

ART. LV.—*Geology of Virginia :—Balcony Falls. The Blue Ridge and its geological connections. Some theoretical considerations*; by J. L. CAMPBELL, Washington and Lee University.

AMONG the many localities in the mountains of Virginia that are peculiarly interesting to the geologist, very few offer attractions superior to those found in the great natural section of the Blue Ridge at Balcony Falls, where the James River passes from the Valley to Piedmont Virginia. The canal from Lynchburg to Lexington passes through this mountain gorge, and renders the exposures of the rocky formations easily accessible. Here both the Archæan and the Primordial formations are displayed in their relative positions, and their contact laid bare to inspection. Reference was made to this point in a former paper (July No. of this Journal, pp. 22, 23), by way of illustration. I now propose to discuss some of its interesting features more in detail.

Topography.—The accompanying map and section will serve to throw light upon both the topographical and the geological features of the locality. Leaving out of view a number of irregular foot-ridges on the southeast side, we may regard the

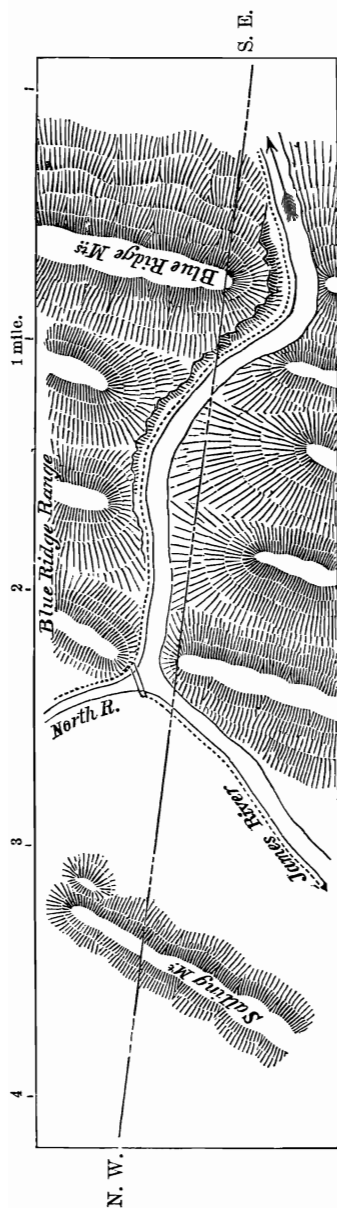
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range of mountains here, known as the "Blue Ridge Range," to consist of, (1) the real Blue Ridge on the southeast border—the long water-shed between the valley and Piedmont Counties—between Rockbridge on the northwest and Amherst and Bedford on the southeast. Here and for some miles along its line both ways, this ridge is flanked by Archæan rocks on the southeast and Primordial rocks on the northwest—the latter resting unconformably upon the former. (2) Skirting the northwest side of this leading ridge, and parallel with it, are two well defined lines of broken ridges that have evidently been once continuous, but now consist of short, abruptly terminating mountains, of rounded dome-like hills, and of rugged conical peaks. These all have a frame-work of Primordial sandstones, with the less durable shales of the same period lying along their flanks or filling the depressions between them. Of these lines of ridges the one bordering on the great limestone valley, heretofore described, (see July No.), is by far the most conspicuous, and the most uniform in its physical features. It consists essentially of the durable masses of the Upper Potsdam sandstones, so durable that many parts of it have maintained a height almost equal to that of the main ridge, the average height of which, in this region, somewhat exceeds 2500 feet. The mean bearing of this portion of the range is about N. 35° E.

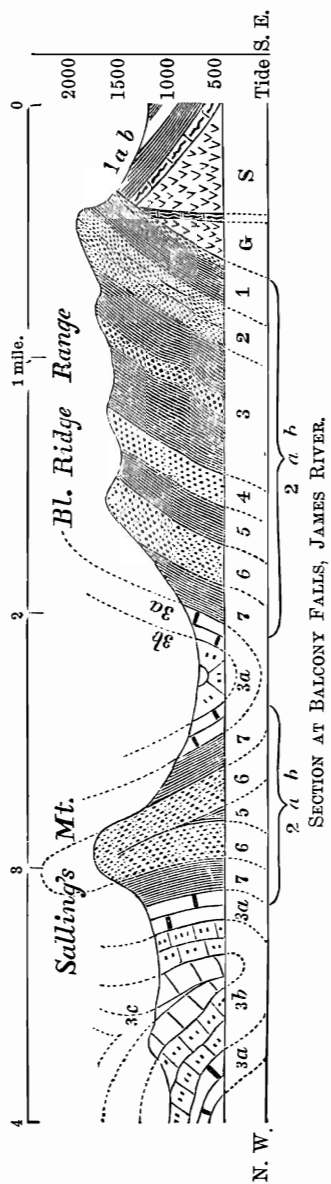
Salling's Mountain, seen on the left of the map, is an outlying ridge of Primordial sandstones and slates, cut off at its northeastern end by the North River, and at its southwestern end by James River. It is separated from the principal chain by a narrow synclinal valley of limestone (Lower Silurian), most of which is concealed from view by an extensive bed of *alluvium*, accumulated by the two rivers that meet here; but accumulated originally in a Y-shaped lake, through which they seem to have flowed at some former period of their history.

The two rivers above mentioned, traverse the little valley obliquely, and meet at a very obtuse angle just where their waters, as one united stream, enter the deep gorge or cañon by which they pass through the mountain range. Just below their junction are mills for grinding hydraulic lime burnt from the ledges that crop out a little higher up the James River. "Balcony Falls" is the name given to a succession of "rapids," beginning about half-a-mile below the Cement Mills, and continuing to the southeast limit of the gorge. The river here is 700 feet above tide level.

Geology.—The foregoing outline of the topography of the region will enable the reader to understand more clearly its geological peculiarities, and to interpret more readily than he otherwise could, the ideal section accompanying the map.



MAP OF CANON AT BALCONY FALLS, VIRGINIA.



SECTION AT BALCONY FALLS, JAMES RIVER.

Conceive a vertical plane with its edge resting on a line represented by the broken line of the map, marked "S.E.," and "N.W.," and having a height of 1500 feet above the bed of the river. Then imagine all the outcropping faces and edges of all the eroded rocks of the gorge, and all that the plane itself would cut (including those of Salling's Mountain), to be pictured on the plane, and you will have a mental conception of what the section is designed to represent.

The student of geology will find here a somewhat intricate, but a very interesting problem for solution. By a series of careful observations along the canal and bed of the river, and also by the turnpike that crosses the mountain near the canal, very satisfactory conclusions may be reached. In the gorge we have the rocks of two distinct eras so meeting as to enable us to study not only their composition and structure, but also their relative positions, and some of the metamorphic influences they have exerted upon one another. These two eras are, (1) the Archæan, represented on the accompanying section by the rocks on the right marked G, S, and 1 *a*, *b*; (2) a portion of the Lower Silurian covering the remainder of the section.

Let us begin at the base of the Archæan. Here we find two masses, or a sort of double mass, marked G. and S.—the former a mass of Granulite, and the latter of Syenite. These are usually regarded as igneous, or perhaps with more propriety, aqueo-igneous rocks. They underlie the stratified rocks of this era; but, considered as solid rocky masses, they are probably of more recent date than any other rocks represented on the section—having been thrust upward beneath the overlying stratified beds in a plastic (semi-fused) condition, and subsequently hardened into their present condition.

G. is "granulite"*—a granitoid rock, eruptive in its origin. It is composed of granular quartz mixed with feldspar, both white and pale flesh-colored; and has numerous crystals of garnet, and occasional crystals and blotches of epidote disseminated through it, giving it a spotted appearance. This is about 100 feet wide at the base, and seems to be separated from the larger mass of syenite (S.) by a crushed and greatly metamorphosed bed of gneissoid rock, in which distinct traces of the original bedding can be seen. The syenite is well exposed from a short distance below the limit of the granulite, as far down the canal as to lock No. 15. It also forms a rugged bed for the river in this part of its course, and rises to the height of several hundred feet beneath the mountain on the opposite side. Syenite is a granitoid rock composed essentially of quartz, feldspar and hornblende, in varying proportions.

* So classed by Professor Dana, to whom a specimen was submitted.

Besides these constituents we find the mass at Balcony Falls containing, in some places, considerable quantities of epidote, both crystalline and amorphous, giving the rock a green color, and in others numerous crystals of garnet.

The bedded rocks (1, *a*, *b*,) that rest upon the syenite, are very much metamorphosed, are gneissoid in character, and dip toward the southeast. These are succeeded by beds of red and brown slates. Then follows a bed of forty or fifty feet of conglomerate quartzite, bearing some resemblance to the conglomerate sandstones on the opposite side of the ridge, but so unlike in composition, texture, position and thickness as to preclude the idea that they have any historical connection. Over this again we find another bed of slate. These beds all dip towards the southeast, while their upper margins reach beyond the underlying syenite and granulite, and with their edges support the lowest beds of Primordial rocks where they extend high up on the ridges, beyond the limit of the igneous beds. The two series here, and at other points along the ridge, are entirely unconformable. Such are the Archæan rocks.

Starting again on the northwest side of the granulite, let us briefly sketch the remarkable beds that make up the remainder of this massive range. In the Archæan rocks we have just described there are no traces of fossil remains, nor do we find any in the lowest beds of what we call Primordial. If organic remains have ever been imbedded in them here, they have either been obliterated or remain yet to be discovered.

Subdivisions.—On the section illustrating a former article (July No.), the classification of Professor Rogers in his reports was employed, and subdivisions of my own introduced. In a second article (August No.), the classification and notations* of Professor Dana's Manual were introduced. This latter system I shall employ in this paper—introducing subdivisions only in the Primal period, numbered, 1, 2, 3, etc.

The Primal or Potsdam period is often divided into Acadian and Potsdam epochs—*2a* and *2b*—but as it is very doubtful whether both of these, as they occur farther north, have equivalents here, or if they have, where the horizon between them is to be found, I shall designate the whole period as *2a, b*, and its subdivisions 1, 2, 3, 4, etc. These will correspond with the subdivisions, *1a, 1b, 1c*, etc., on my former section. As these were then regarded as only of secondary importance to my main object—the Silurian limestones—a very brief description of them was deemed sufficient; but now they become of prime importance in our discussion, and demand a more full and detailed examination.

* Professor Rogers himself has partially adopted this system in his article on the Geology of Virginia, in Macfarlane's Geol. R. R. Guide.

Without repeating in each case the notation, *2ab*, the several subdivisions will be referred to by the simple numbers, 1, 2, 3, etc. All the beds of this period, with some local and limited exceptions, dip toward the northwest. The slight alternations and variations of dip are confined almost entirely to the thinner beds of sandstone, and the shales contiguous to them (especially in 3), and are limited apparently to points near the margin of the river. Variations in the steepness of dip in the heavy beds of sandstone as they rise toward the crests of the ridges, are, however, common throughout the whole range. The limited irregularities may, with much plausibility, be referred to the undermining action of the river; for there are abundant indications that the water once stood several hundred feet higher in this pass, and in the little valley west of its entrance, than the present height of the river bed.

Subdivision 1 is a bed of conglomerate about fifty feet thick, resting unconformably against the Archæan rocks, and composed of sand, rounded quartz pebbles, fragments and worn crystals of feldspar, with some fragments of epidote, all firmly cemented together, and hardened by the action of heat from the contiguous igneous rocks; followed by several alternations of slates and conglomeritic sandstones, with an aggregate thickness of about 120 feet. This division has been considerably affected by heat throughout. Its position, too, has protected it against the erosive action of the river which has been far less here than it has been among the slates higher up in the series.

Number 2 is a heavy mass of sandstone fully 350 feet thick, and so hard that we may call it "quartzite." It consists of three tolerably distinct beds varying in hardness and color; the lowest being very hard and of a light gray, sometimes pinkish color; the middle one of coarser texture, partly conglomerate and mostly of a greenish gray color; the upper bed is more brittle than either of the other two, and of darker color. These heavy beds of hard sandstone seem to have presented one of the most durable barriers to the passage of the river through the mountain, and doubtless obstructed its flow to such an extent as to keep the water in contact with the higher beds for a period long enough to cause some modifications already mentioned, and others to be noticed hereafter. Before the canal was constructed the steep rugged outcrop of this massive ledge projected considerably over the left margin of the river, and was known as "Balcony Rock"—hence the name of the falls. For some little distance on the west side of this sandstone the river runs nearly with the strike of the strata, exposing in succession the rugged edges of the several beds.

Number 3 consists of two heavy beds of slates separated by a stratum of hard conglomeritic sandstone about sixty feet

thick, and greenish gray color. The slates are of brown, purple and yellow colors, with some thin beds of argillaceous sandstones interstratified. At this point the river has left some marked traces of its former action in eroding the softer, and undermining the harder strata. The most conspicuous irregularity has been caused by the undermining of the interstratified bed of sandstone just mentioned, so as to give it a low and sometimes waving dip, and to cause a mass of it to slip from its normal position and modify both dip and strike, as seen just above the margin of the canal. This seems to me the only rational way of accounting for the anomalous position of this bed of sandstone at this point, compared with its position at several other points remote from the river. It also explains its want of conformity with the general structure of the whole Primal period, as exhibited all along this part of the Blue Ridge range. These local irregularities are not represented on the section.

It is a little difficult to determine, even approximately, the thickness of this double bed of slates with its enclosed sandstone, but the aggregate must be at least six hundred feet.

Number 4 is not well defined below, since 3 becomes more and more siliceous and blends gradually into it; but the greater part of it is a bed of brownish gray sandstone with a well defined upper surface. It crosses the river at the Cement Mills, and its highest ledge forms the abutment of the dam on the opposite side of the river. Where a deep channel was washed out by a freshet a few years ago, this rock is well exposed on the lower margin of the turnpike, and its upturned edges may be conveniently examined. A considerable exposure of it also crops out above the turnpike between the houses of Messrs. Locker and Campbell, while the corresponding ledge may be seen on the cliff beyond the river. It has a very regularly jointed structure—the cleavage planes being so distinct as to have been mistaken by an unpracticed observer for planes of stratification dipping to the southeast, while the true planes of stratification dip with considerable uniformity and great constancy toward the N.W.

In this and some of the lower beds of sandstone, very faint impressions of fucoids and occasional *Scolithus* borings are found; but the conglomerate structure is much less prominent here than in the older beds.

Number 5 is made up of numerous thin beds of slate quite different in color and texture from any that we find lower down. They exhibit, where recently exposed in repairing the canal, a great variety of color from nearly pure white kaolin to various shades of yellow, red and brown, and abound in fine scales of mica; but no distinct traces of fossil remains have

been found in them. In the portion near the river their dip varies from 25° to 50° . I estimate their thickness at 180 feet.

Number 6 is, in some respects, the most interesting of all the subdivisions of this Primal group. It is the sandstone that "constitutes the type of this formation." It differs from the beds already described in both its lithological and fossil peculiarities, (see July No., p. 22). It may well be called the "Scolithus sandstone," if we call the primal worms (?) that had their millions of habitations in this rock the "*Scolithus linearis*."

Its entire thickness (including some quite brittle beds that underlie and overlie the more massive portion), is about 340 feet. The dip at the base of the ridge, where the two rivers meet at the entrance of the gorge, is fully 65° , while it falls gradually to 40° before it reaches the summit—looking as if it might once have been one leg of a grand natural arch, which still stands up with one exposed face forming an almost perpendicular cliff nearly 800 feet in height. There is, however, no point in this portion of the range where I have found it reaching beyond the northwestern line of ridges, of which it generally forms the crest and the greater part of the western slope, as represented on the accompanying section. A part of this sandstone, with the next beds of slate and sandstone below it, has broken loose from the upper outcrop of the ledges on the S.W. side of the river, and slipped down the eastern face of the ridge without any great change of dip. This displaced mass may be seen as a very conspicuous object nearly opposite, though a little below the Cement Mills. It is apparently one of the effects of undermining by high water in the remote past.

Division 7—the upper Potsdam shale—usually extends some distance up the slope of 6, where the normal dip has been preserved, as may be seen at the iron mines a short distance to the N.E., or opposite the Cement quarries, a short distance S.W. of the entrance of the gorge; but just at the entrance it has been eroded by the river and then concealed very much from view by the drift and diluvium of the valley. Its dip increases toward the valley. As nearly as can be determined here, the thickness is fully 600 feet. A sufficient additional description of it may be found in the July number, p. 23. This brings us to the top of the Primordial period.

The next is the Canadian Period (3)—sometimes called, "Middle Cambrian"—and, like the Primordial, belongs to the Lower Silurian Age. It has three epochs, Calciferous (3a), Quebec (3b) and Chazy (3c). The first of these, named from the prominent character of its rocks in New York, might well be called "Hydraulic," in Virginia, as it is generally characterized by the presence of one or more beds of hydraulic limestone. Where our section crosses, this limestone is quarried

from a bed twelve or thirteen feet thick, interstratified with shales and other beds of impure limestone. It dips steeply to the northwest, and again crops out at the base of Salling's Mountain, on the west side of the little valley in which the two rivers meet. Over it lies a part of the Quebec (*3b*), that has escaped the denuding agencies that have operated so extensively over the whole of the Great Valley. It crops out at a number of points along the James River near the cement quarries, and along the base of Salling's Mountain. We have thus a synclinal trough of limestone resting upon the Primordial shales and sandstones, which we find rising again on the west side and forming the mass of the bordering mountain.

In a depression of Salling's Mountain, about half-a-mile to the right of the point cut by the section, and where the turn-pike leading from Balcony Falls to the Natural Bridge crosses, we find the shales and thin beds of sandstone of *2ab, 7*, extending to the top of the ridge, but where the mountain is more elevated, the heavy beds of Scolithus sandstones (*2ab, 6*), form the core of the ridge, all dipping steeply to the southeast; while beyond, the mountain shales of *7* again appear, dipping toward the mountain and apparently beneath the sandstone which elsewhere underlies them. Then as we descend into the valley beyond the mountain we again meet with the limestones and interstratified shales of *3a* and *3b*, dipping under *7*. These facts lead to the conclusion that the mountain is a closed fold of Primordial strata pushed over toward the northwest, so as to invert all the strata on that side, and place the older above the newer. But on crossing a low ridge half-a-mile from the mountain and parallel with it, the limestones appear again on its western side still dipping southeast, but in their normal order. From an examination of this limestone ridge at different points, the conclusion to which my mind is drawn is, that it consists of a closed synclinal fold, the middle portion of which is the lower part of the Chazy (*3c*), all higher beds having been pressed out and subsequently swept off. This part of the section will be readily understood from simple inspection.

Salling's Mountain will serve as a type of a considerable number of nearly parallel outliers of the main Blue Ridge chain, extending for thirty miles toward the southwest; and consisting of arches of the upper Primordial strata of sandstones and slates, as may be seen on the road leading from Buchanan to the Peaks of Otter, or of closed and inverted folds, a conspicuous example of which may be found in the ridge that separates Buford's Valley in Bedford from the Great Valley in Botetourt County, and is here called Blue Ridge, because it is the geographical watershed between the two counties—not because it is a continuation of that ridge geologically.

Ridges of this class generally lie off from one to several miles from the main range, and seem to have been thrust up beneath the limestones of the Canadian Period, the folds of which were probably much shattered at the time, and subsequently worn or swept away, so as to leave the ridges of more durable sandstone naked for some distance down their steep sides, and flanked along both bases by slates and limestones—the latter often occupying narrow valleys or troughs, like the one above described, or like Buford's Valley in Bedford county, traversed by the A. M. and O. R. R., in going from Lynchburg to Salem.

Theoretical considerations.—1. The Primal strata, as well as all those of later date, given on my two former sections, (July and August Nos.), are of oceanic origin, and the sandstones and conglomerates have evidently been deposited over the bottom of shallow water, and most heavily along the margin of an ancient ocean whose shore-line was the Blue Ridge. The earliest of these beds—those found at the very bottom, and for some distance upward in the series, are composed of the debris of still older rocks that composed the ancient shore land, and that seem to have been metamorphosed before they were worn down as material for the Primordial strata; for in the latter we find fragments of metamorphosed slate, with both fragments and crystals of feldspar, epidote, etc., more or less water-worn, mingled and cemented together, but not otherwise differing from the same material, as we now find it broken down by the weather from the metamorphic rocks of the Archæan land.

2. The irregular, unbedded masses of syenite and granulite that constitute the base of the Blue Ridge, have evidently been erupted since the deposition of the Primordial strata. This is evident from the mode of contact of the two classes of rock—the stratified resting at a high dip against the igneous masses; and also from the influence the heat of the igneous rocks has exerted upon the slates and sandstones overlying them. Again, the higher we ascend in the series the fewer traces we find of the metamorphic changes.

3. As far as we can read the records left upon the Silurian rocks from the Primordial upward, mechanical force seems to be entirely inadequate alone, without the aid of heat from other sources, to produce any very great amount of metamorphism. The extent to which the rocks represented on the several sections I have given—especially on the first—have been subjected to bending and pressure, and consequent friction, ought, according to the mechanical theory of metamorphism, to have made the Great Valley of Virginia one vast mass of metamorphic strata. But no such effect has followed. The limestones have their fossils beautifully preserved. The sandstones have

not been changed to quartzite. The shales are still nothing but fragile shales (with a few exceptions); while the embedded limonite iron ores still retain their water of crystallization. There has been metamorphism, but only limited, not general, except so far as it has been produced through other agencies than heat, or even super-heated water under pressure.

4. Such closed folds as we find in Salling's Mountain, and in many localities among the lower Silurian limestones, seem to have been great wrinkles in the strata, pushed upward (or downward in the case of synclines), and then pressed together by mechanical force acting from a southeasterly direction and in a horizontal plane. This is the only way we can plausibly account for the numerous troughs and arches and folds found along the lines of the several sections we have had under discussion.

5. The flexures and folds of course produced numerous fractures, especially in the limestone beds, and thus prepared the way for the action of the denuding agencies that stripped this great limestone valley of thousands of feet of its original covering. As the pressure was most powerful on the margin nearest the Blue Ridge, so we should expect to find there the flattest folds and the most numerous fractures, and consequently the greatest amount of denudation. Such we find to be the case; for in the first place, we find the higher—the Trenton—limestones from the James to the Potomac nearly all gone from that side of the valley; and in the second place, all the waters in this region flow toward that side, until they approach the base of the mountain near which they continue till they find an outlet by some one of the great streams that carry them through the mountains and finally to the Atlantic Ocean.

Water acting alone could hardly have been the cause of the vast amount, and peculiar kind of denudation we find extending over nearly the whole 6,000 square miles of this limestone valley, unless it had swept over it in one vast torrent sufficiently deep and powerful to have carried whole mountain chains before it. A much more probable hypothesis is that ice as well as water was an important agent in bringing about the great changes of surface that have given this valley its wonderful fertility.

There are indications throughout this whole region of two great flood periods, since the close of Paleozoic time, when the great Appalachian revolution left the vast accumulations of stratified rocks of that remote age in essentially the same relative position they now occupy. But further notice of these must be postponed for the present.