manner altogether inconsistent with the character of the Keweenaw Series. In the Hungarian Ravine the dips of the Eastern Sandstone are similarly discordant with those of the Keweenaw Series, and such an abrupt change in the general character of the dips as that which occurs at the junction is nowhere known in the undoubted Keweenaw Series of this district. There is an entire incongruity between the stratigraphical characteristics of the Eastern Sandstone in these ravines and the adjacent Keweenaw Series. Were it not for this conspicuous incongruity, and were it not for the fatal evidence at several other points, the fact that in the Hungarian Ravine, and in part in the Douglass

Houghton Ravine, the beds of the Eastern Sandstone at the immediate contact are bent downward in approximate conformity to the overhanging Keweenaw beds might afford some apparent support for the hypothesis. But this is so manifestly one of the several phases of the distortion that accompanies the contact of these diverse formations that we do not see how any weight could be attached to it, even if the nature of the junction and the other classes of evidence did not stand so completely in antagonism to it. So far as we can see, there is no single instance along the whole line which conforms, even approximately, to a consistency of dip between the Eastern Sandstone and the immediately adjacent portion of the Keweenaw Series. In other words, we hold the theory to be entirely without stratigraphical support.

The interstratifications of the Eastern Sandstone and traps in the Douglass Houghton Ravine we do not accept, for reasons already given at some length.

As to the induration of the Eastern Sandstone by the heat of trappean overflow at the junction, we have to say that we find no greater induration at the contact than at points distant from it; besides which, it is to be remarked that even were such induration present it would, in our view, be no proof of heat action, unless it were proved to be baking, as of argillaceous materials, or semi-fusion.

With regard to the absence of pebbles from the trappean series in the Eastern Sandstone below the contact, we would say that we find such pebbles in the greatest abundance and *no others*. These pebbles are from both the acid and basic eruptives of the Keweenaw Series. Mr. Wadsworth recognizes the presence of the acid pebbles, describing a number, and showing that they are identical with the acid pebbles of the conglomerates of the trappean series itself. His denial of the occurrence in the Eastern Sandstone of fragments from the supposed Keweenaw Series is based upon a lack of fragments from the ordinary basic eruptives of that series. It seems evident that when he wrote he did not regard the acid pebbles as of Keweenawan derivation. Yet the rocks represented by these pebbles occur abundantly in the Keweenaw Series, and especially in the lower horizons of that series nearest to the contact line; and there is no other group of rocks known to exist in the entire Lake Superior region from which these pebbles could possibly have been derived naturally in the variety and assortment in which they exist. Moreover, pebbles of the basic Keweenawan eruptives, whose presence in the Eastern Sandstone is denied by Wadsworth, are to be found there in the greatest abundance, and often of a character not merely in a general way corresponding to that of the Keweenawan basic rocks, but of kinds corresponding in every detail with individual rocks *in situ* at the immediate contact. Again, as these pebbles range from three to five hundred feet below the uppermost beds of the Eastern Sandstone, we see no tenable explanation of their occurrence under Wadsworth's hypothesis. Furthermore, the distribution and the spe-





cial character of these pebble seer
local derivation from an immediat

In addition to the foregoing co
Eastern Sandstone is a lower co
Series, the contact between the t
depositional forms. In this instar
been overflowed by a flood of lav
istics of such a succession. This
that the underlying sandstone was
we have shown, by extensive exc
Houghton and Wall Ravines, and
there lies a bed of mixed trappea
clay, and quartzose sand, all of w
the slightest evidence of baking
thermore, we have found the basa
sent a poorly defined surface inste
which the lava flows of the region
we have found the adjacent surface
plete, instead of presenting the
have possessed when overspread b
tion of the problematical rock in t
described above, we find nowhere
overflow which Mr. Wadsworth
find specific evidence which we co

There is an additional and grav
ern Sandstone is a conformable lov
be the one always in contact and
of the trappean series. But at
tion, have we found the same be
Grise Bay locality (B of Plate II)
base of the Keweenaw Series. A
the sandstone rests upon a luste
we place low in the series. In t
next to porphyritic conglomerate
Saint Louis Ravine it adjoins a di
below the Saint Louis conglomera
it comes in contact with a decom
horizon, while at the Hungarian
immediately underlies a thick, co
considered that the last four local
other, the whole four lying within
violence to the known character
that these differences of contact
beds. For, whatever may be the
ency of the lava flows, the beds

astern Sandstone at the immediate
roximate conformity to the over-
rd some apparent support for the
ly one of the several phases of the
act of these diverse formations that
be attached to it, even if the nature
of evidence did not stand so com-
as we can see, there is no single
n conforms, even approximately, to
astern Sandstone and the immedi-
eenaw Series. In other words, we
at stratigraphical support.
stern Sandstone and traps in the
ot accept, for reasons already given

ern Sandstone by the heat of trap-
have to say that we find no greater
ints distant from it; besides which,
such induration present it would,
on, unless it were proved to be bak-
semi-fusion.
ebbles from the trappean series in
contact, we would say that we find
ance and *no others*. These pebbles
erup[illegible]s of the Keweenaw Series.
nce of the acid pebbles, describing
e identical with the acid pebbles of
eries itself. His denial of the occur-
agments from the supposed Kewee-
fragments from the ordinary basic
evident that when he wrote he did
Keweenawan derivation. Yet the
occur abundantly in the Keweenaw
orizons of that series nearest to the
roup of rocks known to exist in the
which these pebbles could possibly
ariety and assortment in which they
asic Keweenawan eruptives, whose
is denied by Wadsworth, are to be
ance, and often of a character not
nding to that of the Keweenawan
ding in every detail with individual
act. Again, as these pebbles range
ow the uppermost beds of the East-
xplanation of their occurrence under
more, the distribution and the spe-

70)



cial character of these pebble seems to us to quite clearly indicate their local derivation from an immediately adjacent shore.

In addition to the foregoing considerations we may urge that if the Eastern Sandstone is a lower conformable member of the Keweenaw Series, the contact between the two should assume one of the usual depositional forms. In this instance the sandstone is supposed to have been overflowed by a flood of lava and should present the characteristics of such a succession. This Mr. Wadsworth assumes, and asserts that the underlying sandstone was baked by the igneous overflow. But we have shown, by extensive excavations in the Hungarian, Douglass Houghton and Wall Ravines, and on Bête Grise Bay, that at the contact there lies a bed of mixed trappean fragments, comminuted trap, joint clay, and quartzose sand, all of which remain soft and do not present the slightest evidence of baking due to the supposed overflow. Furthermore, we have found the basal portion of the igneous rock to present a poorly defined surface instead of the definite amygdaloidal base which the lava flows of the region usually present. So, in like manner, we have found the adjacent surface of the Eastern Sandstone also incomplete, instead of presenting the determinate surface which it should have possessed when overspread by the lava. In short, with the exception of the problematical rock in the Hungarian Ravine, which we have described above, we find nowhere the slightest evidence of the igneous overflow which Mr. Wadsworth advocates; but, on the contrary, we find specific evidence which we conceive to be altogether fatal to it.

There is an additional and grave objection to this view. If the Eastern Sandstone is a conformable lower member, its uppermost bed should be the one always in contact and it should underlie the basal member of the trappean series. But at no two localities, within our observation, have we found the same beds in contact. At the eastern Bête Grise Bay locality (B of Plate II) the sandstone joins an ordinary diabase of the Keweenaw Series. At the western locality (A of Plate II) the sandstone rests upon a luster-mottled melaphyr. Both of these we place low in the series. In the Wall Ravine the sandstone stands next to porphyritic conglomerate much higher in the series. In the Saint Louis Ravine it adjoins a diabase which lies but a short distance below the Saint Louis conglomerate. In the Douglass Houghton gorge, it comes in contact with a decomposed diabase occupying a different horizon, while at the Hungarian locality it touches a diabase which immediately underlies a thick, coarse conglomerate. Now, when it is considered that the last four localities are immediately adjacent to each other, the whole four lying within a space of six miles, it is doing great violence to the known character of the Keweenaw Series to suppose that these differences of contact are due to replacements in its basal beds. For, whatever may be theoretically held concerning the persistency of the lava flows, the beds of conglomerate cannot be hypothet-

ically produced and dismissed with such license. But, in fact, it is quite at variance with the ascertained character of the Keweenaw Series to suppose that either the igneous or detrital beds enter and disappear with the suddenness which this view assumes.

On the other hand, the member of the Eastern Sandstone which makes the contact does not appear to be the same in the several instances. At the eastern locality, on Bête Grise Bay, a conglomerate lies next to the diabase. At the western locality, the contact member is the peculiar shale breccia above described. In the Wall Ravine, the junction member is a sandstone some distance below the most conglomeratic beds. In the Saint Louis Ravine, the contact is formed by sandstone and conglomerate lying close below the most conglomeratic beds. In the Douglass Houghton Ravine, the junction beds are sandstone and shales above the most conglomeratic beds; while in the Hungarian Ravine the junction is made with a thick sandstone stratum which appears to lie some distance above the most conglomeratic beds. On the view which we hold, that these sandstones, shales and conglomerates were formed along a shore line at the base of the Keweenawan escarpment, it is not improbable that frequent minor changes of character occur in the beds as traced along the shore, and we do not, at present, feel prepared to assert that the conglomeratic beds in the several sections are necessarily the same; yet, even under our view, we believe that they are essentially identical, at least so far as the coarse "mud and shingle" deposits of the last four adjacent localities are concerned. But under the hypothesis that these are members of the Eastern Sandstone of distant derivation, a much greater uniformity must be postulated, for they are not within twenty miles of any supposable shore line. It seems to us, therefore, altogether incredible that, under that hypothesis, contacts should occur which were never the same at any two localities, even though they are only one or two miles apart.

It appears to us, therefore, that the view is fatally defective in not coinciding with the facts at the contact line.

Several additional objections lie against this view, but we do not deem it needful to urge them in the wake of these that seem to us so conclusively fatal.

## OUR OWN CONCLUSIONS.

Our own previous expressions of opinion regarding the phenomena observed along the south face of the Keweenaw Range are contained in the following quotations:

*T. C. Chamberlin.* (In Geology of Wisconsin, Vol. I, Part I, 1883, pp. 105–106): "Parallel to the southwestern projection of Lake Superior, in Douglas and Bayfield Counties, there runs a cliff formed by the upturned edges of igneous southward-dipping beds, against which a later formed horizontal sandstone (Potsdam) abuts, show-





ing that it stood as a sea-cliff in
similar phenomenon of more striking
exposing in the opposite direction a n
sandstone. This may all possibly b
wise demonstrated to exist between
the extent and the regularity of the
phenomenon is due to displacement
were produced by faulting, the displ
approach to a great convulsion th
amount to the settling down of a s
one ten-thousandth part of its distar
of great importance, to be sure, but

*R. D. Irving.* (In Copper-Bearin
States Geological Survey, Vol. V, 1
the Keweenaw Range is both a fault
Eastern Sandstone was laid down, bu
ing took place again after or else co
stone. The original faulting seems
structural relations of the Keweena
page, and by the absence of outli
Keweenaw Range to the southward
subsequently to this first faulting is e
in which the pebbles are frequentl
acid (Bête Grise Bay), and by the v
South Range beds. That faulting
or during the deposition of the Easte
the sandstone dips southward along
naw Range (p. 365)."

"The relation of the rocks of the So
is one of the greatest interest. A n
serve to show that towards the east t
between them, even west of the Ont
further west they rapidly approach,
northward. Should we suppose a cor
tal sandstone, we should obtain an
must diminish with an incredible rap
total apparent thickness of the Lowe
feet, or only 8,000 feet more than on
the sandstone-filled area seems improl
the south side of the Keweenaw Ran
its junction with the South range. I
exist, Foster and Whitney in their re
along the son h side of the Keweena
examination that no southern dip exi

"To explain the sudden break on t
the Keweenawan beds and the East
supposed this line to be one of fault
of that on the west side of the range,
latter position I shall show subsequen
has taken place on this line, even a
plainly enough by the fact that at th
markable manner, presenting for sho
dips. On Bête Grise Bay these dips re
within 200 feet and to horizontality v

ich license. But, in fact, it is quite
racter of the Keweenaw Series to
letrital beds enter and disappear
assumes.

ie Eastern Sandstone which makes
he same in the several instances.
e Bay, a conglomerate lies next to
, the contact member is the pecu-
In the Wall Ravine, the junction
ce below the most conglomeratic
ie contact is formed by sandstone
he most conglomeratic beds. In
junction beds are sandstone and
beds; while in the Hungarian Ra-
ick sandstone stratum which ap-
nost conglomeratic beds. On the
stones, shales and conglomerates
base of the Keweenawan escarp-
nent minor changes of character
shore, and we do not, at present,
lomeratic beds in the several sec-
even under our view, we believe
least so far as the coarse "mud
adjacent localities are concerned.
ire members of the Eastern Sand-
reat uniformity must be postu-
iles of any supposable shore line.
ıcredible that, under that hypoth-
never the same at any two local-
or two miles apart.
view is fatally defective in not
ct line.
igainst this view, but we do not
wake of these that seem to us so

CLUSIONS.

pinion regarding the phenomena
Keweenaw Range are contained

sin, Vol. I, Part I, 1883, pp. 105-106):
ake Superior, in Douglas and Bayfield
urned edges of igneous southward-dip-
ntal sandstone (Potsdam) abuts, show-



ing that it stood as a sea-cliff in the Potsdam seas. Keweenaw Point presents a similar phenomenon of more striking character, its beds dipping northwestward and exposing in the opposite direction a mural face against which abuts a similar horizontal sandstone. This may all possibly be the work of erosion in the great interval otherwise demonstrated to exist between the Keweenawan period and the Potsdam, but the extent and the regularity of the cliff-faces lends support to the hypothesis that the phenomenon is due to displacement, afterwards modified by erosion. If these cliffs were produced by faulting, the displacement was doubtless attended by the nearest approach to a great convulsion that the period witnessed. At best, this might amount to the settling down of a small bit of the globe's crust to a depth perhaps one ten-thousandth part of its distance from the earth's center—a local phenomenon of great importance, to be sure, but relative to the whole globe, only trivial."

*R. D. Irving.* (In Copper-Bearing Rocks of Lake Superior, Monographs United States Geological Survey, Vol. V, 1883). "It seems to me that the south face of the Keweenaw Range is both a fault cliff and a shore cliff, against which the newer Eastern Sandstone was laid down, but not until after a large erosion; and that faulting took place again after or else continued until after the deposition of the sandstone. The original faulting seems to be demanded on this line by the general structural relations of the Keweenaw and South ranges, as shown on a previous page, and by the absence of outliers of the immense thickness of rocks of the Keweenaw Range to the southward. That the Eastern Sandstone was deposited subsequently to this first faulting is evidenced by its containing conglomerate layers in which the pebbles are frequently of Keweenawan eruptives, basic as well as acid (Bête Grise Bay), and by the way in which it cuts across the course of the South Range beds. That faulting motion took place along the fault line after or during the deposition of the Eastern Sandstone is indicated by the way in which the sandstone dips southward along the junction at the south side of the Keweenaw Range (p. 365)."

"The relation of the rocks of the South Range to those of the Keweenaw Point Range is one of the greatest interest. A moment's inspection of the map of Plate I will serve to show that towards the east the two ranges are widely separated, the distance between them, even west of the Ontonagon, being as much as 18 miles, while still further west they rapidly approach, and finally join. The beds of both ranges dip northward. Should we suppose a continuous series beneath the intervening horizontal sandstone, we should obtain an incredible thickness, and one which westward must diminish with an incredible rapidity, for after the two ranges have joined the total apparent thickness of the Lower Division of the series does not exceed 33,000 feet, or only 8,000 feet more than on Keweenaw Point. That there is a fold beneath the sandstone-filled area seems improbable. There is no sign of a southern dip along the south side of the Keweenaw Range during all its course from Bête Grise Bay to its junction with the South range. I had at one time the idea that such a fold might exist, Foster and Whitney in their report indicating the existence of a southern dip along the south side of the Keweenaw Range, but I have since convinced myself by examination that no southern dip exists.

"To explain the sudden break on the south side of the Keweenaw Range between the Keweenawan beds and the Eastern Sandstone, Foster and Whitney long since supposed this line to be one of fault and the Eastern Sandstone to be the equivalent of that on the west side of the range, the two separated only by the faulting. The latter position I shall show subsequently to be untenable; and yet that some faulting has taken place on this line, even after the deposition of the sandstone, is proven plainly enough by the fact that at the contact the sandstones commonly rise in a remarkable manner, presenting for short distances from the junction high southern dips. On Bête Grise Bay these dips reach 50° at the contact, lessening to 40° and 30° within 200 feet and to horizontality within a mile or less. Farther west the dips at

the contact lessen in amount, becoming scarcely perceptible at Portage Lake, beyond which to the west they again become high. These phenomena are beautifully displayed at a number of points along the west branch of the Ontonagon, east of Lake Agogebic.

"These facts render it plain enough that some faulting took place on this line after the deposition of the sandstone, but the main faulting, I conceive, took place before. By this fault the Keweenaw Range escarpment and the valley south of it were first made, the width of the valley depending on the amount of throw of the fault, which was thus greatest to the eastward. Subsequently, the newer sandstone was deposited in this valley, and, after its deposition, a comparatively insignificant amount of faulting took place on the same line. On this view the South Range beds are the basal beds of the series, while the underlying basement of the intermediate sandstone-filled valley is composed, in a measure, of the same beds as those forming the Keweenaw Range (pp. 203–205)."

Preliminary to a renewed and fuller presentation of our conclusions we desire briefly but distinctly to set forth (1) certain prime characteristics of the formations under consideration with which any tenable view must be in harmony; and (2) certain specific conditions which an adequate hypothesis must satisfy.

*The bedded nature of the Keweenaw Series.*—Among the prime characteristics it is important to reaffirm the bedded nature of the Keweenaw Series, not because it is disputed but because it needs emphasis. With the exception of the Bohemian Range, there never has been any ground for questioning the thoroughly stratified condition of the formation of the Keweenaw peninsula. That the great terrane consists of detrital beds, definitely interstratified with lava sheets, has been most thoroughly demonstrated both by geological investigation and by industrial exploitation. With the determination made by one of us that the Bohemian Range is likewise bedded, in the main, there passes away the last definite ground for regarding the Keweenawan rocks as otherwise than thoroughly stratified.[1] There is no sanction in the observed phenomena for any appeal to the assumed license of "eruptive geology" The structure of Keweenaw Point is in no proper sense eruptive. Essentially all its beds are the result of fluidal deposit. The one class, lava flows, distributed and deposited themselves by virtue of their own fluidity; the other, the clastic beds, by the borrowed fluidity of water. The products of both are alike amenable to the common laws of stratigraphy, and, for the purpose of general structural conceptions, it is quite immaterial whether the stratified condition arose from the one or the other variety of fluidal deposition. We conceive it to be a grave

[1] The Copper-Bearing Rocks of Lake Superior, Monograph V, United States Geological Survey, pp. 179–187. Through the kindness of Dr. C. Rominger, State geologist of Michigan we have been allowed to look over the MS. of his forthcoming report on the Keweenawan rocks of Michigan, and find that he has quite independently come to the same conclusion as to the bedded structure of the Bohemian range. Dr. Rominger's detailed studies have also brought out many new points with regard to this interesting part of Keweenaw Point.





error to confuse the phenomena
deposition of erupted material.
mixed contents the *eruption* belc
but the descent of the fluid ma
the domain of fluvial geology;
valley belongs to the domain of
flows of lava issue from the e
sphere of eruptive geology; but
vast sheets over adjacent or pe
posit that is amenable in every
of sedimentary stratigraphy. W
elementary statements did not
gion seem to render them imper

Whatever explanation of the s
must, therefore, conform to simp

*The uniformity and steadines*
Series thoroughly bedded, but, in
presents a uniformity and stead
tilted. It is notably free from
changes of dip that are commo
original horizontal condition t
bedding was of very exceptiona
the series, as well as the struc
pourings of lava were copious
so, they must have spread the
horizontality. The extent and
the detrital beds, strongly confi
find their best modern exempl
Idaho, and adjacent Territories.
bald Geikie fits the phenomena
essentials: "We rode for hours
stretching southward and west
seemed as if the plain had bee
which surged along the base
leaving there a solid floor of
basalt plain near some springs
its edge. Wandering over th
which not a vestige of vegetati
vividness the truth of an asser
generally neglected by geologi
Vesuvius or Ætna, present us
volcanic action, but rather belc
have been periods of tremen
escaping from a local vent, lil
its way to the surface by innun
crust of the globe over thous

ly perceptible at Portage Lake, beyond
These phenomena are beautifully dis-
branch of the Ontonagon, east of Lake

me faulting took place on this line after
faulting, I conceive, took place before.
nt and the valley south of it were first
he amount of throw of the fault, which
ntly, the newer sandstone was deposited
comparatively insignificant amount of
his view the South Range beds are the
basement of the intermediate sandstone-
same beds as those forming the Kewee-

presentation of our conclusions we
h (1) certain prime characteristics
with which any tenable view must
ific conditions which an adequate

*e Series.*—Among the prime char-
the bedded nature of the Kewee-
ed but because it needs emphasis.
Range, there never has been any
ly stratified condition of the forma-
That the great terrane consists of
ed [illegible] lava sheets, has been most
eological investigation and by in-
ermination made by one of us that
ded, in the main, there passes away
ig the Keweenawan rocks as other-
here is no sanction in the observed
umed license of "eruptive geology"
s in no proper sense eruptive. Es-
of fluidal deposit. The one class,
d themselves by virtue of their own
, by the borrowed fluidity of water.
enable to the common laws of stra-
eneral structural conceptions, it is
ified condition arose from the one or
tion. We conceive it to be a grave

uperior, Monograph V, United States Geo-
kindness of Dr. C. Rominger, State geolo-
look over the MS. of his forthcoming re-
igan, and find that he has quite independ-
o the bedded structure of the Bohemian
ave also brought out many new points with
aw Point.





error to confuse the phenomena of eruption with the phenomena of the deposition of erupted material. When a mud volcano belches forth its mixed contents the *eruption* belongs to the domain of eruptive geology, but the descent of the fluid mass down the mountain side belongs to the domain of fluvial geology; and the deposition of the mass in the valley belongs to the domain of sedimentary geology. So, when great flows of lava issue from the earth, the extravasation belongs to the sphere of eruptive geology; but the distribution of molten material in vast sheets over adjacent or perchance distant plains, results in a deposit that is amenable in every essential respect to the recognized laws of sedimentary stratigraphy. We should need to crave pardon for these elementary statements did not the history of the discussion of this region seem to render them imperative.

Whatever explanation of the structure of Keweenaw Point is adopted must, therefore, conform to simple stratigraphic laws.

*The uniformity and steadiness of dip.*—Not only is the Keweenaw Series thoroughly bedded, but, in the region involved in this discussion, it presents a uniformity and steadiness of dip unusual in a series so highly tilted. It is notably free from those warpings, foldings, and sudden changes of dip that are common characteristics of tilted series. In its original horizontal condition there is every reason to believe that its bedding was of very exceptional uniformity. The enormous extent of the series, as well as the structure of the beds, implies that the outpourings of lava were copious in a most extraordinary degree, and, if so, they must have spread themselves into sheets of almost absolute horizontality. The extent and persistence of the igneous, as well as of the detrital beds, strongly confirm this view. The phenomena probably find their best modern exemplification in the lava fields of Oregon, Idaho, and adjacent Territories. The following graphic sketch by Archibald Geikie fits the phenomena of the Superior basin in all structural essentials: "We rode for hours by the margin of a vast plain of basalt, stretching southward and westward as far as the eye could reach. It seemed as if the plain had been once a great lake or sea of molten rock which surged along the base of the hills, entering every valley, and leaving there a solid floor of bare black stone. We camped on this basalt plain near some springs of clear cold water which rise close to its edge. Wandering over the bare hummocks of rock, on many of which not a vestige of vegetation had yet taken root, I realized with vividness the truth of an assertion made first by Richthofen, but very generally neglected by geologists, that our modern volcanoes, such as Vesuvius or Ætna, present us with by no means the grandest type of volcanic action, but rather belong to a time of failing activity. There have been periods of tremendous volcanic energy, when, instead of escaping from a local vent, like a Vesuvian cone, the lava has found its way to the surface by innumerable fissures opened for it in the solid crust of the globe over thousands of square miles. I felt that the

structure of this and the other volcanic plains of the far West furnish the true key to the history of the basaltic plateaux of Ireland and Scotland, which had been an enigma to me for many years."[1]

*The enormous thickness of the Keweenaw Series.*—An acceptable view must take account of the stupendous depth of the Keweenaw Series. If the Eastern Sandstone is to be held the equivalent of the upper member of the Keweenaw Series, and has been separated from it by a downthrow, the thickness of the series is a measure of the faulting. If the measure were only moderate this hypothesis would be put to no unbearable strain, but when it is shown that the thickness of the beds reaches some such minimum measure as 35,000 feet, the burden laid upon the hypothesis is great and it staggers under its own load. Before it can stand it must be supported by the strongest direct evidence.

If, again, the Keweenaw Series is thought to be sandwiched between the upper and nether members of the Potsdam Sandstone, the thickness of the Keweenaw Series is a measure of the strain of distension put upon the Potsdam. As we know it, the Potsdam is, at most, a series of 1,000 feet in thickness. It may somewhere be thicker. But when we theoretically imbed within it 35,000 feet of strata, or any more moderate measure to which the Keweenaw Series can possibly be reduced, the strain put upon the hypothesis is unbearably severe. It bellies out the Potsdam to an inordinate extent. A boa may swallow an ox, but not an elephant.

*The general horizontality of the Eastern Sandstone.*—The proximity of a horizontal series to a highly dipping series of enormous thickness is a factor of which cognizance must be taken in framing an hypothesis concordant with the phenomena. It is not a fact which necessarily presents supreme difficulties, but is one which must fall into easy concordance with the true hypothesis, while it will be apt to display some incongruity with a false one.

*The quartzose character of the Potsdam sands in distinction from the silicate nature of the Keweenawan sands.*—Had the Eastern Sandstone been a gray shale it would probably never have been regarded as the equivalent of any portion of the Keweenaw Series, because of the differences in the conditions of derivation which such a character would imply. It is doubtful, however, whether such differences of implied condition would be really much greater than those which are now implied. The conditions which produced the silicate Keweenawan sands must have been notably different from those which gave rise to the quartzose Potsdam sands.

*Mutual relations and distribution of the two series.*—There must also be a due consideration of the great relations of the two series, in their mutual positions and in their distribution. The consideration of this lies mainly outside of our present province, and we will not here attempt

[1] Geological Sketches, p. 237.





its discussion, contenting ourse
publications;[1] but the subject
formation of a just and compreh
the question of the relations be
anything less than all the inforr
dangerous to safe conclusions a

*Relations to topography.*—Eve
teachings of topography profou
ture and past history. It lend
inferences and in suggesting t
peninsula now consists of an elo
by erosion nor deeply undulate
teemed by topographic student
any hypothesis that postulates
The fact, on the other hand, t
stone, 100 miles in length, the
will likewise weigh in the adjudi
that the tract was once overlai
are other features of topography
which lend more or less specifi
of the several structural hypoth

*The relation of the two serie*
trict under consideration canno
of its significant drainage featu
fact that no great stream trav
Sandstone. It is a depressed
than the ridged tracts on eith
any great stream. The draina
weenawan ridge, and empty in
that plowed along this belt did
The Ontonagon River and the
plain and cut through the Kewe
by Portage Lake appears to be
other transverse drainage featu
ing of the history of the region

The foregoing may be said t
the true explanation must be
specific requisitions which it m

*The comparative straightness*

[1] American Journal of Science, 187
Age of the Copper-Bearing Rocks of
tion of the Lake Superior Synclinal
pp. 1–25, R. D. I.: Vol. I, Geology o
Vol. I, pp. 453–455, T. C. C.; Third A
R. D. I.; Copper-Bearing Rocks of L
logical Survey, 1883, p. 356, *et seq.*

ıic plains of the far West furnish
basaltic plateaux of Ireland and
:o me for many years."[1]

*:naw Series.*—An acceptable view
s depth of the Keweenaw Series.
ıeld the equivalent of the upper
ıd has been separated from it by
eries is a measure of the faulting.
his hypothesis would be put to no
wn that the thickness of the beds
:e as 35,000 feet, the burden laid
ggers under its own load. Before
the strongest direct evidence.
thought to be sandwiched between
he Potsdam Sandstone, the thick-
sure of the strain of distension put
the Potsdam is, at most, a series of
ıewhere be thicker. But when we
feet of strata, or any more moder-
w Series can possibly be reduced,
; unl[illegible]ably severe. It bellies out
t. [illegible]oa may swallow an ox, but

*Eastern Sandstone.*—The proximity
pping series of enormous thickness
be taken in framing an hypothesis
t is not a fact which necessarily pre-
which must fall into easy concord-
it will be apt to display some incon-

*ıtsdam sands in distinction from the*
*ands.*—Had the Eastern Sandstone
y never have been regarded as the
Keweenaw Series, because of the
ration which such a character would
hether such differences of implied
eater than those which are now im-
ced the silicate Keweenawan sands
from those which gave rise to the

*ı of the two series.*—There must also
relations of the two series, in their
ribution. The consideration of this
rovince, and we will not here attempt

Sketches, p. 237.





its discussion, contenting ourselves with a reference to our previous publications;[1] but the subject cannot be thus lightly passed in the formation of a just and comprehensive judgment. To attempt to settle the question of the relations between two such extensive series upon anything less than all the information obtainable from all sources, is as dangerous to safe conclusions as it is illiberal in method.

*Relations to topography.*—Every geologist of acumen has found the teachings of topography profoundly instructive concerning both structure and past history. It lends most valuable aid in correcting false inferences and in suggesting true ones. The fact that the Keweenaw peninsula now consists of an elongated promontory, not greatly dissected by erosion nor deeply undulate or serrate in its crest line, will be esteemed by topographic students a witness of much value in weighing any hypothesis that postulates extraordinary elevation by faulting. The fact, on the other hand, that over the area of the Eastern Sandstone, 100 miles in length, there is an absence of outlying remnants, will likewise weigh in the adjudication of any hypothesis which assumes that the tract was once overlain by the great trappean series. There are other features of topography that do not admit of a brief statement, which lend more or less specific testimony to the verity, or otherwise, of the several structural hypotheses.

*The relation of the two series to drainage.*—The history of the district under consideration cannot be truly read without taking thought of its significant drainage features. Among these is the remarkable fact that no great stream traverses the low-lying tract of the Eastern Sandstone. It is a depressed belt of land, 100 miles in length, lower than the ridged tracts on either hand, and yet it is not the valley of any great stream. The drainage channels of this belt cross the Keweenawan ridge, and empty into the great basin. Even the glaciers that plowed along this belt did not obliterate these interesting features. The Ontonagon River and the Presque Isle river cross the sandstone plain and cut through the Keweenawan uplift. The great cut occupied by Portage Lake appears to be a similar preglacial channel. These and other transverse drainage features must find a meaning in any full reading of the history of the region.

The foregoing may be said to be general characteristics with which the true explanation must be harmonious. The following are more specific requisitions which it must directly meet:

*The comparative straightness but gentle undulation of the junction line*

[1] American Journal of Science, 1874, Third Series, VIII, 46–56, R. D. I.; "On the Age of the Copper-Bearing Rocks of Lake Superior, and on the Westward Continuation of the Lake Superior Synclinal," Vol. III, Geology of Wisconsin, 1880, Part I, pp. 1–25, R. D. I.; Vol. I, Geology of Wisconsin, 1883, pp. 94–118, T. C. C.; Science, Vol. I, pp. 453–455, T. C. C.; Third Annual Report United States Geological Survey, R. D. I.; Copper-Bearing Rocks of Lake Superior, Monograph V, United States Geological Survey, 1883, p. 356, *et seq.*

*throughout its course of nearly one hundred miles.*—If it is a fault line, directness of course is precisely what is to be expected. If it is merely an erosion cliff, formed by the cutting back of the Keweenaw Series, its directness of course and its freedom from headlands, retreating embayments and deep incisions, are quite remarkable. If it is the compound product of faulting, determining a general line of escarpment, and of erosion, subsequently working upon that, an average directness of course, with subordinate undulations, will satisfy the hypothesis.

*The coincidence of the line of escarpment with the line of junction of the two series.*—The term "escarpment" is a convenient one, almost indispensably so, but does not quite accurately express the facts, since the surface does not always drop suddenly down in a precipitous face, but in some districts curves smoothly, though steeply, down to the lower tract. The phenomenon is not the familiar one of a mural face set forth by the undermining of a softer stratum, and the coincidence of the brow of the trappean series with the junction line has more than a mere fortuitous significance.

*Disturbance along the line of contact.*—A factor of supreme moment is the distortion of strata that everywhere, so far as observed, prevails along the junction line. This is the more emphatically significant since it does not notably affect the immediately adjacent region. The Keweenawan beds on the one side are almost wholly uninfluenced, while the Eastern Sandstone, at a short distance from the junction, lies essentially as first deposited. It is further to be noted that the distortion is almost wholly suffered by the sandstone series, or what we conceive to be the later, weaker and merely superficial series, while the deep, massive Keweenawan terrane was not visibly flexed.

*The special character of the distortions.*—Not only must the true view take account of the fact of disturbances along the junction, but it must recognize the special character of the dislocations The beds are bent up in the majority of instances, but in two notable cases they are bent down. There are also sudden warpings and angulations of the sandstone for which an adequate cause must be found.

*Character of the junction.*—There must also be a consideration of the contact relations between the Eastern Sandstone and the trappean terrane. A complete view must comprehend in its scope the overlying junctions, as at Bête Grise Bay, and the underlying contacts, as in the Douglass Houghton and Hungarian Ravines.

*The junction débris.*—Coming down to the immediate contact, the true view must embrace a consideration of the junction débris. Account must be taken of its partly trappean and partly detrital composition, of its foliated structure, of its slickenside markings, of its inconstant thickness and of its entire freedom from any indications of direct igneous action.

*The contact faces.*—The true view must also recognize the fact that the traps at the junction have not been found to possess definite amyg-





daloidal surfaces, such as charact
where, but present irregular and
that the surfaces are not original.
not show completed beds or depo

*Contact of different members.*—
take note of the fact that the Ea
with different members of the Ke
that these members are not alone
persistency some may question,
servation has shown that both th
gree of persistency, we do not thi
does not explain this diversity o
beds have been replaced by othe
with different members is so clo
quite violent.

*Discordance of strike.*—The tr
of the fact that the contact line
strike line of the Keweenaw Seri
eral line of junction is closely ap
but in detail there are notable
ignored.

The disturbed condition of the
its lines of strike quite varying, a
the line of contact and with the
We must deal, therefore, not o
strikes of the two series of strat
between each and the common j

*The derivation of the pebbles of*
must give a satisfactory accou
the Eastern Sandstone. It mu
derivatives from the igneous mer
they were taken from no single
some acidic, some basic.

*The distribution of the pebbles.*
vation that pebbles are abunda
vicinity of the Keweenaw Series
from it.

*The imperfect assortment of t*
consider the fact that the sep
finer material is incomplete, th
fying process did not complete
deposit, and not a thoroughly a
conglomerates.

*The angularity of the pebbles*
that the pebbles are singularly
in others.

*ndred miles.*—If it is a fault line, is to be expected. If it is merely g back of the Keweenaw Series, its rom headlands, retreating embay- markable. If it is the compound general line of escarpment, and of that, an average directness of will satisfy the hypothesis.

*pment with the line of junction of* " is a convenient one, almost indis- rately express the facts, since the ly down in a precipitous face, but hough steeply, down to the lower familiar one of a mural face set r stratum, and the coincidence of the junction line has more than a

*ct.*—A factor of supreme moment where, so far as observed, prevails nore emphatically significant since diately adjacent region. The Ke- almost wholly uninfluenced, while tance from the junction, lies essen- r to noted that the distortion is one series, or what we conceive to rficial series, while the deep, mass- ibly flexed.

*ons.*—Not only must the true view ances along the junction, but it of the dislocations. The beds are , but in two notable cases they are warpings and angulations of the ise must be found.

nust also be a consideration of the ern Sandstone and the trappean prehend in its scope the overlying the underlying contacts, as in the Ravines.

wn to the immediate contact, the ation of the junction débris. Ac- appean and partly detrital compo- slickenside markings, of its incon dom from any indications of direct

must also recognize the fact that een found to possess definite amyg-

8)



daloidal surfaces, such as characterize the limits of the lava flows elsewhere, but present irregular and broken faces, or give other evidences that the surfaces are not original. In like manner, the sandstone does not show completed beds or depositional terminations.

*Contact of different members.*—A true conclusion must furthermore take note of the fact that the Eastern Sandstone comes into contact with different members of the Keweenaw Series at different points and that these members are not alone of the igneous class, whose extent and persistency some may question, but of the detrital order. Since observation has shown that both these members have a very notable degree of persistency, we do not think that any view is satisfactory which does not explain this diversity of contact without supposing that the beds have been replaced by others. Indeed, the proximity of contacts with different members is so close as to render such an explanation quite violent.

*Discordance of strike.*—The true view must further take cognizance of the fact that the contact line is not precisely concordant with the strike line of the Keweenaw Series at the points of contact. The general line of junction is closely approximate to the general line of strike, but in detail there are notable deviations from it, which cannot be ignored.

The disturbed condition of the Eastern Sandstone is such as to make its lines of strike quite varying, and they are often discordant both with the line of contact and with the line of strike of the Keweenaw strata. We must deal, therefore, not only with the discordance between the strikes of the two series of strata mutually, but with the discordance between each and the common junction.

*The derivation of the pebbles of the Eastern Sandstone.*—The true view must give a satisfactory account of the derivation of the pebbles of the Eastern Sandstone. It must recognize that they are undoubted derivatives from the igneous members of the Keweenaw Series, and that they were taken from no single stratum, but from the various members, some acidic, some basic.

*The distribution of the pebbles.*—It must further recognize the observation that pebbles are abundant, and often large, in the immediate vicinity of the Keweenaw Series, but are not known at great distances from it.

*The imperfect assortment of the pebbles and matrix.*—It must further consider the fact that the separation of the pebbles from the much finer material is incomplete, the assortment is imperfect, the classifying process did not complete its work; it is a "mud and shingle" deposit, and not a thoroughly assorted series of sandstones, shales and conglomerates.

*The angularity of the pebbles.*—It must also take note of the fact that the pebbles are singularly angular in some situations and rounded in others.

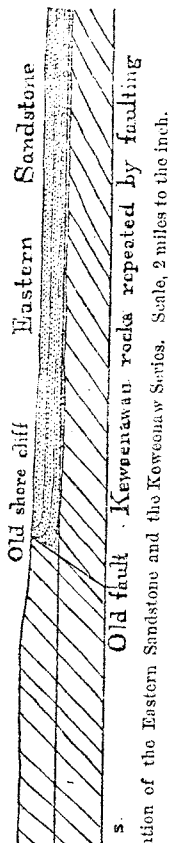



FIG. 23.—Section of Keweenaw Point, showing true relation of the Eastern Sandstone and the Keweenaw Series. Scale, 2 miles to the inch.

*The absence of large fallen cliff masses.*—It must account for the still further observation that while there are pebbles of trappean origin in the Eastern Sandstone, there is at the contact a general absence of great fallen cliff masses.

*The proximity and relations of the Trenton Limestone.*—It must also account for the fact that at no greater distance than seven miles from the upturned edge of the great Keweenaw Series, Trenton Limestone, in horizontal attitude, crowns a hill lying in the Eastern Sandstone area.

The foregoing are a full score of specifications which a true structural hypothesis must satisfy. We regard them as so significant in their character and so exacting in their demands that little latitude is permitted in the formation of our views. Taken together, they seem to us to point with great definiteness and with quite unequivocal directness to a true conception of both the genesis and the structural relations of the formations in question. Our chief conclusions are as follows: *That the Keweenaw Series is much older than the Eastern (Potsdam) Sandstone; that it was upturned, faulted along the escarpment, and much eroded before the deposition of the Eastern Sandstone; that the latter was laid down unconformably against and upon the former, and that subsequently minor faulting along the old line ensued, disturbing the contact edge of the sandstone.*

It remains to show specifically how these views meet the foregoing requirements, or, as we should prefer to phrase it, it remains to show how the foregoing requirements demand the views to which they have led us up. We will follow essentially in order the foregoing list of imperative qualifications.

In common with most students of the region, we hold that the bedded nature of the trappean series was due to a succession of immense floods of lava, which spread themselves widely over the plain of the Superior basin. Contemporaneously with this, subaqueous sedimentation was in progress, introducing, at intervals throughout the gigantic pile, clastic beds, whose character and surface markings demonstrate their horizontal deposition. Unlike some others, however, we do not conceive the Keweenaw peninsula, nor indeed the great basin generally, to have been the immediate region of important eruption. The evidence leads us to believe that the loci of eruption





lay around the rim of the basin, a
In the discussion of the bedded s
the assumed license of "eruptiv
more than the most trivial igne
bate. We believe its structural
from the phenomena of intrusion

We conceive the uniformity ar
the Keweenaw peninsula, and, ir
basin itself, to be the result of a
basin center during the long pr
This central depression we beli
elevation of the rim in the dist
of this in the certainty that th
Series are chiefly derived from
rived from any series now know
We find further evidence of thi
that the lowermost beds come to
uppermost ones. It appears tha
being eaten away by drainage e
sedimentation in progress in the
this, we conceive that the basi
freely into the basin plain, and
the more viscous acid eruptions
bossments in the districts of e
were exposed to easy degradatio
a larger percentage of detritus th
brittleness and relative lightness
ing conditions.

Now, a dip formed by progress
ning apace, is most naturally fr
total dip observed cannot hav
beds known to belong to this se
at most localities and at the mou
at an angle of between 80° an
appears to have been but an exte
localities, the most notable of
Mountains, that anything appro
served. Into the later moveme
something of the lateral thrust
distortion; but if so, it has left

The enormous thickness of t
dinary deluges of lava which w
plain; molten deluges which hav
course of known geological hist
that twelve or fifteen thousand

*fallen cliff masses.*—It must account
bservation that while there are peb-
n in the Eastern Sandstone, there is
l absence of great fallen cliff masses.
*relations of the Trenton Limestone.*—
for the fact that at no greater dis-
les from the upturned edge of the
ies, Trenton Limestone, in horizon-
hill lying in the Eastern Sandstone

a full score of specifications which a
othesis must satisfy. We regard
in their character and so exacting
t little latitude is permitted in the
s. Taken together, they seem to us
efiniteness and with quite unequiv-
ue conception of both the genesis
lations of the formations in ques-
usions are as follows: *That the Ke-*
*h older than the Eastern (Potsdam)*
*s upturned, faulted along the escarp-*
*bef[illegible]e deposition of the Eastern*
*tter was laid down unconformably*
*former, and that subsequently minor*
*line ensued, disturbing the contact*

specifically how these views meet
nents, or, as we should prefer to
o show how the foregoing require-
ws to which they have led us up.
ally in order the foregoing list of
ns.

t students of the region, we hold
of the trappean series was due to
se floods of lava, which spread
the plain of the Superior basin.
h this, subaqueous sedimentation
icing, at intervals throughout the
ds, whose character and surface
their horizontal deposition. Un-
er, we do not conceive the Kewee-
ed the great basin generally, to
te region of important eruption.
o believe that the loci of eruption



lay around the rim of the basin, and not immediately in and beneath it. In the discussion of the bedded series, we, therefore, make no appeal to the assumed license of "eruptive geology." We find no evidence of more than the most trivial igneous intrusions in the region under debate. We believe its structural problems must be solved entirely apart from the phenomena of intrusion.

We conceive the uniformity and steadiness of dip which characterize the Keweenaw peninsula, and, in a somewhat similar degree, the great basin itself, to be the result of a slow and progressive settling of the basin center during the long process of deposition of the deep series. This central depression we believe to have been accompanied by an elevation of the rim in the districts of eruption. We find evidence of this in the certainty that the clastic members of the Keweenaw Series are chiefly derived from the series itself. They cannot be derived from any series now known to occupy the surrounding territory. We find further evidence of this in the fact, which generally obtains, that the lowermost beds come to the surface at higher angles than the uppermost ones. It appears that the rim of the basin was continually being eaten away by drainage erosion and contributing material to the sedimentation in progress in the settling central portion. Further than this, we conceive that the basic lavas, being the most liquid, flowed freely into the basin plain, and spread themselves widely over it, while the more viscous acid eruptions accumulated more largely in thick embossments in the districts of eruption about the margin, where they were exposed to easy degradation, and that, therefore, these furnished a larger percentage of detritus than the basic members. The hardness, brittleness and relative lightness of the acidic material were also favoring conditions.

Now, a dip formed by progressive subsidence and sedimentation, running apace, is most naturally free from great irregularities. But the total dip observed cannot have been so attained; for the uppermost beds known to belong to this series are themselves considerably tilted at most localities and at the mouth of the Montreal River are upturned at an angle of between 80° and 90°. The later movement, however, appears to have been but an extension of the earlier. It is only at a few localities, the most notable of which is the vicinity of the Porcupine Mountains, that anything approximating abrupt warpings have been observed. Into the later movement of the strata there may have entered something of the lateral thrust that is so common a factor in stratal distortion; but if so, it has left but feeble evidence of its action.

The enormous thickness of the series is largely due to the extraordinary deluges of lava which were successively poured over the basin plain; molten deluges which have rarely, if ever, been surpassed in the course of known geological history. But we must not ignore the fact that twelve or fifteen thousand feet of detrital beds were interspersed

among or laid down over them. This detritus presents evidences of derivation by the usual agents of erosion and deposition. The igneous products doubtless greatly facilitated such derivation by affording material and conditions especially favorable for degradation and transportation. There may have been important contributions of ash and scoriæ, but we have found little clear evidence of this. The igneous action, we think, belonged to the class of massive fissure eruptions of Richthofen and not to the trivial Vesuvian type. But making such allowances for accelerating agencies as we are able, we are still impressed with the magnitude of the clastic series, and with the lapse of time requisite for its production, for the deposit of the last 12,000 feet took place after the lava floods ceased. This large conception of the time element is an important factor in our views. We have endeavored to fully recognize its magnitude, and at the same time, and for that very reason, to restrain ourselves from unnecessary assumptions that increase its extent. We have, therefore, inclined to those structural and genetic views which give sufficient latitude for these great processes and yet at the same time limit their magnitude to the least permissible measure. We incline to reject every view that unnecessarily magnifies the profound depth of the series, the vast lapse of time requisite for its production, the extraordinary amount of faulting necessary to its total displacement, or the inordinate strain of distension requisite to embody it in the midst of a trivial series.

We believe that the general horizontality of the Eastern Sandstone finds a perfectly simple explanation in the fact that it was laid down upon and against the Keweenawan, Huronian and Laurentian Series long after these had suffered their various upheavals, and that there has since been no considerable movement of the strata, except such crust oscillations as were common to the whole region. The sandstone has, therefore, remained essentially in its depositional attitude. Never having formed a part of the Keweenaw Series, nor having been in any close sense a partaker in its formative history, the discordance between the stratifications of the two series is precisely that which exists between the Potsdam and the other more ancient series of the region. Between the formation of the Eastern Sandstone and that of the Keweenaw Series, we think we find specific evidence of a great time gap.

We have previously indicated how, in our view, the Keweenawan sands were formed. Being derived from the upturned edges of the igneous series, they partook of the nature of the parent rock. The rim of the basin being at the time largely occupied by the extravasated igneous material, comparatively little drainage from the Archæan terranes beyond found access to the basin; hence the small percentage of material derived from other than Keweenawan sources. At the time of the formation of the Eastern Sandstone, on the contrary, there





had intervened a vast lapse of time,
away in the production of the 12,
which overlie the lava flows. Ther
sion which had brought the sea ag
Series that had previously been exp
and hills testify. These conditions
the region beyond the Keweenawa
inance of quartzose material from
very much as at the present day.

Furthermore, it is to be noted th
the decomposition of crystalline
centage of quartz, for, in a slow d
factor and a greater proportion of
save the obdurate quartzose mat
The degradation of the basin rim n
derivation and increased the quar
somewhat felt in the closing Ke
grade the two series toward each
tions that renders uncertain the
outlet of Portage Lake Canal.

The Eastern Sandstone must, h
derived a portion of its material
element so derived we fully rec
quartzose element is no more to b

In thus widely separating the
of the diversity in their distributi
The phenomena about Lake Gogeb
lies the trappean series and exte
explanation in the erosion of the
sition of the later series.

So also the diverse relations o
its elucidation in the difference
under which the two series were
without our special field and de
ment to be fittingly discussed h

We find a very satisfactory e
features of the region in the vie
overlying Silurian deposits pas
of the Keweenaw Series and b
sloping toward the axis of the g
zoic plain the drainage system
the irregularities of contour of
having once established itself,
relative resisting power of the

This detritus presents evidences of erosion and deposition. The igneous ited such derivation by affording mate- orable for degradation and transporta- rtant contributions of ash and scoriæ, lence of this. The igneous action, we assive fissure eruptions of Richthofen pe. But making such allowances for able, we are still impressed with the d with the lapse of time requisite for the last 12,000 feet took place after e conception of the time element is We have endeavored to fully recog- ame time, and for that very reason, essary assumptions that increase its ned to those structural and genetic le for these great processes and yet ade to the least permissible measure. hat unnecessarily magnifies the pro- t lapse of time requisite for its pro- t of faulting necessary to its total in of distension requisite to embody

zontality of the Eastern Sandstone n in the fact that it was laid down n, I bian and Laurentian Series various upheavals, and that there ovement of the strata, except such o the whole region. The sandstone in its depositional attitude. Never naw Series, nor having been in any ve history, the discordance between precisely that which exists between ient series of the region. Between lstone and that of the Keweenaw dence of a great time gap.

ow, in our view, the Keweenawan from the upturned edges of the ature of the parent rock. The rim gely occupied by the extravasated le drainage from the Archæan ter- basin; hence the small percentage n Keweenawan sources. At the Sandstone, on the contrary, there



had intervened a vast lapse of time, and the rim had been largely cut away in the production of the 12,000 feet of Keweenaw sandstones which overlie the lava flows. There had, furthermore, been a depression which had brought the sea again over portions of the Keweenaw Series that had previously been exposed to erosion, as its buried valleys and hills testify. These conditions greatly increased the drainage from the region beyond the Keweenawan borders and brought in a predominance of quartzose material from the surrounding Archæan terranes, very much as at the present day.

Furthermore, it is to be noted that a slow derivation of detritus from the decomposition of crystalline rocks would give an increased percentage of quartz, for, in a slow derivation, decomposition is a larger factor and a greater proportion of the silicates is disintegrated, little save the obdurate quartzose material being left intact to form sand. The degradation of the basin rim naturally slackened the rate of detrital derivation and increased the quartzose element. This it appears was somewhat felt in the closing Keweenawan deposition and serves to grade the two series toward each other. This is one of the considerations that renders uncertain the reference of the sandstones near the outlet of Portage Lake Canal.

The Eastern Sandstone must, however, in the nature of the case, have derived a portion of its material from the Keweenaw Series, and the element so derived we fully recognize; but its subordination to the quartzose element is no more to be neglected than its presence.

In thus widely separating the two series, we find our explanation of the diversity in their distribution and in their relations to each other. The phenomena about Lake Gogebic, where the Eastern Sandstone overlies the trappean series and extends itself through gaps in it, finds its explanation in the erosion of the interval and the unconformable deposition of the later series.

So also the diverse relations of these two series to topography finds its elucidation in the difference of age and the diversity of conditions under which the two series were formed. But this topic lies too largely without our special field and demands too great elaborateness of statement to be fittingly discussed here.

We find a very satisfactory explanation of the remarkable drainage features of the region in the view that the Potsdam Sandstone and the overlying Silurian deposits passed completely over the upturned edges of the Keweenaw Series and buried them beneath a sedimentary plain sloping toward the axis of the great basin. On the surface of this Paleozoic plain the drainage system first developed itself in entire neglect of the irregularities of contour of the buried Keweenaw Series below, and, having once established itself, cut its channels down irrespective of the rela ive resisting power of the terranes it encountered. It is a beauti-

ful instance of superimposed drainage, according to the classification of Gilbert.[1]

We shall again recur to some of the special conditions under which the Eastern Sandstone derived detritus from the Keweenaw Series.

The comparative straightness but gentle undulation of the junction line between the Keweenaw Series and the Eastern Sandstone is a point which bears rather upon the naturalness and rationality of our conceptions of the history of the region than upon their demonstrative character. It has not the direct logical bearing of some other features, but tests the several hypotheses mainly in respect to their appropriateness to the phenomena. We hold this long, gently curving line to be the result of ancient faulting, modified by subsequent erosion and by still more recent slight faulting. The earlier fault, in our view, antedates the deposition of the Eastern Sandstone. The erosion was probably in part contemporaneous with the faulting, in part intermediate between the faulting and the deposit of the Eastern Sandstone, and in part contemporaneous with and a part of the necessary work of the later epoch. The last faulting was posterior to the Potsdam epoch.

To be more precise in the statement of the time and of the amount of the first faulting is venturesome; and we hold no very firm convictions concerning its details, and yet certain considerations seem to justify a little light speculation upon the subject. Since the faulting was a factor in the crust movements of the region, we naturally connect it either with the final upheaval of the Keweenaw Series or with the subsidence which subsequently depressed the region beneath the Potsdam seas. We do not, of course, exclude the view of movement along the fault plane at both stages. On some accounts we incline to the view that it was a feature of the subsidence immediately antedating the Eastern (Potsdam) Sandstone deposition. If the Keweenaw peninsula had been elevated long anterior to its burial beneath the Potsdam and Silurian sediments, it would be rational to suppose that it would have been extensively dissected by erosion and would have presented a ragged line of hills or scattered knobs, instead of an almost unbroken ridge. It seems further probable that the Potsdam Sandstone would have been found more freely inserted in the valleys which the long erosion would have formed. From these considerations we draw a not very confident inference that the movement which elevated the Keweenaw peninsula or, as it may have been, depressed the basin now occupied by the Eastern Sandstone, was a movement that did not much antedate the Potsdam deposition, and was hence probably contemporaneous with the subsidence which brought again the seas into the basin. The little force of this presumption is mainly destroyed if we conceive the whole region to have been reduced to a base level of erosion and ascribe the relative prominence which the Keweenaw Series now has to the later faulting.

[1] Geology of the Henry Mountains, p. 144.





But this makes the later
otherwise conceive it to be.
In so far as we have sou
strain which gave rise to th
connecting it with the resid
Keweenawan age. The are
are most displayed, so far as
which, as a kind of nucleus,
shore of the lake in Minneso
numerous and extensively in
of eruption these regions felt
extruded lavas, as well as th
expanded condition was the
the general truth that a stat
mescence, is a common accon
to this or some other cause.
the temperature of the expan
common temperature of the c
which accompanied this may
quate or not, of the differen
against the Marquette region
it, and over against the other
Bayfield Counties, Wisconsin,
and along the north shore of L
Under the view that a fau
weenawan terrane, the corresp
carpment and junction line fin
co-ordinate phenomena.
The disturbances along the
anchor of our convictions. The
the line is now placed upon an
tion. Nowhere have the forma
proach unattended by notable ev
as we can ascertain, are closely c
turbances, we maintain, furnish
Along this line a movement has
disturbing way, affect the body c
have heretofore maintained that
convincingly to a faulting action.
added a large mass of new testim
In the fact that the Eastern San
the contact, is curved upwards,
done, we find evidence that the

ND KEWEENAW SERIES. [BULL. 52

age, according to the classification

he special conditions under which
tus from the Keweenaw Series.
gentle undulation of the junction
id the Eastern Sandstone is a point
ness and rationality of our concep-
an upon their demonstrative char-
pearing of some other features, but
in respect to their appropriateness
ong, gently curving line to be the
by subsequent erosion and by still
rlier fault, in our view, antedates
one. The erosion was probably in
ing, in part intermediate between
Eastern Sandstone, and in part
the necessary work of the later
or to the Potsdam epoch.
t of the time and of the amount of
l we hold no very firm convictions
n considerations seem to justify a
ct. Since the faulting was a fac-
on, we naturally connect it either
naw Series or with the subsidence
gion beneath the Potsdam seas.
w of movement along the fault
nts we incline to the view that it
iediately antedating the Eastern
he Keweenaw peninsula had been
neath the Potsdam and Silurian
pose that it would have been ex-
ld have presented a ragged line
an almost unbroken ridge. It
an Sandstone would have been
ys which the long erosion would
ns we draw a not very confident
vated the Keweenaw peninsula
basin now occupied by the East-
l not much antedate the Potsdam
ntemporaneous with the subsid-
the basin. The little force of
f we conceive the whole region
erosion and ascribe the relative
s now has to the later faulting.

ountains, p. 144.



But this makes the later faulting more considerable than we would otherwise conceive it to be.

In so far as we have sought for a probable cause of the differential strain which gave rise to the fault, we have found most satisfaction in connecting it with the residual effects of the eruption of the preceding Keweenawan age. The areas in which the eruptive phenomena proper are most displayed, so far as we know, are the Marquette region, around which, as a kind of nucleus, the lake is bowed, and the northwestern shore of the lake in Minnesota and Canada. In both regions dikes are numerous and extensively intersect the crust. During the long process of eruption these regions felt the effects of the heat of the injected and extruded lavas, as well as the mechanical effects of the intrusion. An expanded condition was the natural consequence. This accords with the general truth that a state of progressive elevation, if not of intumescence, is a common accompaniment of volcanic action, whether due to this or some other cause. After the cessation of the igneous activity the temperature of the expanded mass doubtless slowly returned to the common temperature of the crust of the earth; and in the contraction which accompanied this may perhaps be found a cause, whether adequate or not, of the differential subsidence of these regions. Over against the Marquette region is the great Keweenaw fault, as we view it, and over against the other, the similar fault found in Douglas and Bayfield Counties, Wisconsin, and perhaps projected under the lake and along the north shore of Isle Royale, determining its prominence.

Under the view that a fault line runs along the face of the Keweenawan terrane, the correspondence between the present line of escarpment and junction line finds a ready explanation, since these are co-ordinate phenomena.

The disturbances along the contact line constitute the great sheet anchor of our convictions. The existence of these disturbances all along the line is now placed upon an unquestionable basis by direct observation. Nowhere have the formations been seen to come into close approach unattended by notable evidences of dislocation, and these, so far as we can ascertain, are closely confined to the contact line. These disturbances, we maintain, furnish unequivocal and decisive testimony. Along this line a movement has taken place which did not, in a similar disturbing way, affect the body of the formations on either hand. We have heretofore maintained that the evidence was such as to point convincingly to a faulting action. To that general evidence we have now added a large mass of new testimony of a very specific character.

In the fact that the Eastern Sandstone, at most observed points along the contact, is curved upwards, and in the manner in which this is done, we find evidence that the Keweenaw Series was elevated and

pushed against the Eastern Sandstone, or, reversing the conception, that the latter was depressed and underset. Whether the actual movement was made by the Keweenaw Series or by the sandstone, or whether both partook in an antagonistic motion, we do not know. From the fact that the former is a deep-seated, down-bowed formation in which any movement which tended to reduce its curvature would produce such an oblique thrust, we have preferred the first hypothesis. But this is quite immaterial. That a relative movement took place posterior to the formation of the Eastern Sandstone is, in our judgment, unequivocally demonstrated by the phenomena.

In the facts shown at the four sections in the vicinity of Torch Lake, we find a nearer approximation than elsewhere to a specific indication of the character of the faulting. In the absence of sufficient direct evidence, we have heretofore taken no account of a possible hade in the fault line, and, as yet, we know of no direct evidence touching the original fault line. It seems to us, however, most rational to assume that the earlier and later faulting occurred along a coincident plane. We entertain the view that a great line of weakness, once established, is likely to be selected by a subsequent differential strain. Observation, however, has taught that a later faulting does not necessarily follow the plane of an earlier one, even where its general course and position are essentially coincident with it, so that no very confident conclusions concerning the precise nature of the earlier fault can be entertained. Whatever may be true of the earlier fault in this case, the facts developed in the vicinity of Torch Lake in respect to the later movement seem to point clearly to a hade *from* the downthrow. The overhanging contacts in the Douglass Houghton and the Hungarian Ravines, the overturned dip in the Saint Louis Ravine, as well as the phenomena of offset in the Wall Ravine, all seem coincident with this view. As we interpret the phenomena, they testify to a movement of the Keweenaw Series upwards and slightly against the Eastern Sandstone, or, if you choose, a subsidence and underthrust of the latter.

Several special hypotheses may be framed to explain the precise facts which the phenomena, as now known, present. We select the following as being, on the whole, seemingly most closely in accord with the evidence:

In Figure 24 is represented diagramatically the nature of the primitive fault on the hypothesis that it was coincident with the plane of later faulting, as indicated by the contacts in the Torch Lake region. The amount of faulting movement we make no attempt to indicate. How great it was we have, as yet, found no means of determining. Our general hypothesis merely postulates that it was less than the total thickness of the series. Two general considerations limit our theoretical latitude. The greater the amount of the fault, the less the estimate of total thickness necessary to be made; and since that thickness, as exhibited in the exposed terrane, is already oppressively great, we feel





the less at liberty to unnecess
and therefore we incline to m
thickness of the series. On
multiply the amount of erosio
and the burial of the series in t
of adjacent regions indicates
very great, we do not feel at li

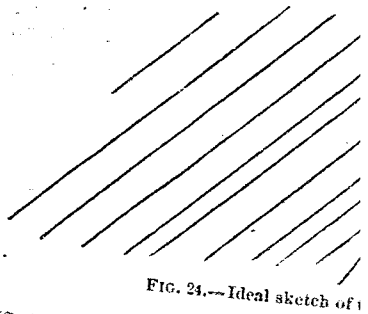


FIG. 24.—Ideal sketch of

of its amount as to suppose a fa
turned beds. A widespread dep
thousand feet we consider to be de
tion of a mountain range several
sume, even if there were no objecti
We are therefore checked in both d
the truth lies somewhere between t

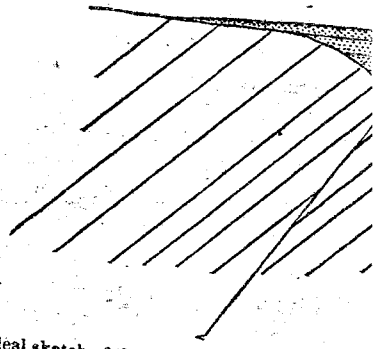


FIG. 25.—Ideal sketch of the Keweenaw fault, after the
the secondary fa

Figure 25 is an ideal section across t
the crest of the upthrow and the deposi
and upon it. It is clear that the brow
favorable conditions for the derivation
the Keweenaw Series and that the shore

, or, reversing the conception, that
. Whether the actual movement
or by the sandstone, or whether
ion, we do not know. From the
, down-bowed formation in which
its curvature would produce such
the first hypothesis. But this is
ovement took place posterior to
one is, in our judgment, unequiv-
a.

ons in the vicinity of Torch Lake,
elsewhere to a specific indication
he absence of sufficient direct evi-
account of a possible hade in the
irect evidence touching the origi-
r, most rational to assume that the
ng a coincident plane. We enter-
kness, once established, is likely
ential strain. Observation, how-
r does not necessarily follow the
s general course and position are
no very confident conclusions con-
r fault can be entertained. What-
in case, the facts developed
ct to the later movement seem to
hrow. The overhanging contacts
ngarian Ravines, the overturned
as the phenomena of offset in the
this view. As we interpret the
ent of the Keweenaw Series up-
n Sandstone, or, if you choose, a
ter.

e framed to explain the precise
known, present. We select the
ingly most closely in accord with

rtically the nature of the primitive
oincident with the plane of later
in the Torch Lake region. The
ke no attempt to indicate. How
means of determining. Our gen-
t it was less than the total thick-
siderations limit our theoretical
the fault, the less the estimate of
; and since that thickness, as ex-
ready oppressively great, we feel



the less at liberty to unnecessarily add to the estimate of its magnitude, and therefore we incline to magnify the fault that we may minimize the thickness of the series. On the other hand, to magnify the fault is to multiply the amount of erosion which took place between its production and the burial of the series in the Potsdam epoch. While the testimony of adjacent regions indicates that the denudation of that interval was very great, we do not feel at liberty to so largely increase the estimate

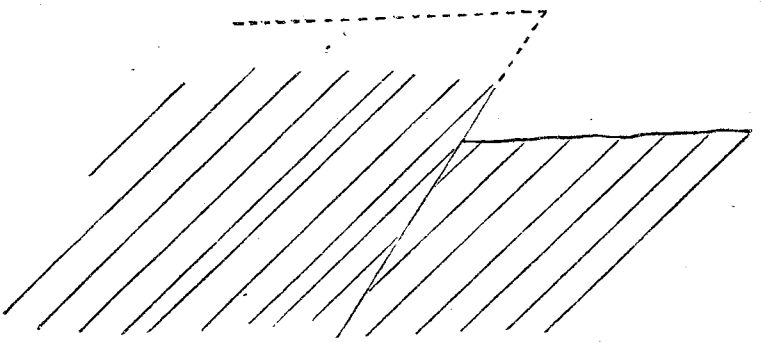


FIG. 24.—Ideal sketch of the primitive Keweenaw fault.

of its amount as to suppose a fault equal to the thickness of the upturned beds. A widespread denudation of several hundred or a few thousand feet we consider to be demonstrated, but the complete truncation of a mountain range several miles high we do not feel free to assume, even if there were no objections to supposing so great faulting. We are therefore checked in both directions, and have little doubt that the truth lies somewhere between the extremes in either direction.

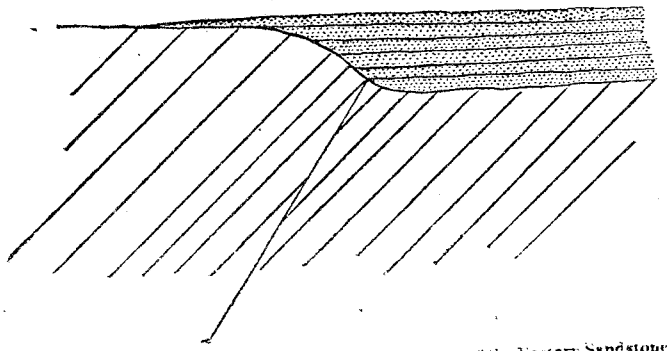


FIG. 25.—Ideal sketch of the Keweenaw fault, after the deposition of the Eastern Sandstone and before the secondary faulting.

Figure 25 is an ideal section across the fault line after the erosion of the crest of the upthrow and the deposition of the later strata against and upon it. It is clear that the brow of the upthrow would furnish favorable conditions for the derivation of pebbles and bowlders from the Keweenaw Series and that the shore line would be suitable for the

accumulation of "mud and shingle" deposits; in other words, under these conditions, the derivation of the pebbles of the Eastern Sandstone is satisfactorily elucidated.

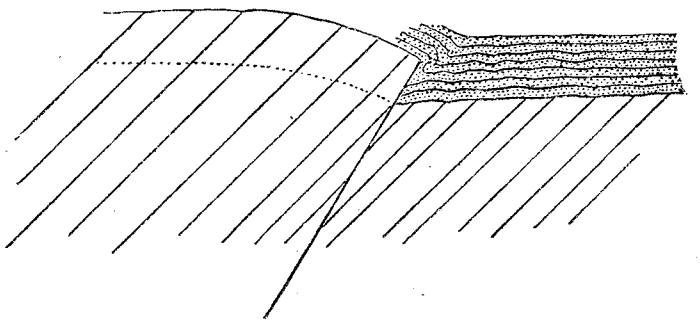


FIG. 26.—Ideal sketch of the Keweenaw fault, after the secondary faulting.

Figure 26 represents the supposed result of a further slight faulting along the old line. The Keweenaw beds on the upthrow side are pushed obliquely upward and against the Eastern Sandstone. The general effect was to upturn the sandstone and bow it into undulations for a moderate distance adjacent to the fault line, beyond which it remains undisturbed. We conceive that on account of the inclination of the upthrust (or downthrow, as it may have been) some beds at the immediate contact line were bent under while the majority were turned upward. The action was like the pushing of a blunt wedge obliquely into the edges of the sandstone strata. The one result is the expression of the element of upward thrust and the other of the lateral push. We conceive, also, that, on account of the oblique thrust, there would be a faulting movement along the line of unconformable contact on the sloping brow of the Keweenawan uplift. Now, since decomposition of the Keweenawan beds along this line of contact had probably greatly softened the edges of the trappean beds, in accordance with the general law of contact decomposition, comparatively little force and motion were necessary to reduce the already softened material to the condition in which we find the junction débris.

In those instances in which the pre-Potsdam erosion had produced slight valleys or embayments along the face of the old Keweenawan uplift, the later movement would naturally have the effect of pushing the beds up into a curved sinuous rim.

Now, if denudation be conceived to have since cut the disturbed beds down to different depths, the several sections which we have heretofore constructed in a purely empirical manner, on the basis of observation, may find elucidation in the rational results involved in this hypothesis. The truncating of the curved rim formed by the turning up of the embayed beds of the sandstone along the junction would display such sinuous margins as constitute the beautiful phenomena of Bête Grise





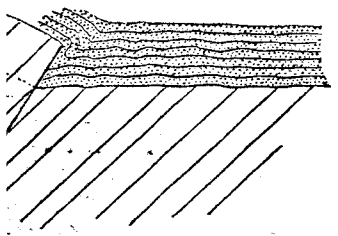
Bay. In cases where the ero
tirely the overlapping beds
the overthrust would be displa
Wall, Saint Louis and Douglas
of the action, while the down-t
Hungarian ravines exemplify
the overlying and the underlyi
downturning of the sandstone
oblique thrust of the wedge-l
strata.

Similar results, however, mig
the original fault, if it be assume
Keweenawan beds on each oth
That faulting may be distribute
paratively small shearing resista
tions, experimentation and obse
been inclined to believe that the
slight irregular movement of thi
at command seems to strengthen
nite, and not inconsiderable, faul
above indicated.

To us the nature of the cont
were revealed by excavation, seen
lutely demonstrate, the correctn
form any satisfactory conception
junction débris — consisting of tra
mingled with joint clay and sand f
reduced to a foliated structure, t
slickensides — could be produced,
ing movement. Nor are we able o
nation of the imperfect basal face
hand, or of the bent and truncate
The contact is clearly not that of a
markedly diverse from that. It i
contact of depositional superpositio
conformity and of the structural ch
relation. The contact faces furnis
faulting movement.

Not only do we appeal to the nat
débris, but to the fact that differe
into conjunction. Along Bête Gris
Sandstone is made with different me
specifically pointed out above. All t
the Bohemian Range and are relativ
Lake region, several distinct membe

" deposits; in other words, under
pebbles of the Eastern Sandstone



fault, after the secondary faulting.

result of a further slight fault-
aw beds on the upthrow side are
the Eastern Sandstone. The gen-
e and bow it into undulations for
ult line, beyond which it remains
account of the inclination of the
ve been) some beds at the imme-
ile the majority were turned up-
g of a blunt wedge obliquely into
ie o[illegible]esult is the expression of
other of the lateral push. We
oblique thrust, there would be a
unconformable contact on the
ft. Now, since decomposition of
of contact had probably greatly
s, in accordance with the general
ively little force and motion were
ied material to the condition in

-Potsdam erosion had produced
face of the old Keweenawan up-
y have the effect of pushing the

ave since cut the disturbed beds
ctions which we have heretofore
er, on the basis of observation,
ults involved in this hypothesis.
ed by the turning up of the em-
ie junction would display such
tiful phenomena of Bête Grise



Bay. In cases where the erosion progressed so far as to cut away entirely the overlapping beds of sandstone, the various phenomena of the overthrust would be displayed. Such upturned beds as those of the Wall, Saint Louis and Douglass Houghton Ravines illustrate one phase of the action, while the down-bent beds of the Douglass Houghton and Hungarian ravines exemplify another phase. We conceive that both the overlying and the underlying contacts, as well as the upturning and downturning of the sandstone strata, may be the results of a simple oblique thrust of the wedge-like edge of the uplifted Keweenawan strata.

Similar results, however, might be produced, whatever the hade of the original fault, if it be assumed that some individual movement of the Keweenawan beds on each other took place during the last faulting. That faulting may be distributed along several planes that offer comparatively small shearing resistance is affirmed by theoretical considerations, experimentation and observation in nature. We have, at times, been inclined to believe that the post-Potsdam disturbance was due to a slight irregular movement of this kind, but the increased evidence now at command seems to strengthen the probability that there was a definite, and not inconsiderable, faulting movement somewhat of the kind above indicated.

To us the nature of the contacts, at the several points where they were revealed by excavation, seems to strongly corroborate, if not absolutely demonstrate, the correctness of our views. We are unable to form any satisfactory conception of the precise method in which the junction débris — consisting of trappean fragments and comminuted trap, mingled with joint clay and sand from the Eastern Sandstone, the whole reduced to a foliated structure, though still very soft, and marked by slickensides — could be produced, unless it be the product of a faulting movement. Nor are we able otherwise to find a satisfactory explanation of the imperfect basal face of the overhanging trap, on the one hand, or of the bent and truncated face of the sandstone on the other. The contact is clearly not that of a shore cliff, for its characteristics are markedly diverse from that. It is to us equally clear that it is not a contact of depositional superposition, for it is devoid of the stratigraphic conformity and of the structural characteristics which belong to such a relation. The contact faces furnish, as we think, specific evidence of faulting movement.

Not only do we appeal to the nature of the contact and the contact débris, but to the fact that different members of the two series come into conjunction. Along Bête Grise Bay the contact of the Eastern Sandstone is made with different members of the Keweenaw Series, as specifically pointed out above. All these members belong to the base of the Bohemian Range and are relatively low in the series. In the Torch Lake region, several distinct members are shown in contact; but all be-

long to a considerably higher horizon than those of Bête Grise Bay. At Wall Ravine the junction is made with a porphyritic conglomerate; in the Saint Louis Ravine with diabase, lying not far below the thin Saint Louis conglomerate bed. In the Douglass Houghton Ravine, the junction is made with a broken diabase. In the Hungarian Ravine the contact is with diabase immediately underlying a thick conglomerate bed. In no two of the above localities does the Eastern Sandstone come in contact with the same member of the Keweenaw Series. While the junction line approaches the strike of the beds, it nevertheless crosses it at a small angle and continually brings into contact different members.

So, on the other hand, different horizons of the Eastern Sandstone come into junction with the Keweenaw Series at different points. The beds at Bête Grise Bay are the peculiar soft breccia shales. In the Wall Ravine they are of sandstone, several hundred feet below the most conglomeratic horizon. In the Saint Louis Ravine they are sandstone, likewise below the conglomeratic horizons. In the Douglass Houghton they are sandstone, shales and the conglomeratic horizons themselves. In the Hungarian Ravine the contact beds are sandstones that appear to be considerably above the most conglomeratic beds. It is not absolutely certain that the conglomeratic beds in the last four localities are the same. But there is a general correspondence in their characters, and it seems not improbable that the conglomeratic beds of the four localities are essentially identical; but whether this be so or not, it is clear that beds of quite different characters and stratigraphical relations appear in contact at the several points. Now we esteem this altogether fatal to a view that makes the Eastern Sandstone a conformable basal member of the Keweenaw Series. It is not necessarily fatal to views which postulate faulting other than that which we advocate nor to views which assume the escarpment to be an old erosion cliff.

Of like import to the above is the discordance in the strike of the two series near the junction. The strike of the sandstone series was partly determined by the form of the basin in which it was deposited and partly by the tilting to which it was afterward subjected. The fault line and the agencies associated with it were chiefly influential, in our view, in determining both of these factors, and as that fault line was not strictly concordant with the strike of the Keweenawan beds and as the strikes of the Eastern Sandstone were not strictly in concord with the fault line, a very considerable discordance between the strikes of the two series was the result. At the same time there were no very large departures from each other. The angles between the strikes, in the cases examined by us, were mainly less than 45°.

Passing to the Eastern Sandstone, we find in its pebbles evidence of a significant character. We hold that the appeal of Agassiz and Pumpelly to the evidence presented by the existence of these trap-





derived pebbles is fully sus
additional facts we now pr
have been exposed to shore a
the deposition of the Easter
clusion from the facts. These
are derived from no single K
several members of the com
varieties found in the adjacen
in similar assortment and kin
within the range of known fac
Their mere existence, howev
ern Sandstone belongs to any
conglomerates of the Keweena
facts relating to their characte
demonstration.

In support of this claim we
rived pebbles near the junctio
know, at any considerable dista
quite extensively displayed alo
distances not greatly removed
where have we found it, or ar
characterized by the pebbles in
ravines in the vicinity of Torch
the junction line, pebbles are re
be in part due to the horizons wh
may be true that some of the co
back from the junction line. Bu
that show a definite disposition o
in number and size toward of th
observations to be representative

We also appeal to the imperfe
conglomerates. If the material
had been rolled to and fro for long
dent to such transportation must
definite association of material of
is common to the great widely-dis
ably have resulted. But, on the c
Agassiz and fully supplemented b
is of that peculiar type happily s
which signifies a limited action on
We follow Agassiz in believing thi
the shore line whence the pebbles w

We appeal, furthermore, to the
exposures at Bête Grise Bay. This

derived pebbles is fully sustained and is greatly emphasized by the additional facts we now present. That the Keweenawan beds must have been exposed to shore action and drainage erosion at the time of the deposition of the Eastern Sandstone seems to be a necessary conclusion from the facts. These pebbles, as we have fully specified above, are derived from no single Keweenawan bed, but, variously, from the several members of the complex terrane. There are all the leading varieties found in the adjacent trappean series, but found nowhere else in similar assortment and kind. There is no other conceivable source within the range of known facts.

Their mere existence, however, does not demonstrate that the Eastern Sandstone belongs to any other category than the sandstones and conglomerates of the Keweenaw Series, but we think that the specific facts relating to their character and distribution do constitute such a demonstration.

In support of this claim we appeal to the abundance of trap-derived pebbles near the junction line and to their rarity, so far as we know, at any considerable distance from it. The Eastern Sandstone is quite extensively displayed along the borders of Keweenaw Bay, at distances not greatly removed from the Keweenaw Series, and yet nowhere have we found it, or are we aware that others have found it, characterized by the pebbles in question. Furthermore, in the several ravines in the vicinity of Torch Lake, at distances a mile away from the junction line, pebbles are relatively rare. It is true that this may be in part due to the horizons which there chance to be exposed, and it may be true that some of the conglomeratic beds extend much farther back from the junction line. But we made some specific observations that show a definite disposition on the part of the pebbles to increase in number and size toward of the contact line, and we believe these observations to be representative of the general fact.

We also appeal to the imperfect assortment of the material of the conglomerates. If the material had been of distant derivation and had been rolled to and fro for long distances; the assorting action incident to such transportation must have been of a high order, and the definite association of material of definite degrees of coarseness such as is common to the great widely-distributed conglomerates would probably have resulted. But, on the contrary, as previously described by Agassiz and fully supplemented by our own observations, the deposit is of that peculiar type happily styled "mud and shingle" deposit, which signifies a limited action on the part of the assorting agencies. We follow Agassiz in believing this to surely indicate a proximity of the shore line whence the pebbles were derived.

We appeal, furthermore, to the angularity of the pebbles in the exposures at Bête Grise Bay. This is a very notable feature. The

amount of wear which the pebbles have suffered, while noticeable, is very limited, and the result is a breccia rather than a pudding-stone. It seems to us quite impossible that the material of this deposit was derived from any distant source. But in the sections near Torch Lake, the angularity is not a notable feature, and a somewhat more distant derivation is indicated or else a larger measure of sub-aërial rounding of the fragments before they were brought within reach of the depositing waves.

Concurrent with this measurable rounding of the pebbles is the absence of great fallen cliff masses and of exceedingly large bowlders. From the absence of these, at the contact, we infer the absence of beetling cliffs from which such masses would inevitably have been thrown down and buried. This is another form of saying that after the first great faulting, and previous to the incursion of the Potsdam shore line, there had been sufficient erosion to cut away the great fault cliff and reduce the surface contours to moderate slopes. Against these moderate slopes we conceive the sandstone to have been deposited, and, from their declivities, the constituent pebbles to have been derived.

Larger observation may modify the special phases of the conception to be derived from these details of the structure of the border belt, but, in the formation of our opinions concerning these particulars, we have endeavored to follow the legitimate conclusions to which the phenomena seem to point.

The occurrence of Trenton Limestone, capping a hill which reposes centrally upon the tract of Eastern Sandstone, leaves us no choice but to regard the latter as Potsdam, and, in this one conclusion, at least, we are fortunately in harmony with all our fellow-students. The existence of Silurian limestone at this point seems to indicate that it once spread extensively over the Lake Superior basin. From the fact that in the vicinity of Torch Lake the Eastern Sandstone rises to near the crest of the peninsular ridge, and near Houghton is thought to be represented by a remnant actually overlying it, we infer that the Silurian limestone may have been originally deposited over the peninsula. It is quite possible also, that later formations once overlay this. Under such conditions, the origin of those streams which cross the peninsula is easily understood, as heretofore remarked.

## SUMMARY.

Recapitulated, the history of events, as we read them, was essentially as follows: The Keweenaw Series very greatly antedated in its formation the Potsdam Sandstone, and occupied a lapse of time immensely vaster than the Potsdam as that formation is known in its unquestionable localities east or west. It was a period characterized by





some of the most remarkable dis
world has been a witness. Acco
orographic movements of a protra
acter. These were succeeded by
so far as we can see, by any know
Indeed, the very conditions whic
depositions which would now be
before the close of this erosion, a
along what is now the face of the
insula. Subsequently, submerge
and the Eastern Sandstone was
upon the Keweenaw Series. Up
possibly other members of the Silu
At a later stage these were remo
time not more definitely determi
minor fault movement along, or
which the beds of the Eastern
contact, and various faulting phe

s have suffered, while noticeable, is
reccia rather than a pudding-stone.
at the material of this deposit was
But in the sections near Torch Lake,
ure, and a somewhat more distant
ger measure of sub-aërial rounding
rought within reach of the deposit-

rounding of the pebbles is the
nd of exceedingly large bowlders.
ntact, we infer the absence of beet-
ould inevitably have been thrown
orm of saying that after the first
incursion of the Potsdam shore
to cut away the great fault cliff
moderate slopes. Against these
ndstone to have been deposited,
ituent pebbles to have been de-

special phases of the conception
structure of the border belt, but,
rning these particulars, we have
clus[redacted] to which the phenomena

ne, capping a hill which reposes
ndstone, leaves us no choice but
this one conclusion, at least, we
fellow-students. The existence
s to indicate that it once spread
sin. From the fact that in the
stone rises to near the crest of
n is thought to be represented
nfer that the Silurian limestone
ver the peninsula. It is quite
overlay this. Under such con-
h cross the peninsula is easily

we read them, was essentially
reatly antedated in its forma-
d a lapse of time immensely
tion is known in its unques-
s a period characterized by



some of the most remarkable displays of igneous activity of which the world has been a witness. Accompanying and succeeding this, were orographic movements of a protracted, though apparently gentle, character. These were succeeded by a long interval of erosion, unbridged, so far as we can see, by any known deposit in the Lake Superior basin. Indeed, the very conditions which made the erosion possible forbade depositions which would now be accessible. At an undetermined time before the close of this erosion, a longitudinal fault line was developed along what is now the face of the trappean terrane of Keweenaw Peninsula. Subsequently, submergence beneath the Potsdam seas ensued, and the Eastern Sandstone was laid down unconformably against and upon the Keweenaw Series. Upon this the Trenton Limestone, and possibly other members of the Silurian series, accumulated conformably. At a later stage these were removed by secular erosion, and, at some time not more definitely determined than that it was post-Potsdam, a minor fault movement along, or near, the old break took place, by which the beds of the Eastern Sandstone were disturbed along the contact, and various faulting phenomena developed.

# INDEX.


Page.

Agassiz, Alexander, on sandstones of Saint Louis Ravine ..... 27
views of, on sandstones of Saint Louis Ravine, examined ..... 29
on sandstone and trap of Douglass Houghton Creek ..... 31
views of, on contact at Douglass Houghton Ravine, mentioned ..... 44
on relations of Eastern Sandstone to trappean series ..... 86
Bête Grise Bay, topography of ..... 12
Foster and Whitney on sandstone of ..... 16
melaphyrs of, described ..... 17
occurrence and lithological characteristics of sandstones of ..... 18, 22
shale and breccias of ..... 20
melaphyrs of ..... 21
pebbles and conglomerates of ..... 24
R. D. Irving on dip of sandstone at ..... 99
character of pebbles at ..... 117
and Douglass Houghton Ravine, pebbles and conglomerates of, contrasted ..... 47
Bohemian Range, Whitney and Foster on conglomerates and sandstone of ..... 73
effect of, on inclinations in Eastern Sandstone ..... 83
Carp Lake Landing, analysis of sandstone of ..... 81
Chamberlin, T. C., on dip of sandstone beds at Keweenaw Point ..... 98
Chauvenet, W. M., on conglomerates and sandstones of Douglass Houghton Ravine ..... 34
on dip of sandstone in Torch Lake Quarry ..... 52
on characteristics and dip of sandstone of Hungarian Ravine ..... 56
on sandstones of Hungarian River ..... 60, 65
Contact faces, irregularity of ..... 104
Contact line, discordance of strike of Eastern Series with strike line of Keweenaw Series ..... 105, 116
Copper Harbor, Whitney and Foster on relations of detrital rocks and trap at ..... 73
Credner, H., on relations of Eastern Sandstone to trappean series ..... 91
views of, on relation of Eastern Sandstone to trappean series, criticised ..... 92
Douglas County, contact of trap and sandstones in ..... 70
Douglass Houghton Ravine, junction on ..... 30
Eastern Sandstone, exposure of, on Douglass Houghton Ravine ..... 39
occurrence of Keweenawan detritus in ..... 48
occurrence of pebbles from trappean series in ..... 96
contact of, with trappean series ..... 97
horizontality of ..... 102
character of pebbles of ..... 105, 116
time of deposition of ..... 108
and Keweenaw Series, relation of, with respect to drainage ..... 103
strike of junction line of ..... 103, 110
line of escarpment and line of junction of ..... 104, 116
summary statement of relations of ..... 118

Page.

Emerson, L. G., on junction of trap and sandstone ..... 31
Foster, J. W., on bearing and inclination of trap and sandstone of Bête Grise Bay. 14
on dip of sandstone of Bête Grise Bay ..... 15
on sandstones of Douglass Houghton Ravine ..... 30
on formations of Torch River ..... 31
views of, on contact at Douglass Houghton Ravine, criticised ..... 44
on relations of Eastern Sandstones and trappean series ..... 73, 75
views of, on relations of Eastern Sandstone and trappean series, examined ..... 78
Geikie, Archibald, sketch of basaltic plains by ..... 101
Houghton, Mich., contact of Eastern Sandstone and trap near ..... 68
Hungarian Ravine, topography of the ..... 54
Hungarian River, Whitney and Wadsworth on sandstone and conglomerate on. 37
exposures of sandstone on ..... 64
Irving, R. D., on formations of Bête Grise Bay ..... 16
on sandstones of Douglass Houghton Ravine ..... 33
on sandstones of Douglass Houghton River ..... 34
views of, on junction at Douglass Houghton Falls, criticised ..... 37
on sandstone of Torch Lake Quarry ..... 51, 52
on sandstone exposures on Ontonagon River ..... 69
on relations of sandstone and trap at Keweenaw Point ..... 99
Isle Royale, Foster and Whitney on conglomerates of ..... 75
Jackson, C. T., on geology of Bête Grise Bay ..... 13
on relations of Eastern Sandstone and trappean series ..... 71
Jasper Point, trap of ..... 13
Junction débris, character of ..... 104
Junction débris as a product of faulting movement ..... 115
Keweenaw Peninsula, topography of ..... 103
eruptions in ..... 106
elevation of ..... 110
Keweenaw Point, topography of ..... 12
Foster on bearing and dip of sandstone of ..... 15
Whitney and Wadsworth on the deposition of conglomerates at ..... 36
Whitney on contact of trap and sandstone at ..... 73
section of, on Foster and Whitney view ..... 80
views of Foster and Whitney as to eruptions of, criticised ..... 85
dip of sandstone beds at ..... 98
ideal sketches of primitive and secondary faults of ..... 114
Keweenaw Range, R. D. Irving on fault of ..... 100
Keweenaw Series, bedded nature of ..... 100
uniformity and steadiness of dip of ..... 101
thickness of ..... 102
conclusions respecting relations of, to Eastern Sandstone ..... 106
and Eastern Sandstone, relation of, with respect to drainage ..... 103
strikes of junction line of ..... 103, 110
disturbance along the line of contact of ..... 104, 111
line of escarpment and line of junction of ..... 104, 116
summary statement of relations of ..... 118
Lac la Belle, breccia, trap, and sandstone of ..... 13, 14
Foster on sandstone of ..... 15
junction at ..... 68
Lake Superior sandstones ..... 75
Little Montreal River, trap rocks of ..... 13







Merriam, W. N., examination by, of cont
Montreal River, sandstone of ...
Ontonagon River, characteristics of sand
sandstones and conglomerates on
Point Isabelle, geology of ...
Portage Canal, analysis of sandstone of.
Portage Lake region, occurrence of trap
Potsdam sands, quartzose character of,
Keweenawan sands ...
Pumpelly, Raphael, on contact at Dougl
views of, on contact at Douglass
on relations of Eastern Sandstone
Rominger, C., on contact of sandstone a
on sandstones and conglomerates
on sandstone of Hungarian Creek
on sandstones and trap near Hou
on relations of Eastern Sandstone
views of, on relation of Eastern
cised ...
Saint Louis Ravine, junction on ...
Sandstone series, lithological character
Sweet, E. T., on contact of traps and sa
Torch Lake, topography of ...
Whitney and Wadsworth on junc
nature of sandstone at ...
Whitney and Wadsworth on sand
dip of sandstone at quarry near
character of faulting near ...
character of pebbles near ...
Torch River, Foster on sandstones of .
Foster and Whitney on junction
Trenton Limestone, occurrence of, in E
Van Hise, C. R., on character of sandst
Wadsworth, M. E., on sandstones and m
on contact at Douglass Houghto
observations of, on intercalatio
Houghton Ravine, criticised ..
on contact at Douglass Houghto
on sandstone of Torch Lake Qu
views of, on sandstone of Torch
criticism by, of Irving's views o
on conglomerate of Hungarian
criticism by, of Irving's views o
views of, on junction at Hungar
views of, on relation of Eastern
on pebbles from trappean series
views of, on relation of Eastern
cised ...
and Whitney, views of, on conta
cised ...
Wall Ravine, sandstone and conglome
Wall Creek Ravine, sandstones of ...

EX.


| | Page. |
|---|---|
| dstone | 31 |
| ap and sandstone of Bete Grise Bay | 14 |
| | 15 |
| Ravine | 30 |
| | 31 |
| ghton Ravine, criticised | 44 |
| l trappean series | 73, 75 |
| ndstone and trappean series, ex- | |
| | 78 |
| by | 101 |
| ne and trap near | 68 |
| | 54 |
| n sandstone and conglomerate on | 37 |
| | 64 |
| | 16 |
| ivine | 33 |
| ver | 34 |
| hton Falls, criticised | 37 |
| | 51, 52 |
| iver | 69 |
| eweenaw Point | 99 |
| rates of | 75 |
| | 13 |
| appean series | 71 |
| | 13 |
| | 104 |
| nent | 115 |
| | 103 |
| | 106 |
| | 110 |
| | 12 |
| f | 15 |
| n of conglomerates at | 36 |
| e at | 73 |
| | 80 |
| ons of, criticised | 85 |
| | 98 |
| faults of | 114 |
| | 100 |
| | 100 |
| | 101 |
| | 102 |
| ern Sandstone | 106 |
| spect to drainage | 103 |
| | 103, 110 |
| of | 104, 111 |
| on of | 104, 116 |
| | 118 |
| | 13, 14 |
| | 15 |
| | 68 |
| | 75 |
| | 13 |





| | Page |
|---|---|
| Merriam, W. N., examination by, of contact at Douglass Houghton Ravine | 46 |
| Montreal River, sandstone of | 82 |
| Ontonagon River, characteristics of sandstone on | 69 |
| sandstones and conglomerates on | 77 |
| Point Isabelle, geology of | 14 |
| Portage Canal, analysis of sandstone of | 81 |
| Portage Lake region, occurrence of trap and conglomerate in | 74 |
| Potsdam sands, quartzose character of, distinguished from silicate nature of Keweenawan sands | 102 |
| Pumpelly, Raphael, on contact at Douglass Houghton Ravine | 31 |
| views of, on contact at Douglass Houghton Ravine, mentioned | 44 |
| on relations of Eastern Sandstone to trappean series | 86 |
| Rominger, C., on contact of sandstone and trap at Bête Grise Bay | 17 |
| on sandstones and conglomerates of Douglass Houghton Ravine | 35 |
| on sandstone of Hungarian Creek | 57 |
| on sandstones and trap near Houghton | 62 |
| on relations of Eastern Sandstone to trappean series | 88 |
| views of, on relation of Eastern Sandstone to trappean series, criticised | 89 |
| Saint Louis Ravine, junction on | 27 |
| Sandstone series, lithological characteristics of | 42 |
| Sweet, E. T., on contact of traps and sandstones in Douglas County | 70 |
| Torch Lake, topography of | 12 |
| Whitney and Wadsworth on junction at | 36 |
| nature of sandstone at | 37 |
| Whitney and Wadsworth on sandstone and conglomerates of | 37 |
| dip of sandstone at quarry near | 49 |
| character of faulting near | 112 |
| character of pebbles near | 118 |
| Torch River, Foster on sandstones of | 30 |
| Foster and Whitney on junction of sandstone and trap on | 31 |
| Trenton Limestone, occurrence of, in Eastern Sandstone area | 106, 118 |
| Van Hise, C. R., on character of sandstone at Torch Lake Quarry | 52 |
| Wadsworth, M. E., on sandstones and melaphyrs of Douglass Houghton Ravine | 32 |
| on contact at Douglass Houghton Ravine | 25 |
| observations of, on intercalations of trap and sandstone at Douglass Houghton Ravine, criticised | 49 |
| on contact at Douglass Houghton Ravine | 49 |
| on sandstone of Torch Lake Quarry | 49 |
| views of, on sandstone of Torch Lake Quarry, criticised | 51 |
| criticism by, of Irving's views on sandstone of Torch Lake Quarry | 52 |
| on conglomerate of Hungarian Ravine | 55 |
| criticism by, of Irving's views on sandstone of Hungarian River | 57 |
| views of, on junction at Hungarian River, criticised | 62 |
| views of, on relation of Eastern Sandstone to trappean series, criticised | 92, 94 |
| on pebbles from trappean series in Eastern Sandstone | 86 |
| views of, on relation of Eastern Sandstone and Keweenaw Series, criticised | 97 |
| and Whitney, views of, on contact at Douglass Houghton Ravine, criticised | 45 |
| Wall Ravine, sandstone and conglomerates of | 23 |
| Wall Creek Ravine, sandstones of | 20 |

| | Page. |
|---|---|
| Whitney, J. D., on dip of sandstone of Bête Grise Bay | 15 |
| on formations of Torch River | 31 |
| on contact at Douglass Houghton Ravine | 35 |
| on relations of Eastern Sandstones and trappean series | 73, 75, 77 |
| views of, on relations of Eastern Sandstones and trappean series, examined | 78 |
| and Wadsworth, views of, on contact at Douglass Houghton Ravine, criticised | 45 |




DEPARTMEN

BU

UNITE

GEOLOGIC

VO


WASHI

GOVERNMENT PR

18