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CRETACEOUS STRATIGRAPHY AND BIOSTRATIGRAPHY IN THE SOUTHERN SAN ANDRES MOUNTAINS, DOÑA ANA COUNTY, NEW MEXICO

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Abstract—Cretaceous strata exposed in the southern San Andres Mountains belong to the Sarten, Dakota, Mancos, Tres Hermanos, and Gallup Formations. The Sarten Formation is as much as 12.3 m thick and mostly consists of very fine, silty hematitic sandstone. A poorly preserved Late Albian fossil assemblage from the Sarten Formation is dominated by specimens of the bivalves *Texigryphaea washitaensis*, *Protocardia texana*, and *Neithea texana*. The Dakota Sandstone is as much as 50 m thick and consists mostly of trough-crossbedded quartzarenitic sandstone. The 13-m-thick Rio Salado Tongue of the Mancos Shale above the Dakota contains a thin nodular limestone interval 4.5 m above its base correlated to the Bridge Creek Member of the Greenhorn Limestone. The Rio Salado strata produce inoceramids and ammonoids that indicate they belong to the *Mammites nodosoides* Zone of late Early Turonian age. The Atarque Sandstone is 14 m thick, mostly fine-grained sandstones and produces a bivalve assemblage dominated by *Lopha bellaplicata*. The overlying 11 m of marine(?) shale are assigned to the D-Cross Tongue of the Mancos Shale. The preserved Cretaceous section in the southern San Andres Mountains is capped by about 27 m of sandstone assigned to the Gallup Sandstone.

INTRODUCTION

Cretaceous strata that crop out on the White Sands Missile Range in the southern San Andres Mountains in Doña Ana County (Fig. 1) are one of the southernmost outcrops of Upper Cretaceous strata deposited in the Western Interior Basin, and one of the northernmost outcrops of Lower Cretaceous strata deposited in the Tethyan marine embayment often termed the Chihuahua trough or Bisbee Basin. Therefore, the Cretaceous strata exposed in the southern San Andres Mountains provide a potential link in the correlation of strata of two distinct depositional systems. Here, we describe the stratigraphy and biostratigraphy of these rocks, and present their regional correlation. NMMNH refers to the New Mexico Museum of Natural History and Science, Albuquerque.

PREVIOUS STUDIES

Kottlowski et al. (1956) provided most of what is known in the published literature about Cretaceous strata exposed in the southern San Andres Mountains. They assigned these strata to the Sarten Formation, Dakota(?) Sandstone and Mancos–Eagle Ford "Beds" (Fig. 2). Seager (1981) provided the only other published treatment of the Cretaceous section in the southern San Andres Mountains, based in part on the unpublished studies of S. C. Hook. Seager (1981) assigned the Cretaceous section to the Sarten, Dakota, Mancos (including Tres Hermanos Member), and Gallup Formations (Fig. 2). The stratigraphic units we recognize are similar to Seager's scheme (Fig. 2); the main difference is that we assign less strata to the Sarten Formation than did previous workers (see below).

STRATIGRAPHY

Lower Cretaceous

Sarten Formation

Like previous workers, we assign the oldest Cretaceous strata in the southern San Andres Mountains to the Sarten Formation (Fig. 3). Here, strata of the Sarten Formation are as much as 12.3 m thick and are mostly very fine, silty, hematitic sandstone. Sandy shale and bioclastic limestone are minor lithologies (Fig. 4B). Grayish orange, moderate yellowish brown and dark yellowish orange are characteristic colors. A poorly preserved late Albian bivalve-dominated fossil assemblage is found in these rocks (see below).

Strata of the Sarten Formation rest with profound erosional and angular unconformity on dark gray, micritic limestone of the Permian San Andres Formation (Fig. 3). Both Kottlowski et al. (1956) and Seager (1981) expressed uncertainty about the upper contact of the Sarten with the Dakota Sandstone. Kottlowski et al. (1956) assigned about 30 m of strata to the Sarten, but Seager (1981) mapped the Sarten and Dakota together as a single unit. However, in his summary stratigraphic section, Seager (1981, sheet 3) assigned about 55 m of strata to the Sarten, and only about 15 m to the Dakota.

We identify the base of the Dakota Sandstone at a distinct change in lithology from the immature, silty sandstones of the Sarten Formation to much more mature quartzarenites of the Dakota. This placement of the contact identifies a much thicker Dakota (~50 m) than Sarten (~12 m) in the southern San Andres Mountains. However, G. Mack (written commun., 1998) suggests the Sarten and Dakota may be of nearly equal thickness in the southern San Andres Mountains.

Upper Cretaceous

Dakota Sandstone

Strata we assign to the Dakota are as much as 50 m thick and consist mostly of trough-crossbedded quartzarenitic sandstone (Fig. 4D). They typically form a ridge or hogback in the southern San Andres Mountains between a short, slope-forming interval of the Sarten Formation and a much longer slope of Mancos Shale (Fig. 4A, C). No fossils other than indeterminate burrows and plant impressions were observed in the Dakota Sandstone.

Rio Salado Tongue of Mancos Shale

Shaly strata up to 13 m thick overlie the Dakota Sandstone in the southern San Andres Mountains (Figs. 3, 4E–F). These strata are extremely fossiliferous, yielding a diverse assemblage of bivalves and ammonoids (see below) that supports correlation to the Rio Salado Tongue of the Mancos Shale northward.

Bridge Creek Member of Greenhorn Limestone

A thin (0.2- to 0.3-m-thick) limestone concretion zone 4.5 m above the base of the Rio Salado Tongue (Fig. 3) may represent the Bridge Creek Member of the Greenhorn Limestone (Hattin, 1975).

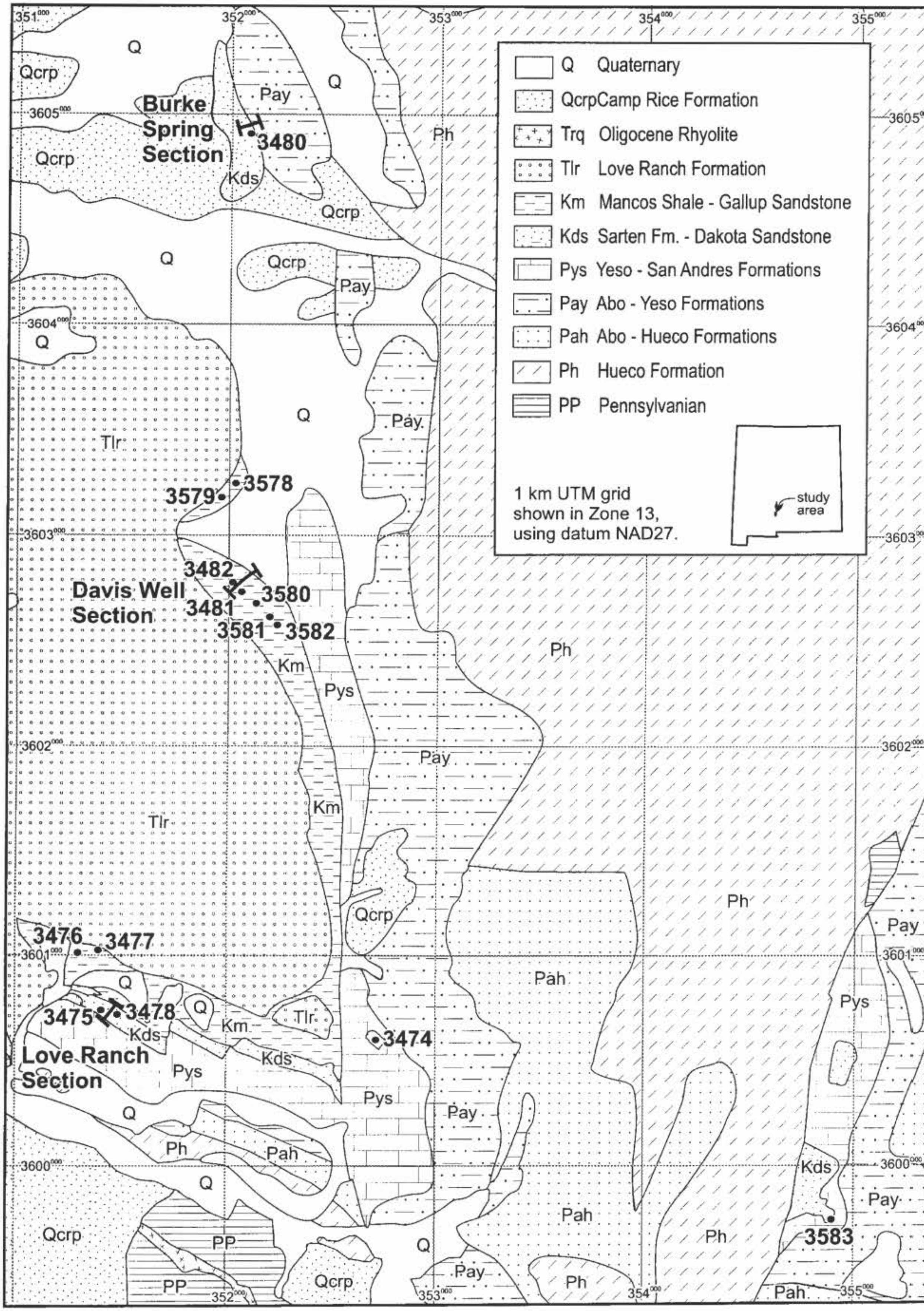

FIGURE 1. Map showing location of Cretaceous outcrops, measured sections, and fossil localities in the southern San Andres Mountains.

Stratigraphic position and lithology justify assignment of this zone to the Bridge Creek Member, but no fossils were found in the limestones.

Atarque Sandstone

Strata we assign to the Atarque Sandstone are only exposed at the Davis Well section (Figs. 3, 4E). They are about 14 m thick and consist of yellowish gray, yellowish brown, and olive-gray fine-grained sandstones and thin bioclastic limestones that produce numerous shells of *Lopha bellaplicata*.

D-Cross Tongue of Mancos Shale

In the Davis Well section, 11 m of medium gray shale with limestone nodules forms a largely covered slope above the Atarque Sandstone (Figs. 3, 4E). No fossils were found in this unit, but lithology and stratigraphic position support correlation to the D-Cross Tongue of the Mancos Shale (see below).

Gallup Sandstone

The Cretaceous strata exposed at the Davis Well section are capped by about 27 m of sandstone that we correlate to the Gallup Sandstone (Figs. 3, 4E), although, strictly speaking, they may in part also be correlative to the lower part of the Crevasse Canyon Formation (Mesaverde Group). These strata are light olive-gray and yellowish brown, silty trough-crossbedded litharenites. Some coquinoid limestone lenses are present, but we could not recover identifiable fossils. Limestone-cobble conglomerate of the Eocene(?) Love Ranch Formation unconformably overlies the Gallup Sandstone at Davis Well (Figs. 3, 4E).

BIOSTRATIGRAPHY

Two stratigraphically-distinct assemblages of invertebrate fossils can be recognized in the Cretaceous strata exposed in the southern San Andres Mountains. These are from the upper Albian (Sarten Formation), and lower Turonian (Rio Salado Tongue of the Mancos Shale and Atarque Sandstone).

Upper Albian

We collected a poorly preserved, bivalve-dominated assemblage from four localities in the Sarten Formation: NMMNH L-3475, L-3478, L-3480, and L-3583 (Figs. 1, 3, 4B). These localities produce three characteristic late Albian bivalves: *Texigryphaea navia* (Hall) (Fig. 5A-B), *Protocardia texana* Conrad (Fig. 5C), and *Neithea texana* (Roemer) (Fig. 5D).

Specimens of *T. na ia* (NMMNH P-26990 from locality L-3475, P-27021 from locality L-3480, and P-26972 from locality L-3583) are relatively small (left valve height < 35 mm), have thick valves, and possess a well-developed keel from near the beak to the ventral margin (cf., Kues, 1989). Poorly preserved specimens of *Protocardia texana* (NMMNH P-26988 from locality L-3475, P-27019 and P-27020 from locality L-3480, and P-26973 from locality L-3583) have rounded concentric ribs with interspaces wider than the ribs (cf., Scott, 1986, p. 1198, fig. 12.11). Specimens of *Neithea texana* (NMMNH P-26989 from locality L-3475 and P-26992 from locality L-3480) have ribs subequal in size with relatively narrow interspaces (cf., Adkins, 1928, p. 127, pl. 17, fig. 4; Stanton, 1947, pl. 38, fig. 5, pl. 39, fig. 5.)

Other fragmentary and poorly preserved bivalves are present in the Sarten Formation, but cannot be identified. *Texigryphaea*, *Protocardia* and *Neithea* are also known in the lower assemblage of the Sarten Formation in the Cooke's Range (Lucas et al., 1988). The species of these genera identified in the southern San Andres Mountains are also known from the Smeltertown and Muleros

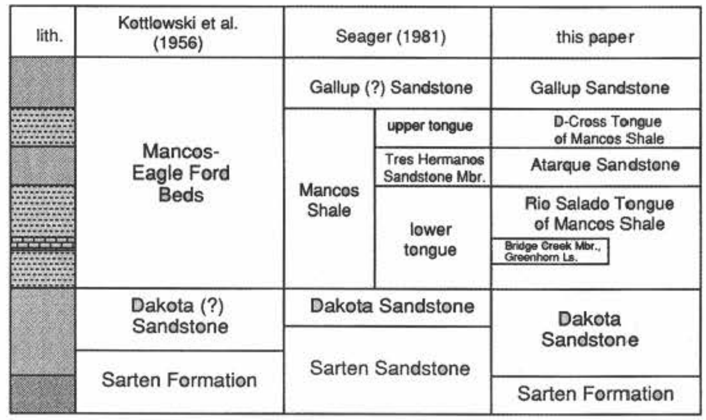

FIGURE 2. Evolution of stratigraphic nomenclature applied to Cretaceous rocks exposed in the southern San Andres Mountains.

Formations at Cerro de Cristo Rey near El Paso (Bóse, 1910; Strain, 1976). These are units of well-established late Albian age, as is the lower Sarten Formation (e.g., Lucas et al., 1988). Therefore, we assign a late Albian age to the Sarten Formation in the southern San Andres Mountains. Precise correlation of these strata to an upper Albian ammonite zone is not possible with the data at hand, but the most likely correlation is to either the *Eopachydiscus marcianus* Zone, or the *Mortoniceras equidistans* Zone, or to both.

Lower Turonian

An ammonite- and inoceramid-dominated assemblage was collected throughout the Rio Salado Tongue of the Mancos Shale at the Davis Well section (Fig. 3).

Bivalves from the Rio Salado Tongue are mostly inoceramids, but include numerous *Pleuriocardia (Dochmocardia) pauperculum* (Meek) (Fig. 5E). These are small, have a prominent beak, an inflated shell and more than 25 radiating costae (cf., Stanton, 1893, p. 99, pl. 22, figs. 9–12). They occur at NMMNH localities L-3474, 3477, 3578, 3582 and 3583.

The inoceramids from the Rio Salado Tongue are dominated by specimens of *Mytiloides incertus* (Jimbo) (Fig. 5F-G) and were collected at NMMNH localities L-3474, 3476, 3479, 3481 and 3579. The *M. incertus* have a slightly oval outline, distinct sharp-edged ribbing with ribs eccentrically placed around the beak, and 3–4 weaker, less distinct intermediate growth lines. Other inoceramid taxa are present in our collections, but we did not attempt precise identifications.

Baculites yokoyami Tokunaga and Shimizu (Fig. 5L–M) is common in some concretions in the Rio Salado Tongue at NMMNH localities L-3476, L-3481, L-3579 and L-3581. These baculites are straight with a slight taper, have an oval, slightly elongated cross section and have delicate, closely-spaced ribs across the venter that arc toward the aperture (cf., Cobban and Hook, 1983, p. 7, pl. 1, figs. 1–7).

The most common ammonite in the Rio Salado Tongue is *Placenticeras cumminsi* Cragin (Fig. 6F-I) from NMMNH localities L-3479, 3481 and 3579. These ammonites have smooth body chambers, diameters range from 30 to 130 mm, and the development of ventral tubercles is variable (cf., Cobban and Hook, 1983, p. 8, pl. 3, figs. 12–18, pl. 5, figs. 4–5).

Specimens of *Cibolaites molenaari* Cobban and Hook (Fig. 6A–B) from NMMNH localities L-3479, 3481 and 3579 have straight, radial ribs that continue from the umbilical shoulder to the ventro-lateral shoulder, with umbilical nodes on every other rib.

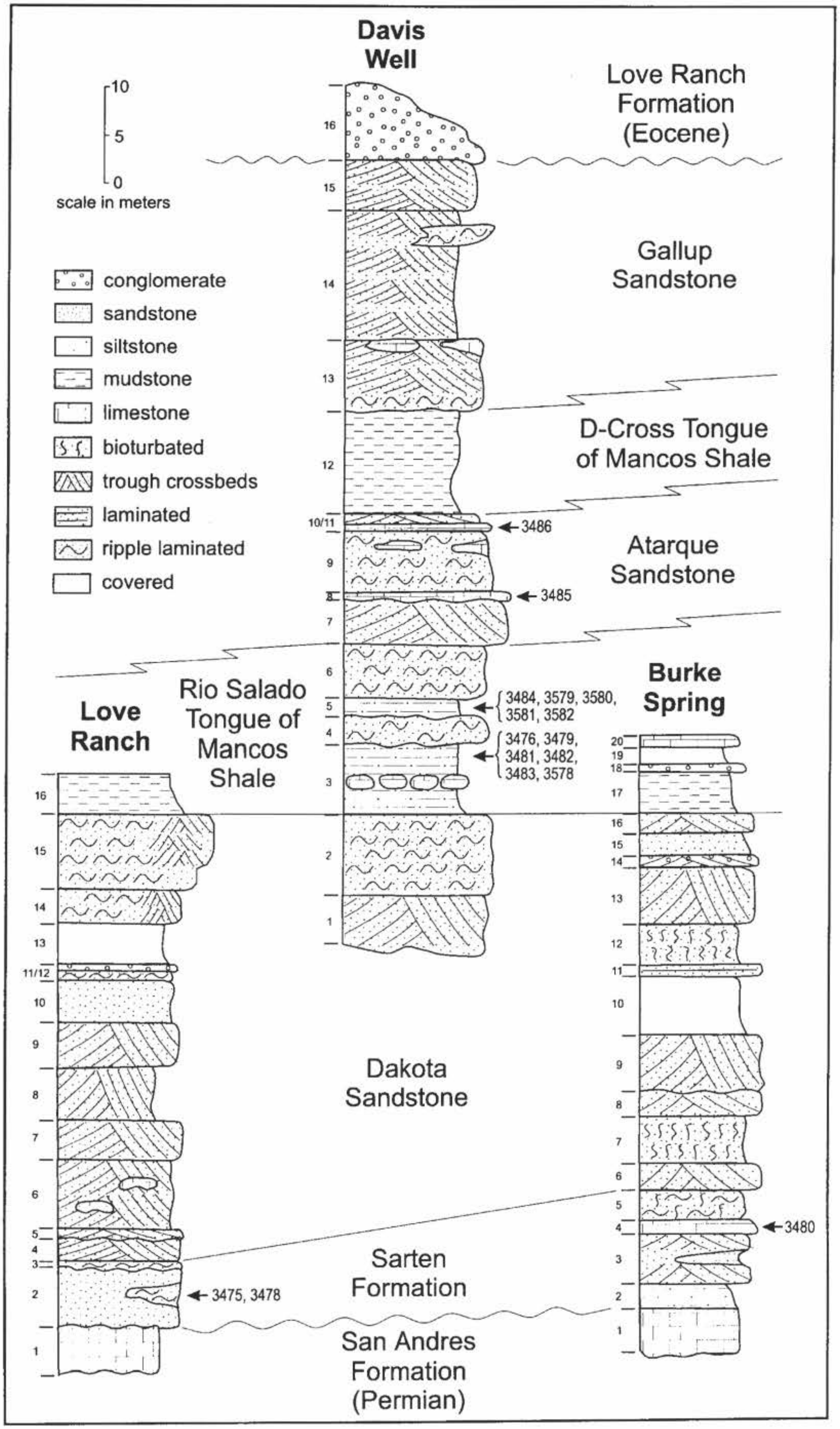

FIGURE 3. Correlated measured sections of Cretaceous strata exposed in the southern San Andres Mountains. See Appendix for description of numbered lithologic units.

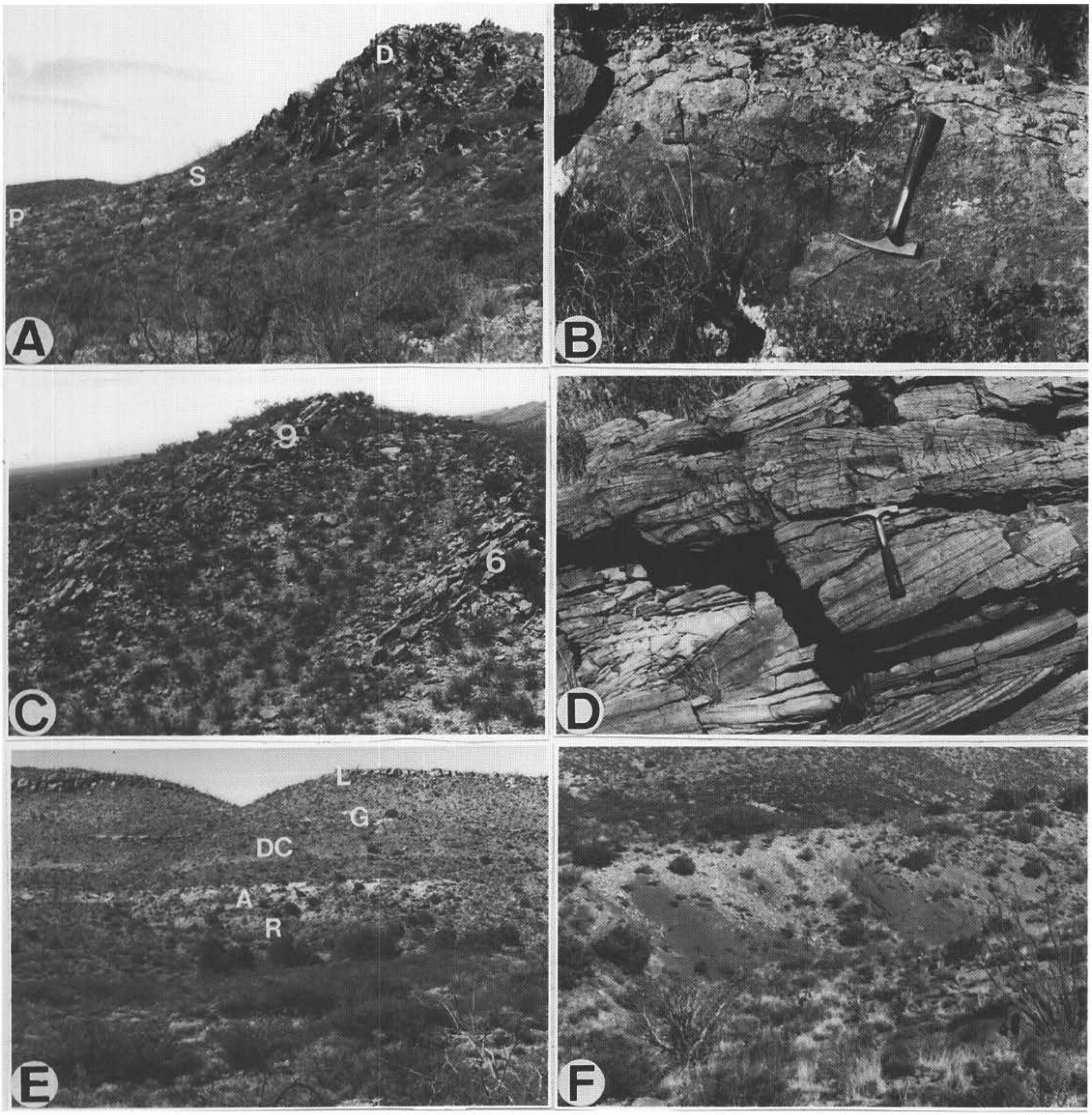

FIGURE 4. Selected outcrops of Cretaceous strata in the southern San Andres Mountains. **A,** View of lower part of Love Ranch section, showing San Andres Formation limestones (P) overlain by slope-forming sandstones of Sarten Formation (S) capped by hogback of Dakota Sandstone (D). Note that strata are overturned toward the left of the photograph. **B,** Closeup of fossiliferous, bioclastic limestone in lower part of Sarten Formation in Burke Spring section (NMMNH locality L-3480). **C,** Overview of Dakota Sandstone in the Burke Spring section. Units 6 and 9 of the measured section are labeled. **D,** Closeup of unit 6 of Dakota Sandstone in Burke Spring section. **E,** Overview of Davis Well section showing Rio Salado Tongue of Mancos Shale (R), Atarque Sandstone (A), D-Cross Tongue of Mancos Shale (DC), Gallup Sandstone (G) and Love Ranch Formation (L). **F,** Sandy shales and fine sandstones of Rio Salado Tongue of Mancos Shale at Davis Well section (units 3–6). Note that strata dip toward right of photograph.

Each rib has a clavate node on the outer lateral margin, terminating in a prominent, sharp-edged clavate node at the ventro-lateral shoulder. The venter also has clavate tubercles located slightly apical to the ventro-lateral nodes, which gives the venter a sinusoidal profile (cf., Cobban and Hook, 1983, p. 16, pl. 2, figs. 1–9, pl. 3, figs. 3–8, pl. 8, figs. 6–8, pl. 13, figs. 1–5).

A specimen of *Scaphites whitfieldi* Cobban (Fig. 6C) from NMMNH locality L-3476 has open coiling in the last half whorl, fine, close, equally spaced ribs with 18 strong primary ribs, and 3–4 finer ribs between them (cf., Cobban, 1951, p. 24, pl. 4, figs. 30–40, pl. 5, figs. 1–4).

Specimens of *Prionocyclus novomexicanus* (Marcous) (Figs. 6J–K)

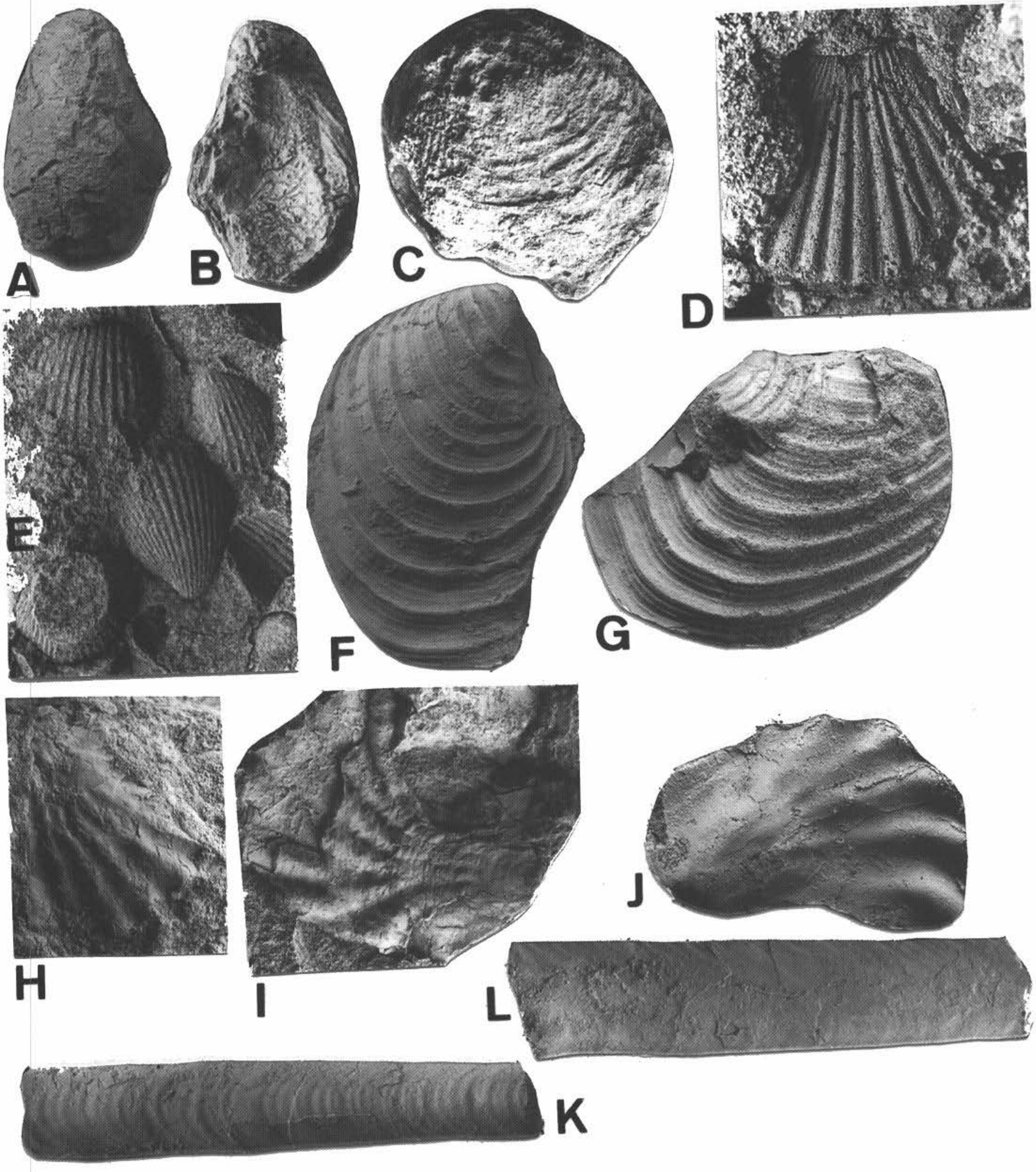

FIGURE 5. Cretaceous bivalves from the southern San Andres Mountains. **A–B,** *Texigryphaea navia,* NMMNH P-27244 from locality L-3475, x 1.3. **C,** *Protocardia texana*, NMMNH P-27243 from locality L-3480, x 1. **D,** *Neithea texana*, NMMNH P-27245 from locality L-3480, x 3. **E,** *Pleuriocardia pauperculum* (Meek), NMMNH P-27250 from locality L-3477, x 3. **F–G,** *Mytiloides incertus,* NMMNH P-27242 from locality L-3579, x 1.3. **H–J,** *Lopha bellaplicata*; (H), NMMNH P-27252 from locality L-3484, x 1.9; (I), NMMNH P-27266 from locality L-3582, x 2.5; (J), NMMNH P-27044 from locality L-3582, x 2.5. **K–L,** *Baculites yokoyamai*, NMMNH P-27267 from locality L-3581, x 1.7.

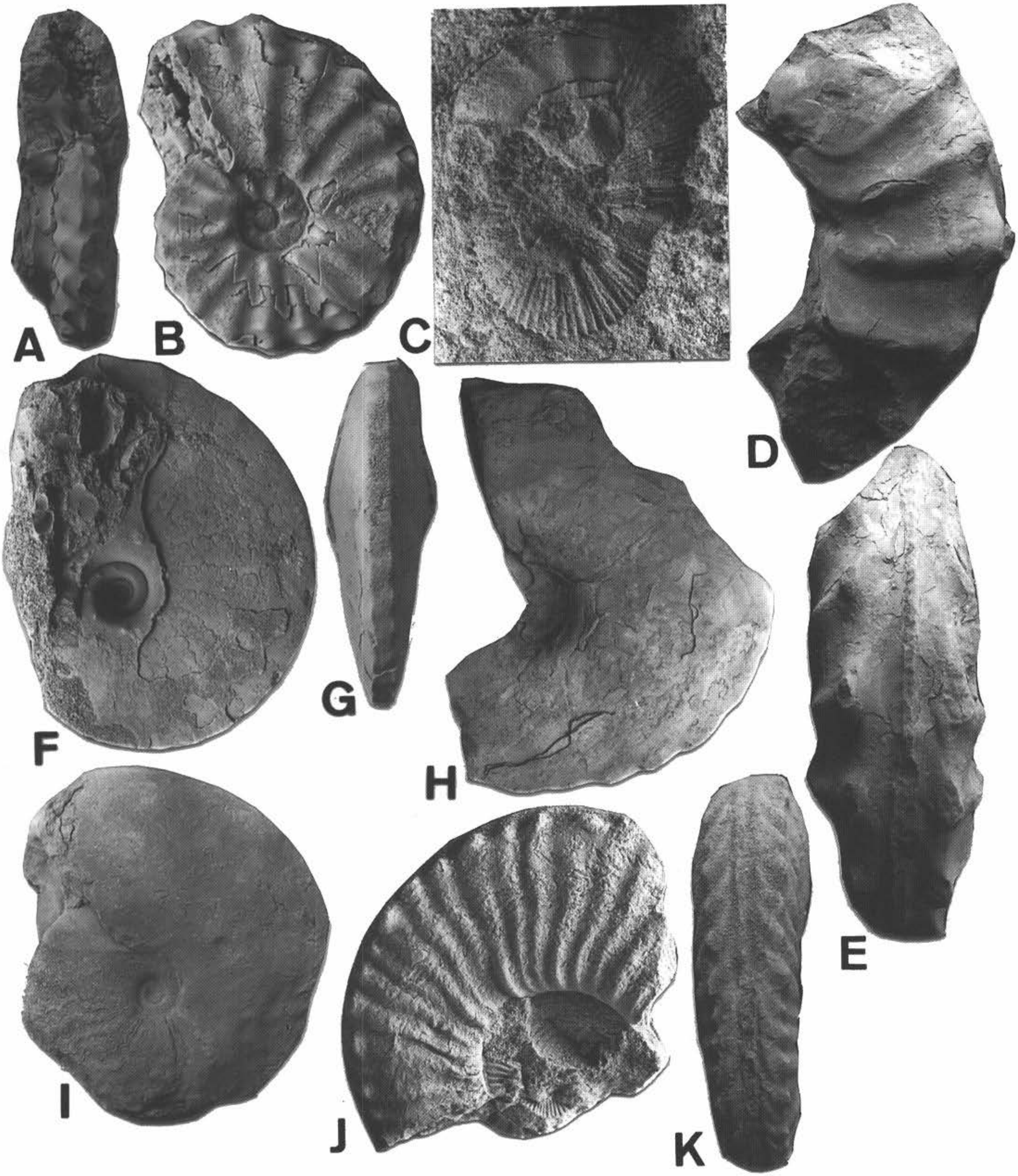

FIGURE 6. Ammonites from the Rio Salado Tongue of the Mancos. **A–B,** *Cibolaites molenaari*, NMMNH P-26984 from locality L-3476, x 1.1. **C,** *Scaphites whitfieldi*, NMMNH P-26985 from locality L-3476, x 1.8. **D–E,** *Prionocyclus* sp., NMMNH P-27004 from locality L-3579, x 0.6. **F–G,** *Placenticeras cumminsi*, NMMNH P-27248 from locality L-3479, x 1.3. **H,** *Placenticeras cumminsi*, NMMNH P-27015 from locality L-3380, x 0.3. **I,** *Placenticeras cumminsi*, NMMNH P-27247 from locality L-3479, x 0.3. **J–K,** *Prionocyclus novomexicanus*, NMMNH P-27251 from locality L-3477, x 2.

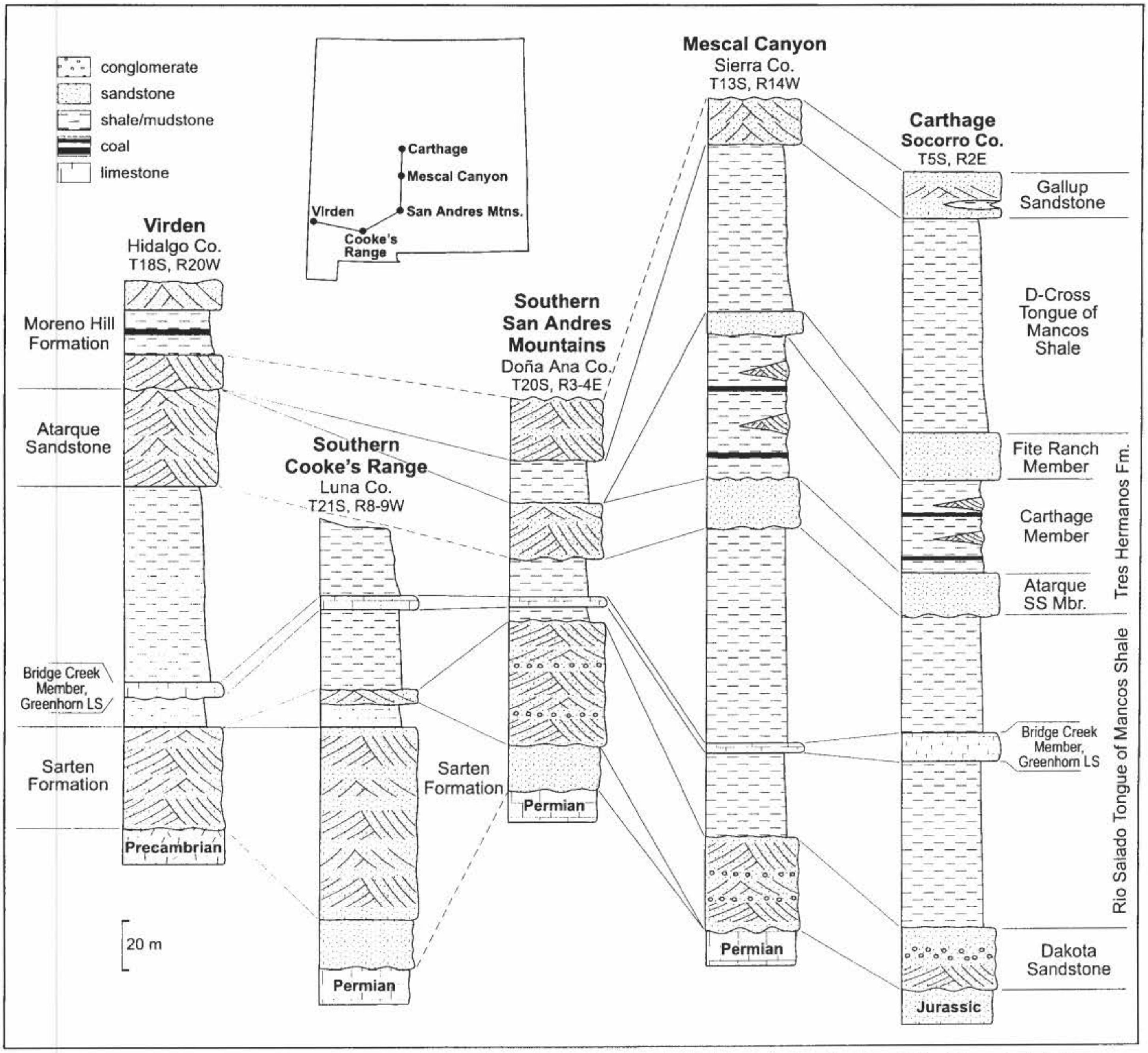

FIGURE 7. Correlation of Cretaceous strata in southwestern and south-central New Mexico. Virden section based on unpublished data. Cooke's Range section based on Lucas et al. (1988). Southern San Andres Mountains section from this paper. Mescal Canyon section based on Melvin (1963) and Wallin (1983). Carthage section from Hook et al. (1983).

and *Prionocyclus* sp. (Fig. 6D–E) from NMMNH localities L-3476, 3479, 3483 and 3579 are evolute with a strong ventral keel bordered by a sulcus. They have distinct ribs that start with a moderate umbilical node, extend to the ventro-lateral shoulder, and terminate with a large, sharp, horn-like clavate node. Ventro-lateral nodes extend ventrally (are higher than the ventral keel), (cf., Stanton, 1893; Cobban and Hook, 1989).

The stratigraphically highest fossils we collected are from the middle and upper part of the Atarque Sandstone. These are specimens of the bivalve *Lopha bellaplicata* (Fig. 5H–J) from localities L-3485 and 3486. We also collected some *L. bellaplicata* in the Rio Salado Tongue at localities L-3481, 3484 and 3582. The radial plicae of these specimens from the southern San Andres Mountains are not as curved, prominent or rugose as those of *L. sannionis*, justifying identification as *L. bellaplicata* (cf., Kauffman, 1977, pl. 9, figs. 11–20; Hook and Cobban, 1981, fig. 1; Cobban and Hook, 1989, figs. 9S, 10A–E).

REGIONAL CORRELATION

Regional correlation of the Cretaceous strata exposed in the southern San Andres Mountains is based upon, and is consistent with, both lithostratigraphy and biostratigraphy (Fig. 7). Upper Albian strata of the Sarten Formation in the southern San Andres Mountains correlate to the lower part of the Sarten Formation in the Cooke's Range. This means most of the Sarten Formation (middle and upper parts) preserved in the Cooke's Range is not present in the southern San Andres Mountains (Fig. 7).

The Rio Salado Tongue of the Mancos and Bridge Creek interval correlate to thicker sections to the north in Sierra and Socorro counties. The tripartite Tres Hermanos Formation of these more northerly sections is only represented by the Atarque Sandstone in the southern San Andres Mountains.

However, Hook et al. (1983, p. 21) reported the occurrence of *Mammites nodosoides* in the basal Atarque Sandstone Member near Love Ranch, so this indicates a relatively old age (late Early Turonian) for the Atarque Sandstone in the southern San Andres Mountains; the unit becomes progressively younger to the north and northwest (Hook et al., 1983; Molenar, 1983).

Post-Atarque correlation of the Cretaceous section in the southern San Andres Mountains is based strictly on lithology and stratigraphic position because no age-diagnostic fossils are available. The D-Cross Tongue of the Mancos Shale, like the Rio Salado Tongue, is much thinner in the southern San Andres Mountains than in sections to the north. The Gallup Sandstone retains similar thickness, but whether it can be definitely correlated to Virden, as shown in Figure 7, is uncertain.

ACKNOWLEDGMENTS

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APPENDIX: DESCRIPTION OF MEASURED SECTIONS

Love Ranch

Measured southwest of the abandoned Love Ranch headquarters. Base at UTM 351300E, 3600828N; top at 351411E, 3600774N (in UTM Zone 13 using datum NAD27). Strata are overturned 24° to the SW.

unit	lithology	thickness (m)
Mancos Shale, Rio Salado Tongue:		
16	Covered	not measured
Dakota Sandstone:		
15	Sandstone; pale yellowish brown (10YR6/2); fine- to medium-grained; litharenite; ripple laminated with some trough crossbeds and bioturbation; forms a slope.	7.3
14	Sandstone; same color and lithology as unit 15; forms the top ridge of a prominent hogback.	3.8
13	Covered.	3.2
12	Conglomeratic sandstone; pinkish gray (5YR8/1); medium- to coarse-grained; quartzarenite; clasts are yellow, pink and tan calcareous clay pellets up to 1 cm in diameter; trough crossbedded.	0.5
11	Sandstone; pinkish gray (5YR8/1); very fine-grained; quartzarenite; silty; not calcareous; ripple laminated.	1.0
10	Sandstone; grayish orange pink (5YR7/2) with moderate red (5R5/4) and greenish black (5G2/1) mottles; very fine-grained; quartzarenite; calcareous; massive; forms a slope.	3.8
9	Sandstone; grayish orange pink (5YR7/2) with light brown (5YR5/6) hematitic mottles; fine-grained; quartzarenite; trough crossbedded; principal spine of hogback.	4.6
8	Sandstone; grayish orange pink (5YR7/2); fine-grained; quartzarenite; trough crossbedded; forms a slope.	6.0
7	Sandstone; same color and lithology as unit 9; forms a ridge.	4.3
6	Sandstone; grayish orange pink (5YR7/2); fine- to medium-grained; quartzarenite; contains some limey nodules that are light brown (5YR5/2); trough crossbedded.	7.5
5	Metaquartzite; light brownish gray (5YR6/1); trough crossbedded; ledge.	0.6
4	Sandstone; same color and lithology as unit 6.	2.8

unconformity

Sarten Formation:

unit	lithology	thickness (m)
3	Sandstone; medium dark gray (N4); medium-grained; lithic wacke; ripple laminated; ledge.	0.3
2	Sandstone; very pale orange (10YR8/2); very fine-grained; quartzarenite; contains coquina lenses that are pale yellowish brown (10YR6/2); bioturbated.	6.1
unconformity		
San Andres Formation:		
1	Limestone; dark gray (N3); micritic.	not measured

Davis Well

Section measured near Davis Well. Strata dip 15° to S80°W. Start at arroyo bottom at UTM 352065E, 3602764N (in UTM zone 13, using datum NAD27).

unit	lithology	thickness (m)
Love Ranch Formation:		
16	Conglomerate, mostly of limestone cobbles.	not measured
unconformity		
Gallup Sandstone:		
15	Sandstone; pale yellowish brown (10YR6/2); silty, fine- to medium-grained litharenite; not calcareous; trough crossbedded.	5.1
14	Sandstone; soft friable, similar to unit 15; mostly covered; with a calcarenite coquina lens near top.	13.8
13	Sandstone; light olive gray (5Y6/1); very fine- to fine-grained silty litharenite; some limestone cannonball concretions in top of unit; lower 1 m is ripple laminated, rest of unit is trough crossbedded.	8.3
Mancos Shale, D-Cross Tongue:		
12	Shale; medium gray (N5); calcareous; has medium dark gray (N4) calcareous limestone nodules; forms a slope.	11.0
Tres Hermanos Formation, Atarque Sandstone Member:		
11	Sandstone; light olive gray (5Y6/1); very fine- to fine-grained; silty litharenite; trough crossbedded and extensively bioturbated; forms a bench.	1.1
10	Bioclastic limestone; forms a ledge; *Lopha*.	0.3
9	Sandstone; pale yellowish brown (10YR6/2); same lithology as unit 11; hummocky and ripple laminated.	7.0
8	Limestone; same lithology as unit 10; *Lopha*.	0.5
7	Silty sandstone; yellowish gray (5Y7/2); very fine-grained; litharenite; not calcareous; some bioturbation and crossbeds, but mostly massive; forms a prominent white bench.	5.0
Mancos Shale, Rio Salado Tongue:		
6	Sandstone; same color and lithology as unit 4.	6.0
5	Sandy shale; same color and lithology as unit 3.	1.9
4	Sandstone; pale yellowish brown (10YR6/2); very fine-grained; litharenite; calcareous; ripple laminated; forms a ledge.	3.3
3	Sandy shale; dark yellowish brown (10YR4/2); calcareous; contains fossiliferous limestone concretions particularly near its base.	7.5
Dakota Sandstone:		
2	Sandstone; grayish orange (10YR7/4); silty; very fine-grained; litharenite; calcareous; ripple laminated with some trough crossbeds.	8.0
1	Sandstone; pale yellowish brown (10YR6/2) and very pale orange (10YR8/2); fine-grained; silty; quartzarenite; not calcareous; numerous dark brown, hematitic cannonball concretions; trough crossbedded.	5.5+

Burke Spring

Base at UTM 352362E, 3604764N; top at 352284E, 3604571N (in UTM zone 13, using datum NAD27). Strata dip 36° to S70°W.

unit	lithology	thickness (m)
Mancos Shale; Rio Salado Tongue:		
20	Bioclastic sandy limestone; grayish orange pink (5YR7/2); forms a ledge; fossil shells are bivalves, possibly *Pycnodonte*.	1.3
19	Covered.	1.8
18	Metaquartzite; grayish orange pink (5YR7/2); fine-grained; bioturbated and massive; forms a ledge.	1.2
17	Covered.	4.8
Dakota Sandstone:		
16	Sandstone; pale brown (5YR5/2); fine-grained; quartzarenite; planar crossbeds.	1.5
15	Sandstone; very pale orange (10YR8/2); very fine-grained; quartzarenite; bioturbated with some mudchips.	1.8
14	Sandstone and conglomeratic sandstone; light brownish gray (5YR6/1) with dark gray (N3) speckles; fine- to medium-grained quartzarenite; pebbles are mostly pink chert up to 1.5 cm in diameter; trough crossbedded.	2.0
13	Sandstone; pinkish gray (5YR8/1) with light brown (5YR5/6) hematitic spots; medium- to coarse-grained; quartzarenite; trough crossbedded; forms low cuestas.	6.0
12	Metaquartzite; light brownish gray (5YR6/1); fine- to medium-grained; extensively bioturbated.	4.5
11	Sandstone; grayish orange pink (5YR7/2) with light brown (5YR5/6) hematitic spots; very fine- to fine-grained; quartzarenite; laminated.	1.3
10	Covered.	6.1
9	Sandstone; pinkish gray (5YR8/1) with light brown (5YR5/6) specks; fine- to medium-grained; quartzarenite; hematitic; trough crossbedded; units 8 and 9 form a cuesta.	6.5
8	Sandstone; same colors and lithology as unit 9; trough crossbeds and overturned crossbeds.	2.5
7	Silty sandstone; grayish orange pink (5YR7/2) with moderate red (5R5/4) mottling; very fine-grained; hematitic quartzarenite; bioturbated.	6.0
6	Sandstone; very pale orange (10YR8/2); very fine-grained; quartzarenite; slightly hematitic; trough crossbedded with some clay-pebble conglomerate lenses; dip changes above here to 23°; forms a prominent ledge.	2.8
unconformity		
Sarten Formation:		
5	Sandstone; brownish gray (5YR4/1); fine- to medium-grained; litharenite; calcareous; ripple laminated and bioturbated.	3.0
4	Bioclastic limestone; sandy; ledge.	1.3
3	Silty sandstone; pinkish gray (5YR8/1) and dark yellowish orange (10YR6/6); fine-grained; hematitic litharenite; calcareous; trough crossbedded; some lenses of sandy shale like unit 2.	5.5
2	Sandy shale; moderate yellowish brown (10YR5/4) with dark reddish brown (10R3/4) mottles; slope.	2.5
unconformity		
San Andres Formation:		
1	Limestone; micritic; dark gray (N3).	not measured