ART. XXXIX.—*On the Primordial Strata of Virginia*; by WM.
M. FONTAINE.

MY investigations in the strata of the Primordial period in Virginia were confined to the immediate vicinity of the Blue Ridge, near Harper's Ferry, Rockfish Gap, Balcony Falls, and the Peaks of Otter. They extended to the rocks of the Cal-

ciferous epoch. These strata are well exposed along the west base of the Blue Ridge throughout the State.

The careful and accurate studies of these and the overlying formations, made by Prof. Wm. B. Rogers, have thrown much light on the complicated stratigraphy of the region. He shows that in the northern portion of the State, extending from Harper's Ferry to the south end of Page County, the Primordial slates are inverted so as to overlie the later formations on the west, and to pass with a high southeast dip under the like dipping strata of the Blue Ridge. In the middle counties, especially near Balcony Falls, these strata lie with a gentle northwest dip on the west slopes of the Blue Ridge. In some of the more northerly portions of this district, they lie immediately on the edges of the southeast dipping older slates, while at Balcony Falls and its vicinity the two systems of strata are separated by a ridge of syenitic rocks. Farther to the southwest inversion again occurs. This inverted dip is found in all the strata of Silurian age and extends into those of the Devonian. The former occupy nearly all of the "Great Valley of Virginia," while the latter appear in the Great North Mountain, and its prolongations, which bound this valley on the west. The strata of the valley lie generally in a closed synclinal, producing a continued series of southeast dips. This compressed mass of rocks, on the west side of the valley, is thrust up against, and partly over, the Devonian strata, affecting them also with a southeast dip, producing a long line of fault, and bringing Hudson River shales up so as to overlie even strata of the Subcarboniferous period.

It will thus be seen that the amount of displacement produced is enormous. Owing to the contortions thus caused, and the possibility of repetitions from closed folds, all estimates of thickness, unless based upon long-continued examinations, must be received with caution.

I shall in this paper commence with the description of the section obtained at Balcony Falls. This I do because the strata there appear to present their normal development and dip; and also for the reason that here alone has Prof. Rogers given, in any detail, a description of the Primordial strata. It will be seen that my results do not agree entirely with his, and I must confess that I cannot reconcile them. In view of this difference, I should hesitate to maintain the correctness of my observations were it not that they are substantially verified by the section made at Rockfish Gap. This last was made along the cuttings for the railroad at that point, which were not in existence when Prof. Rogers made his examinations.

Before giving my own results at Balcony Falls, I will quote Prof. Rogers's description of the strata there found. He says:

"The formation (his No. I) here rests on igneous rocks, mostly syenitic in character, which form the main axis of the Blue Ridge. These are well seen along the pass. As we approach its termination, we mark the commencement of the rocks of No. I, which are seen on the side of the canal lying on the syenitic mass, with a northwest dip.

The lowest stratum next the syenite is a brownish, decomposing slate, evidently much altered by the syenite. Next is a grayish and reddish sandstone; then a slate similar to the former: then a repetition of the sandstone; again a slate, and, at the termination of the gap, heavy beds of massive white sandstone, the typical rock of this series. The average dip of the latter is, in the cliffs at the entrance of the pass, 55° northwest.

If we now return to the east, by the road leading over the mountain, we are accompanied for a long distance by these upper sandstones, and we then pass in succession over the underlying strata, which extend with a gentle dip almost to the summit of the mountain."

I now proceed to give the result of my own observations. Referring to a former article,* the reader will remember that the last rock described in the Balcony Falls section of the crystalline strata of the Blue Ridge, was a syenite of probably later age than the mass of the ridge. Next to this occurs the first of the rocks which I hold to be of Primordial age. We have: (1.) Unbedded quartzite, with crystals of feldspar, 120 feet. (2.) Brown, crumbling, argillaceous rocks or sandy shale, conglomeritic in its upper portion, 40 feet. (3.) Brown, decomposing, thinly laminated, and contorted shale, 10 feet (4.) Conglomerate, like the upper portion of (2), 20 feet. (5.) Shales, like (3), 12 feet. (6.) Conglomerate, like (4), 15 feet. (7.) Crumbling, brownish shales, passing in the upper portion into argillaceous sandstones of the same hue and texture, 200 feet. (8.) Massively bedded, coarse white quartzite (apparently Rogers's typical No. I), 500 feet. Up to this point the rocks are well exposed in the cliffs which closely border the canal. Hence there is no danger of overlooking reduplications.

The dip of (3) is confused by contortion; that of (4) is 70° . From this point the inclination gradually declines, until in (8) it is about 55° . Proceeding west across the strike, we next encounter a series (9) of thinly laminated shales, with some beds of red and gray sandstones. This series is much more disturbed than the preceding, and, owing to its having been long subjected to the action of the river, in its efforts to cut through the massive barrier interposed by (8), it presents

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to the canal, slopes covered with debris. Hence details of the succession and dip of the strata cannot be given with accuracy.

A better exposure is given on the road mentioned above in Rogers's description. Here, too, however, great confusion exists. By far the greater portion of the mass is composed of thinly laminated, gray and reddish shales. Some beds of brick-red and gray sandstones of coarse texture occur, much indurated, and sometimes impregnated with epidote, chlorite, etc. Also, one or two beds of diorite apparently. Probable thickness, 600 feet.

To the west this is overlaid by a great series (10) of alternating beds of quartzite and kaolin shales. These rocks, where they join (9), present the same contortions and confused stratification, but in passing farther west, the folds open out, and are finally seen well displayed in the high mountain through which the river cuts its way at the "Cement Mills."

This mountain is the most westerly of the parallel ranges which compose the Blue Ridge at this place. At its western base the James and North Rivers meet, and force a passage, exactly at the point of junction. We thus find here the same features as those presented by the Potomac and Shenandoah at Harper's Ferry.

Standing at the Cement Mills, just where the river issues from the gorge and in this first barrier, the perpendicular walls of the opposite bank are seen to be composed of beautifully regular arches of No. (10), piled one above another to a great height. Probable thickness, 700 feet.

Both (9) and (10) seem, by a mighty thrust from the west, to have been crowded high up against the firm barrier opposed by the syenitic mass. This accounts for the gentle northwest dip which, as Prof Rogers correctly states, is shown by these upper strata in passing over the mountain to the east. In taking the section along this road, I did not find this to be true of the lower strata up to No. (8). They, even near the top of the syenitic mountain, show the same high dip that is seen along the canal. The massive, unyielding plates of No. (8) seem to have protected them to a certain extent, but have themselves been extensively fractured. Hence, in passing along the mountain road from the mills to the east, we observe the following typographical features: Looking westward, we see the strata of (10) rising and falling in rapid symmetrical undulations and forming the lofty range which fronts the valley of the river. Proceeding eastward, up the western slopes of the syenitic range, we pass first over the broken fragments of (10) and then of (9). Both, by the flattening out of the undulations, have a gentle northwest dip, and are partly crowded

over the fractured outcrop of (8). Next appear the lower strata in unchanged position.

Returning to the line of section, we find the western slopes of the mountain overlooking the valley of the James to be covered high up with boulders and alluvial matter, by which the junction of (10) with the next series (11), and some adjoining space, is concealed. The river has at some time flowed several hundred feet higher than its present level.

The series of strata which I have numbered (11) in this section occupies a narrow belt between the mountain last mentioned and James River. The dip is very regular, being about 55° to the northwest. The rocks, so far as seen, next to the mountain, are more or less ferruginous, and local pockets of iron ore occur in the sandstones of (10) forming the mountain, especially near the line of junction.

The first rock seen next to the mountain is thinly laminated, fragile shale, of yellowish and reddish hues, not fully exposed. Next, to the west, we have bluish calcareous slate, and slaty limestone, 50 feet. Then very thinly laminated, firm, deep red slates, 60 feet. Next a similar slate of blue color, 15 feet. Then a bed of dark blue, hard, and dense limestone, used for cement, 13 feet. Then thinly laminated red slates, 20 feet. Then coarser, and thicker bedded, blue slates, 40 feet. Lastly, a coarse, rough, massive, siliceous limestone, 40 feet.

These strata are all well exposed in the excavations made for gaining the cement stone. This group of impure limestones is the equivalent, in Virginia, of the "Calcareous sandrock," and is present at all the sections examined by me, holding a similar position with respect to the Potsdam strata. They present, also, remarkably constant features in composition, especially the last mentioned, which, both at Rockfish Gap and Harper's Ferry, may be recognized at a glance. The cement limestone, from its physical appearance, is the purest of the group. The following is its analysis, obtained from the owner of the mills: SiO_2 34.225; Al_2O_3 with a little Fe_2O_3 7.8; CO_2 30.4; CaO 17.380; MgO 9.513; KO .12; water and organic matter, .5; loss, .062. The thickness of this group, up to the last mentioned limestone, is probably 600 feet, including the concealed ground. My section did not continue beyond this point.

On the west side of the river is a valley, from half to three-quarters of a mile wide, which is bounded on the west by a range of heights called "Salling's Mountain." I observed in the western banks of the stream about eighty feet of fine-grained kaolin shales and sandstone, like those of (10), but more shaly. These have the same northwest dip; how far they extend into the valley I do not know. Prof. Rogers says

that Salling's Mountain is composed of brown shales, which he makes the upper member of his No. I, or Potsdam formation. He further says that in them the dip is inverted, or to the southeast, the limestones of the Great Valley, i. e., the Trenton, Chazy, &c. (his No. II), passing under them. My section not having extended into these strata, I can say nothing concerning their age, except that they would seem to overlie the Calciferous sandrock, as the continued section above given extends through the Potsdam strata to those of the Calciferous. From this change of dip it appears that in this region the break and overturn of strata, which elsewhere extends through all the Primordial rocks, is found only in the strata overlying the Calciferous.

Some of the strata given in the above section present features of special interest, which must now be noticed.

The quartzite, No. (1), which immediately joins the syenite, is noteworthy as being the most completely metamorphosed rock seen in the entire section. This is evidently due to its contact with the crystalline rock. It is without bedding, and is affected by the same system of northeast and southwest joints seen in the syenite, and apparently forms one mass with the latter, no distinct line of junction being visible. The texture is nearly compact, from the fusion of the quartz grains. Numerous brilliant, perfectly crystallized, particles of white feldspar of small size occur. A few small, imperfectly crystallized garnets are seen in it. The next rock, No. (2), next to the quartzite, is a brown, crumbling, shaly mass, without bedding, which at its western edge terminates in a bed of feldspathic conglomerate. This has a high inclination to the northwest. The appearance of the lower portion of No. (2), and the highly altered condition of (1), seem to show that the upheaval of the adjacent portion of the syenite took place after their deposition, while the succeeding conglomerates are evidently the products of this disturbance. These conglomerates all closely resemble each other, and present some interesting features. They are composed of water-worn particles of quartz and red feldspar, of all sizes, up to that of a buckshot. The feldspar largely predominates, and is remarkable for its freshness, showing even in very small particles brilliant cleavage surfaces. Both it and the quartz are plainly derived from the neighboring syenite. The deposition must have taken place rapidly. The coarser particles are cemented together by a dark gray, very fine-grained paste, having the appearance, texture, and hardness of talc slate. It is apparently formed of finely comminuted feldspar and argillaceous matter. The entire mass weathers by exfoliation of concentric crusts, producing rounded boulders most strikingly like an igneous rock. Indeed, I

was induced by this peculiarity to study closely its composition, under the impression that such was its nature.

These conglomerates crop out on the top of the mountain, and are partially exposed in the road. Here I discovered that the upper part of No. (4) was composed of a mass of angular fragments of slate cemented together by conglomeritic matter. These fragments of slate, sometimes as large as the hand, are of precisely the same character as the argillites which make up so large a part of the Blue Ridge, especially to the north. Their existence here shows not only that these argillites are older than the lowest Primordial rocks, but that they were already in a metamorphosed condition prior to the Primordial Period. The shales lying between the beds of conglomerate are very much contorted, and they, with the succeeding strata up to (8), seem to be mainly composed of finely comminuted feldspathic and argillaceous material, which had not been long exposed to decomposing and dissolving agencies.

The massive beds numbered (8) in the section differ strikingly from the underlying rocks in every respect. The material composing them is almost entirely quartz and of a white color, the grains being more or less rounded and cemented together. A few specks of yellow earthy matter occur, marking the position of decomposed particles of feldspar. With this exception, the rock is remarkably free from all minerals except quartz. If I mistake not, this is the rock mentioned by Prof. Rogers as typical No. 1, or Potsdam. But from his descriptions, given elsewhere in his reports, the strata which I have numbered (10) coincide more nearly with his sandstone, No. I. This also agrees best with the relative positions of No. (10), and of the Calciferous sandrock, which forms the upper part of No. (11).

We may pass over the strata forming (9) in the section, as they lie in such confusion that it would be unsafe to attempt to give details. I may state, however, that the sandstones which occur in the shales of this series are quite thin. The coarsest and most massive layers are not more than 8 or 10 feet thick. It is worthy of note that these sandstones are much more altered than the shales by the disturbances to which they have been subjected. The shales seem hardly at all affected, while the sandstones are much indurated and often impregnated with epidotic and other metamorphic products. The material composing the shales is gray, argillaceous matter, with some beds of brown and reddish colors.

No. (10). This series, which is probably the equivalent of the Potsdam sandstone of New York, is composed of alternating strata of quartzite and kaolin shales. The quartzite layers vary in thickness from 20 feet to 3 or 4 feet. Many are quite compact, and some resemble vein quartz in fracture and other features.

The quartzites predominate in the lower beds. The kaolin shales often pass into a fine-grained sandstone, in which the grains of sand and kaolin of uniform size are equally and uniformly mixed. This latter rock, which is very common in the Potsdam of the northern part of the State, appears in great force at Rockfish Gap, and will be described in the section there more fully. The strata of (10) are remarkable for their freedom from coloring matters, and for the thorough decomposition of the feldspathic matter present. The kaolin shales and shaly sandstones occur in plates of a few inches to a foot or more in thickness. They are much fractured by the extraordinary disturbance to which they have been subjected. Notwithstanding the great amount of motion which has taken place in these strata, the shales do not seem to be metamorphosed beyond perhaps a partial loss of plasticity. Here again the sandstones show greater alteration. It is generally true, I think, that beds of pure argillaceous matter undergo far less metamorphosis in composition and texture than the siliceous layers which are interstratified with them. This at least is very generally true of the disturbed rocks of the Silurian and Devonian areas in Virginia and elsewhere, where I have observed them. The usual effect on these shales of the compression, &c., produced by disturbances is to cause them to assume more or less of the slaty cleavage, but I have never seen any approach to general crystallization of the constituents, even in the most profoundly convulsed districts. Again, the change in the beds of sandstone is usually the consolidation of the individual grains of sand. When foreign material is introduced, it is always in the form of local impregnations, plainly caused by circulating heated waters. I will return to this subject later. The strata of No. (11) do not require a further description.

The following section, No. I, represents the strata from (1) to (8) inclusive. No. (8) rises in a cliff 200-300 feet high, leaning over in an arch toward the syenite.

In this section, (a) represents the bed of quartzite mentioned in a former paper, as occurring on the east side of the syenitic mountain, while (b) denotes a portion of the mica slates which lean against this range on the east, with a southeast dip. The

strata numbered from (1) to (8) denote those thus numbered in the descriptions, while (c) represents the syenites against which these lean with a high northwest dip. This section represents the stratification on the canal, but on the slopes of the mountain ascending from the west (8) and the overlying strata are crowded over to some extent on the outcrop of the subjacent rocks.

From the occurrence of the quartzite stratum at (a), and the fact that the Primordial strata ascend to the summit of the syenitic mountain, it might, at the first glance, be supposed that the slates at (b) are merely the extension of the strata on the west in a more highly altered condition. But this idea is forbidden by the great difference in the thickness of the western and eastern quartzites, and by the total change in the character of the beds, those on the east being a great mass of mica slates, quite regularly bedded, and showing none of the alternations of strata seen but a little distance away on the west. This relative position of the two systems of bedded rocks explains the fact mentioned by Prof. Rogers as occurring in the more northerly portion of the State, where Primordial strata with northwest dip lie upon the edges of the slates of the ridges which dip to the southeast. This would occur here were the syenitic mass absent, and, as we shall see, it does not form a dividing ridge farther north. The following section, No. II, gives a representation of the stratification of series (9), (10) and (11). As far as (9) and (10) are concerned, it is in part ideal, and I do not insist upon the correctness of my estimate of their thickness.

SECTION II.

A. No. (8) with subjacent strata. (9) Gray and reddish shales and sandstones. (10) Potsdam shales and quartzites. (11) Upper shales and Calciferous strata.

PEAKS OF OTTER.

No detailed examination was made at this point of the Primordial rocks. At the west base of the syenitic range, gray shales and kaolin shales, very imperfectly exposed, were seen to pass a little distance up the mountain. They have a high southeast dip, showing the inversion of the lowest portion of the Primordial strata in this region. It is probable that some of the lower strata have been engulfed in the overturn. Prof. Rogers states that from this point to the southwest the inversion generally prevails.

[To be continued.]