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EXCEPTIONALLY PRESERVED INVERTEBRATE FAUNA FROM THE UPPER CRETACEOUS PAGUATE MEMBER OF THE DAKOTA FORMATION, RIO PUERCO VALLEY, NEW MEXICO

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ABSTRACT.—We document a very well preserved bivalve and gastropod fauna associated with *Acanthoceras amphibolum* Morrow in the Paguate Member of the Dakota Formation on the western side of the Rio Puerco northwest of Albuquerque, New Mexico. This fauna includes *Pycnodonte* cf. *P. kellumi* (Jones), *Exogyra trigeri* (Coquand), cf. *Phelopteria aguilerae* (Böse), *Legumen ellipticum* Conrad, *Ostrea* sp., *Granocardium enstromi* (Bergquist), *Idonearca blanpiedi* Stephenson, and *Turritella* cf. *T. shuleri* (Stephenson). Other than a single specimen of *Turritites acutus americanus* Cobban & Scott, all other ammonites collected are *A. amphibolum*. These fossils are from the *A. amphibolum* Zone, which is of middle Cenomanian age.

INTRODUCTION

Few detailed studies have been done on the occurrence of *Acanthoceras amphibolum* and the other invertebrates in the Paguate Member of the Dakota Sandstone in New Mexico. In 1874, C. A. White reported on molluscan fossils from “Pajuate” (Paguate), New Mexico. Cobban (1977, p. 5) mentioned that one of the ammonites listed by Lee in 1912, from the Paguate in the Rio Puerco valley near San Francisco, is probably *Acanthoceras amphibolum*. Cobban (1977) and Cobban and Hook (1989) published on molluscan fossils, including *Acanthoceras amphibolum*, from the Paguate Member in west-central New Mexico. For a detailed history of molluscan fossils collected from the Paguate Member, the reader is referred to Cobban (1977, p. 3-10).

The Paguate Member is named after the town of Paguate in west-central New Mexico, where the type section was measured (Landis et al., 1973a, p. 33). The purpose of this report is to illustrate and describe an exceptionally well preserved invertebrate fauna from the Paguate Member of the Dakota Formation. NMMNH refers to the New Mexico Museum of Natural History and Science, Albuquerque. All dimensions are given in millimeters; U = umbilical diameter; Wh = whorl height, and Wb = whorl breadth.

LOCALITIES AND STRATIGRAPHY

The *Acanthoceras amphibolum* Zone is present in the Paguate Member of the Dakota Formation on the western side of the Rio Puerco northwest of Albuquerque, New Mexico, at NMMNH localities 3263, 4406-4409, and 4429-4432, all located in secs. 27 and 29, T13N, R2W and sec. 33, T12N, R2W.

The stratigraphic section exposed at these localities (Fig. 1) fits well into the regional lithostratigraphy of the intertongued Dakota-Mancos succession in north-central and northwestern New Mexico (Owen, 1966; Landis et al., 1973b; Molenaar, 1983; Cobban and Hook, 1989; Lucas et al., 1998; Owen and Head, 2001; Lucas, 2002). Thus, at the base of this section, the top of the Cubero Member of the Dakota is a bench of extensively bioturbated, fine-to medium-grained quartz sandstone. It is overlain by a slope composed of about 20 m of gray shale with some septarian limestone concretions, the Clay Mesa Member of the Mancos Shale.

The overlying sandstone cliffs and benches are the Paguate Member of the Dakota Sandstone. About 22 m thick, the Paguate

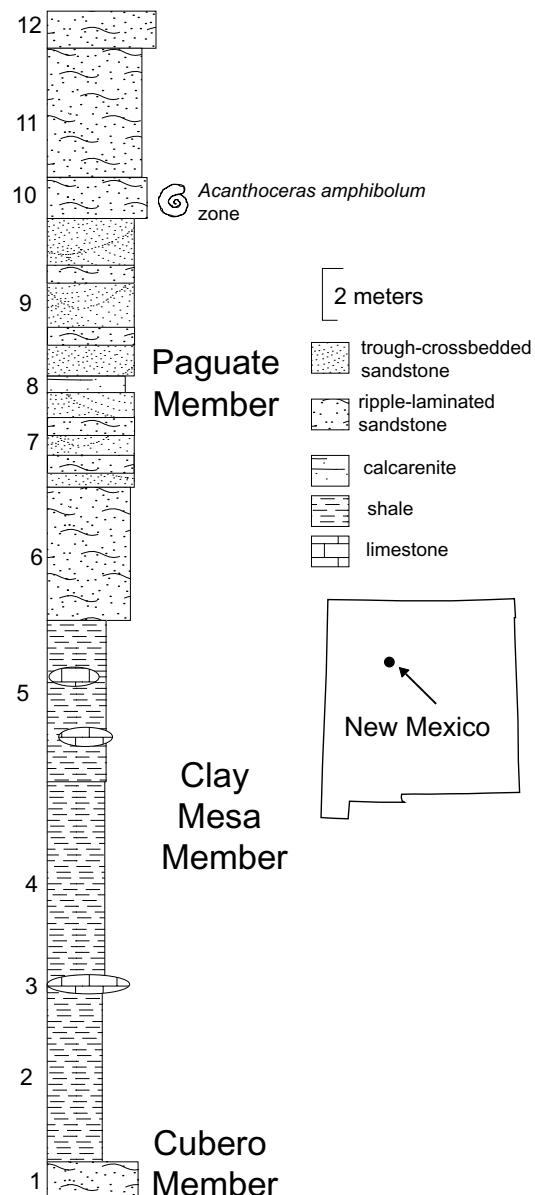


FIGURE 1. Index map and measured stratigraphic section of the Paguate and Cubero members of the Dakota Formation and the Clay Mesa Member of the Mancos Shale exposed on the western side of the Rio Puerco northwest of Albuquerque, New Mexico. All fossils described and illustrated here are from the fossiliferous horizon in unit 10.

consists of ripple-laminated and trough-crossbedded grayish orange, fine-grained quartz sandstones with some dark yellowish brown ferruginous concretions. All fossils reported here are from a 1.5-m thick ripple-laminated and concretionary calcareous sandstone, 15–16 m above the Paguate base (Fig. 1). The bivalve and gastropod fossils are slightly recrystallized shells, but almost all of the ammonites are preserved as steinkerns.

PALEONTOLOGY

Bivalvia

Pycnodonte cf. *P. kellumi* (Jones, 1938)

NMMNH P-31978 (Fig. 2A-B) from locality L-4406 is a complete, well preserved left valve of *Pycnodonte* cf. *P. kellumi*. It possesses moderately pronounced growth lines and a well defined auricular sulcus, with a conspicuous posterior auricle that is more pronounced than on other specimens collected from the same area. NMMNH P-31978 could be referred to *Pycnodonte* aff. *P. kellumi* (Jones) because this variety has a more pronounced posterior auricle and a better defined auricular sulcus than *P. cf. P. kellumi* (Cobban, 1977, p. 17), but the length of this specimen falls within the size range of *P. cf. P. kellumi*.

NMMNH P-37866 (Fig. 2C-D) from locality L-4406 is larger, has a less defined auricular sulcus, and less pronounced posterior auricle than NMMNH P-31978. It is a complete, slightly weathered left valve with moderately pronounced growth lines and a broad umbo. *P. cf. P. kellumi* differs from *Pycnodonte washitaensis* by possessing a longer hinge line, less convexity and a broader umbo (Cobban, 1977, p. 17). Jones (1938, p. 107) description of *Gryphaea washitaensis* var. *kellumi* (synonym of *P. kellumi*) states that there is an extension of the shell on each side of the beak, with the posterior extension being longer. This is consistent with our specimens of *P. cf. P. kellumi*. *P. cf. P. kellumi* is common in the study area.

Exogyra trigeri (Coquand, 1869)

A specimen of *Exogyra trigeri* from locality L-4432 (NMMNH P-31992; Fig. 2E-F) is a well preserved, complete right valve. It possesses an ovoid shape and conspicuous growth squamae that radiate from the beak on the exterior side of shell. NMMNH P-31992 is almost identical to the specimen of *E. trigeri* illustrated by Cobban (1977, pl. 17, fig. 3).

NMMNH P-31998 (Fig. 2G-H) from locality L-4406 is a complete left valve of *E. trigeri*. It possesses rough, conspicuous growth squamae that are moderately spaced, moderate to high convexity, a strongly coiled beak, and lacks radial ribs. Although the left valve of *E. trigeri* possesses low convexity, the Paguate specimens tend to have a left valve with higher convexity (Cobban, 1977, p. 20). *E. trigeri* is common in the study area.

cf. *Phelopteria aguilerae* (Böse, 1918)

NMMNH P-31989 (Fig. 2I-J) from locality L-4406 is a large, smooth, incomplete shell with prominent wings and two unequal, inequilateral, fairly convex valves that are missing the ventral portion. The left valve is slightly more inflated than the right valve. A relatively small beak is oblique to, and rises above a fairly long

but incomplete hinge line with a furrow on either side. Our specimens are better placed in the taxon cf. *Phelopteria aguilerae* than *Avicula gastrodes* Meek (*contra* Sealey and Lucas, 2000).

A small, very incomplete left valve from locality L-4407 (NMMNH P-32000; Fig. 2K-L) possesses a smooth surface and a beak that rises above and is oblique to an incomplete hinge line. The cardinal area is very thick (wide), lacks ligamental pits, and is almost identical to an illustration of cf. *Phelopteria aguilerae* by Cobban (1977, pl. 7, fig. 9).

NMMNH P-37867 (Fig. 2M-N) from locality L-4406 is a relatively large, incomplete shell with two unequal, inequilateral valves that possess a fairly long, complete hinge line. The left valve is more inflated than the right. The wings are prominent but not as prominent as in *Phelopteria dalli* (Stephenson). The posterior wing is longer on *P. dalli* (Stephenson, 1952, pl. 14, fig. 5), and the shell is much smaller than *P. aguilerae*. The posterior wing is longer and protrudes from the margin of the valve more than the anterior wing. Specimens of *P. cf. P. aguilerae* are fairly common in the study area.

Legumen ellipticum Conrad, 1858

An almost complete, weathered specimen of *Legumen ellipticum* (NMMNH P-31993; Fig. 3A) from locality 4432, possessing both valves, is elongate in shape, equivalve, and narrow. Our specimen of *L. ellipticum* differs from *Legumen ligula* Stephenson in being longer and more compressed laterally (Stephenson, 1952, p. 110). Ribbing is distinct, and fairly widely spaced, with the interspaces being wider than the ribs. The beak is weathered but appears to be small. It is situated approximately one third of the length of the shell from the anterior edge. Stephenson (1941, p. 215) described his specimens as having the beak situated approximately one fourth the length of the shell. This taxon is rare, as only a single specimen of *L. ellipticum* was collected from the study area.

Granocardium enstromi (Bergquist, 1944)

NMMNH P-31979 (Fig. 3B) from locality 4406 is a fairly complete, slightly weathered specimen with every other rib being tuberculate. It possesses fewer ribs than *Granocardium trite* (White) (Cobban, 1977, p. 21), with the interspaces being wider. NMMNH P-31979 possesses a prominent, pointed, incurved beak that is almost central to the axis of the shell (Bergquist, 1944, p. 22). Our specimen of *Granocardium enstromi* is narrower anteriorly-posteriorly than specimens illustrated by Cobban (1977, pl. 8, figs. 5, 6 and 10). Although Cobban (1977, p. 21) states that this taxon is common in the Paguate, only one specimen of *G. enstromi* was collected by us at our localities.

Idonearca blanpiedi Stephenson, 1953

NMMNH P-31987 (Fig. 3C-D) from locality 4432 is a fairly complete, very convex right valve that possesses an incurved beak that is not very prominent, a short hinge line, weak radial ribs over the posterior side of the shell and irregularly spaced growth lines that are prominent over the ventral half of the shell. *Idonearca depressa* White, 1877 differs from *Idonearca blanpiedi* by having conspicuous radial ribbing over the entire shell (Cobban, 1977, p. 13). Sealey and Lucas (2000, p. 51) incorrectly listed NMMNH P-31987 as *I. depressa*.

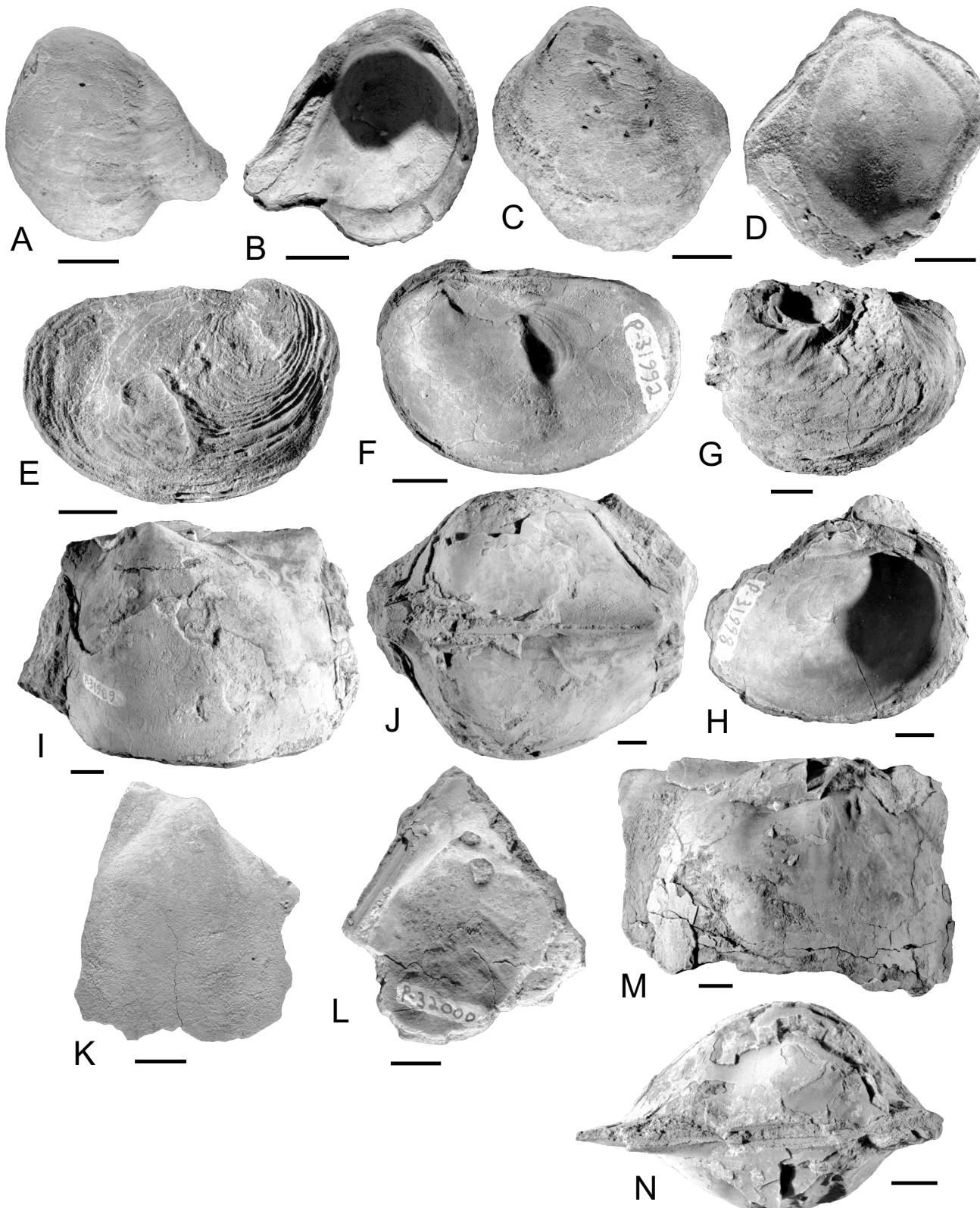


FIGURE 2. Bivalves from the Paguate Member of the Dakota Formation. A-B. *Pycnodonte* cf. *P. kellumi* (Jones), exterior (A) and interior (B) views of left valve, NMMNH P-31978 from locality L-4406; C-D. *Pycnodonte* cf. *P. kellumi* (Jones), exterior (C) and interior (D) views of left valve, NMMNH P-37866 from locality L-4406; E-F. *Exogyra trigeri* (Coquand), exterior (E) and interior (F) views of right valve, NMMNH P-31992 from locality L-4432; G-H. *Exogyra trigeri* (Coquand), exterior (G) and interior (H) views of left valve, NMMNH P-31998 from locality L-4406; I-J. cf. *Phelopteria* *P. aguilerae* (Böse), lateral (I) and dorsal (J) views of both valves that are missing the ventral part, NMMNH P-31989 from locality L-4406; K-L. cf. *Phelopteria* *P. aguilerae* (Böse), exterior (K) and interior (L) views of left valve, NMMNH P-32000 from locality L-4407; M-N. cf. *Phelopteria* *P. aguilerae* (Böse), lateral (M) and dorsal (N) views of both valves that are missing the ventral part, NMMNH P-37867 from locality L-4406. Scale bars equal 1 cm.

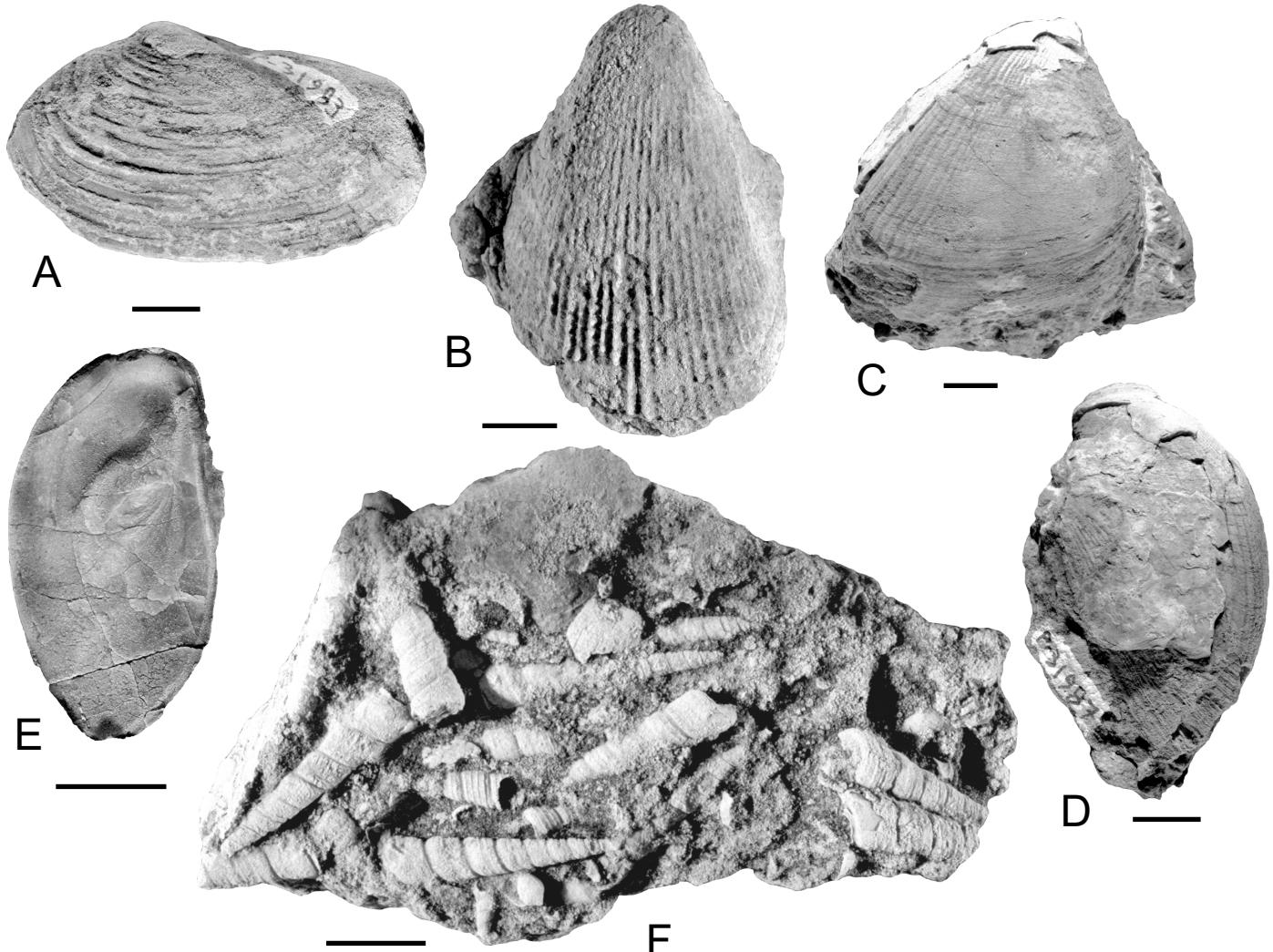


FIGURE 3. Bivalves and gastropods from the Paguate Member of the Dakota Formation. A. *Legumen ellipticum* Conrad, lateral view, NMMNH P-31993 from locality 4432; B. *Granocardium enstromi* (Bergquist), exterior view, NMMNH P-31979 from locality L-4406; C-D. *Idonearca blanpiedi* Stephenson, exterior (C) and side (D) views of right valve, NMMNH P-31987 from locality L-4432; E. *Ostrea* sp., interior view, NMMNH P-31991 from locality L-4432; F. *Turritella* cf. *T. shuleri* Stephenson, many specimens in matrix, NMMNH P-31981 from locality L-4406. Scale bars equal 1 cm.

NMMNH P-36636 (not illustrated) from locality 4432 is a partial left valve of *I. blanpiedi*, with obscure radial ribs, and prominent growth lines toward the ventral side. Although Cobban (1977, p. 13) states that *I. blanpiedi* is common in the Paguate, only two specimens were collected by us at our localities.

Ostrea sp.

NMMNH P-31991 (Fig. 3E) from locality L-4432 is an interior view of an oblong, slightly curved shell of *Ostrea* sp. in rock matrix. The shell is smooth and relatively flat. *Ostrea* sp. is fairly common in the study area.

Gastropoda

Turritella cf. *T. shuleri* Stephenson, 1953

NMMNH P-31981 (Fig. 3F) from locality 4406 is many complete gastropod shells with very high spires that are embedded in rock matrix. We tentatively assign NMMNH P-31981 to *Tur-*

ritella shuleri on the basis of possessing high-turreted shells with not very prominent ribs on the body whorls. Stephenson (1952, p. 153) states that the whorls of *T. shuleri* are ornamented with four primary rows of beaded spirals. However, these beads are difficult to discern on our specimens because of recrystallization. NMMNH P-31981 includes the only specimens of *T. cf. T. shuleri* found in the study area.

Ammonoidea

Acanthoceras amphibolum Morrow, 1935

A specimen of *Acanthoceras amphibolum* (NMMNH P-7888: Fig. 4A-B) from locality 3263, weathered on one side, is nearly complete with a body chamber. It possesses ventrolateral horns on the outer part of the whorl and a broadly arched venter with only a slight indication of a mid-ventral ridge. These features are characteristic of the adult whorl of *A. amphibolum* (Cobban and Scott, 1972, p. 66). The ribs on the early whorl extend to the

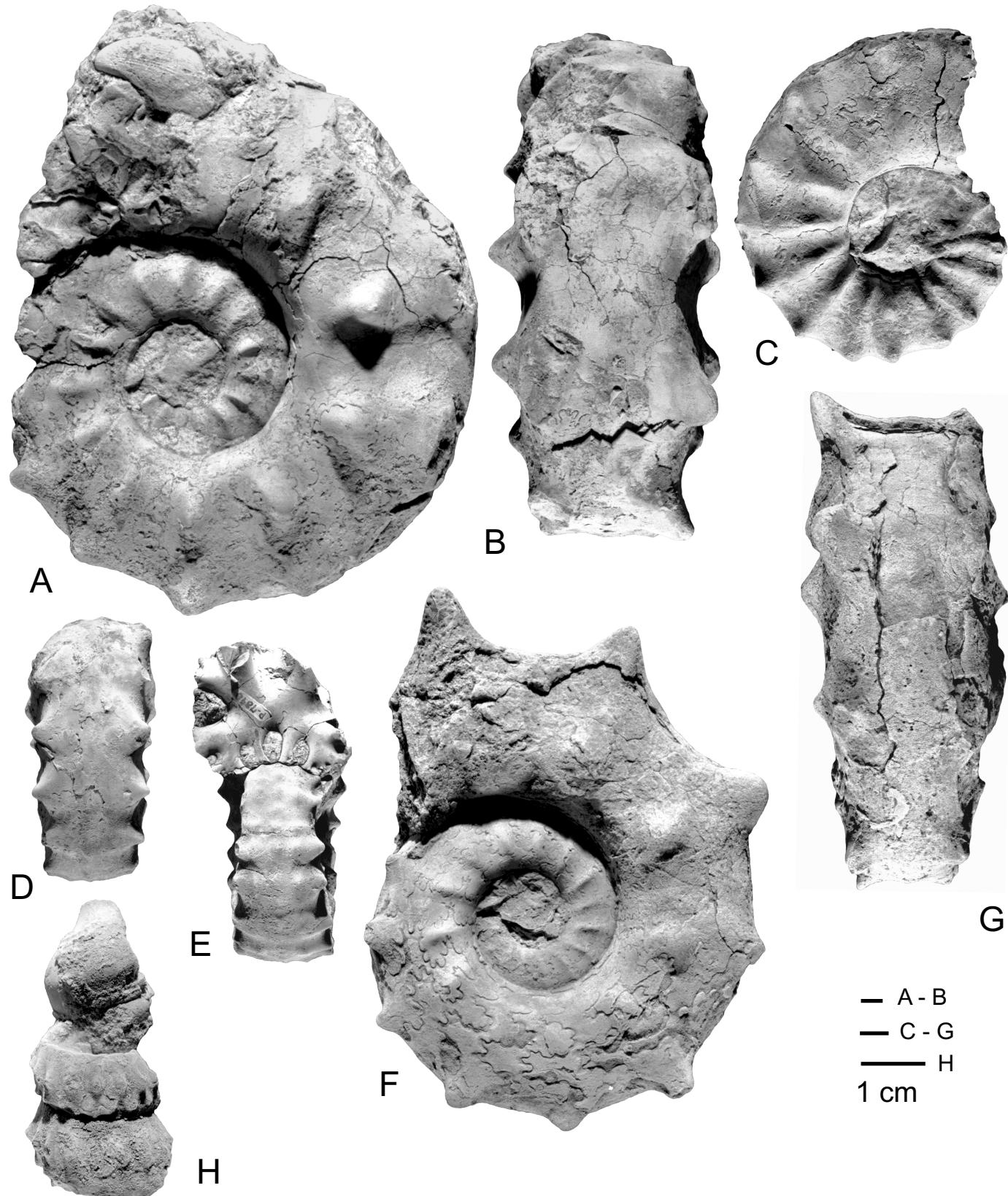


FIGURE 4. Ammonites from the Paguate Member of the Dakota Formation. A-B. *Acanthoceras amphibolum* Morrow, lateral (A) and posterior (B) views of an adult, NMMNH P-7888 from locality L-3263; C-E. *Acanthoceras amphibolum* Morrow, lateral (C), posterior (D) and anterior (E) views of an inner whorl, NMMNH P-7898 from locality L-3263; F-G. *Acanthoceras amphibolum* Morrow, lateral (F) and posterior (G) views of an almost complete adult, NMMNH P-31994 from locality L-4431; H. *Turrilites acutus americanus* Cobban and Scott, lateral view of an incomplete shell, NMMNH P-31986 from locality L-4431.

umbilicus, whereas on the later whorls the ribs are not as distinct and are more widely spaced. The specimen possesses bullate umbilical tubercles on the inner whorl and large, conical, umbilical tubercles on the outer whorl. The suture pattern is weathered and incomplete, but saddles surrounding nodes are typical of *Acanthoceras*. NMMNH P-7888 is 211 mm in diameter, at which $U = 88.6$, and $Wb = 82.7$.

NMMNH P-7898 (Fig. 4C-E) from locality L-3263 is an inner whorl of *A. amphibolum* that possesses a typical *Acanthoceras* suture—saddles surround every other row of umbilical and lower ventrolateral tubercles on the outer part of the whorl. The first lateral saddle is broad and asymmetrically bifid, whereas the second lateral saddle is not as broad or divided. The first lateral lobe is relatively large and wide, whereas the second lateral lobe is very small (Morrow, 1935, p. 472). Distinguishing features include nodate lower ventrolateral tubercles, clavate upper ventrolateral tubercles, clavate siphonal tubercles, and bullate umbilical tubercles. NMMNH P-7898 differs from *Plesiacanthoceras wyomingense* (Regan) by retaining the siphonal tubercles to a larger diameter (Cobban and Scott, 1972, p. 67). The mid-ventral ridge is low but more conspicuous than the adult specimens described here. The ribs are recirradiate and extend to the umbilicus. NMMNH P-7898 is 101 mm in diameter, at which $U = 42$, $Wh = 45$, and $Wb = 47.5$.

NMMNH P-31994 (Fig. 4F-G) from locality 4431 is an almost complete, well preserved adult specimen, including most of the body chamber, of *Acanthoceras amphibolum*. The inner whorl possesses bullate umbilical tubercles becoming nodate on the outer part of the whorl. The lower ventrolateral tubercles become widely spaced ventrolateral horns toward the latter part of the whorl. The suture surrounds the lower ventrolateral and umbilical tubercles and is very similar to published illustrations of the suture of *A. amphibolum* (Cobban, 1977, p. 24, fig. 5). The ventral lobe is long and narrow. The first lateral saddle is very broad and is asymmetrically bifid, whereas the second lateral saddle is narrow. The ribs extend to the umbilicus on the inner whorl and become less distinct and more widely spaced on the outer whorl. NMMNH P-31994 possesses a low, inconspicuous mid-ventral ridge. *P. wyomingense* differs from our specimens by retaining double ventrolateral tubercles to a large diameter. NMMNH P-31994 is 177.6 mm in diameter, at which $U = 66.4$, $Wh = 65$, and $Wb = 64.5$. We follow Cobban (1993, p. 439) in the use of the original generic name *Acanthoceras* instead of *Cunningtoniceras* (Cobban, 1987, p. 13).

A. amphibolum is fairly common in the study area. It also occurs in the Paguate Sandstone Tongue of the Dakota Sandstone in the Laguna area, west-central New Mexico (Cobban and Hook, 1989, p. 250).

Turrilites acutus americanus Cobban and Scott, 1972

A specimen of *Turrilites acutus americanus* (NMMNH P-31986; Fig. 4H) from locality 4431 is a partial shell with a few whorls that possesses three rows of tubercles, with the smallest, weakest row at the base of the whorl. *T. acutus americanus* Cobban and Scott differs from *Turrilites acutus* Passy in possessing smaller and weaker tubercles at the base of the whorls (Cobban, 1977, p. 22). Ribs are oblique to the whorl, not prominent, and do not extend to the edge of the whorl (Cobban and

Scott, 1972, p. 54). The base of the whorl is moderately crenulated due to the first row of tubercles at the base. The space between the second and third rows of tubercles is relatively smooth. In the second row, the tubercles are conical and sharp and are approximately half as large as the third row, which are also conical and sharp. No suture is visible on our specimen.

T. acutus americanus is found only in the Paguate or age-equivalent shale (Cobban, 1977, p. 22). Only one specimen of *T. acutus americanus* was collected in the study area.

CONCLUSION

Here, we follow the ammonite zonation of Cobban (1993, p. 438, fig. 2). The presence of the *Acanthoceras amphibolum* Zone in the Rio Puerco Valley suggests correlation with the Paguate Member of the Dakota Formation northeast of Thoreau, in the Laguna area, and at other locations in west-central and north-central New Mexico (Cobban, 1977; Lucas et al., 1998). This zone has also been reported from near Oscura, New Mexico in Lincoln County (Cobban, 1986, p. 78). The *Acanthoceras amphibolum* Zone is of middle Cenomanian age (Cobban, 1993, fig. 2, p. 438; Cobban and Hook, 1989, p. 250).

Cobban (1977) well represents the state of the art of knowledge of the Paguate invertebrate fauna from New Mexico. Many of the specimens illustrated here are as well or better preserved than the Paguate specimens he illustrates, so they add to our knowledge of the morphology of the Paguate invertebrate fauna. Furthermore, our collections reveal differences in the relative abundances of elements of the Paguate invertebrate fauna when compared to the collections studied by Cobban (1977). These differences in abundance surely reflect differences in lithofacies, biofacies and / or taphonomy in the Paguate interval that merit further study.

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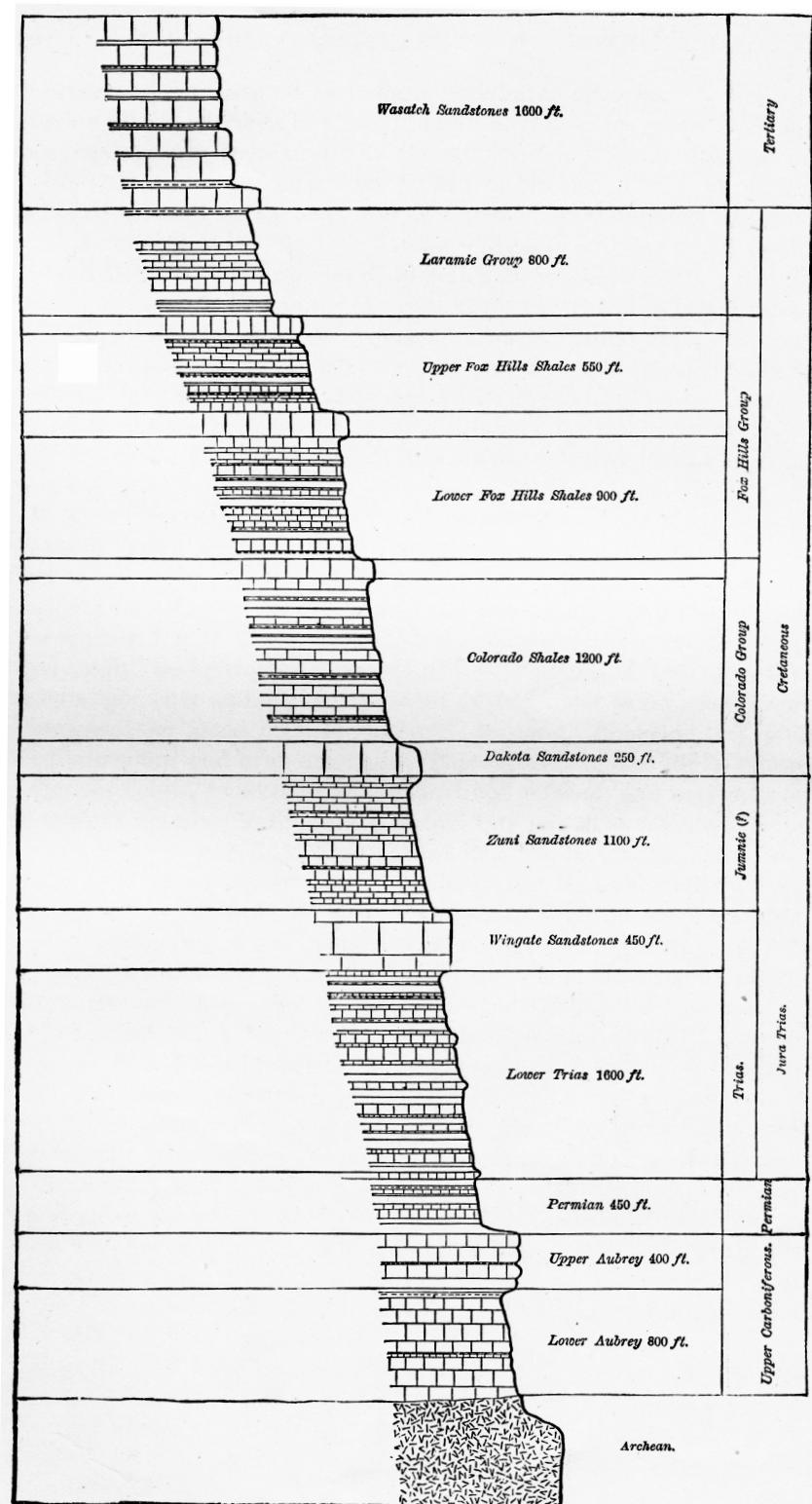
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APPENDIX—MEASURED STRATIGRAPHIC SECTION

Measured in the SW1/4 sec. 27, T13N, R2W, Sandoval County (Fig. 1). Base of section at UTM zone 13, 314221E, 3910460N, and top at 314519E, 3910382N. Strata are flat lying.

| unit | lithology | thickness (m) |
|--------------------------|---|---------------|
| Dakota Formation: | | |
| <i>Paguate Member:</i> | | |
| 12. | Sandstone; dark yellowish brown (10 YR 4/2); fine-grained; subangular, quartzose; ferruginous; calcareous; concretionary; contains some bivalve shell fragments. | 0.6 |
| 11. | Sandstone; grayish orange (10 YR 7/4) and dark yellowish orange (10 YR 6/6); fine grained; subangular; quartzose; calcareous; ripple laminated. | 4.5 |
| 10. | Sandstone; grayish orange (10 YR 7/4) and dark yellowish orange (10 YR 6/6); fine grained; subangular; quartzose; calcareous; ripple laminated; very fossiliferous; <i>Acanthoceras amphibolum</i> zone, NMMNH fossil localities. | 1.5 |
| 9. | Sandstone; very pale orange (10 YR 8/2) and grayish orange (10 YR 7/4); very fine to fine grained; subangular; quartzose; some bioturbation on top of bed; trough crossbedded and ripple laminated. | 5.8 |
| 8. | Calcareneite; grayish orange (10 YR 7/4); ripple laminated and concretionary; forms a prominent notch. | 0.5 |
| 7. | Sandstone; very pale orange (10 YR 8/2) and grayish orange (10 YR 7/4); very fine to fine grained; subangular; quartzose; some bioturbation on top of bed; trough crossbedded and ripple laminated. | 3.2 |
| 6. | Sandstone; very pale orange (10 YR 8/2) and grayish orange (10 YR 7/4); very fine to fine grained; subangular; quartzose; some bioturbation on top of bed; ripple laminated. | 4.8 |
| <i>Mancos Shale:</i> | | |
| <i>Clay Mesa Member:</i> | | |
| 5. | Shale; medium gray (N3); calcareous; a few septarian limestone concretions. | 6.0 |
| 4. | Shale; light brownish gray (5 YR 6/1); not calcareous; contains a few thin lenses of bioturbated sandstone. | 7.0 |
| 3. | Limestone; light olive gray (5 Y 6/1) and pale brown (5 YR 7/2); large septarian concretions. | 0.3 |
| 2. | Shale; olive gray (5 Y 4/1); sandy; not calcareous. | 6.0 |
| Dakota Formation: | | |
| <i>Cubero Member:</i> | | |
| 1. | Sandstone; grayish orange (10 YR 7/4) and dark yellowish orange (10 YR 6/6); fine to medium grained; subangular; quartzose; not calcareous; extensively bioturbated. | |

- 1.



Dutton's (1885, pl. 16) summary of the stratigraphic section in west-central New Mexico.