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NEARSHORE FAUNA OF THE TUCUMCARI FORMATION (LOWER CRETACEOUS, ALBIAN), QUAY COUNTY, NEW MEXICO

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Abstract.—The Lower Cretaceous Tucumcari Formation of Quay County, New Mexico, contains a diverse marine fauna of early late Albian age. In this paper, 49 taxa from relatively nearshore, sandy facies of the Tucumcari (predominantly a midshoreface environment) are briefly discussed and illustrated, many for the first time. The taxa include one foraminiferan, three coral, one annelid, one ctenostome bryozoan, 29 bivalve, seven gastropod, one scaphopod, one ammonite, three echinoid, and two fish species. Taxa from more offshore, open-bay environments, represented by dark gray mudstone and shale facies of the Tucumcari, are not considered here. The nearshore fauna is dominated by bivalves, which account for nearly 60% of the total diversity and more than 90% of the total abundance of specimens. Common to abundant bivalves include *Texigryphaea pitcheri, Neithea occidentalis, Plicatula incongrua, Peilinia levicostata, Scabrotrigonia emoryi,* and *Protocardia texana,* whereas the only other species approaching these bivalves in abundance at some localities is the gastropod *Turritella "seriatimgranulata"*. Rare taxa represent a significant percentage (39%) of the total number of species. Among these rare taxa are the first reported occurrences in the Tucumcari Formation of colonial corals, ctenostome bryozoa, scaphopods, regular and spatangoid echinoids, and shark and pycnodontid fish teeth.

INTRODUCTION

The Tucumcari Formation and the basal sandstone of the overlying Mesa Rica Sandstone contain a marine fauna of early late Albian age, coeval with that of the lower Washita Group of Texas and Oklahoma. These formations are well exposed and locally abundantly fossiliferous in east-central New Mexico, especially in Quay and eastern Guadalupe Counties. Although the Tucumcari fauna has not been studied monographically, it is reasonably well known taxonomically (e.g., Stanton, 1947; Scott, 1974; Kues et al., 1985) and from the perspectives of community structure and biostratigraphic and paleobiogeographic relationships (e.g., Scott, 1970b, 1974, 1975, 1986a).

Kues et al. (1985) provided a summary of Tucumcari paleontology, including a catalog of all species reported from the formation at that time, and illustrations of some common taxa. Since that time, additional study of some elements of the fauna and of the stratigraphy and regional correlation of the Tucumcari Formation have been accomplished. Scott (1986a), in considering the paleobiology of late Albian faunas in the Texas and southern Western Interior regions, included the Tucumcari fauna in a western endemic center of the Southern Western Interior faunal province, noting significant differences of this fauna from those of the Caribbean province to the south and east, the Boreal province to the north, and an eastern endemic center (Kiowa Formation of Kansas and western Oklahoma) to the northeast. Later, Scott (1986b) studied protocardiid bivalve taxa, including species present in the Tucumcari, a paper similar to his earlier study of Albian carditid bivalves (Scott, 1977), which was inadvertently omitted in the summary of Kues et al. (1985). Cobban (1985) and Lucas and Hunt (2000) reported on specimens of the important index fossil *Mortoniceras equidistans* from the basal Mesa Rica Sandstone, and Kietzke (1985) illustrated numerous species of foraminiferans and ostracods from the Tucumcari Formation at its type locality on Pyramid Mountain. Kues (1989) studied the most abundant fossil in the Tucumcari Formation, the oyster *Texigryphaea tucumcarii* (Marcou), and concluded that it is synonymous with *T. pitcher* (Morton), based on extensive collections of both species from New Mexico, Texas, and Oklahoma. Later, Kues (1997) studied the fauna of the basal Tucumcari at the San Jon hill locality, describing new species of *Plicatula* and *Gyrostrea*, and establishing a new genus and species, *Peilinia levicostata,* for the common arcuate ostreid that previously had been called *Lopha quadriplicata* (Shumard). Kues (1986) and Kues and Lucas (1993) reported on the faunas of small outliers of the Tucumcari Formation in Roosevelt and northern Lea Counties, south of the main Tucumcari outcrop belt, and Kues and Lucas (1987) studied the stratigraphy and paleontology of the Glencairn Formation, the unit correlative with the Tucumcari to the north. Kauffman et al. (1993, fig. 6), in discussing the biostratigraphy of Cretaceous strata of the Western Interior, provided range zones for some species occurring in the Tucumcari Formation.

Since 1985, additions to our knowledge of Tucumcari stratigraphy have also been published. Lucas and Kisucky (1988) designated the exposure on Pyramid Mountain (first described by Marcou, 1855, 1858, and relocated by Kues and Kietzke, 1985), as the type section of the Tucumcari Formation, described the San Jon hill exposure as a reference section, and designated type sections for the overlying Mesa Rica and Pajarito formations as well. Holbrook and Dunbar (1992) discussed the sedimentology and sedimentary tectonics of the Tucumcari and related formations in the Tucumcari and Dalhart basins. Dyman et al. (1994) portrayed the Glencairn (and by implication, the Tucumcari) Formation as an Albian unit separated from the overlying Mesa Rica Sandstone, which they believed to be of Cenomanian age, by a 5-million-year unconformity. Kues (1997) discussed the biostratigraphy of the Tucumcari and correlative formations and considered the Tucumcari, Mesa Rica and Pajarito formations to be Albian, with the Albian-Cenomanian boundary within the overlying Romeroville Sandstone (fig. 2) or possibly within the Pajarito Formation (p. 834). He also suggested, based on lithologic similarity, that thin outliers of Albian strata around numerous playa lakes in west-central Texas, called Kiamichi and Duck Creek by Brand (1953), might well be considered part of the Tucumcari

Formation, in some cases representing deposition preceding the earliest Tucumcari strata exposed in Quay and Guadalupe Counties. Lucas and Estep (2000) briefly summarized Tucumcari stratigraphy and age in an overview of Lower Cretaceous stratigraphy throughout New Mexico. Their view of the late Albian sequence in east-central New Mexico as including, in ascending order, the Tucumcari, Mesa Rica, and Pajarito formations, with the Pajarito overlain unconformably by the lower Cenomanian Romeroville Sandstone, accords best with the biostratigraphic and stratigraphic evidence, and is accepted here.

Scott (1974), in a pioneering study of the Tucumcari Formation, recognized several lithofacies and corresponding substrates within the Tucumcari Formation, including dark gray mudstone, gray-brown to dark gray clayey-silty sandstone, yellow-brown to gray brown thin-bedded sandstone, and shell conglomerate. A fifth lithofacies, yellow-brown to brown-gray bioturbated sandstone, said to occur in the uppermost Tucumcari, is included by us in the basal Mesa Rica Sandstone on lithological grounds. Scott (1974) also defined several faunal associations that were utilized to reconstruct open-bay, lower, mid-, and upper shoreface, and biostromal communities. Our observations of Tucumcari stratigraphy and faunas accord with Scott's conclusions.

In this paper, we summarize the faunal constituents of the more sandy, shallow marine Tucumcari facies — predominantly the biostromal *Texigryphaea-Lopha*, and mid-shoreface *Scabrotrigonia-Turritella* communities of Scott (1974) — based on collections made since 1984. Sampling and study of the more seaward communities, especially those of the open-bay, dark-gray mudstone and lower shoreface, clayey to silty sandstone or mudstone environments, is incomplete, and the taxa restricted to those environments are not discussed here. Illustrations and brief descriptions are provided of the shoreward marine taxa, many of which have not previously been illustrated from the Tucumcari Formation, and some of which have been first identified since the review of Kues et al. (1985). Specimens mentioned in the text are reposited in the University of New Mexico Department of Earth and Planetary Sciences paleontology collections (UNM), Albuquerque, the collections of the New Mexico Museum of Natural History and Science (NMMNH), Albuquerque, and in the Mesalands Dinosaur Museum (MDM), Tucumcari, NM.

LOCALITIES

For a complete list of Tucumcari localities from which fossils have been collected, see Kues et al. (1985). Specimens illustrated in this paper are from the following six localities, all in Quay County, New Mexico (Fig. 1).

1. Pyramid Mountain: SE¼SW¼ sec. 19, T9N, R29E.
2. Apache Canyon: exposures along NM-278, NE¼ sec. 8, T8N, R33E.
3. San Jon hill: roadcut along NM-469, 14.6 km south of San Jon, SE¼ sec. 20, T9N, R34E.
4. Mesa Quemado outlier: small outcrop a little SE of Mesa Quemado, on S side of unpaved road (Quay County road QR-54), 7.0 km W of NM-209, SE¼SE¼ sec. 1, T9N, R29E.
5. West of Tucumcari: roadcut on U.S.-66, 14.1 km W of Tucumcari, SE¼ sec. 4, T10N, R29E.
6. Palomas locality: exposures ENE of Palomas railroad siding, west of Tucumcari, N½ sec. 32, T11N, R29E.

STRATIGRAPHY

The principal outcrops of the Tucumcari Formation are in Quay and eastern Guadalupe Counties, New Mexico (Fig. 1). Here, the Tucumcari Formation is up to about 25 m thick and consists dominantly of olive-gray shale and mudstone. Minor lithotypes are yellowish-brown and yellowish-orange locally bioturbated sandstone and siltstone, and dark yellowish-brown fossiliferous limestone. The Tucumcari Formation disconformably overlies the Upper Jurassic Morrison Formation (e.g., Lucas and Kisucky, 1988; Holbrook and Dunbar, 1992) and is overlain conformably or with minor disconformity by the Lower Cretaceous Mesa Rica Sandstone (Fig. 1).

Marcou (1889) first used the term "Tucumcari beds" for the fossiliferous strata he considered Jurassic (see Kues, 1985, for a summary of the development of lithostratigraphic terminology in this region). Marcou's main reference section for his "Tucumcari beds" was Pyramid Mountain, southwest of Tucumcari (sec. 19, T9N, R29E). This is the type section for the Tucumcari Formation, where it is about 9 m thick (Lucas and Kisucky, 1988; Fig. 1). It is also the type locality of "*Gryphaea dilatata* var. *tucumcarii*" (now *Texigryphaea pitcheri*), which Marcou (1855, 1858) described from fossils collected at Pyramid Mountain, probably about 1 m above the base of the Tucumcari Formation.

A much thicker (about 25 m) section of the Tucumcari Formation about 14.6 km south of San Jon, at "San Jon hill" (sec. 20, T9N, R34E) is probably the most intensively studied section of the formation, and was designated a reference section by Lucas and Kisucky (1988; Fig. 1). This section yields nearshore marine megafossils mainly from four distinct stratigraphic levels (Fig. 1): 1) the basal 1.2 m of the formation contain a distinctive bivalve assemblage including *Ceratostreon texanum, Gyrostrea hinchada,* and *Plicatula quayensis* (Kues, 1997); 2) about 3 to 4 m above the base, a shale and ledge-forming limestone and sandstone interval (best exposed towards the top of the southern roadcut at San Jon hill) contains a *Texigryphaea* and *Peilinia* dominated assemblage; 3) a pair of thin, light-gray, fine-grained sandstone intervals a little above the middle of the section, within the thick gray shale/mudstone interval comprising most of the Tucumcari Formation, is rich in *Texigryphaea* and other bivalves; and 4) the basal part of the overlying Mesa Rica Sandstone also yields marine, mostly bivalve, taxa that are generally identical to those of the Tucumcari Formation (Kues, this volume). This last interval is disconformably overlain by Mesa Rica channel deposits, and the contact is the SB3 erosion surface of Holbrook and Dunbar (1992).

The distinctive assemblage at the base of the formation is older than the basal Tucumcari in other areas of its outcrop belt in Quay County (Kues, 1997). Its preservation here reflects either a slightly lower paleotopography or slight differential subsidence in this area as the advancing Tucumcari sea spread into this area from the south and east. Albian sediments older than are present

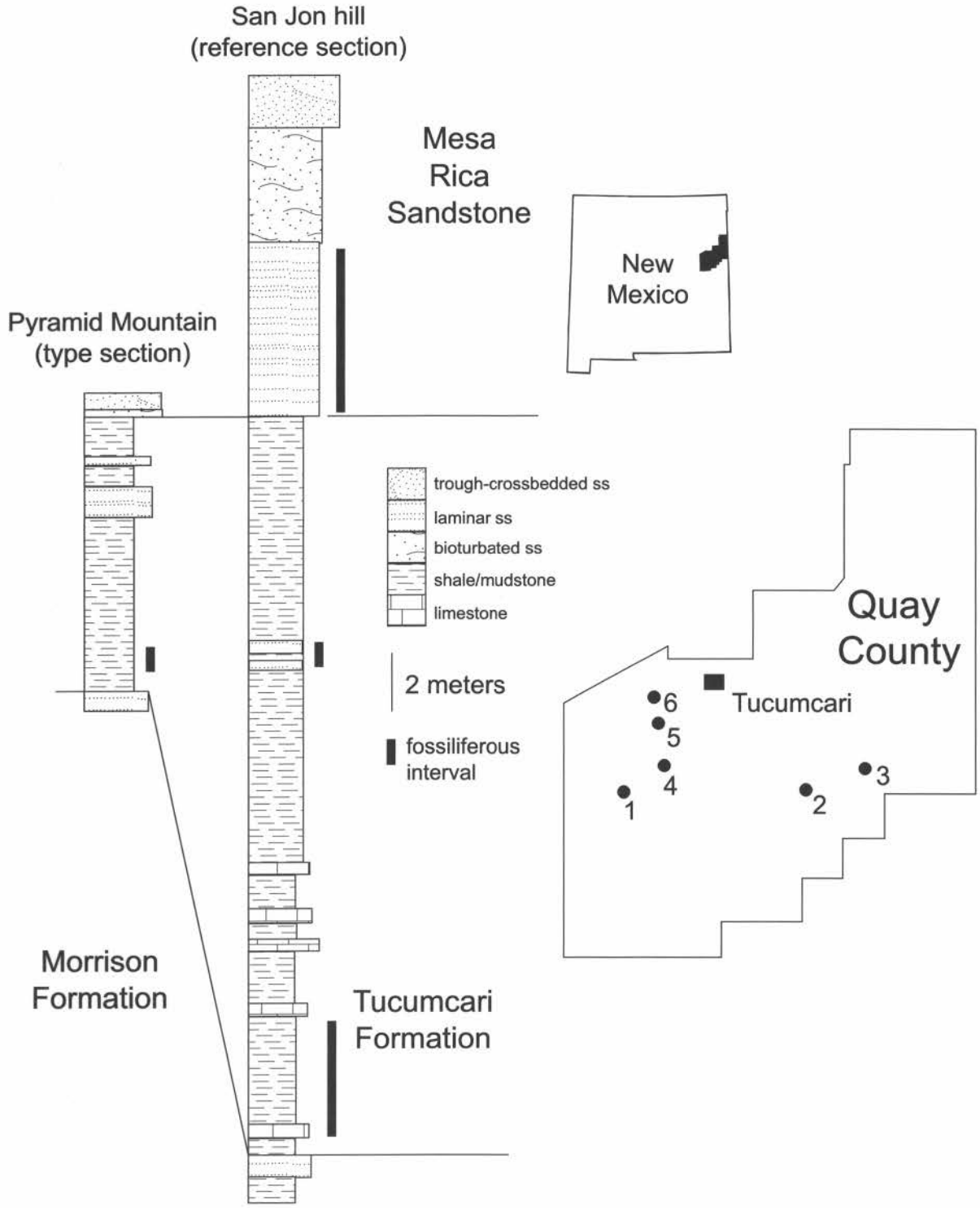


FIGURE 1. Map showing Quay County, localities of the Tucumcari Formation yielding fossils discussed in this report, and the type and reference sections of the Tucumcari Formation. Localities: 1, Pyramid Mountain; 2, Apache Canyon; 3, San Jon hill; 4, Mesa Quemado outlier; 5, roadcut west of Tucumcari; 6, Palomas locality. See text for exact coordinates of localities.

in the Quay County Tucumcari exposures are exposed in outliers to the south (e.g., in Roosevelt County; Kues, 1986) and in several restricted outcrops around playa lakes in west-central Texas, to the east (Brand, 1953; Kues, 1997).

THE NEARSHORE TUCUMCARI FAUNA

The nearshore, sandy facies of the Tucumcari Formation discussed here includes a total of 49 identified taxa: one large

foraminiferan, three coral, one annelid worm, one bryozoan, 29 bivalve, seven gastropod, one ammonite, three echinoid, and two fish species (Table 1). Bivalves dominate this fauna, both in diversity and in abundance. As is typical of diverse marine assemblages, a few taxa are common to abundant, and a significant number are rare (defined as being limited to one or two specimens in our collections). The dominant elements of the nearshore Tucumcari fauna are the bivalves *Texigryphaea pitcheri, Neithea occidentalis, Plicatula incongrua, Peilinia levicostata, Scabrotrigonia emoryi, Protocardia texana,* and the gastropod *Turritella "seriatimgranulata"*. These taxa are characteristic of the *Scabrotrigonia-Turritella* and *Texigryphaea-Lopha* associations or communities discussed by Scott (1974). Rare taxa comprise 19 of the 49 species (39%) identified in this study. Among these rare taxa are the first reported occurrences in the Tucumcari Formation of a colonial coral, ctenostome bryozoan, scaphopod, regular and spatangoid echinoids, and shark and pycnodontid fish teeth.

Quality of preservation varies considerably among the nearshore Tucumcari faunal elements. The valves of oysters, the epizoans on them, and other pteriomorph bivalves (e.g., *Neithea, Plicatula, Lima*) are generally preserved well, although many are fragmented. Preservation of other bivalves ranges from weathered valves to steinkerns and molds that are rarely complete. Gastropod remains are typically weathered shells or steinkerns. Fragmentary steinkerns of some bivalves and gastropods are unidentifiable, suggesting that the total number of species in this nearshore fauna is probably greater than the number of species identified here, and that further collecting will probably yield additional taxa. Scott (1974) observed that the dark-gray mudstone and clayey-silty sandstone facies, representing offshore, open-bay and lower shoreface environments, respectively, have benthic communities that are taxonomically different from those of the nearer-shore, sandy lithologies. The lithofacies representing more offshore environments compose much of the total thickness of the Tucumcari Formation at most localities. We have not yet sampled these facies extensively, and description of the taxa preserved within them remains for the future. Similarly, detailed study of the stratigraphy, facies, and paleontology of most portions of the Tucumcari outcrop belt have not yet been done. Such studies would add much to our present knowledge of the taxonomic composition, geographic and stratigraphic distribution, and paleoecology of the Tucumcari faunas.

Foraminifera

Kietzke (1985) reported a richly diverse (66 taxa) foraminiferan fauna from the lower Tucumcari Formation at Pyramid Mountain, derived from offshore dark gray shale facies. Here, we document *Cribratina texana*, probably the only nonattached foraminifer large enough to be noted and collected routinely from outcrops, and which was a probable inhabitant of nearshore, sandy facies of the Tucumcari sea.

Cribratina texana (Conrad)

The test of these unusually large foraminiferans (Figs. 2A, B) is uniserial, consisting of a series of six or more convex chambers of gradually increasing diameter, and often attaining a length of more

TABLE 1. Fauna of the nearshore sandy facies of the Tucumcari Formation, Quay County, New Mexico, discussed in text. Abundance estimates are subjective, based on number of specimens and number of localities yielding specimens of each species. A = abundant; C = common; MC = moderately common; UC = uncommon; R = rare.

Foraminifera	
	Cribratina texana (Conrad) (MC)
Cnidaria	
	Rennensismilia stainbrooki (Wells) (MC)
	Coelosmilia texana (Conrad) (UC)
	Montastraea? sp. (R)
Annelida	
	Serpula (Cycloserpula) cragini Twenhofel (MC)
Bryozoa	
	Vinella sp. (R)
Bivalvia	
	Pinna guadalupae Böse (UC)
	Phelopteria aff. *P. salinaensis* (White) (R)
	"Inoceramus" bellvuensis Reeside? (R)
	Neithea texana (Roemer) (MC)
	Neithea occidentalis Conrad (C)
	Plicatula incongrua Conrad (C)
	Plicatula quayensis Kues (UC)
	Lima wacoensis Roemer (UC)
	Lima utahensis Stanton (UC)
	Lima n. sp (MC)
	Lima sp. (UC)
	Texigryphaea pitcheri (Morton) (A)
	Ceratostreon texanum (Roemer) (UC)
	Gyrostrea hinchada Kues (UC)
	Nicaisolopha subovata (Shumard) (UC)
	Peilinia levicostata Kues (C)
	Scabrotrigonia emoryi (Conrad) (C)
	Parvilucina? sp. (R)
	Ludbrookia belviderensis (Cragin) (R)
	Crassatellina oblonga Meek (R)
	Pleuriocardia kansasense (Meek) (UC)
	Protocardia texana Conrad (C)
	Protocardia filosa (Conrad) (MC)
	Linearia (Liothyris)? aff. *L. (L.)*? *kansasensis* Twenhofel (R)
	"Isocardia" aff. *"I." slatana* Stephenson (R)
	Aphrodina? sp. (R)
	Cyprimeria cf. *C. washitaensis* Adkins (MC)
	Flaventia belviderensis (Cragin) (MC)
	Pholadomya sp. (R)
Gastropoda	
	Turritella "seriatimgranulata" Roemer (C)
	Turritella n. sp. (UC)
	Amberleya mudgeana (Meek) (MC)
	Calliostoma cragini Stanton (UC)
	Drepanochilus aff. *D. mudgeana* (White) (UC)
	Euspira cragini (Stanton) (R)
	Hillites newberryi (Cragin) (UC)
Scaphopoda	
	Dentalium (Dentalium) sp. (R)
Cephalopoda - - Ammonoidea	
	Mortoniceras equidistans (Cragin) (R)
Echinoidea	
	Regular echinoid spines (two types) (R)
	Washitaster bravoensis (Böse) (R)
Vertebrata	
	aff. *Cretodus* sp. (R)
	Coelodus sp. (R)

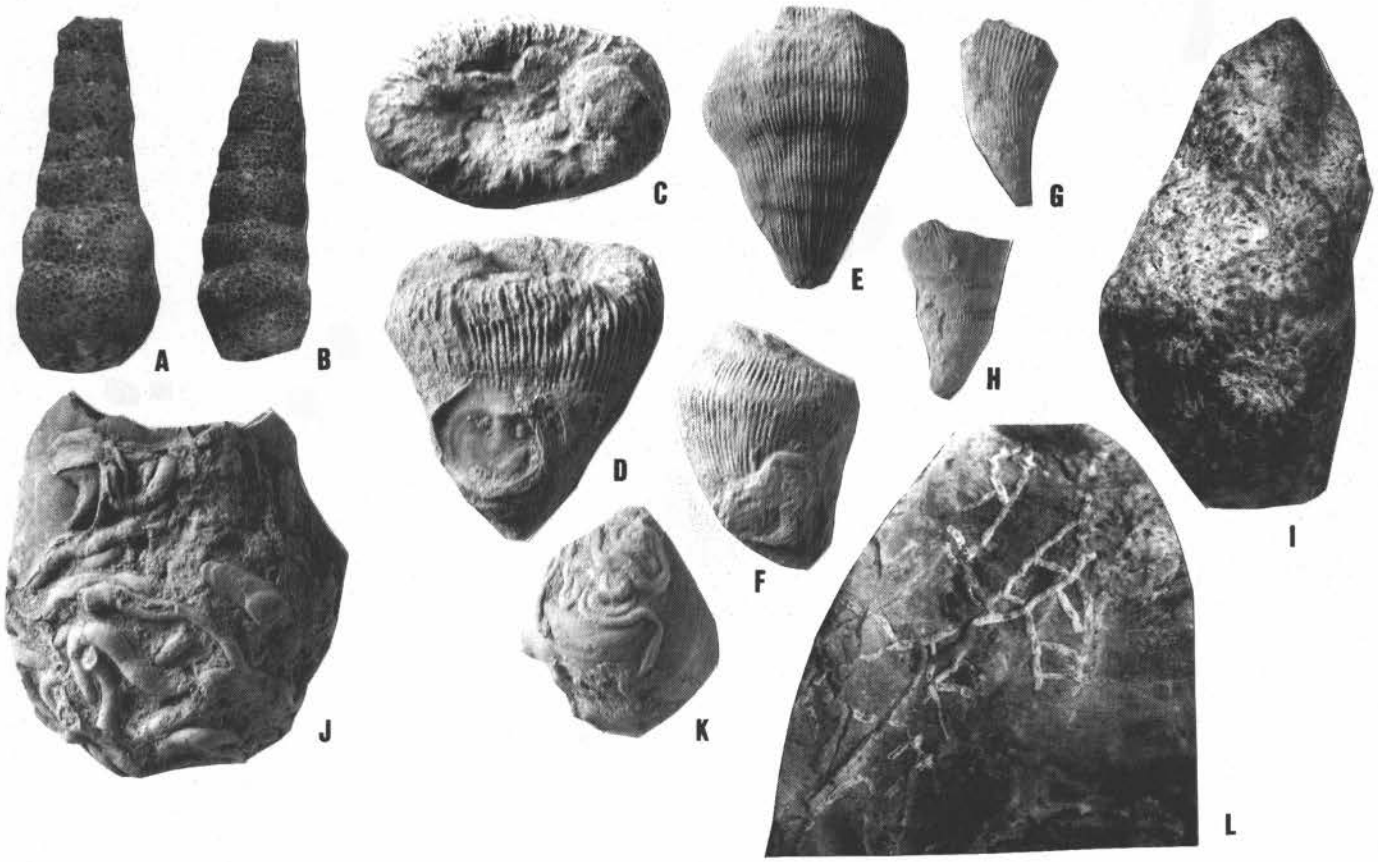


FIGURE 2. Protista, corals, annelids, and bryozoans from the Tucumcari Formation, Quay County, New Mexico. **Protista.** A-B. *Cribratina texana* (Conrad), two tests, NMMNH P-33,451A and P-33,451B, x7. **Corals.** C-F. *Rennensismilia stainbrooki* (Wells). C-D. top and side view (with attached oyster), UNM 13,115, x1.25; E. convex side view, UNM 13,117, x1.25; F. side view, with attached oyster, UNM 13,116, x1.25. G-H. *Coelosmilia texana* (Conrad). G. side view, UNM 13,114, x 1.25; H. side view, UNM 13,113, x1.25. I. *Montastrea*? sp., small corallum with several corallites, top view, UNM 13,136, x6. **Annelid worms.** J-K. *Serpula (Cycloserpula) cragini* Twenhofel. J, large specimen attached to fragment of *T. pitcheri* left valve, UNM 13,009, x1.65; K. small specimen, attached to surface of small *T. pitcheri* left valve, UNM 13,100. **Ctenostome bryozoan.** L, *Vinella* sp., NMMNH P-33, 452, x5.75. Localities: A, B, L, San Jon hill; C-K, Apache Canyon.

than 5 mm. *Cribratina texana* is a good late Albian index fossil with a wide distribution in New Mexican strata of that age, ranging from Caribbean province faunas of extreme southern New Mexico, through the western endemic center as far north as the Glencairn Formation of northeastern New Mexico. Kues and Lucas (1987, fig. 11K), Lucas et al. (1988, fig. 8C), Lucas (1991, fig. 2C), Kues and Lucas (1993, fig. 8W) and Lucas and Estep (1998, figs. 5A, B) have documented the species from other areas in the state.

Cnidaria

Numerous Albian coral species have been reported from the Caribbean province, in Texas (e.g., Wells, 1933) and south-central New Mexico (at Cerro de Cristo Rey; Turnšek et al., 1983), but only two species have previously been reported from the Tucumcari Formation. These are *Coelosmilia* [?*Desmophyllum*] *texanum* and *Platycyathus scottianus* (Kues et al., 1985), both solitary forms. We have not observed the latter species in our collecting, but the first species is present, together with two others not previously reported from the Tucumcari Formation.

Rennensismilia stainbrooki (Wells)

These solitary corals (Figs. 2C-F) have a broadly conical, straight to somewhat arcuate corallite, that is nearly circular to oval in cross section. A typical large specimen (Figs. 2C, D) is 33 mm high, with a diameter of the oval corallite measuring 32 mm by 20 mm. The septa are thin and closely spaced; exact counts were not possible on the specimens at hand because of poor preservation and matrix within the calices, but the number of septa observed or extrapolated on 10 specimens from the Apache Hill locality ranges from 74 to 100. The septa converge towards the center of the calice, but no columella was observed on any specimen, probably because they are obscured by matrix. The calicular margin is broad and rounded, and the septa cross the margin to become conspicuous, sharp, strongly nodose costae on the external surface of the corallite. A peculiarity of this species, noted by Wells (1933) on the type specimens and observed on many of the Tucumcari specimens as well, is that the costae on the convex side of an arcuate corallite extend from the calicular margin to the base (apex), whereas costae on the concave side extend downward towards the base but intersect the first group of costae, typi-

cally at angles of 30° to 45°, before reaching it.

Wells (1933) initially described this species from Kiamichi-equivalent exposures around several of the playa lakes not far east of the New Mexico-Texas border, in west-central Texas, where they occur with *Platycyathus scottianus* Wells and *Coelosmilia texana* (Conrad), associated with *Texigryphaea pitcheri*. It also occurs in the Smeltertown and Mesilla Valley Formations at Cerro de Cristo Rey (Turnsek et al., 1983). In the Tucumcari Formation, *Rennensismilia stainbrooki* is moderately common at a few localities in silty-sandy lithologies, but is rare to absent at most outcrops. Epizoans, especially serpulids and juvenile oysters, are present on the external surfaces of many specimens.

***Coelosmilia texana* (Conrad)**

The corallite of *Coelosmilia texana* (Figs. 2G, H) is relatively small, narrowly conical, typically gently arcuate, and subcircular in cross section. The largest specimen in our collections is 21 mm high, with a maximum diameter of 9 mm by 12 mm. Although poor preservation prevents accurate determination of septa number on most specimens, 48 septa are present on the best preserved specimen (Fig. 2G), which is the constant number characteristic of the species (Wells, 1933). The septa cross the calice border and become an equal number of fine, sharp costae on the external corallite surface. These costae tend to be smooth to obscurely nodular. This species is readily distinguished from *Rennensismilia stainbrooki*, with which it may co-occur in the Tucumcari Formation, by its more narrowly conical shape, smaller size, and much fewer septa and costae. In north Texas, it ranges from the Walnut to Kiamichi Formation and at Cerro de Cristo Rey it occurs in the Del Norte Formation (Turnšek et al., 1983).

***Montastraea?* sp.**

A single small, worn specimen of a colonial coral, the first reported from the Tucumcari Formation, was recovered from the Apache Canyon locality. The specimen is an elongate, knob-like mass 11.5 mm long, 7 mm wide, and 6 mm high, consisting of seven closely packed circular, cerioid corallites (Fig. 2I). The calices are 2.0 to 2.5 mm in diameter; because they are filled with matrix, the presence of a columella cannot be ascertained. The septa number 24, in two or possibly three cycles, and continue as relatively coarse costae across the swollen calice margins. The costae are generally confluent with those of adjacent corallites.

Wells (1933) described numerous species of colonial corals from the upper Albian of Texas. Of these, the Tucumcari specimen most closely resembles several species of *Orbicella* that range from the Edwards Limestone to the Main Street Formation, although it is not obviously conspecific with any of them. *Orbicella* was considered a synonym of *Montastraea* by Wells (1956). Turnsek et al. (1983) reported 21 species of corals from the Albian at Cerro de Cristo Rey, most of them solitary; none of the colonial species resemble the Tucumcari specimen. Only a single colonial coral is known from the Kiowa Formation of Kansas (*Actinastraea nidiformis* (Cragin); Scott, 1970a), but it differs from *Montastraea*? sp. in having much smaller, polygonal rather than circular corallites, and thin septa that do not extend across the corallite margins as costae.

Annelida

***Serpula (Cycloserpula) cragini* Twenhofel**

This serpulid worm (Figs. 2J, K) is characterized by cylindrical, unornamented tubes, occurring as twisted masses cemented to the shells of other organisms, most often the valves of *Texigryphaea pitcheri*. The tubes are typically 1.5 to 2.25 mm in diameter, display fine growth lines and local discontinuities probably reflecting temporary cessation of growth, and may expand or constrict slightly along their length. The walls of the tubes are thick, up to 0.5 mm in a tube 2.25 mm wide, and are composed of at least three shell layers. In these features, the Tucumcari specimens agree closely with *Serpula (Cycloserpula) cragini,* described initially from the Kiowa Formation of Kansas (Twenhofel, 1924). No comparable Albian species of *Serpula* have been described from the Texas region, but some Late Cretaceous species, such as the late Cenomanian *S. (C.) intrica* White, are quite similar to *S. (C.) cragini* (Kirkland, 1996).

Serpula (Cycloserpula) cragini is one of the most common epizoans of the Tucumcari fauna, and its tubes sometimes cover several cm^2 of the shell surface of a large host.

Bryozoa

In addition to rare, small colonies of membraniporoid cheilostome bryozoan colonies encrusting valves of *Texigryphaea*, the following ctenostome bryozoan also occurs in the Tucumcari Formation.

***Vinella* sp.**

Two examples of ctenostome bryozoan, one on a left valve, and the other on a right valve, of *Texigryphaea pitcheri*, were recovered from the Tucumcari Formation at the San Jon hill locality. The colonies consist of branching, stoloniferous tubes about 0.1 to 0.15 mm in diameter, forming an interconnected network on the surface of the valves. The stolons are compressed locally along their length, forming "segments", and display widely-spaced, round pores along their upper surface. The best-preserved colony (Fig. 2L) also includes a cluster of radiating stolons extending from a central node. These specimens fit the definition of *Vinella*, as diagnosed by Condra and Elias (1944). The type species of *Vinella* is of Ordovician age, and the range of the genus is Ordovician to Cretaceous (Bassler, 1953).

Bivalvia

***Pinna guadalupae* Böse**

Most specimens of *Pinna* from the Tucumcari Formation are small fragments, but a few nearly complete, albeit poorly preserved, specimens are as much as 170 mm long. The best preserved specimen (Figs. 3A, C) expands from the apex (anterior end) at a 30° to 35° angle, and has a nearly circular cross section near the apex, which becomes broadly fusiform with later growth. Each valve has a low median longitudinal carina. Ornamentation consists of approximately 15 strong, sharp, widely-spaced longitudinal costae on each valve, which are crossed by fine, very

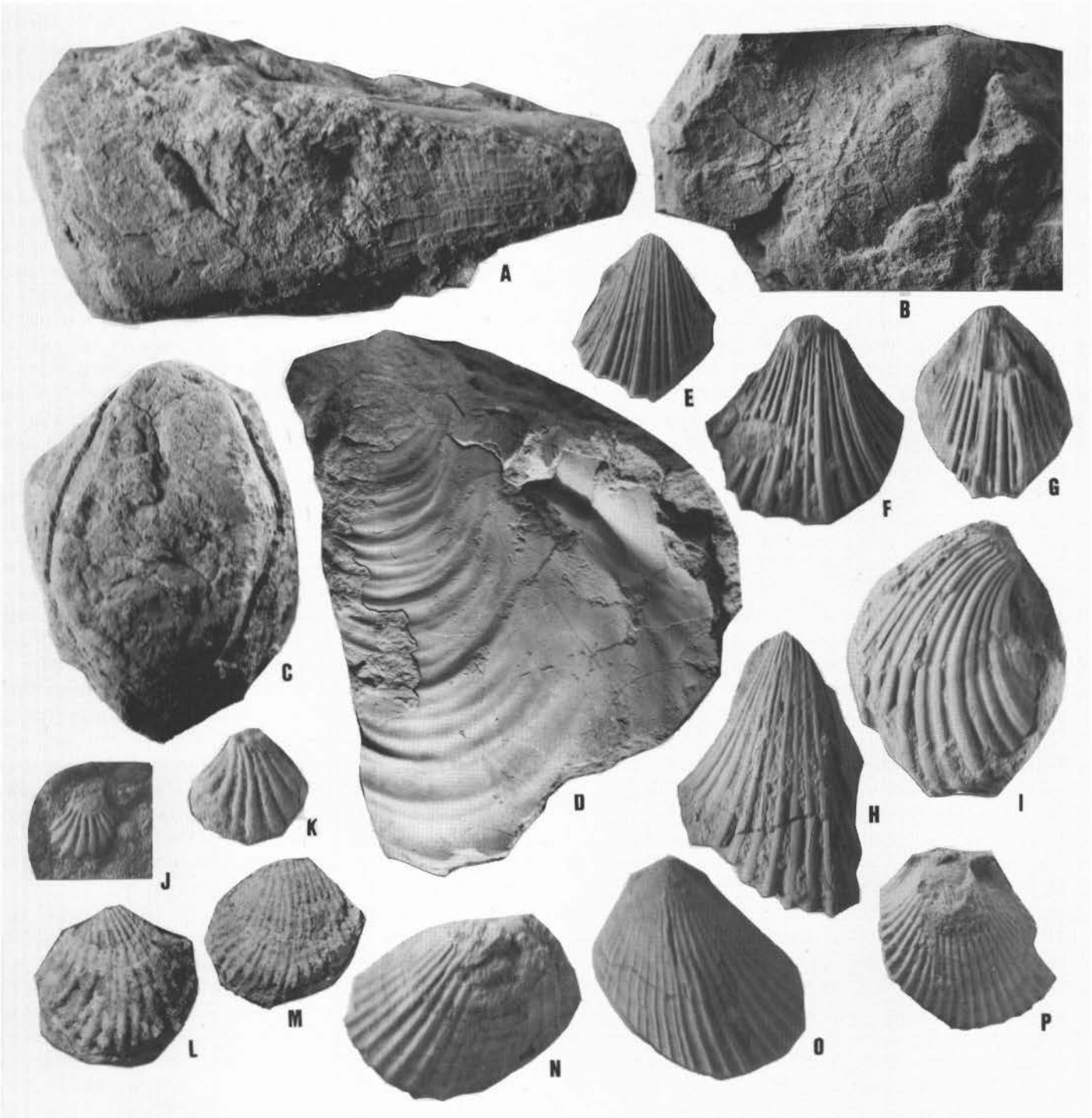


FIGURE 3. **Bivalves** from the Tucumcari Formation, Quay County, New Mexico. A and C. *Pinna guadalupae* Böse, nearly complete right valve, x0.75 (A) and posterior cross-sectional view, x0.85 (B), UNM 13,062. B. *Phelopteria* aff. *P. salinaensis* (White), partial right valve, UNM 9,093, x0.85. D. *"Inoceramus" bellvuensis* Reeside?, partial left valve, MDM 205, x0.50. E-G. *Neithea occidentalis* Conrad. E. Small right valve, UNM 13,086, x2; F. Large right valve, UNM 13,084, x1.4; G. Right valve, UNM 13,085, x1.25. H-I. *Neithea texana* (Roemer). H. Laterally compressed right valve, UNM 13,088, x1.33; I. Laterally compressed right valve, UNM 13,089, x1.4. J-K. *Plicatula incongrua* Conrad. J. Small right valve, with attachment scar, UNM 13,096, x2; K. Right valve, UNM 13,097, x2. L-M. *Plicatula quayensis* Kues. L. right valve, holotype, UNM 11,987, x1.5; M. Right valve, paratype, UNM 11,988, x1.5. N. *Lima wacoensis* Roemer, incomplete left valve, UNM 13,090, x2. O. *Lima utahensis* Stanton, right valve, UNM 13,095, x2. P, *Lima* n. sp., right valve, UNM 13,094, x2. Localities: A, C, D, L, M, O, San Jon hill; B, Mesa Quemado locality; E-K, N, P, Apache Canyon locality.

closely-spaced growth lines. The longitudinal costae begin at the apex and extend the entire length of the valve.

Kues and Lucas (1987, p. 182) discussed the uncertainties in identifying Albian species of *Pinna* from the Texas-southern Western Interior region, especially in distinguishing *P. comancheana* (Cragin, 1894) from *P. guadalupae* (Böse, 1910). *Pinna comancheana* has been reported in numerous faunal lists from the Tucumcari Formation (see Kues et al., 1985), but Cragin's original description was vague, the species was not illustrated, and the location of the type specimen was not given. Scott (1970a, p. 54) reported that the type specimens of species established by Cragin (1894) are lost, so it may never be possible to ascertain in detail the characteristics of *P. comancheana*. The type specimen was collected from the Kiowa Formation of Kansas (Cragin also noted its presence in the Tucumcari Formation), yet the species was not collected by either of the two workers (Twenhofel, 1924; Scott, 1970a) who have monographed the Kiowa fauna. Adkins (1928, pl. 18, fig. 6) illustrated a poorly preserved specimen from an unknown location having much coarser and more closely-spaced longitudinal costae than is suggested by the original description of *P. comancheana*.

In contrast, *Pinna guadalupae* was well described and illustrated by Böse (1910), from Albian strata (Del Norte and Mesilla Valley formations) at Cerro de Cristo Rey, south-central New Mexico. The Tucumcari pinna specimens are conspecific with *P. guadalupae*. It is uncertain whether *P. guadalupae* is the same species as *P. comancheana*, but because the characteristics of *P. comancheana* are so poorly known, and the type and topotypic specimens are unavailable, we are referring the Tucumcari specimens to *P. guadalupae*. *Pinna comancheana* is probably best deemed a *nomen dubium*.

Phelopteria aff. *P. salinaensis* (White)

Phelopteria aff. *P. salinaensis* was first documented from the Tucumcari Formation by Kues et al. (1985, fig. 9A). Unfortunately, no additional specimens have been collected that would allow a better determination of the morphology and identity of this large pterioid. This specimen (Fig. 3B), a right valve, is incomplete, but displays a straight hingeline about 55 mm long, a small beak extending slightly above the hingeline, a small, subtriangular anterior auricle, and a very wide, flaring posterior auricle that extends from the hingeline to the posteroventral margin of the valve. The main body of the value and umbo are only gently inflated. The specimen agrees in its relatively large size with *P. salinaensis*, originally described from the Kiowa Formation (Twenhofel, 1924; Scott, 1970a), but differs in having a smaller anterior and wider posterior auricle, and in having less inflated valves.

Phelopteria belviderensis, also from the Kiowa, is a large, poorly known species that may be synonymous with or a variant of *P. salinaensis* (Twenhofel, 1924; Scott, 1970a). The only extant illustration of *P. belviderensis* (Twenhofel, 1924, pl. 19, fig. 10) is of a poorly preserved right valve that is vaguely similar to that of the Tucumcari specimen in apparently having a short anterior auricle and broad posterior auricle, but the axial portion of the valve was said to be "quite convex", in contrast to the low convexity of the Tucumcari specimen.

"Inoceramus" bellvuensis Reeside?

Specimens of *"Inoceramus"* are rare in the Tucumcari Formation; even small, fibrous-prismatic fragments of their distinctive shell are uncommon. The most complete specimen available to us (courtesy of A. Hunt, Mesalands Dinosaur Museum, Tucumcari, NM) is a steinkern with some shell adhering of a partial left valve (Fig. 3D), collected from San Jon hill. The valve is about 190 mm in length along the growth axis, but was even larger when complete, as the ventral margin of the valve is not preserved. It is moderately inflated, bears a relatively small beak that projects slightly beyond the hingeline, and is ornamented with generally strong but unevenly spaced comarginal folds that vary considerably in size. Because the anterior part of the valve is missing, its exact shape cannot be observed, but the hingeline is relatively long and the posterior region broad. The angle between the hingeline and the principal valve axis changed with growth, beginning at nearly 90° and curving gradually to produce a final angle of about 60°.

Scott (1970a) noted the difficulties in distinguishing *"I." comancheanus* Cragin from *"I." bellvuensis* Reeside, the two species of *"Inoceramus"* known from upper Albian strata of the southern Western Interior. From published descriptions, *"I." bellvuensis* has a larger, broader and more subquadrate shell, less convex valves, a larger angle between the hingeline and anterior margin, and narrower, more widely spaced comarginal folds. However, Reeside's (1923) descriptions and illustrations of both species suggest significant overlap in the distinguishing characters, especially among smaller specimens, but no large assemblages of either species have been reported that would allow biometric analysis of their morphology and the degree of overlap in various features.

Positive assignment of the large Tucumcari specimen is hindered by its incomplete state. Valve convexity and ornamentation seem closer to that of *"I." comancheanus,* but extrapolated shell shape, low obliquity and very large size are more characteristic of *"I." bellvuensis,* to which we questionably assign this specimen. It is quite different from the inoceramids (species and morphs of *Actinoceramus*) reported recently from the Comanche Peak and Kiamichi formations of eastern Texas (Kennedy et al., 1999).

Neithea texana (Roemer)

Neithea texana (Figs. 3H, I) is common in the Tucumcari Formation and represents a large species, attaining a valve height of 40 mm or more, although complete valves are rarely found. The moderately convex right valve is ornamented with simple, strong, high, rounded radial ribs that are of approximately equal size and wider than the intervening interspaces, which have the appearance of deep troughs between the ribs. Early ribs are fine, sharp, about of equal size, and display few bifurcations; splitting of ribs is restricted to early growth. The left valves are flat to very gently convex and bear simple, strong, relatively narrow ribs. The auricles are seldom preserved, but are relatively small and lack radial ornamentation. Sharp, closely-spaced comarginal growth lines are present on the valve body and auricles.

Stanton (1947) noted that some specimens have six slightly enlarged primary ribs on the right valve, with two slightly smaller secondary ribs between each primary pair, but this variation was not observed on the Tucumcari specimens.

***Neithea occidentalis* Conrad**

Neithea occidentalis (Figs. 3E-G) is more abundant in the Tucumcari Formation than *N. texana*. It is easily distinguished from that species by its generally smaller valves and especially by its distinctive ornamentation. Six primary ribs on the right valves are larger than the secondary ribs between each pair of primaries, and all of the ribs tend to be more sharply rounded than on *N. texana*. In addition, much finer, narrow, radiating lirae are present along one or both sides of each primary rib. These develop early in growth by bifurcation of the primary ribs and are never present on *N. texana*. Small specimens of *N. occidentalis* display a delicate array of fine ribs, with the primary ribs being more conspicuously enlarged relative to the secondary ribs than is the case of fully grown specimens.

***Plicatula incongrua* Conrad**

Plicatula incongrua (Figs. 3J, K) is a small (typically 10-12 mm high), strongly costate bivalve with subtriangular to suboval valves. The right valve is moderately convex and on some specimens bears an attachment scar near the beak, whereas the left valve is nearly flat. Both valves bear eight to 12 strong, closely-spaced radiating ribs that are nodose and may bear small hyote spines. *Plicatula incongrua* was first described by Conrad (1857) from upper Albian strata at Cerro de Cristo Rey, and Kues (1997) discussed the possible synonymy of *P. incongrua* and *P. subgurgitis*, described from the same or nearly the same locality and stratum by Böse (1910). Tucumcari specimens of *P. incongrua* are variable, and some display features supposedly characteristic of *P. subgurgitis*, such as a strong ventral bend in the right valve.

***Plicatula quayensis* Kues**

This species (Figs. 3L, M) was described by Kues (1997) from the basal Tucumcari Formation at the San Jon road cut locality. It differs from the far more common and widespread *P. incongrua* in being much larger (attaining a height of 20+ mm), having a subcircular rather than subtriangular valve outline, and in possessing as many as 30 radiating ribs on the valves, which tend to be more irregular and spinose than the ribs of *P. incongrua*.

***Lima wacoensis* Roemer**

Lima wacoensis (Fig. 3N) is distinguished by its strongly oblique, nearly subrectangular valves, having sharp, widely-spaced radiating ribs. The angle between the short hingeline and the principal valve axis is typically low, between 30° and 35°, and the auricles are very small. A typical specimen is about 18 mm long and 13 mm high. Stanton (1947) provided a detailed description of this species, and the Tucumcari specimens closely resemble his specimens. The species ranges widely through the Fredericksburg and Washita Groups of the Texas region, and was previously reported from the Tucumcari Formation by Stanton (1947). However, it is much less common than other species of *Lima* in the Tucumcari.

***Lima utahensis* Stanton**

Scott (1974, 1986a) first reported *Lima utahensis* from the Tucumcari Formation, an unusual occurrence of a species first described from the Cenomanian of the Western Interior (Stanton, 1893) appearing in the Albian of New Mexico. Earlier, White (1877) had reported Cenomanian specimens of this species as *L. wacoensis*. Most of our specimens are fragmentary, but a complete right valve (Fig. 3O) from the San Jon roadcut locality displays the relatively erect proportions and fine radiating ribs characteristic of *L. utahensis*.

***Lima* n. sp.**

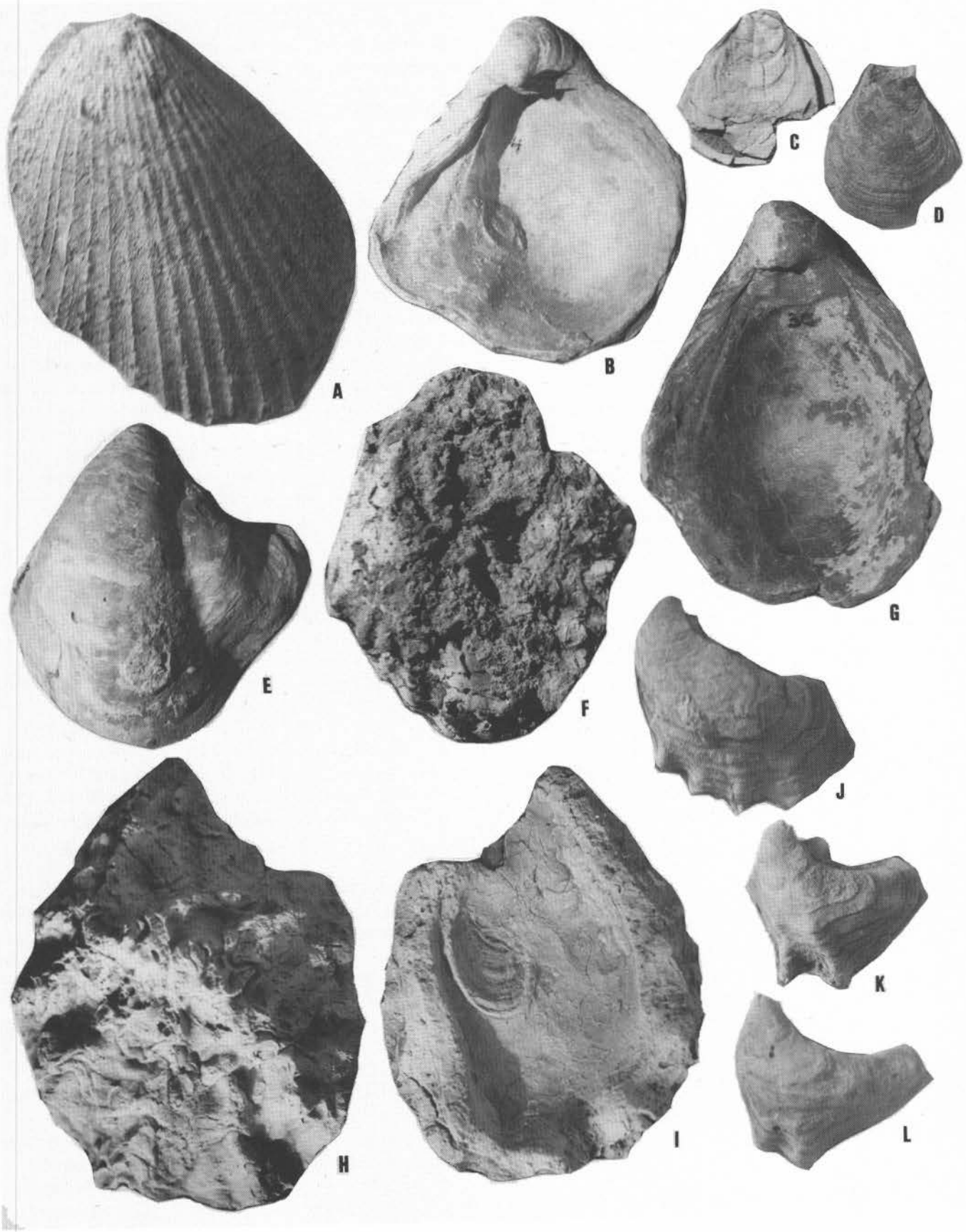
The most abundant species of *Lima* in the Tucumcari Formation (Fig. 3P) is a relatively small (height to about 20 mm) form having erect valves, with the principal axis of growth diverging from the narrow hingeline at an angle of 50°+. The valves are more inflated than those of *L. wacoensis* and *L. utahensis,* and possess coarser, more closely spaced radial ribs. These are strong, sharp crested, number 25-30 on a valve, and are broadly triangular in cross section, creating a finely undulating commissure. Some specimens possess a fine radial thread at the bottom of interspaces between pairs of major ribs. Fine, closely-spaced growth lines cross the ribs and locally produce small nodes at the crest of the ribs. This species is about the same size as *L. wacoensis* and *L. utahensis*, and other Albian species from the region (e.g., from Cerro de Cristo Rey, see Böse, 1910), but differs sufficiently in valve convexity and coarseness of ribbing to suggest that it is an unnamed species.

***Lima* sp.**

A few molds and one nearly complete steinkern (Fig. 4A) of an articulated specimen, indicate the presence of an unusually large species of *Lima* in the Tucumcari Formation. The best specimen has fairly erect valves (50°-55°), and has a height of 58 mm and length of 46 mm. The radiating ribs are relatively fine, and are widely separated by interspaces two or three times the width of a rib. A total of about 26 ribs occur on the valves. This taxon is considerably larger than typical specimens of *L. wacoensis* and *L. utahensis.* Stanton (1947) mentioned that some Washita specimens of his variety *L. wacoensis quadrangularis* attain a length of 56 mm, but the valves of that form are strongly oblique and subrectangular in shape.

***Texigryphaea pitcheri* (Morton)**

Specimens of *Texigryphaea pitcheri* (Figs. 4B, E, G) from the Tucumcari Formation were originally described as *Gryphaea tucumcarii* by Marcou (1855), based on specimens collected near Pyramid Mountain. However, Kues (1989) showed that *T. tucumcarii* was based on unusually large, deep, elongate left valves of *T. pitcheri*, a morph that is completely gradational with typical morphs of *T. pitcheri* in Texas, Oklahoma, and in the Tucumcari Formation of east-central New Mexico. Thus, *T. tucumcarii* is a synonym of the earlier described species *T. pitcheri*. *Texigryphaea pitcheri* is the only species of the genus observed in the main outcrop belt of the Tucumcari Formation, where it is by far the most abundant invertebrate species, occurring in huge numbers, sometimes in biostromal accumulations, throughout the formation. The species has been extensively described and illustrated by Kues et al. (1985), Kues and Lucas (1987), and Kues (1987, 1989).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Outliers of Albian strata, representing deposition preceding that of the main Tucumcari outcrop belt, contain earlier species of *Texigryphaea*, such as *T. navia*, at localities in Roosevelt County, New Mexico (Kues, 1986), and several Kiamichi-equivalent exposures in west-central Texas (Brand, 1953; Kues, 1997).

Kues (1989) noted that valves of *T. pitcheri* from the Tucumcari Formation are typically colonized by a variety of epizoans, including small texigryphaeas and other oysters, serpulid worms (see above), clinonid sponge and acrothoracic barnacle borings, endolithic algae, and rare membraniporoid bryozoans. As noted above, rare ctenostome bryozoans also colonized the valves of *T. pitcheri.*

***Ceratostreon texanum* (Roemer)**

Ceratostreon texanum (Fig. 4F) is a distinctive large oyster characterized by its suboval to reniform valves, strongly coiled beak, and ornamentation of large, arcuate, rugose, irregularly branching, radiating ribs. The valves attain a height of up to about 75 mm. This species, which is widespread and abundant in strata of the Fredericksburg Group in Texas and Oklahoma, and in equivalent strata in southern New Mexico, is present only at the very base of the Tucumcari Formation in Quay County, where it has been observed at San Jon hill (see Kues, 1997). It became extinct prior to the onset of Tucumcari deposition in most areas of east-central New Mexico; its uppermost occurrence coincides, or nearly so, with the first appearance of *Peilinia levicostata*.

***Gyrostrea hinchada* Kues**

Kues (1997) described this medium-sized oyster (Figs. 4C, D) from the basal part of the Tucumcari Formation at the San Jon road cut. The species is characterized by a fairly deep, subcircular left valve with low, lamellate growth lines, and a smaller, flat to slightly convex right valve. Most specimens are 15 to 40 mm high, but the largest specimen observed is 57 mm high. Most specimens display conspicuous attachment scars (flattened areas or concave pits) on the beak of the left valve. Some of these are large, extending for most of the height of the valve, and indicate that the individual remained cemented to its host organism for much of its life. Isolated left valves cemented to the shell surfaces of other organisms, especially *Texigryphaea pitcheri*, are common in the Tucumcari Formation.

FIGURE 4. **Bivalves** from the Tucumcari Formation, Quay County, New Mexico. A. *Lima* sp., right valve steinkern, UNM 13,091, x1.4. B, E, G, *Texigryphaea pitcheri* (Morton). B. interior of left valve, UNM 9077, x1; E, exterior, left valve, UNM 9078, x1; G. Interior of left valve, relatively narrow specimen, UNM 9085, x1. C-D. *Gyrostrea hinchada* Kues. C. Right valve view of articulated specimen, paratype, NMMNH P-18774, x1; D. Left valve with prominent attachment scar at beak, paratype, UNM 12,526, x1. F. *Ceratostreon texanum* (Roemer), external surface of large left valve, with gypsiferous encrustations, UNM 13,133, x1. H-I. *Nicaisolopha subovata* (Shumard), external (H) and internal (I) views of partial left valve, MDM 206, x0.5. J-L. *Peilinia levicostata* Kues. J. External view, large left valve, UNM 13,082, x1.5; K. External view, left valve, UNM 13,083, x1.5; L. External view, juvenile left valve, x2. Localities: A, J-L, Apache Canyon locality; B, E, Pyramid Mountain; C, D, F, San Jon hill; G, West of Tucumcari locality; H, I, Palomas locality.

***Nicaisolopha subovata* (Shumard)**

Fragmentary valves of this large oyster are occasionally encountered in sandy facies of the Tucumcari Formation, but complete valves are rare. The largest complete valve in our collections (Kues et al., 1985, fig. 9H) is about 110 mm in height, but incomplete valves (e.g., Figs. 4H, I) suggest a maximum height of about 175 mm or more. The valves are suboval to subtrigonal in shape, with a relatively short hingeline, and overall are not very convex. Both valves bear up to 8 to 10 low, wide plications that produce a pronounced plicate commissure, and these are crossed by coarse, comarginal growth lamellae. As this species was among the largest organisms living on the Tucumcari seafloor, its valves invariably host epizoans, especially oysters, which on some specimens completely cover the external surface of the valves. The species has a wide geographic distribution in upper Albian strata, from the Kiowa Formation of Kansas, through east-central and southern New Mexico, to north-central Texas.

Malchus (1990) provided evidence to indicate that true *Lopha* originated in the Tertiary, and that Mesozoic species assigned to that genus are not closely related to *Lopha*. *"Lopha" subovata* agrees morphologically with *Nicaisolopha* Vyalov, as redefined by Malchus (1990, p. 171), and is here transferred to that genus.

***Peilinia levicostata* Kues**

Peilinia levicostata (Figs. 4J-L) was described in detail by Kues (1997), who established the new genus and species for Tucumcari Formation specimens that previously had been referred to *Lopha quadriplicata* (Shumard). *Peilinia levicostata* appears to be restricted to the western and possibly eastern endemic centers of the southern Western Interior province, whereas *P. quadriplicata* appeared somewhat later in the southern New Mexico and Texas-Oklahoma areas of the Caribbean province. Fully grown specimens of *P. levicostata* are characterized by moderately large (40+ mm long), arcuate valves. The left valve is relatively convex and bears strong growth lamellae and five or six prominent radial costae that often extend past the ventral margin of the valve, whereas the right valve is smaller, nearly flat, and lacks costae. The shape and ornamentation of this species is highly variable, especially in the earlier growth stages, which lack or may have only one or two small costae, and may have strongly arcuate to even L-shaped valves. The species is common in the Tucumcari Formation, and at some localities, such as San Jon hill, is present in large numbers in some horizons.

***Scabrotrigonia emoryi* (Conrad)**

This large distinctive bivalve (Figs. 5A-C) is abundant in sandy facies of the Tucumcari Formation. It attains a valve height of 45 mm or more, and its valves are strongly arcuate in shape, with prominent, strongly opisthogyrate beaks situated anterior of mid-length. The anterior margin is broadly convex, and the concave posterodorsal margin extends to a moderately elongate, rather sharply convex posterior margin. A long, depressed escutcheon occupies the posterodorsal margin along the hingeline. The valves are strikingly ornamented with 25 or more strong, widely spaced, comarginal costae, which are sharply rounded near the beak but display conspicuous, closely spaced nodes along their

length later in growth, across most of the valve surface. On some specimens these nodes are developed into short, sharp, conical spines. The costae are deflected posteriorly across a pair of fine radial ridges bordering the escutcheon, and become smaller, nodose, chevron-shaped ribs across the escutcheon.

The Tucumcari specimens display no significant differences from Conrad's (1857) types or from Böse's (1910) specimens from the Muleros and Mesilla Valley formations of Cerro de Cristo Rey. *Scabrotrigonia emoryi* is widely distributed in correlative strata in the Texas-southern Western Interior region.

***Parvilucina*? sp.**

One small left valve (Fig. 5D) from the San Jon hill locality is questionably assigned to *Parvilucina* based on valve shape and nature of the beak and umbonal areas; dentition and other internal valve features are unknown. The valve is 6.1 mm long and 5.4 mm high at the beak. It is subcircular in outline, with a small, slightly prosogyrate beak extending a little beyond the dorsal margin, has a broadly convex posterodorsal/posterior margin, and a straight anterodorsal margin that curves rather abruptly into the somewhat truncated anterior margin. The umbo is small and slightly inflated, and ornamentation is limited to fine, slightly irregular growth lines. The dorsal margin displays neither a lunule nor an escutcheon but appears to be slightly thickened; otherwise the valve is thin.

The small size of this valve suggests it may be a juvenile, but its shape is distinctive and closely resembles that of several small to moderately small Late Cretaceous species assigned to *Lucina* or *Parvilucina* (probably all belong to *Parvilucina*). *Parvilucina juvensis* (Stanton, 1893; see also Kirkland, 1996), *L. dentonana* (Stephenson, 1952) and *L. parvilineata* Shumard (Stephenson, 1941) are all species that appear to be related to the Tucumcari specimen, although lacking knowledge of the dentition, even its generic identification must remain tentative.

***Ludbrookia belviderensis* (Cragin)**

Scott (1977) described *Ludbrookia belviderensis* (Fig. 5E) and illustrated specimens from the Tucumcari Formation at San Jon hill. This species is small, with subtrigonal to suborbicular valves that are higher than wide, a prominent, prosogyrate, curved beak, and numerous strong radial ribs. It is rare in our Tucumcari collections.

***Crassatellina oblonga* Meek**

Crassatellina oblonga, described initially from the Kiowa Formation of Kansas, is a relatively small, elongate species; a typical specimen (Fig. 5F) measures 18 mm long and 11.5 mm high. The hingeline is long and slopes gently posteriorly, curving sharply ventrally to form a moderately acute, spatulate posterior margin. The posterior umbonal ridge is sharp and separates the moderately inflated valve body from a depressed posterodorsal region. The beaks are small and situated about one third of the distance from the evenly convex anterior margin.

***Pleuriocardia kansasense* (Meek)**

Pleuriocardia kansasense (Fig. 5G) is characterized by relatively small, subcircular, moderately inflated valves with sharp, nearly central beaks. Ornamentation consists of fine, evenly spaced, radial riblets that develop small nodes where crossed by growth lines. The posterior margin of the valves is nearly straight and gently truncated, whereas the anterior margin is moderately convex. The riblets produce a finely crenulated commissure. A typical specimen is 28 mm high and 27 mm long.

This species was originally described from the Kiowa Formation of Kansas (e.g., Scott, 1970a), and was assigned to the new genus *Pleuriocardia* in Scott's (1978) study of Comanche cardiids. Scott (1986a) first reported it from the western endemic center (Tucumcari and related formations of New Mexico), where it is an uncommon species.

***Protocardia texana* Conrad**

Protocardia texana (Figs. 5H-J) in the Tucumcari Formation is characterized by relatively large (up to 50 mm long) valves that are slightly longer than high, have a suboval, subcircular, to vaguely subtrigonal shape, and posses a prominent slightly prosogyrate beak situated subcentrally, slightly closer to the anterior than to the posterior margin. Ornamentation consists of numerous comarginal lirae across most of the valve, which are fine on the umbo but become coarser towards the ventral margin, and prominent, sharp, closely-spaced radial ribs, numbering from 12 to 15+, across the posterior part of the valve. Variation in the strength of the comarginal lirae is significant among individuals within an assemblage, ranging from relatively fine throughout growth, to conspicuous coarsening of the lirae towards the ventral margin of larger valves. These lirae are as wide or a little wider than the interspaces between them.

The Tucumcari specimens do not correspond exactly to any of the taxa described by Scott (1986b), but are clearly part of the *Protocardia texana* complex of forms. They differ from the type specimens of *P. texana texana* in having a subovate to subcircular rather than subquadrate shape. Shape and ornamentation of the more finely lirate specimens are similar to *P. texana salinaensis* Scott, from the Kiowa Formation of Kansas, but the Tucumcari specimens attain a larger size and develop stronger, more widely spaced comarginal lirae, both characters of *P. texana texana*. The Tucumcari specimens are either steinkerns or rather severely weathered valves, with the fine detail of the ornamentation obscured. Here, we assign these specimens to *P. texana*, without reference to subspecies. Of the taxa of *Protocardia* discussed by Scott (1986b), only *P. texana texana* was cited from eastern New Mexico.

***Protocardia filosa* (Conrad)**

Protocardia filosa (Fig. 5K) is characterized generally by its high, subtriangular shell with prominent, sharp, nearly central prosogyrate beaks; its sharp, steeply sloping posterior umbonal ridge; a narrow, gently concave posterior area with numerous (20 to 25+) fine radiating ribs; and relatively coarse comarginal lirae across the remainder of the valve surface. These features allow *P. filosa* to be distinguished readily from *P. texana*, with which it may co-occur in the Tucumcari Formation.

Scott (1986b) showed that several Albian species are synonyms of *P. filosa*, including *Roudaria quadrans* Cragin, which

was cited in some early reports from the Tucumcari Formation (see Kues et al., 1985, as *Veniella quadrans*). Some specimens from the Tucumcari are unusually large for the species, attaining a height of nearly 50 mm.

***Linearia (Liothyris)*? aff. *L. (L.)*? *kansasensis* Twenhofel**

The best preserved specimen of this rare species (Fig. 5L) is an incomplete, weathered right valve, missing the posterior margin and measuring 31 mm long and 24 mm high. The valve is suboval, only slightly inflated at the umbo, with a small, prosogyrate, slightly curved beak situated a little closer to the anterior than to the posterior end. The slightly convex anterodorsal margin slopes gently from the beak into a broadly convex anterior margin. A lunule and escutcheon appear to be lacking. The valve surface is characterized by somewhat irregular, raised, widely-spaced growth lines and by fine (5/mm) radiating lirae, visible on the posterodorsal and anterodorsal portions of the valve, but possibly extending across more of the valve.

Twenhofel (1924) described *Linearia kansasensis* from the Kiowa Formation of Kansas, emphasizing the radial lirae (which he termed striae) and noting the presence of even finer concentric striae as well. His illustrations (pl. 12, figs. 9, 10) are of steinkerns displaying internal molds, which show neither of these features. Scott (1970a) redescribed the species but provided no illustrations. The Tucumcari specimens appear to be slightly more elongate than those from the Kiowa, although exact proportions cannot be determined because the posterior margin is absent. The type species of *Linearia (Linearia)* is heavily costate, with a central beak, but gradation among species through forms with restricted fine lirae to smoothness and a somewhat elongate form (subgenus *Liothyris*) was noted by Stephenson (1952). We questionably assign this taxon to *Linearia* (*Liothyris*) on the basis of its subdued radial ornamentation and slightly elongate form.

***"Isocardia"* aff. *"I." slatana* Stephenson**

This taxon is represented by several small, poorly preserved specimens (Fig. 5M). The valves are distinctive among Tucumcari bivalves in being high-subtrigonal in shape, strongly inflated, and having a strongly prosogyrate, very incurved beak situated nearly centrally. The anterodorsal margin slopes steeply away from the beaks and is gently concave, and the posterodorsal margin slopes steeply into the broadly convex posterior margin. The shell surface on all specimens is strongly weathered, so nothing may be said about ornamentation. The best-preserved specimen is articulated, with some valve distortion and lateral slippage, but shows this species to be equivalved.

The Tucumcari specimens closely resemble the taxon named *Isocardia slatana* by Stephenson (1952), from the Cenomanian of Texas, but poor preservation precludes positive assignment to that species. The Treatise (Cox et al., 1969, p. 657) treats the type species of *Isocardia* as a synonym of the Cenozoic genus *Glossus*, and distributes other species originally assigned to *Isocardia* among numerous genera within three different families, based mainly on characters of the dentition. Because the teeth of the Tucumcari specimens are unknown, reassignment of this taxon to a different genus is not possible. Albian species assigned by early workers to *Isocardia* (e.g., *I. washita* Marcou; *I. medialus* Conrad) are far larger than the Tucumcari specimens, although generally similar in valve morphology.

***Aphrodina*? sp.**

Specimens assigned questionably to the veneroid genus *Aphrodina* (Fig. 5N) have small, subtrigonal valves, with a high, prominent, prosogyrate beak and broadly convex anterior and posterior margins. Both posterodorsal and anterodorsal margins slope steeply away from the beak; the former is moderately convex and the latter is distinctly concave. No lunule or escutcheon were observed along the hingeline and the nature of the dentition is unknown. Ornamentation is limited to fine (5-6/mm), closely-spaced, low, rounded, comarginal lirae.

This taxon does not closely resemble any species reported from the Kiowa Formation by Twenhofel (1924) or Scott (1970a). It most closely resembles species of *Callistina* reported from the Cenomanian of Texas (Stephenson, 1952); *Callistina* was considered a synonym of *Aphrodina* in the Treatise (Cox et al., 1969).

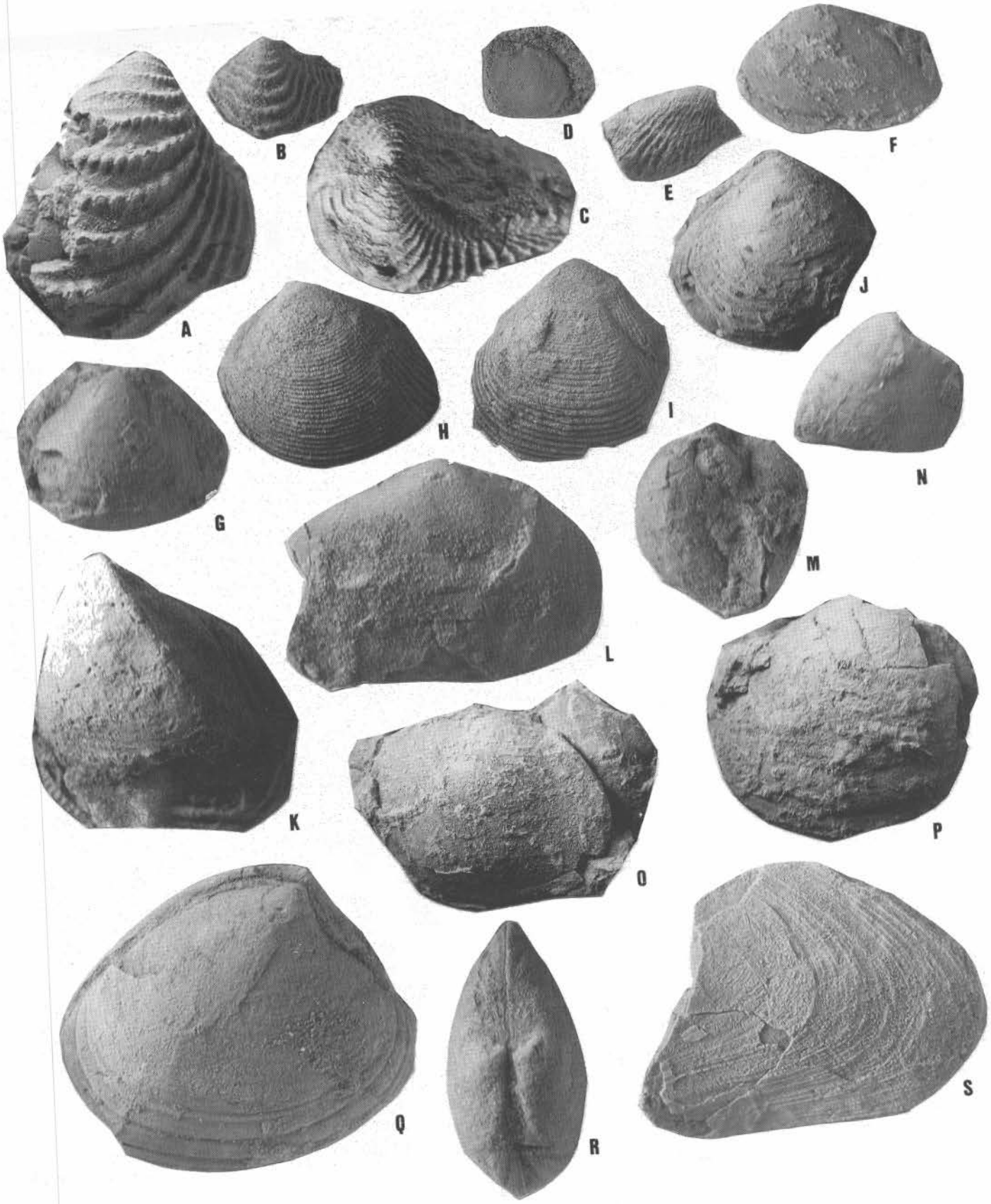
***Cyprimeria* cf. *C. washitaensis* Adkins**

Fragments of a large species of *Cyprimeria* (Figs. 5O, P) are locally common in sandy facies of the Tucumcari Formation. Maximum estimated valve length is about 85 mm. The valve outline is subcircular to slightly elongate-subovate, with length slightly exceeding height, and the valves are gently inflated and possess a small anterior beak.

Several species of *Cyprimeria* in this size range have been described from the Albian of the Texas and southern Western Interior regions, but typically on the basis of incomplete specimens or steinkerns, so adequate comparison of the species is difficult. The size and slightly ovate outline of the Tucumcari specimens closely resemble the characters of *C. washitaensis*, described by Adkins (1918) from the Weno Formation of eastern Texas. *Cyprimeria kiowana* Cragin appears to have a higher, more closely circular valve outline, and *C. texana* (Roemer), reported from the Tucumcari by Scott (1974), is a smaller species that was originally described on the basis of steinkerns (Adkins, 1928) from Fredericksburg Group strata. It is possible that with better specimens and more study of these species, differences in size and outline reported for these species may be found to be not especially significant, and that some are synonyms.

***Flaventia belviderensis* (Cragin)**

Flaventia belviderensis (Figs. 5Q, R) is a medium-sized bivalve (length up to about 40 mm) with high, sharp, strongly curved, prosogyrate beaks situated about 35 to 40% of the distance from the anterior to posterior valve margins. The valves are a little longer than high (length/height averages about 1.25), are moderately inflated (articulated width/length is about 0.45), and lack ornamentation except for growth lines, which typically become conspicuous comarginal folds near the moderately convex ventral margin. The posterodorsal margin is strongly convex, and the anterodorsal margin, just below the beaks, is straight to gently concave. The lunule and escutcheon along the hingeline are both narrow and poorly developed. Specimens are almost always preserved with the valves articulated.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Flaventia belviderensis, initially described from the Kiowa Formation by Cragin (1894), is uncommon at most Tucumcari localities, but may be abundant locally in sandy to silty lithologies.

***Pholadomya* sp.**

A fragment of the posterior portion of a medium-sized *Pholadomya* (Fig. 5S) from Apache Canyon is 34 mm long and 28 mm high, indicating an elongate shell with a length estimated at 75+ mm when complete. The posterior margin is evenly and relatively sharply convex, and appears to have gaped slightly. The umbonal ridge is inflated and distinct, and sloped gently away from the (unpreserved) beak area to terminate at the posterior margin. Ornamentation consists of relatively strong, closely spaced growth lines that trend posteriorly near the dorsal margin and curve sharply anteriorly across the umbonal ridge. The growth lines are crossed by faint, finer radiating lirae, forming obscure nodes at their intersection with growth lines.

Although only the posterior one third or so of the valves are present, they closely resemble the typical morphology of this part of the shell of *Pholadomya*. Numerous species of *Pholadomya* and the closely related *Homomya* have been described from the Albian of Texas and Mexico (e.g., Adkins, 1928; Perkins, 1961), but too little of this Tucumcari specimen is preserved to assign it to a species. Scott (1974) reported *P.* sp. from the Tucumcari Formation, and Kues et al. (1985) added two unidentified species of *Homomya*. The present specimen belongs to *Pholadomya* based on the presence of radiating ornamentation, which *Homomya* lacks.

Gastropoda

***Turritella "seriatimgranulata"* Roemer**

These large, high-spired gastropods (Figs. 6A-E) attain a height of more than 70 mm and are the most abundant gastropods in the Tucumcari Formation. Ornamentation consists of four strong, nodose spiral lirae on each whorl. The upper one or two lirae often are conspicuously larger than those below, and single fine lirae may be present between pairs of major lirae. Five or more less-nodose lirae are present on the base of the body whorl. Stanton (1947, pl. 56, figs. 19, 21) illustrated typical specimens from Mesa Tucumcari (now Tucumcari Mountain). Large collections from several localities display relatively little variation in shell proportions or ornamentation; some specimens possess somewhat finer lirae and a few have a fifth lira exposed just above the lower suture.

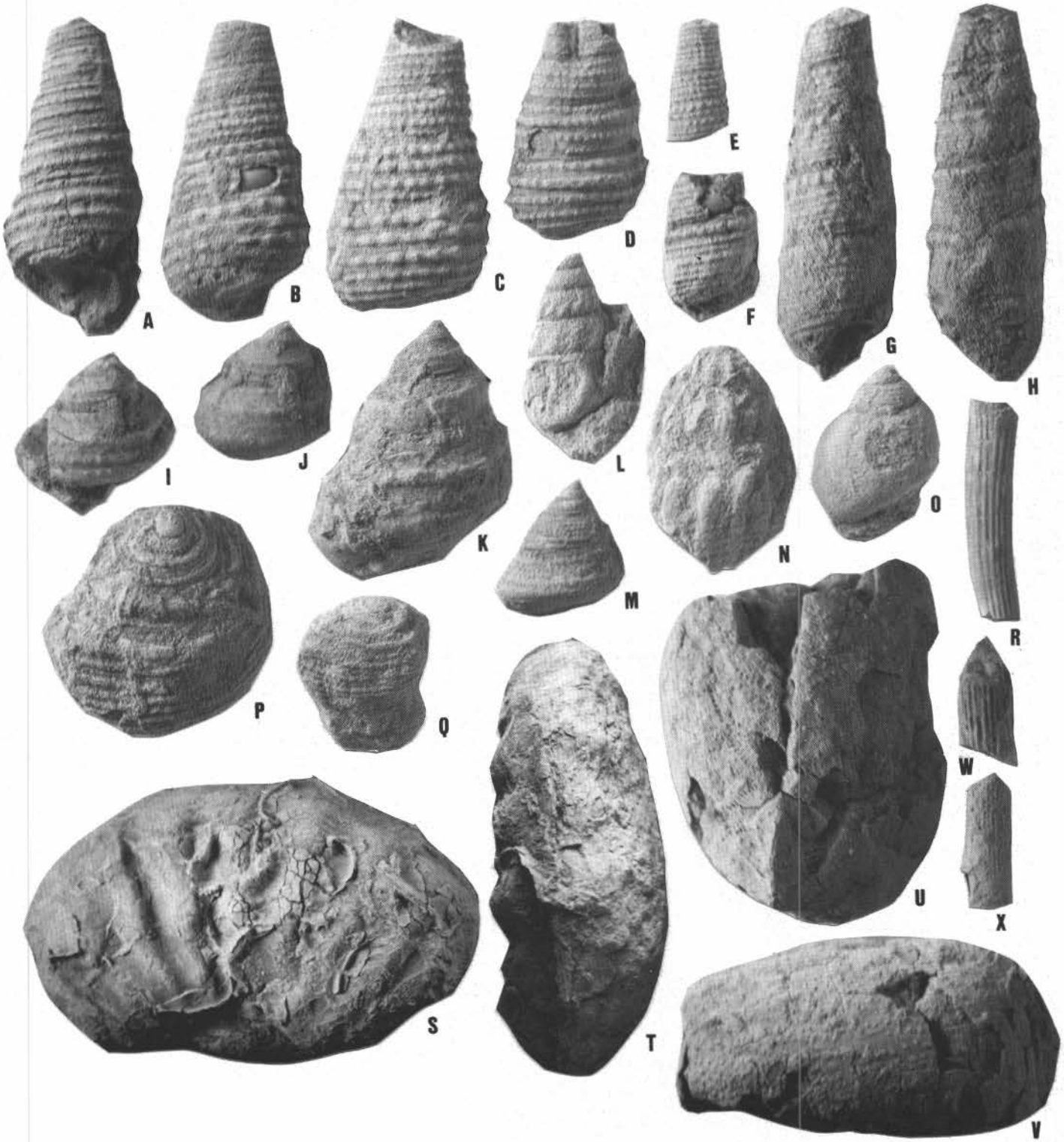
It is not certain that this distinctive Tucumcari species is properly assigned to *Turritella seriatimgranulata*. Roemer (1852) characterized *T. seriatimgranulata* by a strongly noded spiral cord just below the upper suture and four finer cords, with additional finer lirae sometimes inserted at later growth stages. The species was based on a single specimen from the Fredericksburg Group (Walnut or Comanche Peak Formation) of east Texas (Roemer, 1849, 1852), which, according to Stanton (1947, p. 75) "left the impression of its outer surface on the beak of the lower valve" of the oyster *Ceratostreon texanum*. An artificial mold of the impression of the holotype (Stanton, 1947, pl. 56, fig. 7) indicates ornamentation of five, relatively fine, nodose spiral lirae of equal size per whorl, and a shell no more than about 25 mm high when complete. Stanton doubted that the Tucumcari forms warranted even varietal separation from *T. seriatimgranulata*, but his concept of the species seems excessively broad, including also specimens from Sonora, Mexico, that have much finer ornamentation and which we would regard as distinct (see below). The same may be true of the Tucumcari specimens Stanton assigned to *T. seriatimgranulata*, which not only differ significantly from the holotype, but are also considerably younger. Specimens conspecific with *T. "seriatimgranulata"* were described as *T. macropleura* by Stainbrook (1940), from the "Kiamichi" Shale at Guthrie Lake, west-central Texas. Kollman (written communication, R.W. Scott, 2001), noted that the ornamentation of *T. seriatimgranulata,* with a dominant spiral cord at the upper suture that is separated from the other spiral cords by a broad space, is characteristic of *Turritella (Torquesia) granulata* J. de C. Sowerby, a species abundant in the upper Albian of Europe, and suggested that the two species may be synonyms.

Tucumcari specimens of *T. "seriatimgranulata"* have been compared with collections of a related species, *T. belviderei* Cragin, from the Kiowa Formation of Kansas. The latter species attains nearly the size of the former, but is distinguished by more numerous (typically seven per whorl), finer, less coarsely nodose spiral lirae. Although *T. belviderei* has been reported from the Tucumcari Formation (Scott, 1974), we have encountered no specimens that can be unquestionably assigned to that species.

***Turritella* n. sp.**

A second species of *Turritella* (Figs. 6F-H) that locally occurs with *T. "seriatimgranulata"* has a smaller, more slender shell, with a flat rather than gently convex whorl profile, and distinctive ornamentation that differs considerably from that of *T. "seriatimgranulata"*. Based on fragments, this species attains a maxi-

FIGURE 5. **Bivalves** from the Tucumcari Formation, Quay County, New Mexico. A-C. *Scabrotrigonia emoryi* (Conrad). A. Incomplete left valve, showing typical ornamentation, UNM 13,074, x2; B. Beak area of small left valve, UNM 13,076, x2; C. Top view of articulated specimen showing beaks and early ornamentation, UNM 13,073, x 1.8. D. *Parvilucina*? sp., left valve on matrix, UNM 13,065, x2.5. E. *Ludbrookia belviderensis* (Cragin), incomplete, weathered right valve, UNM 13,071, x2. F. *Crassatellina oblonga* Meek, left valve, UNM 13,067, x2. G. *Pleuriocardia kansasense* (Meek), weathered left valve, in matrix, UNM 13,080, x2. H-J. *Protocardia texana* Conrad. H. left valve, UNM 13,118, x1; I. incomplete, rather coarsely lirate left valve, UNM 13,120, x1; J, weathered left valve, with strong ventral comarginal lirae, UNM 13,119, x 0.9. K. *Protocardia filosa* (Conrad), weathered left valve, UNM 13,121, x1.4. L. *Linearia (Liothyris)*? aff. *L. (L.)*? *kansasensis* Twenhofel, incomplete right valve, UNM 13,070, x1.8. M. *"Isocardia"* aff. *"I." slatana* Stephenson, oblique, anterodorsal view of articulated, slightly distorted specimen, UNM 13,072, x1.5. N. *Aphrodina*? sp., incomplete right valve, UNM 13,079, x2. O-P. *Cyprimeria* cf. *C. washitaensis* Adkins. O. incomplete left valve, UNM 13,123, x0.7; P. incomplete right valve, UNM 13,124, x0.7. Q-R. *Flaventia belviderensis* (Cragin). Q. right valve, UNM 13,125, x1.75; R. dorsal view of articulated specimen, UNM 13,126, x1.75. S. *Pholadomya* sp., fragment of left valve, UNM 13,066, x2. Localities: A, B, F, G, N, S, Apache Canyon locality; C, E, H-M, O-R, Mesa Quemado locality; D, San Jon hill.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mum height of about 50 mm, but is considerably narrower, with a lower spiral angle, than comparable specimens of *T. "seriatimgranulata"* of similar height. The ornamentation consists of a single prominent nodose lira just below the upper suture, followed ventrally by five to seven much finer lirae of approximately equal size that bear fine nodes or are subnodose. At least five sharp, non-nodose spiral lirae occupy the base of the body whorl. These specimen most closely resemble forms Stanton (1947, pl. 56, figs. 17, 18, 23, 24) described from the Potrero Formation of Sonora, Mexico, and which he assigned to *T. seriatimgranulata*. As noted above, however, we doubt that specimens of this kind are conspecific with the distinctive large Tucumcari turritellas we refer to *T. "seriatimgranulata."*

***Amberleya mudgeana* (Meek)**

Amberleya mudgeana (Figs. 6I-K) is a medium-sized, low-spired anomphalous turbiniform species of four or five whorls that locally is moderately common in the Tucumcari Formation. Smaller specimens are slightly wider than high, but with growth the shell becomes higher spired, so that height/width of the largest specimens (height = 27+ mm) is about 1.2 to 1.35. Three widely spaced, sharp to nodose, spiral carinae are present on the shell, the highest just below the upper suture, the second forming a sharp angulation between the upper and outer whorl faces, and the lowest at the angular intersection of the outer and basal surfaces of the whorl. Most specimens display a conspicuous medial lira on the outer whorl face, and some possess one or two additional fine lirae on the upper or outer whorl faces.

FIGURE 6. Gastropods, scaphopod, ammonite, and echinoids from the Tucumcari Formation, Quay County, New Mexico. **Gastropods.** A-E. *Turritella "seriatimgranulata"* Roemer. A. Apertural view, UNM 9090, x1.25; B. Lateral view, UNM 13,107, x1.25; C. Adapertural view, UNM 13,106, x1.25; D, adapertural view, UNM 13,108, x1.25; E. Adapertural view, early whorls, UNM 13,109, x1.25. F-H. *Turritella* n. sp. F. Apertural view, incomplete small specimen, UNM 13,112, x1.75; G. Apertural view, incomplete weathered specimen, UNM 13,110, x1.75; H. Adapertural view, incomplete weathered specimen, UNM 13,111, x1.75. I-K. *Amberleya mudgeana* (Meek). I. Adapertural view, specimen with nodose spiral carinae, UNM 13,104, x1.75; J. Adapertural view, specimen with relatively smooth carinae, UNM 13,105, x1.75; K. Adapertural view, large specimen, UNM 13,103, x1.75. L-N. *Drepanochilus* aff. *D. mudgeana* (White). L. Adapertural view of small specimen, UNM 13,101, x1.75; N. Adapertural view, incomplete larger specimen, UNM 13,102, x1.75. M. *Calliostoma cragini* Stanton, adapertural view, UNM 13,068, x1.75. O. *Euspira cragini* (Stanton), apertural view, UNM 13,069, x1.75. P-Q. *Hillites newberryi* (Cragin). P. Oblique adapertural view, large specimen, UNM 13,078, x1.75; Q. Apertural view, small specimen, UNM 13,077, x1.75. **Scaphopod.** R. *Dentalium (Dentalium)* sp., shell fragment, NMMNH P-33,449, x2. **Ammonite.** S-T. *Mortoniceras equidistans* (Cragin), side view of part of outer whorl (S) and view of venter (T), NMMNH P-33,447, x0.75. **Echinoids.** U-V. *Washitaster bravoensis* (Böse), dorsal view, x1.75 (U) and side view, x2 (V) of an incomplete specimen, NMMNH P-33,448. W. Small fragment of spine of regular echinoid, type 1, UNM 13,063, x2. X. Small fragment of spine of regular echinoid, type 2, UNM 13,064, x2. Localities: A-L, N-Q, Mesa Quemado locality; M, W, X, Apache Canyon locality; R, U, V, San Jon hill; S, T, Pyramid Mountain.

Variation in the shells of *A. mudgeana* in the Tucumcari Formation occurs mainly in the degree to which nodes have developed on the three major carinae. On one extreme are specimens having sharp, smooth carinae, whereas on the other extreme are specimens on which the carinae are strongly nodose. Cragin (1894) described the latter form as a separate species, *Margarita marcouana*, but Stanton (1947) considered the two species, both of which were originally described from the Kiowa Formation of Kansas, as synonyms based on the intergradational nature of the ornamentation.

***Calliostoma cragini* Stanton**

These Tucumcari specimens (Fig. 6M) agree closely with specimens of *Calliostoma cragini* described by Stanton (1947) from the Kiowa Formation in Kansas, and from Kiamichi-equivalent strata near Tahoka Lake, west-central Texas. The shell is relatively low spired and turbinate, small (less than 20 mm high), and consists of about seven whorls. The whorl profile is slightly convex, the sutures shallowly incised, and the surface of the shell is ornamented by about six coarsely nodose cords on the outer whorl face. The lowest one or two of these above the lower suture are a little larger and form the whorl periphery, with an additional 10 nodose cords on the flattened, anomphalous whorl base. The surface of the whorls is covered by very fine spiral lirae superimposed upon the nodose primary ornamentation.

Before Stanton's work, Kiowa and west-central Texas "Kiamichi" shells of this type had been assigned to *Trochus texanus* Roemer (e.g., Twenhofel, 1924; Stainbrook, 1940), a species somewhat more evenly conical in shape and with a tooth-like fold on the columella.

***Drepanochilus* aff. *D. mudgeana* (White)**

Three severely weathered, incomplete specimens appear to be closely related to *Drepanochilus mudgeana* (Figs. 6L, N). These fragments indicate a shell about 25 to 30 mm high when complete, with coarse, gently arcuate to nearly straight, opisthocline collabral ribs numbering 12 to 14 per whorl, crossed by much finer spiral lirae. The expanded, wing-like outer lip is not preserved on these specimens. Stanton (1947) noted the close similarity between *D. mudgeana* and *D. kiowana* (Cragin); the latter species has been reported from the Tucumcari Formation (Scott, 1974). *Drepanochilus kiowana* was characterized by Stanton (1947) as being considerably smaller and more slender, with finer and more numerous ribs, and a narrower, more carinate wing, as compared with *D. mudgeana*. He suggested that the relationship between the two species is sufficiently close to suggest that *D. kiowana* is no more than a variety of *D. mudgeana*.

The Tucumcari specimens were compared with well-preserved specimens of *D. kiowana* from the Kiowa Formation near Belvidere, Kansas, in the UNM collections, and were found to be larger, with fewer, coarser, collabral ribs and more pronounced spiral lirae. The Tucumcari specimens more closely resemble a specimen from the Kiowa Formation described as Aporrhaid gastropod indet. by Scott (1970a). Restudy of the type specimens of *D. mudgeana* and *D. kiowana*, and better preserved material from the Tucumcari Formation, are needed to ascertain accurately the relationships of these species.

***Euspira cragini* (Stanton)**

The single specimen (Fig. 6O) available is small (height = 16.1 mm; width = 11.5 mm), rather soleniscoid in shape, and consists of five whorls. The shell is severely weathered, and lacks ornamentation except for fine, moderately prosocline growth lines across the body whorl. The aperture is obscured by matrix but appears to be suboval, higher than wide, and rather large. This specimen corresponds well with, but is somewhat smaller than, *Lunatia*? *cragini,* described by Stanton (1947) from the Kiowa Formation near Belvidere, Kansas. Sohl (1960) considered *Lunatia* a synonym of *Euspira.* His Late Cretaceous species of *Euspira* are generally very similar to the Albian Kiowa specimens and to the Tucumcari specimen.

***Hillites newberryi* (Cragin)**

The shell of this species (Figs. 6P, Q) is low spired, with about four whorls, the last of which is greatly inflated. The largest specimen is about 22 mm high, and its aperture is large and subcircular, with its base extended into a curved siphonal canal. Ornamentation consists of two strong, rather widely separated spiral ribs on the upper whorl surface, one immediately below the upper suture and the other marking a rounded shoulder between the upper and outer whorl surfaces; and 10 to 13 strong spiral cords across the outer whorl surface and base of the body whorl. These cords are subnodose, especially where crossed by growth lines, and a much finer, sharp lira occupies the interspace between some pairs of cords.

The few available specimens, all of which are distorted, most closely resemble two poorly known species, originally described from the Kiowa Formation of Kansas, *Margarita newberryi* Cragin, 1894, and *M. ornata* Twenhofel, 1924. Neither Twenhofel nor Scott (1970a) obtained species of *M. newberryi* in their Kiowa faunal studies, but Stanton (1947) redescribed the species (as *Turbo*? *newberryi*) based in part on a specimen from the Tucumcari Formation at Tucumcari Mountain. Twenhofel (1924) based *M. ornata* on one incomplete specimen. Its relationship with *M. newberryi* is unclear; neither Twenhofel nor Stanton compared the two species. The descriptions and illustrations available suggest that they are closely related, if not conspecific. *Margarita ornata* appears to have fewer, coarser, spiral cords; its aperture is unknown so detailed comparison with *M. newberryi* is not possible.

Both species, as well as closely related forms described by Stanton (1947) as *Turbo*? *cookensis* and *T.*? *gainsvillensis* closely resemble *Hillites multilirata* Stephenson, the type species of *Hillites* (Stephenson, 1952). All of these species appear to best be placed within that genus, as Stephenson (1952, p. 81) and Scott (1970a, p. 57) suggested for some of them.

Scaphopoda

***Dentalium (Dentalium)* sp.**

A single fragment of a small scaphopod shell (Fig. 6R) was recovered from the San Jon road cut locality. It is slender and gently arcuate in shape, and is 21 mm long. The fragment is probably part of a much longer shell, as it increases only slightly, from 4.0 to 4.6 mm, in diameter along its length. The internal cross section on both ends is circular, and the thin shell is ornamented by 22 strong, rounded, longitudinal ribs, separated by interspaces of equal width. At the posterior (narrower) end of the fragment, a smaller internal tube (pipe) projects slightly and bears ornamentation similar to that of the external shell surface. At the anterior (wider) end of the specimen, in cross-sectional view, there appear to be at least three nested pipes, probably the result of additional secretion of shell material internally towards the posterior end after full growth of the external shell had occurred. Because this fragment does not include the apical end of the shell, the presence of a notch or slit there could not be determined. The ornamentation and circular internal cross section suggest assignment to *Dentalium (Dentalium)*, following the classification of Palmer (1974).

Scaphopods are apparently quite rare in the Albian of the Texas-southern Western Interior region. One species of *Cadulus* is present in the Kiowa Formation (Scott, 1970a), but scaphopods are not known in the Albian sequence at Cerro de Cristo Rey (Böse, 1910, and collections by BSK), and are not cited in monographs and compilations of Albian taxa from Texas (e.g., Adkins, 1928; Brand, 1953; Perkins, 1960; Lokke, 1967), nor by any other author so far as we are aware. The only previous reports from the New Mexico Albian is a fragmentary specimen of *Dentalium* from the Mesilla Valley Shale at the Lee Ranch locality west of the Cornudas Mountains (Kues and Lucas, 1993, fig. 8X), and reports in faunal lists of *Dentalium* and *Cadulus* from the Mojado Formation, Big Hatchet and Animas Mountains, by Zeller (1965) and Zeller and Alper (1965). Although several species of *Dentalium* have been described from Cenomanian strata in Texas (Stephenson, 1952) and in the Western Interior (e.g., Kirkland, 1996), none of them appear closely related to the Tucumcari specimen.

Ammonoidea

Although several species of ammonites have been reported from the main outcrop belt of the Tucumcari Formation (Kues et al., 1985), none have been illustrated. We have collected specimens of only one species of ammonoid during our long-term studies of the Tucumcari, and it is discussed below.

***Mortoniceras equidistans* (Cragin)**

The best specimen of *Mortoniceras equidistans*, collected from the Tucumcari type section at Pyramid Mountain, is a fragment of the outer whorl of a large individual (Figs. 6S, T). Its length is 107 mm, whorl height is 55 mm, and whorl width about 35 mm, all suggesting that the complete shell had a diameter of at least 150 mm. The fragment is weathered and heavily encrusted with juvenile oysters, and displays ornamentation on only one side. A low keel is present along the venter, and preserved suture lines are limited to a single lobe and saddle. The ornamentation consists of strong, straight, relatively closely spaced simple ribs, each of which bears a wide ventral-lateral, a narrower lateral, and a minor umbilical node.

Although assigned to *M. equidistans*, the specimen is somewhat atypical in having relatively coarse, closely-spaced ribs, seven occurring within a circumference distance of 100 mm,

compared to five or six per 100 mm on the youngest part of the shell of Cragin's type specimen from the Duck Creek Formation of Texas (see Cobban, 1985), a somewhat smaller whorl than the Tucumcari specimen. Specimens of *M. equidistans* illustrated from the overlying basal Mesa Rica Sandstone (e.g., Kues et al., 1985; Lucas and Hunt, 2000) in Quay County likewise bear somewhat finer, more widely-spaced ribs.

Arthropoda

Although we observed no arthropods in the Tucumcari Formation, Kietzke (1985) reported 20 species of ostracods from the Pyramid Mountain locality and illustrated most of them.

Echinoidea

Echinoids are very rare in the Tucumcari Formation, and the taxa discussed here are the first reports of this group in the formation. Fragments of two types of regular echinoid spines, both having a diameter of 4.0 to 4.6 mm and probably measuring 40 to 50 mm in length when complete, are present. The ornamentation of the first type (Fig. 6W) consists of sharp, high, longitudinal ribs that are subtly nodose, with about 8 ribs across 5 mm of circumferance. The second type (Fig. 6X) displays longitudinal rows of isolated nodes, about 4 or 5 rows per 2 mm of circumferance. The third type of echinoid, a spatangoid represented by a single incomplete test, is described below.

Washitaster bravoensis (Böse)

One incomplete specimen (Figs. 6U, V) from the San Jon road cut is the first record of an echinoid test from the Tucumcari Formation. The specimen is laterally crushed, and is missing the anterior, most of the ventral, and part of the right dorsal portions of the test, with much of the left dorsal region covered with matrix. Because of lateral compression, the right side of the posterior part of the test has overridden part of the left side, making the test appear narrower than it was originally, and obscuring the periproct, which was situated high on the posterior surface. The specimen is about 37 mm long, 28 mm wide, and 18 mm high.

Because of poor preservation, a complete description of the morphology of this specimen cannot be given. However, parts of the left anterior, left posterior, and right posterior petals are preserved, and those plates of the test that are visible are unweathered and preserve surface details excellently. In addition, portions of the lateral and peripetalous fascioles are well preserved.

The anterior petals are long, relatively narrow, and gently arcuate, whereas the posterior petals are straight, moderately wide, less than half the length of the anterior petals, and diverge at a 90° angle. The outer portions of the anterior petals consist of paired pores, with the external pore elongate and the internal pores circular, and this pattern is visible on the posterior petals as well. Ornamentation is limited to small round tubercles on the interambulacral plates, ranging from two or three per plate near the petals but increasing in number on the plates forming the lateral and posterior test surfaces. The lateral fasciole band is relatively wide and extends along the test a little above midheight.

The shape and proportions of the test, orientation of the petals and ambulacral pores, fascioles, and ornamentation all indicate assignment to *Washitaster bravoensis*, originally described from the Muleros and Mesilla Valley formations of Cerro de Cristo Rey by Böse (1910; see also Cooke, 1955). Most Albian spatangoids of similar size and characters with which this specimen might be confused (especially species of *Heteraster*) lack fascioles.

Vertebrata

Fossils of vertebrates are extremely rare in the Tucumcari Formation, never having been previously reported. Here, we document two taxa of fishes based on isolated teeth from the Apache Canyon locality.

aff. *Cretodus* sp.

A single tooth with an incomplete root base (Figs. 7A-C) clearly belongs to a lamniform selachian. The crown is dominated by

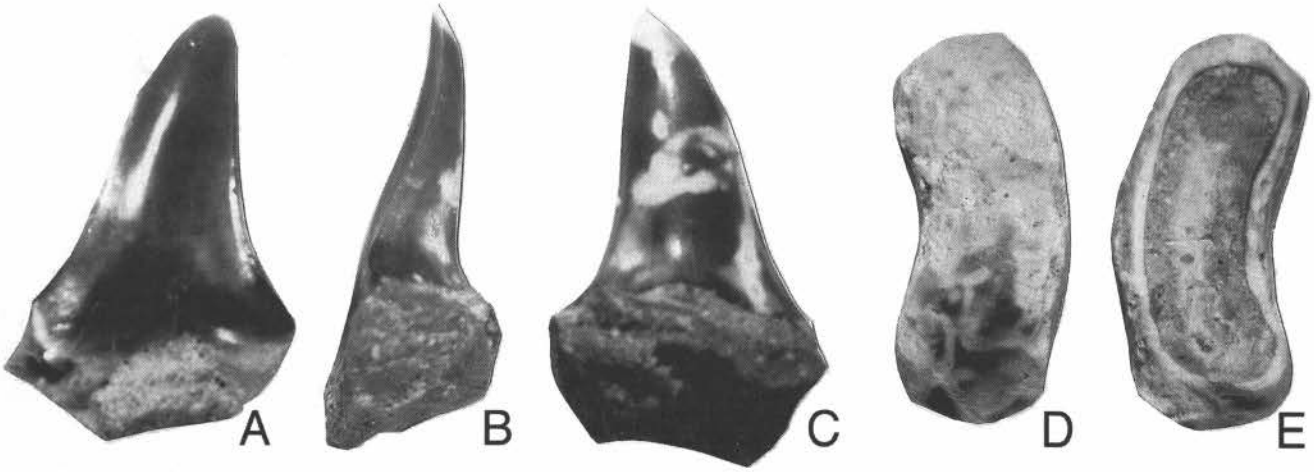

FIGURE 7. **Fish teeth** from the Tucumcari Formation, Quay County, New Mexico; all from the Apache Canyon locality. A-C. aff. *Cretodus* sp., lingual (A), lateral (B) and labial (C) views, UNM 13,134, x5. D-E. *Coelodus* sp., crown (D) and root base (E), UNM 13,135, x5.

a broad, smooth, slightly sigmoid, triangular cusp that is about 9 mm high. Breakage of the crown at its base makes it impossible to determine if the main cusp was flanked by two smaller accessory cusps, as is common among lamniforms (Welton and Farish, 1993). The root base appears to be broad and thick, but it is incomplete. Definite assignment of this tooth to a lamniform genus is not possible because of its incomplete crown base and root. However, greatest similarity is to *Cretodus* (Welton and Farish, 1993, p. 98), and we tentatively identify it as aff. *Cretodus* sp.

***Coelodus* sp.**

An isolated reniform tooth is readily recognized as that of a pycnodontid osteichthyan. This tooth (Figs. 7D-E) has a crown that measures about 11 by 4 mm, is slightly convex and covered with a smooth (though highly weathered), thick enamel cap. The root base of the tooth is a convex depression that underlies the entire crown. This tooth is identical to teeth of the pycnodontid *Coelodus*, from the Kiowa Formation of Kansas (Williston, 1900, p. 254-255, pl. 26, fig. 6), to which we assign it. However, an isolated tooth is not a sufficient basis for a species-level identification.

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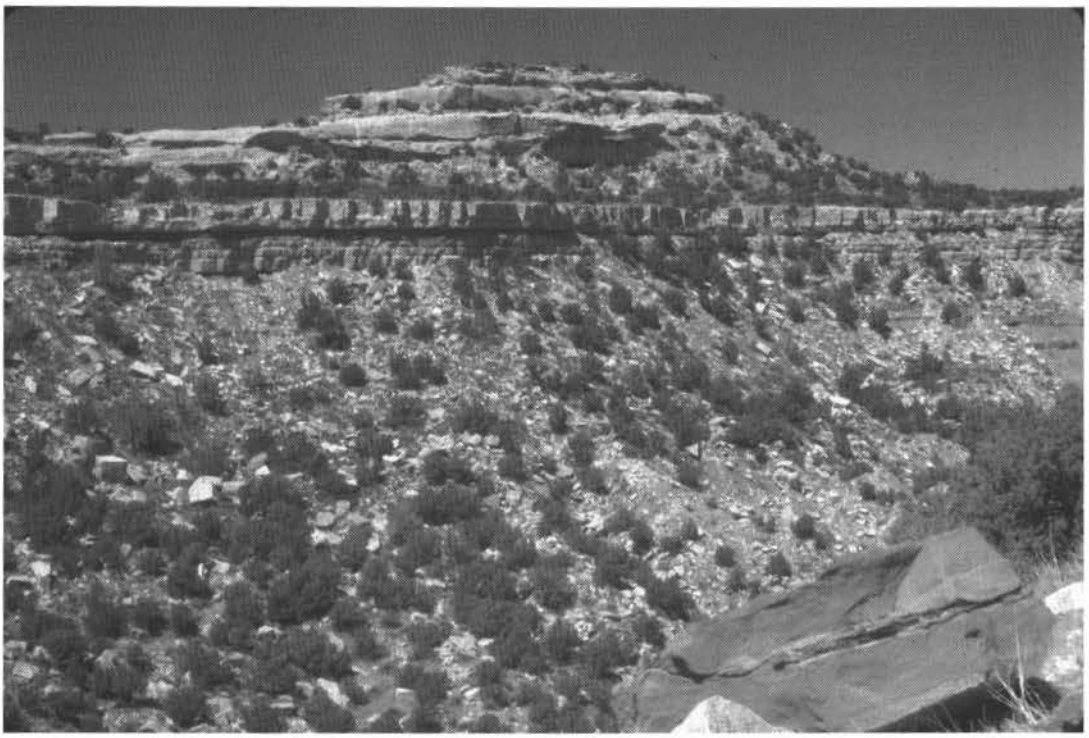

At Mesa Redonda in Quay County, the type section of the Redonda Formation forms red-bed slopes and ribbed cliffs underneath a locally thick, cliff-forming sandstone of the Middle Jurassic Entrada Sandstone. Mesa Redonda is close to the southern margin of the vast Middle Jurassic San Rafael basin that extended from here into Utah.