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 NW¼ 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 grivels.

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 mi² 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 brawensis (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, Clevis sheet (Barnes, 1978).

Stratigraphy

At the Rogers locality (Fig. 3) about 15 ft of Lower Cretaceous strata overlie 8 ft of un-
fossiliferous, brick-red to green-mottled Triassic mudstones, which are similar lithologically to intervals in the Chinde 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. Distinctly different valves of Ceratostreon texanum (Roemer) are common, as are large steinkerns of Cyprimeria sp. and Cucullaea? cf. C.? herculae 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 beds 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 conditions, with the bivalves occupying a substrate that included numerous large pebbles.

The uppermost Cretaceous section consists 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.

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 Caenidae. 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 collected. 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 conditions, with the bivalves occupying a substrate that included numerous large pebbles.

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 non-marine 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 moluscan 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 specimens 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 Cragan, and C. washtenensis Adkins. The largest Texas Washita species, C. gigantea Cragan, 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.? herculae (Fig. 5U) reach a length of 112 mm, have a high, anterior beak, and are similar in shape to C. herculae 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 hinges of a few specimens. Fragments of shell adhering to several steinkerns indicate that ornamentation...
lected from the Rogers locality. Eighty-eight 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 curvature of the posterior lobe, and ornamentation of the beak area. 

As 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 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 Kiamic 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 Kiamicich, which he believed was phylogenetically intermediate between *T. mucronata* and *T. navia*.

Two closely similar, gradational groups of large, relatively elongate specimens compose about 30% of the measured mature *Texigryphaea* in the Rogers assemblage. One group, here referred to as *T. sp. (“narrow-sulcate” form)*, 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 spines and thicken lamellae on the valve surface. These features that characterize *T. navia*.

The second group, *T. sp. (“narrow-carinate” form)*, Fig. 6K–L, possesses a higher, steep-sided, carinate left valve, with a subduced sulcus, moderately to weakly deflected beak, and a moderately 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. 6L–V) has rounded, radial costae extending from the umbo to the ventral valve margin. This feature is fairly 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 recognize on the basis of mature

**Figure 5**—Molluscs from the Kiamicich Shale at Rogers locality. All figures × 1 unless otherwise indicated. A–C, *Texigryphaea mucronata* (Gabb), upper, lower, and unlateral 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 9413; 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, *Manuanniceras elongatum* lynnensis Young, fragment of phragmocone steinkern, UNM 9425 (× 0.5); Q, *Adkinsites imlayi* Young, fragment of phragmocone steinkern, UNM 9425 (× 0.5); R, *Eunotia* cf. A. belknapi (Marcou), small fragment of phragmocone steinkern, UNM 9427 (× 0.5); S, *T. fragile* (Conrad), external views of left valves of UNM 9428 and 9429 (× 0.7)—note pebble to which valve in view T is cemented; T, *Cucullites cf.* C. hercules Tвеннхоф and Tesler, right view of steinkern, UNM 9430 (× 0.67); U, *Cypris sp.*., right view of steinkern, UNM 9431 (× 0.6); W, *Netheoa occidentalis* (Conrad), right valve, UNM 9432; X, Y, caprinid rudist, top (× 1) and side (× 0.8) views of a shell fragment, UNM 9433.
valves could not be definitely identified. Some small valves are broad, low, and sharply carinate (Fig. 5I, K; 6R, S); they clearly represent juveniles of \textit{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 \textit{T. mucronata} illustrated by Hill and Vaughan (1898, pl. 2) as \textit{T. marcoui}, a synonym of \textit{T. mucronata}.

The wide range of variation displayed by this assemblage of \textit{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 \textit{Texigryphaea} from elsewhere in the southern Western Interior display the same array of morphological variation observed among the specimens in the assemblage described here.

**Biostatigraphy**

Correlation of the Lower Cretaceous strata at the Rogers outlier is based mainly on ammonoids and \textit{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 [\textit{Adkinsites inlaiyi} Young, A. \textit{cf. A. belknapi} (Marcou), and \textit{Manucantarica elaboratum lynnesii} Young], together with \textit{A. bravoensis} (Böse) reported by Young (1966) all characterize the Kiamichi Shale in Texas. The type locality for \textit{A. inlaiyi} and \textit{M. elaboratum lynnesii} is a Kiamichi outlier near Guthrie Lake in Lynn County, west-central Texas (Young, 1966), within 100 mi of the Rogers outlier. \textit{Adkinsites inlaiyi} is also known only from the Kiamichi, and the zone of \textit{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, \textit{Texigryphaea naaia} occurs abundantly in the Kiamichi of central and eastern Texas (Sheblurne, 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, \textit{T. navia} is confined to the basal part of the Kiamichi (Brand, 1953). It has never been reported from the Tucumcari Shale. \textit{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; Sheblurne, 1959), which is here considered to be the lowest formation of the Washita Group.

\textit{Cerastostreon 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 (Sheblurne, 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 \textit{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.

\textit{Protocardia texana} is a Kiamichi outlier near Guthrie Lake (Scott, 1975), and optimum conditions for \textit{T. navia} may have lasted longer in the east than along the western margins of the Washita sea. Thus, the stratigraphic range of \textit{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 due to greatly reduced temperatures, which were not as strongly influenced by the Cordilleran Province (Scott, 1975), and optimum conditions for \textit{T. navia} may have lasted longer in the east than along the western margins of the Washita sea. Thus, the stratigraphic range of \textit{T. navia} in west central 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),
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 *Tegyrophya* 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.

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**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).**