ART. XV.—*On the Age of the Quartzites, Schists, and Conglomerates of Sauk County, Wisconsin*; by ROLAND IRVING, M. E., Professor of Geology, Mining, and Metallurgy at the University of Wisconsin.

THROUGH the central portion of the county of Sauk, Wisconsin, run two ranges of hills or ridges, having an east and west trend, and a height varying from a mere rise above the general prairie to an altitude of five hundred feet. The width from north to south never exceeds three or four miles, and in

places is much less than one mile. The total lengths from east to west, or rather, the exact points at which the peculiar rocks which make up the ridges give place to the ordinary country rock, are not as yet accurately known. These lengths, however, seem to be from fifteen to twenty miles.

The rock material of the ridges is mainly a hard dark-colored quartzite; with this in some places are siliceous and talco-siliceous schists, and two or three kinds of conglomerate. The dip of the strata, which, though in some places obscure, is in others very marked—and can *everywhere* be determined by careful observation—is *uniformly* toward the north. The angle varies from 20°–25° in the south range, to 75°–80° in the north.

The occurrence of these bold ridges in the midst of a prairie country, together with the marked contrast between their upturned and metamorphosed layers and the entirely undisturbed strata of the Potsdam and Calcareous epochs, which for miles around form the country rock, has caused much speculation and discussion. From time to time, during the past twenty years, brief notices have appeared in various journals and reports, but no careful investigation of the localities in question seems ever to have been attempted. In most of these notices, or rather in most of those that are not absurdly inaccurate in their statements and wild in their ideas, the main point under discussion has been the relative age of the metamorphic strata. Do they, or do they not, antedate the Potsdam period? Are they the results of local metamorphism on the Potsdam sandstones, or are they the remnants of pre-existing rocks? The advocates of the former theory have had the last word in the discussion.

The facts recorded in the present article are the results of a series of visits made to the localities by the writer, during the months of September, October and November of this year (1871), and they will, I think, be seen to prove beyond all doubt or cavil, that the quartzites and schists antedate entirely the Potsdam epoch, i.e., are either Huronian or Laurentian in age.

Of all of the notices mentioned, none are more than brief mentions and only a few seem to have any value at all. Dr. Shumard, in Owen's report on Wisconsin, Iowa and Minnesota, makes the first mention of the quartzite. He gives no opinion. Dr. James G. Percival, in the report of progress of the Wisconsin survey for 1856, refers again to the quartzites, calling them merely "metamorphic sandstones," but intimating that they result from a change on the Potsdam sandstones. Mr. James Hall, in his report of progress to the governor of Wisconsin for 1860, gives by far the most accurate description I have been able to find. He refers the quartzites unhesitatingly to the Huronian—but gives no proofs whatever. His pam-

phlet did not fall into my hands until after my own investigations were entirely completed. In the first volume of his final report, Mr. Hall again mentions the quartzites, but still more briefly, expressing the same opinion as before, and still giving no proofs. In 1864 there appeared in this Journal (II, vol. xxxvii, p. 226) an article by Mr. Alexander Winchell of Michigan, in which he describes, among others, some fossils from the conglomerates overlying the quartzites; and upon them bases his claim that the quartzites are a downward continuation of the Potsdam sandstones. He himself never visited the localities. Finally, Mr. James H. Eaton of Beloit College, in a paper read before the Wisconsin Academy of Science, in February, 1871, expresses the same opinion, though on somewhat different grounds. The foregoing list includes everything of any value that has been published on the subject.

The accompanying map includes those portions of the two ridges where most of my observations have been made.

I. The South Range, to which my attention was first directed, presents, on approaching it from Sauk Prairie on the south, a bold, and, in places, precipitous rise from the plain of from 350–450 feet. The northern side of this ridge has, however, in all places as yet studied, a much more gradual slope down to the valley of the Baraboo river, this slope being in many places determined by the northward dip. Running entirely through this ridge is a deeply cut valley, which has at first, for about two miles, a direction slightly north of west, and then turns due north quite abruptly. This northern end holds the Devil's Lake, which entirely fills the valley from side to side. Throughout its whole length the sides of this cleft are precipitous masses of quartzite rising everywhere more than four hundred feet above the bottom, and reaching at the lake an altitude of 501 feet above its level, and of 1,474 feet above the sea. The bottom of the valley is covered with a heavy mass of Drift material, and the lake is held in its position by low Drift hills at its northern and southeastern extremities. The bottom of the lake itself seems to be in a Drift sand, and is over most of its area about thirty feet below the surface of the water. The lake has no outlet; but draining as it does a very small amount of surface, the extraordinary evaporation caused by reflection from the cliffs above, together with the high winds of Wisconsin, is quite sufficient to account for its maintenance of level; whilst the character of the surrounding rock shows readily the reason for its not becoming saline.

The great exposures of cliff at this locality, and the deep rock cuttings on the newly-opened railroad, afford most excellent opportunities for study. The change of direction, too, of the valley, gives facilities for approaching the rocks from different sides, not elsewhere easily obtainable.

The rock here is mainly a hard, dark-colored, very compact quartzite, though the colors vary from a very light grey in places to deep brownish-red. The bedding joints of the quartzite are in some places rather obscure, but the railroad cuttings have so far exposed them, that with a little care I was able readily to ascertain the dip. This on both sides, and throughout the whole length, of the valley, is uniformly about 20° – 25° a little west of north. Some of the writers mentioned, and notably Winchell, have described this valley as corresponding to an old anticlinal axis, but the uniform dip of the strata throughout its length proves of course that this is not the case.

SECTION I.—North and South through the south range on section, line 1 of map. A, quartzites; A', quartzites with some schists; C, conglomerate; S P, Sauk Prairie; B V, Baraboo Valley; L, level of Lake.

The quartzite, although often looking massive, show in many places on weathered surfaces the lamination and cross-lamination of more modern sandstones. Many of the fallen masses show, too, on exposed surfaces of lamination, the most distinct ripple markings I have ever seen. On the shallow sandy bottom at the north end of the lake below, may be found their very counterparts. Between the beds of quartzite, in many places, are thin layers of a schist principally siliceous, but having always some talcose material. These correspond apparently to the clayey or shaly layers between the beds of sand now represented by the quartzite. In some places these layers seem to be merely a thinly laminated quartzite, with talcose films covering the laminæ; in others the talcose material pervades and gives character to the whole mass, the siliceous material, however, always being present.

The most remarkable feature of this locality is, however, the very striking system of vertical joints which everywhere intersect the quartzite. The bearings of these joints, taken in some fifty or sixty different localities, I found to be uniformly N.E. and S.W. and S.E. and N.W., the variations in a few places being evidently due to local displacement. On the cliff sides, and more especially about the lake, these joints, together with the bedding joints, have so cut the rock into separate blocks, that these have from time to time been thrown down the bluff by frost and atmospheric agencies in huge rectangular masses, weighing by calculation from seventy-five to two hundred tons apiece.

In many places along the north flank of this ridge and lying always above the quartzite, are outcrops of a conglomerate, containing pebbles unmistakably from the quartzite below, always rounded, and in size varying from a few lines to four or five inches in diameter. In some few places there seems to be a second conglomerate in which the sandy cement itself appears altered to a quartzite. This is a point, however, deserving of further investigation. There are also places where distinct layers of coarse and fine conglomerate occur, the latter always above and graduating into a simple sandstone.

In this conglomerate are found in one locality just north-east of the lake, the Potsdam fossils described by Mr. Winchell in the article referred to, viz: *Scolithus linearis* Hall, *Orthis Barabuenensis* Hall, *Delphinocephalus Minnesotensis* Owen, &c. I have examined a collection of these fossils from the above locality in the possession of Dr. Lapham of Milwaukee, and have seen the fossils and quartzite pebbles in the same fragments side by side.

II. The observations on the North Range were made about the Lower Narrows of the Baraboo river and westward from there about half a mile. This north range seems to be less continuous both as to elevation and as to the character of its rock material. I am told by Dr. Lapham that it seems rather to be made up of detached masses of metamorphic rocks. The rising ground, however, never entirely disappears, and the quartzite seems to be found as far to the east and west as in the south range. At the Baraboo Narrows the metamorphic rocks are in great force, the cliffs on either side the river, which here makes a direct cut through the range from south to north, being as much as four hundred feet in height. The body of the bluff on the west side is made up of heavy beds of quartzite, with, in places, intercalated beds of a metamorphic conglomerate, and of a talcose schist like that in the south range. These beds all stand at a very high angle, between 75° – 80° from the horizontal, the dip being north with possibly a slight inclination to the east. At the bottom of the hill on the south side is an exposure of a peculiar light-colored siliceous schist, entirely different from any of the other rocks of the series. An old shaft sunk some thirty feet on the schist, affords most excellent opportunity for examination. The total thickness seen was about twelve feet, the layers varying in thickness from a few lines to four or five inches. Very thin films of a talcose material sometimes appear between the layers. Directly above this schist, I found a horizontal undisturbed sandstone, laid open for some distance by quarrying. The beds are generally a foot or two in thickness. In the loose pieces near by are found *Scolithus linearis*, and I was assured by residents of the fossil-

iferous nature of the sandstone in places to which we did not have time to go. The sandstone is, of course, the Potsdam of the surrounding valleys. Section 2 will serve to give a clear idea of the structure of this bluff.

SECTION 2.—Through North range at W. Bluff of Baraboo Narrows. A, thick-bedded dark colored quartzites, with some talco-siliceous schist; B, siliceous schist; C, horizontal sandstone; B V, Baraboo Valley.

The narrow detached ridge just to the westward, represented on the map, is also made up of horizontal Potsdam sandstone. There are many other such detached ridges along the Baraboo valley, bearing the same relation to the quartzite ranges and showing the same horizontality of strata.

The following arguments in favor of the priority of these rocks to the Potsdam period will, I think, after what has been said, be admitted as valid. I give them in the order in which they became apparent to me.

1st. *The limited area of disturbance*; the undisturbed Potsdam and Calciferous strata being found north, south, and between the ridges, and in close proximity to them.

2d. *The absence of any anticlinal axes*. Dipping as the rocks do uniformly to the north, in order to place them in the Potsdam category, we must imagine a metamorphism of the strata accompanied by a great fault, having on one side the unchanged sandstones, and on the other the tilted quartzites and schists, an idea new, I think, to geology.

3d. *The occurrence of rounded pebbles of quartzite in the conglomerate on the north side of the south range*. To suppose this conglomerate, which by its fossils is unmistakably Potsdam, to be of the same period as the quartzites below, we must suppose that period to have lasted long enough to cover the deposition of the quartzites as sandstones, their metamorphism, and the rounding of the pebbles by beach action, before the formation of the conglomerate; not to speak of the time sufficient to erase all signs of an anticlinal.

4th. *The occurrence of horizontal sandstones resting unconformably on the flanks of the tilted strata*. This last is, of course,

absolutely conclusive as to the *north range*, but lest it might be claimed that the two are independent, I have given the others.

Mr. Winchell argues, that, since Mr. Hall states that the fossils I have mentioned as occurring in the conglomerate are restricted to the Middle Potsdam, either this statement must be untrue or the quartzite must be the downward continuation of this formation. This argument, however, loses all force when we regard these ranges as high ridges in the Potsdam seas, never having been entirely covered by these seas, but having merely had the new sandstones and conglomerates deposited about their flanks. The place where these fossils were found must be *at least* 200 feet above the base of the sandstones of the surrounding country. A single glance at Dr. Lapham's geological map of Wisconsin will show this. The conglomerate is by no means necessarily the *base* of the Potsdam because it rests immediately on Huronian or Laurentian rocks.

In the final report of Mr. Hall already referred to, he mentions a low hill north of Baraboo, in which the middle of the hill is quartzite, and the flanks conglomerate and sandstones graduating upward into calcareo-sandy layers, without giving any further explanation. This statement, before somewhat unintelligible to me, now throws further light on my own results.

To my mind, these ridges were unquestionably islands in the Potsdam sea, and a more beautiful illustration, than is furnished by the sandstones and conglomerates of wave action on a rocky coast, can hardly be imagined.

There are several more of these scattered quartzite ranges in Wisconsin, all but one of them occurring within the Potsdam and Calcareous areas. During the coming season, I hope to be able to make a connected study of them.

University of Wisconsin, November 18th, 1871.