

T H E

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ART. XLIII.—*Geology of the Little Colorado Valley*;\* by  
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THE geology of the Grand Canyon region of northern Arizona has received much attention on the part of geologists and considerable has been written on the higher beds of Mesozoic age that lie to the eastward in Marble Canyon and farther north, but very little study seems to have been made of the Little Colorado Valley above the point at the north end of the Colorado Plateau, where it broadens out into a plain. The strata of the Grand Canyon up to and including the junction of the Little Colorado with the Colorado River, consist, as all know, entirely of Paleozoic and pre-Paleozoic rocks, and it is the Carboniferous limestones, or sometimes sandstones (Upper Aubrey), that occupy the surface of both the Colorado and the Kaibab plateaus. But the entire system dips sensibly to the northeast and at any point some distance back from the canyon remnants of Mesozoic rocks occur for many miles before reaching the bed of the Little Colorado. That river, therefore, practically flows for almost its entire length over Mesozoic strata, but these do not attain their great development except on the northeastern slope of the valley. Here they form several series of terraces, rising one above another as one recedes from the river, and forming at their maximum development lofty and picturesque escarpments, with brilliantly colored stratification, rivaling in many respects the Grand Canyon itself. The broad arid plains that lie to the southwest of these cliffs have received the name of the Painted Desert, from the circumstance that from any point on this desert these painted cliffs are always in full view. From a great distance they may

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under certain conditions appear beautiful and innocent, but any attempt to invade this desert or to scale these cliffs, except by means of the few well known Indian trails, is certain to be met with defeat, and the hardships that have to be endured in striving to traverse this region are of the severest kind. Lieut. Ives described the region in the following language :

“The scene was one of utter desolation. Not a tree nor a shrub broke its monotony. The edges of the mesas were flaming red, and the sand threw back the sun’s rays in a yellow glare. Every object looked hot and dry and dreary. The animals began to give out. We knew that it was desperate to keep on, but felt unwilling to return, and forced the jaded brutes to wade through the powdery impalpable dust for fifteen miles. The country, if possible, grew worse. There was not a spear of grass, and from the porousness of the soil and rocks it was impossible that there should be a drop of water. A point was reached which commanded a view twenty or thirty miles ahead, but the fiery bluffs and yellow sand, paled somewhat by distance, extended to the end of the vista. Even beyond the ordinary limit of vision were other bluffs and sand fields, lifted into view by the mirage, and elongating the hideous picture. The only relief to the eye was a cluster of blue pinnacles far to the east that promised a different character of country. It was useless, however, to take the risk of proceeding directly thither. The experience of the day had demonstrated the hopelessness of trying to drive the mules for any length of time through an untrodden and yielding soil, and it was determined, as a last chance, to go back to Flax River and ascend the bank, at the hazard of having to make a long circuit, till some Indian trail should be encountered leading in the desired direction, and affording a beaten way practicable to be followed.”\*

Very little seems to be known of the more detailed nature of these deposits. They are usually spoken of as a single great system of beds, and I am not aware of any serious attempt to subdivide them or arrange them into anything like a successive series of varying deposits. It was my chief object during my entire stay in that country to subject these deposits to a searching analytical study and to work out, if possible, their true succession. I began this study by a reconnaissance of the Little Colorado Valley. After making camp at Tanner’s Crossing, which is only 12 miles above the point where the Little Colorado enters the limestone canyon at the foot of Coconino Point, I set about mastering the details of the stratigraphy of that general region. Later on, and in the

\* Report upon the Colorado River of the West, explored in 1857 and 1858 by Lieutenant Joseph C. Ives, Washington, 1861, Part I, p. 117.

light of information thus obtained, I studied the various remnants of the Mesozoic that are scattered over the Colorado Plateau, and especially Red Butte, which is the most conspicuous and best known of these remnants. Finally, as a concluding task, I returned to the upper portion of the valley of the Little Colorado and made a study of the formation there similar to that which I had made below.

I will not introduce here the details of this investigation and shall be obliged to omit a great amount of important data, including many sections recorded in my note-book, but I will merely give the most general and essential results and the general section.

First of all, let me say, that I think I have succeeded in dividing the formation into three entirely distinct series or classes of deposits. One of these, the thickest of them and the one which is best known, has already been named by Major Powell the Shinarump.\* This, however, occupies the central portion of the beds in their geological sequence. The other two divisions are, so far as I am aware, unnamed and I have ventured to give names to them. The lower beds I, therefore, designate as the Moencopie beds, from having first found them in their full development at the mouth of the Moencopie Wash. To the other or highest of the series I have thought it appropriate, from the considerations already set forth, to give the name of Painted Desert beds.†

#### *The Moencopie Beds.*

These occupy the lowest portion of the formation, having a maximum observed thickness of between 600 and 700 feet. They present several distinct phases, but the greatest part of them consists of dark reddish brown, soft, laminated, argillaceous shales, nearly destitute of silica, highly charged with

\* Geology of the Uinta Mountains, etc., 1876, pp. 68-69. See Twentieth Ann. Rep. U. S. Geological Survey. Pt. II, p. 318.

† The name "Painted Desert" occurs, apparently for the first time, in the contents to Chapter IX of Part I of Lieut. Ives's Report upon the Colorado River of the West, pp. 15 and 113, but is not used in the description of the desert on pp. 116-117, from which the above extract is taken. It is used by Dr. Newberry in Part III, on pp. 76-83, and to it he devotes a section. These early uses of the term show that it refers to an area lying opposite to the region between Wolf's Crossing and Winslow, but Dr. Newberry says (p. 76) "that the peculiar physical aspect and geological structure of the Painted Desert prevail over a wide belt of country bordering the Little Colorado on the east, and extending at least as far northward as our Camp 73." This camp appears from the very imperfect map accompanying the report to have been about on the latitude of Tanner's Crossing, but far to the westward. On this map the Painted Desert is represented as occupying all that region lying along the southwestern base of the painted cliffs from the line of their route through the gap at Blue Peaks and Pottery Hill northwestward to an indefinite distance. On the latest Land Office maps, however, it seems to be restricted to that portion of the desert lying north of the Moencopie Wash and along the base of Echo Cliffs. There seems to be no good reason for thus restricting it.

salt\* and gypsum, tending on exposure to assume the character of nearly homogeneous marls and to form low ridges, but-tresses and even isolated knolls or buttes, at the bases of cliffs and in eroded valleys. The gypsum often forms thin sheets which appear as fine white lines and which do not follow the planes of stratification but cross the beds irregularly and also cross one another, giving the exposures a peculiar striped appearance.

Between these beds of shale there occur, usually at more than one horizon, brown sandstones. These are more or less argillaceous and their exposed faces do not present sharp angles but have rounded forms, due in the main to the influence of winds which wear off the jagged appearance but do not tend to form chimneys or assume fantastic shapes. These sandstone ledges, which are very uniform in composition, sometimes have a thickness of 100 feet or more, though such heavy beds are usually interrupted by several layers of the shale.

Toward the lower part of the Moencopie beds the shales gradually become calcareous and there is in nearly all good exposures a horizon of white impure limestone, well laminated in its central portion, but becoming very thin and hard below and finally passing either into the typical shale or into homogeneous marls. The extreme upper and also the extreme lower portions of the Moencopie beds always consist, so far as observed, of the typical dark brown argillaceous shale, and the whole series, wherever the contact can be found, always rests in marked unconformity upon the underlying Paleozoic rock (Upper Aubrey).

\* An artesian well was bored at Adamana on the Santa Fe Pacific railroad, eight miles north of the Petrified Forest and in the valley of the Rio Puerco. At a depth of 305 feet water was struck which had sufficient force to rise 19 feet above the surface and discharge 25 gallons per minute. The water was very salt, reported at 3 per cent chloride of sodium, so as to be wholly unfit for any use. Mr. James Swainson, in charge of the work, which was done by the American Well Works of Aurora, Ill., was good enough to send me the "log" (record of boring), which is as follows:

	Feet.
Surface sand and adobe .....	55
Sandstone .....	3
Cement gravel .....	1
Sandstone .....	29
Water at 88 feet only slightly salt.	
Sandstone .....	20
Brown shale .....	43
Red shale .....	49
Hard brown and blue shale .....	5
Red shale .....	70
Sandstone .....	10
Hard brown shale .....	20
Intensely salt water at .....	305

The lower 200 feet of this section clearly belong to the Moencopie beds.

*The Shinarump.*

This constitutes a vast series with a maximum observed thickness of at least 1600 feet. It presents a number of phases, some of which are so distinct that if studied in only one locality they would naturally be regarded as separate subdivisions, but such a general survey as I have been making points to a certain homogeneity in all these beds, or at least establishes the unmistakable tendency towards the recurrence in any of the phases of features that are prominent in other phases. The Shinarump constitutes the horizon of silicified trunks and there is no part of it in which fossil wood does not occur in great abundance. It also marks the limit of the wood-bearing deposits of this region. For this reason alone, in view of the etymology of the name, I should be justified in extending the Shinarump as far as the fossil trunks occur, and it is obvious from the language used that Major Powell had the upper portions of the formation in view as well as the lower when giving the name, although other geologists in speaking of the Shinarump usually seem to have in mind only those beds which I include under the conglomerate. It is doubtful, however, whether the remainder of the formation has really been studied or carefully observed by others, and I fancy that in dealing with it I am entering upon a sort of geological *terra incognita*.

*The Shinarump Conglomerate.*—I am using this expression, which is the one most commonly found in works that treat of these beds, in a somewhat comprehensive sense, the necessity for which will be apparent. As thus used this part of the Shinarump occupies the lower half of that series and has a maximum thickness of 800 feet. Although perhaps the most prominent feature of it is the so-called conglomerate, which sometimes is in truth deserving of that name, and contains somewhat large but always well-worn pebbles and cobbles derived from underlying formations, still, it rarely happens that this aspect of the beds constitutes the major portion of them. In the first place the conglomerate tends to shade off into coarse gravels and then into true sandstones. These sandstones are of a light color, contrasting strongly with the dark brown sandstones of the Moencopie beds already described. They are, moreover, always more or less cross-bedded and usually exhibit lines of pebbles running through them in various directions. These are true sandstones, very hard, devoid of alumina, and scarcely affected by the winds, so that their angles are usually sharp and the ledges they form are abrupt and jagged. Although the sandstones proper generally occur lower down, still, there is no uniformity in this arrangement, and sandstones are often found in the middle and con-

glomerates more rarely at the top. But in addition to these the Shinarump Conglomerate embraces other classes of beds. There is a well-stratified layer of thinnish sandstone shales that is often seen immediately under the heavy sandstone cap. Some of these shales have a grayish color and are highly argillaceous. These layers tend to thicken even within the formation itself, but especially farther out, and what is more significant, they often become transformed into a bluish white marl. This condition can be seen between the beds of conglomerate in places where the Shinarump Conglomerate is comparatively thin, as in the lower valley of the Little Colorado, where it is only about 300 feet in thickness. This feature is not very prominent, but at other places, as in the Petrified Forest region where the Shinarump attains its maximum thickness of 700 or 800 feet, this tendency on the part of certain beds to become transformed into marls is the most marked feature of the formation. The marls here occupy much more than half of the beds. They are very varied in color, showing besides the white and blue tints a great variety of darker ones such as pink, purple, and buff. These heavy marl beds, of which there may be several in the same cliff, are interstratified between conglomerates, coarse gravels, and cross-bedded sandstones, all of which taken together form the beautifully banded cliffs that are seen throughout the Petrified Forest, and especially along its northern flank. It thus becomes necessary to include under one designation all of these varying beds, which often change the one into the other even at the same horizon within short distances, and rather than adopt a new name I have preferred to call them all the Shinarump Conglomerate.

It remains to mention certain minor features, which are not universal, but which, nevertheless, have considerable importance. In the lower Little Colorado Valley there occur numerous somewhat calcareous clay lenses, the lime taking the form of bright white stripes, while the clay is usually purple or pink. These are very distinct objects and vary in size from lenses 10 or even 20 feet in length to small lenticular blocks or somewhat oval or even spherical clay balls or pellets. These calcareous clay inclusions are scarcely seen farther to the southeast, but on Red Butte they are well marked and here the clay becomes brilliant red and constitutes a true paint stone. Another fact to be noted in connection with the Shinarump Conglomerate is that at certain localities, and notably on Red Butte, there is at its base a clear indication of a transition to the Moencopie beds. The conglomerates proper are underlain by argillaceous shales closely resembling those of the Moencopie beds, but beneath these is a sandstone ledge which cannot be referred to the lower division, as it is more or less

cross-bedded, possesses considerable grit, and has small clay pellets included in it similar to those of the true conglomerate series, in which I have for this reason included it. This condition of things may be somewhat puzzling from the stratigraphical point of view, but the disadvantage in this respect is much more than compensated for by the evidence that it furnishes in favor of the view that all of these beds really constitute one great system, and as opposed to the view which it may be inferred that certain geologists hold, that the series of beds which I have included under the name of the Moencopie beds belongs to a different system, and are in some way connected with the underlying Paleozoic rocks. This view, in the light of the above mentioned facts is, in my opinion, quite untenable.

*The Le Roux Beds.*—Under the name of Le Roux beds I include the remainder of the Shinarump, deriving the name from Le Roux Wash,\* which enters the Colorado Valley two miles below Holbrook, and on which some 15 miles north of Holbrook this series attains the greatest development that I have observed, probably reaching its maximum of 800 feet. These beds, too, if studied at localities where they are less developed, might be supposed to form several quite distinct subdivisions. Indeed I was of this opinion during most of my stay in the lower Little Colorado Valley, but even before leaving there the proofs of their homogeneity had become abundant.

At least the lower half consists of that remarkable formation in which I found vertebrate bones in 1899 and in which alone thus far vertebrate remains have been observed. I have sometimes designated it as the Variegated Marls, sometimes as the Belodont beds. The distinguishing features of these beds is the presence of great numbers of small buttes, the smaller ones appearing to be blue clay knolls, but the larger ones showing other colors, especially purple, and sometimes several bands of different hues. Almost everywhere at this horizon there exist plains, dotted all over with these remarkable little buttes, varying from 3 or 4 feet to 20 or 30 feet in height, usually isolated from one another and having a form peculiar to them. They are not conical in the true sense of the word, since they do not rise to a point at the summit, but are always rounded off and have the form of a well made haystack, the smaller ones looking like haycocks in a field. These butte-studded plains are of course simply the remains of a plateau or mesa which has

\*The name "Leroux's Fork" was given to this wash by Lieut. Whipple's party, who followed it down some distance and encamped at its junction with the Little Colorado on Dec. 5, 1853, this being their Camp 79. See Pacific Railroad Reports, vol. iii, part i, p. 75. The name is written in two words on the Land Office map of Arizona.

been worn away, primarily by the action of water, but for a very long period there can be no doubt that wind has been the more potent agency. There is evidence throughout that entire region that the amount of precipitation was formerly much greater than at present, and in so speaking I do not refer to a very remote date geologically, but to a period which was probably post-Tertiary. Indeed, from the present condition of many of the regions where we know that the early Indians dwelt, and who must necessarily have had access to water, now perfectly dry, with all sources of water so remote that they can no longer be inhabited, it must be inferred that there has been a change in the climate within the period of human occupancy. Certain it is that water is doing very little relatively in this region now, while the agency of wind is conspicuously marked wherever it can produce effects. The peculiar form of these buttes is not such as water could have produced, while it is precisely the form that wind would naturally produce, acting upon the very fine and soft materials, somewhat resembling ashes, that compose these buttes.

Further evidence of this, if any were needed, is found in the fact that in approaching the general escarpment, which bounds these plains, the buttes tend to lose their isolated character and form ridges projecting out from the cliffs. It never happens that an entire valley or plain is covered by a single system of buttes. These systems are separated by wide intervals, often of nearly flat country, but through which it can be easily seen that water once flowed, at least in the form of temporary floods, and in such a manner as to have swept away every vestige of the former plateau, and in crossing which there are encountered one or several wide beds to which the term "wash" is popularly applied. In descending the Little Colorado this condition of things is not met with until within some 8 or 10 miles of the Lee's Ferry road. A large system of buttes is then found extending some 5 or 6 miles down the river and across the plain to the first terrace, a distance of 3 to 5 miles; then occurs the first wash, 2 miles in width, followed by another system of buttes, which is nearly due east of Tanner's Crossing, and in which most of the bones were collected by our party. There is then another wide wash, but the next system of buttes does not reach the river, but trends off in a direction nearly due north. There is still another wash before the great Moencopie Wash is reached, the direction of which is such as to be highly favorable for the preservation of these buttes, and accordingly we find their greatest development, so far as this region is concerned, along the Moencopie Wash. They do not however follow the stream up in the direction of Tuba City, but continue to trend northward along the wide valley that lies to the west of Willow Springs and Echo Cliffs.

The reason why these conditions are not earlier met with in the valley of the river is simply that the river does not follow the line of strike, and these beds, being common to the entire formation, must always occupy the same horizon. Above the point mentioned, therefore, they must be looked for farther in the interior. We found them in fact five miles east of Black Falls, or 25 miles southeast of Tanner's Crossing. The great bend in the river culminating at Winslow keeps these beds constantly so far to the northeast, and in a region where it is so difficult to penetrate, that their exact condition for a distance of over 50 miles is little known. But farther up the river, where they approach somewhat to the region of settlement, they again admit of access, and as already remarked, they appear in great force in the valley of Le Roux Wash. Here they cover an area of nearly 100 square miles and form two great amphitheatres of veritable bad lands, but in which the great variety and symmetry in the form of these buttes and ridges, as well as the variegated and iridescent colors that prevail, render them a magnificent spectacle. They can be seen from the southeast for a distance of 20 miles as a white line. Viewed from the top of the mesa out of which they have been carved, the denudation having been arrested at a particular point, they reveal more completely than at any other place the true character of this formation. In the Petrified Forest the Le Roux beds are also well developed and the variegated marls are found only half a mile east of the Lower Forest. The buttes here are quite large and well developed and bones of the *Belodont* occur in them. In the northern part of the Petrified Forest region the variegated marls lie somewhat farther to the eastward. What is called the Middle Forest lies in the midst of them, and the petrified wood, as everybody has observed, differs here considerably in its constitution and coloration from that of the upper and lower forests, which lie in the horizon of the conglomerate series.

As was remarked when treating of the conglomerates, these variegated marls are actually found stratified between the sandstones by the transformation of certain shales into marls. If these beds are carefully traced a short distance in the direction of the dip, they will be seen to thicken very rapidly and soon to take on the character of the true variegated marls. As they start from underneath a bed of sandstone which caps the conglomerates, and which does not so readily pass into marl, the buttes that are first formed are usually topped out by a block of this sandstone, and it is necessary to proceed some distance farther in the direction of the dip to reach a point where the sandstones disappear. This however ultimately takes place and the marl beds thicken to such an extent

that they have to be regarded as virtually overlying the conglomerates. In fact, in the bed of the Moencopie Wash, on both sides of which these beds are so well developed, the conglomerates can be seen distinctly passing under the marls.

So much for the variegated marls, which, for the purposes of our expedition, constituted the most important subdivision of the entire formation. But as we have seen, their maximum thickness is about 400 feet and there remain still another 400 feet before we reach the base of the painted cliffs. Throughout the whole of this fossil wood is abundant, but the character of the beds as variegated marls no longer continues. In the lower Colorado Valley, where I know it best, the variegated marls are succeeded by a sandstone ledge at least 100 feet in height, yielding black logs of very fine structure. At this point these sandstone beds constitute an escarpment and form a small terrace, the summit of which is a dip plane. Upon this lie the remains of the next set of beds, which are somewhat remarkable, primarily in being essentially limestones, but they consist mainly of loose material somewhat resembling dried mortar, for which reason I have designated them mortar beds. They are, however, very irregular in structure and contain much impure flint and large flinty stones. In the midst of them there occurs a true limestone ledge, well stratified, succeeded by a continuation of the mortar beds. In the region mentioned these beds extend to the limit of what I regard as true Shinarump, and petrified wood was found above the limestone ledge.

A wider acquaintance with this part of the formation shows that the conditions above described do not hold at all points and may even be regarded as exceptional. Nowhere else except at Black Falls did I find the lower sandstone ledge, and at most other points the limestones gradually supervene upon the variegated marls. In fact, it should be remarked, that not only the variegated marls but also the shales of the conglomerate series, which become transformed into marls, are more or less calcareous; and when we find that the entire upper portion of the Shinarump consists mainly of limestones and calcareous materials, we may regard all of this, including the variegated marls, as virtually a calcareous deposit. If we were to look abroad for its homologue in the Trias of the Old World we would find it in the Muschelkalk, while the conglomerate series might well be compared with the Buntersandstein, and the Painted Desert beds with the Keuper, to which the French term *Marnes Irisées* is only locally applicable.

In the extensive exposures on Le Roux Wash these relations are brought out with great force. Overlying the true variegated marls which stretch out for a distance of three miles across the broad eroded valley, the limestone series comes in gradually and scarcely differs except in the degree of calcareousness

from the underlying beds, but the limestone ledge is ultimately reached and is sharp and definite. It has a thickness of about 10 feet. Over it lie very heavy beds of calcareous materials beginning as mortar beds, such as I have described, but soon taking on more symmetrical forms, closely resembling the marl buttes of the valley below. The color also changes, and many of the buttes are, in whole or in part, of a deep blue or a lively purple. These constitute here the highest beds of the Shinarump and fossil wood is abundant throughout. Much the same conditions prevail in the Petrified Forest region, but the development is here much less extensive.

*The Painted Desert Beds.*

It remains to consider the third and highest series of the Older Mesozoic of Arizona. As already stated, these constitute the elevated cliffs that bound the valley of the Little Colorado on the northeast. Although broken through in many places, and practically wanting for long distances, they still constitute what may be regarded as a great wall separating the valley from the region of high mesas that lie in the Moqui and Navajo country. As these beds seem to contain no fossil remains, and as they are throughout the greater part of their extent practically inaccessible from the absence of water, their detailed study has been neglected, and I was able to acquaint myself with them only imperfectly and at a few points.

There is, however, no place where they are better developed than directly east of Tanner's Crossing, where we remained longest, and on several occasions the attempt was made to reach them from our camp and to examine them closely. Enough was learned to justify the positive statement that they consist almost entirely of sandstones, perfectly stratified, the different layers differing mainly in color, thickness, and fineness of structure. The great central portion constituting the escarpment and having a thickness of about 800 feet is, within these limitations, practically homogeneous. The series begins, however, with a bed of orange red sandstone, highly argillaceous, and soft in structure, easily eroded, and readily yielding to the influence of the wind. It has a thickness of about 100 feet and in the lower Colorado region stretches across the broad valley at the base of the escarpment and lies directly upon the uppermost limestones of the Shinarump. Here it forms picturesque and fantastic buttes and chimneys standing out upon the plain. It occurs in the same position overlying the Shinarump on Le Roux Wash and forming the top of the mesa which overlooks the amphitheatres that I have described. It is also seen above the Shinarump series to the east of the Petrified Forest. It is therefore probably safe to assume that this bed is continuous from Echo Cliffs to the boundary line of New Mexico.

Of the painted cliffs, considering the little that is known of them, there seems to be nothing more to say. In looking at these cliffs from a distance it is seen that they are overlain by a white formation, the nature of which it is important to consider. Before we had visited the region, so as to obtain a close view of them, it was natural to suppose that they might constitute Jurassic limestones and that the Triassic system might terminate at the line which separates them from the variegated sandstones. But upon close examination this was found not to be the case, and these white rocks were found to consist of sandstones often very pure and cross-bedded, with scarcely any admixture of marl. These without question constitute the summit of the Triassic system in this region. They are, however, not always white, or at least in some places, as for example in the vicinity of Tuba City, they are underlain by a still thicker bed of soft brown sandstone, which is somewhat argillaceous and easily worn by the wind, forming chimney buttes and ruins. This bed has a thickness along the headwaters of the Moencopie Wash of about 200 feet and is overlain at the highest points by the white sandstones to a thickness of 100 feet more. These sandstones are very porous and all the waters that fall in that region immediately pass through them, but as they approach the summit of the much harder and firmer beds that constitute the lower portions of the series these waters are arrested and come out in the form of springs, sometimes almost of small rivers, along the crest of the cliffs above the Moencopie Wash. It is on one of these springs that the little Mormon town of Tuba City is located, and this is true also of Moa Ave, Willow Springs, and other settlements in that country. Still farther back the Cretaceous lignites and limestones lie unconformably upon these uppermost sandstones of the Trias, and the Jurassic is wanting altogether.

The following columnar section of the strata of the Little Colorado Valley will make the above descriptions more clear.

## DESCRIPTION OF THE SECTION. (See page 413.)

	Feet		Feet
1. Argillaceous shales .....	100	6. Shinarump Conglomerate .....	300
2. Calcareous shales .....	100	7. Variegated marls .....	400
3. Argillaceous shales .....	200	8. Sandstones .....	100
4. Sandstones .....	100	9. Limestone ledge .....	20
5. Argillaceous shales .....	200	10. Mortar beds .....	80
	-----	11. Calcareous marls .....	200
Total thickness of Moencopie beds	700		-----
		Total thickness of the Shinarump	1,600
			-----
			Feet
		12. Orange red sandstone .....	100
		13. Variegated sandstones .....	800
		14. Brownsand stones .....	200
		15. White sandstones .....	100
			-----
		Total thickness of Painted Desert beds..	1,200
		Total thickness of Trias .....	3,500

White sandstones.	15		Painted Desert beds.
Brown sandstones.	14		
Variegated sandstones, regularly stratified and brilliantly colored; the well-known Painted Cliffs.	13		
Red-orange sandstones.	12		
Calcareous marls sometimes worn into buttes.	11		Le Roux beds.
Mortar beds, flint stones.	10		
* Sandstone ledge.	9		
Variegated marls argillaceous and calcareous with bones of beldonts, labyrinthodonts, and dinosaurs.	8		
Conglomerates and coarse cross-bedded sandstones with clay lenses interstratified with gray argillaceous shales and variegated marls.	6		Shinarump Conglomerate.
Dark chocolate-brown argillaceous shales; saliferous.	5		
Argill. sandstones, soft, dark brown.	4		Moencopie beds.
Argillaceous shales, dark brown	3		
Calcareous shales, white.	2		
Saliferous shales (=3 and 5).	1		
Unconformable limestone or sandstone.			Carboniferous (Upper Aubrey).

Shinarump.

\* 9. Limestone ledge, definitely stratified.