Oölites in the Green River Formation of Central Utah, and the Problem of Oölite Growth

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Oölitic limestone occurs in the Green River formation, of Eocene age, at Manti, in central Utah. A microscopic study of thin sections of the rock suggests conditions under which the oölite originated.

As described by Bradley (1), and others, the Green River formation was deposited in a great fresh-water lake, or several lakes—an environment contrasting strongly with the highly saline environment of Great Salt Lake, where oölitic grains are now forming, and less strongly with the marine conditions under which many oölites of the geologic column probably originated.

Description.—The oölites are composed of calcium carbonate, chiefly as calcite, with an admixture of silt. Some of the material has been recrystallized, and some is now silicified. The average diameter of the grains is between 0.4 and 0.5 mm. They are circular in cross-section, elongate or oval, triangular, and irregular. In general, the outline conforms with the shape of the nucleus, if one is present, but there are grains in which the outer zones are eccentric (Fig. 1, *A*).

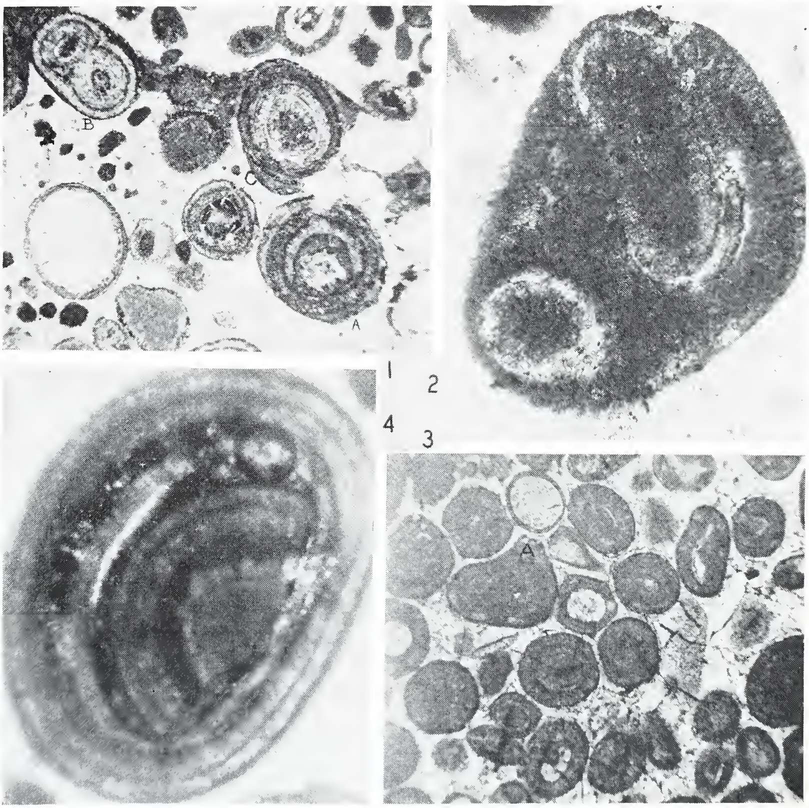
Uncommonly the oölitic grains contain mineral fragments as nuclei, but, even under high magnification, the centers of most of the grains appear simply as structureless spherical bodies of the same material as the rest of the grain. Hence the nuclei suggest little as regards causes for precipitation of calcium carbonate.

Figure 1, *B* and Figure 2 illustrate grains with two centers of growth. One grain with three centers was noted. Concentric zones are present in some of the centers as well as in the outer zones, without the irregularities that might be expected if one growing grain absorbed a neighbor. Growth must have started at two adjacent loci at nearly the same time and continued without mutual interference until deposition was taking place about the two together. It hardly seems that the grains could have grown together if they were being rolled about by waves.

The grains at *A* in Figure 3 are closely spaced and irregular in shape. The irregularity is thought to be due to mutual interference during the later stages of growth, because in some grains, at least, the distortion is confined to the outer zones. Schrock (2) offered this explanation for the polyhedral shape of pisolites in a glacial cobble collected near Logansport, Indiana. This phenomenon is further evidence that the grains were not agitated while growing.

The concentric zones in some grains are of different thickness on different sides, yet there seems to have been no abrasion. It appears possible that the side with the thin part of the zone was resting on the bottom, and therefore grew more slowly. Thus Davidson and McKinstry (3) placed a small piece of andesite in a nearly stagnant pool of water in a cave and, after a year and a half found a coating of crystalline calcium carbonate between 1 and 2 mm. thick on the andesite. The deposit was thinner on the bottom than elsewhere. The andesite had not been rolled over, and the authors suggest that oölitic grains might form similarly without rolling.

Figure 4 illustrates an oölitic grain which contains a fragment of another grain as its nucleus. Concentric structure is well developed in both the nuclear fragment and the material built around it, the later zones conforming to the shape of the fragment. The similarity between the broken grain and other oölitic grains of the same rock suggests that it belongs to the same generation rather than an earlier one. This fragmentation indicates wave or current action, and supports the idea that oölitic grains grow while rolling about. However, in the same rock there are other grains possessing two growth centers—suggesting growth in an undisturbed medium. Probably, then, periods of quiet alternated with periods of agitation. Grains developed at rest were broken up by being washed about, and the fragments became nuclei for later oölitic grains of the same general series—formed, perhaps, during a succeeding period



Figs. 1-4. Fig. 1. *A*, outer zones concentric; *B*, grain with two growth centers; *C*, grain with an incomplete outer zone, probably indicating secondary growth. x 15. Fig. 2. Oölitic grain with two centers of growth. x 40. Fig. 3. *A*, grains with irregular shapes because of mutual interference during growth. x 15. Fig. 4. Grain a fragment of an earlier grain as a nucleus. x 40.

of quiet. If ordinary storms were responsible for the disturbance, growth may have been rather rapid, and the supply of calcium carbonate correspondingly abundant.

The internal structure of the oölitic grains is characteristically concentric, only a very few of them having even a suggestion of radial structure. Even in these few, concentric structure is dominant. Eardley (4) has shown that the carbonate part of the growing oölites from Great Salt Lake is mostly aragonite in concentric bands. Because aragonite is unstable, it alters to calcite with development of radiating structure, yielding a grain combining, in many cases, a concentric and radial structure. The absence of radial structure in the oölite from Manti suggests, therefore, that no alteration has taken place and implies precipitation of calcium carbonate as calcite rather than aragonite. Cause for this difference in mineral composition of newly formed oölitic grains of Great Salt Lake and those of the Green River formation may be found in the difference in environment—the Green River lakes being fresh water, and Great Salt Lake being extremely saline.

Figure 1, *C* shows incomplete outer zone that probably was added after normal growth had ceased. The additional material may have been derived from the surrounding matrix, or aqueous solutions bearing material from an outside source may have been able to reach the grain on only one side.

Origin of Oölites.—There is little organic matter in the oölite from Manti and therefore little to show that organisms such as algae or bacteria were effective. Twenhofel (5) has shown that oölitic grains can be formed artificially, without intervention by organisms, under conditions that would permit rolling. On the other hand, Bucher (6) suggests that oölitic grains grow in a colloidal emulsion and that rolling during growth is unlikely because agitation of the suspending or dispersing medium would not allow development of oölitic structure. He found that the amount of impurity determines whether the growing grain will have radiating or concentric structure, but Spencer (7) says that concentric zoning depends on checking or slowing the rate of crystallization.

Oölitic fragments in the oölite from Manti indicate wave or current action, but grains with two growth centers, distortion of shape due to mutual interference during growth, and variations in thickness of outer zones all indicate a quiet medium. It appears, then, that the oölite may have formed in a colloidal emulsion during periods of quiet, interrupted by periods of agitation.

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Bibliography

1. Bradley, W. H., 1929. Algae reefs and oölites of the Green River formation. U. S. Geol. Surv. Prof. Paper **154-G**, p. 204.
   1931. Origin and microfossils of the oil shale of the Green River formation of Colorado and Utah. U. S. Geol. Surv. Prof. Paper **168**, pp. 54-56.
2. Schrock, R. R., 1930. Polyhedral pisolites. Amer. Jour. Sci., 5th Ser. **19**:372.
3. Davidson, S. C. and McKinstry, H. E., 1931. "Cave pearls," oölites, and isolated inclusions in veins. Econ. Geol. **26**:289-295.
4. Eardley, A. J. Manuscript, not yet published.
5. Twenhofel, W. H., 1928. Oölites of artificial origin. Jour. Geol. **36**:564-568.
6. Bucher, W. H., 1918. On oölites and spherulites. Jour. Geol. **26**:593-609.
7. Spencer, E., 1925. On occurrences of spherulitic siderite in sediments. Quart. Jour. Geol. Soc. of London **81**:667-703.