* Evidence for the second partial reaction going on from left to right has been obtained recently by Millikan and Cameron. As the intensity of the cosmic radiation is of the same order of magnitude as the total intensity of star light, the building up process of matter from simple nuclei seems to go on at the same rate as the burning up of matter in the stars.

[1] See, for instance, Jeans, *Nature*, April 28, 1928.

[2] O. Stern, *Zeitschr. Elektrochemie*, **31**, 448, 1925. R. C. Tolman, these PROCEEDINGS, **12**, 670, 1926.

[3] Lenz, *Physik. Zeitschr.*, **27**, 642, 1925.

[4] R. C. Tolman, these PROCEEDINGS, **14**, 353, 1928.

[5] R. C. Tolman, *J. Am. Chem. Soc.*, **44**, p. 1902.

[6] Ehrenfest and Trkal, *Proc. Amst. Acad.*, **23**, 162, 1920.

ALGAL DEPOSITS OF UNKAR PROTEROZOIC AGE IN THE GRAND CANYON, ARIZONA

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The Algonkian Proterozoic of the Grand Canyon consists of two groups of sedimentary formations about 12,000 feet in aggregate thickness, and collectively separated by one or more periods of mountain building and profound erosional effacement both from the underlying Archean Vishnu schist and the overlying Cambrian of the Paleozoic. The upper group, the Chuar, composed mainly of shales, sandstones and thin limestones, bluish, greenish gray or red, and aggregating 5120 feet, was found by Walcott to contain "a Stromatopora-like form," later described as *Collenia*, and, in the upper division, several obscure organic traces, one of which, first characterized as Discinoid, was subsequently designated as *Chuaria.*

The lower group, the Unkar, over 5500 feet thick, separated from the Chuar by a minor unconformity, embraces sandstones and shales, mainly red or purple in color, with a relatively small proportion of limestone. No traces of life have heretofore been recognized in the Unkar group. On the basis of the general characters of these two Proterozoic groups and the diastrophic evidence, Van Hise suggested the tentative correlative reference of the Unkar, which is rather heavily charged with iron, to the Lower Huronian, notwithstanding its relatively slight metamorphism on account of which he called attention to this group as a most promising series of sediments in which to search for traces of life in this ancient period.

As the result of downfaulting of masses of sediments into the Archean schist, portions of several blocks of Unkar escaped complete pre-Cambrian erosion and now lie almost entirely below the level of the Tonto platform at or near the mouth of Bright Angel Creek.

Immediately above the heterogeneous boulder bed forming the base of the Unkar follow bluish and white limestones and dolomites, generally crystalline and chert-bearing, interspersed with thin shales and banded and mottled with red or purple, in all about 300 feet, which compose the Bass limestone. On the Bass limestone rests the Hakatai shale, about 600 feet thick, composed of alternating sandy shales and quartzites overwhelmingly hematite red, and strikingly suggestive of the "Penokee" (Animikie) of the Lake Superior region. This is followed by the Shinumo quartzite, mostly quartzite and sandstones, purple and subordinately green or white, 1564 feet thick where measured by Noble in the Shinumo quadrangle. Sandstones, red, gray and greenish, about 2500 feet in thickness, form the upper part of the Unkar, the more complete section of which is found only in the eastern area studied by Walcott.

Reefs unmistakably of algal deposition and several other types of deposit very probably of algal origin were found by the writer at different levels in the Bass limestone in Bright Angel Canyon, in May, 1927, and molds fucoidal in aspect and possibly of animal but surely of organic origin, were found at about the same time by G. E. Sturdevant in the lower part of the Hakatai shale.

Four distinct forms of deposit of organic origin are recognized in the Bass limestone, besides two or three more problematic types. The first form comprises upward-arched, concentrically placed and successively overreaching, irregular concavo-convex lenses piled so as to compose very large, round-topped, biscuit-like growths, similar in many respects, at least, to the form collected by Walcott from the Chuar group and referred by him to *Collenia*. Algal deposits of comparable form and superficial structure are being laid down in some of the lime-charged streams of the Appalachian Valley at the present time.

A second type of deposit is built up in thin tabular layers increasing in size and separated by thin layers of rock of different color and texture. The organic layers are successively rolled downward at the overlapping edges. These reefs are of greater horizontal extent than those of the first type, which may be only four or five feet in greatest diameter. Additional specimens of the second or tabular form were gathered by F. E. Wright and Mr. Sturdevant in the autumn of 1927.

A third type of growth embraces small lenticular cherty bodies, about 2 to 5 centimeters in diameter and one to two centimeters thick, weathering in the form of rosettes of rather rough concentric zones of variable thickness, and darker and more ferruginous than the surrounding matrix.

The fourth type forms irregular winding and branching knobby masses, lenticular in cross-section and of slightly nodular aspect, weathering a pale greenish blue in a surrounding reddish coarse-grained limestone. The blue rock shows an irregularly concentric zonal structure, in general aspect slightly suggestive of some of the material referred by authors to *Girvanella*.

Another type of deposit, probably of algal origin, consists of thin scales, ungulate in size, form and aspect, scattered flatwise in certain layers but not always parallel to the bedding. They weather white or very light-gray, in contrast with the darker, bluish matrix, and resemble some of the scale growths produced by modern calcareous algæ. No definite traces of organic structure have yet been noted in this type, the upper surface of which has the velvety aspect of the deposits of the scale-forming coralline.

Still another form of deposit, of chalcedonic aspect and weathering strongly in contrast with the matrix, comprises thin irregular vertical plates, 2 to 3 millimeters thick, winding and coalescing in very irregular polygonal meshes. These appear to be marked by vertical pores, somewhat variably and distantly spaced in two rows, each a little within the border. The nature of this type, which has not been studied under the microscope, is highly uncertain. It may be animal rather than vegetable or it may even be mere crack-filling, though the pattern does not appear to conform to any system of normal shrinkage or cleavage.

A form closely related to if not generically identical with Walcott's *Chuaria*, from the Chuar, also is present. It may be of plant origin, and can hardly be a bivalve.

Traces of alga tubes, and cavities similar to those in some of the reef heads formed by blue-green algæ at the present day are more or less obscurely visible in the first, third and fourth of the enumerated types. Some are visible under very low powers. They lie in oblique as well as vertical and horizontal positions. Branching is distinct in some cases. The walls of lime deposited about the living algæ were generally of smaller crystals, less strongly knit, and now in many cases appear lighter in color than the coarse interlocked calcitic crystals which fill the cavities and intervening spaces. The original tube walls are however weaker in some cases, and fractures tend to follow them, thus making their detection easier under the hand lens. Evidently most of the original matter has been obliterated by recrystallization; magnification only emphasizes crystal details, and it remains to be seen whether any minute features of the algal thalli may be detected by selective etching, or by the discovery of material better preserving the forms of the plant parts.

The material noted above but not yet fully studied was discovered in the course of the search for data relating to the conditions of deposition, the life and the history of the older formations in the Grand Canyon, and, in particular, in the preparation of exhibits of the remains of life *in situ* in locations visible from the scientific observation station on Yavapai Point. The research was carried out mainly under a grant from the Carnegie Institution of Washington, and was conducted in coöperation with the work of the National Academy of Sciences on the development of the inspirational and educational resources of the Grand Canyon. The research and investigation conducted under the auspices of the Academy is supported by a grant from the Carnegie Corporation of New York.

The fossil remains discovered in the Unkar are the oldest yet brought to light in the southwest and, notwithstanding the fortunately relatively slight degree of metamorphism of the sediments, may be as old as the lower Huronian. On the other hand, they may not be older than the Keweenawan.

It is probable that some at least of the types of organic deposits in the Unkar which are shown to have been laid down in very shallow waters disturbed by winds and currents, sometimes beneath rainy skies, sometimes under a hot sun, are due to algæ of the blue-green family, the Cyanophyceæ. The abundance and indicated variety of forms of deposit, some of which may be of animal origin point encouragingly to the possibility of greatly adding to our knowledge of the certainly highly differentiated late Proterozoic life, which may have had its beginnings as long in advance of the Paleozoic as from the beginning of the Paleozoic to the present. They also give promise of paleontological criteria characteristic of the different groups of sedimentary rocks and far more valuable for the time classification and correlation of the not too far altered pre-Cambrian formations than any means now available.

ERRATA TO THE NOTE: "On Some Properties of One-Valued Transformations of Manifolds," these PROCEEDINGS, **14**, 206–214, 1928.

P. 208, lines 1, 2, 5, 7, read p instead of π; p. 209, line 8, read $|A_\nu|$ instead of A_ν; p. 211, lines 20, 21, read ϵ instead of e; p. 211, last line, the homology should be numbered (13*b*); p. 212, line 9, read β instead of B; p. 214, line 10, read J. instead of Y.; p. 214, line 12, read 71.1 instead of 1.1.