

CEREBROID OOLITES

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The oolitic deposits along the shores of the Great Salt Lake, Utah described by Eardley (1938) do not seem to have attracted the attention they deserve as remarkable examples of application of the principle of uniformitarianism.

These sediments display several peculiar types of oolites, the equivalent of which occur in the geological column. Among them are the broken and regenerated oolites described from limestones and iron ores which may be seen forming today along the shoreline deposits of the Great Salt Lake as the result of reciprocal mechanical impacts (Carozzi, 1961).

The present paper describes and discusses the significance of the so-called "cerebroid oolites" also forming at the present time and frequently reported in the Ste. Genevieve Formation (Mississippian) of Illinois and adjacent states.

Oolitic deposits of the Great Salt Lake, Utah. Our investigation of the Great Salt Lake oolitic deposits has revealed six distinct types of oolites. These are:

1. Spherical body with pearl-smooth surface showing in section regular and fine concentric rings of impure aragonite consisting of small radial needles with interstitial clay minerals (Fig. 1,A). These layers are developed around nuclei of detrital minerals or faecal pellets of brine shrimps. This is the original type of oolite as formed in the shallow
2. Spherical body with pearl-smooth surface showing in section a few concentric layers of impure aragonite coating an internal spherical part which is calcitic and displays an interference between fibro-radiated and concentric structures (Fig. 1,B). This is the incipient result of the inversion to calcite and of the recrystallization which takes place from February to May in correspondence with the period of maximum inflow during which the resulting dilution of the waters generates conditions of little or no precipitation of calcium carbonate. In these oolites the inversion and recrystallization processes have not yet affected the newly deposited aragonite layers. The central portion of calcite shows small prismatic crystals in radial position and usually limited to a given concentric layer. The degree of recrystallization is rather uniform, however some radial areas are better crystallized than others but their distribution is random and different from one layer to another. The outside shape of the recrystallized central part is not appreciably affected and remains spherical.
3. Spherical body with finely granular and crystalline surface ap-

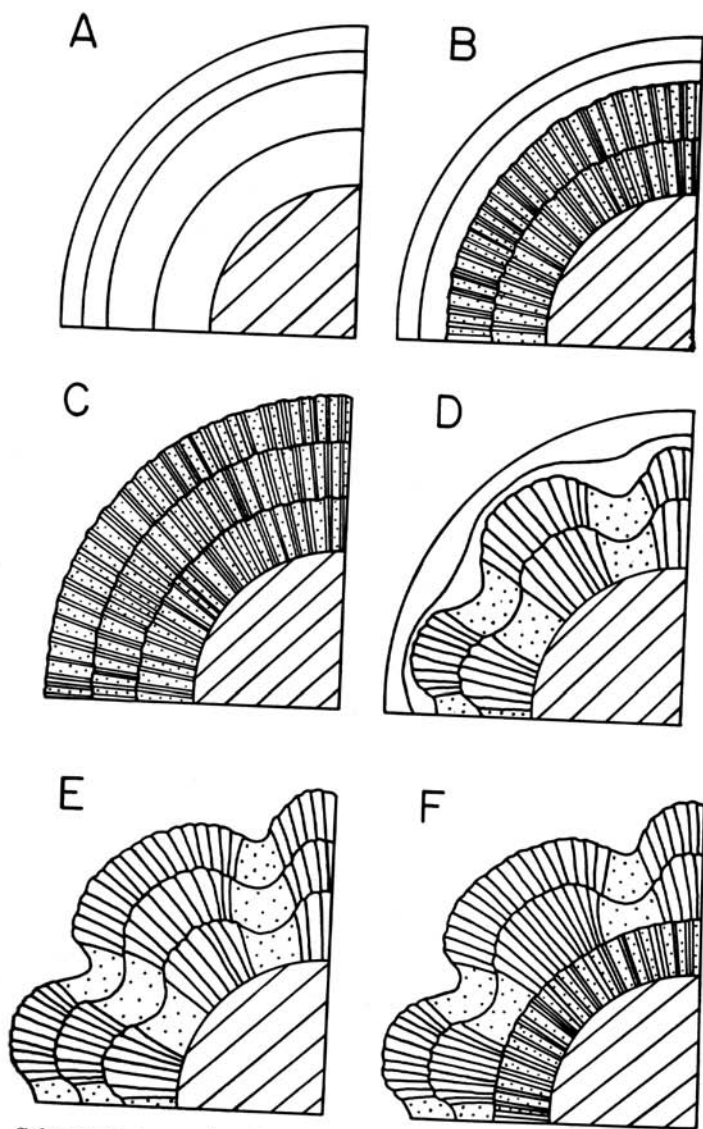


FIGURE 1. Schematic segments of the six types of oolites occurring in the present deposits of the Great Salt Lake, Utah.

A: aragonitic oolite with normal concentric rings
 B: aragonite concentric rings over fibro-radiated calcite
 C: calcitic oolite entirely fibro-radiated
 D: aragonite concentric rings over cerebroid calcite
 E: calcitic oolite entirely cerebroid
 F: cerebroid calcite over fibro-radiated calcite

pearing in section as entirely calcitic and displaying an interference between fibro-radiated and concentric structures (Fig. 1,C). This is the completed stage of the preceding type.

4. Spherical body with pearl-smooth surface showing in section a few concentric layers of impure aragonite of variable thickness coating an internal portion of calcite displaying an interference between a peculiar type of fibro-

radiated structure and the original concentric one. This interference generates a festooned or "cerebroid" outline (Fig. 1,D) which consists of juxtaposed convex and concave segments corresponding to the alternation of radial bundles of clear calcite with darker areas of cryptocrystalline calcite.

5. Mottled and speckled spherical body resulting from numerous light-colored and well-crystal-

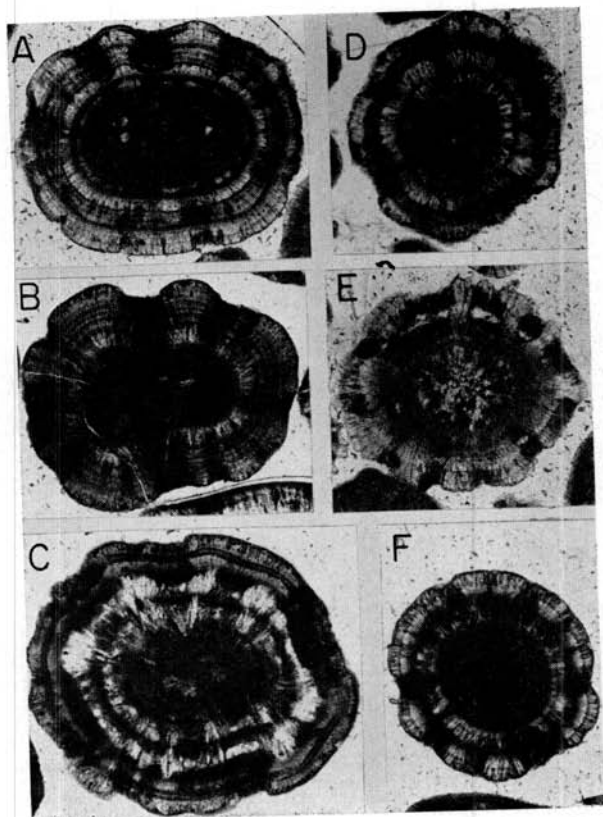


FIGURE 2. Cerebroid oolites from the present deposits at the northern tip of Stansbury Island, Great Salt Lake, Utah. Nicols not crossed, X 88. See text for additional explanations.

lized bulging areas separated by darker and concave zones with cryptocrystalline structure. (Fig. 1,E) In section such an oolite displays a festooned or cerebroid aspect representing the completed stage of the preceding type. These bodies have been described by Eardley (1938: 1380-84, pl. 8, 10 a, 12 b) under the name of "mottled oolites" and are the main subject of the present paper.

6. In this last type (Fig. 1,F), the bundles of clear calcite crystals, instead of originating at the nucleus boundaries, start on top of one or several concentric layers displaying uniform fibro-radiated structure.

Description of cerebroid oolites in the Great Salt Lake deposits. Typical sections of cerebroid oolites show, starting from the nucleus or from a given concentric ring, wedge-shaped bundles of radial crystals of clear calcite (Fig. 2,A and B) or occasionally single wedge-like crystals (Fig. 3,C and E). Both types reach the external surface where they distinctly protrude as flat-topped or convex bulges displaying often a well-developed fan-shaped structure (Fig. 2,C and E).

The bundles of clear calcite fibers are composite structures which increase irregularly in width toward the outside of the oolite and consist of a superposition of constricted and expanded segments with straight or fan-shaped boundaries (Fig. 2, C; Fig. 3,D). These segments always correspond to the intersection with a given concentric ring or a particular set of them. In some of the more

constricted parts, the prismatic bundles may be reduced to a few fibers of calcite or even to a single one. The modifications of section of the bundles express actually a variable lateral extension of the prismatic recrystallization which may in some cases develop laterally far enough to join adjacent prismatic areas along one or several concentric rings.

Inside the bundles of clear calcite crystals are abundant narrow and irregular radial zones of cryptocrystalline calcite also closely related to the intersection with given concentric layers (Fig. 3,G). Some of these radial zones appear limited to the basal portion of the bundles and wedge out toward the outside whereas others indent the terminal parts of the bundles which appear as irregularly crenulated. These darker areas contain a concentration of impurities, particularly clay minerals which also line the boundaries of many prisms as discontinuous films. Most of the bulging areas are irregularly convex and some of the flat-topped ones not corresponding to single crystal terminations may have undergone a slight abrasion.

It is important to point out for the understanding of the genesis of the cerebroid oolites that in the bundles of clear calcite fibers the original concentric rings are wider than in the adjacent areas and their boundaries appear as "ghost lines" displaced toward the outside with *an increased curvature* (Fig. 2,A; Fig. 3, D and G).

The intermediate radial spaces between the projecting bundles of clear calcite consist of dark cryptocrystalline calcite containing an ex-

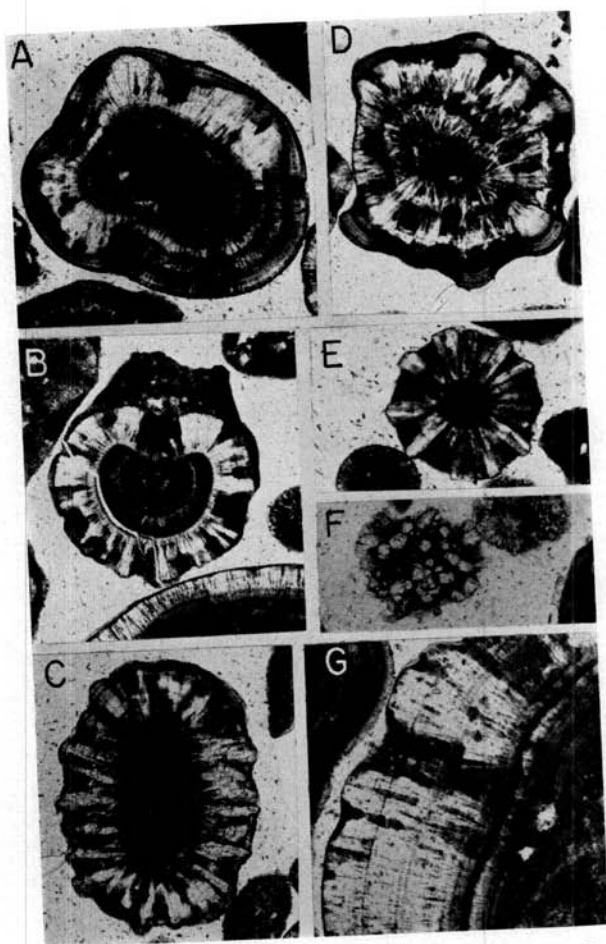


FIGURE 3. Cerebroid oolites from the present deposits at the northern tip of Stansbury Island, Great Salt Lake, Utah. Nicols not crossed, B and D :X 55, all the others X 88.

- A: concentric rings of aragonite over cerebroid calcitic core
 B: broken and recoated oolite
 C and E: wedge-like calcite crystals
 F: tangential section
 G: details of cerebroid structure

cess of impurities and clay minerals. In these darker areas the original concentric rings are barely visible, they are in a depressed position, thinner compared to those preserved in the prismatic bundles and *con-*

cave toward the outside (Fig. 2, A; Fig. 3, A and G). The shape of the cryptocrystalline areas is actually a function of the adjacent bundles being either conical with the apex directed toward the outside of the

oolite, or straight or irregular.

The darker zones may be occasionally interrupted by recrystallized concentric rings when the prismatic crystals of the bundles spread laterally and eventually join. The peripheral boundary of the darker areas is not always a regularly curved line parallel to the concave concentric rings, but is quite irregular and cuts across some of the thinnest concentric laminae indicating that some solution or abrasion has taken place (Fig. 3,G).

It is not possible to determine the reason for the localization of the bundles of clear calcite crystals particularly in oolites with well-rounded cores where they seem to be quite regularly spaced. In oolites with irregular cores, the bundles are definitely located in greater proportion on the protruding areas of the nuclei which display the smallest radii of curvature. In both cases, the final result in cross-section is to change the original circular outline of the oolite into a cerebriform one consisting of a juxtaposition of light-colored convex areas and dark-colored concave ones.

Formation of cerebriform oolites in the Great Salt Lake deposits. The sections across cerebriform oolites indicate that they result from a type of fibro-radiated recrystallization which, instead of being uniformly distributed in the spheroidal bodies, has preferentially taken place along certain radii generating wedge-like bundles of calcite fibers.

Let us consider one layer of impure aragonite deposited by the oolitization processes over a nucleus

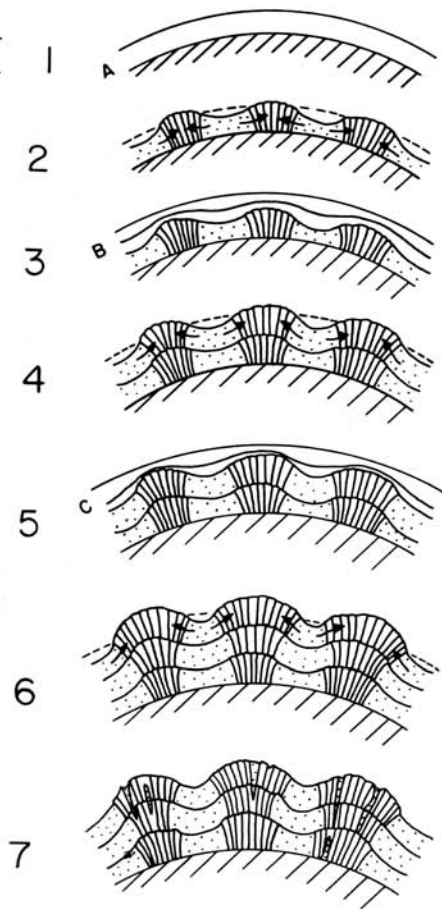


FIG. 4.—Diagrams illustrating the formation of the cerebriform structure in the oolites of the present deposits of the Great Salt Lake, Utah.

The aragonite layers (A, B and C) are left blank, the bundles of prismatic calcite alternate with dark areas of cryptocrystalline calcite (stippled). See text for additional explanations.

and inverting to calcite (Fig. 4, stage 1). The growth of the bundles of radial crystals corresponds to an expansion of the original layer at these particular places expressed by

an increased curvature and peripheral bulging (Fig. 4, stage 2).

Such a process of local growth requires an addition of calcite which has taken place at the expense of the adjacent crypto-crystalline areas which contain an addition of clay impurities expelled by the growth of the calcite fibers. Since the loss of calcite predominates in the darker areas over the addition of impurities, a decrease of volume has taken place in them accompanied by a partial destruction of the original concentric structures. This exchange is demonstrated by the thinning of the original concentric layers which become concave outwards (Fig. 4, stage 2).

The final result of this process of segregation during which clear calcite crystals have grown along certain radii and impurities have been concentrated in the poorly crystallized intermediate areas, is to change the original circular outline of the concentric rings into a juxtaposition of convex and concave segments expressed in the cerebroid aspect (Fig. 4, stage 2).

This differential recrystallization into fibro-radiated bundles apparently takes place from February to May. It corresponds to the time of maximum inflow in the Great Salt Lake during which the related dilution of the waters allows little or no precipitation of calcium carbonate; solution of the smallest crystals could even take place (Eardley, 1938: 1373). This solution would account for some of the peripheral irregularities of the darker crypto-crystalline areas described above. Agitation and rolling around of the

oolites during the same period could also be responsible for slight erosion in the same poorly crystallized depressions as well as for the flat-topped ends of some calcite bundles.

The differential fibro-radiated recrystallization appears completed before deposition of the next set of aragonite layers during the following June to November period (Fig. 4, stage 3). These new layers of impure aragonite have a tendency to re-establish spherical outlines and are normally thicker above the concave areas and thinner over the bulges.

During the following winter-spring season, inversion to calcite and recrystallization of these new concentric layers take place. The underlying prismatic bundles offering better conditions for renewed growth than the poorly crystallized intermediate areas, the new groups of calcite prisms tend to grow in the same particular places as the underlying ones but with a variable width related to the properties of the concentric layers involved. In such a manner, the cerebroid structure is perpetuated from one set of layers to the overlying one (Fig. 4, stage 4).

The process just described is then repeated after deposition of every set of aragonite layers with possible intermediate episodes of slight erosion or solution and new segments are added to the composite bundles of calcite fibers (Fig. 4, stages 5 and 6). As mentioned above, the latter are in fact quite complex and contain numerous radial patches of poorly crystallized material (Fig. 4, 7).

In conclusion, cerebroid oolites in the Great Salt Lake deposits result from the seasonal alternation of summer-fall periods of oolitization with winter-spring periods of inversion to calcite and differential fibro-radiated recrystallization. It is possible that the inversion of aragonite to calcite may have no genetic relation with the cerebroid structure which could then develop also in oolites originally calcitic.

The rapid internal change of the oolites from a concentric to a predominant radial structure of any kind is of great interest because it explains the shape of broken and regenerated oolites found in the Great Salt Lake deposits as well as in the geological column (Berg, 1944; Carozzi, 1961). In both instances oolites undergoing mechanical impacts during reworking processes penecontemporaneous with deposition are broken in most of the cases in clean-cut halves or quarters of spheres indicating a stronger control of the fibro-radiated structure over the concentric one in the pattern of rupture.

Description of cerebroid oolites in the Ste. Genevieve Formation (Mississippian). To our knowledge cerebroid oolites have been reported for the first time in the Fredonia Member of the Ste. Genevieve Formation of Southern Illinois by Graf and Lamar (1950: 2327, Fig. 7), and their interpretation will be discussed later.

The specimens described in this paper have been collected from the Levias Member of the Ste. Genevieve Formation on the east wall of a road cut on the northbound lane of In-

terstate Route 37, SW $\frac{1}{4}$ sec. 6, T.13 S. R.1 E, three miles north of Don-gola, Illinois. The particular limestone containing the cerebroid oolites is the basal bed of the Levias Member and corresponds to unit 7 of stop 7, of the 25th Annual Tri-State Geological Field Conference (Harris, 1961).

In general cerebroid oolites are rather rare in the Ste. Genevieve oolitic limestones and this applies to the investigated bed in which they represent never more than 2 to 5% of the total number of oolites present in a given thin section. The Mississippian cerebroid oolites display all the major characters of those described above from the Great Salt Lake and their detailed description appears superfluous. However a few small differences may be noticed (Fig. 5). The prismatic bundles do not appear so well crystallized in spite of their distinct peripheral bulging as they are in the specimens from the Great Salt Lake and also they do not show accentuated constrictions and expansions. This last observation indicates that the superposed concentric layers were rather uniform in original composition and structure.

It is interesting to mention here that one calcitic oolite with an outer shell of concentric rings coating a central portion with cerebroid outline has been described from the Rogenstein of Vienenburg, Germany (Berg, 1944: 48, Fig. 67). In this specimen similar to our type 4 of the Great Salt Lake deposits, the fibro-radiated structure has clearly affected the deposition of the last set of concentric rings. More recent-

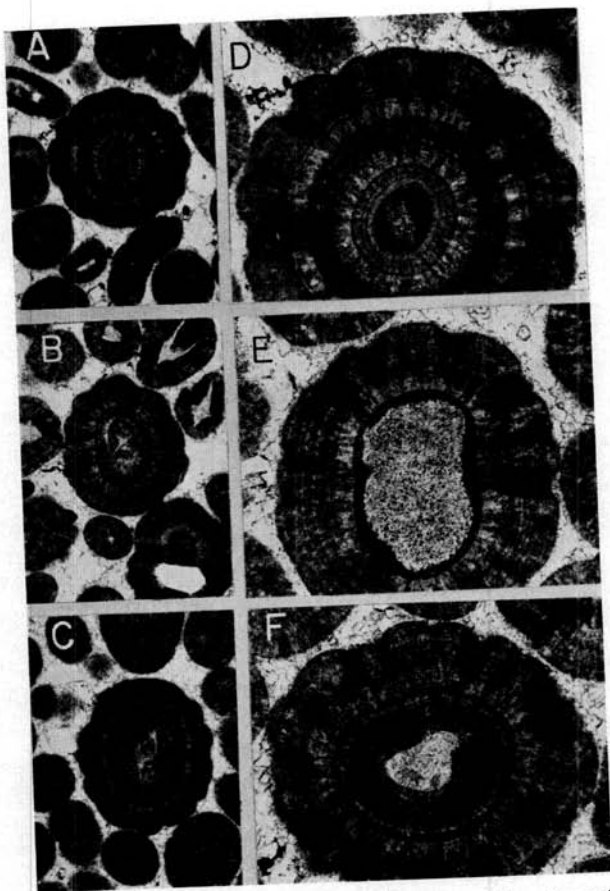


FIGURE 5. Cerebroid oolites from the Levias Member, Ste. Genevieve Formation (Mississippian), Dongola, Illinois. Nicols not crossed, A to C: X 22, D to F: X 55.

ly Usdowski (1962: 167, Fig. 20) described oolites with "Kegelstruktur" from the Lower Buntsandstein of Northern Germany which somewhat resemble cerebroid oolites. He assumed for their formation the existence of several nuclei which would have interfered during growth. This mechanism does not seem to apply to the oolites discussed in this paper.

Formation of cerebroid oolites in the Ste. Genevieve Formation (Mississippian). In their original description Graf and Lamar (1950: 2327, Fig. 7) considered the cerebroid oolites to result essentially from a marginal replacement of the brown calcite of the oolites by the interstitial clear calcite. However they also assumed that a few broader arcs of the oolite margins might be

of primary origin or due to compaction effects.

In the light of the observations of Berg (1944) and of the preceding description it is difficult to visualize a replacement mechanism because the cerebroid outline is not a superficial feature but only the peripheral expression of an internal modification of the oolites. Indeed many oolites display marginal irregularities reaching a depth of 0.1 mm or more attributable to mechanical impacts during deposition, or replacement by the interstitial cement or compaction. However the designation of cerebroid should be restricted to those owing their peculiar festooned shape to differential fibro-radiated recrystallization which displays a certain number of transitional terms to uniformly fibro-radiated types as would be expected whenever the bundles of radial calcite are poorly developed.

On the basis of the evidence from the Great Salt Lake deposits, it is suggested that the cerebroid structure is generated during phases of interruption of the accretion process and consequently before any precipitation of clear interstitial calcite.

The abundance of cerebroid oolites (30 to 50% of the oolites in a given thin section) in the Great Salt Lake deposits compared to the relatively rare occurrence (2 to 5%) in the Mississippian oolitic rocks may be an expression of the peculiar present-day physico-chemical conditions (high salinity and temperature) in the Great Salt Lake.

SUMMARY

A large proportion of the aragonite oolites forming at present in the Great Salt Lake, Utah display a peculiar type of fibro-radiated structure generated during their seasonal inversion to calcite. The recrystallization instead of being uniformly distributed in the spheroidal bodies has preferentially taken place along certain radii generating wedge-like bundles of clear calcite fibers separated by intermediate areas of dark cryptocrystalline calcite enriched with clay impurities. The final result in cross section is to change the original circular outline of the concentric rings into a juxtaposition of convex and concave segments self-perpetuating from one season to another. The name of cerebroid oolite is applied to these peculiar bodies which are the modern equivalents of similar forms described in the Ste. Genevieve Formation (Mississippian) of Illinois and adjacent states. It is suggested that the differential recrystallization which generated cerebroid oolites in the past may not necessarily have been restricted to oolites originally aragonitic.

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