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New Mexico Geology, v. 8, n. 4 pp. 88-94, Print ISSN: 0196-948X, Online ISSN: 2837-6420.
https://doi.org/10.58799/NMG-v8n4.88

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Paleontology and correlation of a Lower Cretaceous (Albian) outlier in Roosevelt County, New Mexico

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Introduction

The Tucumcari Shale is a fossiliferous formation of Late Albian age that is extensively exposed in Quay and eastern Guadalupe Counties. The Tucumcari biota is reasonably well known (Scott, 1970a, 1974; Kues et al., 1985), although it has not been studied systematically. The formation has generally been considered correlative with the Duck Creek Formation in Texas (Scott, 1974; Scott and Taylor, 1977), or the Duck Creek plus part of the underlying Kiamichi Shale (Brand, 1953; Brand and Mattox, 1972). These two formations represent the lower part of the Washita Group in Texas. The Tucumcari outcrop belt is 350 mi west of the well developed Washita sequence in eastern Texas (Fig. 1), but several limited Kiamichi and Duck Creek exposures, mainly around playa lake depressions, were reported by Brand (1953) from west-central Texas near the New Mexico border. Two similar Washita-age outcrops have also been reported in New Mexico far south of the Tucumcari area: one near Portales in Roosevelt County, and the other northwest of Tatum in Lea County. Neither locality has been studied in detail from a biostratigraphic or paleontological perspective, although such information would be useful in furthering our knowledge of the paleogeography, history, and faunal distribution of the Albian southern Western Interior seaway. In this paper the stratigraphy of the Roosevelt County outlier is described, and its paleontology is summarized to provide the basis for correlation with the Tucumcari Shale to the north and with the Kiamichi–Duck Creek sequence to the east in Texas. Brief mention of the correlation suggested here was made by Kues (1986). Illustrated specimens have been assigned University of New Mexico (UNM) Department of Geology catalog numbers.

Location and previous studies

The thin Lower Cretaceous section discussed in this paper is best exposed along the east side of an unnamed arroyo, near the center of the NW1/4 sec. 30, T3S, R36E (Figs. 2, 3). This locality is 3 mi north of the village of Rogers and 14 mi south–southeast of Portales. Lower Cretaceous sediments in this area are mostly covered by a veneer of Quaternary alluvium and gravels.

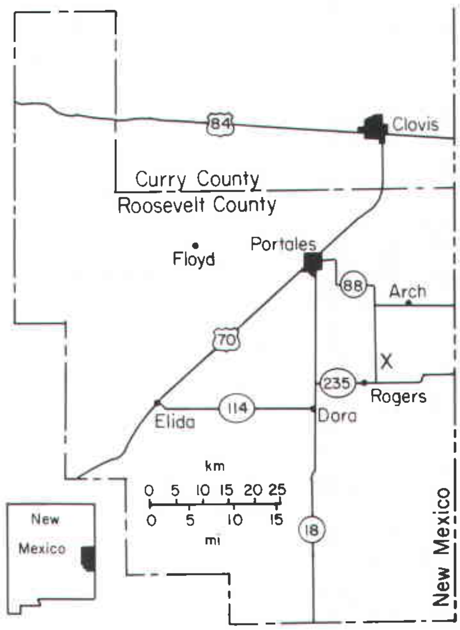


FIGURE 2—Location of the Lower Cretaceous outlier (X) in Roosevelt County.

The first mention of Cretaceous rocks in this area was by Darton (1928, p. 39), who stated "W. B. Lang recently found outcrops containing Comanche fossils 13 mi southeast of Portales . . ." Theis (1932) reported a 16-ft-thick Comanchean interval in section 30, and Robbins (1941, p. 7) listed nine "typical Kiamichi" mollusc taxa from the area. Lang (1947, p. 1476) referred to "limestones of the Kiamichi Formation [overlying] a thin basal sandy conglomerate, which in turn rests on Triassic rocks," in Rogers Draw, and he located the probable Washita shoreline about 20 mi west of the Rogers locality. Galloway (1956) summarized these exposures and suggested that the lower part of the section was equivalent to the lower Tucumcari Shale and to the Kiamichi, whereas the upper part was correlative with the upper Tucumcari and the Duck Creek Formation of western Texas. He also showed that the Lower Cretaceous strata exposed near Rogers were present in the subsurface through an area of 100 mi^2 that extended from Roosevelt County eastward into Bailey County, Texas. Young (1966, p. 49) referred these strata to the Tucumcari Shale and reported the ammonoids *Adkinsites bravoensis* (Böse) and *A. imlayi* Young from three localities in section 30. These exposures were considered to be probably correlative with the Tucumcari Shale by Dane and Bachman (1965) and were mapped as "Cretaceous, undivided" on the *Geologic atlas of Texas, Clovis sheet* (Barnes, 1978).

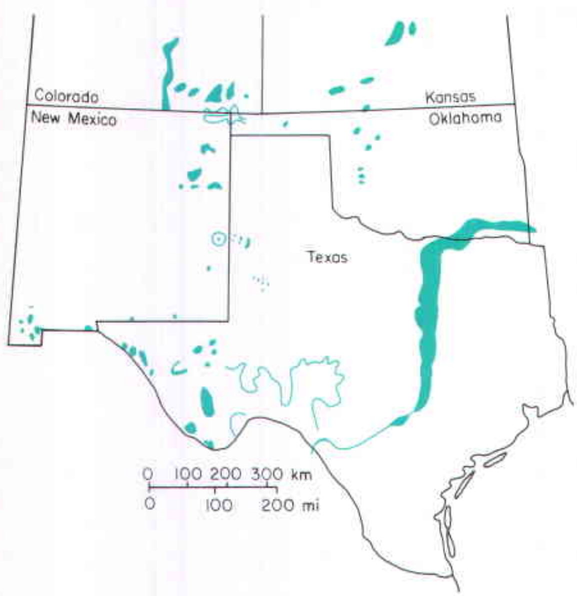


FIGURE 1—Distribution of fossiliferous marine Washita-age outcrops in the southern Western Interior (modified from Scott, 1975). The circled locality is discussed in this paper.

Stratigraphy

At the Rogers locality (Fig. 3) about 15 ft of Lower Cretaceous strata overlie 8 ft of un-

FIGURE 3—Eroded Kiamichi exposure along unnamed arroyo north of Rogers. **K** indicates locality from which the fossils discussed in this paper were collected. View is to the north–northeast.

fossiliferous, brick-red to green-mottled Triassic mudstones, which are similar lithologically to intervals in the Chinle Formation to the northwest and the Dockum Group in Texas. The Cretaceous sequence consists of a basal conglomerate, alternating thin ledge-forming limestone beds and covered slopes of light brown to gray shale, and an upper, massive, well-indurated sandstone. The basal conglomerate (Fig. 4) is about 3 ft thick and is composed of gray to brown limestone with a large amount of quartz sand grains and subrounded to angular pebbles of quartz and quartzite up to 1.5 inches in diameter. Disarticulated valves of *Ceratostreon texanum* (Roemer) are common, as are large steinkerns of *Cyprimeria* sp. and *Cucullaea*? cf. *C.*? *herculea* Twenhofel and Tester. One *C. texanum* specimen (Fig. 5T) was cemented near its beak to an isolated pebble. This conglomerate reflects a nearshore marine environment that periodically received influxes of coarse clastic grains from adjacent land areas to the west. The generally unfragmented *C. texanum* valves and the articulated state of the bivalve steinkerns in the conglomerate bed indicate relatively quiet normal marine conditions, with the bivalves occupying a substrate that included numerous large pebbles.

The middle part of the Cretaceous section is 8–10 ft thick and consists of covered shale slopes with two thin limestone beds in the lower 4 ft. The lower of two conspicuous ledges in this interval is a light brown, indistinctly bedded limestone filled with fine quartz grains. Locally this unit has more the appearance of fine-grained quartz sandstone with a calcareous matrix. Steinkerns of high-spired gastropods (probably *Turritella*), *Cyprimeria*, *Protocardia*, and *Cucullaea* are common, together with sparse shark teeth, ammonoid impressions, and oyster shell fragments. An upper ledge-forming sandy limestone occurs about 3.5 ft above the top of the conglomerate bed and 1.5 ft above the first ledge-forming limestone. It contains specimens of *Texigryphaea navia* (Hall), *T. mucronata* (Gabb), and related forms. Shells of *Texigryphaea* are abundant on the covered slopes below this unit, and most of the ammonoid specimens also came from this covered interval. This sequence of shales and sandy limestones represents shallow marine deposition somewhat farther offshore than the conglomerate bed, but still relatively close to the shoreline.

Very few fossils were observed on the covered slope above the upper ledge-forming limestone bed. The massive, hard, 3–4-ft-thick sandstone that caps the section is conspicuous along the upper edge of the arroyo (Fig. 3) and is seen in isolated blocks elsewhere in the vicinity. It is a dense, brown, fine-to-medium-grained sandstone weathered to a brownish-maroon color. Except for a *Thalassinoides*-bearing bed near its base, no fossils were observed in this sandstone. It was deposited in a marginal marine to possibly nonmarine environment. The entire Lower Cretaceous sequence here represents a brief transgression of the Washita sea into Roosevelt County from Texas.

Paleontology

A moderately diverse, predominantly molluscan fauna occurs at the Rogers locality (Table 1). Some of the most conspicuous or unusual elements of this fauna are discussed briefly here, with the *Texigryphaea* specimens considered separately below. The steinkerns of *Cyprimeria* (Fig. 5V) are nearly circular (height = 90% of length) and range from about 65 to 90 mm in length. Most Lower Cretaceous species of *Cyprimeria* from Texas and Kansas were established on the basis of steinkerns and are differentiated by slight differences in size and proportions. The Rogers specimens are considerably larger than *C. texana* (Roemer), the most commonly reported species, and they are within the size range of *C. crassa* Meek, *C. kiowana* Cragin, and *C. washitaensis* Adkins. The largest Texas Washita species, *C. gigantea* Cragin, reaches a length of 118 mm (Adkins, 1928) and is apparently inequivalve, whereas the specimens at hand indicate symmetrical valves. The vague criteria used in separating Lower Cretaceous *Cyprimeria* species and the poor preservation of the Rogers specimens preclude definite assignment of these specimens.

Large steinkerns assigned to *Cucullaea*? cf. *C.*? *herculea* (Fig. 5U) reach a length of 112 mm, have a high, anterior beak, and are similar in shape to *C. herculea* from the Kiowa Formation of Kansas. Some smaller specimens (length about 80 mm) are posteriorly elongate and have a relatively low longitudinal profile. Molds of taxodont dentition are present along the hingelines of a few specimens. Fragments of shell adhering to several steinkerns indicate that ornamentation consisted of fine, sharply rounded, closely spaced, concentric lirae, about 8 to 10 per 10 mm near the ventral margin of the shell. Several steinkerns are encrusted by small oyster shells.

FIGURE 4—Basal fossiliferous conglomerate of Kiamichi Shale at Rogers outlier.

Ceratostreon texanum (Fig. 5S, T), the most abundant fossil in the lower part of the section, occurs primarily as complete, disarticulated valves. Specimens ranging from juveniles to mature valves reaching a length of 90 mm were collected. Variation in valve shape, from narrow to nearly circular, is pronounced. A single, columnar, slightly curved shell fragment about 65 mm long and having an oval cross section documents the presence of rudist bivalves (Fig. 5X, Y) at this locality. The fragment is calcareous and composed of numerous long, vertical pallial canals that are oval to polygonal in cross section. Thin tabulae cross the canals at intervals along their length. The thick, vesicular shell structure suggests tentative assignment to the Caprinidae. One specimen of a solitary coral was recovered from the basal conglomerate. Gastropods are common as steinkerns in the lower ledge-forming sandy limestone; the few specimens retaining part of the shell have an ornamental pattern suggestive of *Turritella belviderei* Cragin.

Several fragmentary, but identifiable, ammonoids (Fig. 5P–R) were collected from the *Texigryphaea* horizon. These Kiamichi species were described and illustrated by Young (1966).

Texigryphaea

Approximately 150 specimens of *Texigryphaea*, mainly isolated left valves, were col- ☞

TABLE 1—Lower Cretaceous fossils identified from the Kiamichi exposures near Rogers, Roosevelt County, New Mexico. See text for details on taxa grouped here as *Texigryphaea* spp.

COELENTERATA
Solitary coral, unidentified

ANNELIDA
Serpula cragini Twenhofel

BRYOZOA
Pyripora sp.

MOLLUSCA—BIVALVIA
Caprinidae? (rudist)
Ceratostreon texanum (Roemer)
Cucullaea? cf. *C.*? *herculea* Twenhofel and Tester
Cyprimeria sp.
Neithea occidentalis (Conrad)
Protocardia texana (Conrad)
Pseudoperna? sp.
Scabrotrigonia emoryi (Conrad)
Texigryphaea mucronata (Gabb)
T. navia (Hall)
T. spp.

MOLLUSCA—GASTROPODA
Turritella cf. *T. belviderei* Cragin

MOLLUSCA—AMMONOIDEA
Adkinsites cf. *A. belknapi* (Marcou)
A. imlayi Young
Manuaniceras elaboratum lynnense Young

VERTEBRATA (shark teeth)
cf. *Plicatolamna*
cf. *Odontaspis*

lected from the Rogers locality. Eighty-eight percent of these valves had been colonized by encrusting and/or boring epizoans, particularly clionid sponges, acrothoracic barnacles, small oysters, serpulid worms, and bryozoans. Twenty percent of the valves had been considerably damaged by boring, especially around the left valve margins and in the beak area. Fourteen measurements (not included in this paper) and six additional subjective observations were made on each complete valve in order to characterize the variation present in this assemblage.

The *Texigryphaea* left valves display a remarkable range of variation. Specimens clearly referable to *T. navia* and *T. mucronata* are present, together with numerous individuals that depart to a greater or lesser degree from the typical morphologies of these species. Variation was observed especially in valve shape and thickness, size and curvature of the beak, inclination of the umbonal region, degree of carina development along the umbo to the ventral valve margin, size of sulcus, development and degree of posterior extension of the posterior lobe, and ornamentation. Comparison of all specimens within the assemblage resulted in recognition of several intergrading groups, in addition to *T. navia* and *T. mucronata.* Variation in these texigryphaeas is discussed below and illustrated in Figures 5 and 6. Terminology for *Texigryphaea* valves follows Stenzel (1959) and Fay (1975).

About 15% of the specimens are very similar or identical to the type specimens of *T. navia* (Hall, 1856) and *Exogyra forniculata* (White, 1880, 1884), a synonym of *T. navia.* These valves (Fig. 6A, B) are large (up to 71 mm high), thick, and have a sharp carina or keel extending from the umbo across the central part of the valve. The umbo is considerably inclined away from vertical, making the valve appear relatively flat. The beak is short, not inflated, and it is strongly deflected posteriorly. The external shell surface is marked by imbricating lamellae that locally are extended into hyote spines along the carina and/or posterior lobe. The sulcus is weak to absent and the posterior lobe is low, gently rounded, and inconspicuous. A few specimens (*T.* aff. *T. navia,* "inflated form," Fig. 6W, X) possess an inflated, carinate left valve with a strongly deflected beak and are closely related to typical specimens of *T. navia.* Another group of specimens assigned to *T. navia* (Fig. 6C–E) display a relatively wide, moderately deep sulcus and less pronounced carina, but otherwise are similar to typical specimens.

Several variants are connected through gradational sequences of specimens with these sulcate examples of *T. navia.* One series of specimens developed an exceptionally deep sulcus with a prominent ventral margin invagination that separates the posterior lobe from the rest of the valve (Fig. 6L–N). A second group (*T.* cf. *T. navia;* Fig. 6O–Q) possesses a left valve that is higher, less carinate, and has a less inclined umbo and less deflected beak than the sulcate form of *T. navia.* The sulcate form of *T. navia* also grades smoothly into a large group characterized by a rather high left valve, concave postero-dorsal margin, and an extended posterior lobe that imparts an arcuate shape to the valve (Fig. 6F–H). The umbo of this arcuate form varies from carinate to rounded and is less steeply inclined than on typical specimens of *T. navia.* The degree of posterior beak deflection is moderate rather than strong. The sulcus is subdued but the posterior lobe may be somewhat elevated, giving the external valve surface a "bilobed" appearance. Several arcuate specimens (Fig. 6I–K) display an unusually narrow, extended beak; they are similar to a specimen illustrated by Hill and Vaughan (1898, pl. 18, fig. 12), which they stated "probably should be referred to [*T.*] *navia.*"

Some of these arcuate specimens approach the shape of some valves that have been assigned to *T. pitcheri* (Morton) (= *T. corrugata* of Hill and Vaughan, 1898). However, the ontogenetic and ecological variation within *T. pitcheri* is not well documented, and for the present I have not assigned specimens in east-central New Mexico collections to *T. pitcheri* unless they closely resemble the holotype, a relatively small specimen illustrated by Hill and Vaughan (1898), Stanton (1947) and Fay (1975). No specimens of this nature were observed in the Rogers assemblage, although co-occurrence of *T. navia* and *T. pitcheri* elsewhere has been reported by several workers.

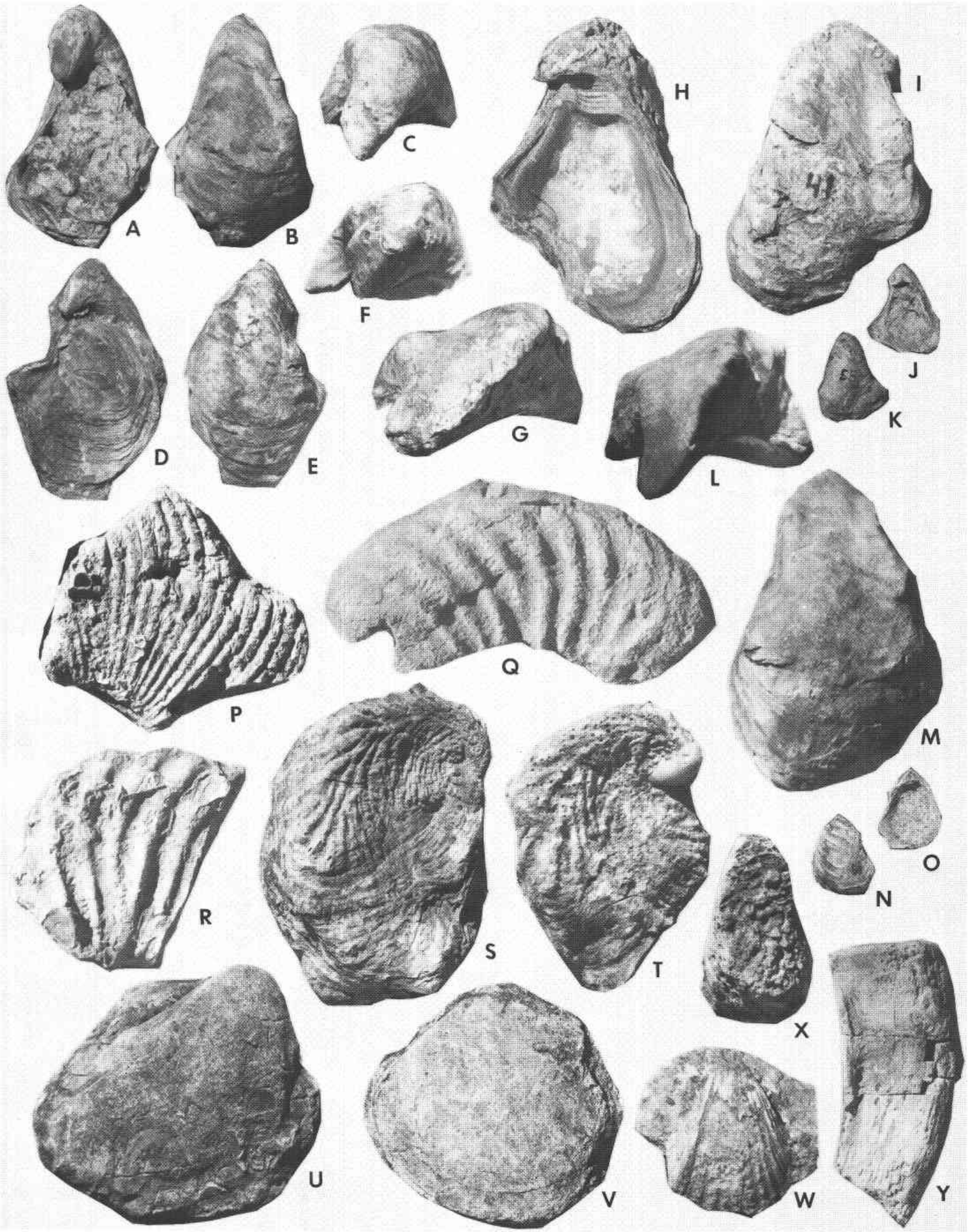
The several groups assigned to or believed closely related to *T. navia* mentioned above all possess relatively broad to arcuate left valves having a mean length/height ratio of 0.82 or greater. However, approximately 40% of the measured mature valves in the Rogers locality collections have a more narrow, elongate shape, with length/height ratios of 0.60 to 0.75. They also tend to have a less steeply inclined umbonal plane and therefore a higher shell that is more symmetrical around the region of maximum convexity. They also have only slightly to moderately deflected beaks, in contrast to the strongly deflected beaks of *T. navia.*

Among these relatively narrow forms, the narrowest specimens are *T. mucronata.* The best preserved example of this species (Fig. 5A–C) displays no extension of the posterior lobe and possesses a large, inflated, strongly curved but slightly deflected beak that is far more prominent than the beaks of *T. navia* and similar forms. The umbo and area of maximum convexity on the valve are evenly rounded and noncarinate. Shelburne (1959, pl. 37, figs. 7–9) illustrated a nearly identical specimen from the basal Kiamichi of central Texas. Specimens of *T. mucronata* intergrade with forms (*T.* cf. *T. mucronata,* Fig. 5D–F) that are less elongate and have less prominent beaks but are otherwise similar. Some of these specimens have an incipient carina and increased development of the posterior lobe that impart a mildly "bilobed" appearance to the valve. These "bilobed" forms are similar to a specimen illustrated by Shelburne (1959, pl. 37, figs. 4–6) from the middle Kiamichi, which he believed was phyletically intermediate between *T. mucronata* and *T. navia.*

Two closely similar, gradational groups of large, relatively elongate specimens compose about 30% of the measured mature texigryphaeas in the Rogers assemblage. One group, here referred to as *T.* sp. ("narrow-sulcate" form; Fig. 5G–I), has a deeply incised, narrow sulcus, a moderately to strongly deflected beak, and moderately inclined umbonal plane. Some specimens, including the illustrated one, show a tendency toward carina development and have a thickened shell with imbricating lamellae and hyote spines—features that characterize *T. navia.* The second group, *T.* sp. ("narrow-carinate" form, Fig. 5L, M), possesses a high, steep-sided, carinate left valve, with a subdued sulcus, moderately to weakly deflected beak, and a moderately to barely inclined umbonal plane. Some specimens have a raised posterior lobe and the "bilobed" appearance mentioned above for other groups. In general, these groups appear to be intermediate between *T. mucronata* and *T. navia* in the shape and characteristics of the left valve. One specimen in the second of these groups (Fig. 6T–V) has rounded, radial costae extending from the umbo to the ventral valve margin. This feature is faintly present on some specimens in other groups as well, and is probably of no taxonomic significance.

Small *Texigryphaea* valves (height less than 30 mm) were also present in the collections. Although the range of variation in valve form is considerable, juvenile representatives of each group recognized on the basis of mature

FIGURE 5—Molluscs from the Kiamichi Shale at Rogers locality. All figures × 1 unless otherwise indicated. **A–C,** *Texigryphaea mucronata* (Gabb), upper, lower, and umbonal views of left valve, UNM 9410; **D–F,** *Texigryphaea* cf. *T. mucronata,* right valve and external and umbonal views of left valve of an articulated specimen, UNM 9411; **G–I,** *Texigryphaea* sp. ("narrow-sulcate" form), umbonal, internal, and external views of left valve, UNM 9421; **J, K,** *Texigryphaea navia,* upper and external views of juvenile left valve, UNM 9422; **L, M,** *Texigryphaea* sp. ("narrow-carinate" form), umbonal and external views of left valve, UNM 9423; **N, O,** *Texigryphaea* sp., external and internal views of a broadly rounded juvenile left valve, UNM 9424; **P,** *Manuaniceras elaboratum lynnense* Young, fragment of phragmocone steinkern, UNM 9425 (× 0.5); **Q,** *Adkinsites imlayi* Young, fragment of phragmocone steinkern, UNM 9426 (× 0.67); **R,** *Adkinsites* cf. *A. belknapi* (Marcou), small fragment of phragmocone steinkern, UNM 9427 (× 0.5); **S, T,** *Ceratostreon texanum* (Roemer), external views of left valves of UNM 9428 and 9429 (× 0.7)—note pebble to which valve in view T is cemented; **U,** *Cucullaea*? cf. *C.*? *herculea* Twenhofel and Tester, right view of steinkern, UNM 9430 (× 0.67); **V,** *Cyprimeria* sp., right view of steinkern, UNM 9431 (× 0.6); **W,** *Neithea occidentalis* (Conrad), right valve, UNM 9432; **X, Y,** caprinid rudist, top (× 1) and side (× 0.8) views of a shell fragment, UNM 9433.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valves could not be definitely identified. Some small valves are broad, low, and sharply carinate (Fig. 5J, K; 6R, S); they clearly represent juveniles of *T. navia*. Many small specimens (Fig. 5N, O) are relatively elongate, weakly sulcate, and have moderately deflected beaks and weakly inclined umbos that vary from broadly rounded to slightly carinate. Identification of these valves to species was not possible. Some of them resemble juveniles of *T. mucronata* illustrated by Hill and Vaughan (1898, pl. 2) as *T. marcoui*, a synonym of *T. mucronata*.

The wide range of variation displayed by this assemblage of *Texigryphaea* illustrates the difficulties in assigning individual specimens to currently recognized species. These species were, for the most part, established in the 19th century on typological grounds, and the range of variation within each species (and degree of intergradation between species) is not well known. It remains to be seen whether contemporaneous assemblages of *Texigryphaea* from elsewhere in the southern Western Interior display the same array of morphological variation observed among the specimens in the assemblage described here.

Biostratigraphy and correlation

Correlation of the Lower Cretaceous strata at the Rogers outlier is based mainly on ammonoids and *Texigryphaea*—two groups having numerous, well-documented, stratigraphically restricted species in Albian units through much of the southern Western Interior. The three ammonoids collected from the Rogers locality [*Adkinsites imlayi* Young, *A.* cf. *A. belknapi* (Marcou), and *Manuaniceras elaboratum lynnense* Young], together with *A. bravoensis* (Böse) reported by Young (1966) all characterize the Kiamichi Shale in Texas. The type locality for *A. imlayi* and *M. elaboratum lynnense* is a Kiamichi outlier near Guthrie Lake in Lynn County, west-central Texas (Young, 1966), within 100 mi of the Rogers outlier. *Adkinsites belknapi* is also known only from the Kiamichi, and the zone of *A. bravoensis* is essentially the Kiamichi Shale, although this species ranges from just below to just above the Kiamichi (Young, 1966). None of these ammonoids occurs in the extensive Tucumcari Shale exposures in Quay and Guadalupe Counties, New Mexico (Kues et al., 1985).

Among the texigryphaeas, *Texigryphaea navia* occurs abundantly in the Kiamichi of central and eastern Texas (Shelburne, 1959; Bishop, 1967) and southeastern Oklahoma (Huffman et al., 1975, 1978). In these areas it ranges to the top of the Kiamichi and into the basal Duck Creek and equivalent Caddo Formations. The species is also present in the lower part of the Kiowa Formation of Kansas (Scott, 1970b) and western Oklahoma (Fay, 1978). In west-central Texas, however, *T. navia* is confined to the basal part of the Kiamichi (Brand, 1953). It has never been reported from the Tucumcari Shale. *Texigryphaea mucronata* is abundant in Fredericksburg units in Texas, especially the Walnut Formation (Perkins, 1960; Moore, 1964; Flatt, 1976), but also ranges locally into the basal part of the Kiamichi (Winton, 1925; Shelburne, 1959), which is here considered to be the lowest formation of the Washita Group.

Ceratostreon texanum, abundant in the lower part of the Rogers outlier section, is a common Fredericksburg species in Texas (Adkins, 1928; Stanton, 1947), but has also been reported from the Kiamichi (Shelburne, 1959; Bishop, 1967), which is its highest stratigraphic occurrence (Young, 1982). Brand (1953) did not find it above the Kiamichi in west-central Texas. The presence of *C. texanum* in the Tucumcari Shale is doubtful. Several authors (cited by Kues et al., 1985) have reported it in the Tucumcari but extensive examination of the Tucumcari fauna at many localities by the author and others has failed to produce a single specimen of this large, distinctive species. Scott (1970a, 1974) likewise did not report it from the Tucumcari, giving the upper limit of its stratigraphic range as basal Kiamichi.

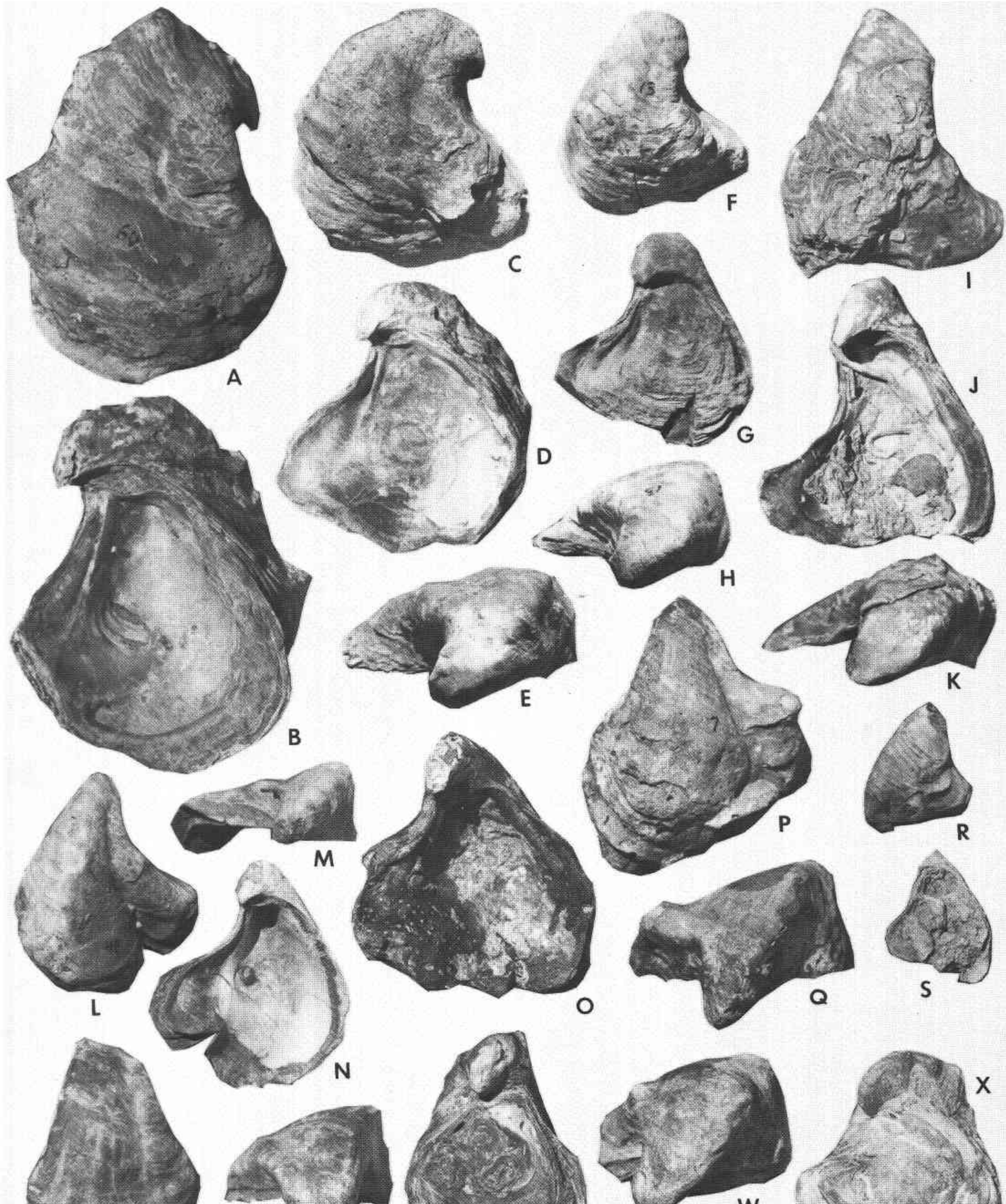
Taken together, the evidence cited above indicates that the Lower Cretaceous strata near Rogers are within the *Adkinsites bravoensis* ammonoid zone of Young (1966, 1967). The important elements of the Rogers fauna are common in the Kiamichi Shale of central and eastern Texas, and most are not present in units overlying the Kiamichi. The fauna of the Tucumcari Shale, on the other hand, is quite different from that at the Rogers locality. None of the *A. bravoensis* zone ammonoids present there has been reported from the Tucumcari Shale, and Scott (1970a) noted that this zone is not recognized in northeastern New Mexico. The earliest ammonoid (tentatively) identified (Brand and Mattox, 1972) in the Tucumcari is *Craginites serratescens* (Cragin), which defines the zone immediately above the *A. bravoensis* zone in north Texas (Young, 1967). The latest ammonoid is *Mortoniceras equidistans* (Cragin), which occurs in both the Tucumcari and overlying Mesa Rica Sandstone (Kues et al., 1985). The *C. serratescens* through *M. equidistans* zones are within the Duck Creek Formation of north Texas (Young, 1967).

The dominant *Texigryphaea* in the Tucumcari Shale is *T. tucumcarii*, instead of the earlier species *T. navia* and *T. mucronata* that characterize the Rogers outlier. *Texigryphaea washitaensis*, a species with a range that begins in the Duck Creek (Fay, 1975; Young, 1982), is also sparsely present in the Tucumcari, but absent at the Rogers locality. Only long-ranging taxa, such as *Scabrotrigonia emoryi* and *Protocardia texana*, are common to both units. Thus, the Tucumcari Shale appears to represent part of the time of Duck Creek deposition in northern and eastern Texas, whereas the Rogers strata were deposited during Kiamichi time, before the deposition of any part of the Tucumcari. Brand (1953) observed *T. navia* only from the base of the Kiamichi in west-central Texas. The presence of *T. navia* at the Rogers outlier, together with the occurrence there of species such as *T. mucronata* and *C. texanum*, which barely continued past the end of Fredericksburg deposition suggests that the Rogers strata are best correlated with the lower part of the Kiamichi as it has been recognized in west-central Texas (Fig. 7).

The restriction of *T. navia* to the base of the Kiamichi in west-central Texas contrasts with its abundant occurrence to the top of the Kiamichi and into the overlying Duck Creek Formation in northeastern Texas and southeastern Oklahoma. Kessinger (1967) suggested, on the basis of foraminiferal evidence, that the upper Kiamichi of the Llano Estacado is temporally equivalent to the lower Duck Creek of north Texas, implying that these formations are time-transgressive units that were deposited somewhat later in western Texas than those deposited 350 mi to the east. The stratigraphic occurrence of *T. navia* in these widely separated areas would support this idea. The Washita sea transgressed westward through Texas and into the southern Western Interior (Scott, 1975), and the succession of environments and biotas represented by Kiamichi and Duck Creek deposition undoubtedly began in the east before the advancing sea brought them into west-central Texas and eastern New Mexico. East Texas/Oklahoma Washita marine environments were also characterized by greater habitat diversity, stability, and predictability than were those of the southern Western Interior (Scott, 1975), and optimum conditions for *T. navia* may have lasted longer in the east than along the western margins of the Washita sea. Thus, the stratigraphic range of *T. navia* in western Texas and New Mexico may be shorter and was terminated earlier (because of less favorable environments) than was the case in eastern Texas and Oklahoma.

The Lower Cretaceous exposures near Rogers lithologically resemble those of the Kiamichi Shale described by Brand (1953) in several counties immediately east of the New Mexico–Texas border. Personal examination of several Kiamichi localities in Bailey County, Texas (15–25 mi east of the Rogers locality),

FIGURE 6—*Texigryphaea* from the Kiamichi Shale at Rogers locality. All figures × 1. **A, B,** *Texigryphaea navia* (Hall), external and internal views of left valve similar to syntypes, UNM 9412; **C, D,** *T. navia* (Hall), external and internal views of a sulcate left valve, UNM 9413; **E,** *T. navia* (Hall), umbonal view of a sulcate left valve, UNM 9434; **F–H,** *T.* aff. *T. navia* ("arcuate" form), left, right, and umbonal views of an articulated specimen, UNM 9414; **I–K,** *T.* aff. *T. navia* ("narrow-beaked" form), external, internal, and umbonal views of left valve, UNM 9415—valve is partly covered by *Serpula cragini;* **L–N,** *T.* aff. *T. navia* ("deeply sulcate" form), external, umbonal, and internal views of left valve, UNM 9416; **O–Q,** *T.* cf. *T. navia*, internal, external, and umbonal views of left valve, UNM 9417; **R, S,** *T. navia*, external and internal views of a juvenile left valve with large attachment scar on beak, UNM 9418; **T–V,** *T.* sp. ("ribbed" form), left, umbonal, and right views of articulated specimen, UNM 9419; **W, X,** *T.* aff. *T. navia* ("inflated" form), umbonal and right views of articulated specimen, UNM 9420.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revealed similar sequences of shales and argillaceous limestones. It should be mentioned, however, that typical specimens of *T. navia* were not observed at the Bailey County localities. The abundant *Texigryphaea* specimens at these localities appear to be *T. pitcheri*, and the exposed units represent a higher level within the Kiamichi than the section near Rogers. In conclusion, based on lithological and paleontological evidence, the Lower Cretaceous strata at the Rogers locality are best interpreted as an isolated remnant of the Kiamichi Shale, deposited near the western shoreline of the early Washita sea before the deposition of any part of the Tucumcari Shale.

ACKNOWLEDGMENTS—I thank Robert W. Scott, Amoco Production Co., Tulsa, Oklahoma, and Robert O. Fay, Oklahoma Geological Survey, for reviewing the manuscript and offering suggestions that helped improve it.

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Northeast Texas (Young, 1967)				Tucumcari, New Mexico, area	Bailey County, west-central Texas (Brand, 1953)	Rogers outlier (this paper)
Stage		Formations	Ammonoid zones			
Upper Albian	Washita Group (part)	Weno Formation	*Mortoniceras wintoni*	Pajarito Shale		
		Denton Formation	*Drakeoceras*	? Mesa Rica		
		Fort Worth Formation	*lasswitzi*	Sandstone		
		Duck Creek Formation	*Mortoniceras equidistans*	Tucumcari		
			Eopachydiscus brazosensis		Duck Creek Formation	
			Craginites serratescens	Shale	Kiamichi	
		Kiamichi Shale	*Adkinsites bravoensis*		Shale	Kiamichi Shale

FIGURE 7—Correlation of Upper Albian (Lower Cretaceous) strata at the Rogers outlier with northeast Texas, west-central Texas, and Tucumcari, New Mexico, areas. The Tucumcari section is based on recent studies by B. S. Kues, S. G. Lucas, K. K. Kietzke, M. Kisucky, and R. Wright (in preparation).