Middle Turonian (Late Cretaceous) rudistids from the lower tongue of the Mancos Shale, Lincoln County, New Mexico

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Abstract

Rudistids are uncommon fossils in Upper Cretaceous rocks of the Western Interior of the United States. Since 1856 there have been fewer than 40 occurrences noted in the literature, many of these without descriptions or illustrations. Only six of these occurrences are from New Mexico. Therefore, the discovery of two fragments of solitary radiolitid rudistids and one fragment of a small bouquet from a sandy concretionary bed in the lower tongue of Mancos Shale in Lincoln County, New Mexico, is of some importance. Associated fossils in the concretions include the ammonites Spathites riensis, Morrowites depressus, and Collignonica woollgari woollgari, placing the rudistid bed in the lower part of the middle Turonian C. woollgari Zone. Although specifically indeterminate, the rudistids are probably conspecific with a large rudistid bouquet composed of Durania corneopatula that was described and illustrated from rocks in the same zone in the Greenhorn Limestone of Colorado.

Introduction

Rudistids (or rudists) are an extinct group of aberrant, inequivalved bivalves that were generally attached to the substrate by either the right or left valve; they could be solitary or gregarious, but not colonial. When gregarious, they could form large wave- and current-resistant structures called reefs. Since 1775 when they were illustrated for the first time, they have been classed as brachiopods, corals, cephalopods, or cirripeds. Deshayes (1825) appears to have been among the first naturalists to determine that the group belonged in the Bivalvia (Dechaseaux 1969, p. N749). In most cases the larger (attached) valve ranges from conical to gently curved to spirally coiled and from 2 cm to 2 m in length and 8 mm to 0.6 m in diameter. The smaller (free) valve ranges from flat to slightly convex and lidlike to conical, or coiled. In some cases the larger (free) valve was coiled and the smaller (attached) valve was conical to slightly coiled. Shell wall thickness could vary from less than 2 mm to more than 10 cm. Their geographic range extends from the Upper Jurassic to the Upper Cretaceous.

Even though Late Cretaceous marine faunas from the Western Interior of the United States are dominated by mollusks, rudistid bivalves are uncommon elements (Fig. 1), presumably because the boreal waters of the Western Interior Seaway were too cold. The lone exception is the Niobrara Formation of Kansas, where rudistids are relatively abundant (Cobban et al. 1991, p. D2). Cobban et al. (1991, pp. D2–D3) provide a summary of rudistid occurrences in the Western Interior as of 1990; this summary is updated in the Appendix. A web catalog of worldwide occurrences of rudistids can be found at http://www.paleotax.de/ rudists/locality.htm#MU.

Formation of Kansas, where rudistids are relatively abundant (Cobban et al. 1991, p. D2), Cobban et al. (1991, pp. D2–D3) provide a summary of rudistid occurrences in the Western Interior as of 1990; this summary is updated in the Appendix. A web catalog of worldwide occurrences of rudistids can be found at http://www.paleotax.de/ rudists/locality.htm#MU. Since then, Hall and Meek’s species has been reassigned to the genus Ichthyosarcolites. Caldwell and Evans (1963) redescribed Hall and Meek’s holotype and described a Campanian specimen of I. coralloidea from the Bearpaw Shale of Saskatchewan, Canada, making it the northernmost rudist in the Western Interior.

Mudge (1876, p. 216) was probably the first to note the occurrence of rudists in the Cretaceous chalk of Kansas, where they are fairly abundant; Williston (1897, p. 239) referred to these beds as “Rudistes Beds.” Logan (1898, p. 494, pl. 115, pl. 119, fig. 1) was the first to describe the Kansas rudists as the new species Radiolites maximus.
The oldest occurrence in the Western Interior is from the Thatcher Limestone Member of the Graneros Shale in northeastern New Mexico. This occurrence is in the middle Cenomanian *Conlinoceras tarrantense* Zone, indicating that the rudists established a presence in the Western Interior soon after the Late Cretaceous seaway entered New Mexico. This was merely an observation made by W. J. Kennedy (in Cobban et al. 1991, p. D2) with no locality data and no specific determination of the rudistid.

The second oldest occurrence is from dark-brown-weathering sandstone concretions in the Paguate Tongue of the Dakota Sandstone in McKinley County at USGS Mesozoic locality D7333. The fragmentary from the Campanian Niobrara Chalk; *R. maximus* was described in more detail and illustrated by Miller (1968, pp. 37–38, pl. 4, figs. 6–8; 1970 pl. 1, fig. 2).

Since Hall and Meek’s (1856) work on the Campanian of South Dakota, rudists from the Western Interior have been reported or described from every stage of the Upper Cretaceous, with occurrences in New Mexico, Arizona, Colorado, Wyoming, Montana, Kansas, and Saskatchewan (Appendix). The six occurrences in New Mexico (Fig. 1) are typical: they range in age from the Cenomanian to Santonian; the taxonomic assignment of the specimens has varied from very generalized (“rudistids”) to a specific identification (*Ichthyosarcolites coraloidea*); and the documentation of the occurrence has varied from an observation, to placement in a measured section, to a description with illustration(s).

**New Mexico’s Upper Cretaceous rudistids**

The oldest rudistid occurrence in the Western Interior is from the Thatcher Limestone Member of the Graneros Shale in New Mexico’s Upper Cretaceous rudistids

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...
rudistid has affinities to Ichthyosarcolites. Associated fossils include Inoceramus ruthfordi, Ostrea beloiti, Acanthoceras amphibolium, and Turrilites acutus (Cobban et al. 1991, p. D2). This faunal assemblage places the rudistid in the middle Cenomanian A. amphibolium Zone, four standard ammonite zones higher than the previous Graneros Shale specimen. See Cobban et al. (2006, fig. 1) for the standard zonal table for the Upper Cretaceous of the Western Interior.

The third oldest occurrence is from two localities in the lower tongue of the Mancos Shale in Bull Gap Arroyo, Lincoln County (Figs. 1–3). The three fragmentary specimens from USGS Mesozoic localities D14973 and D15025 are referred to cf. Durania cornupastoris. Associated fossils place these rudistids low in the middle Turonian Collignoniceras woollgari Zone, 15 standard ammonite zones above the previous Dakota Sandstone specimen. These Bull Gap rudistids will be discussed in detail in the next section of the paper.

The third youngest occurrence is from 50 ft (15 m) above the base of the lower shale unit of the Smoky Hill Shale Member of the Niobrara Formation in Colfax County. Scott et al. (1986, p. 31) report only that a rudist had been discovered. Cobban et al. (1991, p. D2) assign this oyster-encrusted specimen to Durania aff. D. austinensis from USGS Mesozoic locality D1432. Scott et al. (1986, p. 14) report Cremnoceramus broani from the same interval as the rudist, which places the interval in the lower Coniacian Scaphites ventricosus Zone, 11 standard ammonite zones above the previous Dakota Shale specimen. These Bull Gap rudistids are 7.5 min quadrangle. Geographically, locality D15025 is 0.32 mi (0.51 km) due east of Mesozoic locality D15025; geologically, it lies in the hanging wall block of a normal fault that juxtaposes the rudistid bed against the base of the Bridge Creek Limestone Beds in the footwall. The rudistid bed at locality D14973 is 213 ft (65 m) above the top of the Bridge Creek Limestone Beds of the lower tongue of the Mancos Shale and 75 ft (23 m) below the base of the Atarque Sandstone Member of the Tres Hermanos Formation (Fig. 3). Although much of the Mancos Shale section both above and below the rudistid occurrence is covered, the section between the base of the Bridge Creek Limestone Beds and the base of the Atarque Sandstone Member at Bull Gap could be about 20% too great. This interval at Carthage is 275 ft (84 m), whereas at Bull Gap Canyon, it is 339 ft (103 m).

**Bull Gap Canyon rudistids**

The three rudistid fragments collected from sandy limestone concretions in the lower tongue of the Mancos Shale south of Bull Gap Canyon, Lincoln County, New Mexico, are from two localities approximately 0.32 mi (0.51 km) apart. The largest and best preserved fragment is from USGS Mesozoic locality D14973 in the SE¼ SE¼ SW¼ sec. 24 T9S R9E, Bull Gap 7.5-min quadrangle. The two smaller fragments are from the same level at USGS Mesozoic locality D15025 in the SE¼ SW¼ SW¼ sec. 24 T9S R9E, Bull Gap 7.5-min quadrangle. Geographically, locality D15025 is 0.32 mi (0.51 km) due east of D14973, geologically, it lies in the hanging wall block of a normal fault that juxtaposes the rudistid bed against the base of the Bridge Creek Limestone Beds in the footwall. The rudistid bed at locality D14973 is 213 ft (65 m) above the top of the Bridge Creek Limestone Beds of the lower tongue of the Mancos Shale and 75 ft (23 m) below the base of the Atarque Sandstone Member of the Tres Hermanos Formation (Fig. 3). Although much of the Mancos Shale section both above and below the rudistid occurrence is covered, the section between the base of the Bridge Creek Limestone Beds and the base of the Atarque Sandstone Member of the Tres Hermanos Formation appears to be stratigraphically complex. However, reliable dip and strike measurements could be made on only the limestone beds within the Bridge Creek interval; the sandy beds containing the rudistid produced only an approximate set of measurements. The much better exposed, but lithologically and biostratigraphically similar, section at the Carthage coal field, 40 mi (65 km) to the northwest (Fig. 1; Hook et al. 2012, fig. 5), suggests that the stratigraphic interval between the base of the Bridge Creek Limestone and the base of the Atarque Sandstone Member at Bull Gap could be about 15% too great. This interval at Carthage is 275 ft (84 m), whereas at Bull Gap Canyon, it is 339 ft (103 m).

**Measured section**

The graphic section at Bull Gap Canyon (Fig. 3) is drawn to emphasize: (1) the relative position of the rudistid bed within the upper part of the lower tongue of the Mancos Shale; (2) the lithology and thickness of the sandy beds in which the rudistid occurs; (3) the lithology and thickness of...
the Bridge Creek Limestone Beds; and (4) the paleontology of this part of the lower tongue of Mancos Shale and the overlying Atarque Sandstone. At the same time, Figure 3 de-emphasizes the thickness of the two large covered intervals in the upper shale unit of 200 ft (61 m) and 75 ft (22.9 m), which together comprise not only 81% of the measured section, but also 100% of the thickness error.

Three thin, resistant, concretionary sandstones interbedded with silty shale (Fig. 3, units 13-17) form an inconspicuous hill about three-quarters of the way between the base of the Bridge Creek Limestone and the base of the Atarque Sandstone Member of the Tres Hermanos Formation (Fig. 2B). The rudistid (D14973) is in a 6 inch- (15 cm-) thick sandy concretionary bed (unit 17) at the top of this series that forms a prominent dip slope. A 200 ft- (61 m-) thick, soft, covered interval (unit 11) separates this outcrop from the top of the Bridge Creek; a 75 ft- (23 m-) covered interval (unit 18) separates it from the base of the Atarque.

The Bridge Creek Limestone Beds of the lower tongue of the Mancos Shale are 46.2 ft (14.1 m) thick and consist of five thin limestone beds interbedded with four highly calcareous shale beds (Fig. 3, units 1-10). The lowest bed (unit 1) is a hard, dense, very dark gray, almost lithographic limestone that weathers pale yellowish orange and is 8 inches (20 cm) thick. It breaks with a conchoidal fracture and forms a prominent ledge. The other limestone beds are not as hard or resistant, are a lighter gray, weather to an off white, and do not form as conspicuous an outcrop. All five limestone beds tend to pinch and swell along strike.

Surprisingly, the Bridge Creek Limestone Beds are only sparsely fossiliferous in the Bull Gap Canyon area, especially the lower four limestone beds. The hard, dense limestone at the base of the beds has yielded only one ammonite species, _Metococeras gesliniunum_ (D10640), indicative of the upper Cenomanian _Euxomphaloceras septemseriatum_ Zone. Only a few very small _Pycnodonte newberryi_ shells (D14871) have been collected as float from the shale (unit 4) between the second and third limestones in the sequence. However, this collection constitutes the earliest occurrence of _P. newberryi_ in New Mexico. Fragments of inoceramids have been observed in the lower four limestone beds, but are specifically indeterminate, e.g., D10640 from unit 5.

The uppermost of the five limestone beds (unit 10) is quite fossiliferous in Bull Gap Canyon itself, where several very nice internal molds of the inoceramid _Mytiloides puelboense_ (D14945) have been collected from an inch or so below the top of the bed. In New Mexico, _M. puelboense_ is the most common indicator of the basal lower Turonian _Watinoceras devonense_ Zone. The base of unit 10 is the Cenomanian–Turonian stage boundary; its top is the upper lithologic boundary of the Bridge Creek Limestone Beds in the area. The higher, thin calcarenites that lie in the _Mammites nodosoides_ Zone and form the top of the Bridge Creek at Carthage are not present at Bull Gap. These calcarenites are either covered or, more likely, not developed at Bull Gap.

The next higher fossil in the section occurs at the base of the sandy interval that contains the rudistid. Several very well preserved internal molds of _Spathites rioensis_ (D14987) have been recovered from unit 13, a 7 inch- (18 cm-) thick, light-brown-weathering, fine-grained sandstone. _Spathites rioensis_ is the oldest of three chronologic species in central New Mexico and is indicative of the lower part of the lowermost middle Turonian _Collignoniceras woollgari_ Zone, four standard ammonite zones higher than the _Watinoceras devonense_ Zone. Fragments of the very large ammonite _Morrowites depressus_ (D14988) are present with _S. rioensis_ in a 6 inch- (15 cm-) thick concretionary sandstone, 2.0 ft (61 cm) higher. Approximately 4.5 ft (1.37 m) higher, the best rudistid fragment (D14973) was found in a 6 inch- (15 cm-) thick concretionary sandstone (unit 17). Associated fossils include _Collignoniceras woollgari_ _woollgari, Morrowites depressus, calcareous worm_
from locality D10643. Cobban (1986) illustrated a specimen part of the lower tongue of the Mancos Shale that both Atarque Sandstone and the upper of the Tres Hermanos Formation indicates basal part of the Atarque Sandstone Member. "woollgari***, Collignoniceras woollgari woollgari***, cumminsi, Spathites rioensis*, Morrowites sp.* hercynicus, Camptonectes platessa, Cymbophora worm tubes, from USGS locality D10643: calcareous but did not include a rudistid. Cobban 15, and 17) contained a more diverse fauna from this entire sandy interval (units 13, 14, and 17) contained a more diverse fauna. In the interval. Subzone, just as ammonites reveal the indeterminate bivalve internal molds. These tubes, and a few fragments of large, but indeterminate bivalve internal molds. These ammonites reveal the C. woollgari woollgari Subzone, just as S. rioensis did at the base of the interval.

A 1979 collection made by the authors from this entire sandy interval (units 13, 15, and 17) contained a more diverse fauna but did not include a rudistid. Cobban (1986, p. 81) listed the following fossils from USGS locality D10643: calcareous worm tubes, Phelopteria gastronidae, Mytiloides hercynicus, Camptonectes platessa, Cymbophora sp., Trugodesmoceras socorroense, Placenticeras commissi, Spathites rioensis*, Morrowites depressus*, Collignoniceras woollgari woollgari*, and Baculites yokoyamai. An asterisk indicates that Cobban (1986) illustrated a specimen from locality D10643.

A specimen of Collignoniceras woollgari woollgari (D14971) collected as float from the basal part of the Atarque Sandstone Member of the Tres Hermanos Formation indicates that both Atarque Sandstone and the upper part of the lower tongue of the Mancos Shale lie within the C. woollgari woollgari Subzone.

**Systematic paleontology**

**Family RADIOLITIDE**

**Gray 1847**

Inequivalve rudistids in which the right (attached) valve is conical and the left (free) valve is operculiform; the surface of the right valve is without furrows but has two concave, flat, or convex siphonal bands separated by an interband. The ligamental ridge can be present or absent. Stratigraphic range: Lower Cretaceous (Barremian) through Upper Cretaceous (Maastrichtian).

**Subfamily SAUVAGESINAE**

**Douvillé 1908**

Right valve is composed of cells that are polygonal in transverse section and prismatic in longitudinal section. Stratigraphic range: Lower Cretaceous (Albian) through Upper Cretaceous (Maastrichtian).

**Genus DURANIA**

(Des Moulins 1826)

**Type species**—Hippurites cornupastoris Des Moulins 1826

Right valve is cylindrical but can be short or elongate; left valve is operculiform. Siphonal bands can be concave, smooth, or ribbed. The ligamental ridge is absent, but bifurcating radial furrows are present on the upper surface of the outer wall in many species. Stratigraphic range: Upper Cretaceous (Turonian–Maastrichtian). Geographic range: Europe, North Africa, Asia, South America, and North America.

**cf. Durania cornupastoris** (Des Moulins); Skelton in Cobban et al. (1991, pp. D3–D7, fig. 1, pls. 1–3)

**Description**—The best preserved of the three rudistid specimens from Bull Gap Canyon is a fragment of the right (attached) valve of a large solitary individual (USNM 558700) from USGS Mesozoic locality D14973 (Fig. 4C, D). The specimen appears to be conical and has an elliptical cross section with a maximum diameter of 98.6 mm, a height of 81.4 mm, and a maximum shell wall thickness of 20.9 mm. This rudistid is the nucleus of a cannonball-type concretion with a diameter of at least 100 mm. The sandy limestone concretion is broken to expose a transverse section of the rudistid, revealing the telltale polygonal structure of a sauvesginae radiolitid (Fig. 4C). The longitudinal (radial) structures necessary to place the specimen in a genus or species are not preserved or obscured by the outer part of the concretion. The elliptical mantle cavity of the specimen, which filled with sediment after the death of the individual, has a maximum diameter of 49.6 mm and a minimum diameter of 37.2 mm.

The other two specimens (not illustrated) are of right valves of smaller individuals from USGS Mesozoic locality D15025. The solitary rudistid (USNM 558702) is preserved in a portion of a sandy limestone concretion 51 mm long by 42 mm wide by 16 mm deep. A broken surface formed within the concretion cuts across the rudistid in a transverse orientation and reveals an elliptical cross section with a maximum diameter of 18.3 mm and a minimum diameter of 15.03 mm; the shell wall is 1.33 mm thick. The second specimen (USNM 558701) is a small association of two closely spaced individuals that are preserved on the outer surface of a fragment of sandy limestone concretion that is 73 mm long by 65 mm wide by 26 mm deep. The better preserved of the two has an elliptical cross section with a maximum diameter of 20.32...
Paleoecology—Radiolitid rudistids are an extinct group of sessile, filter-feeding, epifaunal bivalves with massive shells that were attached as larvae to objects on the sea floor and grew most perpendicular to the sea floor. They preferred shallow, warm, clear water of normal salinity and are commonly found in carbonate deposits. Although gregarious, they were not colonial. They lived as individuals and in conjoined groups that could contain a small number of individuals called bouquets or a large number of individuals called reefs.

The large size of the illustrated specimen (Fig. 4C, D) suggests that it had lived for some time, perhaps a year or so, and was attached to some large, heavy object on the sea floor. The attachment point would have been at the small end of its slightly conical shell. If it had been attached to a smaller or lighter object—such as a small ammonite’s shell or clam’s shell—the rudistid’s high center of gravity and large surface area would have allowed currents to push it over into an unfavorable living position.

The paleogeography and stratigraphy at the measured section indicate that the rudistid lived in a nearshore environment—probably less than 35 mi (56 km) from the strand line (see Fig. 1)—on a relatively soft bottom of silty to sandy clay (Fig. 3). The relatively soft bottom conditions lead to the question of the nature of the holdfast object for a large, erect, heavy animal such as the illustrated rudistid (Fig. 4C, D). Kauffman and Sohl (1979, fig. 1) refer to Durania as a “...large, barrel-shaped [genus],” suggesting that it had a fairly large attachment area relative to other rudistid genera that would provide more stability on the sea floor. They (Kauffman and Sohl 1979, p. 725) state that the “...open cellular structure of the rudist shell permitted rapid growth without great expenditure of calcium carbonate, and this resulted in the construction of very large massive shells in short periods of time. Filling of these cells with fluid would have provided the necessary density to make the rudist shells stable on the sea floor as exposed epifaunal organisms.”

One possibility as an attachment object is presented by the large ammonite Morrowites depressus (Fig. 2D; see Cobban, 1986, fig. 10 for a large specimen from the area). An oyster-encrusted internal mold of M. depressus was collected at USGS Mesozoic locality DI5025 along with the two unfigured rudistid specimens. Hook and Cobban (1981, p. 13) interpret similar oyster-encrusted molds in New Mexico as evidence for discontinuity surfaces. The scenario they envision involves burial of the sediment-filled ammonite shell; dissolution of the aragonitic shell resulting in prefossilization of the sediment filling (internal mold); erosion of the sediment surrounding the hardened internal mold; and colonization by oysters (and, here, rudistids) of the discontinuous hardground provided by the internal mold(s), which form a lag deposit on the sea floor (Fig. 5). The mere presence of internal molds of at least two species of ammonites in this bed (Fig. 3, unit 17) indicates that their sediment-filled shells accumulated on the sea floor. Before complete burial, these shells could have acted as heavy, attachment sites for the rudistids, regardless of whether the internal molds were later prefossilized and eroded from the sediment.

Geologic occurrence—Middle Turonian lower tongue of the Mancos Shale, Collignoniceras woollgari woollgari Subzone of the C. woollgari Zone, 75 ft (22.9 m) below the base of the Tres Hermanos Formation and 213 ft (65 m) above the top of the Bridge Creek Limestone Beds of the lower tongue of the Mancos Shale.

Geographic occurrence—D14973: SE¼SE¼ SW¼ sec. 24 T9S R9E, Bull Gap Canyon 7.5-min quadrangle, Lincoln County, New Mexico; and DI5025: SE¼SW¼SW¼ sec. 24 T9S R9E, Bull Gap 7.5-min quadrangle, Lincoln County, New Mexico.

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Appendix
Compilation of Upper Cretaceous rudistid occurrences in the Western Interior of the United States from published records and unpublished collections housed in the USGS Mesozoic Invertebrate collections in the Denver Federal Center. These occurrences are arranged stratigraphically from lowest (no. 1) to highest (no. 37). Although rudists are rare faunal elements in the Upper Cretaceous of the Western Interior, there is at least one occurrence from each stage. Geographically, they range from New Mexico (NM) on the south to Saskatchewan (SK), Canada, on the north. CSK = Cobb, W. A., Skelton, P. W., and Kennedy, W. J. (1991).
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<th>No.</th>
<th>Stage</th>
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