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New Mexico Geology, v. 31, n. 3 pp. 59-64, Print ISSN: 0196-948X, Online ISSN: 2837-6420.
https://doi.org/10.58799/NMG-v31n3.59

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Abstract

A small assemblage of invertebrate fossils from the Cretaceous Dakota Sandstone at Arroyo del Yeso near Ghost Ranch, Rio Arriba County, New Mexico, is the first age-diagnostic fossil assemblage documented from the intertongued Dakota–Mancos succession in the Chama Basin. The fossils are assigned to the bivalves *Legumen* sp., *Exogyra* sp., *Inoceramus arvanus* Stephenson, and *I. prefragilis* Stephenson and the ammonite cf. *Acanthoceras amphibolum* Morrow. They indicate the *Acanthoceras amphibolum* Zone of middle Cenomanian age and support lithostratigraphic identification of the fossil-bearing strata as the Paguate Sandstone Tongue of the Dakota Sandstone.

Introduction

Newberry (1876) first identified Cretaceous strata in the Chama Basin of northern New Mexico, and many subsequent workers in the Chama Basin (e.g., Dane 1960; McPeek 1965; Landis and Dane 1967; Landis et al. 1973; Grant and Owen 1974; Saucier 1974) have recognized the Dakota Sandstone as an approximately 30–60-m-thick sandstone-dominated interval at or near the base of the Cretaceous section. The most recent synthesis of Dakota Sandstone stratigraphy in the Chama Basin (Owen et al. 2005) identified formal units of the intertongued Dakota–Mancos succession that were first identified to the south, in west-central New Mexico. These are, in ascending order, the Encinal Canyon and Oak Canyon Members of the Dakota Sandstone, the Cubero Sandstone Tongue of the Dakota Sandstone, the Clay Mesa Shale Tongue of the Mancos Shale, the Paguate Sandstone Tongue of the Dakota Sandstone, the Whitewater Arroyo Shale Tongue of the Mancos Shale, and the local Las Jollas bed of the Dakota Sandstone, an apparent localized correlative of the Twowells Sandstone Tongue of the Dakota Sandstone to the west (Owen et al. 2005; Fig. 1). Identification of these units has been based on detailed lithostratigraphic correlation of surface outcrops and subsurface data, particularly relying on correlation of regionally traceable bentonite beds of the Dakota–Mancos succession.

In west-central and central New Mexico, the Dakota–Mancos succession yields marine invertebrate fossil assemblages that identify several ammonite zones of middle Cenomanian age (e.g., Cobban 1977; Cobban and Hook 1989). These fossils are thus useful in correlation of the Dakota–Mancos succession, but no age-diagnostic fossils have been reported from the Dakota–Mancos succession in the Chama Basin. Here, we document a small but age-diagnostic assemblage of fossil invertebrates from the Dakota–Mancos succession at Arroyo del Yeso near Ghost Ranch in Rio Arriba County (Fig. 1). These fossils identify the *Acanthoceras amphibolum* ammonite zone of Cenomanian age and thus support correlation of the strata that produced them to the Paguate Sandstone Tongue of the Dakota Sandstone. They are the first biostratigraphically significant fossils to be reported from the Dakota Sandstone in the Chama Basin.

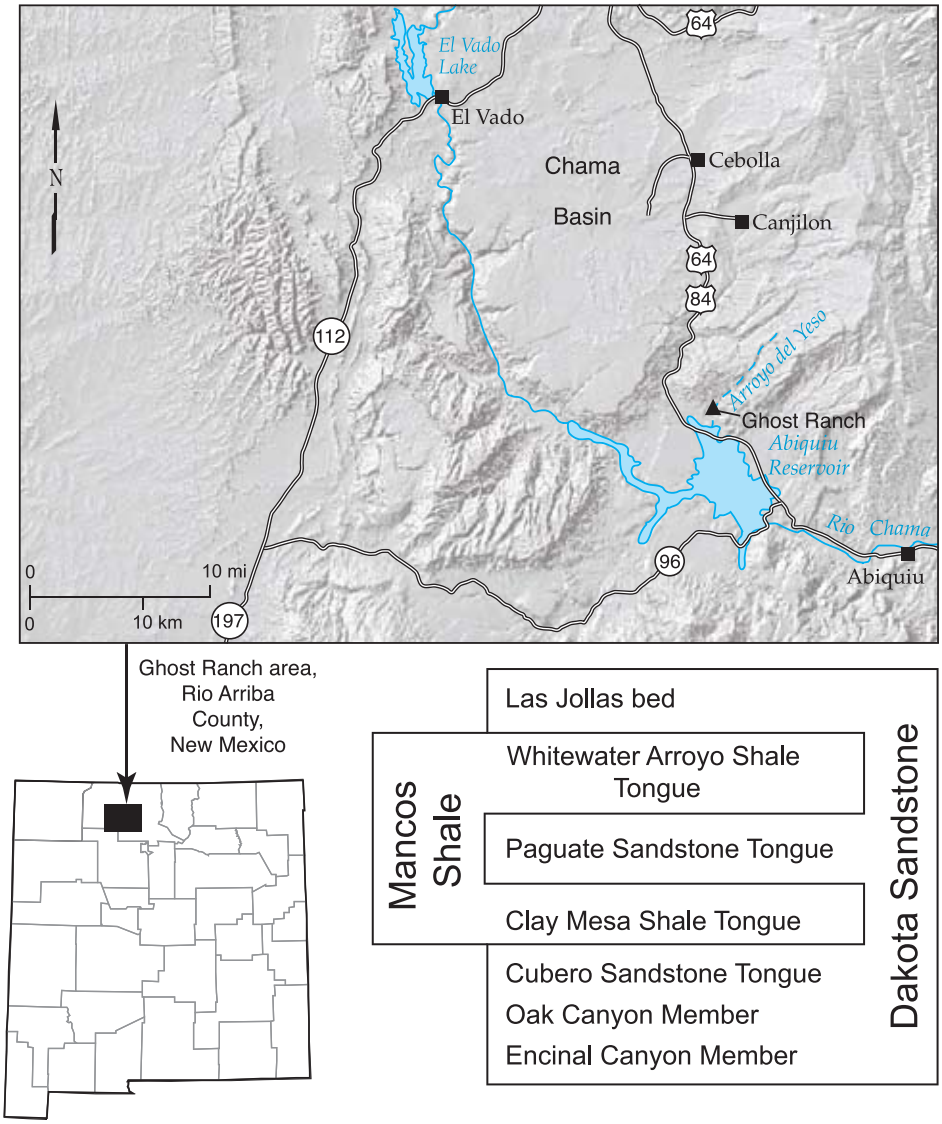

FIGURE 1—Map showing location of Ghost Ranch and chart of the stratigraphic terminology of the intertongued Dakota–Mancos succession in the Chama Basin.

In this article, NMMNH refers to the New Mexico Museum of Natural History and Science, Albuquerque.

Lithostratigraphy

The fossils reported here were collected as part of the mapping of the Ghost Ranch 7.5-min quadrangle by Koning et al. (2006). They were collected along the Arroyo del Yeso, where the lower part of the Cretaceous section is very well exposed (Figs. 2, 3, 4).

Along Arroyo del Yeso, the base of the Cretaceous section is the Burro Canyon

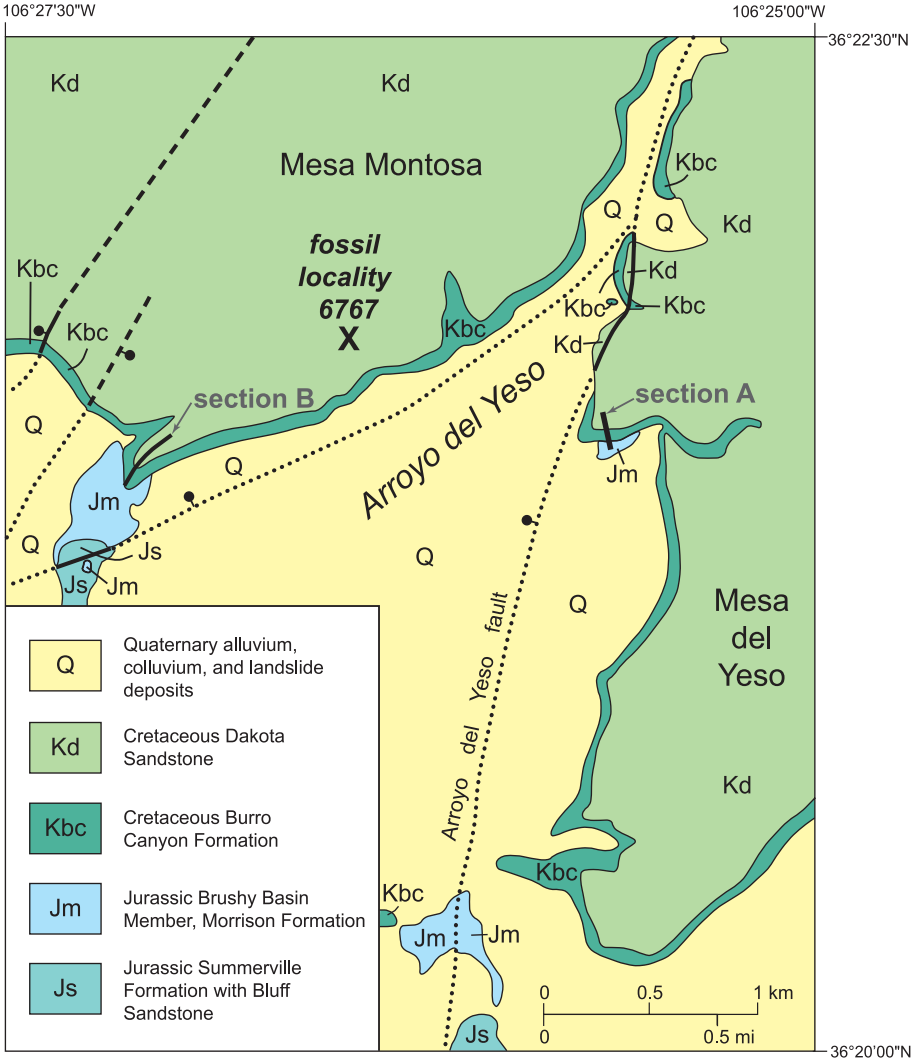

FIGURE 2—Geologic map of the Arroyo del Yeso area (after Koning et al. 2006).

Formation (Fig. 3), which rests disconformably on the Upper Jurassic Brushy Basin Member of the Morrison Formation (Koning et al. 2006). Here, the Burro Canyon Formation is as much as 40 m thick and consists of white, light-yellow, and buff conglomeratic sandstone with thin lenses of pale-green and pink mudstone (Saucier 1974). Small-scale trough crossbeds are evident in the conglomeratic channels and are more common near the base of the unit. Grant and Owen (1974) reported polymodal crossbedding from the Chama Basin Burro Canyon (their lower sandstone unit), including northerly and southerly modes at Mesa del Yeso. Conglomerate clasts are mostly varicolored quartzite and chert pebbles that reach a maximum of 2.5 cm in diameter, with a few sandstone and limestone clasts. Laminar, low-angle wedge and high-angle planar wedge crossbedding are common in the sandier parts of the unit. Chert gravel is rare near the top of the unit, but green and red mud rip-up clasts are common.

The Dakota Sandstone disconformably overlies the Burro Canyon Formation along Arroyo del Yeso (Fig. 3), as it does at many other Chama Basin outcrops (e.g., Saucier 1974; Owen et al. 2005; Koning et al. 2006). It mostly consists of tan to yellow-brown quartzose sandstone with thinner beds of dark-gray and brown carbonaceous shale, siltstone, and minor greenish-gray mudstone and bentonite. In ascending order, the members exposed are the Encinal Canyon, Oak Canyon, Cubero, and Paguate (Figs. 3, 4).

The Encinal Canyon Member is quite variable in thickness and can be as much as 10 m thick locally. This unit is absent elsewhere, and the Oak Canyon Member sits directly on the Burro Canyon Formation. The Encinal Canyon Member consists of tan, crossbedded quartz sandstone (Fig. 4A) in thin to medium beds; woody plant impressions are common at the upper contact. The fine- to medium-sized sand grains are subangular to subround and well sorted. Bioturbation is not common in the Encinal Canyon Sandstone.

The overlying Oak Canyon Member is much as 11 m thick and consists of black, muddy siltstone interbedded with thin (which here means beds thinner than 1 m) beds of ledgy and commonly lenticular, white to orange, crossbedded, bioturbated sandstone (Fig. 3). The Cubero Sandstone Tongue is mostly cliff-forming, thick-bedded, tabular (even-bedded) sandstone approximately 34 m thick (Figs. 3, 4B–E). It is orange to tan, with fine- to medium-grained, subangular, well-sorted sand grains and is mostly intensely bioturbated, though in places remnant crossbedding, ripple marks, and thin to thick bedding is preserved. Approximately 7 m above the base of the Cubero Sandstone Tongue is a locally persistent, 1–3-m-thick interval of black sandy shale and siltstone with thin (2–3 cm) beds of ripple-laminated sandstone (Fig. 3). This separates lower and upper parasequences of the Cubero regionally (Owen et al. 2005).

The upper part of the Dakota Sandstone at Arroyo del Yeso is the Paguate Sandstone Tongue. It is approximately 17 m thick and consists of grayish-yellow, thin-bedded sandstone and siltstone that forms a distinctive, rusty-yellow slope (Figs. 3, 4E–F). The local top of the Paguate is a bench-forming, white quartz sandstone (Fig. 4F) that caps the highest knobs on Mesa Montosa and Mesa del Yeso. Bentonite X, a widespread tuffaceous deposit that is present in the Whitewater Arroyo Shale Tongue of the Mancos Shale approximately 3–6 m above the top of the Paguate Sandstone Tongue (Owen et al. 2005), was not encountered in either measured section or observed during mapping of the mesa tops. The mesa tops are covered by Quaternary eolian deposits reworked by sheetwash that are as much as 3 m thick, so the chances of finding the bentonite on the mesas are small.

The fossils documented here are from NMMNH locality 6767 in unit 27 of our measured section B, Arroyo del Yeso (Fig. 3). The fossils are preserved in lenses of grayish-orange, medium- to coarse-grained, subangular, quartzose sandstone. Most of the fossils are steinkerns, and what carbonate shell material remains is recrystallized.

Paleontology

Legumen sp.

One bivalve from locality 6767, NMMNH P-57138 (Fig. 5A), is elongate and narrow with a small beak about one-fourth of the distance from the edge of the shell. This specimen is very similar to illustrated specimens of *Legumen ellipticum* (e.g., Cobban 1977, pl. 9, figs. 1–3; Sealey and Lucas 2003, fig. 3A). However, the fossil is too poorly preserved to be confidently assigned to a species of *Legumen*.

Exogyra sp.

The most common fossils at locality 6767 are steinkerns of a small, moderately convex bivalve with a coiled beak (e.g., Fig. 5B–C). These are readily referred to *Exogyra*, but without more complete material a species-level identification is not possible (cf. Stephenson 1952, pl. 18, figs. 1, 4, 5).

Inoceramus arvanus Stephenson

The most common inoceramid bivalve from localitiy 6767 (specimens are NMMNH P-57128–57133) is a prosoclinal

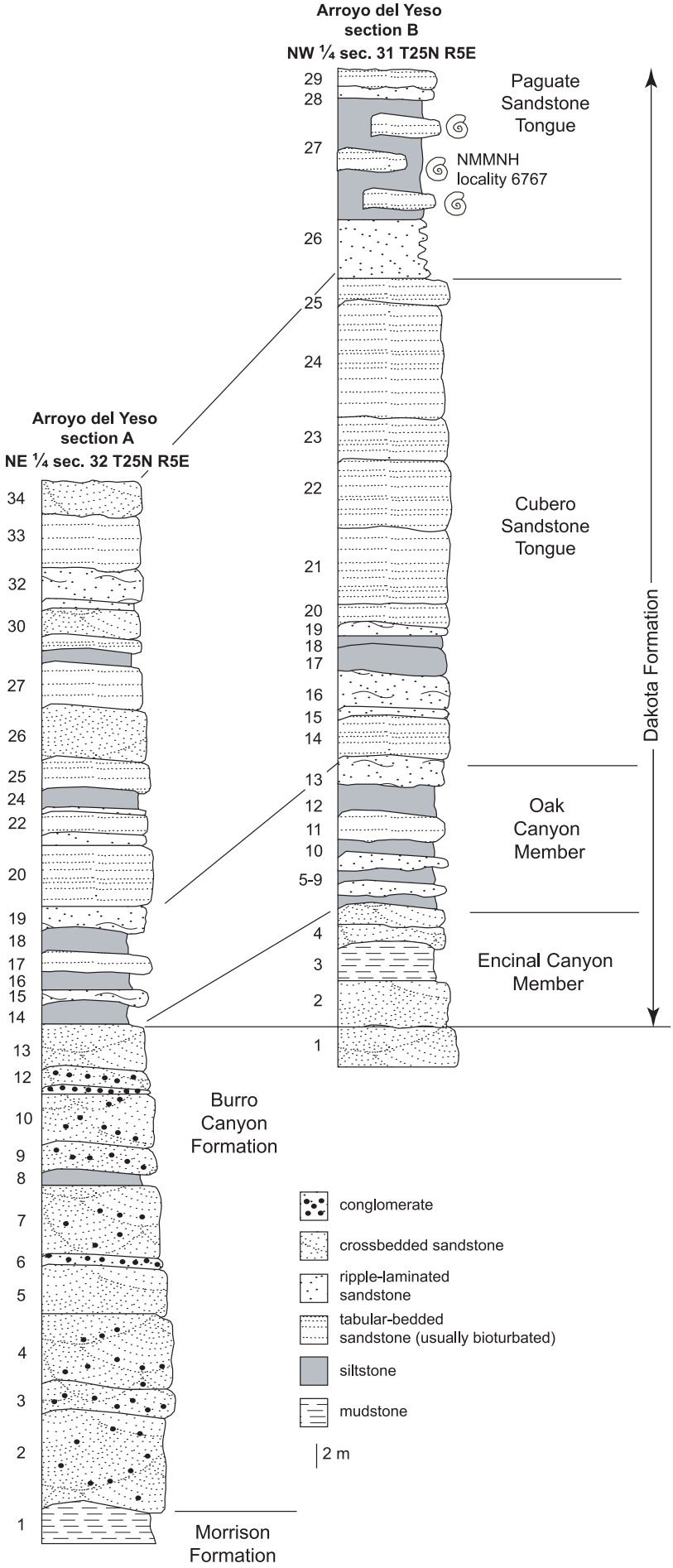

FIGURE 3—Measured stratigraphic sections of Burro Canyon and Dakota Formations along Arroyo del Yeso, Ghost Ranch 7.5-min quadrangle.

form characterized by a subquadrate outline, distinct auricles and sulci and fine growth lines between irregularly spaced concentric folds (Fig. 5D–E). It closely resembles illustrated specimens of *Inoceramus arvanus* (e.g., Stephenson 1952, pl. 12, figs. 6–9, 1955, pl. 4, figs. 1–3; Cobban 1977, pl. 6, fig. 27; Kauffman 1977, pl. 4, fig. 5; Akers and Akers 2002, fig. 87; Lucas and Lawton 2005, fig. 4C–D).

Inoceramus prefragilis Stephenson

One inoceramid (NMMNH P-57135: Fig. 5F) from locality 6767 has a prominent terminal beak that is strongly incurved, a straight anterior margin and ornamentation of closely spaced, low, narrow, concentric ridges that are most prominent umbonally. It closely resembles illustrated specimens of *Inoceramus prefragilis* (e.g., Stephenson 1952, pl. 12, figs. 10–12; Cobban 1977, pl. 19, figs. 1–2, 4; Lucas et al. 1998, fig. 11A; Lucas 2002, fig. 2D–E; Lucas and Lawton 2005, fig. 4A).

Cf. *Acanthoceras amphibolum* Morrow

Specimens of ammonites from locality 6767 consist of shell fragments with strong tubercles cataloged as NMMNH P-57126 and 57127. One specimen (NMMNH P-57127; Figs. 5G–H, 6) preserves a suture line very similar to that of *Acanthoceras amphibolum*, which does have similar tubercles. Thus, note the close match of suture lines between NMMNH P-57127 from locality 6767 to that of NMMNH P-7898, a nearly complete specimen of *A. amphibolum* illustrated by Sealey and Lucas (2003, fig. 4C–E) from the Paguate Sandstone Tongue along the Rio Puerco of west-central New Mexico (Fig. 6). Based on these features, we assign the locality 6767 ammonite fragments to cf. *A. amphibolum*. These fossils are found at about the same stratigraphic position with respect to the base of the Paguate at Ghost Ranch (12 m above the base) and along the Rio Puerco (16 m above the base).

The reason we do not present a more definite identification of the ammonite fragments from NMMNH locality 6767 is that they are also very similar to tubercles and the suture line of *Plesiacanthoceras wyomingense* (e.g., Reagan 1924; Hattin 1968; Cobban 1977, 1987). Indeed, the incomplete ammonite fragments from locality 6767 could belong to *P. wyomingense*, which is known from the Paguate Sandstone Tongue in west-central New Mexico (Cobban 1977; Cobban and Hook 1989). Pending more complete material, we thus tentatively identify the ammonite fragments from NMMNH locality 6767 as cf. *Acanthoceras amphibolum*.

Discussion

The inoceramid and ammonite fossils described here from NMMNH locality 6767 near Ghost Ranch are certainly of

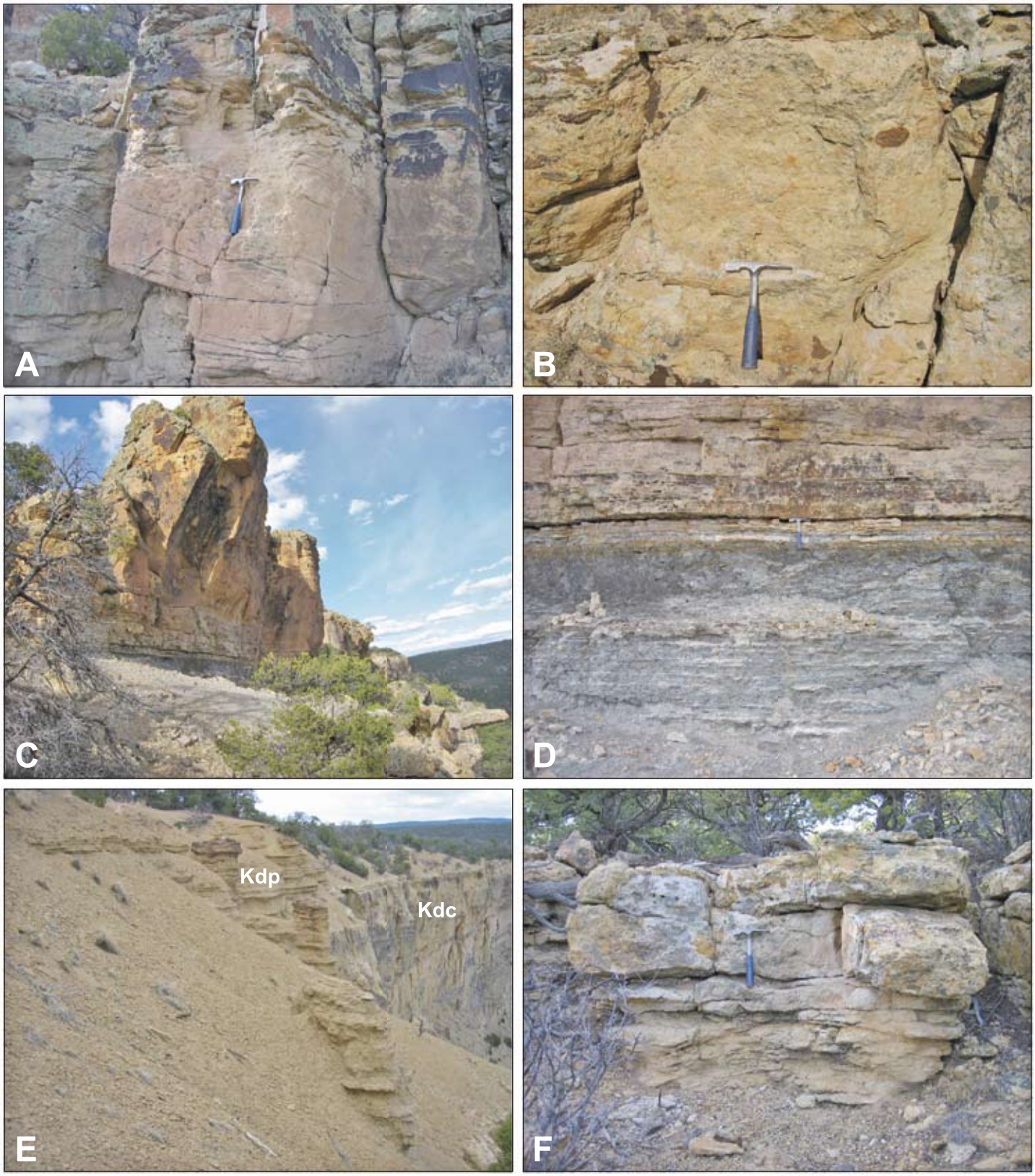

FIGURE 4—Selected outcrops of the Dakota Formation at the Arroyo del Yeso section B (NW ¼ sec. 31 T25N R5E). **A**—Typical crossbedded sandstone of Encinal Canyon Member. **B**—Extensively bioturbated sandstone of Cubero Sandstone Tongue. **C**—Bold cliff of Cubero Sandstone Tongue. **D**—Close-up of sandstone above prominent siltstone interval (units 17–21 of Arroyo del Yeso section B in Fig. 3) of Cubero Sandstone Tongue. **E**—Ribbed slope of sandstone and siltstone of lower part of Paguate Sandstone Tongue (**Kdp**) above cliff of Cubero Sandstone Tongue (**Kdc**). **F**—Coarse, bioturbated sandstone at top of Paguate Sandstone Tongue outcrop (unit 29 of Arroyo del Yeso section B in Fig. 3).

middle Cenomanian age. The inoceramid bivalves *I. arvanus* and *I. prefragilis* are well-known middle Cenomanian taxa in Texas and the Western Interior (Kauffman et al. 1993; Cobban et al. 2006). The ammonite cf. *Acanthoceras amphibolum* from NMMNH locality 6767 also is consistent with the zone of *Acanthoceras amphibolum* of middle Cenomanian age (e.g., Cobban and Hook 1989; Cobban et al. 2006).

Koning et al. (2006) identified the slope-forming, fossiliferous strata at Arroyo

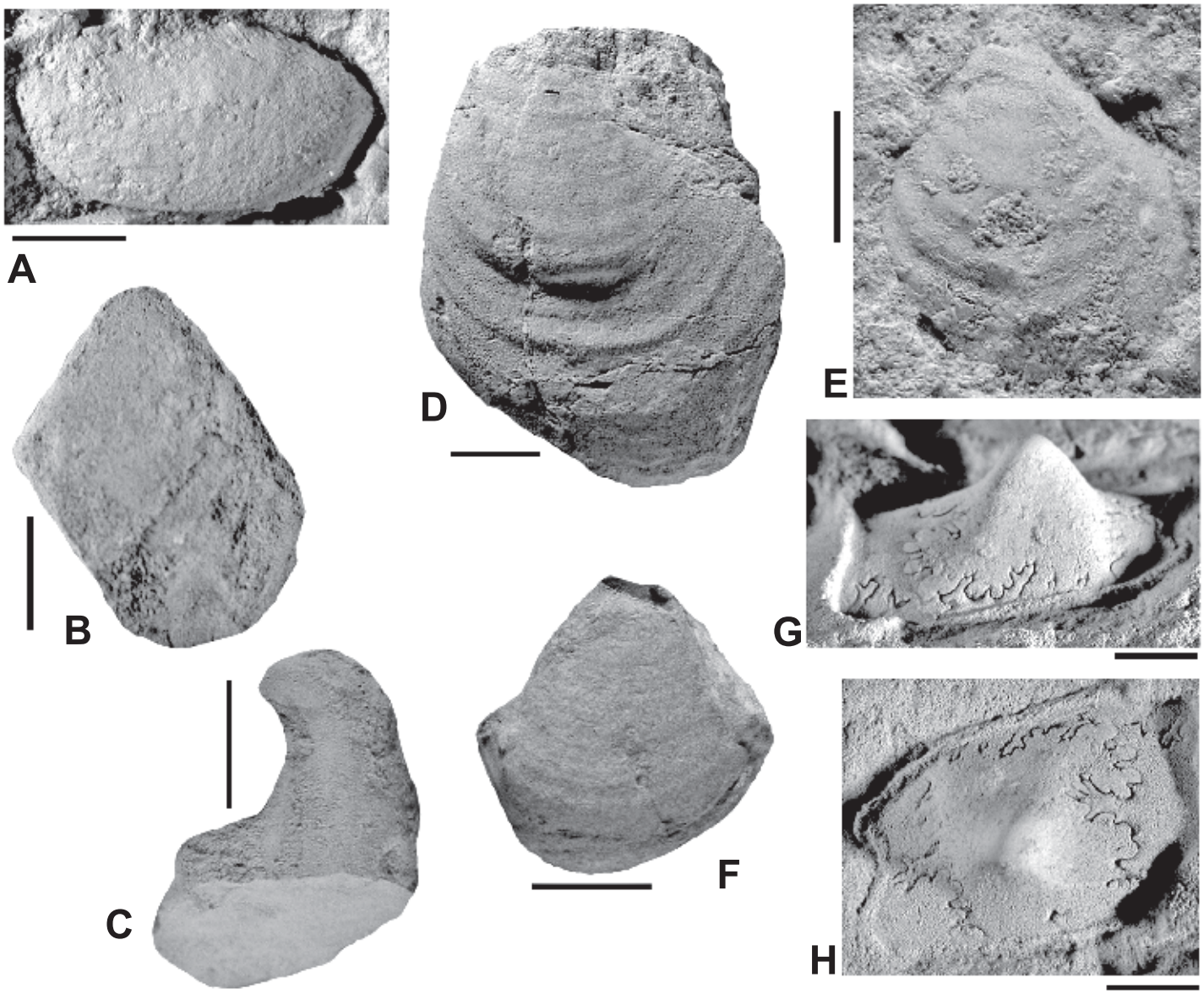

FIGURE 5—Selected middle Cenomanian invertebrate fossils from the Paguate Sandstone Tongue of the Dakota Sandstone at NMMNH locality 6767 **A**, NMMNH P-57138, *Legumen* sp. **B-C**, NMMNH P-57137, *Exogyra* sp. **D**, NMMNH P-57132, *Inoceramus arvanus*. **E**, NMMNH P-57130, *I. arvanus*. **F**, NMMNH P-57135, *I. prefragilis*. **G-H**, NMMNH P-57127, cf. *Acanthoceras amphibolum*. Bar scales = 1 cm.

del Yeso as the Whitewater Arroyo Shale Tongue of the Mancos Shale (units 26–27 of the Arroyo del Yeso section B in Fig. 3) overlain by an uppermost, ledge-forming sandstone approximately 2 m thick (units 28–29 of the Arroyo del Yeso section B in Fig. 3) that they assigned to the Twowells Tongue of the Dakota Sandstone. They also identified units 17–18 of the Arroyo del Yeso section B (Fig. 3) as the Clay Mesa Shale Tongue of the Mancos Shale, so they assigned units 19–25 to the Paguate Sandstone Tongue and units 14–16 to the Cubero Sandstone Tongue. However, the invertebrate fossils documented here do not support this purely lithostratigraphic correlation. Indeed, the Whitewater Arroyo Shale Tongue yields invertebrate fossils of the *Plesiacanthoceras wyomingense* ammonite zone, which is a zone younger than the *Acanthoceras amphibolum* ammonite zone (cf. Cobban and Hook 1989; Cobban et al. 2006). The possibility that the Dakota–Mancos units are time transgressive regionally could allow an invertebrate assemblage of the *Acanthoceras amphibolum* Zone to be present in the Whitewater Arroyo Shale Tongue at Ghost Ranch. However, such time transgression has not been demonstrated anywhere in the intertongued Dakota–Mancos succession, although a condensed interval of five of the six middle Cenomanian ammonite zones has been reported recently from Socorro County (Hook and Cobban 2007).

As Owen et al. (2005) noted, the Cubero Sandstone is relatively thick in the Ghost Ranch area. In contrast, the Paguate Sandstone is a poorly indurated, rusty-yellow slope-forming unit above the cliff-forming Cubero Sandstone (D. Owen, written comm. 2008). The Clay Mesa Member pinches out to the east and to the north of the Ghost Ranch area, so the Paguate Sandstone Tongue sits directly on a thick Cubero Sandstone Tongue that contains some locally persistent shaley intervals. No Twowells Sandstone is present in the Ghost Ranch area, but a siltstone equivalent of the Twowells is present at El Vado Dam, and the localized Las Jollas bed is present south of Cebolla and Canjilon.

The fossils documented here thus support the lithostratigraphic correlations of Owen et al. (2005) and require some modification of the member assignments by Koning et al. (2006) of the intertongued Dakota–Mancos succession in the Ghost Ranch area. The unit identified as the Paguate Sandstone Tongue of the Dakota Sandstone in the southern Chama Basin on a lithostratigraphic basis by Owen et al. (2005) contains an invertebrate fossil assemblage of "Paguate age" (middle Cenomanian *Acanthoceras amphibolum* ammonite zone) at Arroyo del Yeso near Ghost Ranch.

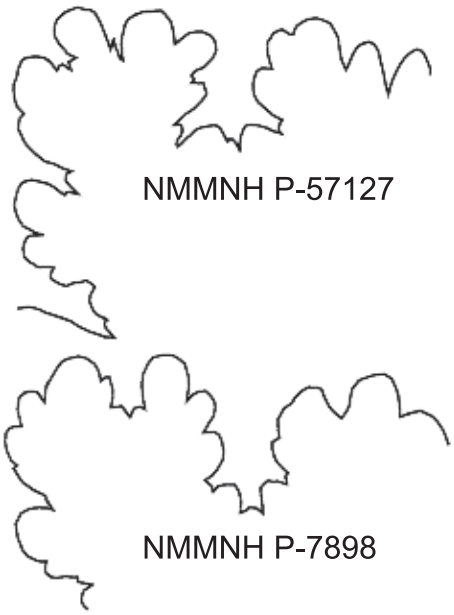

FIGURE 6—Suture lines of two specimens of the ammonite *Acanthoceras amphibolum*. **NMMNH P-57127** from locality 6767 at Arroyo del Yeso near Ghost Ranch and **NMMNH P-7898** from the Paguate Sandstone Tongue of the Dakota Sandstone along the Rio Puerco (see Sealey and Lucas 2003).

Acknowledgments

Don Owen provided helpful comments on the stratigraphy. Reviews by Neal Larson, Norman King, and Don Owen improved the manuscript.

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