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4 February 1966

Precambrian Mollusc-like Fossils from Inyo County, California

Abstract. Probable molluscan fossils have been discovered in the Reed Dolomite, White-Inyo Mountain area, Inyo County, California. They consist of small orthoconic shells with relatively large bilaterally symmetrical protoconch-like initial termini. Some individuals have a "U-shaped" (in transverse section) internal structure. The fossils occur at least 900 meters below the strata containing the earliest known olenellid trilobites and are therefore considered Precambrian.

Problematical fossils from the Precambrian Reed Dolomite in the White-Inyo Mountain area of southeastern California were collected in 1962 by Professor J. Wyatt Durham and Roland A. Gangloff, University of California, Berkeley. The fossils occur about 3 meters below the top of the formation and range through a vertical stratigraphic distance of about 12 meters. The locality is in the NW ¼, SW ¼, NE ¼, Sec. 16, T. 7 S., R. 35 E., Blanco Mountain quadrangle (1951 edition), Inyo County, California.

The Reed Dolomite in general consists of rather coarse-textured, white-weathering, thickly bedded to massive dolomite. Incompletely dolomitized carbonate rocks, such as those in which the fossils occur, are rare in the area examined.

Stratigraphic and age evaluation of Cambrian and Precambrian rocks in the White-Inyo Mountain area is not available except for a note by Nelson (1) who presented the rock-stratigraphic terminology currently used in the area and a cursory discussion of the age relationships (Fig. 1).

The faunule is separated from the lowest occurrence of olenellid trilobites by at least 900 meters of strata. The intervening strata consist of a sequence (probably of continuous deposition) of interbedded limestone, orthoquartzite, calcareous sandstone (Deep Springs Formation), and massively bedded quartz sandstone, with minor amounts of interbedded siltstone and shale (Andrews Mountain member, Campito Formation) (1).

Earliest recognized olenellid trilobites are *Fallotaspis* spp. from the Andrews Mountain member (2) and the overlying

Montenegro member of the Campito Formation. The earliest occurrence of archeocyathids is in a biohermal limestone in the Montenegro member (3).

Fallotaspis spp. occupy a similar low stratigraphic position in the Lower Cambrian of the Atlas Mountains in

Morocco (2, 4). In the Atlas Mountains area archeocyathids range below the first occurrence of *Fallotaspis*.

Fallotaspis spp. from the White-Inyo Mountains are closely related to forms from Morocco (2). From Nelson's discussion it would seem that the lower boundary of the *Fallotaspis* biozone provides an excellent biostratigraphic basis for recognition and correlation of the Lower Cambrian-Precambrian boundary. The influence of the range of the archeocyathids on this interpretation will not be known until more data are accumulated on the systematic relationships of the geographically widely separated faunas.

The true shape of the shells, which appear as randomly oriented sections on a given rock surface, was ascertained by serial sectioning and a combination dye-peel technique (5). Two peel compounds, cellulose acetate (5) and liquid parlodion (6), were used. Alizarin red-S was the staining agent.

Sections were made through blocks having surface areas of about 10 cm square. Individual shells were then selected and "mapped" on the initial peel so that they could be located in subsequent peels. Five to ten serial sections were made in sequence, 0.1 to 0.2 mm apart, through about 100 individual fossils.

The fossils consist of secondarily dolomitized shells and shell fragments in a slightly dolomitic microcrystalline matrix. The shells are conically shaped and bilaterally symmetrical, with a bulbous protoconch-like terminus. An internal structure present in some individuals is "U-shaped" in transverse section (Fig. 3). The shells range in size from 4 to 6 mm in length and from 2 to 3 mm in diameter. Outer shell thicknesses range from 0.15 to 0.23 mm.

There are three layers in the shell wall in some thin sections: outer and inner dolomite layers, and a middle calcite layer. To what extent diagenesis has been responsible for the observed three layers is not known. Since the middle calcite layer has a finer texture than the outer and inner dolomite layers, the three layers may represent a gross approximation of the primary shell structure. This deduction is supported by the fact that diagenetic replacement of primary carbonate minerals is generally accompanied by increased coarseness of mineral texture (7).

The original shell layers may have

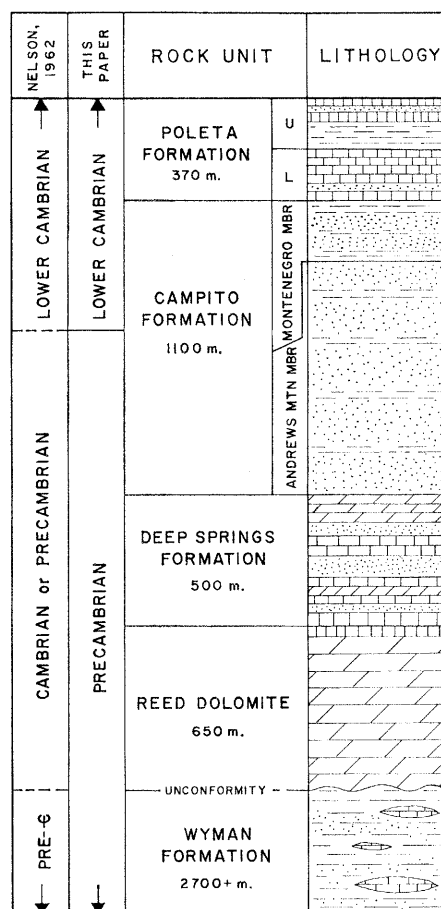


Fig. 1. Columnar stratigraphic section showing rock terminology and time-rock interpretations. The occurrence of the fossils in these strata is discussed in the text.

consisted of either calcite or aragonite which, through diagenesis, were differentially replaced by magnesium-rich interstitial fluids acting on the most readily exposed inner and outer surfaces of the shell. Preferred longitudinal orientation of dolomite rhombs is present in some completely dolomitized fragments, with two layers resulting. The dolomite layers may be

expected if the above-mentioned hypothesis is correct and the process was carried to completion.

An alternative interpretation of the observed shell structure is that original structure was lost prior to dolomitization, and the apparent layering is entirely a product of diagenesis. This alternative cannot be eliminated without a detailed study of the diagenetic

history of the Reed Dolomite. Similarly the "U-shaped" internal structure in some specimens may also be entirely the result of diagenesis and not reflective of the original shell organization.

The conically shaped shells are sufficiently distinct from other known fossils to warrant formal naming. Systematic position is discussed below.

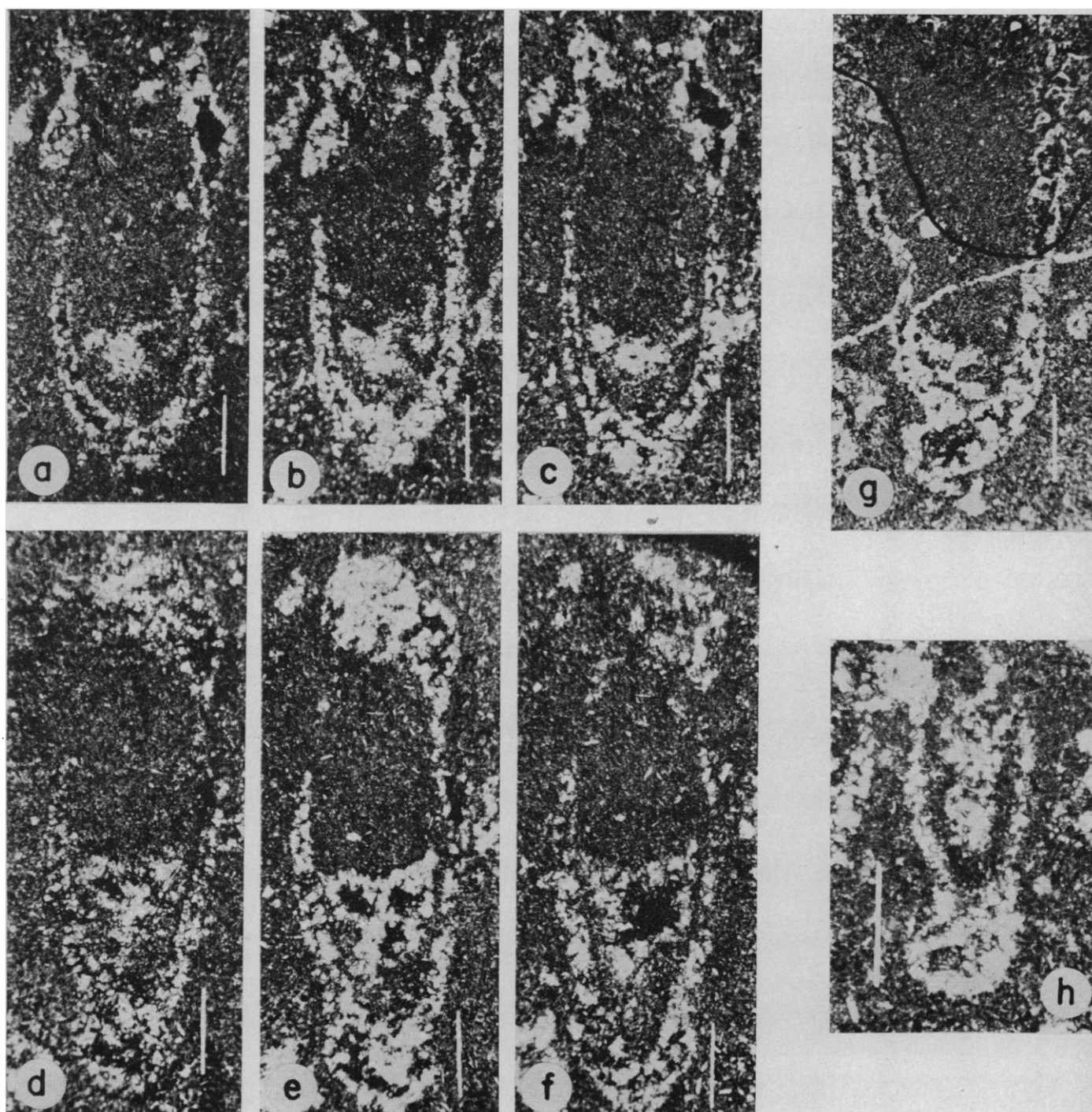


Fig. 2. *Wyattia reedensis* n. gen., n. sp. Fig. 2, a-f, UCMP 33256a-f, holotype specimen. Figures are serial sections about 0.1 to 0.2 mm apart through one individual shell. Fossil is oriented with axis inclined at about 10-degree angle (apex down) to the plane of section. Fig. 2g, UCMP 33301c and Fig. 2h, UCMP 33304c, paratype specimens. Plane of sections parallel to axis. Plane of section medial in Fig. 2g and submedial in Fig. 2h. Parts g and h are rotated 90 degrees from plane of section of Fig. 2, a-f (scale, 1.0 mm).

Class ?Calypptomatida Fisher,
1962
Order ?Globorilida Syssoiev, 1957
Wyattia new genus

Diagnosis: Small conical shells with bulbous initial termini inclined at an angle to the main growth axis. Shell containing a conically shaped internal structure separated (?) from the outer shell.

Type species: *Wyattia reedensis* n. sp., holotype UCMP (University of California Museum of Paleontology) 33256a-f, Fig. 2, *a* to *f*; paratypes UCMP 33301c, Fig. 2g; and UCMP 33304c, Fig. 2h.

Description: Small conically shaped shells from 4 to 6 mm in length and from 2 to 3 mm in diameter; outer shell wall probably originally consisting of three carbonate layers from 0.15 to 0.23 mm in total thickness; aperture circular and normal to axis of growth; raised external ridge formed by thickening of shell slightly posterior to aperture; apical end with bulbous, bilaterally symmetrical, protoconch-like terminus about 1.2 mm long and 1.5 mm wide; terminus slightly inclined from main axis of shell (Fig. 2, *g* and *h*); apical angle 12 to 25 degrees.

Interior of shell contains conically shaped structure moderately to strongly concave on the anterior surface (Fig. 2, *d* to *f*); internal structure extends $\frac{1}{2}$ to $\frac{2}{3}$ length of shell; generally separated from inner shell wall by distance of about 0.08 mm; internal structure unattached (?) to outer shell.

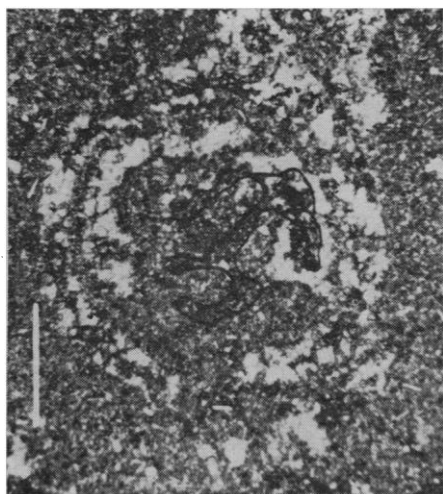


Fig. 3. Transverse section of problematical fossil (UCMP 33365a) showing "U-shaped" internal structure. Microphotograph selected from serial sequence of four sections spaced about 0.1 mm apart. Serial sections show that fossil is not spherical. Irregular-shaped dark line is an air bubble (scale, 1.0 mm).

Discussion: The outer shell of *Wyattia reedensis* seems to have grown from a bilaterally symmetrical protoconch-like initial structure. Shape and position of the apical terminus suggest a slight initial coil (Fig. 2, *g* and *h*).

The illustrated specimens in Fig. 2, *a* to *h*, are considered conspecific. The differences in shape of the apical terminus shown in Fig. 2, *g* and *h*, are interpreted as being a result of rotation through an angle of 90 degrees from the orientation of Fig. 2, *d* to *f*. Rotation of plane of section 90 degrees would result in the apical terminus appearing symmetrical as in Fig. 2, *d* to *f*.

The axis of growth of the mature shell is orthoconic. This represents a change in axis of growth from the embryonic stage of development. The thickened shell posterior to the aperture seems to result from a thickening of the middle layer rather than either the inner or outer layers. The thickened ring may represent an adult feature of the shell since the ring is absent in smaller (immature?) specimens.

Individuals with a "U-shaped" (in transverse section) internal structure (Fig. 3) exhibit a layered organization similar to that of the outer shell. Whether *Wyattia reedensis* had such a structure that was later obliterated by recrystallization is not known. Such specimens as in Fig. 3 are not referred to *W. reedensis* at this time.

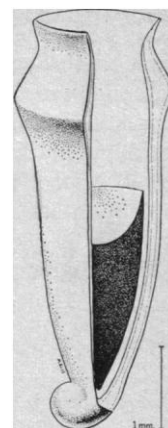
A suggested reconstruction of the shell of *Wyattia reedensis* is shown in Fig. 4.

Interpretation of the systematic position of *Wyattia reedensis* is difficult because of the lack of well-preserved specimens and the uncertain original character of the internal structure and outer shell wall. Some generalizations can be made, however, on the basis of general form, character of the apical terminus, inferred original shell-wall composition and structure, and symmetry of the shell.

The conical forms are tentatively considered to be molluscan in character. The interpretation is based on bilateral symmetry of the shell, and the presence of a slightly curved initial protoconch-like terminus. Algal or protozoan affinities cannot be ruled out with certainty, but this interpretation seems less tenable on the basis of plan of growth (nonalgal) and the presence of an internal conical structure (nonprotozoan).

Evidence suggests that an annelid relationship should be ruled out since

Fig. 4. Interpretive reconstruction of shell of *Wyattia reedensis*. Initial protoconch-like terminus based on Fig. 2, *d* to *h*. Inferred shell structure based on Fig. 2, *a* to *g*, and unfigured specimens.



the calcareous tube-secreting annelids (such as serpulitids) generally grow calcareous tubes by superposition of laminae normal to the axis of growth (8). The protoconch-like structure of *W. reedensis* is also different from the initial chamber secreted by some annelids.

Some morphologic similarities exist between *Wyattia* and members of the class Tentaculita (8). The Tentaculita are an extinct group of fossils now considered to be closely related to the Annelida (8). The class includes many small, hollow, conically shelled organisms that generally possessed external or internal transverse angular or rounded ribs, or both. Some members of the family Styliolinidae (*Styliolina*) are small conical shells with smooth internal and external surfaces and a slightly inflated initial chamber at the apical end (8). The initial chamber and plan of shell growth are similar to the protoconch-like structure and external shell of *Wyattia*, but the absence of any internal structures in *Styliolina* (and all other tentaculitids) seems sufficient evidence to exclude *Wyattia* from the class Tentaculida.

Some similarities exist between *Wyattia* and some members of the molluscan subclass Bactritoidea (Cephalopoda). The presence of a globular protoconch situated asymmetrically in relation to an orthoconic shell and bilateral symmetry occur in both *Wyattia* and some bactritoids (9). The bactritoids, however, always have a ventral hyponomic sinus (9). The lack of a sinus and the absence of demonstrable septa in *Wyattia* seem to rule out affinities with the Bactritoidea.

Another group of molluscs, of uncertain systematic position, are the Volborthellida (10). The order Volborthellida consists of *Volborthella*, from Lower and Middle Cambrian rocks; and *Salterella*, known only from the Lower

Cambrian (10). The group possess orthoconic shells that taper to a point at the apical end. Well-preserved specimens of *Salterella* (11) are septate and have a central siphuncle-like tube connecting the apex and body chamber. Well-preserved specimens of *Salterella* (*S. mexicana* Lochman from Caborca, Mexico; and *Salterella* sp. from York County, Pennsylvania) were examined (12) and compared with *Wyattia reedensis*. The specimens have an outer shell formed by superposed sinuous laminae of calcite separated from a series of conical septa, an internal phragmocone-like structure being formed. In other species of *Salterella*, such as *S. rugosa* (11), the outer wall is formed by the invaginating septa so that two distinct structural elements seem to be absent.

In *Salterella* sp. from York County, Pennsylvania, the phragmocone-like structure must have been very fragile since it is not always preserved even in a rock showing only slight evidence of diagenetic alteration. When *Salterella* is preserved in this manner the shell takes on the appearance of a simple cone, so that some apparent similarities with *Wyattia* result. For this reason the possibility exists that *Wyattia* may be a poorly preserved salterellid-type fossil shell. The remaining difference between *Salterella* and *Wyattia* that cannot be explained by this hypothesis is the presence of a globous apex in *Wyattia*, in contrast with a tapering apex in *Salterella*. This difference may not be of great systematic significance since some groups of molluscs (for example, gastropods) have developed highly diverse apical structures.

The molluscan class Calyptoptomatida was established in 1962 by D. W. Fisher (13) for "... the long-known group of hyolithids and their allies." The calyptoptomatids consist of "... bilaterally symmetrical, conoid, calcium carbonate shells that taper to a closed point or rounded apex and are open at their widest portion, the aperture." The class was subdivided on the basis of morphology of the initial chamber or embryonic portion of the shell. On the basis of this criterion Fisher recognized three orders: Hyolithida (conical embryonic stage) (14), Globorilida (globular embryonic stage), and Camerothecida (cylindrical embryonic stage) (13).

The order Globorilida is a monotypic taxon consisting of one genus, *Globorilus*, based on the species *Globorilus globiger* (Saito) from the Lower

Middle Cambrian of northwestern Korea (13). *Globorilus* has a bilaterally symmetrical, small, smooth, conical shell slightly curved ventrally near the apex, and has a slightly inflated initial chamber at the apex (15). The slight curvature of the distal end of the shell results in the initial chamber being asymmetrical to the main axis of growth as in *Wyattia reedensis*. Whether internal structures were present in *G. globiger* is unknown, but the shell was probably operculate (15).

Examination of the earlier portion of the shell of *G. globiger* (15) shows that the early curvature of the shell and asymmetrical position of the initial chamber are results of curvature immediately after the development of the earliest part of the shell. In *Wyattia reedensis* the asymmetry results within the initial chamber, with the later formed shell being essentially orthoconic.

Based on the similarity in embryonic portions of the shells and general shell shape, *Wyattia* is tentatively classified in the calyptoptomatid order Globorilida. However, since the type of preservation reflected by the *Wyattia* fossil material does result in apparent similarities with some occurrences of *Salterella* it seems desirable to query the higher classification of *Wyattia* until more data are available.

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raised them to a separate molluscan class—Hyolithida. The remaining calyptoptomatid orders—Globorilida and Camerothecida—are also of questionable monophyletic origin. However, because of the enigmatic character of these poorly known and relatively scarce fossils, the use of embryonic development (as deduced from apical morphology) by Fisher (13) represents a reasonable tentative approach to their classification until more data become available.

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16. I thank E. C. Allison, W. B. N. Berry, D. B. Blake, P. E. Cloud, Jr., J. W. Durham, R. L. Hay, C. A. Nelson, C. M. Nelson, and C. J. Stubblefield for reading the manuscript and offering criticism. I also thank M. Bloss for drawing the reconstruction of *Wyattia reedensis*, and J. H. Peck, Jr., for providing technical assistance.

18 April 1966

Mexican Freetail Bats: Photography

Abstract. A method is described for photographing bats or other rapidly moving objects as they intercept in space a particular area which is covered by a camera system. Photographs taken at Carlsbad Caverns show that the tail membrane of the Mexican free-tail bat is extended when the animal is in flight.

Bats in free flight were photographed, with electronic flash, at the mouth of the Carlsbad Caverns. The timing of the flash was determined with a photomultiplier trigger system. About one-quarter of a million bats leave the cavern each night for the Pecos River feeding area, some 64 km away. Since bats must circle many times to clear the cave entrance, there are numerous opportunities for pictures. The cave entrance is about 30 by 45 meters at a steep angle (some 30°).

The operation of the equipment (Fig. 1) was as follows. First, a white object was placed on a collapsible tripod at the desired distance (about 3 meters) from the camera lens (15-cm focal length at *f*/11). Then a battery-operated spotlight was directed onto the white object. Next a photomultiplier tube at the focus of a 15-cm lens was pointed at the white object, and the gain was adjusted so that a signal was received from the light reflected from the white object. The signal triggered a spotlight-type of electronic flash unit which had three FX-33 flash lamps at the focal point of a (17.5-cm) reflector. Each lamp was excited from two 250- μ farad capacitors in series at 900 volts. The output was 3200 beam candle power seconds (BCPS) with a flash duration of 70 μ sec. Finally the camera