position of the sandstone exposure at C, where the material is mainly white silicious sandstone, with but little interstratified shaly material, it is evident that the junction of the sandstone with the trap is some distance farther west at the bottom of the ravine than at the top. But here again the same tree-covered depression baffled our efforts towards uncovering the exact junction. At the point L we dug a pit, which disclosed sandstone of the same character as at C, and immediately above and to the west uncovered trap; but we did not feel entirely confident that the latter was in place.

However, just across the ravine from the projecting point at C we noted, at a considerable elevation in the bank, and partially uncovered by an old slide, exposures of sandstone, shale, and trap in such proximity as to promise the finding by digging of the exact junction. The exposures here (point A of the plat of Plate XII), and the positions of our trenches are shown in Figure 6. Beginning at the covered

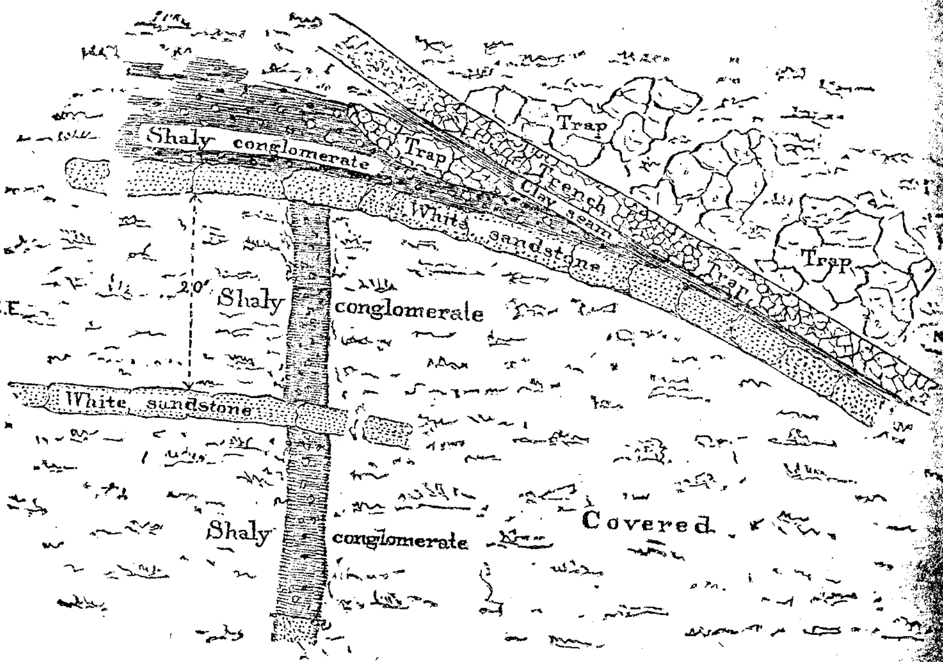

FIG. 6.—Junction of the Eastern Sandstone and Keweenawan diabase, south side Douglass Houghton Ravine, Keweenaw Point, Michigan. Scale, 20 feet to the inch.

space on the east side of that portion of the slide represented in the wood-cut, we noted portions of two of the white sandstone layers, similar to those seen on other exposures, lying about 20 feet apart on the slope of the bank. Each of these layers is about three or four feet thick, is composed in the main of silicious material, and is affected in each case by an irregular but at times a very considerable degree of induration. Each of the layers, as seen on the face of the bank, shows a nearly

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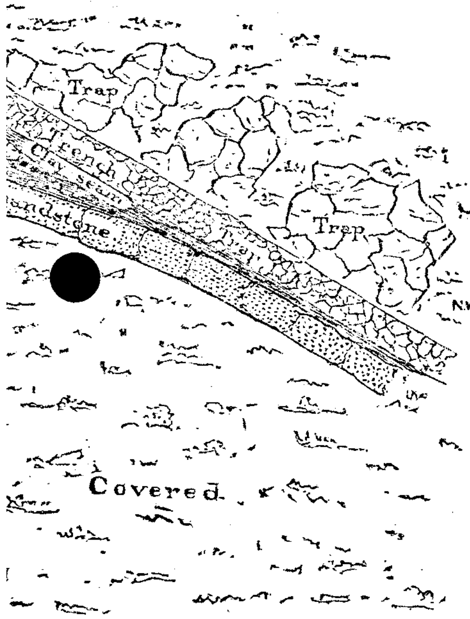

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horizontal position, but on closer inspection is found to dip slightly into the hill, the exact direction of the dip being about westward and the inclination ranging from 2° to 5°, the smaller angle having been observed at the easternmost ends of the layers. On each side of the uppermost of these layers we found exposures of the usual conglomeratic red shale, the pebbles coming wholly—as we satisfied ourselves by opening many on the ground and studying subsequently a number of thin sections—from the eruptives of the Keweenaw Series, some of them being indistinguishable from traps *in situ* farther up this same ravine. Following these sandstone layers westward, we noted them rapidly increasing in westward inclination, the angle at 20 to 25 feet from the beginning being 12° and at 50 feet as much as 20°. The uppermost of the two layers was then traced, partly by natural exposure and partly by being uncovered, to the junction with the trap, as shown on the sketch, where it was found to incline to the northwestward at an angle of 30°, or not far from parallelism with the bedding structure of the traps themselves. With the aid of a force of miners we uncovered this junction very thoroughly. At the point of the sketch where the uppermost of the two sandstone layers described passes beneath the trap, we uncovered, immediately above the sandstone:—(1) about six inches of soft red clay, including shattered and angular masses of amygdaloid; (2) much altered and fissured amygdaloid apparently in place, about one foot; (3) the non-amygdaloidal trap, very much and irregularly fissured. In the amygdaloid was noted a tendency to a schistose structure parallel to the red-clay seam at the junction. Following this clay seam up the bank with our trench, we found it soon departing from contact with the white sandstone and traversing obliquely the red shaly conglomerate immediately above that sandstone layer, and a little farther leaving below it a mass of the trap ten feet in length by four in width. This mass is badly decomposed, is affected throughout by a strongly marked schistose structure parallel to the clay seam, and shows along its sides and along the fissures which produce the schistose structure shining "slickensided" surfaces. Carrying the trench still farther in the same direction we soon reached the drift material forming the upper part of the bank, and after a good deal of digging here, with the hope of carrying the junction still farther, we concluded that we had reached the original sub-drift surface. Turning our attention next to the other end of the trench, we carried it down the hill until the detritus and material from above were too heavy for us to remove. We were thus unable to reach a point at which the junction should leave the sandstone layer and pass on to the next broad conglomerate beneath it, which it was evidently soon about to do. From the last point reached we ran a trench some ten feet down the bank, in which we found the layers of red shaly conglomerate conforming in position in a general way to the sandstone at the junction but lessening in amount of westward dip as we carried the trench downward. Returning now to about the middle point of the slide we ran a long trench from the upper one of the sandstone layers down the bank, in all some 40 feet, uncovering continuously the soft red conglomerates interstratified with the harder sandstone layers, and just reaching at the bottom of the trench a third sandstone layer. Throughout this trench the inclination of the layers is uniform, being slightly westward, or into the hill.

Before proceeding to notice the exposures above the junction of the sandstone and trap, we wish to speak somewhat more definitely with regard to the lithological characteristics of the sandstone series. So far as the exposures in this ravine are concerned this series may be described as a succession of alternations of quite white to red, much indurated to friable, moderately heavy, nearly purely silicious sandstone layers and thinly laminated red layers of a shaly or clayey conglomerate. The sandstone layers (which in portions of the thickness are greatly subordinated to the softer conglomerate layers, while in other portions equaling or even exceeding the latter in amount) are often nearly white, but more frequently are somewhat tinted with brown or red. The thin sections show them always to be composed in great preponderance of quartz fragments, mingled with which in subordinate quantity are fragments of feldspars and of felsitic material, and fragments referable to the basic members of the Keweenaw Series. There is also more or less red oxide of iron mingled with a clayey decomposition-product, which is most abundant in the least indurated and most deeply colored varieties. The induration varies greatly in amount and occurs irregularly with regard to any one layer, the layers in which the strongest indurations were noted being those interstratified with a large proportion of the shaly conglomerate. This induration evidently bears no relation to the proximity to the junction with the traps, having been noted at various horizons and places distant from as well as near to the trap, while the sandstone found actually at the contact was often but little indurated, and in no place markedly more so than noted in the case of certain layers many feet below the junction. In all the thin sections of sandstone examined, covering in some measure each of the exposures mentioned, the induration of the rock when present was seen plainly to be due to a quartz infiltration, the original fragments having received enlargements sufficient to make the areas interlock to some extent. This is a form of induration wholly independent of igneous agencies, and is one which we have observed carried out in a high degree in undisturbed sandstones many miles distant from any known eruptive material. The only exception to the induration by quartz is met with in the presence, in certain sections from layers close to the junction with the trap, of a notable quantity of crystalline calcite. This calcite occurs in addition to the indurating quartz and not to its exclusion.

With regard to the softer conglomeratic layers of the sandstone series, it is to be said that their matrix, while mainly clayey, varies between

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[1] Monographs United States

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Turning now our attention to that portion of the ravine above the junction, we have to note in the first place that nearly all of the way up to the falls the exposures, while nearly continuous on one or other side of the ravine, show much shattering; the confused appearances produced by which have been enhanced by considerable decomposition, and by the slipping along the very steep sides of the ravine in great slides of much of the shattered material. On a careful examination of both sides of the ravine, however, these exposures showed us nothing but some of the usual eruptives of the Keweenaw Series, for the most part diabases and amygdaloids, with the usual northwesterly dip, here about 25°, as seen very distinctly on the beds at and above the falls. At the point J, near the top of the south bank, a felsite or quartz porphyry occurs, and a corresponding rock is met with on the opposite side of the stream in a proper position, considering the dip and strike of the beds, to be part of the same layer. The occurrence of this rock here, first observed by Mr. W. N. Merriam, is a point of considerable interest. The layer or bed of felsitic porphyry whose existence here is thus indicated seems to be the same as that which makes quite a broad exposure on the line of the Hecla and Torch Lake Railroad, in the southern part of section 36, as already described by one of us in another place.[1]

[1] Monographs United States Geographical Survey, Vol. V, p. 196.

Our reading of the structure indicated by the exposures along this ravine is given in Figure 2 of Plate XII, our conclusions being that the sandstone is altogether newer than the Keweenaw Series, whose fragments it contains so plentifully; that the present line of contact shown on this ravine is a fault line; and that the bowed and, at the contact, crushed condition of the sandstone is due to the faulting. The arguments upon which these conclusions are based are given more fully in the general discussion at the end of this paper.

It remains for us to examine the already quoted descriptions of earlier observers, that we may see how far their statements may be reconciled with our own, and that, in so far as they cannot be so reconciled, we may give our reasons for declining to accept them.

In Mr. Foster's account, which is for the most part of so general a nature as to be reconcilable with quite discordant detailed descriptions, there are yet two or three statements with which we cannot at all agree. In speaking of the pebbles of the conglomerates here exposed as "for the most part of white quartz," he is certainly wrong. Such pebbles may occur, but after breaking open a large number of pebbles at various exposures, we failed to discover any such. He is also as certainly wrong in saying that the sandstone rests "on the trap in large blocks, 70 feet above its bed." The only possible warrant for any such statement, so far as we were able to see, consists in the occurrence of trap in the stream-bed, and, some little distance to the eastward, of sandstone high in the bank. In speaking of the sandstone as dipping southerly near the junction, he certainly states what is true, but it is equally true that in the same vicinity it lies horizontally and dips in various other directions. Upon these statements of Mr. Foster are based, we suppose, those quoted above from Foster and Whitney's joint report. The latter do not seem to call for any additional remark.

In Mr. Agassiz's description, except in one or two minor points, we find nothing with which we cannot agree. All that he says with regard to the general horizontal position of the sandstone, subordinate to which are variations from horizontality, and with regard to the nature of the sandstone and conglomerate, coincides with our own observations. In comparing the conglomerate beds to the mixtures of "mud and shingle" met with on sea shores, Mr. Agassiz notes what is perhaps the most interesting feature of these conglomerates, viz, the singular lack of any assortment of the materials composing them. In speaking of the falls as *at* the junction of the trap and sandstone instead of as at some little distance above that junction, it seems evident that Mr. Agassiz is speaking in a general way only, since he speaks in the same connection of the chloritic bed of Whitney and the other traps as showing on the sides of the ravine below the falls.

Professor Pumpelly's statements being, so far as they refer to this ravine, merely confirmatory of those of Mr. Agassiz, do not require any especial attention in the present connection. We may merely say, with regard to the "chloritic fluccan" (since it seems evident that by this expression they cannot have referred to the red shaly débris which, as subsequently shown, we have uncovered by excavating along the junction with the Eastern Sandstone at various points) mentioned by both of these gentlemen (following the earlier geologists) as occurring at the contact between the sandstone and the traps, that it appears to us to be nothing more than a shattered and somewhat altered condition of the trappean beds themselves. It will be seen hereafter that we regard this shattered trappean material as the result of faulting motion, thus far dissenting from the position taken by Messrs. Agassiz and Pumpelly.

Not stopping now to discuss the statements in the above given quotations from Messrs. Whitney and Wadsworth as to the general condition of things in the Keweenaw Series, in which statements we find much with which we cannot agree, we note, so far as the Douglass Houghton ravine is concerned, three principal points in which their descriptions conflict with our own. These are: (1) as to the inclination of the sandstones below the junction; (2) as to the interstratifications of traps and sandstones at the junction; and (3) as to the non-occurrence of trappean pebbles in the sandstone below the last trappean bed.

According to Mr. Wadsworth, his "examinations showed that the sandstone and conglomerate were not horizontal, but had a gradually increasing dip, as the falls were approached, from 5° up to 25°." This statement is several times repeated, but after a very careful examination of both sides of the ravine throughout nearly all of its length we feel entirely safe in saying that no such gradually increasing northwestern dip exists. Northwestern dips are seen, as we have shown above, and sometimes at a considerable angle, but the condition of the whole sandstone series is a bowed one, and the northwestern dips are but local, being replaced in each instance within a few feet by inclinations in other directions or by an entire lack of inclination. Moreover, as above shown, between those points which present the steepest northwestern dips and the junction with the traps, exposures occur in which the sandstone layers are horizontal, and the changes from steep inclinations to horizontality are most strongly marked at the contact of the two formations. In these statements, which we make after the most careful examinations and with full realization of the controversial nature of the case, we find ourselves confirmed more or less completely by the accounts of Messrs. Agassiz, Pumpelly, Chauvenet, and Rominger.

A still more important discrepancy between Mr. Wadsworth's descriptions and our own lies in his statement that at the junction of the sandstone and trap the two formations exhibit a series of interstratifications. As to this Mr. Wadsworth's reiterated statements are so exceedingly definite—except with regard to the exact positions of the interstratifications on the ravine and their exact number, which points are unfortunately left vague—that we fully expected to find such interstratifications without any difficulty. We knew that in 1880 Mr. W. M. Chauvenet, with Mr. Wadsworth's descriptions in hand, had made a diligent attempt to find these interstratifications without success, but notwithstanding this we could not help feeling that such definite statements as Mr. Wadsworth's must have a substantial basis in fact. After a most careful search for them, however, with the aid of a company of skilled miners, and after two days' work on both banks of the ravine, we failed entirely to discover any such interstratifications as Mr. Wadsworth describes. Since this has been the experience also of Messrs. Chauvenet and Rominger, both of whom made examinations with this special point in view, we cannot but feel that we are warranted in discrediting the existence of these intercalations of trap and sandstone. Of one thing at least we feel entirely confident, viz, that whatever interstratifications of sandstone and trap may here exist are in no sense interstratifications of the Eastern Sandstone with the Keweenawan traps. If they exist at all, they lie above the junction of the easternmost trap with the Eastern Sandstone, or in other words are included within the Keweenaw Series. After uncovering thoroughly the junction of trap and sandstone at the point A of the plat of Plate XII, we made our search for interstratifications of trap and sandstone both above and below this junction, and subsequently Mr. W. N. Merriam made independently a minute examination of both banks of the ravine, at all levels, to the west of the westernmost sandstone exposures, with no more success than we met with. Below the junction at A of Plate XII, we call everything the Eastern Sandstone, and feel confident that there are no trappean beds. To the west of that junction and up to the falls we have seen nothing to suggest the existence of interstratifications of detrital material with the traps, but, since there is here much confusion and much fallen material, we are unwilling to assert positively that no such interstratifications exist. If detrital beds do exist above that point, they are quite certainly wholly different in nature from the beds of the Eastern Sandstone, being either igneo-detrital rocks of some sort or the usual non-quartzose sandstones of the Keweenaw Series. How Mr. Wadsworth may have been misled as to this, we cannot say. In the junction sketch of Fig. 6 it is shown that the joint clay, lying between the sandstone and the overlying trap in our long trench, passes, as it is followed upwards, above a detached and "slicken-sided" mass of trap. Possibly, when ill exposed, such a mass of trap, with red joint clay on one side of it and the red conglomerate of the Eastern Sandstone on the other, might be mistaken for a continuous bed of trap included within the sandstone. It is also possible that in a hasty observation one might mistake the indurated sandstone layers, here seen to be interstratified with soft conglomerates, for trappean beds; but it is difficult to believe that Mr. Wadsworth could have been misled in either of these ways.

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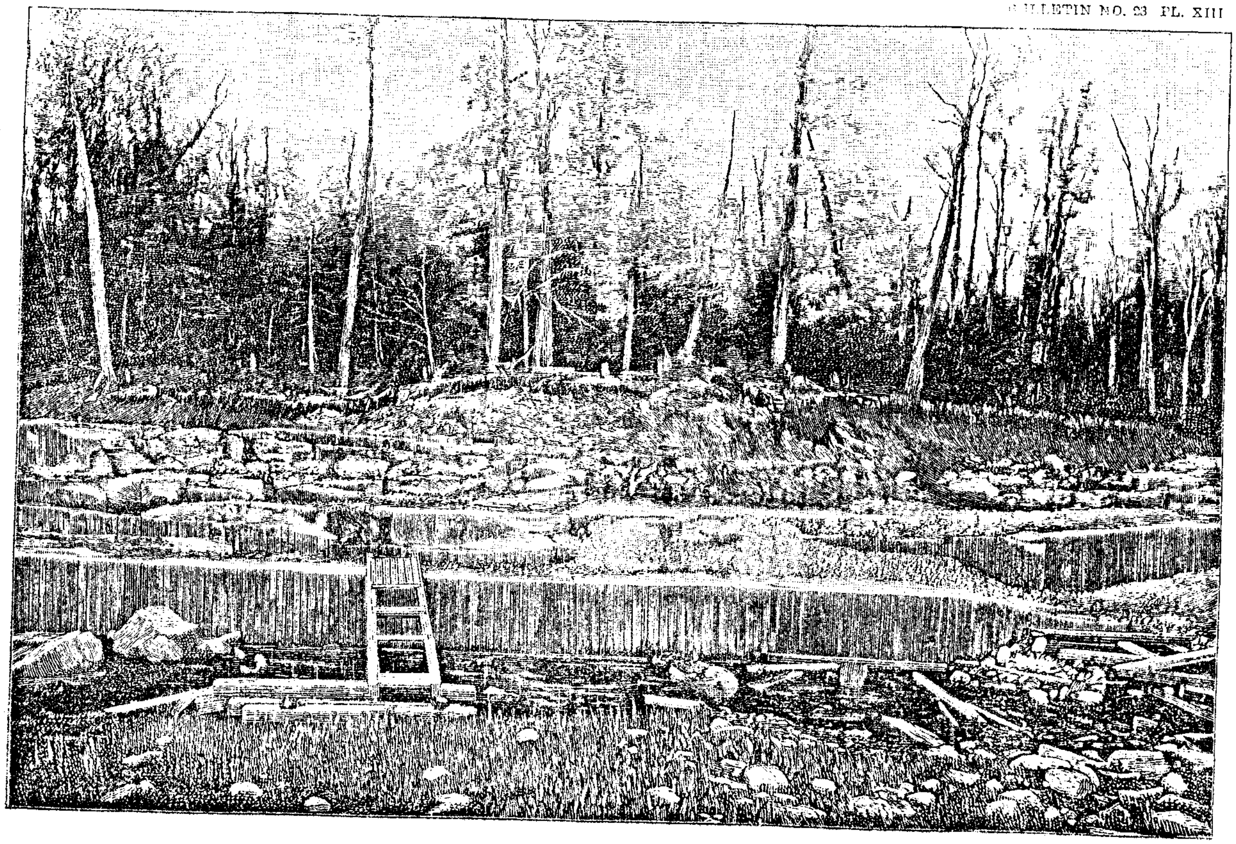
tlemen and our own lies in the matter of the occurrence of trappean pebbles within the sandstone below the junction, they holding that none of the basic eruptives of the Keweenaw Series are represented in the Eastern Sandstone below — or to the east of — its junction with the traps. In their arguments as to the structure here obtaining, this lack of basic pebbles in the Eastern Sandstone below the junction forms an important point, since they regard it as going to confirm their view as to the inferior position of the Eastern Sandstone in relation to the entire trappean series. It is to be observed, however, that even if we admit this absence of basic pebbles no such conclusion can follow, for of all the other classes of pebbles described by Mr. Wadsworth as actually occurring here there is not one that does not represent some acid rock which occurs abundantly in the Keweenaw Series and which has as yet *been nowhere recognized outside of that series in the entire Lake Superior region.* At the time that Mr. Wadsworth wrote the descriptions of these pebbles he seems to have been unacquainted with the fact that they represented rocks which occur in original masses as important constituents of the Keweenaw Series. One of the acid rocks plentifully represented among these pebbles occurs in the Keweenawan in this immediate vicinity. Moreover, as we have said above, the basic rocks of the Keweenaw Series *are* represented by pebbles in this conglomerate quite plentifully, as we satisfied ourselves on the ground and by studying thin sections of the specimens subsequently; and this not merely in the immediate vicinity of the junction with the trap, but at other exposures within 100 to 300 paces below the junction. We have shown above that on Bête Grise Bay the pebbles of the conglomerates, wholly of Keweenawan derivation, are predominantly of the basic kinds. Here, on the other hand, they are mainly of the acid varieties. On Bête Grise the pebbles of the conglomerate are very noticeably angular, while here they are well rounded. Between these two facts we think there is a connection, and conceive that basic pebbles are relatively less abundant on the Douglass Houghton Ravine, because of the greater amount of attrition the fragments have had here. The acid rocks and the highly silicified basic fragments would of course stand such attrition much longer than would the softer diabases and amygdaloids.

In still one other point our description of the Douglass Houghton ravine differs from that of these gentlemen. At the contact of the sandstone and trap they speak of the former as much indurated, regarding this induration as proving the subsequent formation of the trap. So far as our own observations extended, there is always a soft clay, which we look upon as a joint or fault clay, between the sandstone series and the trap at the junction, an observation which entirely coincides with those made by us at each of the other localities at which we examined the contact of these two formations. Disregarding this joint clay, we find at the contact in one part of its extent on the south side of the Douglass Houghton Ravine a soft shaly conglomerate of the Eastern sandstone series, and in another part, one of the harder sandstone layers; while on the north side of the ravine there is a contact with a soft non-conglomeratic shale. Even the hard sandstone layer, however, is no more indurated than portions of certain other layers, distant from the junction. Indeed, there is distinctly less induration here than at some of the latter points. Even if this were not the case, and the induration at the contact were relatively great, we should not regard it as necessarily proving the relative recentness of the trap. The induration of rocks beneath overlying lava flows we do not find in our experience to be at all universal; nor yet, when it occurs, save perhaps in the case of highly argillaceous rocks (and here we should note the entire absence of induration in the clayey shale and shaly conglomerate seen respectively in contact with the trap on the north and south sides of the ravine), do we consider it as at all necessarily the result of the heat of the overlying lava, but rather as the result of the infiltration of calcareous or silicious solutions from the superior rock, such as might occur long subsequent to the cooling of the lava. If, then, a mass of rock fitted to supply the proper material to form indurating solutions be superposed in any way—whether by igneous outflow, sedimentation, or faulting movement—upon a rock capable of receiving induration by percolating solutions, then such induration is liable to occur quite independently of the modes or relative times of formation of the two rocks concerned. A calcitic induration we have frequently observed developed to a far greater degree than we have yet observed in the case of any of the Keweenawan sandstones in places on the contact between the silecious sandstones of the Potsdam and the limestones of the overlying Lower Magnesian, in Wisconsin. A calcitic induration, then, might well result along such a contact as we have on the Douglass Houghton River by the downward percolation of lime-bearing solutions. We may also repeat in the same connection the reference several times made already to the abundant occurrence in many sandstones of strong silicious indurations wholly apart from and manifestly independent of any igneous agency.

In the account above quoted as given by one of us in his volume on the Copper-Bearing Rocks of Lake Superior, he takes the position, as Rominger did independently afterwards, that the true Keweenawan beds extend for some 300 paces below the falls, beyond which, after passing a covered interval of some width, the horizontal sandstone beds next met with were regarded as belonging to the true Eastern Sandstone. In explanation of this position, which he finds himself now forced to abandon, he has to say that at the time of his own examination no question had been raised as to the correctness of Agassiz's and Pumpelly's views with regard to the existence here of a true unconformity. His object was chiefly to satisfy himself as to the occurrence of Keweenawan detritus in the true Eastern Sandstone. Having succeeded in this, no further detailed examinations were made at the time, although the northwesterly



TORCH LAKE QUARRY KEWEENAW POINT. FROM THE EAST.

[From a photograph. The vertical lines on the edges of the layers are drill holes.]

dipping sandstone beds near to the traps were observed and the query was raised as to whether they were not probably part of the Keweenaw Series. Subsequently, when Mr. M. E. Wadsworth's very explicit statements as to the occurrence here of intercalations of trap and sandstone were published, these statements were accepted without question, and considered to prove that the query above referred to should be answered in the affirmative. Some time afterwards Mr. W. M. Chauvenet made a further examination of the ravine, and made some more detailed measurements of dip, with the results recorded above, which results, as will be seen from his notes, coincide closely with our own observations. Mr. Chauvenet was unable to find the intercalations of trap and sandstone, but, so explicit were Mr. Wadsworth's statements, it was supposed that he might not have looked for them in just the right place. Taking all these things into consideration a conclusion was reached as above given. Our further examination has served to show, however, beyond all question, that the true quartzose Eastern Sandstone extends to within 130 steps of the falls, and that the northwesterly dipping layers, before considered to be part of the Keweenaw Series, belong unmistakably to the Eastern Sandstone. In the quotation above given from the manuscript notes of Dr. C. Rominger, taken in 1883, it will be seen that he was disposed to give substantially the same explanation of the northwesterly dipping beds, although at the same time he recognized the lithological similarity of these layers to the true Eastern Sandstone farther down the stream.

TORCH LAKE QUARRY.

This quarry, whose position is shown on Figure 7, is of some little interest because of its close proximity to the junction of the Keweenaw Series and the Eastern Sandstone, here covered. Lying at such a considerable altitude as it does—340 feet above the level of Torch Lake, or only 28 feet lower than the top of the Douglass Houghton fall—it is manifest that if those are correct who would regard the Eastern Sandstone as inferior to the Keweenaw Series and as steadily decreasing in northwesterly dip for a mile or more southeast from this contact, then a considerable northwestern dip should be expected in the rock of this quarry.

The following are quotations from those who have examined this quarry, in the order of the time of examination:

M. E. Wadsworth, 1879. (Bulletin Museum of Comparative Zoölogy, Vol. VII, No. 1, pp. 117, 118.) "In the sandstone quarry at the head of the *incline* on the Hecla and Torch Lake Railroad, the sandstone layers have been regarded as being nearly horizontal. The joint planes that form the floors of the quarry are nearly so, having only a slight dip to the northwest; but these joint planes cannot be the bedding planes, for we find on close examination that numerous layers of coarser material, pebbles, clay masses, etc., occur in the rock. These layers extend for long distances through the sandstone, and are always parallel, having the same dip, which is N. 45° W. 15°. These of course, from their character and regularity, must mark the old planes of bedding, while the generally supposed bedding planes are secondary joint planes cutting the bedding planes at a small angle. This sandstone * * * has been leached and acted upon by water the same as that below the Douglass Houghton Falls and its feldspathic material converted into clay or entirely removed. Part of the materials composing the sandstone, especially in the coarser portions, are similar to those in the sandstone

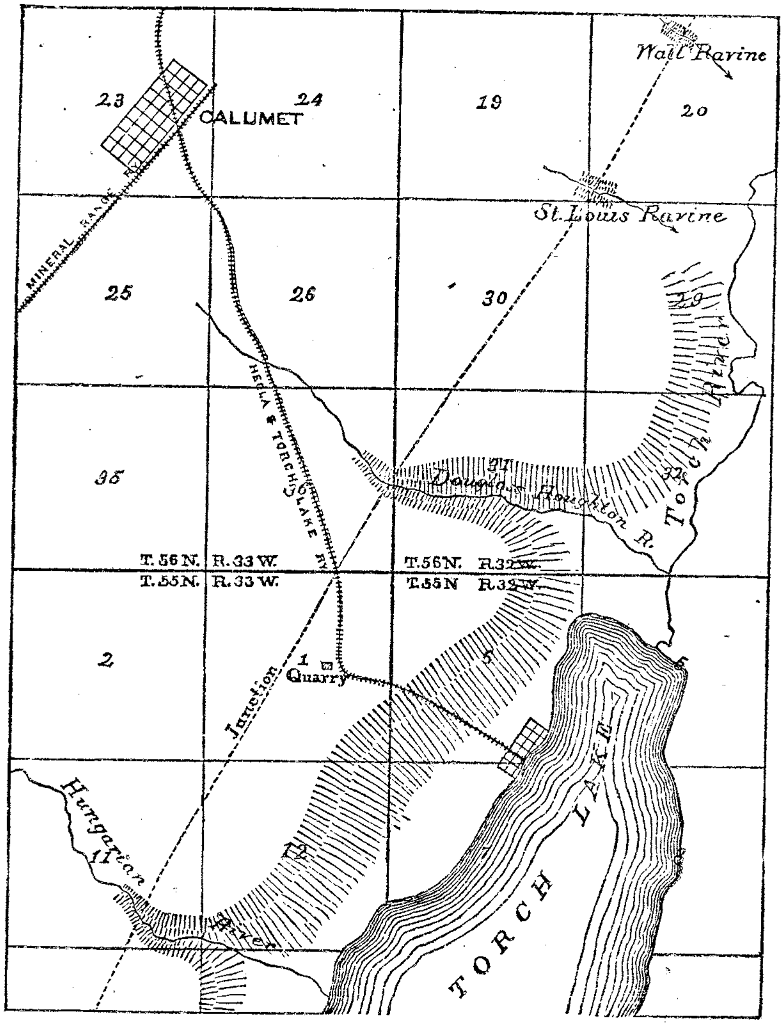


FIG. 7.—Plat of adjoining portions of T. 55, R. 32 W., T. 55, R. 33 W., T. 56, R. 32 W., and T. 56, R. 33 W., Keweenaw Point, Michigan.

at Marquette. The quartz grains are partly water-worn, but a large proportion are seen to be short crystals formed of the hexagonal prism, terminated on both ends by the pyramid, or the usual form found in the acidic porphyritic rocks. It appears, then, as the facets of these crystals are comparatively unworn, that they were derived from the destruction or decomposition of trachytic and rhyolitic rocks (granitic and quartz porphyries), the feldspathic [a misprint for felsitic] material having been removed since by water, leaving a quartzose-sandstone. It is a question worthy of examination whether any other sandstones have been formed from acidic volcanic material, from which nearly all the other parts of the rock have been removed by percolating waters, especially as other sandstones have been said to be composed of quartz crystals.

"As the sedimentary rocks are more and more studied, the evidence comes on every side that, like this sandstone, while their formation may have taken as long as is generally supposed, they may have been deposited very rapidly, some being composed of old volcanic scoria, ashes, and mud. In very many other cases the supposed sedimentary rocks are really volcanic flows or intrusive masses. In the sandstone just described the same masses of clay * * * occur as on the Douglass Houghton River, and they may arise here, as there, from the decomposition of the inclosed feldspathic or argillite pebbles. Another solution of the question of the origin of some of these would be the filling in of cavities formed by the removal of some other material, by the argillaceous material brought from above. This is suggested by the finding of stalactites of the sandstone * * * extending down into the clay. At the spring just above the quarry the sandstone * * * is red spotted with white, and dips N. 45° W. 14°."

R. D. Irving, 1880. (Copper-Bearing Rocks of Lake Superior. Monographs United States Geological Survey, Vol. V, pp. 356-359.) "About a mile south from the head of the Douglass Houghton ravine, on the line of the Torch Lake Railroad, is a large quarry in the Eastern Sandstone. The sandstone is disposed horizontally in heavy massive layers. It is nearly white and almost wholly composed of rolled quartz grains. It also contains here and there grains of feldspar, somewhat altered, but on the whole singularly fresh for such a rock, some particles showing the twin lamellation very beautifully. A very minute quantity of a brownish cement is present, and in each thin section may be seen two or three grains worn from some of the fine-grained diabases of the Keweenaw Series. Not a trace is to be seen of anything like the fragments of porphyry matrix, so abundant in the Keweenawan sandstones; nor was I able to discover any satisfactory indications that the quartz grains are the quartzes of the quartziferous porphyries, although one might expect to do so. In his description of this quarry quoted below, Mr. Wadsworth speaks of the grains of the sandstone as furnished with crystalline outlines, and regards these outlines as showing the derivation of the quartzes from a quartz porphyry. My sections fail to show any such outlines, but if they occur they are probably rather in the nature of those of the crystal grains so frequently met with in the Potsdam Sandstone of the Mississippi Valley, in which case the crystalline outlines are the result of a secondary deposition of quartz upon the surfaces of the originally rolled grains. Rare pebbles of quartz of some size are contained in this sandstone, and patches and lines of red clayey substance, which do not show any persistent inclination in any one direction. The clayey material often expands into large bunches of red clay forming the usual clay-holes so characteristic everywhere of the Eastern and Western horizontal sandstones.

* * * * * * *

"In my examination I failed to find any evidence of the northwesterly dip described by Wadsworth, and a subsequent examination by Mr. W. M. Chauvenet, with Wadsworth's description in hand, was equally futile. The reddish bands, as stated above, showed, so far as I observed, no one direction of inclination any more decided than the others; and even if they did, it would be necessary for any one trying to establish their direction as that of the general bedding of the rock, to prove that they should not rather be taken as instances of the cross-bedding so commonly affecting the similar sandstone of the Mississippi Valley, while both they and the larger clay bunches are precisely what may be seen in the plainly horizontal sandstones of the Apostle Islands. It would seem that Mr. Wadsworth, having previously formed a theory as to the relation of the Eastern Sandstone to the Keweenawan beds, has felt it necessary to explain away the plain horizontality of the rock in this quarry.

"A similar process has led him to the view that the feldspathic ingredient has been leached out of the Eastern Sandstone, in order that he may explain the quartzose character of this sandstone and of that of the Douglass Houghton and Hungarian rivers — a character which is in fact a common one of the Eastern Sandstone, wherever met with on the line between Bête Grise Bay and Lake Agogebic, and again along the north face of the South Range, east of Lake Agogebic. This leaching process would have but a slender theoretical basis at the best, and in the present case seems to be distinctly disproved by the appearance of the thin section, nearly the whole of which is formed of rounded quartz grains without any space for the feldspathic material to have been leached from; while the few feldspar grains present are singularly fresh for the grains of a fragmental rock. Moreover, the qaurtz particles cannot represent a secondary substitute for feldspar, such as so often occurs in the granitic porphyries of the Keweenaw Series. I cannot conceive of a leaching process which leaves neither space nor substitute for the original material. Possibly it is meant that the leaching has affected the rock as a mass and that the remaining material has collapsed. But this could not happen so as to leave the rock so distinctly marked by the original bedding structure. The thin section shows, moreover, the quartz grains frequently in the often observed relation which indicates that they lie where rolled together by shifting waters; *i. e.*, one grain enters a depression in the side of another. Again, it is difficult to see why the supposed hot waters should have selected this one sandstone for leaching, removed as it is, now at least, from the heating lava-flows, while the beds directly intercalated with these flows should in no instance show any signs of such a leaching. Although Mr. Wadsworth seems to have felt it necessary thus to explain away the peculiarly quartzose character of the Eastern Sandstone as compared with the sandstones of the Keweenawan, this lithological dissimilarity seems to me really rather more in favor of his peculiar view as to the structural relations of the Eastern Sandstone than against it."

W. M. Chauvenet, 1880. (Manuscript notes.) "In the sandstone quarry near Torch Lake, the main joints of the quarry, which are the surfaces of the layers, dip as the sandstone rolls, as much in every direction as in any one. Red streaks were occasionally noted running across the layers in a northwesterly direction, but as often rising again so as to present a southeasterly dip. This was seen very plainly marked on a face exposed to the east."

M. E. Wadsworth. (Bulletin Museum of Comparative Zoölogy, Vol. VII, No. 11, p. 564, 1884.) "Irving further denies the general correctness of Wadsworth's previously published statement relating to the sandstone quarry near Torch Lake (*ante*, pp. 117, 118), and maintains that, while he (Irving) finds traces of the trappean material in the sandstone, he does not find any of the porphyry material belonging to the conglomerates of the 'Keweenawan Series.' This claim proves too much; for if this sandstone had been deposited against the mixed lava-flows and detrital rocks of the copper-bearing series, as Irving holds, and made up of their ruins, there the sandstone should be full of their débris and the old rhyolitic and trachytic material ought to be far longer retained than the more easily perishable basaltic material, since even in the sandstones intercalated with the traps the basaltic débris is comparatively rare. Now Irving's statements are directly opposed to his own views; and the same may be said of the testimony of all those who claim that the sandstone near the traps is composed of different materials from those of the detrital rocks of the so-called Keweenawan Series.

"Wadsworth has since re-examined the specimens in the collection made with express reference to retaining the evidence in behalf of his previous statements (*ante*, pp. 117, 118), and he reiterates those statements with the exception of this correction, that on page 117, third line from the bottom, the word *felsitic* is misprinted *feldspathic*, as the context shows. He finds in these specimens an abundance of the bi-pyramidal quartz peculiar to ancient and modern rhyolitic rocks, and also the variation between the bedding planes and jointing, both being evident in the hand specimens."

R. D. Irving and C. R. Van Hise. (Bulletin of the United States Geological Survey,

No. 8, 1884, pp. 40, 41.) "Quarry on Torc
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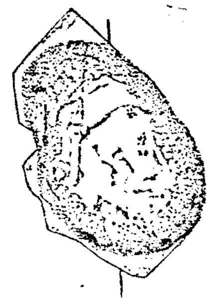

FIG. 8.—Crystal-faced enlargements of quar
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Comparative Zoölogy, Vol. VII, No. 1,
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of the United States Geological Survey,

No. 8, 1884, pp. 40, 41.) "Quarry on Torch Lake Railroad, Keweenaw Point, Michigan. A white to pinkish, feebly indurated quartzose sandstone. Some of the less indurated portions show numbers of faceted grains. The slide here described is from one of these less indurated portions. It is seen to be made up almost entirely of much rolled quartz fragments, which have in nearly every instance been enlarged, the enlargements only occasionally showing crystalline outlines. These crystal outlines are, however, more frequently to be seen in the balsam mounting of crumbled sand. They are not nearly so numerous, however, as in some of the rocks previously described, the grains having interfered too much to form crystal outlines. The outlines of the original grains are usually very strongly marked by brownish iron oxide. There are occasional rounded fragments of feldspar present, and in each thin section may be seen a few particles worn from some of the fine-grained Keweenawan eruptives. * * *

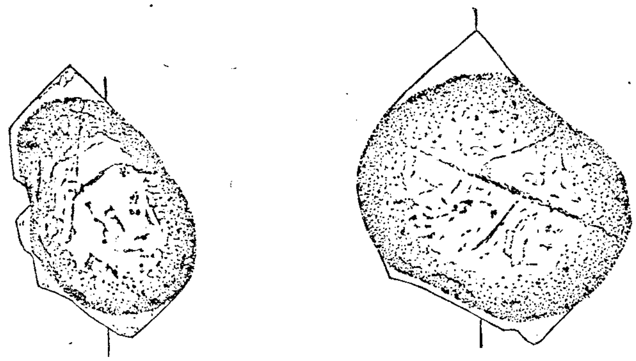

FIG. 8.—Crystal-faced enlargements of quartz fragments from sandstone of Torch Lake Quarry, Keweenaw Point. Scale 67 diameters.

"See, with regard to this rock, also Copper-bearing Rocks of Lake Superior, pp. 356–358. See, also, for an earlier description, M. E. Wadsworth in Bulletin Museum of Comparative Zoölogy, Vol. VII, No. 1, p. 117. Wadsworth found the crystal-outlined grains abundantly in his sections, although we failed to do so in ours until recently. He regarded these crystal grains as being the usual dihexahedral crystals of quartz-porphyries, on which view the crystals antedate the formation of the sandstone instead of being subsequent to it. More recently (Science, Vol. II, No. 23, p. 52, July 13, 1883) he has reasserted this view. But a careful re-examination of this rock, as also of others from other places within the area of the Lake Superior sandstone, has served to convince us that in all of these cases, as in all sandstones yet examined by us provided with such faceted grains, they owe their crystal faces to secondary enlargements of rolled fragments. It is of course possible and even probable that these quartz fragments were once, some of them, the quartzes of quartz porphyries, but if so they have rarely, if ever, retained their crystal faces, as it is, indeed, hardly conceivable that they should do."

To the descriptions of this quarry, already published by one of us as above quoted, we have little to add, and from them nothing to take away. We re-examined the quarry-face carefully together and took the photograph here reproduced. We have no hesitation whatever in saying that the rock is here, as it appears to be, in an essentially horizontal position. There are some indications of bowing, and at the northwestern end of the quarry there are indications of a northwesterly dip, a natural enough occurrence when we consider how near to a junction with the traps we here are, and that the sandstone must be affected here by the same disturbances as seen on the Douglass Houghton River. We examined some of the lines of pebbles, or rather of sandstone, slightly coarser than the rest, referred to by Mr. Wadsworth. These lines, however, certainly do not have any persistent single direction. We were even able to follow single lines through a change from a northwesterly to a southeasterly inclination. Moreover, these lines are most plainly lines of false or cross bedding, and not very pronounced ones at that. Any one who has had much experience among sandstone formations has seen far more strongly marked instances of false bedding and cases more liable to deceive by leading one to regard them as the true lines of bedding; as, for instance, everywhere throughout the Potsdam Sandstone of Central Wisconsin. In the Eastern Sandstone itself false bedding may be seen at several points much more strongly pronounced than here; for instance, on the south side of the mouth of Hungarian Ravine. Furthermore, the bedding planes are perfectly distinct, and present those characters that distinguish bedding planes from joint planes. They are not ripple-marked in the technical sense, but they present those undulatory wave-fashioned surfaces which to the experienced observer are equally decisive of their origin.

HUNGARIAN RAVINE.

The Hungarian River is, after Torch River, the principal tributary of Torch Lake. Heading in the southern part of T. 56, R. 33, in the vicinity of the Osceola mine, it runs in a general southeasterly direction to Torch Lake, which it enters in the northern part of Sec. 13, T. 55, R. 33 W. In the southeast quarter of Sec. 11 it crosses the junction of the Eastern Sandstone and the Keweenaw Series, below which junction it runs through a continually deepening ravine with several heavy falls, until it reaches the narrow strip of lowland bordering Torch Lake. As we learned from Mr. P. C. F. West, chief engineer of the Calumet and Hecla mine, who has kindly furnished us a copy of a carefully leveled profile of the Hungarian River, the entire descent of the river from the top of the uppermost fall to Torch Lake is 361 feet. In this distance the river makes three main falls, besides two smaller ones, all of them over the Eastern Sandstone, except the two uppermost ones. Of these last the upper one is a leap of 25 feet over Keweenawan conglomerate, the lower, only a short distance below, one of 8 feet, over diabase and amygdaloid. The fall nearest to Torch Lake is the main one, having a height, according to Mr. West's measurements, of 144.3 feet. The general position of this ravine is indicated on Figure 7.

So far as we have learned, the only geological examinations of this ravine made before our own have been those by Messrs. M. E. Wadsworth, W. M. Chauvenet and Dr. C. Rominger. The following quotations give the results obtained by these several observers:

M. E. Wadsworth, 1879. (Bulletin Museum of Comparative Zoölogy, Vol. VII, No. I, July, 1880, pp. 113–115.) "As we followed the Hungarian River, a tributary of Torch Lake, upward, starting from the low sandy plains near the lake, the sandstone was first observed forming high bluffs on both sides of the river and dipping N. 45° W. 10°. It occurs in coarse and fine layers often inclosing pebbles. As the river is ascended the layers of pebbles were seen to curve in various directions with an irregular dip, but which in general inclined to the northwest. Some of the pebbles appeared to be of quartzite similar to that at Carp River, Marquette. * * * The Hungarian Falls are formed by the river being precipitated over several ledges of the sandstone and conglomerate. Several specimens were taken, showing the different varieties of pebbles composing the conglomerate. * * * No. 523 is an old trachyte composed of a reddish-brown groundmass, holding white kaolinized feldspars, dark-brown decomposed hornblende crystals, and a little mica. It is closely allied to some of the modern rocks from the Cordilleras. The groundmass is now kaolinized, forming a dirty-white mass holding secondary quartz and feldspar, as well as long narrow ferrite masses. These latter appear to have been formed from the hornblende fibres, so frequently seen in the allied rocks from the Cordilleras. The groundmass has now through its alteration a spherulitic structure. No. 524 is a more compact rock of like character. Its groundmass is kaolinized and holds the quartz and feldspar alteration products. It is filled with grains and masses of ferrite probably derived from hornblende. The feldspar is so decomposed that it cannot be told whether it is plagioclase or orthoclase. * * *

"No. 527 has a more coarsely crystalline, granitoid structure, showing under the lens a reddish and grayish-brown groundmass, holding elongated brownish-black hornblende crystals. In the thin section it is seen to be composed of feldspar, magnetic iron, hornblende, and some quartz. The feldspar is greatly altered, and is now composed of intergrowths of feldspar and quartz, giving rise in it to a structure resembling that of graphic granite, or much of that figured as belonging to the Eozoön Canadense. The quartz is all secondary, and the hornblende altered to reddish or yellowish-brown ferruginous masses.

"No. 528 is a fine-grained granitoid trachyte (granite porphyry), but in the thin section the feldspar is seen to be so altered and filled in with secondary quartz, containing full and bubble-bearing fluid and vapor cavities that the section resembles that obtained from some fragmental rocks.

* * * * * * *

"Below and at the base of the falls the dip remains the same as before, N. 45° W. 10°, but above this locality the inclination varies, rising from 15° to 18° between the first and second falls. In some places a quaquaversal dip was seen. Some five falls exist in the river, and at the last or upper fall the melaphyr was found. The dip of the sandstone has now increased to some 20° but still dips northwest, and the first trappean flow is seen to overlie and greatly indurate and alter it. This immediately underlying sandstone * * * is filled in with little reticulated veins of calcite, a kaolin-like material, etc., and in general resembles the baked sandstone found underlying the trap on the western side of Keweenaw Point. Microscopically, it is seen to be composed of the *débris* of the trachytes previously described. This sandstone was seen within 3 inches of the melaphyr, and although there may have been some sliding motion between the two, as the contact was not seen, yet the induration of the sandstone, its dip, and its relations to the melaphyr, prove that it underlies the latter, which flowed over it. This, then, with evidence obtained on the Douglass Houghton River, settles the long disputed question of the relative age of the traps and eastern sandstones of Lake Superior. The dip of the melaphyr is about the same as that of the sandstone. Immediately above this thin lava sheet, a conglomerate comes in, forming the fifth fall. The base of this conglomerate is composed of a fine-grained detritus formed from the melaphyr and trachyte, and holds numerous pebbles of the melaphyr, as well as of the other rocks. * * * Immediately overlying this conglomerate is another melaphyr flow, and we have here on the eastern side a repetition of the same alternate bands of melaphyr and sandstone that occur on the western side."

W. M. Chauvenet, 1880. (Account prepared from Mr. Chauvenet's notes by R. D. Irving, Copper-Bearing Rocks of Lake Superior. Monographs United States Geological Survey, Vol. V, 1883, pp. 354, 355.) "As the Hungarian River is ascended, the sandstone is first met with on the sides of the ravine, and then in its bed also, where it forms several falls. For the most part the sandstone is light-colored and quartzose, but conglomerate bands are included in which the pebbles are in the main of some of the red acid eruptives of the Keweenawan. Often the sandstone lies horizontally; at times it appears to have a slight northwesterly dip, and as often a slight southeasterly one. These deviations from horizontality are often plainly the result of the undermining on the side of the ravine. At the uppermost fall the contact with the older rocks is seen. The occurrences here, and for some distance below, are as shown in the accompanying sketch, made on the ground by Mr. W. M. Chauvenet, in which B is the bank of the gorge without exposures; A, sandstone layers projecting from the sides of the bank; D, amygdaloid and pseud-amygdaloid dipping northwesterly; E, the continuation of the amygdaloid in a crumbling condition; C, porphyry conglomerate; and F, an overlying diabase. At G, at the very foot of the fall, is a smoothed surface of sandstone jointed in two directions, the two joint surfaces dipping NW. 25° and S. 20° E.; and a few steps farther down the sandstone is seen lying perfectly flat. In the same vicinity true bedding, as shown by the differences in the coarseness and coloring of the sandstone, gave dips of NW. 10°, SE. 20°, NE. 20°. The irregularities seem to be due, in a measure, to undermining on the sides of the ravine, but are also apparently somewhat analogous to those described and figured on a previous page as occurring on the gorge of Black River, in Douglas County, Wisconsin—*i. e.*, are the product of faulting motion.

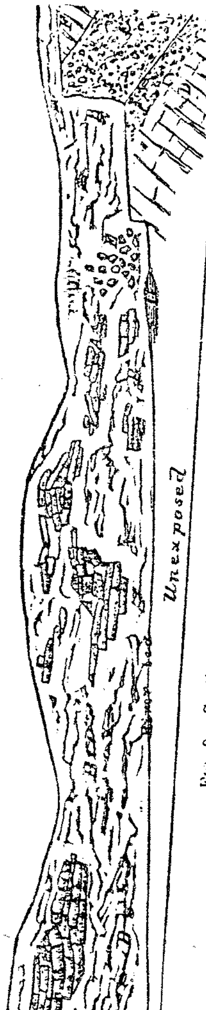

FIG. 9.—Section on the Hungarian River, Keweenaw Point.

"In his account of the occurrences on the Hungarian River, Mr. M. E. Wadsworth has represented the Eastern Sandstone as presenting a gradually increasing northwesterly dip, as it is followed up the stream, until it is plainly seen plunging beneath the Keweenawan diabase and interbedded conglomerate. But neither the increasing northwesterly dip nor the subordinate position of the sandstone to the diabase could be detected by Mr. Chauvenet. Northwesterly dips are found in the sandstone for some distance below the contact, but southeasterly ones just as often or oftener, and both seem distinctly subordinate to a general horizontality. Again, sandstone lies vertically beneath an amygdaloid, but the mass of sandstone appears to be a fallen one, and if it is not, the crumbling amygdaloid above certainly is."

The following are verbatim quotations from Mr. Chauvenet's manuscript notes taken on the ground:

"The sandstone in the stream-bed a short distance below the lower leap seems to lie perfectly flat, and at a point 75 feet below this fall horizontal layers of sandstone rise 30 feet in the south bank.

"There is an exposure of smoother sandstone in the stream-bed below the second jump of the fall. This shows white streaks in a dark reddish-brown mass and joints running in two main directions. The dips measured on these joint surfaces were NW. 20° to 25° and SE. 20°. But immediately below the sandstone is nearly horizontal. Although dips were found on true bedding planes 10° NW. yet at the same place dips 10° and 20° SE. and NE. were obtained. The mass of rock is, in short, fallen and caved and much undermined.

"The amygdaloid is seen on the right bank and in the stream 6 feet from the sand rock. It seems to hang above it on the right, rising 20 feet above the stream in a loose broken mass, but nothing was seen here in place. Just above [up-stream from] the trap comes in with a thickness of 20 feet or more, forming the second leap of the falls and continues to the base of the upper falls, where it passes underneath the overlying conglomerate.

"Following the stream downward from the junction the sandstone is seen rising into bold exposures which show much disturbed jointing. Layers evidently parallel to the true bedding are seen to lie horizontally, although at times seen dipping in many directions."

C. Rominger, 1883. (Manuscript notes taken in the summer of 1883.) "Ascending the ravine of Hungarian Creek, with steep, almost inaccessible sides, I found, below, the sole of the creek formed of horizontal sand-rock beds, and came, in progress of the ascent, to the base of the perpendicular rock-walls, approximately not far from 100 feet in height, over which the creek falls down in a cascade. These rock-walls consist of a succession of reddish-colored horizontal layers of sandstone, similar to the lower beds seen in the creek-bed below. Above the falls the horizontal sandstones continuing to be exposed in the creek bed and on the sides, I came to several other falls from 20 to 25 feet in height, which all were caused by offsets in the great succession of horizontal sandstone beds. Finally, close to the summit of the ridge, I saw another fall about 20 or 25 feet high, which was caused by the projection of a conglomerate belt and of an amygdaloid belt beneath it, both of which layers dipped under an angle of about 45° to the northwest.

"The amygdaloid belt is about 30 feet thick, and is seen to come into immediate contact with horizontal layers of sandstone in the bed of the creek. Sideways from the creek channel the contact cannot be seen, as the surface is covered with loose material.

"A dip of the sandstone under the amygdaloid, as Mr. Wadsworth asserts, is not observable; on the contrary, a slight southern dip of the sandstone strata away from the amygdaloid is noticeable.

"The quartzose, rather light-colored quality of the sandstone forming the contact, is unlike the sand rocks ordinarily found in connection with the copper-bearing rocks, but it exactly corresponds with the usual appearance of the Eastern Sandstone exposed along the shore of Keweenaw Peninsula."

M. E. Wadsworth, 1879. (Bulletin Museum of Comparative Zoölogy, Vol. VII, No. XI, August, 1874, pp. 563, 564.) "Irving further claimed that at the junction of the sandstone and traps on the Hungarian River * * * the sandstone was a loose piece, or, if not, the basaltic rock surely was, and that the prevailing dip of the sandstone was to the southeast.[1] To this Wadsworth replied, "that the dips given in the report (Irving's) appeared to have been taken from the frost-dislocated rock on the sides of the

[1] No such statement was ever made. A reference to the quotation a few pages back will show that my words were, "Northwesterly dips are found in the sandstone for some distance below the contact, but southeasterly ones just as often or oftener, and *both seem distinctly subordinate to a general horizontality*," which is very far from saying that the prevailing dip of the sandstone is to the southeast. (Third Annual Report of the Director United States Geological Survey, p. 150, and Monographs United States Geological Survey, Vol. V, p. 355.)—R. D. I.

stream, while his (Wadsworth's) were taken in the bed of the stream, when the water was exceptionally low.[1] He further stated that the sandstone at the junction was continuous with that seen below; that it extended across the stream and into the banks on both sides; while the baking and induration of it showed that it must have been overflowed by some heated rock. Again: the basaltic rock extended across the stream into both banks and was found to underlie the conglomerate, and that he dug the *debris* of the former out of the overlying base of the latter. All this, he said, showed conclusively that these rocks were *in situ*, and proved that here the eastern sandstone and Keweenawan series were one and the same; also, that this series could not be maintained, as first established."

Following up the ravine of the Hungarian River from Torch Lake, the first rock we encountered is a white to brown quartzose sandstone, in thick beds, dipping up stream, or northwest, at an angle of from 7° to 10°. This is on the south side of the mouth of the ravine. Interstratified with these heavier layers, which at times reach eight and ten feet in thickness, are thinner ones, six inches to two feet in thickness, of red and white banded sand, in which false or current bedding is very beautifully shown. At least 50 feet in thickness of these layers are visible here. There may have been some slipping on the bank, but we think it is evident that these layers occupy essentially their true position. Pebbles are almost entirely wanting, but here and there a small one may be found. So far as we observed these occasional pebbles, they are from some of the acid eruptives of the Keweenaw Series. Immediately opposite to this exposure on the north side of the ravine similar layers are exposed.

As the ravine is ascended still further the sandstone appears at so frequent intervals in both banks as to constitute what amounts to an almost continuous exposure, the sides of the ravine at the same time rapidly increasing in height and the exposures in vertical extent. The dips are all low, ranging from 10° as the highest down to horizontality. On the whole, northwesterly inclinations are perhaps the most common, but southeasterly and southwesterly ones also occur. As the formation is traced up the stream, the pebbles gradually increase in quantity. The distribution of these pebbles is, however, somewhat inconstant, in both vertical and horizontal directions, *i. e.*, they appear in certain layers rather than in others, and in these irregularly. Still, there is a very notable general increase in quantity as the stream is ascended or as the exposures of Keweenawan rocks are approached. In one instance, on the north side of the ravine, some 200 to 300 steps above

[1] As to this, it is to be said (1) that, after making all allowances for dislocation on the sides of the ravine, there remains an unquestionable bowed condition to the sandstone; (2) that this bowed condition was noticed in the bed of the stream as well; (3) that Mr. Wadsworth's own observations must have in large measure depended for that portion of the ravine below the immediate junction on the exposures in the walls of the ravine, there being frequently no exposures in the bed of the stream for long distances; and (4) that while Mr. Wadsworth maintains that on the Hungarian the place to look for dips is the bed of the stream on the Douglass Houghton one must depend on the "slippery sides of the ravine."

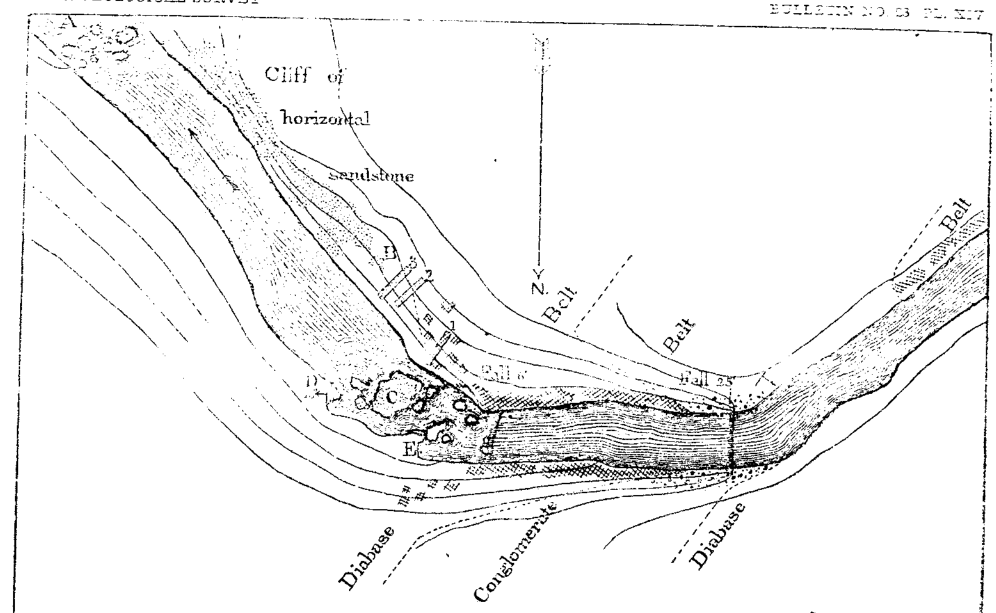

Fig. 1.-Plat of Exposures.

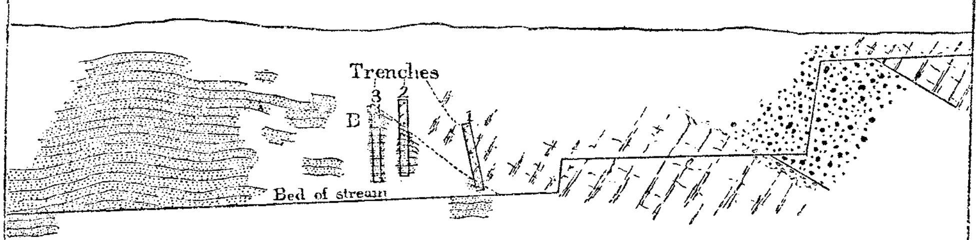

Fig. 2. Elevation of south bank showing Exposures.

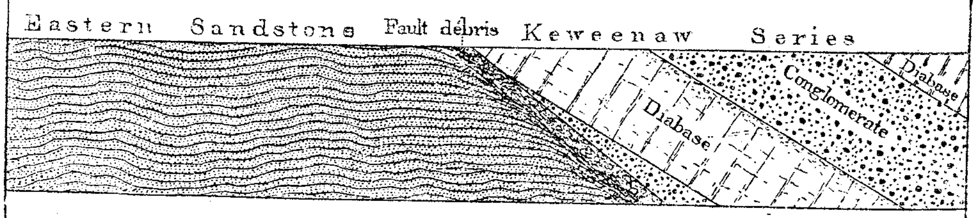

Fig. 3. Ideal section showing structure.

JUNCTION OF THE EASTERN SANDSTONE AND THE KEWEENAW SERIES, HUNGARIAN RIVER.

Scale: 1 inch = 50 feet

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sandstone, shale, and conglomer
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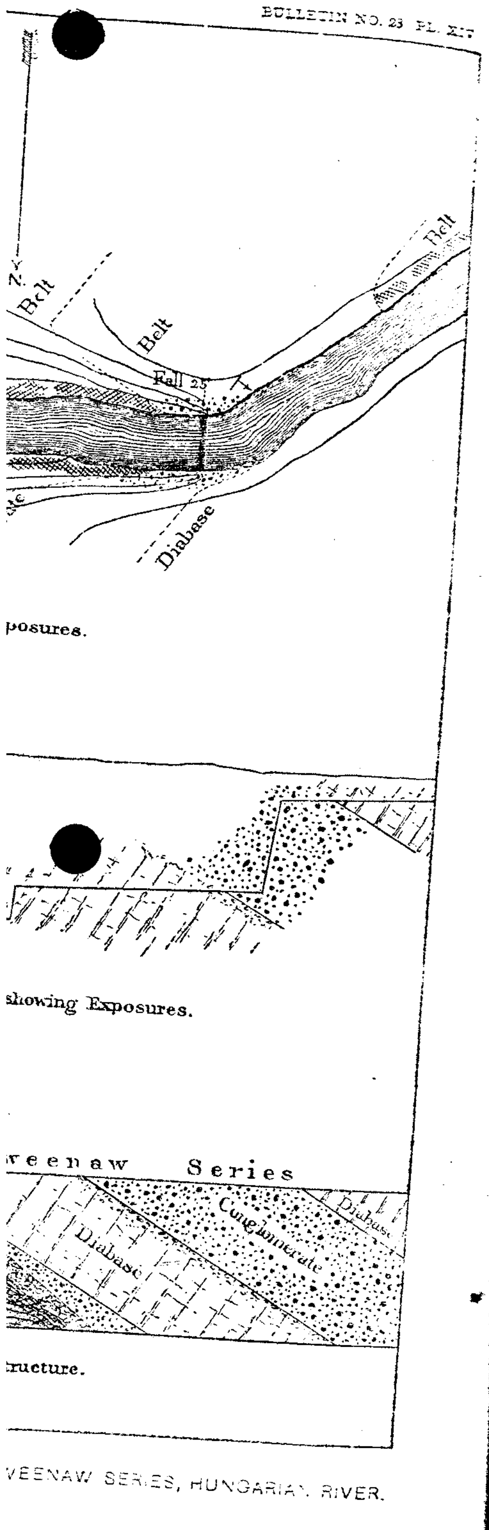

the first exposure mentioned, a conglomerate horizon is seen to come in, along which, as one passes westward, the pebbles increase gradually, but very notably, in number, closeness of setting, and vertical depth of distribution. What is at first a mere line of pebbles increases until it becomes a belt ten feet or more in width. Two important peculiarities of these conglomerates are to be noted. In the first place the pebbles are *scattered through the sandy matrix*, and are generally separated from each other by intervals varying from several inches across downwards. In other words, the assortment and classification of the constituents are not nearly as complete as is common among conglomerates, for instance, the ordinary Keweenawan conglomerates. Had the agencies completed their work, the pebbles would have been gathered into strata with which only so much sand would have been associated as could have found protection from the strong pebble-moving currents by lodging in the interspaces between the pebbles or in the lee of little banks or hillocks of pebbles. While this ideally perfect assortment is often not completely reached, there is in this instance an unusual shortcoming, an unusual dispersion of the pebbles through the sand, which certainly suggests quite pointedly that the process of assortment was not here carried to its usual extent; which conclusion, in its turn, suggests as certainly that the material was not of distant derivation. The other peculiarity referred to is the very striking manner in which the pebbles and bowlders protrude from the rock face. At times this projection is as great as two-thirds of the body of the pebble, which thus retains its position by means of cementation and not by interbedding. This peculiarity is but another expression of the characteristic above noted. The sandstone matrix weathers back with approximate uniformity, leaving the dispersed pebbles projecting as warty protuberances and thus giving a knotty face that we have never before seen in an equally pronounced development.

As the ravine is now ascended farther toward the main falls the sandstone series increases in height of vertical section and embraces sandstones, shales and conglomerates. The included sandstones remain predominatingly quartzose, and of whitish, yellowish or pale reddish casts, but never of dark hues. The shales are of the soft clayey varieties, and usually are of dull but rather dark reddish colors. The pebbles of the conglomerates, so far as those examined by us are concerned, are wholly of Keweenawan derivation. This conclusion we base not only upon the macroscopic notes taken upon the ground, but also upon careful microscopic study of thin sections. On the whole, the pebbles from the acid eruptives of the Keweenaw Series are the most abundant, but pebbles unmistakably from the basic members of that series are also abundant. At the main falls a section of upwards of 100 feet is finely exposed, in which may be well seen the alternations of sandstone, shale, and conglomerate. The position of the layers here is but little, if at all, removed from horizontality.

Above the falls the same general conditions continue, but as the stream is ascended the conglomeratic and red shaly layers lessen, and some little time before reaching the junction are entirely lost, and the only rock seen along this part of the course of the river is white yellowish or reddish very highly quartzose sandstone. This change is manifestly due to an ascent in geological horizon, the uppermost sandstone seen in this part of the ravine lying about 120 feet vertically above the top of the main falls. In this distance the layers seen in the bed and on the sides of the stream present many different inclinations, at times lying horizontally. Some of these variations in inclination are doubtless, as Mr. Chauvenet suggests, the result of undermining on the sides of the stream, but we think there can be no question whatever that they represent on the whole the actual condition of the sandstone; that is to say, they show that its layers lie in a disturbed or bowed condition. We were certainly unable to detect anything like a steady increase in northwestern dip. It is of particular interest to note in this connection that some of the longest stretches through which the layers are essentially horizontal are met with between the junction and a point 200 to 300 steps below.

The positions and relations of the exposures at the junction with the Keweenawan traps are indicated on the map and sections of Plate XIV. Here we found the general situation to be much as described by Mr. Chauvenet and pictured in the section above copied from him. Beginning at the right hand or eastern end, Figures 1 and 2 of Plate XIV—the former of which figures is a plat of the exposures, and the latter a profile section of the south bank of the stream—are designed to show nothing more than may be actually seen here. We note first a quite prominent and bold exposure of the Eastern Sandstone on the south bank of the river. The sandstone here rises in the bank to a height of between 30 and 40 feet, forming in places an overhanging cliff. The rock is a quite purely silicious sandstone, and is in general disposed distinctly in horizontal layers, but subordinate to this horizontality are sudden and abrupt transitions in different directions, the whole presenting the appearance of horizontal layers that have been subjected to a crushing force moving from the west. While a few of the deviations from horizontality may be due to undermining on the banks of the stream it is manifest that for the most part they are not so, since they occur, not merely on the cliffy exposures, but also in the exposures in the bed of the stream, as is seen for instance at the point A on Figure 1 of Plate XIV. At this point, on good-sized exposures extending across the bed of the stream, dips may be obtained plainly parallel to the bedding of the rock, of 5° to 10° in directions both up and down the stream, *i. e.*, both northwest and southeast. In the thin section the sandstone of this cliff shows the ordinary characters of the Eastern Sandstone. The section is made up predominatingly of quartz fragments, with which are mingled others of feldspars and unmistakable pieces of