CAMPANIAN *TRACHYSCAPHITES SPINIGER* AMMONITE FAUNA IN NORTH-EAST TEXAS

by W. A. COBBAN *and* W. J. KENNEDY

ABSTRACT. A horizon 46 m above the base of the Ozan Formation in the North Sulphur River north-west of Ladonia in Fannin County, Texas, yielded a fauna of *Pachydiscus* (*Pachydiscus*) *paulsoni* (Young, 1963), *Eupachydiscus grossouvrei* (Kossmat, 1898), *Placenticeras* sp., *Menabites* (*Delawarella*) *delawarensis* (Morton, 1830), *M.* (*D.*) *danei* (Young, 1963), *M.* (*D.*) *vanuxemi* (Morton, 1830), *M.* (*D.*) sp., *Glyptoxoceras* sp., *Baculites* sp. group of *aquilaensis* Reeside, 1927, *Scaphites* (*Scaphites*) sp. group of *hippocrepis* (DeKay, 1828), *Trachyscaphites spiniger spiniger* (Schlüter, 1872), and *T. densicostatus* sp. nov., together with the bivalve *Inoceramus* (*Endocostea*) *balticus* Böhm, 1909. The presence of *T. spiniger spiniger*, previously known only from western Europe and the USSR, dates the assemblage as early but not earliest late Campanian in a north-west European sense, while stratigraphic relationships to other Gulf Coast Campanian faunas suggest it to be younger than the early Campanian zone of *Scaphites hippocrepis* III and older than the middle Campanian zone of *Baculites mclearni* of the US Western Interior. The Western Interior lower–middle Campanian boundary and the European lower–upper Campanian boundary are approximately coincident; this level can be dated at 80 Ma approximately on the basis of radiometric dates from Western Interior bentonites.

SCAPHITES SPINIGER Schlüter, 1872 is a large, ornately ribbed, tuberculate scaphite, first described from the 'Mucronaten Kreide' of north Germany, and subsequently recognized as an important marker fossil for the upper Campanian in France, Germany, Sweden, The Netherlands, Poland, European Russia, and Soviet Armenia. Recent works by Schmid and Ernst (1975) and Błaszkiewicz (1980) have clarified its range and value in correlation.

Adkins (1929) described, as *Scaphites porchi* and *S. aricki*, two new species of multituberculate scaphites from the 'upper Taylor formation' of Navarro County, Texas. He compared them to '*Acanthoscaphites*' *spiniger* but dismissed any close relationship, stressing the very compressed shell of '*A*' *spiniger* as one of several distinguishing features, being unaware that Schlüter's figured specimens were crushed. Cobban and Scott (1964) studied multituberculate scaphites from the Campanian of the United States Western Interior, and introduced the genus *Trachyscaphites* with *T. redbirdensis* Cobban and Scott 1964 (p. E7. pl. 1, figs 1–7; text-fig. 3 as type species). They recognized *spiniger* as a further member of the genus and divided it into two subspecies, the nominate one and *T. spiniger porchi* Adkins, 1929. The latter was described from both the Gulf Coast and Western Interior, and provided an important link between the cosmopolitan faunas of the former and endemic ones of the latter. It was not possible to correlate Old and New World *T. spiniger* because it was not known if the subspecies recognized were geographical or chronological in nature. It is therefore of some significance that we have recognized abundant specimens of *Trachyscaphites spiniger spiniger* in the Ozan Formation of north-east Texas (Text-figs 1–2) and can show it to precede *T. spiniger porchi*; they are thus chronological subspecies. Furthermore, *T. spiniger spiniger* occurs with abundant texanitid ammonites that have previously been regarded as world-wide markers for the upper lower and middle Campanian (depending on whether a two- or three-fold division of the Campanian is used; there is no general agreement), leading to a review of Campanian ammonite zonation in both the US Gulf Coast and western Europe.

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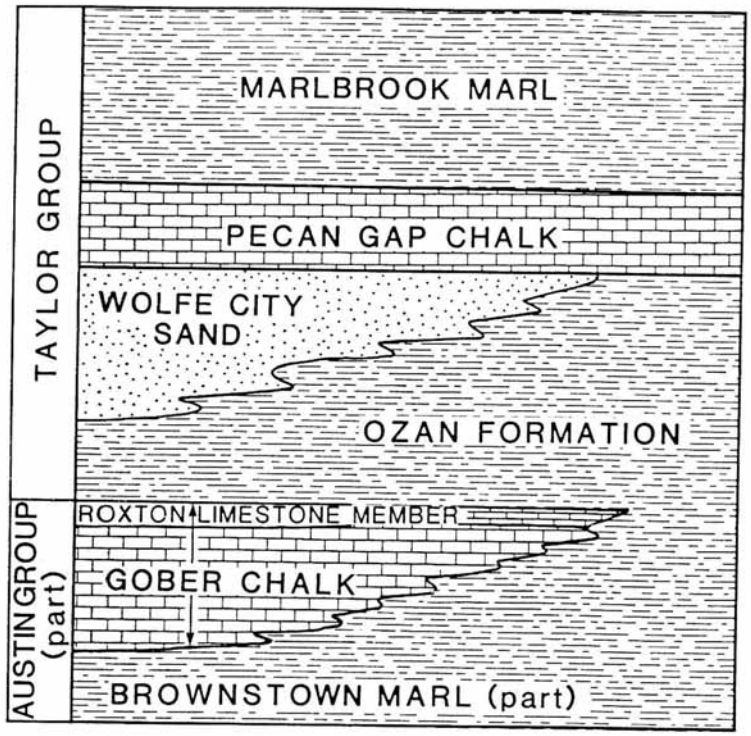
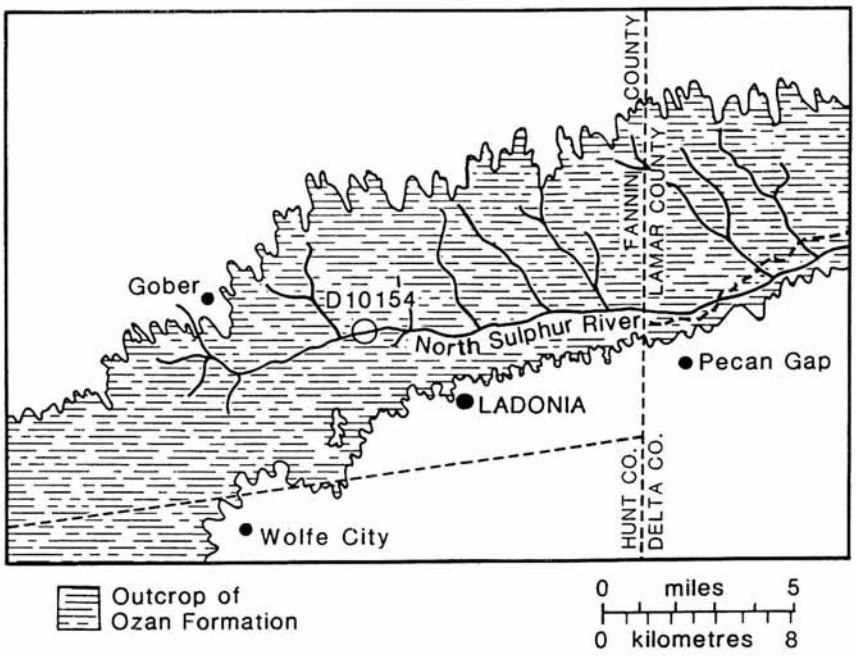


TEXT-FIG. 1. Lithostratigraphic divisions of the upper part of the Austin Group and the Taylor Group in north-east Texas.

STRATIGRAPHIC AND LOCALITY DETAILS

Text-figure 1 shows the lithostratigraphic divisions of the upper part of the Austin Group and the Taylor Group in north-east Texas, modified after Thompson *et al.* (1978) and others. The fossils described here come from the middle part of the Ozan Formation, some 46·m above the base. The term Ozan was introduced by Dane (according to Dane 1929, p. 58, footnote 72) on 10 September 1926, in what is an otherwise anonymous US Department of Interior Memorandum for the Press, No. 8823. The type locality is near Ozan in Hempstead County, Arkansas, and Arkansas outcrops and fossil occurrences are described in detail by Dane (1929). In north-east Texas, beds at this level that are equivalent to the Ozan Formation were termed 'unnamed marl' of the Taylor Group by authors up to and including Adkins (1933), but the term Ozan Formation is now applied to beds above the Gober Chalk and below the Pecan Gap and Annona Chalks (e.g. Geologic Atlas of Texas, Texarkana Sheet, 1966). The sequence is as much as 130 m thick, and consists of light grey-weathering, bluish-grey, calcareous clays with chalky beds and some fine sand units. The material studied here was collected by the late James P. Conlin (Fort Worth, Texas), W. A. Cobban, R. E. Burkholder and others at or close to USGS Mesozoic locality D10154 outcrops in the North Sulphur River 4·1–5·0 km north-west of the centre of Ladonia in Fannin County (Text-fig. 2). This corresponds to locality 15 of Paulson (1960, p. 112) who gives precise details as to how to reach the outcrop ('go 0·5 mi. west of square at Ladonia, Fannin County; turn north 2·0 mi. to North Sulphur River Bridge; walk 1·2 mi. west to the junction of Davis Creek'). The



TEXT-FIG. 2. Locality map for part of north-east Texas showing the source of specimens described in the text.

fossils come from a distinctive glauconitic unit at most a few tens of centimetres thick that overlies a marked omission surface that can be traced widely in the subsurface (Paulson 1960, p. 22) and is here 46 m above the top of the Gober Chalk. The basal unit above the omission surface is a red-weathering, green, glauconitic marl rich in bioclasts. The bed is crowded with black phosphate nodules, many of which are worn moulds of *Baculites* with rarer *Placenticeras*, although bivalves, gastropods and vertebrate debris are the commonest faunal elements. They show many of the complex taphononic features described in the very similar unit at the Austin–Taylor contact as described by Fürsich, Kennedy and Palmer (1981). In contrast, the fauna described here is an indigenous one, commonly crushed and with original aragonitic shell preserved.

AGE AND CORRELATION OF THE FAUNA

The indigenous ammonite fauna from the Ozan Formation north-west of Ladonia is as follows: *Pachydiscus* (*Pachydiscus*) *paulsoni* (Young, 1963) (frequent), *Eupachydiscus grossouvrei* (Kossmat, 1898) (rare), *Placenticeras* sp. (rare), *Menabites* (*Delawarella*) *delawarensis* (Morton, 1830) (rare), *M.* (*D.*) *danei* (Young, 1963) (fairly frequent), *M.* (*D.*) *vanuxemi* (Morton, 1830) (rare), *M.* (*D.*) sp. (rare), *Glyptoxoceras* sp. (frequent), *Baculites* sp. group of *aquilaensis* Reeside, 1927, (abundant), *Scaphites* (*Scaphites*) sp. group of *hippocrepis* (DeKay, 1828) (rare), *Trachyscaphites spiniger spiniger* (Schlüter, 1872) (frequent), *Trachyscaphites densicostatus* sp. nov. (rare). Also present is the distinctive inoceramid bivalve *Inoceramus* (*Endocostea*) *balticus* Böhm, 1909 (Pl. 7, figs 6, 10). No zonation has been developed for the higher Campanian in the Gulf Coast region to date, but Young (1963) proposed the following partial scheme:

	ZONE
upper Campanian (part)	*Hoplitoplacenticeras marroti*
lower Campanian	*Delawarella sabinalensis* *Delawarella delawarensis* *Submortoniceras tequesquitense*

At first sight, the North Sulphur River assemblage, with *P.* (*P.*) *paulsoni*, *M.* (*D.*) *delawarensis*, *M.* (*D.*) *danei* and *M.* (*D.*) *vauxemi*, would seem to fall into the *delawarensis* zone, from details in Young's text-figure 3 and list on p. 28 of that work. Unfortunately Young's specimens of these species are not placed in sequence, rather coming from the Gober Chalk (Text-fig. 1) and correlatives in north-east Texas and south-west Oklahoma. Instead, we believe the present fauna to be much younger.

At Roxton in Lamar County, 26·5 km east-northeast of Ladonia, the Roxton Limestone Member at the top of the Gober Chalk yields *P.* (*P.*) *paulsoni*, *Anapachydiscus* sp. juv., *Placenticeras placenta* (DeKay, 1828), *Hoplitoplacenticeras* aff. *H. plasticum* (Paulcke, 1907), *Menabites* (*Delawarella*) *delawarensis*, *M.* (*D.*) aff. *vanuxemi*, *Submortoniceras vandaliaense* Young, 1963, *Submortoniceras* sp., *Nostoceras* (*Eubostrychoceras*) sp. nov., *Baculites haresi* Reeside, 1927, and *Scaphites* (*Scaphites*) *hippocrepis* (DeKay, 1828) form III (Cobban, 1969). The North Sulphur River fauna occurs 46 m above this. The Wolfe City Sand (Text-fig. 1) at Wolfe City, 11·5 km south-southwest of Ladonia (Text-fig. 2), yielded the following: *Patagiosites* sp., *Placenticeras* sp., *Hoplitoplacenticeras* sp. nov., *Baculites mclearni* Landes, 1940, *Trachyscaphites spiniger porchi* Adkins, 1929, and *Inoceramus azerbaidjanensis* Aliev, 1939. The base of the Pecan Gap Chalk (Text-fig. 1) has yielded ammonites at scattered localities around Pecan Gap and Wolfe City (Text-fig. 2), including *Pachydiscus* (*Pachydiscus*) sp., *Lewyites* sp., *Baculites taylorensis* Adkins, 1929, and *T. spiniger porchi*. Taken together these faunas place the North Sulphur River assemblage in both a US Western Interior and a north-west European context.

Comparison with US Western Interior faunas

Ammonite zonation for the Western Interior Campanian is summarized by Cobban (in press), who recognizes seventeen ammonite zones, with an additional three that may be Campanian or Maastrichtian:

	ZONE
upper Campanian (part)	*Exiteloceras jenneyi* *Didymoceras stevensoni* *Didymoceras nebrascense*
middle Campanian	*Baculites scotti* *Baculites reduncus* *Baculites gregoryensis* *Baculites perplexus* *Baculites* sp. (smooth) *Baculites asperiformis* *Baculites mclearni* *Baculites obtusus*
lower Campanian	*Baculites* sp. (weak flank ribs) *Baculites* sp. (smooth) *Scaphites hippocrepis* III *Scaphites hippocrepis* II *Scaphites hippocrepis* I *Scaphites leei* III

The fauna of the Roxton Limestone Member, with *S. hippocrepis* III and *Baculites haresi*, correlates with the Western Interior zone of *S. hippocrepis* III. The Wolfe City Sand fauna has *Baculites mclearni*, which is restricted to its zone in the Interior. *Trachyscaphites spiniger porchi* is known from the *B. mclearni* zone. *Menabites* (*Delawarella*) *danei*, which occurs in both the Roxton Limestone Member and North Sulphur River faunas, occurs in the *Baculites obtusus* zone in the Western Interior near Pueblo, Colorado. *Baculites* sp. group

of *aquilaensis*, differs from *B. aquilaensis* of the Western Interior lower Campanian, such as to suggest it may be younger. The North Sulphur River assemblage thus lies somewhere around the boundary between the lower and middle Campanian provincial substages of the Western Interior.

Comparison with western European faunas

Kennedy (1986 and references therein) reviewed the 'classic' zonation of the Campanian Stage in the type area of Aquitaine, France. The sequence, based on the work of de Grossouvre (1894, 1901) and Haug (1908–1911) and others is:

	ZONE
upper Campanian	*Nostoceras (Bostrychoceras) polyplocum* *Hoplitoplacenticeras marroti*
lower Campanian	*Menabites Delawarella delawarensis* *Placenticeras bidorsatum*

These are scarcely zones in the accepted sense, as ammonites are rare in Aquitaine (Kennedy saw thirteen *P. bidorsatum*, two *M. (D.) delawarensis*, twenty or so *H. marroti* and fourteen *N. (B.) polyplocum*), and ranges are only incompletely known. The presence of forms intermediate between *S. (S.) hippocrepis* II and III in the *bidorsatum* zone, as well as *M. (D.) delawarensis* in the *delawarensis* zone suggests the Sulphur River fauna corresponds to the latter. But *Trachyscaphites spiniger*, common in the Sulphur River fauna, is also known in Aquitaine, from Assize P^8 of Arnaud at St Médard de Barbezieux, a unit that yields upper Campanian *marroti* and *polyplocum* zone fossils at other localities.

A better control on the age of *T. spiniger* in Europe comes from the careful work of Schmid and Ernst (1975) working on the White Chalk faunas of north Germany (see also Ernst and Schmid 1979; Schulz *et al.* 1984). They divide the upper Campanian as follows:

Micraster grimmensis/Cardiaster granulosus Zone (top)
Belemnitella langei Zone
Bostrychoceras polyplocum Zone
Galerites vulgaris Zone
Pachydiscus stobaei/Galeola papillosa basiplana Zone
Echinocorys conica/Belemnitella mucronata senior Zone (bottom)

Trachyscaphites spiniger has been recorded from the top of the *E. conica/B. m. senior* zone, but Ernst and Schmid found it to occur first as fragments in the lower part of the *P. stobaei/G. p. basiplana* zone, to be rare in the middle of the zone, with a specimen from the upper *G. vulgaris* zone, while noting records from as high as the basal *B. polyplocum* zone.

There are also detailed records from the Vistula Valley in Poland (Błaszkiewicz 1980), where the following sequence is recognized:

	ZONE
upper Campanian	*Nostoceras pozaryskii* *Didymoceras donezianum* *Bostrychoceras polyplocum* *Neancyloceras phaleratum*
lower Campanian	*Gonioteuthis quadrata* *Gonioteuthis granulata granulata*

T. spiniger spiniger and subspecies *T. s. posterior* Błaszkiewicz, 1980, first appear in the *N. phaleratum* zone. The subspecies *T. s. posterior* was differentiated from the nominate species because of a smaller number of ribs

running between the tubercles of the same row on the exposed part of the normal spiral and the presence of lateroumbilical tuberculation on earlier sectors of the exposed normal spiral. It also differs on the whole in a smaller degree of freeing the shaft from the phragmocone and in a frequent lack of ribs between the tubercles on the same row on the shaft (Błaszkiewicz 1980, p. 32). Loss of ribbing on the body chamber is a feature of subspecies *T. s. porchi*, and in terms of an evolutionary progression, a sequence *T. spiniger spiniger*, *T. spiniger posterior*, *T. spiniger porchi* is perfectly feasible.

What is clear is that *Trachyscaphites spiniger spiniger* marks a low upper Campanian horizon in a north-west European sense, in the broad *H. marroti* zone of the Aquitaine succession, the *P. stobaei/G. p. basiplana* zone in north Germany (though reported to have a longer range) and the *N. phaleratum* zone in the Vistula Valley, Poland. This is supported by other, less detailed records from Europe: *T. spiniger sensu lato* is thus known from the lower part of the upper upper Campanian *B. polyplocum* zone in the Kopetdag (Atabekian 1979), upper upper Campanian *Belemnitella langei* zone of the Russian platform (Naidin 1979), and the lower upper Campanian Zeven Wegen Chalk of the Netherlands (Kennedy 1986; Jagt 1988).

Discussion

The previous review indicates that the first appearance of *Trachyscaphites spiniger spiniger* is a good marker for a horizon low in, but not at, the base of the upper Campanian as the substage is defined in north-west Europe. The North Sulphur River fauna is thus low upper Campanian in a north-west European sense, while the Texanitinae, previously thought to die out at the top of the lower Campanian, extend into the upper Campanian. Use of a *Menabites* (*Delawarella*) *delawarensis* zone in the lower Campanian is thus unwise, since the index species clearly extends into the upper Campanian. Correlation with the United States Western Interior is less satisfactory, but the first appearance of *T. spiniger spiniger* is certainly above the zone of *Scaphites hippocrepis* III and below that of *Baculites mclearni*, so that the lower–middle Campanian boundary in the Western Interior must lie very close to the European lower–upper Campanian boundary. This correlation using fossils also provides an indirect numerical age for the lower–upper Campanian boundary in western Europe, because Obradovich and Cobban (1975) dated a series of bentonites, for which Odin and Obradovich (1982, p. 770) provide recalculated ages. A bentonite from either the top of the *Baculites obtusus* zone or base of the *B. mclearni* zone gave apparent ages of $79{\cdot}9 \pm 3{\cdot}2$ Ma and $79{\cdot}2 \pm 1{\cdot}6$ Ma. A bentonite bed from the zone of *Baculites* sp. (weak flank ribs) gave $80{\cdot}0 \pm 1{\cdot}6$ Ma. Kennedy and Odin (1982), followed by Hallam *et al.* (1985) and Snelling (1985) gave numerical ages of 83 ± 1 Ma and 72 ± 1 Ma respectively for the beginning and end of the Campanian. The present correlation suggests the age of the European early or late Campanian boundary to be around 80 Ma, so that the early and late Campanian are of disparate durations. The tripartite subdivision of the American Campanian may be more practical (Cobban, in press).

SYSTEMATIC PALAEONTOLOGY

Location of specimens. All specimens described here are deposited in the National Museum of Natural History in Washington DC, and have USNM catalogue numbers; casts of some are kept at the US Geological Survey at the Denver Federal Center, Denver, Colorado. TMM = Texas Memorial Museum, Austin, Texas. GAB = Geological and Palaeontological Institute of Bonn University.

Conventions. Suture terminology is that of Wedekind (1916) as reviewed by Kullman and Wiedmann (1970): E = external lobe; L = lateral lobe; U = umbilical lobe, I = internal lobe.

Dimensions are given in millimetres, with D = diameter, Wb = whorl breadth, Wh = whorl height, U = umbilicus. Figures in parentheses are dimensions as a percentage of diameter.

Order AMMONOIDEA Zittel, 1884
Suborder DESMOCERATACEAE Zittel, 1895

[*nom. transl.* Wright and Wright 1951, p. 18; *ex.* Desmoceratidae Zittel, 1895]

Family PACHYDISCIDAE Spath, 1922

[*nom. transl.* Spath, 1923, p. 39; *ex.* Pachydiscinae Spath, 1922]

Genus and subgenus PACHYDISCUS Zittel, 1884

[= *Parapachydiscus* Hyatt, 1900, p. 570; *Joaquinites* Anderson, 1958, p. 218; *Pseudomenuites* Matsumoto, 1955, p. 169]

Type species. Ammonites neubergicus Hauer, 1858, p. 12, pl. 2, figs 1–3, pl. 3, figs 1–2, by subsequent designation by de Grossouvre (1894, p. 177).

Pachydiscus (*Pachydiscus*) *paulsoni* (Young, 1963)

Plate 1, figs 4–7; Plate 4, figs 7–9; Plate 5, figs 7–8; Text-figs 3A–C, 4B

1963 *Parapuzosia paulsoni* Young, p. 53, pl. 11, figs 3–5; pl. 12, figs 1–4; pl. 15, fig. 10; pl. 17, fig. 9; pl. 19, figs 3–4; text-figs 8*a–b*; 9*g,j,r*.

Types. Holotype is TMM 30625, from the Gober Chalk in McCurtain County, Oklahoma. Hypotypes are USNM 441382–441388, from the Ozan Formation of Fannin County, Texas.

Dimensions.	D	Wb	Wh	Wb:Wh	U
USNM 441382	103·6 (100)	35·2 (33·9)	47·2 (45·5)	0·75	20·4 (19·7)
USNM 441383	67·0 (100)	22·9 (34·2)	31·5 (47·0)	0·72	13·2 (19·7)

Description. We have thirty-six specimens ranging from 33 to 175 mm in diameter. Coiling is moderately involute, with 65% of the previous whorl covered. The whorl section is compressed, with a breadth to height ratio of 0·70–0·75, the whorl section compressed oval, with the greatest breadth just outside the umbilical shoulder. The umbilicus is small and comprises 20% of the diameter. The umbilical wall is low and flattened, and the umbilical shoulder is broadly rounded. Flanks are broadly rounded and convergent to a narrowly rounded venter. Internal moulds are smooth (Pl. 1, figs 4–5), because ornament is produced by thickening of the shell (Pl. 5, figs 7–8; Text-fig. 3A) rather than by folding. Where shell is present, distant, narrow, wiry ribs that number 12–14 per whorl arise at incipient bullae, while other ribs may extend to the umbilical shoulder as mere striae. Additional ribs intercalate both low and high on the flank to give a total of as many as 60 ribs per whorl; the intercalated ones may be as strong as or as weak as the primaries. Ribs are straight and prorsiradiate to the outer flank, then flex forward and are concave, projecting forward over the ventrolateral shoulder, which they cross in a broad convexity. This pattern of ornament is developed in the largest specimens seen that have well-preserved ornament. In the largest specimen itself, the ornament of the inner whorls is particularly well preserved and shows the presence of well-developed very elongate bullae (Text-fig. 3A). Suture deeply and intricately incised; typical for genus.

Discussion. Young (1963, p. 53) referred this species to *Parapuzosia* Nowak, 1913 (p. 350; type species *Sonneratia daubreei* de Grossouvre, 1894, p. 154, pl. 28; see revision in Immel *et al.* 1982, p. 11, pl. 2, figs 9–10; pl. 3, figs 1–2; pl. 4, fig. 2). Young's species is rather a *Pachydiscus* (*Pachydiscus*), differing from *Parapuzosia* in its lesser compression, feebly bullate primary ribs that are close rather than distant, few intercalated ribs of variable length rather than many that are confined to the outer flank, and lack of constrictions on the inner whorls. Its characters are thus pachydiscid rather than puzosiine. *Pachydiscus* (*P.*) *paulsoni* is closest to *Pachydiscus* (*Pachydiscus*) *duelmensis* (Schlüter, 1872) (p. 52, pl. 16, figs 1–2; see Kennedy 1986, text-fig. 12), from which it differs in the presence of weak bullae, more compressed whorl section and fewer, wider-spaced ribs.

Occurrence. Lower Campanian part of the Austin Chalk, *Submortoniceras tequesquitense* zone of Travis County, Texas; *Delawarella delawarensis* zone in McCurtain County, Oklahoma and Little River County, Arkansas, in equivalents of the Gober Chalk; lower Campanian, Roxton Limestone Member at top of the Gober Chalk at USGS Mesozoic locality D6896, Lamar County, Texas, as well as the present occurrence in the middle Campanian Ozan Formation at USGS Mesozoic locality D10154 in Fannin County.

Genus EUPACHYDISCUS Spath, 1922

[= *Mesopachydiscus* Yabe and Shimizu, 1926, p. 172]

Type species. Ammonites isculensis Redtenbacher, 1873, p. 122, pl. 29, fig. 1; by original designation.

Eupachydiscus grossouvrei (Kossmat, 1898)

Plate 1, figs 8–10

1865	*Ammonites ootacodensis* Stoliczka, p. 109 (*pars*), pl. 57 only.
1898	*Pachydiscus grossouvrei* Kossmat, p. 101 (166).
1922	*Eupachydiscus grossouvrei* (Kossmat); Spath, p. 124.
1931	*Pachydiscus grossouvrei* Kossmat; Basse, p. 26, pl. 2, figs 16–17; pl. 13, fig. 3; *non* pl. 3, figs 8–9; *non* pl. 11, fig. 2 (= *E. pseudogrossouvrei* Collignon, 1952).
1932	*Parapachydiscus grossouvrei* (Kossmat); Collignon, p. 26, fig. 14.
non 1938	*Eupachydiscus grossouvrei* (Kossmat); Collignon, p. 28. (= *Eupachydiscus pseudogrossouvrei* Collignon, 1952).
1952	*Eupachydiscus grossouvrei* (Kossmat); Collignon, p. 39, pl. 7, fig. 2; pl. 28, fig. 1.
1955	*Eupachydiscus grossouvrei* (Kossmat); Collignon, p. 40, pl. 7, fig. 2; pl. 28, fig. 1.
1970	*Eupachydiscus grossouvrei* (Kossmat); Collignon, p. 34, pl. 42, fig. 2307.

Types. Holotype, by monotypy, is the original of Stoliczka 1865, pl. 57, from the Arrialoor Group of Otacod, South India. Hypotype is USNM 441389, from the Ozan Formation of Fannin County, Texas.

Dimensions.	D	Wb	Wh	Wb:Wh	U
USNM 441389	78·5 (100)	40·3 (51·3)	42·8 (54·5)	0·94	16·4 (21·0)

Description. Coiling is moderately involute, with 70% of the previous whorl covered. The umbilicus is small, comprising 26% of the diameter, deep, with a rounded undercut umbilical wall on the mould. The whorl section is slightly compressed, with broadly rounded flanks and venter. Primary ribs arise singly (and, perhaps, in pairs) from feeble umbilical bullae, while additional ribs intercalate below mid-flank. Ribs are narrow and sharp, and separated by somewhat wider interspaces. They are straight and prorsiradiate to the outer flank, where they flex forward and become concave over the ventrolateral shoulder before crossing the venter in a broad convexity. Total rib number per whorl cannot be determined for certain because of poor preservation but it is estimated at 36. Sutures not seen.

Discussion. The present specimen differs in no significant respects from comparable-sized Madagascan specimens figured by Basse (1931) and Collignon (see synonymy) as well as unfigured material from Madagascar in the collections of the Muséum National d'Histoire Naturelle in Paris and in the Collignon Collection at Dijon.

Eupachydiscus jimenezi (Renz, 1936) (p. 3, pl. 2, fig. 4; see also Young 1963, p. 59, pl. 14, figs 1–5; pl. 16, fig. 4; text-fig. 10*k*) has a depressed whorl section and much stronger, distant bullae that give rise to pairs of ribs, with numerous shorter intercalated ribs between bullate ones. *Eupachydiscus gordoni* Young, 1963 (p. 59, pl. 16, figs 1–3; text-fig. 8*e*), a second Texas species, is said to be Santonian. It has twenty umbilical bullae per whorl giving rise to one, sometimes two, ribs, with

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EXPLANATION OF PLATE 1

Fig. 1. *Trachyscaphites densicostatus* sp. nov. USNM 441427; paratype; microconch.
Figs 2–3. *Trachyscaphites spiniger spiniger* (Schlüter, 1872). USNM 411416; microconch body chamber.
Figs 4–7. *Pachydiscus* (*Pachydiscus*) *paulsoni* (Young, 1963). 4–5, USNM 441383, 6–7, USNM 441384.
Figs 8–10. *Pachydiscus* (*Pachydiscus*) *grossouvrei* (Kossmat, 1898). USNM 441389.
All specimens from the Ozan Formation 46 m above the base at USGS Mesozoic locality D10154; Fannin County, Texas. All ×1.

COBBAN and KENNEDY, *Trachyscaphites, Pachydiscus*

TEXT-FIG. 3. *Pachydiscus* (*Pachydiscus*) *paulsoni* (Young, 1963). A, USNM 441387. B–C, USNM 441388. All figures natural size.

about twenty shorter ribs intercalating to give a total of approximately forty-four ribs per whorl. The ribbing is also much sharper than in the present species, but this may be due to differences in preservation. Collignon (1952, 1955) discussed differences between *E. grossouvrei* and other species from outside the United States.

Occurrence. Middle Campanian Ozan Formation of north-east Texas.

Superfamily HOPLITACEAE H. Douvillé, 1890

[for synonymy etc., see Kennedy 1986, p. 56]

Family PLACENTICERATIDAE Hyatt, 1900

[= Hypengonoceratinae Chiplonkar and Ghare 1976, p. 2; Baghiceratinae Chiplonkar and Ghare 1976, p. 3]

Genus PLACENTICERAS Meek, 1876

[for synonymy, see Kennedy and Wright 1983, p. 869]

Type species. *Ammonites placenta* DeKay, 1828, p. 278, pl. 5, fig. 3 (2), by original designation by Meek 1876, p. 426.

Placenticeras sp.

Plate 2, fig. 1

Description. *Placenticeras* is represented by four fragments in the North Sulphur River fauna, the largest and best-preserved (Pl. 2, fig. 1) with a whorl height of 67 mm. Coiling is very involute, with a tiny, deep umbilicus that has a flattened, outward-inclined wall and broadly rounded umbilical shoulder. The inner flanks are broadly rounded, the outer flanks flattened and convergent, the venter narrow and tabulate, with sharp ventral edges. Two of the fragments are smooth; two have umbilical bullae of moderate strength, that number five per half whorl.

Occurrence. Middle Campanian, Ozan Formation, USGS Mesozoic locality D10154, Fannin County, Texas.

Superfamily ACANTHOCERATACEAE de Grossouvre, 1894

[*nom. correct*. Wright and Wright 1951, p. 24 (*pro* Acanthoceratida Hyatt, 1900, p. 585), *nom. transl. ex*. Acanthoceratidae Hyatt, 1900, p. 585, *nom. correct. ex* Acanthoceratidés de Grossouvre, 1894]

Family COLLIGNONICERATIDAE Wright and Wright, 1951

[*nom. subst. pro* Prionotropidae Zittel, 1895, p. 430 (ex *Prionotropis* Meek, 1876, p. 453, *non* Fieber, 1853, p. 127; = *Collignoniceras* Breistroffer, 1947 (unpaged) (= Prionocyclidae Breistroffer, 1947 (unpaged) *ex Prionocyclus* Meek, 1876, p. 298, ineligible as family type]

Subfamily TEXANITINAE Collignon, 1948

[*nom. transl*. Wright 1957, p. L429 *ex* Texanitidae Collignon, 1948]

Genus MENABITES Collignon, 1948

Type species. *Menabites menabensis* Collignon, 1948, p. 7 (64), pl. 17, figs 3 and 4; pl. 18, fig. 1, by subsequent designation by Wright 1957 (p. L432).

Subgenus DELAWARELLA Collignon, 1948, p. 64 (19)

Type species. *Ammonites delawarensis* Morton, 1830, p. 244, pl. 2, fig. 4, by original designation.

Menabites (*Delawarella*) *delawarensis* (Morton, 1830)

Plate 6, fig. 9

1830 *Ammonites delawarensis* Morton, p. 244, pl. 2, fig. 4.

1948 *Menabites* (*Delawarella*) *delawarensis* (Morton); Collignon, p. 29 (86) (with full synonymy).
1986 *Menabites* (*Delawarella*) *delawarensis* (Morton, 1830); Kennedy, p. 81, pl. 11, figs 3–4; text-fig. 30 (with additional synonymy).

Types. These appear to be lost, in spite of the observations of Young (1963, p. 111); see Reeside (1962, p. 132) and Kennedy (1986, p. 81). Hypotype USNM 441391, from the Ozan Formation of Fannin County, Texas.

Description. Four specimens between 93 and 120 mm diameter are referred to this species. All are distorted to varying degrees. Coiling is moderately evolute; U = 30% of diameter with about a third of the previous whorl concealed in the dorsal impressed zone. The umbilical wall is of moderate elevation, flattened and subvertical and notched to accommodate the submarginal tubercles of the previous whorl. The umbilical shoulder is narrowly rounded. Twenty-one sharp umbilical bullae perch on the shoulder, and may project into the interspaces of the previous whorl; they are separated by deep interspaces that notch the shoulder and upper part of the umbilical wall. Broad, straight prorsiradiate ribs arise from these bullae either singly or in pairs and strengthen across the flanks, where they develop into a blunt, bullate lateral tubercle and a much stronger conical submarginal tubercle. A broad rib connects this to a somewhat weaker feebly clavate marginal tubercle, which gives rise to one or a pair of low, broad ribs (the adapical one the weaker) that terminate in strong external clavi. A broad, concave, smooth zone separates these clavi from a blunt siphonal ridge. Suture simple, with broad, bifid E/L and L, U_2 narrower.

Discussion. The North Sulphur River material differs in no significant respects from large collections of New Jersey and Delaware specimens before us. The Texas specimens are somewhat variable in strength of their tubercles versus ribs, notably in the development of the submarginal row. *Menabites* (*D.*) *delawarensis* differs from *M.* (*D.*) *danei* (Young, 1963) (see below) by the much coarser ribbing and tuberculation of *M.* (*D.*) *danei*, in particular the persistence of a strongly trituberculate '*Australiella*' stage to as much as 150 mm diameter in Young's species. Of other Texas species, *M.* (*D.*) *campaniensis* of Young (1963, p. 113, pl. 64, figs 2, 6; pl. 67, fig. 2; text-figs 24*a*, 25*a*) *non* de Grossouvre, 1894, is much more evolute with a much lower whorl expansion rate and widely separated ribs. *Menabites* (*D.*) *sabinalensis* (Young, 1963) (p. 112, pl. 54, fig. 2; pl. 63, figs 1, 3, 4; text-figs 20*c*, 21*e*, 26*c*) is strongly and distantly ribbed with weak tubercles throughout and adults that are quadrituberculate.

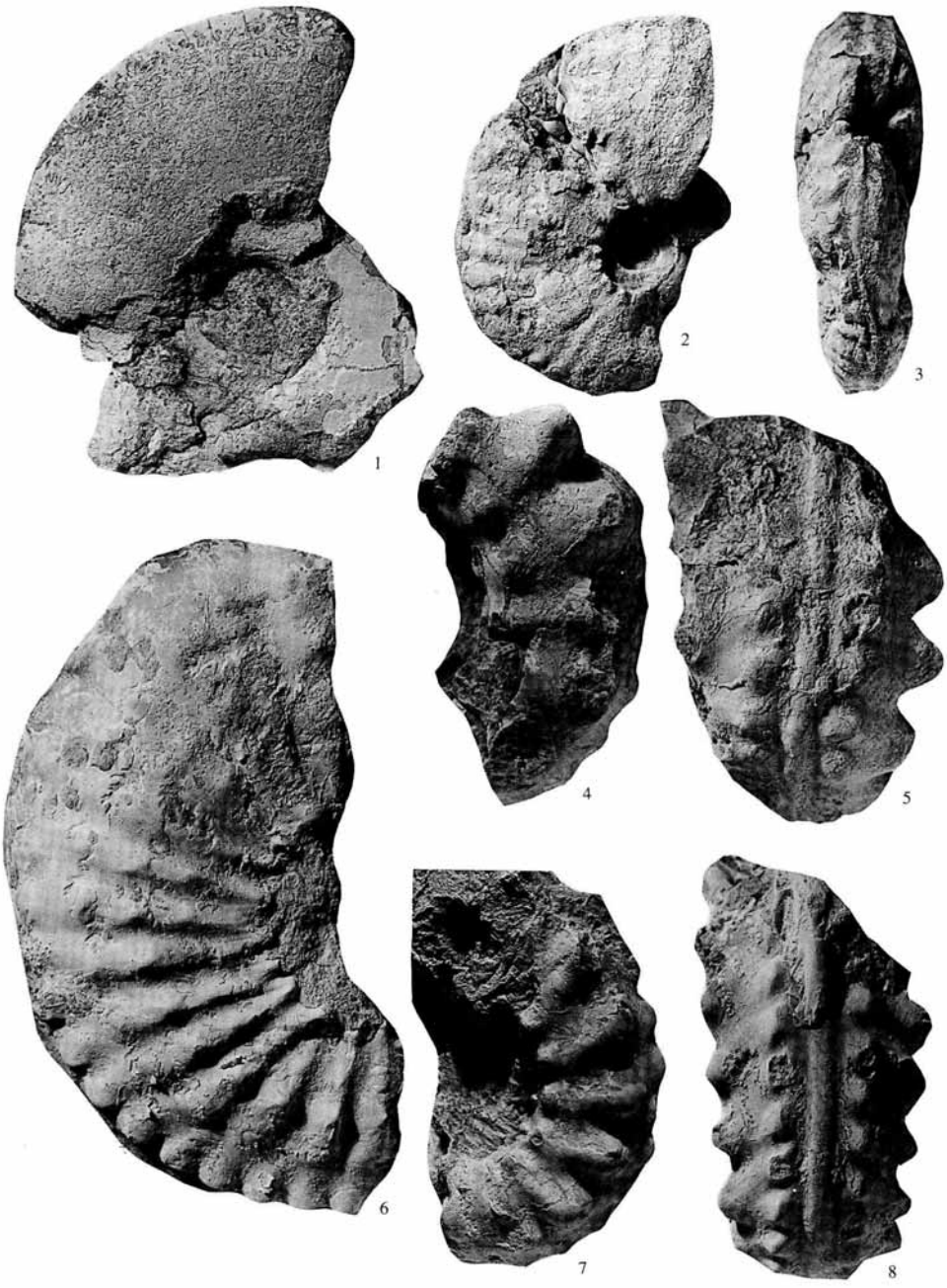
Occurrence. Menabites (*D.*) *delawarensis* has generally been thought of as a late early Campanian species, but is here shown to range to the middle Campanian (early later Campanian in a north-west European sense). It occurs in the Merchantville Formation in Delaware and New Jersey (Sohl and Mello in Owens *et al.* 1970), and in the Austin Chalk in Texas where Young used it as an index for the mid-lower Campanian. Young's specimens from Travis County were said to be from unit D of the Burditt Marl. The species also occurs, but is poorly dated, in the Big Bend National Park. We have seen numerous specimens from the Roxton Limestone Member at the top of the Gober Chalk in Lamar County, where it is dated as late early Campanian and the Middle Campanian Ozan Formation at USGS Mesozoic locality D10154 in Fannin County. The species occurs in what are said to be equivalents of the Gober Chalk in McCurtain County, Oklahoma (Young 1963). A single specimen is known from the upper lower Campanian of Aquitaine, France, and it is also recorded from the lower Campanian of Zululand, South Africa and, possibly, Madagascar.

Menabites (*Delawarella*) *danei* (Young, 1963)

Plate 2, figs 5–8; Plate 3, figs 1–3; Plate 4, figs 1, 12

EXPLANATION OF PLATE 2

Fig. 1. *Placenticeras* sp. USNM 441390.
Figs 2–4. *Menabites* (*Delawarella*) *vanuxemi* (Morton, 1830). 2–3, USNM 441397. 4, USNM 441398.
Figs 5–8. *Menabites* (*Delawarella*) *danei* (Young, 1963). 5–6, USNM 441392. 7–8, USNM 441393.
All specimens from the Ozan Formation 46 m above the base at USGS Mesozoic locality D10154; Fannin County, Texas. All ×1.



COBBAN and KENNEDY, *Placenticeras*, *Menabites*

1929 *Mortoniceras delawarense* (Morton); Dane, pl. 10, figs 1–2.
1963 *Delawarella danei* Young, p. 114, pl. 57, fig. 6; pl. 62, figs 1–2; pl. 64, figs 1, 5; pl. 65, figs 1–2; pl. 66, figs 3–4; text-figs 24*e*, 33*b*.

Types. Holotype, by original designation, is TMM 30646, from 'a formation equivalent to the Gober Chalk' in McCurtain County, Oklahoma, 1·6 km west of the Oklahoma line on the highway from Foreman, Arkansas, to Tom, Oklahoma. Hypotypes USNM 441392–441395, from the Ozan Formation of Fannin County, Texas.

Description. Twelve specimens, ranging from 42 to 160 mm diameter are referred to Young's species. In juveniles up to 70 mm diameter (Pl. 2, figs 5–8), coiling is very evolute with U = 40 % or more of the diameter, deep, and with a flattened, outward-inclined umbilical wall that is notched to accommodate the submarginal spines of the preceding whorl (Pl. 2, fig. 7). The whorls are massive, depressed, reniform in intercostal section with the greatest breadth just below mid-flank and a whorl breadth to height ratio of 1·42. The costal whorl section is polygonal, with greatest breadth at the submarginal spine and a whorl breadth to height ratio of 1·76 in USNM 441393, taken at the basal septum of that spine. There are 7–8 strong umbilical bullae per half whorl, that in places are seen to be the septate bases of umbilical spines. They are separated by deep interspaces that notch the umbilical shoulder and upper part of the umbilical wall, and give rise to single strong, broad, coarse ribs that are slightly prorsiradiate and separated by interspaces of similar breadth or more. Each terminates in a massive rounded submarginal node that is the septate base of a short spine, visible in the inner whorl of USNM 441393 (Pl. 2, fig. 7). These give rise to one or two low broad ribs that connect to coarse external clavi. In a few cases the clavi intercalate, and are not obviously linked to the submarginal nodes. A shallow broad groove separates the external clavi from a coarse, rounded siphonal ridge on the mould, but where shell is preserved on USNM 441393 (Pl. 2, fig. 7), this corresponds to a high, hollow siphonal keel, while the external clavi also seem to have borne a septate spine. USNM 441394 (Pl. 3, figs 1–3) shows this massively tuberculate stage to a slightly larger diameter, with 16 umbilical spines per whorl; there are 17 in USNM 441395 (Pl. 4, figs 1, 12) at an estimated 85 mm diameter. From this diameter onwards the tubercles weaken relative to the ribs (on moulds), with up to 23 ribs per whorl at 140 mm diameter (Pl. 4, fig. 12), and the whorl section becomes less depressed, with costal wb:wh ratios down to 1·3. At a diameter of 70–110 mm the submarginal tubercle splits (Pl. 3, fig. 2; Pl. 4, fig. 12) into a clavate marginal and rounded-bullate submarginal, while a feeble bullate lateral tubercle appears at as little as 70 mm in some specimens (unfigured specimen USNM 441396), but later in others. Suture little incised, with broad, bifid E/L and L and smaller U_2.

Discussion. The diagnostic feature of *Menabites* (*Delawarella*) *danei* is the persistence of the coarsely ornamented trituberculate '*Australiella*' stage prior to acquisition of the pentatuberculate *Delawarella* condition. This, plus the coarseness of ornament, distinguish *M.* (*D.*) *danei* from all other North American species.

Occurrence. Lower Campanian, Roxton Limestone Member at top of Gober Chalk in Lamar County, Texas, and presumed equivalents in McCurtain County, Oklahoma (see under *Types*); middle Campanian Ozan Formation at USGS Mesozoic locality D10154 in Fannin County, Texas.

Menabites (*Delawarella*) *vanuxemi* (Morton, 1830)

Plate 2, figs 2–4

1830 *Ammonites vanuxemi* Morton, p. 244, pl. 3, figs 4–5.
1963 *Submortoniceras vanuxemi* (Morton); Young, p. 98, pl. 54, fig. 3; pl. 56, fig. 2; pl. 57, fig. 7; pl. 58, fig. 3; pl. 67, fig. 3; pl. 69, figs 1, 2, 6; text-figs 12*c*,*e*, 26*d*–*e*.
1980 *Submortoniceras vanuxemi* (Morton); Klinger and Kennedy, p. 232.

Types. Holotype by monotypy is No. 19492 in the collections of the Academy of Natural Sciences,

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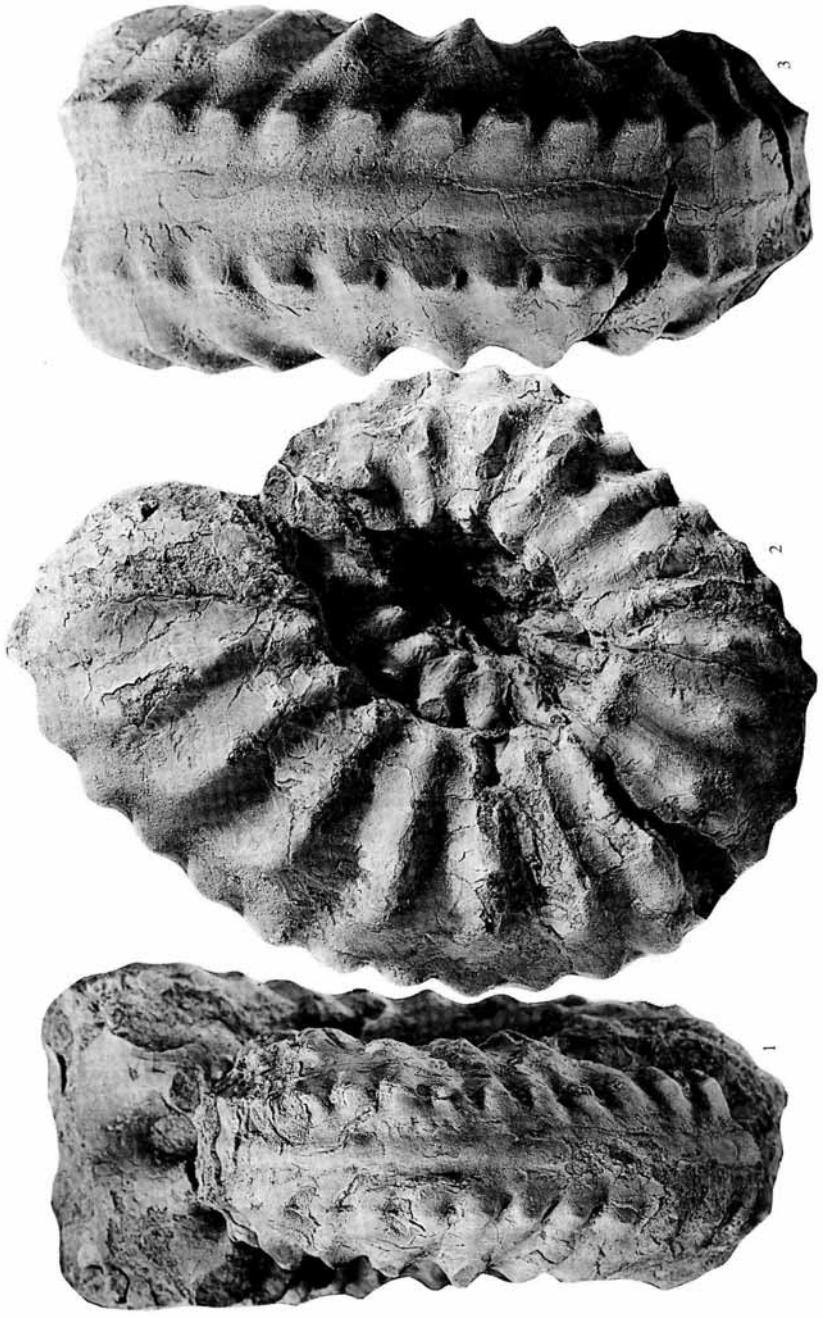
EXPLANATION OF PLATE 3

Figs 1–3. *Menabites* (*Delawarella*) *danei* (Young, 1963). USNM 441394; Ozan Formation 46 m above the base at USGS Mesozoic locality D10154; Fannin County, Texas, × 1.



COBBAN and KENNEDY, *Menabites*

Philadelphia, from the Chesapeake and Delaware Canal, Delaware; refigured by Reeside, 1962, pl. 72, figs 4–5. Hypotypes are USNM 441397 and 441398, from the Ozan Formation of Fannin County, Texas.

Description. USNM 441397 (Pl. 2, figs 2–3) is a poorly preserved juvenile 62·5 mm in diameter, with an umbilicus of 23%, of moderate depth, and with a flattened subvertical umbilical wall and narrowly rounded shoulder. The whorl section is compressed; whorl breadth to height ratio is 0·78, and the greatest breadth is low on the flanks. The inner flanks are broadly rounded, the outer flanks flattened and convergent, the ventrolateral shoulders narrowly rounded. Small umbilical bullae give rise to straight prorsiradiate flank ribs both singly and in pairs, while there are long intercalated ribs. Weak lateral submarginal and marginal tubercles are present on all ribs, as well as small external clavi. A smooth zone separates these from a blunt siphonal ridge. USNM 441398 is a crushed phragmocone 145 mm in diameter, with U = 30% approximately. Only the older one-half is shown here (Pl. 1, fig. 4). There are an estimated twenty-two small umbilical bullae per whorl that project into the umbilicus. These bullae give rise to narrow, straight, prorsiradiate ribs either singly or in pairs. These are initially very narrow, but strengthen and broaden across the flanks, developing weak lateral bullae, stronger bullate submarginal tubercles, and slightly clavate marginal tubercles. External clavi are strong and approximately twice as numerous as the marginal row, to which they are usually linked by a low, weak rib. The venter is too poorly preserved for adequate description, but seems to have borne a siphonal ridge or keel. Suture poorly exposed; moderately incised, with broad bifid E/L and L; U_2 smaller.

Discussion. Collignon (1948, pp. 30, 43) referred *vanuxemi* to *Submortoniceras*, but it is no more than a homoemorphous compressed *Menabites* (*Delawarella*) with weak ornament, as shown by the pattern of ribbing and tuberculation. Compressed whorls, dense crowded ribs and weak tubercles render this species distinct from all other North American *Delawarella*.

Occurrence. Merchantville Formation in New Jersey and Merchantville Formation and Woodbury Clay in the Chesapeake and Delaware Canal according to Reeside (1962), where it is regarded as early Campanian in age. Young (1963, text-fig. 3) shows it occurring in his lower Campanian *Delawarella delawarensis* zone in Texas, but detailed records (p. 100) are less precisely dated although the species is noted from Brewster County and from sandstone beds in the San Carlos area of Trans-Pecos, Texas, and from Uvalde County. References to lower Campanian specimens from the brown bed at the top of the Gober Chalk are from the Roxton Limestone Member and are of late early Campanian age. Young also noted a specimen from the Tombigbee Sand Member of the Eutaw Formation at Plymouth Bluff, Mississippi, but we have not seen this specimen. Ozan Formation at USGS Mesozoic locality D10154 in Fannin County, Texas.

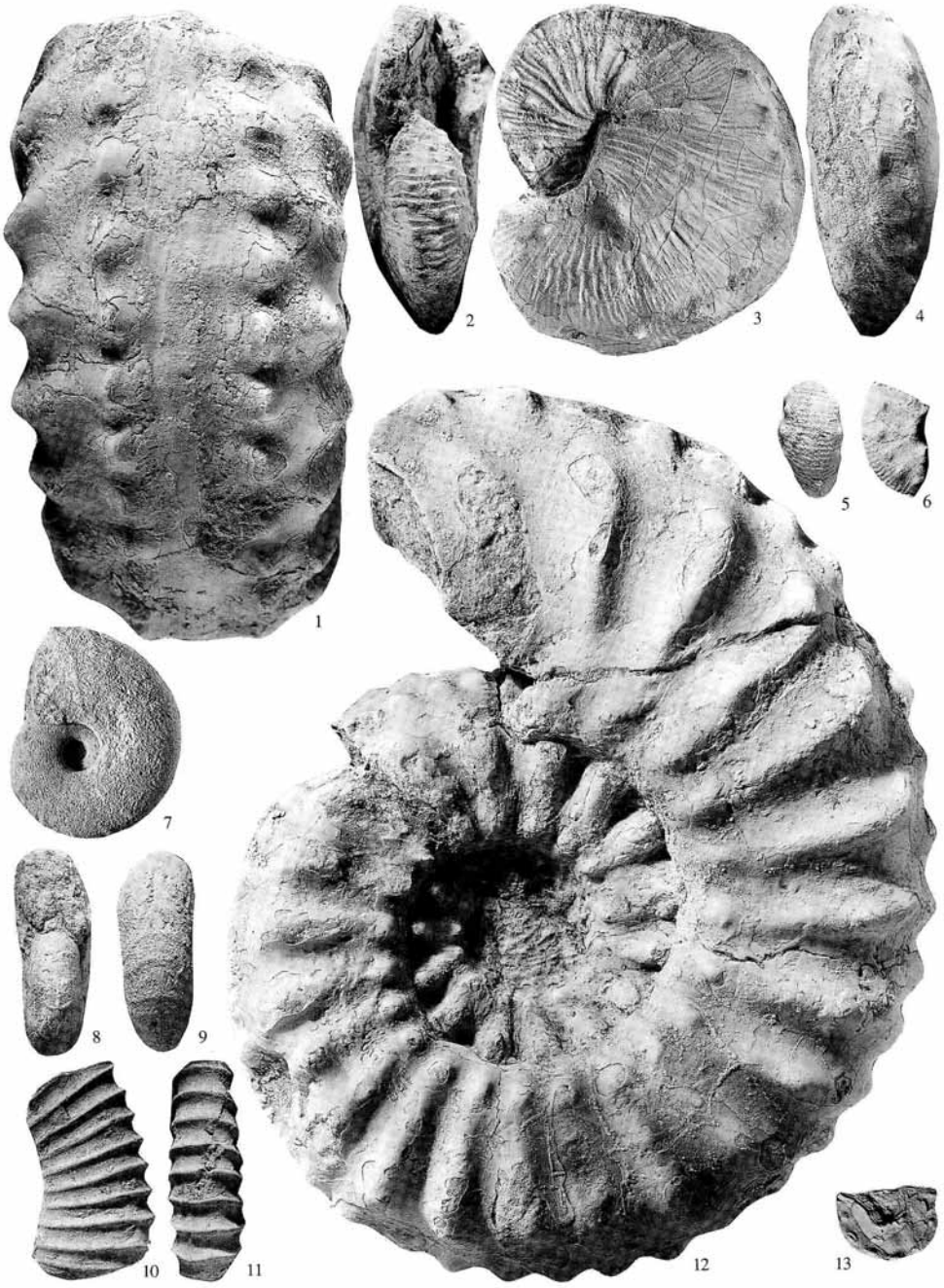
Menabites (*Delawarella*) sp.

Plate 6, figs 1–2

Description. USNM 441399 is a distorted juvenile 43 mm in diameter, with U = 33% approximately of diameter. There are an estimated thirty-six ribs per whorl that arise singly or in pairs from weak umbilical bullae or intercalate low on the flank. The ribs are straight and prorsiradiate, each bears a weak lateral bulla, a clavate tubercle (either submarginal or marginal) at the inner ventrolateral position and an equal number of external clavi. A smooth ventral zone separates the clavi from a sharp, undulose siphonal keel. Sutures not seen.

EXPLANATION OF PLATE 4

Figs 1–2. *Menabites* (*Delawarella*) *danei* (Young, 1963). USNM 441395.
Figs 2–4. *Trachyscaphites densicostatus* sp. nov. USNM 441426; holotype; macroconch.
Figs 5–6, 13. *Scaphites* (*Scaphites*) group of *hippocrepis* DeKay, 1828, form III of Cobban, 1969. 5–6, USNM 441413. 13, USNM 441414.
Figs 7–9. *Pachydiscus* (*Pachydiscus*) *paulsoni* (Young, 1963). USNM 441385.
Figs 10–11. *Glyptoxoceras* sp. USNM 441400.
All specimens from the Ozan Formation 46 m above the base at USGS Mesozoic locality D10154; Fannin County, Texas. All ×1.



COBBAN and KENNEDY, Campanian ammonites

Discussion. This juvenile, quadrituberculate texanitid corresponds in its ribbing to certain juveniles from the Merchantville Formation of New Jersey, but the latter generally have five rows of node at the diameter of our specimen, and seem to be juvenile *M.* (*D.*) *vanuxemi.*

Occurrence. Middle Campanian Ozan Formation at USGS Mesozoic locality D10154 in Fannin County, Texas.

Suborder ANCYLOCERATINA Wiedmann, 1966
Superfamily TURRILITACEAE Gill, 1871
Family DIPLOMOCERATIDAE Spath, 1926
[= Neocrioceratinae Spath, 1953, p. 17]
Subfamily DIPLOMOCERATINAE Spath, 1926
[= Scalaritinae Ward, 1976, p. 455]
Genus GLYPTOXOCERAS Spath, 1925
[= Neohamites Brunnschweiler, 1966, p. 48]

Type species. Hamites rugatus Forbes, 1846, p. 117, by original designation by Spath, 1925, p. 31.

Glyptoxoceras sp.

Plate 4, figs 10–11; Plate 6, figs 5–6; Plate 7, figs 7–8.

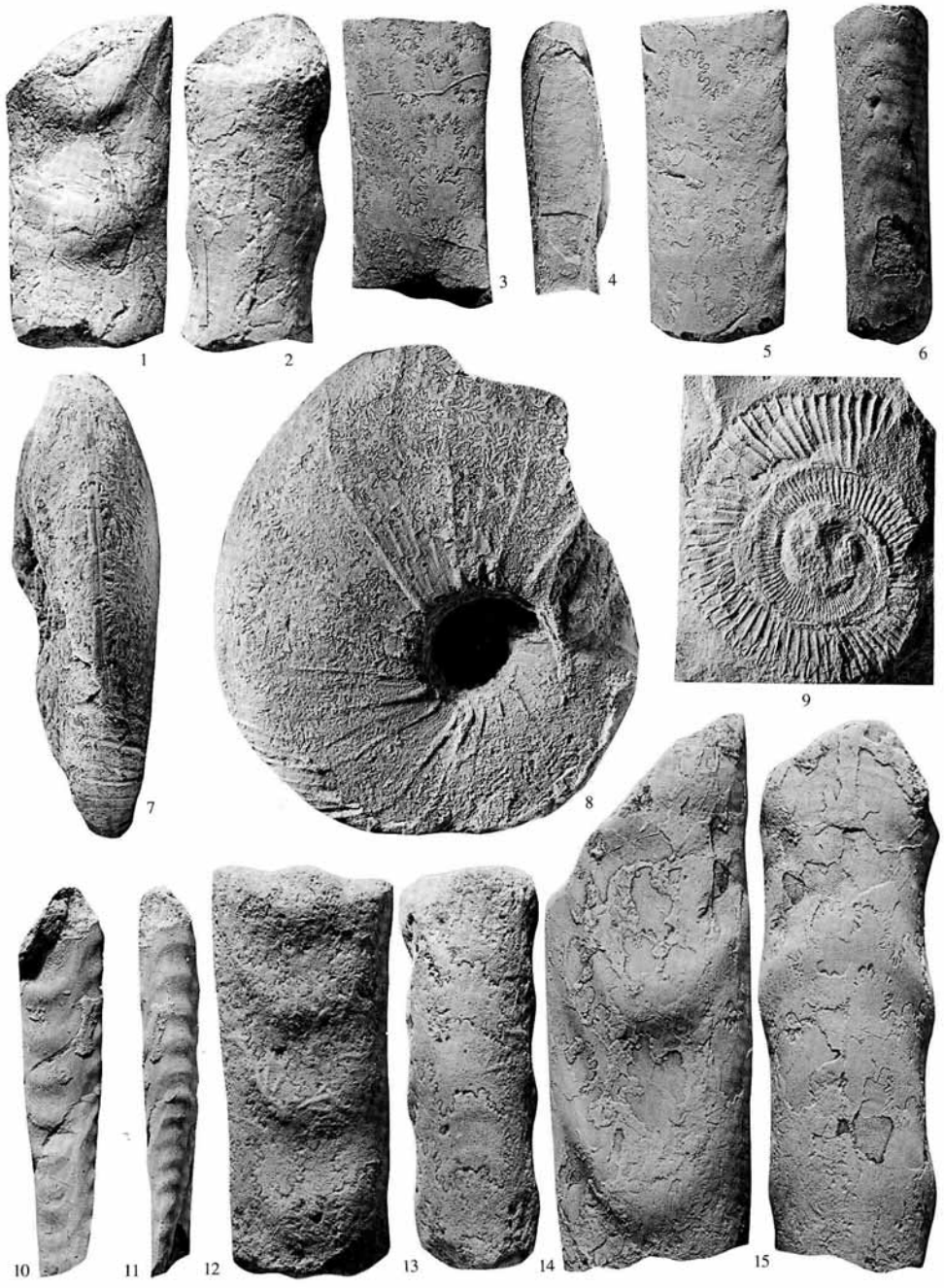
Description. The most complete specimen is USNM 441401 (Pl. 5, fig. 9), a crushed composite mould from the marls above the main fauna described here. The specimen consists of just under two whorls of an open planispiral criocone with the whorls barely separated. It and a second specimen show the earliest preserved section to a whorl height of 7 mm to have been finer ribbed than later sections. The latter are represented by 28 fragments with whorl heights of as much as 17 mm. Most are body chambers, which suggests this to be the adult size of the species. The whorl section is compressed oval with a whorl breadth to height ratio of 0·79; the dorsum and venter are broadly rounded, and the flanks somewhat flattened. The rib index is six. The ribs are weak on the dorsum, but strengthen and sweep back over the dorsolateral area. They are sharp, rursiradiate on the flank, and narrower than the interspaces; they strengthen as they cross the venter transversely. None of the specimens shows the suture.

Discussion. Coiling alone distinguishes the present material from other North American species such as *G. ellisoni* Young, 1963 (p. 46, pl. 1, figs 10–14; pl. 73, fig. 9; pl. 78, fig. 6) of the upper Santonian and lower Campanian in Texas, which has straight or only slightly curved shafts and is much larger. *Glyptoxoceras* [*Helicoceras*] *rubeyi* (Reeside, 1927, p. 14, pl. 3, figs 8–10; pl. 5, figs 3–11) has a nearly circular whorl section and prorsiradiate ribs. Closer is '*Hamites*' *novimexicanus* Reeside, 1927 (p. 8, pl. 4, figs 1–6), but this is much larger and has an elliptical coil.

Occurrence. Middle Campanian, Ozan Formation at USGS Mesozoic locality D10154 in Fannin County, Texas.

EXPLANATION OF PLATE 5

Figs 1–6, 10–15. *Baculites* sp. group of *aquilaensis* Reeside, 1927. 1–2, USNM 441404. 3–4, USNM 441405. 5–6, USNM 441406. 10–11, USNM 441407. 12–13, USNM 441408. 14–15, USNM 441409.
Figs 7–8. *Pachydiscus* (*Pachydiscus*) *paulsoni* (Young, 1963). USNM 441386.
Fig. 9. *Glyptoxoceras* sp. USNM 441401.
All specimens from the Ozan Formation 46 m above the base at USGS Mesozoic locality D10154; Fannin County, Texas. The original of Figure 9 is from chalky beds a little higher in the section than the other specimens. All × 1.



COBBAN and KENNEDY, Campanian ammonites

Family BACULITIDAE Gill, 1871
[Eubaculitinae Brunnschweiler, 1966, p. 24]
Genus BACULITES Lamarck, 1799
[= *Homaloceratites* Hupsch, 1768, p. 110 (*non binomen*); *Euhomaloceras* Spath, 1926, p. 80]

Type species. *Baculites vertebralis* Lamarck, 1801, p. 103, by subsequent designation by Meek 1876, p. 391.

Baculites sp. group of *aquilaensis* Reeside, 1927

Plate 5, figs 1–6, 10–15; Plate 6, figs 3–4; Plate 7, figs 3–4; Text fig. 4D

1927 *Baculites aquilaensis* Reeside, p. 12, pl. 6, figs 11–13; pl. 8, figs 1–14.
1927 *Baculites aquilaensis* var. *separatus* Reeside, p. 12, pl. 8, figs 15–21; pl. 9, figs 6–15; pl. 45, figs 5–6.
1927 *Baculites aquilaensis* var. *obesus* Reeside, p. 12, pl. 10, figs 1–8.

Types. Figured specimens USNM 441404–441412, from the Ozan Formation of Fannin County, Texas.

Description. We have more than 100 fragments, ranging from 10 to 40 mm in whorl height. The collection is highly variable. At one extreme are very weakly ornamented individuals (Pl. 5, figs 3–6) with a compressed, ovoid whorl section (whorl breath to height ratio as little as 0·6), and venter only slightly narrower than the dorsum. Ornament is nearly absent on the flanks, and consists of asymmetrically concave growth lines and lirae that cross the dorsum in a broad convexity. They sweep strongly forward on the ventral part of the flanks and intersect the line of the venter at an acute angle, where they strengthen over the ventrolateral region into regular riblets that cross the venter in a broad convexity (Pl. 5, fig. 6). Stronger ornamented individuals (Pl. 6, figs 3–4) have low, broad, shallow, concave ribs that extend across the dorsal two-thirds of the flank, with a rib index of 4. The ribs project strongly forward on the ventral third of the flanks, where they are accompanied by numerous striae and growth lines, all of which intersect the line of the venter at an acute angle. The ribs strengthen again across the venter (Pl. 6, fig. 4), which is crossed by low, broad, convex ribs, that may be accompanied by intercalated ribs so that there are more ventral than flank ribs (Pl. 5, figs 10–11). Other specimens have less compressed ovoid whorl sections (Wb:Wh ratio up to 0·85). Ornament is much coarser, with rib indices of 1·5–2, the flank ribs extending across the dorsum in a broad convexity (Pl. 5, fig. 15), while intercalated ribs are present on the ventral third of the flanks and venter (Pl. 5, fig. 14) or not (Pl. 6, figs 7–8; Pl. 7, figs 3–4). The suture (Text-fig. 3D) is moderately incised, with rectangular bifid lobes and saddles.

Discussion. This large collection of what is a very generalized *Baculites* shows a wide range of intraspecific variation, as is normal in the genus. The ovoid rather than oval whorl section plus style and variation range of ribbing strongly recall the variable *Baculites aquilaensis* Reeside, 1927, and its varieties *separatus*, with distant ribs, and *obesus*, with coarse ribs and stout whorl section. The present material differs from this lower Campanian species in the relatively uncommon incidence of compressed and closely ribbed specimens like the holotype (Reeside 1927, p. 12, pl. 10, figs 1–3), a fact that presumably reflects the markedly younger age of the present material. Our material is best compared to the baculites in the Western Interior lower Campanian zone of *Baculites* sp. (weak flank ribs) (Gill and Cobban 1966, table 2).

When compared with other Campanian species known from the Gulf Coast, the Ozan Formation specimens can be separated from *Baculites taylorensis* Adkins, 1929 (p. 204, pl. 5, figs 9–11) by the

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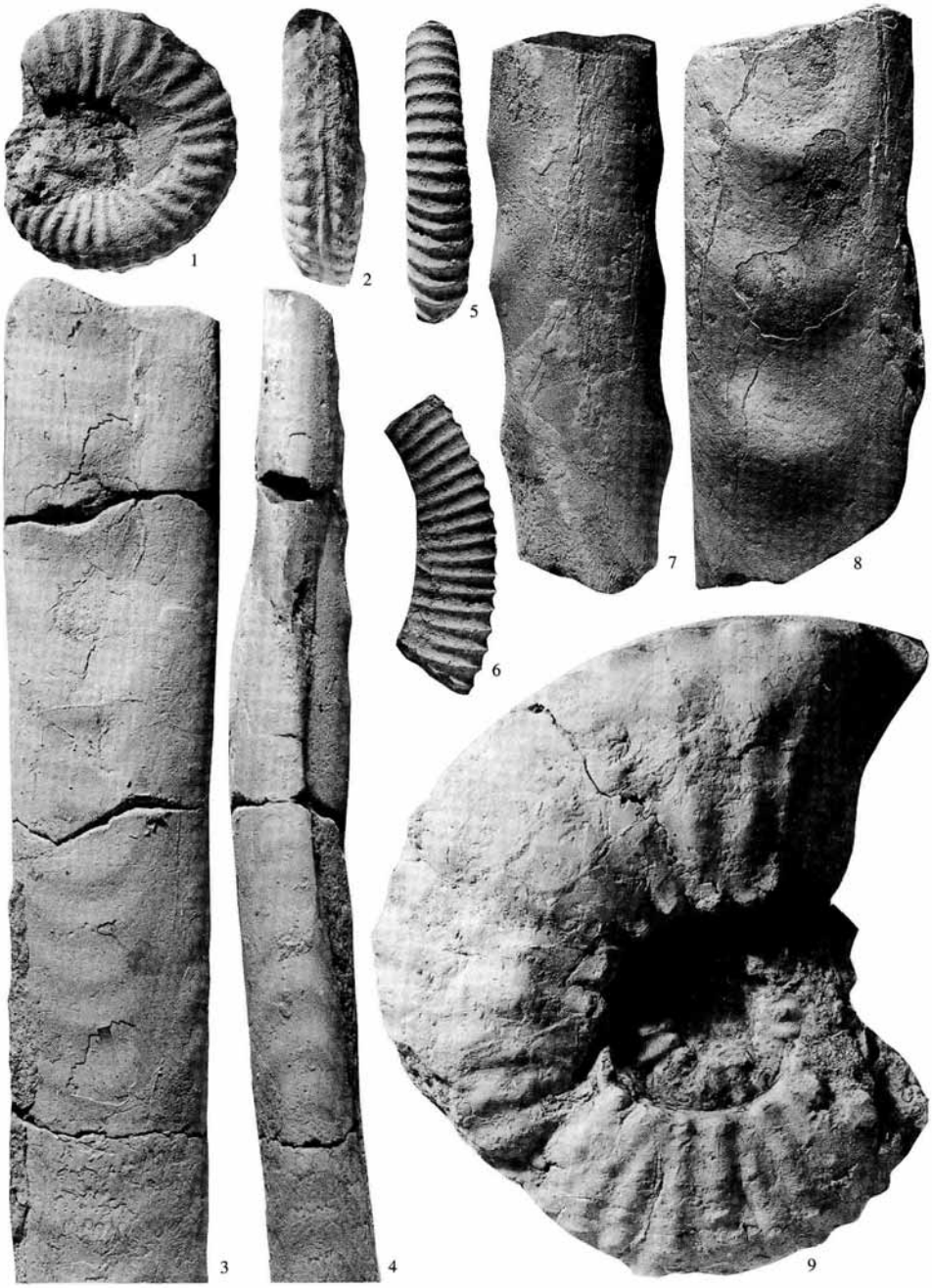
EXPLANATION OF PLATE 6

Figs 1–2. *Menabites* (*Delawarella*) sp. USNM 441399.
Figs 3–4, 7–8. *Baculites* sp. group of *aquilaensis* Reeside, 1927. 3–4, USNM 441411. 7–8, USNM 441410.
Figs 5–6. *Glyptoxoceras* sp. USNM 441402.
Fig. 9. *Menabites* (*Delawarella*) *delawarensis* (Morton, 1830). USNM 441391.
All specimens from the Ozan Formation 46 m above the base at USGS Mesozoic locality D10154; Fannin County, Texas. All ×1.



COBBAN and KENNEDY, Campanian ammonites

strong node-like bullae of that species, lying close to the dorsum, and quite unlike the ribs of our material. *Baculites taylorensis* also has numerous narrow prorsiradiate ribs on the ventral half of the flanks that cross the venter in a broad convexity. *Baculites reduncus* (Cobban 1977, p. 459, figs 2–6), which occurs in the Annona Chalk in Arkansas (unpublished observations by the authors), has a high expansion rate, stoutly ovate whorl section, crescentic ribs on the dorsal half of the flanks but no or very weak ornament on the venter. *Baculites haresi* Reeside, 1927 (= *B. ovatus* var. *haresi* Reeside, 1927, p. 10, pl. 6, figs 5–10; pl. 7, figs 9–10), which occurs at the top of Gober Chalk in north-east Texas, generally has coarse ventral and ventrolateral ribbing only, although a few variants have low, broad, concave crescentic flank ribs with an index of 2 or 3. *Baculites ovatus* Say, 1820 (see revision in Cobban 1974, p. 3, pl. 1, figs 1–32; pl. 2, figs 1–14; pl. 3, figs 1–6, 9–11; text-fig. 4) has an oval whorl section rather than the ovoid one of the present material. Dorsolateral ribs are sparse and distant, whereas ventrolateral and ventral ribs are much more numerous.

Occurrence. Middle Campanian Ozan Formation of USGS Mesozoic locality D10154 in Fannin County, Texas.

Superfamily SCAPHITACEAE Gill, 1871

[*nom. transl.* Wright and Wright 1951, p. 13 *ex* Scaphitidae Gill, 1871, p. 3]

Family SCAPHITIDAE Gill, 1871

Subfamily SCAPHITINAE Gill, 1871

[*nom. transl.* Wright 1953, p. 73, *ex* Scaphitidae Gill, 1871, p. 3]

Genus and subgenus SCAPHITES Parkinson, 1811

[= *Anascaphites* Hyatt, 1900, p. 572; *Jahnites* Hyatt, 1900, p. 572; *Holcoscaphites* Nowak, 1911, p. 564]

Type species. Scaphites equalis J. Sowerby, 1813, p. 53, pl. 18, figs 1–3, by subsequent designation by Meek 1876, p. 413.

Scaphites (*Scaphites*) sp. group of *hippocrepis* (DeKay, 1828)

Plate 4, figs 5–6, 13

Types. Figured specimens USNM 441413 and 441414, from the Ozan Formation of Fannin County, Texas.

Description. Two small fragments are part of the final hook of what were probably adult microconchs. They have clavate umbilical tubercles with effaced flank ornament, conical ventrolateral nodes in one (Pl. 4, figs 5–6) and clavate ones in the other (Pl. 4, fig. 13). The venter is ornamented by fine ribs which loop between the tubercles and intercalate. This type of ornament shows these specimens to belong to the same group as the slightly older Campanian species *S.* (*S.*) *hippocrepis*, relating to some forms of *S. hippocrepis* III of Cobban (1969, pl. 3, figs 1–6, 12–14). The material is inadequate to determine whether these are very late survivors of *S.* (*S.*) *hippocrepis*, or some undescribed form that provides a link between it and the much younger *S.* (*S.*) *pumilis* Stephenson, 1941 (p. 426, pl. 90, figs 10–12).

Occurrence. Middle Campanian, Ozan Formation at USGS Mesozoic locality D10154 in Fannin County, Texas.

EXPLANATION OF PLATE 7

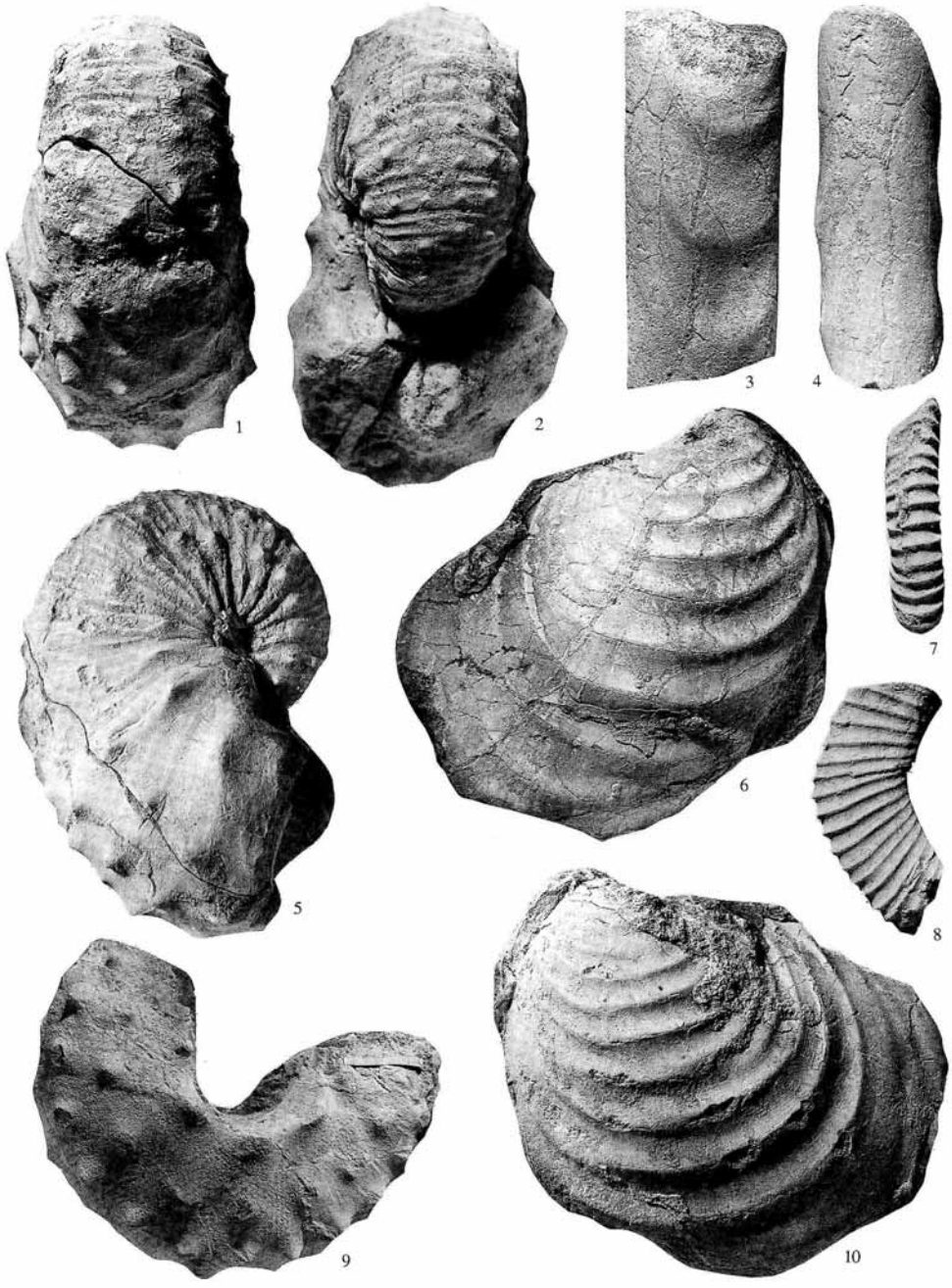
Figs 1–2, 5, 9. *Trachyscaphites spiniger spiniger* (Schlüter, 1872). 1–2, 5, macroconch, USNM 441417. 9, microconch, USNM 441418.

Figs 3–4. *Baculites* sp. group of aquilaensis Reeside, 1927. USNM 441412.

Figs 6, 10. *Inoceramus* (*Endocostea*) *balticus* Boehm, 1909. USNM 441429.

Figs 7–8. *Glyptoxoceras* sp. USNM 441403.

All species from the Ozan Formation 46 m above the base at USGS Mesozoic locality D10154; Fannin County, Texas. All ×1.



COBBAN and KENNEDY, Campanian ammonites

Genus TRACHYSCAPHITES Cobban and Scott, 1964

Type species. Trachyscaphites redbirdensis Cobban and Scott, 1964, p. E7, pl. 1, figs 1–7; text-fig. 3, by original designation.

Trachyscaphites spiniger spiniger (Schlüter, 1872)

Plate 1, figs 2–3; Plate 7, figs 1–2, 5, 9; Plate 8, figs 1–9; Text-fig. 4A

1872 *Scaphites spiniger* Schlüter, p. 82, pl. 25, figs 1–7.
1980 *Trachyscaphites spiniger spiniger* (Schlüter); Błaszkiewicz, p. 30, pl. 13, figs 1–3, 5, 7 (with synonymy).
1986 *Trachyscaphites spiniger* (Schlüter, 1872*a*); Kennedy, p. 130, pl. 22, fig. 4; text-fig. 42A–F (with additional synonymy).

Types. Lectotype, designated by Błazkiewicz 1980, p. 31, is the original of Schlüter 1872, pl. 25, figs 1–3, GPIB unregistered, from the upper Campanian of Darup, Westphalia. Paralectotype GPIB 61*a* is the original of Schlüter 1872, pl. 25, fig. 4; paralectotype GPIB 61*b* is the original of Schlüter 1872, pl. 25, fig. 6, both from the upper Campanian Hügelgruppe of Haldem, Westphalia. Hypotypes USNM 441416–441425, from the Ozan Formation of Fannin County, Texas.

Description. Forty specimens are referred to the nominate subspecies, which is strongly dimorphic; twelve specimens are microconchs, ten are macroconchs, and eighteen are unassigned fragments. Microconchs (Pl. 1, figs 2–3; Pl. 7, fig. 9; Pl. 8, figs 1, 3–4, 8) vary from 57 to 87 mm in length. The phragmocone is very involute with a tiny umbilicus comprising less than 10% of the diameter. The intercostal whorl section is compressed to depressed with broadly rounded flanks and venter, and whorl breadth to height ratios of up to 1·1 in undeformed specimens. Delicate, straight, prorsiradiate ribs arise singly or in pairs at the umbilical shoulder without developing a bulla and number about 15 per half whorl. They strengthen across the flank and link to a small conical outer lateral tubercle either singly or in pairs; there are 10–12 such tubercles per half whorl; they give rise to one to three finer ribs, while some non-tuberculate ribs branch at the same level on the flank. These ribs loop to small conical inner ventrolateral tubercles or intercalate between them, and then loop to small conical outer ventrolaterals. The latter generally alternate on either side of the mid-ventral line such that the fine ribs loop or zig-zag across the venter between the tubercles or intercalate between them. There are generally slightly more ventrolateral than lateral tubercles. The body chamber is slender with a concave profile to the line of the umbilical shoulder in lateral view so that the umbilicus of the phragmocone is visible. The umbilical wall is smooth and concave. There are up to seven strong umbilical bullae; nine subspinose, weakly clavate outer lateral tubercles; thirteen subspinose, clavate inner ventrolateral tubercles and a similar number of subspinose, outer ventrolateral tubercles. The tubercles are offset on the flanks, and alternate on either side of the mid-ventral line (Pl. 1, fig. 2; Pl. 8, fig. 7). Numerous delicate prorsiradiate ribs loop between the rows of tubercles or intercalate between them. The number of ribs increases across the flank so that the whole shell surface has a dense covering of ribs. On the venter the ribs loop, zig-zag and intercalate between the ventral clavi. Tuberculation declines markedly before the adult aperture which is well preserved in USNM 441415; there is a marked constriction with a short dorsal rostrum. Macroconchs (Pl. 7, figs 1–2, 5; Pl. 8, fig. 9) vary from 66 to 100 mm long. They differ from microconchs in the form of the body chamber, which has a weak umbilical bulge at the adapical end. The umbilical shoulder follows a straight course in lateral view (Pl. 8, fig. 9) so that much of the umbilicus of the phragmocone is concealed. The umbilical wall is convex, and the umbilical tubercles, rather than being clavate and perched on a sharp umbilical shoulder, are displaced out to an inner lateral position and are bullate. Outer lateral tubercles and inner and outer ventrolateral tubercles are

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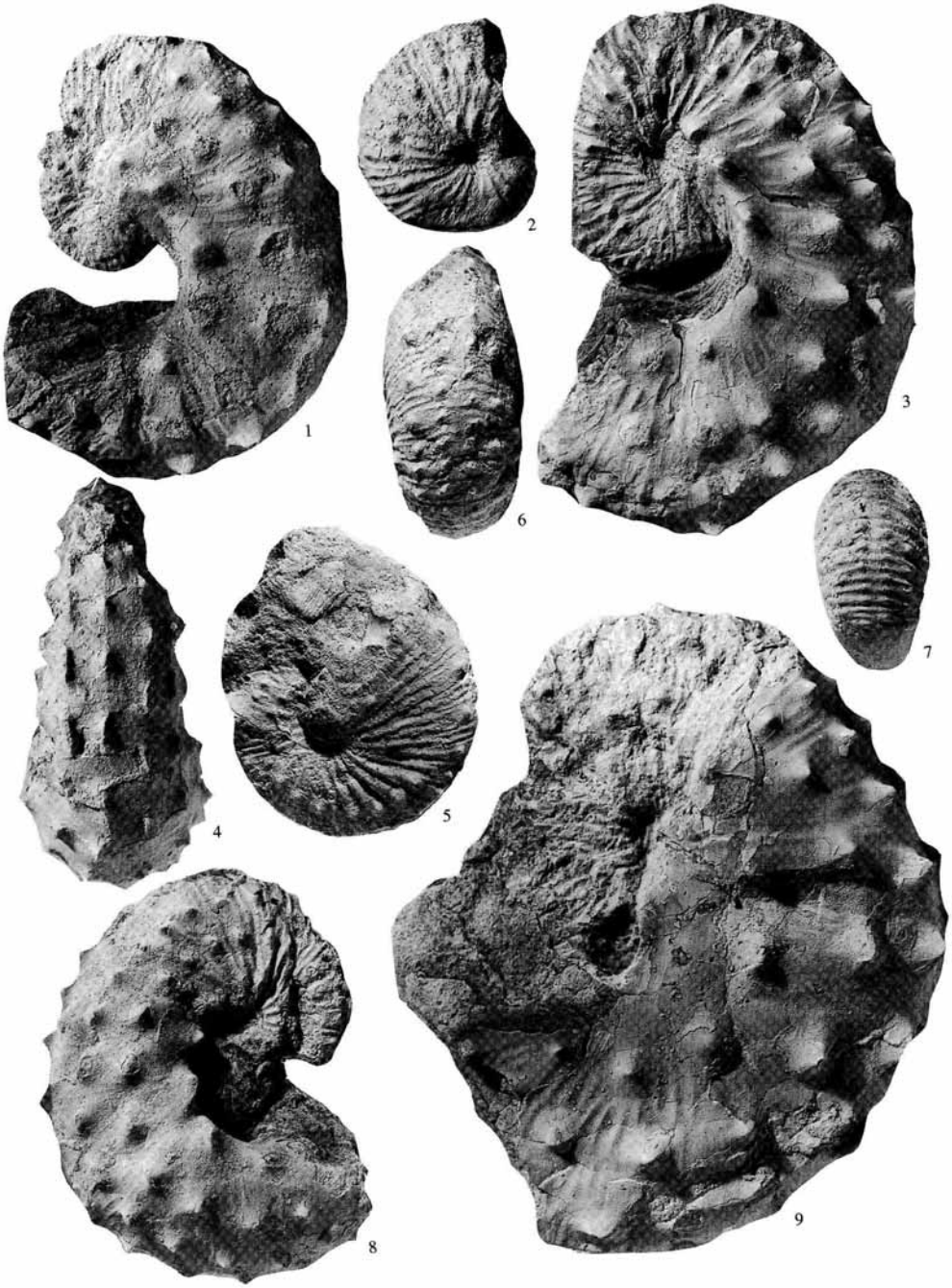
EXPLANATION OF PLATE 8

Figs 1–9. *Trachyscaphites spiniger spiniger* (Schlüter, 1872). 1, microconch, USNM 441419. 2, 7, juvenile, USNM 441420. 3, microconch, USNM 441421. 4, 8, microconch, USNM 441422. 5, 6, juvenile macroconch, USNM 441423. 9, macroconch, USNM 441424.

All specimens from the Ozan Formation 46 m above the base at USGS Mesozoic locality D10154; Fannin County, Texas. All ×1.



COBBAN and KENNEDY, *Trachyscaphites*

only weakly clavate when compared with those of most microconchs. Suture with deeply incised E/L (Text-fig. 4A).

Discussion. This large assemblage differs in no respects other than preservation from the generally crushed types and other specimens from Germany. *Trachyscaphites spiniger porchi* (Adkins, 1929) p. 205, pl. 5, figs 1–3), of which *Scaphites aricki* (Adkins, 1929) (p. 206, pl. 5, figs 7–8) is a synonym (see Cobban and Scott 1964, p. E10, pl. 2, figs 1–23; pl. 3, figs 1–11; text-fig. 4), differs from the nominate subspecies in having fewer tubercles in all rows on the body chamber and generally lacking the dense ribbing so well-displayed by the present specimens. *Trachyscaphites spiniger levantinensis* Lewy, 1969 (p. 132, pl. 4, fig. 1), from the upper Campanian of Israel, is based on a microconch and is probably a synonym of *porchi*. *Trachyscaphites spiniger posterior* Błaszkiewicz, 1980 (p. 31, pl. 13, fig. 4; pl. 14, figs 1–7; pl. 15, figs 2–3; pl. 30, fig. 2), from the upper Campanian of the Vistula Valley, Poland, was differentiated from the nominate subspecies because of the 'smaller number of ribs running between the tubercles of the same row on the exposed part of normal spiral and the presence of lateroumbilical tuberculation on earlier sectors of the exposed, normal spiral. It also differs on the whole in a smaller degree of freeing the shaft from phragmocone and is a frequent lack of ribs between the tubercles of the same row on the shaft.'

Trachyscaphites pulcherrimus (Roemer, 1841) (see revision in Kennedy and Summesberger 1984, p. 171, pl. 11, figs 1–2, 10–22, pl. 13, figs 2–6) is easily distinguished by the presence of five rows of flank tubercles as well as a siphonal row. *Trachyscaphites densicostatus* sp. nov., described below, has only three rows of tubercles on the phragmocone and sparse, distant umbilicolateral tubercles and more numerous inner and outer ventrolateral rows of tubercles on the body chamber.

Occurrence. Upper Campanian of Germany, The Netherlands, Sweden, Poland, the USSR (European Russia, Soviet Armenia and Kopet Dag); the species is restricted to the lower upper Campanian where precisely dated. In the United States it is best known from the middle Campanian Ozan Formation at USGS Mesozoic locality D10154 in Fannin County, Texas. There is a flattened specimen in the USGS Mesozoic collections at Denver from the Annona Chalk at USGS Mesozoic locality 12889 about 6·4 km east of Clarksville, Red River County, Texas.

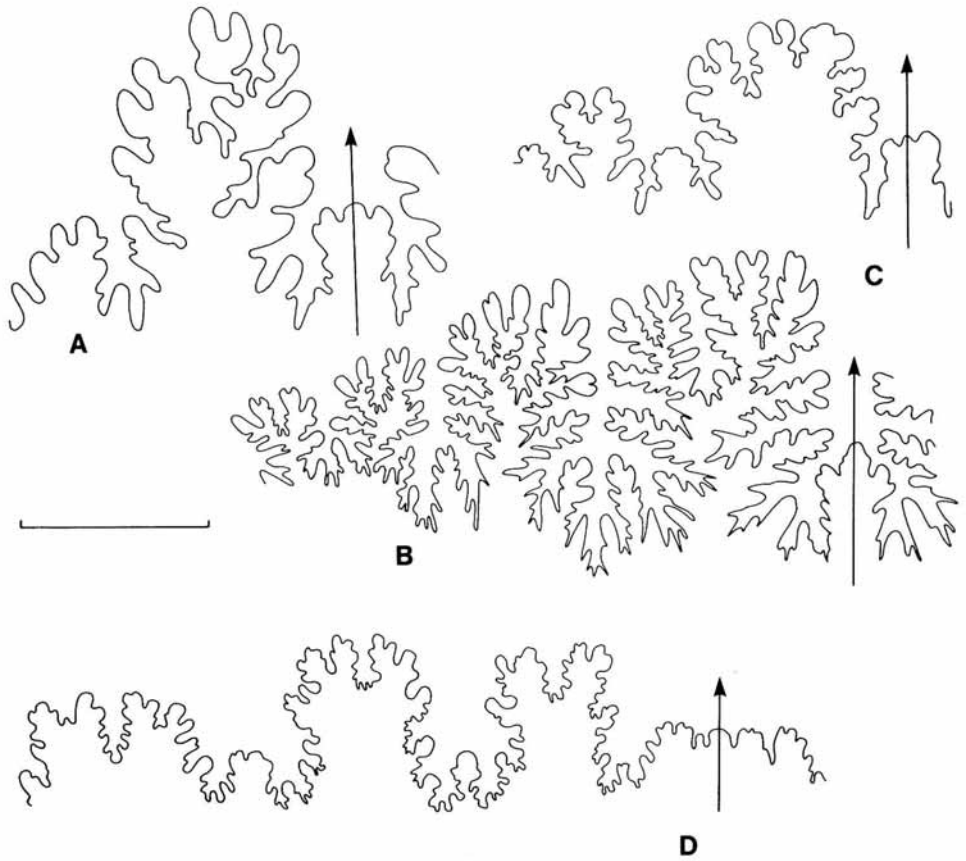
Trachyscaphites densicostatus sp. nov.

Plate 1, fig. 1; Plate 4, figs 2–4; Text-fig. 4C

Types. Holotype USNM 441426, paratypes USNM 441427–441428, from the middle Campanian Ozan Formation at USGS Mesozoic locality D10154 in Fannin County, Texas.

Diagnosis. Trachyscaphites with densely ribbed phragmocone that has small conical outer lateral tubercles and inner and outer ventrolateral tubercles; densely ribbed body chamber that has sparse umbilical/umbilicolateral tubercles and more numerous inner and outer ventrolateral clavi.

Description. The species is strongly dimorphic. Paratype USNM 441427 is a complete microconch 50 mm long. The phragmocone is poorly preserved, but shows fine, dense, prorsiradiate ribs arising either singly or in pairs at the umbilical shoulder, and small outer lateral tubercles and inner and outer ventrolateral tubercles linked by one or more ribs with nontuberculate ribs intercalated. The body chamber is slender with a concave line to the umbilical shoulder when viewed in profile, such that the umbilicus of the phragmocone is visible; the umbilical wall is concave, and the shoulder sharply defined. Five coarse umbilical clavi perch on the umbilical shoulder and give rise to groups of narrow prorsiradiate ribs; some nontuberculate ribs intercalate low on the flank. Ventrolateral and ventral ornament is not preserved, but paratype USNM 441428 has from the beginning of the final hook, small conical inner and outer ventrolateral tubercles linked by delicate ribs with others intercalated between; the outer ventrolateral clavi alternate across the venter and are linked by zig-zagging ribs. The holotype, USNM 441426, is an adult macroconch 57 mm long. The phragmocone is very involute, the body chamber short, with a straight umbilical shoulder in side view such that the umbilicus of the spire is occluded. Ornament on the spire consists of dense rounded prorsiradiate ribs that arise at the umbilical shoulder and are feebly flexuous on the flanks, where they increase by bifurcation and intercalation.



TEXT-FIG. 4. External sutures. A, *Trachyscaphites spiniger spiniger* (Schlüter, 1872). USNM 441425. B, *Pachydiscus* (*Pachydiscus*) *paulsoni* (Young, 1963). USNM 441384. C, *Trachyscaphites densicostatus* sp. nov. USNM 441426. D, *Baculites* sp. group of *B. aquilaensis* Reeside, 1927. USNM 441406. Bar scale is 10 mm.

Some ribs link to tiny outer lateral tubercles, while others intercalate between. Ribs arise in groups of two or three from these tubercles, and link to small conical outer ventrolateral tubercles or intercalate between them; the outer ventrolaterals are also small and conical and similarly linked to the inner ventrolaterals. Tubercles alternate on either side of the venter, across which they are connected by zig-zagging ribs. The body chamber is ornamented by dense, crowded, prorsiradiate, weakly flexuous ribs that arise at the umbilical seam and increase by branching and intercalation across the flanks. Four distant umbilicolateral bullae are present, as are 12 inner ventrolateral clavi which connect groups of ribs with several intercalated between. They alternate in position with an outer ventrolateral row where groups of ribs are again linked, with others intercalated. Delicate ribs connect the alternate outer ventrolateral clavi across the venter. Suture moderately incised with broad, asymmetrically bifid E/L and narrower bifid L and L/U (Text-fig. 4C).

Discussion. The combination of delicate ribbing and multituberculation show this species to be a *Trachyscaphites*. The presence of only three rows of tubercles on the phragmocone, disappearance of the outer lateral row and appearance of an umbilical/umbilicolateral row on the body chamber

with its numerous crowded flexuous branching and intercalating ribs distinguish it from all other species referred to the genus.

Occurrence. As for types.

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