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STRATIGRAPHY, PALEONTOLOGY AND CORRELATION OF LOWER CRETACEOUS EXPOSURES IN SOUTHEASTERN NEW MEXICO

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Abstract—In southeastern New Mexico, limited isolated outcrops of Lower Cretaceous strata occur at Lee Ranch, the Black River valley, North Lake and near several of the peaks of the Cornudas Mountains. Preliminary study of these strata has resulted in a better understanding of their stratigraphic and paleontological relationships with better known Lower Cretaceous units to the south (west Texas), west (Cerro de Cristo Rey) and north (east-central New Mexico). Most of these outliers are less than 20 m thick, but the section on the east slope of Washburn Mountain includes more than 130 m of Fredericksburg- and Washita-age (Albian) strata. Both the Campagrande Formation and a relatively thick (41 m) sequence of Cox Sandstone—formations prominent in west Texas—are recognized in the Cornudas Mountains. Overlying middle-upper Washita strata consist of a massive nodular limestone unit and a slope-forming shale/siltstone/calcarenite unit above it. These appear to be eastern outcrops of the Muleros and Mesilla Valley formations, respectively, of Cerro de Cristo Rey. The Muleros-equivalent limestone contains an abundant and diverse fauna, consisting mainly of bivalves (especially a small form of *Texigryphaea* having affinities to both *T. pitcheri* and *T. washitaensis)*, gastropods and echinoids. The overlying (Mesilla Valley) shale at the Lee Ranch locality contains the foraminifer *Cribratina texana* and a small, coiled oyster transitional between *Exogyra plexa* and *I Imatogyra arietina.* These faunas, present at Lee Ranch, Cornudas Mountains and Black River valley, are quite similar to faunas of correlative units in west Texas and at Cerro de Cristo Rey and represent the Albian Caribbean faunal province. The North Lake exposure, in contrast, is lithologically similar to the Tucumcari Formation of east-central New Mexico and bears a low-diversity fauna characterized by large numbers of *Texigryphaea pitcheri,* sparse *Ceratostreon texana* and *Lopha quadriplicata* and no echinoids. Strata connecting the Albian outcrops along the New Mexico–Texas border and the North Lake exposure (northern Lea County) are not present on the surface or in the subsurface, thus precluding study of the transition between these two faunas.

INTRODUCTION

The southeastern part of New Mexico is mainly covered by Permian and late Tertiary to Quaternary strata and unconsolidated sediments. Lower Cretaceous exposures are sparse and restricted to limited erosional outliers and units associated with exposed igneous intrusions south of the extensive outcrops of the Tucumcari Formation and Dakota Group in Quay and eastern Guadalupe Counties of east-central New Mexico (Fig. I). Although these southeastern outliers have been known for decades and appear on the Dane and Bachman (1965) geologic map of the state, most have received very little attention, and, because of their isolation and great distances from well-exposed Lower Cretaceous sequences, their correlation has remained tentative. We have visited most of these outliers, examined their stratigraphy and assembled collections of fossils that aid considerably in establishing their ages. In this paper we briefly describe the stratigraphy and paleontology of these localities (Fig. 1), and suggest correlations with better exposed Lower Cretaceous sequences in west Texas, at Cerro de Cristo Rey (southern Doña Ana County, near El Paso) and in east-central New Mexico. Greatest attention in this paper is devoted to the discontinuous outcrops around several of the peaks in the Cornudas Mountains, because several formations are represented, the total thickness of the sequence is much greater than at other localities and some units yield abundant and diverse marine invertebrate faunas that have not been studied previously. One erosional outlier within the study area, a thin remnant of Kiamichi-equivalent strata near Rogers (southeast of Portales, Roosevelt County; Fig. I , E), was previously studied by Kues (1986) and is not considered here. Because erosional remnants of Lower Cretaceous strata may be subtle and not easily differentiated from surrounding late Tertiary-Quaternary sediments without on-site field inspection, additional localities probably will be discovered in the future.

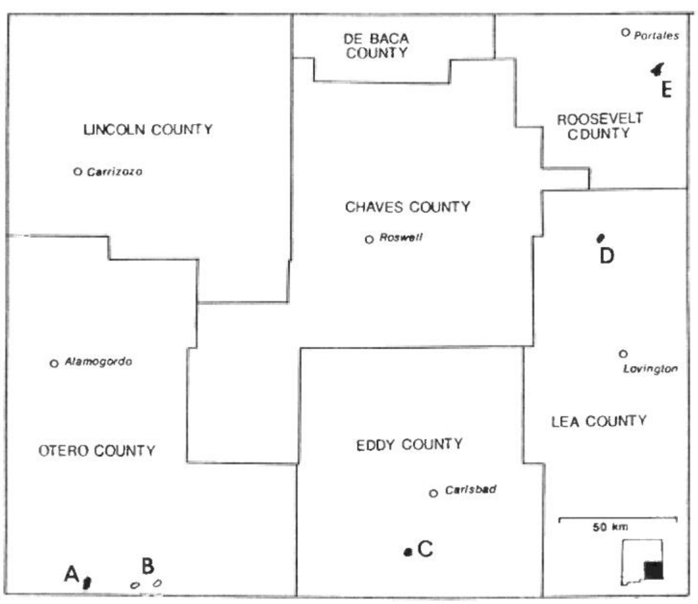

FIGURE 1. Distribution of Lower Cretaceous outliers in southeastern New Mexico. A, Lee Ranch; B, Cornudas Mountains; C, Black River valley; D, North Lake; E, Rogers.

Much work remains to be done on the paleontology of Lower Cretaceous marine units in southern New Mexico and west Texas. Systematic studies of relatively few elements of the west Texas faunas have been published and the paleontology of the well exposed, fossiliferous, lithologically heterogeneous sequence at Cerro de Cristo Rey was last comprehensively treated in 1910, by Bose. A more detailed study of the marine faunas of the southeastern New Mexico Lower Cretaceous localities is in preparation; here, only a few of the most common and biostratigraphically important taxa are noted and illustrated. All specimens are catalogued into the paleontology collections of the Department of Earth and Planetary Sciences, University of New Mexico (UNM).

CORNUDAS MOUNTAINS

Introduction

The Cornudas Mountains are a cluster of nine isolated peaks that straddles the New Mexico—Texas border, about 40 km east of the Hueco

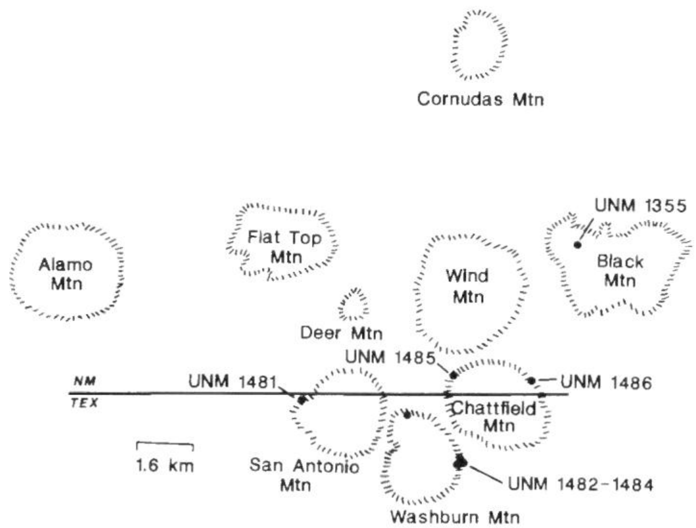

FIGURE 2. Reference map of Cornudas Mountains, New Mexico and Texas, showing UNM Lower Cretaceous localities (see text for exact coordinates). New Mexico peaks are in (west to east) the Alamo Mountain, Cornudas Mountain and McVeigh Hills USGS 7.5′ topographic quadrangle maps; Texas peaks are in Sixteen Mountain and Cerro Diablo 7.5′ maps.

Mountains and 105 km west of Carlsbad Caverns (Figs. 2, 3). These peaks are mid-Tertiary igneous intrusions (see McLemore and Guilinger, this volume) largely surrounded by Permian Yeso, San Andres or Bone Spring strata, but small exposures of fossiliferous Lower Cretaceous units are present along the lower stones of several of them. The occurrence of these Cretaceous exposures has been known at least since Richardson (1904) reported Washita strata between San Antonio and Washburn Mountains. Adkins (1932, p. 354-355, 362) presented a generalized stratigraphic section of Washita (Duck Creek to Fort Worth equivalent) strata and noted a few identified fossils from an unspecified location in the Cornudas Mountains. The geology of most of the peaks was mapped by Timm (1941), Clabaugh (1941) and Zapp (1941), who included faunal lists of marine invertebrates, but this information was never published.

Subsequently, virtually no additional information on the Cretaceous outcrops associated with these intrusions has been reported. King (1949) mapped Washita strata on the west side of Black Mountain and the southeast side of Chattfield Mountain and later (King, 1965) briefly integrated the Cornudas Mountains Cretaceous units into a regional discussion of Cretaceous stratigraphy across the Sierra Diablo region, to the south in Hudspeth and Culberson Counties, Texas. The geologic map of New Mexico (Dane and Bachman, 1965) shows thin bands of Washita outcrops around Alamo, San Antonio, Chattfield and Black Mountains. The Van Horn—El Paso sheet of the Geologic Atlas of Texas (Barnes, 1983) shows a Campagrande outcrop on the west side of San Antonio Mountain and Cretaceous (undivided) on the north and east sides of Washburn Mountain. Here, we present more detailed observations on the stratigraphy and paleontology of several Cornudas Mountains Lower Cretaceous exposures and correlate these exposures with units present to the west, at Cerro de Cristo Rey and to the south, in the Sierra Diablo and Sierra Prieta areas.

San Antonio Mountain

A thin (6 m), areally restricted, mostly covered Lower Cretaceous section (UNM locality 1481) is exposed along a short part of an arroyo on **the** northwestern lower slopes of San Antonio Mountain, about 0.3

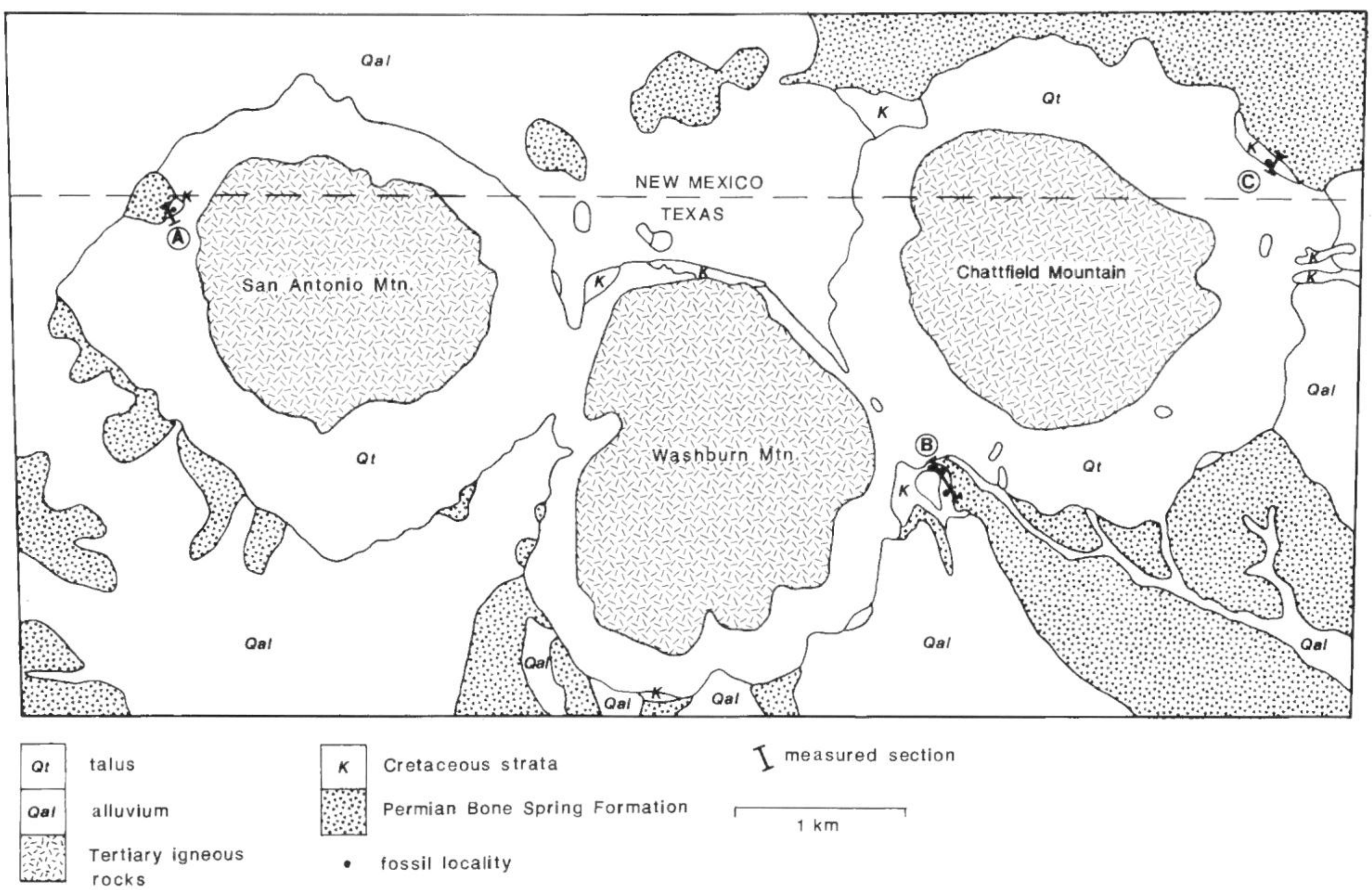

FIGURE 3. Simplified geologic map of the southern three peaks of the Cornudas Mountains (after Timm, 1941), showing locations of measured sections in Fig. 4. A, San Antonio Mountain (UNM locality 1481); B, East slope of Washburn Mountain (UNM localities 1482–1484); C, Northeast slope of Chattfield Mountain (UNM locality 1486). The Lower Cretaceous (K) exposure on the northwest slope of Chattfield Mountain is UNM locality 1485.

km south of the New Mexico–Texas border. These strata are assigned to the Campagrande Formation (Fig. 4). Dolomitic, cherty limestone of the Permian Bone Spring Formation forms a prominent, pale red to medium light-gray ledge beneath the Cretaceous strata. The base of the Cretaceous is marked by a thin siliceous conglomerate of black, gray and red pebbles of chert, quartzite and lithics up to 1 cm in diameter. Overlying, partly covered Cretaceous strata are grayish yellow and pale yellowish orange siltstone and calcarenite.

Only two oyster taxa were observed at this locality. Mostly fragmentary shells of the morphologically variable *Ostrea crenulimargo* Roemer (Fig. 5B) are common near the base of the outcrop and *Ceratostreon texana* (Roemer) (Fig. 5A) is sparsely present in the upper part. *Ostrea crenulimargo* left valves are of medium size (up to 40 mm high), broadly triangular to arcuate in shape and bear about four strong, radiating plications crossed by prominent, uneven growth lines and wrinkles. *O. crenulimargo* ranges from the upper Trinity through lower Fredericksburg Group in central Texas (Stanton, 1947). In west Texas, this species has been reported from the Finlay Limestone of the Sierra Blanca, Sierra Diablo and Kent quadrangle regions (Albritton and Smith, 1965; King, 1965; Brand and Deford, 1958).

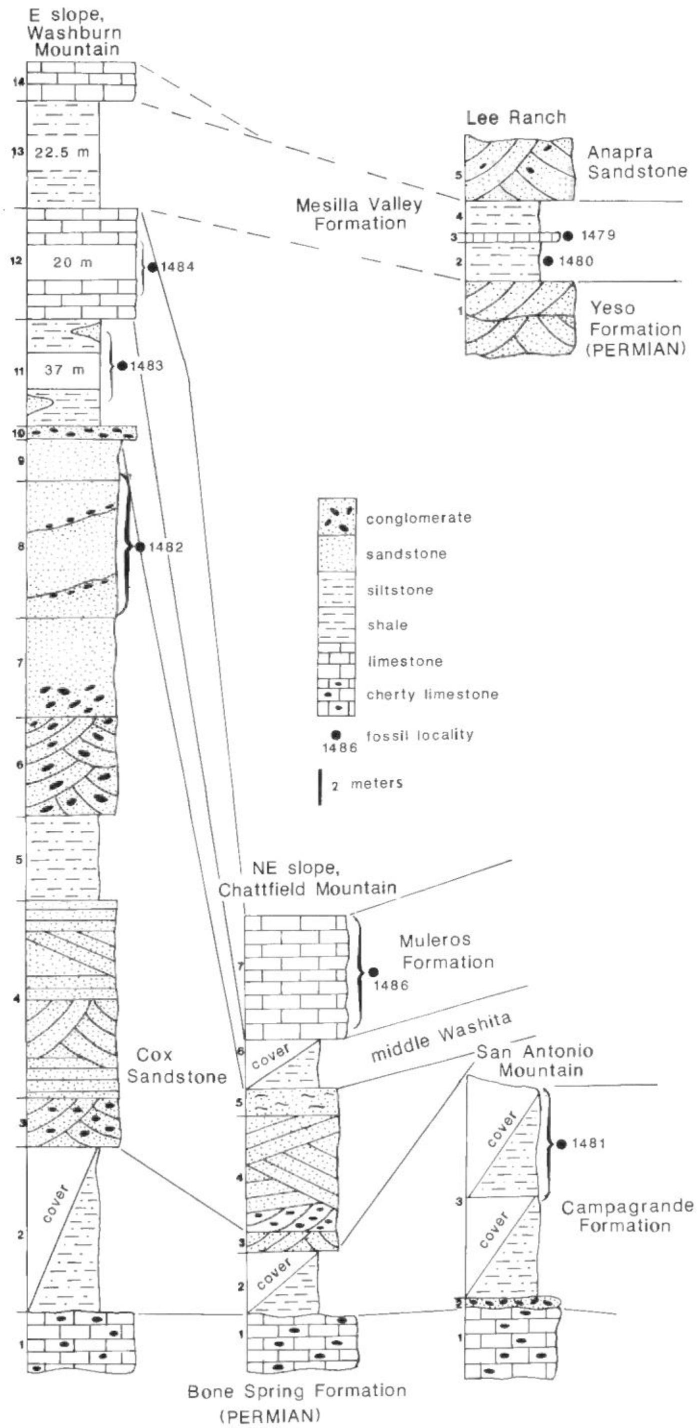

FIGURE 4. Measured stratigraphic sections of Lower Cretaceous strata at Lee Ranch and at several locations in the Cornudas Mountains. See Figs. 1–3 for section locations and the Appendix for a description of the lithologic units in the section on the east slope of Washburn Mountain.

Ceratostreon texana is one of the most distinctive and common bivalves throughout the Fredericksburg Group in central and eastern Texas and Oklahoma. In west Texas, it is present in the Finlay and Kiamichi Formations (Albritton and Smith, 1965; King, 1965) and in the Cox Formation (Albritton and Smith, 1965). In New Mexico it is present in the Finlay and Del Norte Formations of Cerro de Cristo Rey (Bose, 1910; Strain, 1976), in the Kiamichi-equivalent strata in Roosevelt County (Kues, 1986) and at the base of the Tucumcari Formation in east-central New Mexico (Kues, et al., 1985; Vincent, written comm. 1992). The co-occurrence of these two taxa at San Antonio Mountain and in the exposure on the northwest side of Chattfield Mountain (see below) suggests an age no younger than middle Fredericksburg for these two exposures.

The highest stratigraphic occurrence of *O. crenulimargo* in west Texas is the Finlay Limestone, which also contains *C. texana.* In its type area, the Finlay fauna indicates correlation with the Walnut and Goodland Formations (approximately lower to middle Fredericksburg) of central and eastern Texas (Albritton and Smith, 1965). However, the Finlay becomes sandy and loses its identity from south to north across the Sierra Diablo region, becoming lithologically a part of the Cox Sandstone (King, 1965) at Sierra Prieta. The Cox is composed mainly of massive, locally crossbedded, medium- to coarse-grained and conglomeratic sandstones as it thins to the north toward Sierra Prieta, where it is no more than 41 m thick in some areas. As discussed below, we have identified more than 40 m of Cox strata in the Cornudas Mountains, on the east side of Washburn Mountain. The lithology of the Cox in that section does not include the siltstones and limestones observed at San Antonio Mountain and on the northwest side of Chattfield Mountain, nor do the Cox faunas we collected contain *O. crenulimargo* and *C. texana.*

The lithologies of the exposures of these two localities are more similar to those of the Campagrande Formation, which underlies the Cox in many areas of west Texas. The Campagrande thins northward, to as little as 15 m at Cerro Diablo, about 16 km southeast of San Antonio Mountain and its lithology becomes predominantly sandstone (Albritton and Smith, 1965, fig. 34). Although the Campagrande is of late Trinity age at its type locality in the Finlay Mountains, it probably becomes younger as it thins to the north, just as the Cox does. An early Fredericksburg age for the Campagrande in the Cornudas Mountains would not be surprising and would be consistent with the presence of *O. crenulimargo* and *C. texana.* Thus, we correlate the restricted exposure at San Antonio Mountain with the Campagrande Formation, as was done by Barnes (1983). The exposures on the northwest side of Chattfield Mountain, with an identical fauna, are also referred to the Campagrande Formation.

Washburn Mountain–east slope

The thickest, most complete section of Lower Cretaceous strata in the Cornudas Mountains occurs along the lower eastern slopes of Washburn Mountain, where it is exposed mainly on the west side of the unpaved road that leads northward through the gap between Washburn and Chattfield Mountains, about 1.6 to 1.9 km south of the New Mexico–Texas border. The section measured here is more than 130 m thick (Figs. 4; 6C–F; 7A–C; Appendix), but because much of the section is covered we cannot rule out some fault repetition.

Above the dolomitic limestone bench formed by the Permian Bone Spring Formation, about 9 m of poorly exposed yellowish-orange to brown siltstone forms the base of the Cretaceous section. These strata contain unidentifiable oyster debris in packstone lenses and are tenta-

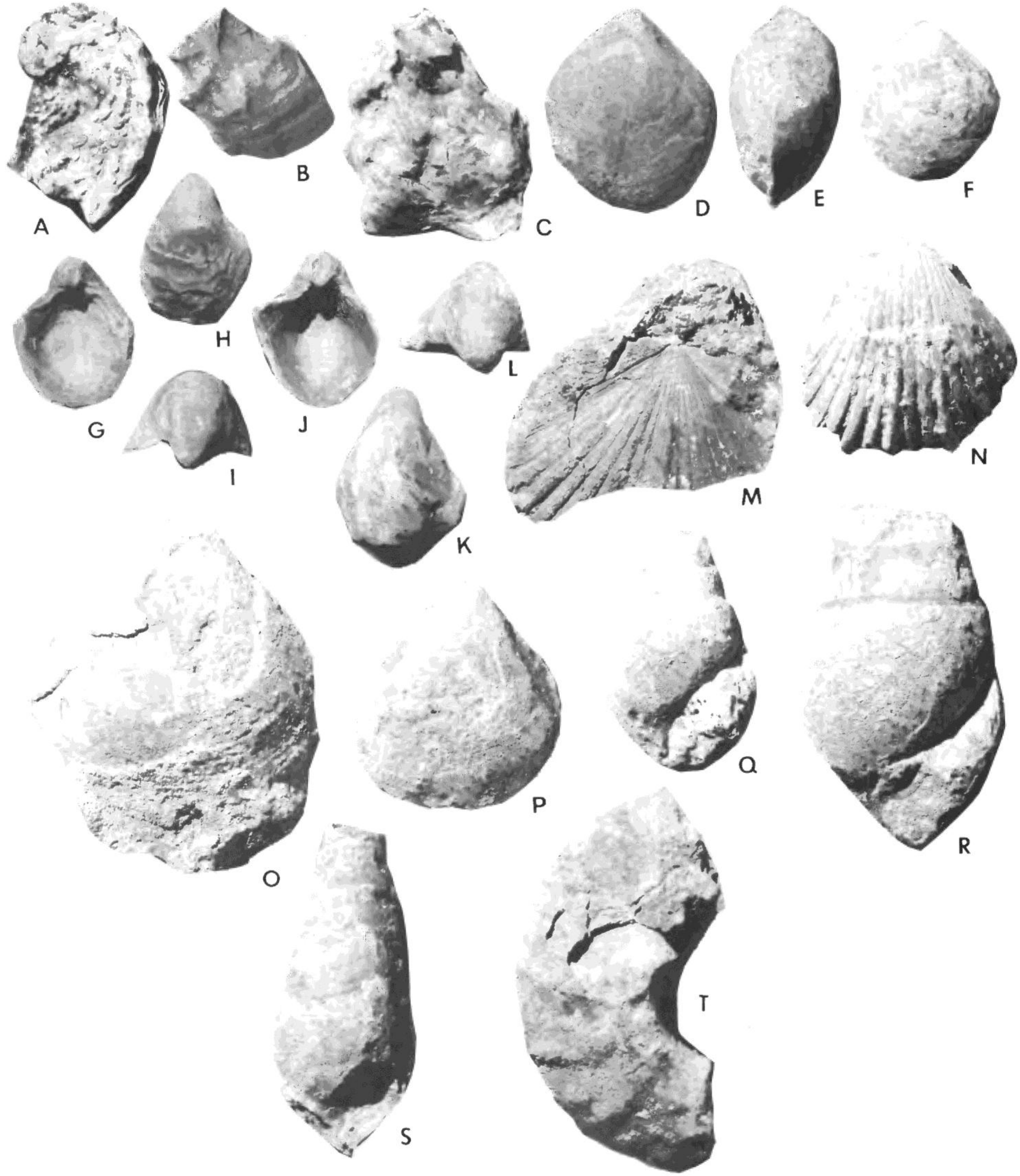

FIGURE 5. Molluscs from Lower Cretaceous strata in the Cornudas Mountains. Localities: A, B, Campagrande Formation, San Antonio Mountain; D–F, T, upper Cox Sandstone (UNM locality 1482), and R, Muleros Formation (UNM locality 1484), east slope of Washburn Mountain; C, Campagrande Formation, northwest slope of Chattfield Mountain; G–Q, S, Muleros Formation, northeast slope of Chattfield Mountain. Figures natural size unless otherwise indicated. A, *Ceratostreon texana*, right valve, UNM 11,926. B, C, *Ostrea crenulimargo*, left valve with large attachment scar, UNM 11,927, and large left valve, UNM 11,928. D–F, *Waconella wacoensis*, brachial and left side views, UNM 11,934, ×1.8, and pedicle view, UNM 11,935, ×1.5. G–L, *Texigryphaea "washitaensis,"* internal, external and umbonal views of left valve, UNM 11,945 (G–I), internal view of left valve, UNM 11,946 (J), and external and umbonal views of left valve, UNM 11,947 (K–L). M, N, *Neithea texana*, internal view of partial right valve, UNM 11,933, and external view of left valve, UNM 11,932. O, *Protocardia* cf. *P. texana*, right valve steinkern, UNM 11,924. P, *Protocardia* aff. *P. denisonensis*, left valve steinkern, UNM 11,925. Q, *Tylostoma* sp., apertural view of steinkern, UNM 11,931. R, *Tylostoma kentense*, apertural view of incomplete steinkern, UNM 11,929, ×0.67. S, *Cimolithium*? *riograndense*, apertural view of incomplete specimen, UNM 11,930, ×0.67. T, *Stoliczkaia*? sp., partial steinkern, UNM 11,936.

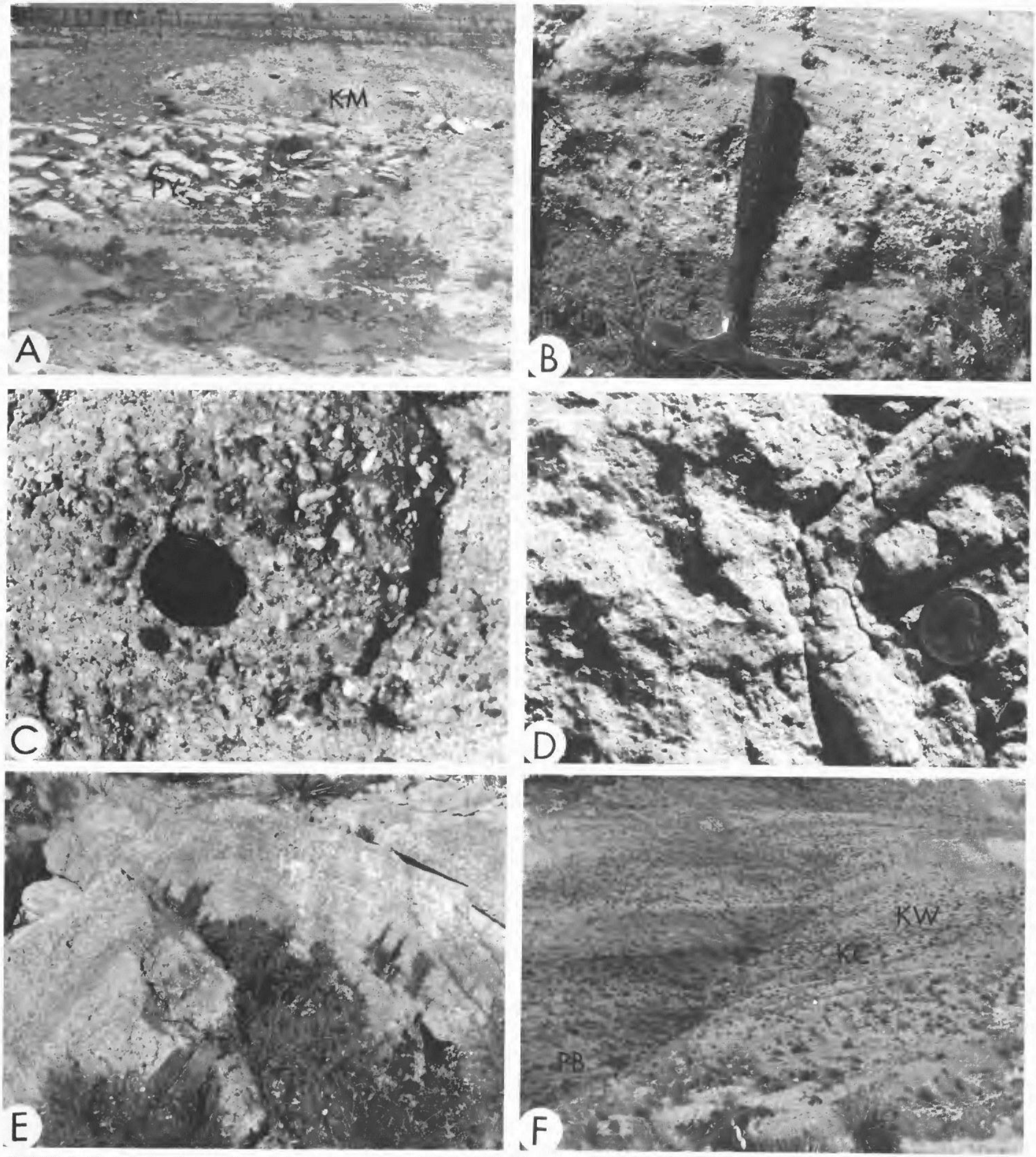

FIGURE 6. Photographs of selected Lower Cretaceous outcrops at Lee Ranch (A–B) and east slope of Washburn Mountain (C–F). A, Yeso Formation (PY) overlain by Mesilla Valley (KM) shales and bioclastic limestones. B, Close view of conglomeratic Anapra-equivalent sandstone. C, Chert-pebble conglomerate (unit 3) at base of Cox Sandstone. D, Thalassinoid burrow in bioturbated sandstone (unit 9) of Cox Sandstone. E, Trough crossbedded conglomerate sandstone (unit 6) of Cox Sandstone. F, Overview of part of section, showing Permian Bone Spring Formation (PB), overlain by Cox Sandstone (KC) and unnamed lower to middle Washita strata (KW).

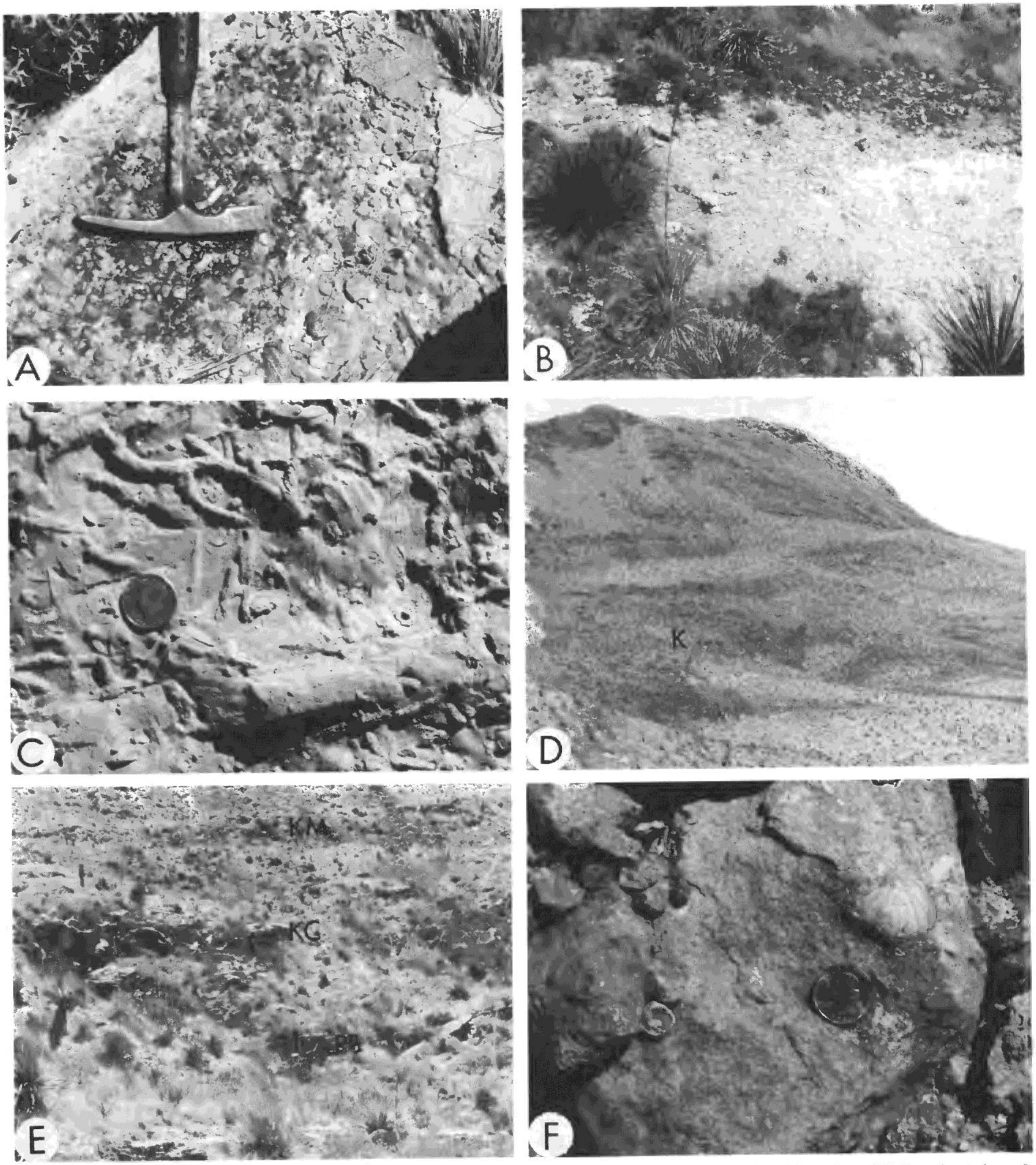

FIGURE 7. Photographs of selected Lower Cretaceous outcrops in the Cornudas Mountains; A–C, east slope of Washburn Mountain, and D–F, northeast slope of Chattfield Mountain. A, Basal lithic conglomerate (unit 10) of lower-middle Washita unit. B, Slope-forming calcareous siltstone/shale (unit 11) of lower-middle Washita interval. C, Bioturbated calcarenite (unit 11) of lower-middle Washita interval. D, Overview of slope with Lower Cretaceous outcrop belt (K) indicated. E, Overview of measured section (Fig. 4) showing Permian Bone Spring (PB), Cox Sandstone (KC) and Muleros Formation (KM). F, Echinoid (*Globator parryi*) weathering out of limestone of Muleros Formation (unit 7).

tively assigned to the Campagrande Formation (Fig. 4). About 41 m of sandstone, conglomerate and minor siltstone (units 3 to 9) overlie the Campagrande Formation and are assigned to the Cox Sandstone. Trough crossbedded, coarse, quartzose sandstones and red chert-pebble conglomerates (Figs. 6C, E) dominate the Cox here, but fossiliferous bioturbated sandstones (Figs. 4, 6D) also are present. Farther south, in the Sierra Diablo region, the Cox consists predominantly of massive, locally crossbedded, pebbly sandstone units interbedded with thinner intervals of shales and nodular limestones (King, 1965). Similarity of lithology and stratigraphic position of the Washburn Mountain sandstone sequence with that of the Cox Sandstone farther south leaves no doubt that the Cox extends into the southern Cornudas Mountains.

The Cox Sandstone is more than 120 m thick at its type section on Cox Mountain, Hudspeth County, Texas. It thickens to more than 300 m to the south and thins northward, to as little as 40 m on Sierra Prieta, 55 km southeast of the Cornudas Mountains (King, 1965). At Cerro Diablo, 15 km southeast of Washburn Mountain, however, the Cox appears to be at least 63 m thick (Gross, 1965). In southern west Texas, the age of the Cox is confined by the underlying, Trinity-age Campagrande limestone and by the overlying lower to middle Fredericksburg Finlay Limestone. However, northward the Cox becomes younger, until at Sierra Prieta, where it includes equivalents of the Finlay and Kiamichi Formations, it is directly overlain by Washita Group (Duck Creek equivalent) strata (King, 1965).

Few well-preserved fossils were observed through the Cox section at Washburn Mountain. However, at the base of unit 9 is a thin horizon of densely concentrated brachiopods formerly identified as *Kingena wacoensis* (Roemer) but now assigned to *Waconella* (Owen, 1970) (Figs. 5D—F). This horizon is the source of scattered specimens collected on the slopes of unit 8. These terebratulids are biconvex, subround to slightly oval in outline, possess a rather acutely rounded beak on the pedicle valve and a small, circular pedicle opening. The Washburn Mountain specimens attain a maximum length of about 27 mm; shell width averages about 90% of length and the thickness of the articulated valves is about 55-60% of the length. The valves are unornamented except for growth lines, but where the outer shell layer was weathered, a distinctive punctate pattern of fine, closely spaced pits is present. A slight to obscure fold and sulcus mark the anterior commissure.

Waconella wacoensis occurs throughout the Georgetown Formation (= Duck Creek through Main Street Members) in central Texas, primarily in six zones of abundance (Dixon, 1967). The species is variable in size and outline through its range (Dixon, 1967). King (1965) reported *Kingena wacoensis* only from Duck Creek beds in Sierra Prieta, but also cited *Kingena?* sp. from younger Washita units in that area. Albritton and Smith (1965) reported the species from the upper Kiamichi of the Quitman Mountains and observed that an unidentified species of *Kingena* occurs in great abundance in overlying Washita strata in the Sierra Blanca region of west Texas. Bose (1910) reported a poorly preserved terebratulid brachiopod only from the Mesilla Valley Formation of Cerro de Cristo Rey. Bose's figure (1910; pl. 32, fig. 3) is of an incomplete specimen that appears to be W. *wacoensis.*

The distribution of *Waconella,* typically in zones of abundance in Washita strata in central and western Texas and at Cerro de Cristo Rey, strongly suggests that unit 9 is of Washita age. Its stratigraphic position, below a thick sequence of Washita shales and limestones and near the top of a predominantly sandstone sequence that we correlate with the Cox Sandstone, suggests an early Washita age. A single incomplete ammonite specimen from the slopes of unit 8 unfortunately is too poorly preserved to add additional information concerning the age of the upper Cox Sandstone here. The ammonite is a weathered steinkern of half a whorl, with a diameter of 67 mm (Fig. 5T). The whorl is moderately compressed laterally, fairly acutely rounded across the venter and bears coarse, slightly curved, widely spaced ribs that extend across the venter and nearly reach the umbilici. In these features the specimen resembles the late Albian to early Cenomanian genus *Stoliczkaia* (see Young, 1978), but better specimens are needed for a positive generic identification. An early Washita age for the top of the Cox Sandstone in the Cornudas Mountains agrees with regional trends in which the age of the upper Cox becomes younger northward and correlates with the Kiamichi Formation (lowermost Washita) south of the Cornudas Mountains.

Strata of early to middle Washita age overlie the Cox Sandstone on the eastern side of Washburn Mountain. The base of these strata (unit 10; Figs. 4, 7A) is a 0.3-m-thick lithic conglomerate, which is overlain by a thick (41 m), mostly covered, slope forming unit of brownish-orange shale and siltstone with intervals of brown, ledge-forming siltstones and calcarenites (unit 11; Figs. 4, 7B—C). Some calcarenite beds, especially near the top of the unit, display dense concentrations of tubular trace fossils (Fig. 7C). Few body fossils were present on the shale slopes, but the sandstone ledges, particularly in the upper third of the unit, contain highly fragmented shell material, mostly from oysters. Specimens of *Neithea texana* (Roemer), *Plicatula* sp., *Protocardia* sp. and the small *Texigryphaea* we are tentatively calling *T. "washitaensis"* were collected. Sparse shark teeth and rare specimens of *Cribratina texana* (Conrad) were also collected as displaced float on the slopes of unit 11.

The stratigraphic position and presence of long-ranging Washita species indicates an early to middle Washita age for unit 11. Because this thick unit has not been studied sufficiently to provide detailed information about its lithology, we have not established its relationships with specific formations regionally. It is probably correlative with the Smeltertown Formation and/or part of the overlying Muleros Formation at Cerro de Cristo Rey. The Smeltertown consists of 30 to 50 m of predominantly black to gray shales, but with significant marl and limestone beds near the top (Strain, 1976). The texigryphaeas of unit 11 are similar to those in the Muleros and Mesilla Valley formations, rather than to *T. navia* (Hall), an earlier, Kiamichi-equivalent species found in the Smeltertown. To the south, across the Sierra Diablo and Sierra Blanca areas of west Texas, rather heterogenous units of undifferentiated Washita strata are present (King, 1965; Albritton and Smith, 1965). Unit 11 almost certainly correlates with the lower parts of these sequences.

Overlying unit 11 (Fig. 4) is a 24-m-thick, generally massive unit of hard, medium-gray, nodular micritic limestone with shaly partings that contains an abundant fauna, mainly of bivalves, gastropods and echinoids. Dense, jumbled accumulations of relatively small texigryphaea shells occur throughout unit 12, but certain identification of these specimens requires further study. Hill and Vaughan (1898, p. 62), in their initial description of *T. washitaensis,* noted that the species is "very abundant in the pass of the Rio Grande west of El Paso" (i.e., Cerro de Cristo Rey) and Bose (1910) described the species from his units 5 and 6 (Muleros and Mesilla Valley formations) at Cerro de Cristo Rey. Specimens from unit 12 at Washburn Mountain and from unit 7 at the locality along the northeast slope of Chattfield Mountain (see below) have been compared with UNM collections from the Muleros and Mesilla Valley formations at Cerro de Cristo Rey and all belong to the same species. However, the present concept of *T. washitaensis* is broad and includes at least two different morphs. One is characterized by a very distinctive, relatively large, broad, deep, thin-shelled left valve, with a flaring anterodorsal margin that is unique among species of *Texigryphaea* (see Fay, 1975). A second morph is smaller, with a rather narrow dorsal margin, a tendency to develop laterally expanded ventral margins and resembles in some respects a small morph of *T. pitcheri* (Morton) (see Stanton, 1947). Both morphs display a nearly vertical beak orientation and often the beak is slightly tilted posteriorly, rather than anteriorly as is the case in other species of *Texigryphaea.* Hill and Vaughan (1898) noted that at some Duck Creek localities in eastern Texas, it is almost impossible to separate *T. washitaensis* from *T. corrugate (=T. pitcheri).* Pending further study of the morphological variability in assemblages currently assigned to *T. washitaensis,* we are referring to the small specimens from the Cornudas Mountains and Cerro de Cristo Rey that typically display only moderate expansion of the antero- and posterodorsal margins as *T. "washitaensis."*

Other bivalves in unit 12 include common specimens of the large pectinid *Neithea texana,* sparse specimens of *Protocardia texana* (Conrad) and *P.* cf. *P. dentonensis* (Cragin) and a single specimen of *Pinna guadalupae* Bose. Most gastropod specimens are incomplete steinkerns of *Tylostoma* and *Turritella?;* one large individual (90 mm high without the first few whorls) is identifiable as *Tylostoma kentense* Stanton (Fig. 5R). Echinoids are fairly numerous and mostly complete, although details of test surfaces have in many specimens been obscured by weathering. By far the most abundant species is *Globator parryi* (Hall). Specimens of *Coenholectypus* aff. *C. transpecosensis* (Cragin), *Pedinopsis (Dumblea) symmetrica* (Cragin) (see Smith et al., 1990), *Washitaster bravoensis* (Bose) and *Phymosoma mexicana* (Bose) (Figs. 8A–B) are rare.

The lithology of unit 12 is similar to that of the limestone units of the Muleros Formation at Cerro de Cristo Rey. In addition, nearly all identified elements of the unit 12 fauna are present in the Muleros Formation (Bose, 1910), strongly suggesting that the two limestone units are coeval. The fauna of the Muleros suggests that the formation correlates with the Fort Worth to Weno interval of the east and central Texas latest Albian sequence. Unit 12 is also correlative with the highly fossiliferous, light grayish-tan limestones constituting unit 7 along the northeast slope of Chattfield Mountain, about 2.6 km to the northeast.

Unit 12 appears to be overlain by a mostly covered, 26.5-m-thick interval (unit 13) consisting of fissile brown shale and siltstones. This unit resembles the thinner shale outcrop at Lee Ranch and is in the stratigraphic position of the Mesilla Valley Shale, which overlies the Muleros Formation at Cerro de Cristo Rey. However, we were not able to sample unit 13 for fossils and the possibility exists that these strata are fault-repeated.

Washburn Mountain—north side

Albian strata are also present along the north side of Washburn Mountain (Fig. 3), just south of the New Mexico–Texas border, but are mostly covered by igneous debris from the intrusion. Sandstone ledges and slabs of bioclastic limestone, probably from an interval equivalent to unit 11 of the section measured on the eastern slopes of Washburn Mountain, were observed but no identifiable fossils were collected and no section was measured.

Chattfield Mountain—northwest slope

A small Cretaceous exposure on the northwest slope of Chattfield Mountain is in the SW'/4 NW'/4 NE'/4 sec. 33, T26S, R14E, Otero County, about 0.4 km north of the New Mexico–Texas border. (Figs. 2, 3; UNM locality 1485). Here, the Permian Bone Spring Formation is overlain by approximately 6 m of poorly exposed, yellowish siltstone and calcarenite with shale intervals and numerous limestone nodules. Overlying conglomerates closely resemble those of the Cox Sandstone on the eastern slope of Washburn Mountain.

The fauna collected from this exposure closely resembles that of the San Antonio Mountain locality discussed above. The base and middle of the sequence contains mainly fragmented specimens of *Ostrea crenulimargo* (Fig. 5C), with sparse shells of *Ceratostreon texana* appearing in the upper part. Although the lithology at the two localities is somewhat different, the identical faunas they contain indicate that they are coeval. Both exposures appear to represent a thin northern extension of the Campagrande Formation.

Chattfield Mountain—northeast slope

A relatively thin section of Albian strata is exposed for a short distance along the northeast side of Chattfield Mountain (Figs. 2, 3), about 0.6 km north of the New Mexico–Texas border, in the NE¹/4 NE'/4 NE¹/4 sec. 34, T26S, RI4E. The section (Figs. 4; 7D-F) rests on gray micritic limestone of the Permian Bone Spring Formation and consists mainly of a series of locally crossbedded and conglomeratic sandstone units in the lower half and a massive, fossiliferous, tan to light gray limestone unit above. The same section appears to be present a little farther south, along the east side of Chattfield Mountain about on the New Mexico–Texas border. We examined only the northern outcrop.

The lower sandstone sequence (units 3-5) is almost 9 m thick and consists of grayish pink and pale red quartzose sandstone and red chert-pebble conglomerate that are mostly planar and trough crossbedded. This sequence is lithologically identical to some of the sandstone beds referred to the Cox Sandstone on the east side of Washburn Mountain, but is only about one fourth the total thickness of the Cox at that location. The upper limestone unit (unit 7) differs from the thick limestone (unit 12) at Washburn Mountain in being light tan instead of mainly gray and in being less than one third as thick, but contains a closely similar fauna. The attenuated thicknesses of the Cox and Muleros-equivalent formations at Chattfield Mountain compared with their much more pronounced development at Washburn Mountain is striking, considering that the two localities are only about 2.6 km apart. Great local differences in paleotopography or depositional rates seem a likely explanation.

An extensive collection of marine invertebrates, predominantly bivalves, gastropods and echinoids, was made from the slopes of the eroded exposures of the upper limestone (unit 7; UNM locality 1486). This assemblage is considerably more diverse than those of correlative limestones on the eastern slope of Washburn Mountain and on Black Mountain. *Texigryphaea "washitaensis"* (Figs. 5G–L) dominates this assemblage in number of specimens and in total estimated biomass, but other bivalves are also well represented. *Neithea texana* (Figs. 5M–N) is common; disarticulated left and right values range up to 55 mm in height. Of the two species of *Protocardia* present, *P.* cf. *P. texana* (Fig. 50) is large, subtriangular in shape, slightly longer than high (both dimensions exceeding 50 mm) and bears coarse concentric ribs. The second species (Fig. 5P) is up to about 50 mm high but has a short, high triangular shape. It resembles *P. filosa* (Conrad) in its shape and conspicuous ligamental areas, but its large size and more numerous radiating posterior ribs suggest a closer relationship to *P. denisonensis* (Cragin), known from upper Washita strata in eastern Texas. *Lima wacoensis* (Roemer), *Ludbrookia* sp. and *Homomya* sp. are also present in unit 7.

A large variety of gastropods are chiefly preserved as incomplete steinkerns, but some possess part of the original shell, coarsely recrystallized, adhering to the steinkern. Studies of these gastropods are in progress; *Turritella, Tylostoma* (Fig. 5Q) and *"Ampullina"* appear to be the most abundant genera. Large specimens of the high-spired *Cimolithium? riograndense* (Stanton) (Fig. 5S) are also conspicuous in this assemblage. This is the species Stanton (1947) originally described as *Cerithium riograndense* from the Washita Group near Sierra Blanca, Texas. Based on close similarity in size, shape and conspicuous subsutural transverse ribs to specimens from Japan assigned to *Cimolithium?* by Kase (1984), this species is here questionably placed in that genus. *Cimolithium* has also been reported from middle Albian strata in Baja California, Mexico (Allison, 1955).

The echinoids from unit 7 are generally the same taxa noted from other Muleros-equivalent limestones in the Cornudas Mountains. *Globator parryi* constitutes about 60% of the echinoid specimens collected, with *Washitaster bravoensis* (Figs. 8C-D) adding another 30%. The remaining species are *Coenholectypus* aff. *C. transpecosensis* (Figs. 8H–J), *C. planatus* , *Pedinopsis (Dumblea) symmetrica* and *Phymosoma mexicana.* Most of the species have been reported from lower to upper Washita faunas to the south, at Sierra Prieta (King, 1965) and from the Muleros Formation at Cerro de Cristo Rey (Bose, 1910).

Black Mountain

Black Mountain, the northeasternmost of the Cornudas peaks, is a large, arcuate, relatively flat-topped mesa with Washita strata near its summit. A brief traverse was made along the north end and fossil collections (UNM locality 1355) were made from a slope beneath the intrusion that marks the northwestern peak of the mesa, in the NE'/4 NW'/4 SE'/4 sec. 14, T26S, R I4E (UNM locality 1355; Fig. 2). Washita exposures continue to the southeast, at least to a point directly north of the Bill Jones ranch house. Immediately beneath the intrusion are ledges of dark orange-brown, bioturbated, medium- to fine-grained sandstone, underlain by a fairly thick gray shale slope. A unit consisting mainly of gray limestone beds with dense concentrations of *Texigryphaea "washitaensis"* either underlies the elastic sequence or is in fault contact with it.

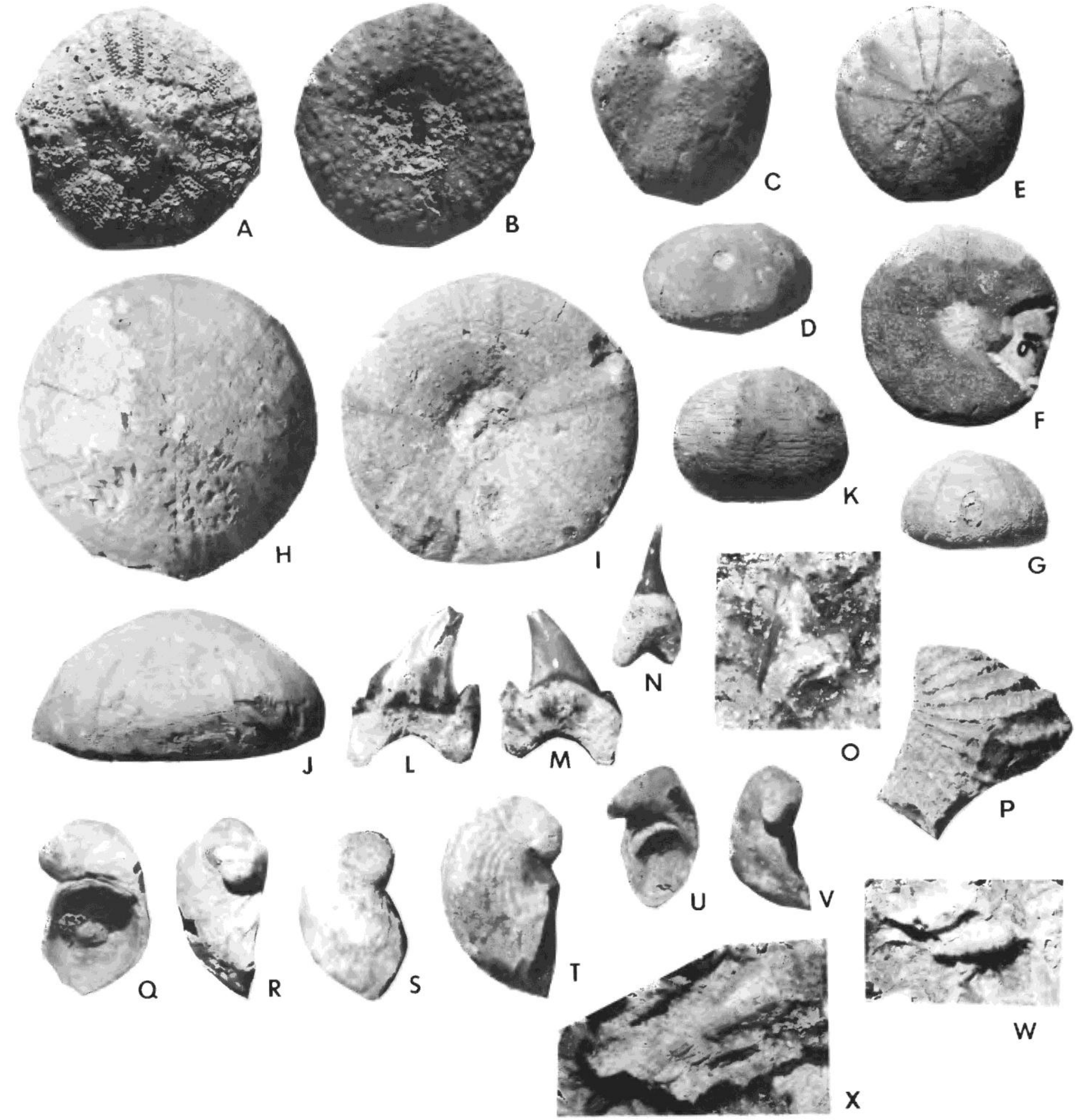

FIGURE 8. Lower Cretaceous fossils form the Cornudas Mountains (A–N) and Mesilla Valley Shale (UNM locality 1479) at the Lee Ranch locality (O–X). Figures natural size unless otherwise indicated. A, B, *Phymosoma mexicana,* dorsal and ventral views, UNM 11,952, Muleros Formation, east slope of Washburn Mountain (UNM locality 1484). C, D, *Washitaster bravoensis,* ventral and posterior views, UNM 11,939, Muleros Formation, northeast slope of Chattfield Mountain. E–G, *Globator parryi,* dorsal and ventral views, UNM 11,954 and posterior view, UNM 11,955, Muleros-equivalent limestone, Black Mountain. H–J, *Coenholectypus* aff. *C. transpecosensis,* dorsal, ventral and side views, UNM 11,938, Muleros Formation, northeast slope of Chattfield Mountain. K, *Pedinopsis* (*Dumblea*) *symmetrica,* side view, UNM 11,953, Muleros-equivalent limestone, Black Mountain. L, M, *Cretodus arcuatus,* labial and lingual views, UNM 11,940, upper sandstone unit, Black Mountain, ×1.5. N, *Cretodus* sp., lingual view, UNM 11,941, upper sandstone unit, Black Mountain, ×1.5. O, *Squalicorax* sp., lingual view, UNM 11,942, ×3. P, *Scabrotrigonia emoryi,* incomplete right valve, UNM 11,937. Q–V, *Exogyra* aff. *E. coahuilensis;* internal and side views of left valve, UNM 11,951, ×2 (Q, R); side view of left valve with large attachment scar, UNM 11,949, ×2 (S); side view of strongly ribbed left valve, UNM 11,950, ×2 (T); internal and side views of left valve, UNM 11,948, ×1.5 (U, V). W, *Cribratina texana,* UNM 11,944, ×2. X, *Dentalium* sp., UNM 11,943, ×2.

Few fossils were observed in the upper sandstone unit; only *Protocardia multistriata* Shumard and *Cribratina texana* have been positively identified. No megafossils were collected from the shale unit, but a sediment sample yielded numerous foraminifera that were identified by K. Kietzke (Table 1) as representing long-ranging, late Albian–early Cenomanian species. The fauna of the limestone unit is dominated by *T. "washitaensis," Neithea texana* and a low diversity of echinoids. More than 90% of the approximately 80 echinoids collected belong to the morphologically variable species *Globator parryi* (Figs. 8E–G). Five specimens of *Washitaster bravoensis* and single specimens of *Tetragramma streeritizi, Pedinopsis (Dumblea) symmetrica* (Fig. 8K) and *Coenholectypus* aff. *C. transpecosensis* complete the list of echinoid species.

Lopha quadriplicata, Protocardia cf. *P. denisonensis* and steinkerns of *Tylostoma* and other gastropods are moderately common in the limestone unit. The fauna of this limestone is quite similar, even in the relative proportions of the various echinoid species, to the faunas of other limestones correlated with the Muleros Formation elsewhere in the Cornudas Mountains, such as unit 12 at Washburn Mountain and unit 7 on the northeast slope of Chattfield Mountain. The thick shale unit, with *Cribratina texana-rich* sandstones near the top, is very probably the Mesilla Valley Shale. The Washita exposures along the upper slopes of Black Mountain appear to be fairly extensive and additional stratigraphic and paleontologic studies are planned.

Alamo Mountain

Both Timm (1941) and Dane and Bachman (1965) noted a thin band of Washita strata around Alamo Mountain, the westernmost of the Cornudas Mountains intrusions. We did not locate Cretaceous rocks in a brief reconnaissance up the north slope of the peak. Cretaceous strata may be only intermittently exposed around the lower slopes of the mountain, as is the case at Washburn and Chattfield Mountains, or the outcrops are mostly concealed by talus from the intrusion and we failed to locate them. A more detailed survey of Alamo Mountain is planned.

LEE RANCH

Dane and Bachman (1965) mapped an area of Washita outcrops along the central eastern side of T26S, R10E, about 9.5 km east of the northern end of the Hueco Mountains and about 22 km west of Alamo Mountain. The authority for the geology of this area was cited as "oil company and independent geologists, modified by reconnaissance mapping" by U.S. Geological Survey geologists. To our knowledge, nothing has been published previously on the stratigraphy and paleontology of this outlier, nor any evidence for its Washita age.

This outcrop of Washita strata is located along a shallow draw just east of the Lee Ranch house (= Hat Ranch on the USGS Mountain Tank 7.5' quadrangle map), in the NE'/4 SW'/4 sec. 24, T26S, RIDE, Otero County (Figs. 1, 4, 6A–B). Just south of the unpaved road leading to the ranch and near a corral, is an eroded slope of dark brown shale with ledges of sandstone and bioclastic limestone, resting on trough crossbedded, pale yellowish orange quartzose sandstones of the Permian Yeso Formation (Figs. 4, 6A). About 0.06 km to the south, this unit is again exposed as low bluffs along the western side of the draw. Here it consists of a thin sequence of alternating concretionary brown sandstone ledges separated by mostly covered intervals of shale and very light gray calcareous siltstone, with a thicker, ledge-forming unit of trough crossbedded, locally conglomeratic orange-brown sandstone capping the bluffs (Fig. 6B).

These exposures are locally abundantly fossiliferous. The fauna is dominated by large numbers of a small *Exogyra* related to *E. plexa* (Cragin), which are present in the soft shales as well as in the hard, argillaceous limestone units. These limestones are packed with small shell fragments and some complete shells of this *Exogyra,* so that it is almost a coquina in some places. Other fossils include abundant specimens of the large foraminifer *Cribratina texana* (Fig. 8W), common small solitary corals and lesser numbers of serpulid worms, *Neithea texana, Lopha quadriplicata, Protocardia* sp., *Scabrotrigonia emoryi* (Conrad) (Fig. 8P) and *Turritella* sp. aff. *T. irrorata* (Conrad). Close examination of numerous slabs of limestone also revealed rare specimens of other taxa, such as the scaphopod *Dentalium* sp. (Fig. 8X) and a finely ribbed pectinid that resembles *Chlamys chihuahuaensis* (Bose).

The specimens of *Exogyra* (Figs. 8Q–V) are small (up to 17 mm high) and the left valve is coiled through about 1.5 whorls, with the beak typically adhering to the surface of the later part of the valve. Many specimens display attachment scars along the side of the beak (Fig. 8S) and left valves are variably ornamented with numerous radial ribs along most of the last whorl (Fig. 8T). Precise taxonomic placement of these specimens must await further study. It has long been recognized that in the late Albian–early Cenomanian strata of Texas two relatively small exogyrine species probably share an ancestor-descendant relationship—Exogyra *plexa* and *Ilmatogyra arietina* (Roemer). *Exogyra plexa,* abundant in the Kiamichi and Duck Creek Formations, has a relatively low, broad left valve with a beak that is moderately coiled in a closed spiral, generally displays strong radial ribs covering most of the valve and resembles juveniles of /. *arietina,* although being much larger. *Ilmatogyra arietina* is a somewhat larger species when fully grown and occurs most abundantly in the Main Street, Grayson and Del Rio Formations in Texas. It has a narrower, more strongly coiled (to 2-2.5 whorls) left valve in which the whorls are more open and often are not in contact with later whorls and which displays less conspicuous ribs that are typically limited to the early part of the valve (Stanton, 1947). Between the stratigraphic ranges of these two species (i.e., Fort Worth, Denton, Weno and Pawpaw interval) small exogyrines have rarely been reported. A few authors (Bose, 1919; Adkins, 1928; Stanton, 1947) have noted forms described as intermediate or transitional between *E. plexa* and *I. arietina* within the interval between the ranges of these species. In addition, Bose (1910) figured specimens (pl. 26, figs. 5-7, I I) from the Anapra Sandstone at Cerro de Cristo Rey as juveniles of *E. clarki* Shattuck, but later (Bose, 1919) indicated them to be similar to transitional forms between *E. plexa* and *1. arietina* and stated that they were probably a separate species ancestral to *I. arietina.*

The specimens from Lee Ranch also fall into this transitional category. They are similar to specimens from the Mesilla Valley Shale in the UNM collections, except that the Mesilla Valley specimens are somewhat larger (up to 23 mm high) and display less pronounced development of the radial ribs. In both assemblages, numerous individuals show conspicuous attachment scars, a characteristic of *Exogyra* but not *llmatogyra* (Stenzel, 1969). Both the Mesilla Valley and Lee Ranch specimens are less coiled than typical specimens of *I. arietina,* but more so than *E. plexa.* In this and other features, such as size and radial rib development, these specimens are also closely similar to a form described as *E. arietina* var. *coahuilensis,* from the Indidura Formation of Coahuila, Mexico (Jones, 1938). This variety occurs in beds above those that contain typical examples of *E. plexa.* It is possible that the best taxonomic placement of the specimens discussed here from Lee Ranch is with *E. coahuilensis,* if that variety is raised to species

TABLE 1. Foraminifera from the Mesilla Valley–equivalent shale unit at Black Mountain; identified by Kenneth Kietzke.

Reophax minuta Tappan
Ammodiscus gaultinus Berthelin
?*Haplophragmoides* sp.
Quasispiroplectammina longa Lalicker
Q. nuda Lalicker
Textularopolis sp.
Ammobaculites cf. *A. variabilis* Tappan
Trochammina sp.
Neobulimina cf. *N. minima* Tappan
Dentalina aff. *D. cylindroides* Reuss

level to accommodate forms transitional between *E. plexa* and typical specimens of I. *arietina.*

Several other bivalves present at Lee Ranch, such as *Neithea texana, Lopha quadriplicata* and *Scabrotrigonia emoryi,* are widespread and long ranging in the Washita Group of Texas and all are present in (and in the case of the last two species, limited to) the Muleros—Mesilla Valley interval at Cerro de Cristo Rey. At Cerro de Cristo Rey, *Cribratina texana* is abundant in association with small exogyras in the Mesilla Valley Shale, just as it is at Lee Ranch. *Cribratina texana* is especially abundant in the upper Weno and Pawpaw Formations of central and eastern Texas and is less common in the younger Del Rio and Grayson Formations (Adkins and Winton, 1919; Zeller, 1965). Albritton and Smith (1965) observed several zones bearing abundant specimens in Washita strata of the Sierra Blanca region of west Texas.

The fauna of the Lee Ranch locality, especially the presence of *Exogyra* sp. aff. *E. coahuilensis* and the abundance of *C. texana,* suggests a middle to late Washita age, approximately equivalent to the Weno—Main Street interval of Texas. The Lee Ranch fauna is closely similar to that of the Mesilla Valley Shale at Cerro de Cristo Rey, although the important oyster *Texigryphaea* is missing at Lee Ranch. Further, this fauna occurs in a unit composed chiefly of thin-bedded soft brown shale, with occasional thin sandstone and bioclastic limestone beds, which is similar to the lithology of the Mesilla Valley Shale. Both lithological and faunal similarities suggest that the strata cropping out at Lee Ranch are an eastern extension of the Mesilla Valley Shale. If this is correct, the upper massive conglomeratic sandstones at Lee Ranch would logically be referred to the Anapra Sandstone, which conformably overlies the Mesilla Valley Shale at Cerro de Cristo Rey (Fig. 4). At present we lack sufficient information to tie the Lee Ranch section securely to the thick Washita section along the east side of Washburn Mountain. However, if the thick, upper, *Texigryphaea-echinoid* limestone there (unit 12) is the Muleros Limestone, as we suspect, then the covered brown shale interval above it (unit 13 at Washburn Mountain) is equivalent to the Lee Ranch shale unit and the Mesilla Valley Shale at Cerro de Cristo Rey.

BLACK RIVER VALLEY

Lang (1947) reported a patch of loose gravel and rock debris containing Washita fossils on a surface of the Permian Castile Formation in the Black River Valley, discovered during road-building activities. We relocated this site, exactly as reported by Lang, in the E'/2, NW '/4 sec. 31, T25S, R25E, Eddy County (Fig. I). It is along the southeast side of US-62/180, immediately south of Eddy County Road 424 (Dillahunty Road), 11.0 km southwest of the intersection of US-62/180 with NM-7 at Whites City. The locality is not shown on Hayes' (1957) geologic map of the Carlsbad Caverns East quadrangle.

The locality consists chiefly of Lower Cretaceous fossils and isolated slabs of hard, gray, highly bioclastic, oyster-rich limestone scattered on the Castile surface. None of the slabs appeared to be in place and no actual Cretaceous outcrops were observed, suggesting that the fossils and limestone slabs represent debris from a small exposure that has been completely eroded away. Lang (1947) proposed an explanation involving the accumulation of eroded Cretaceous debris at the bottom of a solution pit, which gradually became exposed on the surface as the valley floor was eroded downward. Imlay (in Lang, 1947) identified the echinoid *Anorthopygus* n. sp. and the pelecypods *Gryphaea corrugata* (now *Texigryphaea pitcheri), Neithea texana, Opis?* sp. and *Protocardia texana* from the locality and concluded that these fossils indicated an early Washita age, probably equivalent to the Duck Creek Limestone.

Fossil collections we made at this locality include a low diversity of generally weathered, poorly preserved taxa. All of the identifiable echinoid specimens belong to *Globator parryi,* which is a major constituent of the upper limestone assemblages at Washburn Mountain, the northeast slope of Chattfield Mountain and at Black Mountain. The echinoid tests are rather variable in shape, as is characteristic of the species (Cooke, 1946) and the genus *Globator* is closely similar to *Anorthopygus,* which may account for Imlay's report of that genus. Gastropods are represented by *Turritella* sp. and by an unidentified low-spired steinkern. Bivalves include *Neithea texana, Lopha quadriplicata, Protocardia* cf. *P. multistriata* and most commonly, numerous specimens of the small *Texigryphaea* we are referring here to *T. "washitaensis."*

Our collections from this locality, although somewhat different taxonomically from those reported in Lang (1947), also indicate a Washita age. *Lopha quadriplicata* and *N. texana* range throughout the Washita Group, but have rarely and not certainly been reported from earlier strata. *Globator parryi,* as noted elsewhere, is essentially limited to the Fort Worth and Denton Formations in central Texas. All three species have been reported from undivided Washita strata in the Sierra Diablo and Sierra Blanca areas (King, 1965; Albritton and Smith, 1965). At Cerro de Cristo Rey, *G. parryi* (under the names *Pyrina inaudita* and *P. clarki)* was reported from the Muleros and Mesilla Valley Formations and *L. quadriplicata* only from the Mesilla Valley Formation by Bose (1910). The texigryphaeas remain to be studied in detail, but specimens from this locality fall within the range of variation shown by Muleros and Mesilla Valley assemblages that Bose (1910) assigned to *T. washitaensis,* but which also converge upon small specimens of *T. pitcheri.* A middle Washita age, approximately correlative with the Fort Worth and Denton Formations in eastern and central Texas, is indicated for the fauna of this outlier.

NORTH LAKE

The occurrence of limited exposures of Albian strata on the north side of North Lake has been known since Theis (1934) first reported them (see also Theis, 1939; Conover and Akin, 1942). Ash and Clebsch (1961) described this 6-m-thick section in detail and correlated it with the Tucumcari Formation. They listed the following taxa, identified by Stanton: *Gryphaea corrugata* (now *Texigryphaea pitcheri), Ceratostreon texana, Exogyra plexa, Plicatula* cf. *P. incongrua, Neithea texana* and *Serpula?* sp. The senior author made a large collection of fossils from this locality, which includes all of the taxa noted above except *E. plexa* and additional species as well. The locality is on the northwest edge of North Lake, in the SW'/4 SE'/4 SW'/4 and SE'/4 SW'/4 SW1/4 sec. 32, T 10S, R34E, Lea County, about 24 km northwest of the town of Tatum (Fig. 1). The locality consists of weathered exposures of fissile, soft, gray shale and siltstone, with interbedded gray limestone beds and large numbers of *Texigryphaea* valves scattered across the surface.

Mostly disarticulated valves of *Texigryphaea pitcheri* (Figs. 91—R) compose more than 95% of the fossils collected. Mature left valves display a continuum of morphological features between two rather dissimilar endpoints, here designated morph I and morph 2. Various aspects of the morphology of well preserved specimens were measured (see Kues, 1989) in order to quantify some of the differences between the two morphs.

Left valves of morph 1 (Figs 9I—L, P) have prominent curved beaks that extend ventrally past the hingeline; beak length averages 0.31 of total valve height. About 75% of the specimens bear small attachment scars. The valves are relatively deep (width/height = 0.57), narrow (length/height = 0.78) and are strongly arched across the umbonal midline (principal growth axis). The postero- and anterodorsal margins diverge only slightly ventrally from the hingeline before expanding moderately into the posterior and anterior valve margins. These valves possess a moderate to deep posterior sulcus that on some specimens produces an indentation on the ventral valve margin (Fig. 9P). The length of the beak-to-ventral margin periphery of the valve averages nearly twice the height, a reflection of the prominent beaks and the convex outer surface of these relatively deep valves.

Left valves of morph 2 (Figs. 9 M-0, Q—R) are lower and broader (mean width/height = 0.46; length/height =0.95), with short, blunt beaks that do not extend beyond the hingeline (beak length/valve height =0.22). About 86% of the valves display attachment scars that are typically larger than those of morph I. The valves are broadly and gently convex across the umbonal midline and have a beak-to-ventral margin peripheral length of about 1.67 times the valve height, owing to shorter, less curved beaks and a less convex surface than is present in morph I (compare Fig. 9Q and 9K). The antero- and posterodorsal margins diverge laterally from the hingeline to a greater degree than in morph

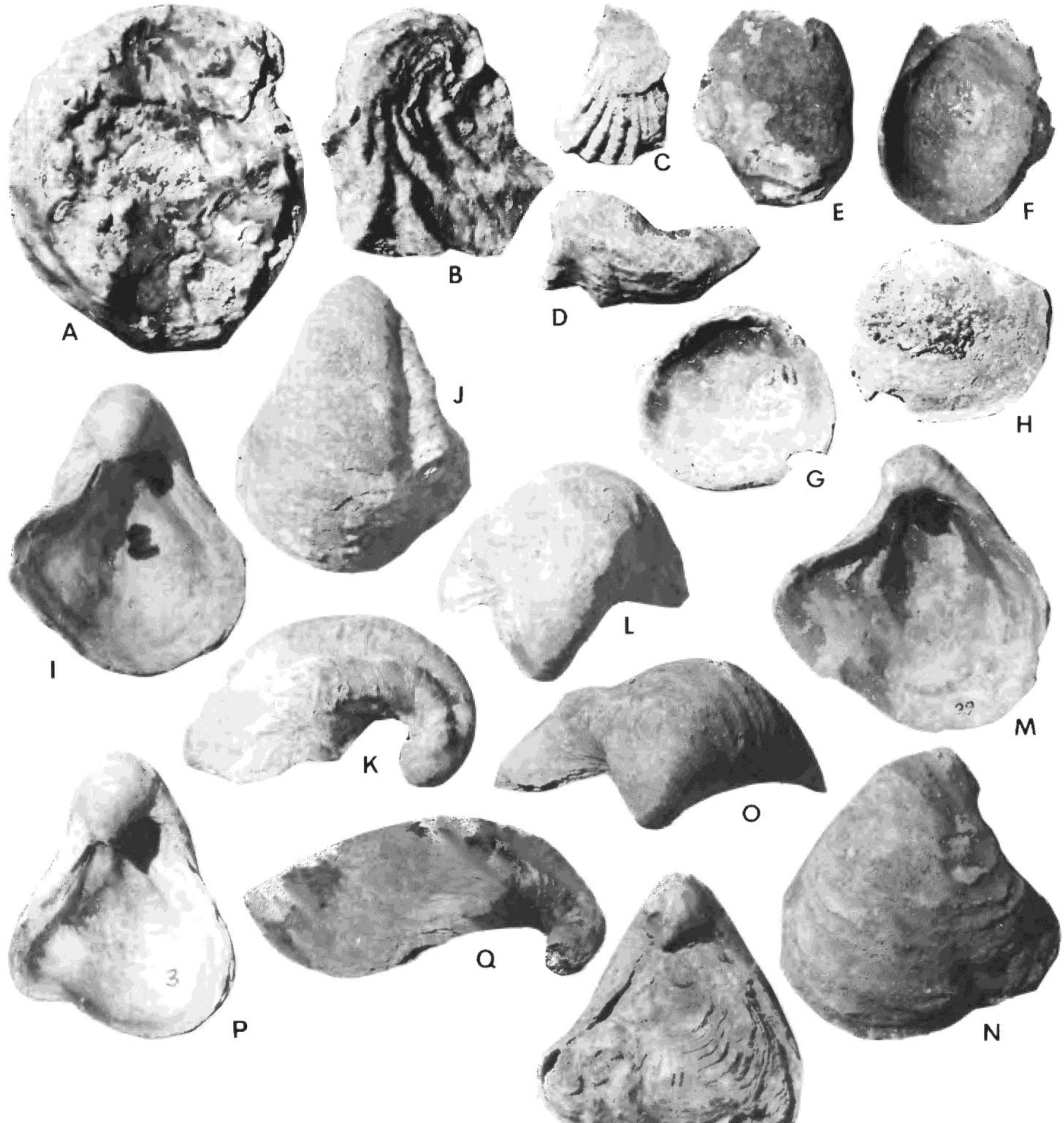

FIGURE 9. Lower Cretaceous bivalves from the Tucumcari Formation, North Lake, Lea County. Figures natural size unless otherwise indicated. A, B, *Ceratostreon texana*, left valves, UNM 11,912 and 11,913, respectively. C, *Plicatula* sp., left valve attached at beak to shell fragment, UNM 11,915, ×2. D, *Lopha quadriplicata*, left valve, UNM 11,914, ×2. E, F, *Ostrea*? sp. 1, left valve exterior and interior views, UNM 11,916. G, H, *Ostrea*? sp. 2, left valve interior and exterior views, UNM 11,917, ×1.75. I–R, *Texigryphaea pitcheri*: I–L, left valve interior, exterior, posterior side, and umbonal views, UNM 11,918; M, N, interior and exterior views of broad left valve, UNM 11,919; O, umbonal view of broad left valve, UNM 11,922; P, interior view of left valve, UNM 11,923; Q, posterior side view of broad left valve, UNM 11,920; R, dorsal view of articulated specimen, UNM 11,921.

1 and the valve develops a strong posteroventral flange, or "wing," resulting in valve length nearly equaling, or in a few specimens exceeding the valve height. The posterior sulcus is typically much shallower than on morph 1.

These two morphs are connected through numerous specimens that are intermediate in morphology between them. Both morphs attain a maximum height of about 66 mm and both have umbos that are slightly inclined anteriorly to the same degree (umbonal angle averages 79° in morph 1 and 78° in morph 2; see Kues, 1989, for discussion of this feature). Casual inspection of the collections indicate that both morphs and transitional forms are common, approaching approximately equal proportions, in the North Lake assemblage. The two morphs begin to become distinct at valve heights of 15 to 20 mm; smaller valves are generally rather inflated, broad, have very sort beaks and very shallow sulci—the typical *Texigryphaea* juvenile morphology. Development of the different left valve morphologies probably reflects both length of time the juveniles remained cemented to a hard substrate and firmness of the substrate individuals subsequently inhabited.

Representatives of *T. pitcheri* at the North Lake locality do not attain the large size of specimens from the Tucumcari Formation in east-central New Mexico, some of which reach heights exceeding 90 mm. Both North Lake morphs are present in moderate abundance in the Tucumcari Formation farther north, but the large, short-beaked, subtriangular to oval morph to which the name *T. tucumcarii* (Marcou) was formerly applied (see Kues, 1989) does not occur at the North Lake locality. Morph 1 occurs in the Del Norte Formation at Cerro de Cristo Rey, where specimens were described by Bose (1910) under the name *Gryphaea pitcheri* var. *tucumcarii.* Serpulid worm tubes, rare bryozoans and juvenile texigryphaeas and other oysters are common epizoans on the North Lake *Texigryphaea* valves.

A moderate number of other bivalves occur in low numbers at North Lake. *Ceratostreon texana* (Figs. 9A–B) is represented by robust, broad specimens up to 65 mm in height and fragments of an even larger oyster, *Lopha subovata,* are also present. Small, relatively smooth and thin-shelled specimens of *Lopha quadriplicata* (Fig. 9D) are identical to specimens occurring in some horizons of the Tucumcari Formation in Quay County. Small, somewhat elongate specimens of *Plicatula* sp. (Fig. 9C) display about nine strong, locally spinose ribs on both valves. Although Ash and Clebsch (1961) reported *P.* cf. *P. incongrua* Conrad from this locality, Conrad's (1857) original description of this species indicated that only one valve possesses prominent ribs. The North Lake specimens appear most similar to *P. subgurgais* Bose from Cerro de Cristo Rey (see also Jones, 1938), and appear to be conspecific with specimens from the Tucumcari Formation of Quay County in the UNM collections.

Two thin, isolated right valves of as yet unidentified ostreids were also collected. One, *Ostrea?* sp. 1 (Figs. 9E–F) is broadly teardrop shaped, about 33 mm high, very gently convex and possesses an irregular fringe of shell material along the posterior margin. *Ostrea?* sp. 2 (Figs. 9 G–H) is also slightly convex and thin, but is longer than high (height = 19 mm) and possesses a slightly elevated beak. Externally, with its low, irregular concentric growth lines, it resembles some Cretaceous shells assigned to *Anomia,* but the hingeline is clearly that of an ostreid.

Correlation of the North Lake exposure with the Tucumcari Formation of east-central New Mexico (Ash and Clebsch, 1961) is reasonable, based on lithologic similarity. Further, the major elements of the North Lake fauna are nearly identical with those of the Tucumcari Formation and the lack of echinoids, so abundant in limestones and calcareous shales to the south, is another point of similarity. The North Lake locality represents the basal part of the Tucumcari Formation, based on the co-occurrence or close stratigraphic proximity of *Ceratostreon texana* and *Lopha quadriplicata.* Although neither Scott (1974) nor Kues et al. (1985) observed *C. texana* in the extensive Tucumcari exposures in Quay County, this species had been reported by earlier workers and specimens collected from the very base of the formation near San Jon were recently shown to the senior author by J. Vincent (personal comm. 1992).

In west Texas and the southern Western Interior, the top of the *C. texana* range zone typically does not quite extend to the earliest occurrence of *L. quadriplicata.* For example, in the Sierra Diablo region, *C. texana* has been reported only as high as the Kiamichi formation, whereas *L. quadriplicata* is present in Duck Creek and younger Washita strata (King, 1965). The two species likewise do not co-occur at Cerro de Cristo Rey (Bose, 1910). In central and eastern Texas and Oklahoma, C. *texana* is generally present to near the top of the Kiamichi Formation and *L. quadriplicata* becomes common only above the Duck Creek, although Huffman et al. (1978) reported possible specimens of both species in the Duck Creek of Oklahoma. Similarly, Brand (1953) reported *C. texana* and *L. quadriplicata* co-occurring only in the basal Duck Creek horizon in Washita outliers of the Llano Estacado of west-central Texas. Thus, the stratigraphic proximity or co-occurrence of these two species at North Lake provides a fairly precise biostratigraphic marker, allowing correlation with the basal Tucumcari Formation to the north and with the basal Duck Creek beds in west-central Texas. The North Lake exposure is slightly higher stratigraphically than the Rogers (Roosevelt County) outcrop (Kues, 1986), which contains *Texigryphaea navia* in association with *C. texana.*

Ash and Clebsch (1961) also noted Cretaceous rocks about 3 mi east of Eunice, Lea County, in the SW^1/4 sec. 29, T21S, N38E. These are displaced, randomly oriented blocks of fossiliferous limestone that had been uncovered in a gravel pit. Small gryphaeas were the only fossils identified and Ash and Clebsch proposed a tentative correlation with the Comanche Peak Limestone (Fredericksburg Group), which is discontinuously exposed around several small lakes in west-central Texas (Brand, 1953). We have not visited this locality and it was not indicated on Dane and Bachman's (1965) geologic map of New Mexico.

SELACHIANS

Isolated shark teeth were collected at three localities in the Cornudas Mountains. Because Albian selachians are less well known than Upper Cretaceous taxa, we discuss and illustrate the more complete of these specimens here. At Lee Ranch locality UNM 1479 a single tooth (Fig. 80) can be referred to *Squalicorax* sp. of Meyer (1974). This tooth is readily assigned to *Squalicorax* because of its large, trenchant and distally pointing, flattened blade followed by a marked posterior notch and its thick, simple roots. However, unlike Late Cretaceous species of *Squalicorax* (e.g., Bilelo, 1969; Meyer, 1974; Williamson et al., 1989; Williamson and Lucas, 1992a, b), the tooth from UNM locality 1479 has a narrower blade, no serrations and a very acute apical angle. This small tooth thus belongs to the primitive anacoracid referred to *Squalicorax* sp. by Bilelo (1969, p. 343, fig. 2R) and Meyer, (1974, p. 297, fig. 88). This taxon was reported by these workers from the Albian Pawpaw Formation of Texas.

Two indeterminate shark teeth were collected at Washburn Mountain (UNM locality 1483, unit 11) and an unidentifiable selachian vertebral centrum was found at Lee Ranch (UNM locality 1480).

Two specimens of *Cretodus arcuatus* were collected, one from Black Mountain (UNM locality 1355) and one from North Lake (UNM locality 1487). The best preserved of the two teeth (Figs. 8L–M) is about 19 mm high and about 15 mm long at the base. These teeth are robust, with triangular blades that are distinctively curved laterally. One pair of lateral cusps is present and the root lacks a nutrient groove, has a concave basal margin and root lobes that are rounded terminally. These teeth closely resemble those of Late Cretaceous *Cretodus arcuatus* (e.g., Williamson and Lucas, 1992b; Figs. 1.31Q–S), except for their ridges along the medial base of the crown.

A second tooth from Black Mountain represents a small lamnoid shark and is tentatively identified as *Cretodus* sp. (Fig. 8N). This tooth has a narrow triangular blade, no lateral cusps and a long root base.

DISCUSSION

These stratigraphic and paleontologic observations of scattered Albian outcrops in southeastern New Mexico permit firmer correlations with better known exposures to the north (in east-central New Mexico), to the west (Cerro de Cristo Rey) and to the south (Culberson and

Hudspeth Counties, west Texas). Although the results presented here are preliminary, we believe that the limited exposures associated with the igneous intrusions of the Cornudas Mountains are sufficient to allow recognition of the Fredericksburg-age uppermost Campagrande and overlying Cox formations of west Texas as far north as the New Mexico—Texas border area and of the Washita-age Muleros and overlying Mesilla Valley formations 75 to 100 km eastward from their type localities.

Regional Albian stratigraphic trends across west Texas are reasonably well known, at least as far north as the latitude of Sierra Prieta, based mainly on the work of King (1965) and Albritton and Smith (1965). In the 55 km between Sierra Prieta and the Cornudas Mountains, extensive outcrops of Campagrande, Finlay and other Albian units are present (Barnes, 1983), but have not been intensively studied. Nearly continuous exposures of Albian strata extend to about 18 km south and southwest of the Cornudas Mountains and small Lower Cretaceous outliers are also exposed around Cerro Diablo, an igneous intrusion about 15 km southeast of Washburn Mountain. More detailed study of these outcrops would aid in the precise correlation of the Cornudas Mountains strata with regionally extensive units to the south.

At Cerro Diablo, Gross (1965) measured a 1 17-m-thick sequence of Fredericksburg-Washita strata consisting, in ascending order, of (1) mostly unfossiliferous brown sandstones, locally with chert-pebble conglomerate intervals (63 m), (2), a I 9-m-thick sandy claystone unit, (3) a nodular, highly fossiliferous limestone (19 m) and (4) an upper yellow to gray shale unit (16 m). This section is broadly similar to the thickest Cornudas Mountains section we measured, along the east slope of Washburn Mountain, which includes 41 m of Cox Sandstone, overlain successively by 37 m of Washita-age siltstones and shales, 20 m of nodular limestones (Muleros Formation) and 22.5 m of shales and siltstones (Mesilla Valley Formation). The diverse faunas of the nodular limestones are similar at the two localities. Moreover, the foraminifer *Cribratina texana* is limited to the upper shale unit of the Cerro Diablo section, in a stratigraphic position similar to that observed in the upper Washita shale at Lee Ranch and in the correlative Mesilla Valley Shale of Cerro de Cristo Rey.

The well-defined, generally fossiliferous Fredericksburg- and Washita-age formations at Cerro de Cristo Rey and small nearby exposures near the Franklin Mountains (see LeMone and Simpson, 1982) are isolated by relatively great distances from other Lower Cretaceous strata in west Texas and southeast New Mexico. The stratigraphic sequence at Cerro de Cristo Rey includes regionally extensive formations (Finlay Limestone, Del Rio Clay, Buda Limestone) and intervening local units, such as the Del Norte, Smeltertown, Muleros and Mesilla Valley formations. The Muleros and Mesilla Valley formations correlate, at least in part, with undivided marine Washita strata in the Sierra Blanca and Sierra Diablo regions. They appear to maintain general lithologic and paleontologic continuity as far east as Lee Ranch (75 km) and the Cornudas Mountains (100 km), based on our recognition of these formations at those localities. These names could also be applied to the upper limestone and shale units at Cerro Diablo.

The slope-forming shale, siltstone and calcarenite unit between the Cox and Muleros formations in the Cornudas Mountains occupies the approximate stratigraphic position of the Smeltertown Formation at Cerro de Cristo Rey. The underlying, Kiamichi-equivalent Del Norte Formation, which consists of calcareous shales and limestones at Cerro de Cristo Rey, is presumably coeval with part of the upper Cox Sandstone in the Cornudas Mountains and in the northern part of the Sierra Diablo area. Typical sandstone/conglomerate Cox lithologies are not present at Cerro de Cristo Rey. The Finlay Limestone is distinct in southern west Texas and northwest along the axis of the Chihuahua trough to Cerro de Cristo Rey, but loses its identity within the Cox elastic sequence toward Sierra Prieta and the Cornudas Mountains to the north, toward the edge of the trough (King, 1965).

The Washita-age faunas of the Cornudas Mountains, which are most abundant and diverse in the limestone units, are essentially the same as in correlative units in west and central Texas and at Cerro de Cristo Rey and belong to the Caribbean faunal province (Scott, 1986). The fauna at the small Black River valley outlier, some 100 km east of the Cornudas Mountains, is composed entirely of species also found in coeval Cornudas Mountains units and in west Texas (King, 1965; Albritton and Smith, 1965). The nearest Albian outcrop to the north is that of North Lake, about 170 km distant, where the lower portion of the Tucumcari Formation crops out. The North Lake fauna is much less diverse than at the southern localities and lacks echinoids and many of the bivalves and gastropods that characterize the Caribbean faunal province. The North Lake fauna closely resembles coeval faunas to the north, in the Tucumcari Formation of east-central New Mexico, which in part composes the western endemic center of the southern Western Interior faunal province of Scott (1986).

Details of the northward transition of Caribbean faunas to those of the western endemic center are not available in New Mexico because of the absence of both outcrops and subcrops between the New Mexico—Texas border area and North Lake. A broad expanse of Albian strata extends in the subsurface from west-central Texas across northern Lea and southeastern Roosevelt Counties in New Mexico (Fallin, 1988, 1989). This sequence, which is exposed only at the North Lake and Rogers localities in New Mexico, attains a maximum thickness of more than 60 m and consists mainly of blue-gray, locally calcareous shales correlated with the Kiamichi—Duck Creek interval in central and eastern Texas. Lithologically, these strata are probably best assigned to the Tucumcari Formation, rather than extending the lithostratigraphic names Kiamichi and Duck Creek into west Texas and New Mexico for strata that differ significantly from these units as they appear nearer their type areas. However, this Lower Cretaceous subcrop thins and pinches out north of Lovington and there is no lithologic continuity of Albian strata in the subsurface between the New Mexico—Texas border and northern Lea County. This absence of preserved Albian strata also extends eastward far into Texas (Fallin, 1989), effectively separating Caribbean faunas of the Chihuahua trough from southern Western Interior faunas of west-central Texas shelf environments.

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APPENDIX—MEASURED SECTION ON EAST SLOPE OF WASHBURN MOUNTAIN

Measured on the eastern slope of Washburn Mountain, Hudspeth County, Texas (see Figs. 2, 3) by Spencer G. Lucas and Barry S. Kues on 30 June 1992—Strata dip 20° to N30°W.

unit	lithology	thickness (m)
Mesilla Valley Formation:		
14	Limestone; light olive gray (5 Y 611); micritic matrix with much shell (oyster) debris; forms a ledge.	Not measured
13	Siltstone; yellowish gray (5 Y 811) and very light gray (N8); calcareous; forms a much-covered slope.	26.5
Muleros Formation:		
12	Limestone; yellowish gray (5 Y 712); nodular micrite with some shaly partings; extremely fossiliferous (UNM locality 1484).	24.0
Middle Washita Group:		
11	Siltstone, dark yellowish orange (10 YR 616); grayish orange (10 YR 714) and moderate yellowish brown (10 YR 514); calcareous; some lenses of yellowish orange (10 YR 606), fine grained, bioturbated calcarenite; forms a slope; UNM locality 1483 is 27 m above base of unit in calcarenite; unit forms a slope.	41.2
10	Conglomerate; light brown (5 YR 614) to dark yellowish orange (10 YR 616); micritic matrix; forms a ledge.	0.3
Disconformity		
Cox Sandstone:		
9	Sandstone; same colors and lithology as unit 7; bioturbated; lower part with horizon of *W. wacoensis;* top of UNM locality 1482.	4.1

unit	lithology	thickness (m)
8	Sandstone and conglomeratic sandstone; same colors and lithology as unit 7; contains shelly lenses (UNM locality 1482); bioturbated.	7.5
7	Sandstone; pale yellowish brown (10 YR 612) and grayish orange (10 YR 714); coarse grained to conglomeratic, subangular to subrounded; poorly sorted; quartzose; some lithics; bioturbated.	8.4
6	Conglomerate; same colors and lithology as unit 3; trough crossbedded.	2.0
5	Sandy siltstone; grayish pink (5 R 812) to moderate red (5 R 514); slightly calcareous; forms a slope; some ripple lamination.	5.3
4	Sandstone; yellowish gray (5 Y 811), dusky red (5 R 314) and pale red (5 R 612); very fine to medium grained; angular; poorly sorted; quartzose; minor lithics; liesegang banding; laminar and trough crossbedded; some siliceous pebbles in trough bottoms; forms a ledge.	10.8
3	Conglomerate; matrix is grayish pink (5 R 812), fine to medium-grained, subrounded, calcareous quartzose sandstone; clasts are red, black and gray quartzite, chert, granite and lithics up to 2 cm in diameter; trough crossbedded.	2.7
Unconformity		
?Campagrande Formation:		
2	Siltstone with minor oyster packstone lenses; dark yellowish orange (10 YR 616) to moderate yellowish brown (10 YR 514); calcareous; unit forms a mostly covered slope.	9.0
Unconformity		
Bone Spring Formation (Permian):		
1	Dolomitic limestone; medium light gray (N6) and yellowish gray (5 Y 712); contains pale red (10 R 612) chert nodules up to 4.5 cm in diameter; forms a ledge.	Not measured