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Kenneth K. Kietzke

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MICROFAUNA OF THE TUCUMCARI SHALE, LOWER CRETACEOUS OF EAST-CENTRAL NEW MEXICO

KENNETH K. KIETZKE
Department of Geology, University of New Mexico, Albuquerque, New Mexico 87131

INTRODUCTION

This paper summarizes our present knowledge of the Foraminifera and Ostracoda from the Tucumcari Shale, with special emphasis on the attached foraminiferans, and includes illustrations of a few common and characteristic species. Previous studies of the Tucumcari microfauna are limited to an unpublished thesis by Brooks (1959) and occasional references to large, agglutinated Foraminifera in studies of the macrofauna (Scott, 1974). Brooks reported 56 species of Foraminifera and 31 species of Ostracoda (see Appendix).

The present study focuses on an exceptionally diverse microfauna from the *Texigryphaea tucumcarii* horizon at Pyramid Mountain, SE¼ SW¼ sec. 19, T9N, R29E, Quay County, New Mexico (Fig. 1). This locality was originally examined by Marcou in 1853 (Marcou, 1858), and has a very interesting history (Kues, 1985). Pyramid Mountain has been referred to as "Crazy Woman Butte" and "Lovers Peak" on various U.S. Geological Survey topographic maps, but there is no doubt that this is the locality Marcou referred to as Pyramid Mountain (Kues and Kietzke, 1985). The *Texigryphaea* horizon at Pyramid Mountain is located within the basal 1 m of the Tucumcari Shale, and is characterized by abundant remains of *Texigryphaea*, and lesser numbers of *Lopha* and other invertebrates (Kues et al., 1985).

METHODS

The samples from this horizon were processed by soaking overnight in water, briefly tumbling the material in a rotary tumbler and sieving the residues. The microfauna was picked from the residues, sorted by morphotype, identified to species, counted, mounted on slides and cataloged into the University of New Mexico (UNM) Department of Geology paleontology collection. Selected specimens were mounted on SEM (scanning electron microscope) stubs and photographed using the Department of Geology Hitachi SEM. The specimens used for illustration were mounted separately and placed in the Geology Department type- and figured-specimen collection. Identification of the Foraminifera was accomplished using Tappan (1940, 1943), Vieaux (1941), Loeblich and Tappan (1946, 1950, 1982), Frizzell (1954), Brooks (1959), Truax (1980) and Jenkins and Murray (1981). The Ostracoda were identified using Alexander (1929, 1933), Sexton (1951) and Howe and Laurencich (1958). Classification was based on Loeblich and Tappan (1964) for the Foraminifera and both Benson et al. (1961) and Van Markhoven (1963) for the Ostracoda.

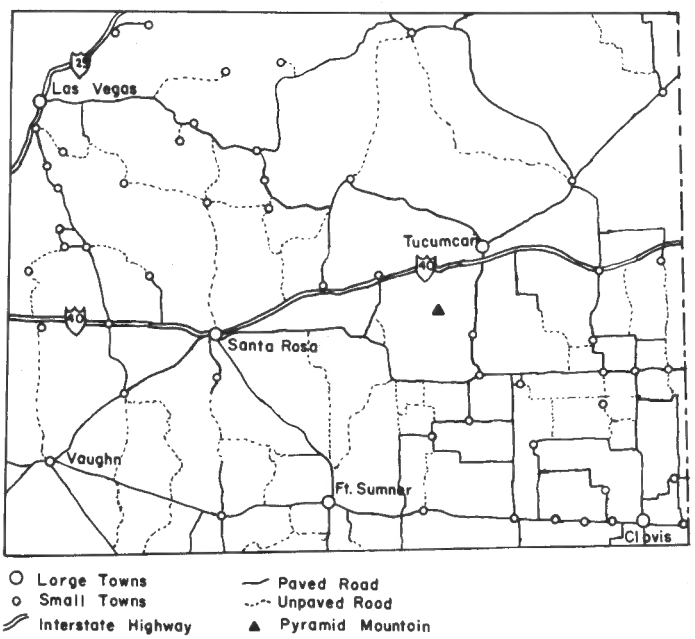


FIGURE 1. Locality map of Pyramid Mountain, SE¼ SW¼ sec. 19, T9N, R29E, Quay County, New Mexico.

MICROFAUNA

The following is a taxonomic listing of the 66 species of Foraminifera and 20 species of Ostracoda recovered from the Tucumcari Shale *Texigryphaea* horizon at Pyramid Mountain, Quay County, New Mexico. An asterisk indicates species found during examination of the megafauna, but not recovered in microfaunal samples. These species are not included in the calculations of relative abundance. Parentheses following the name give species abundance as a percentage of the total number of the respective group (e.g., Foraminifera or Ostracoda). R = rare, <1%; UC = uncommon, 1–5%; C = common, 5–10%; VC = very common, 10–30%; A = abundant, >30%.

Foraminifera
- Textulariina
  - Ammodiscacea
    - Ammodiscidae
      - Ammodiscinae
        - *Glomospira gaultina* (R) (Fig. 7F)
      - Tolypammininae
        - **Lituotuba* spp.
        - **?Ammodiscella* n.sp.
  - Lituolacea
    - Hormosinidae
      - Hormosininae
        - *Reophax ?cylindrica* (R)
        - *R. deckeri* (R)
        - *R.* sp. (R)
      - Cribratininae
        - *Cribratina texana* (R) (Fig. 8C)
    - Lituolidae
      - Haplophragmoidinae
        - *Haplophragmoides* n.sp. (R)
      - Lituolinae
        - *Ammobaculites subcretaceus* (UC)
        - *A. goodlandensis* (UC) (Fig. 8A)
        - *A. variablis* (UC) (Fig. 9D)
        - *Flabellammina* cf. *F. alexandensis* (UC)
        - *Triplasia* cf. *T. goodlandensis* (R) (Fig. 7H)
      - Placopsilininae
        - *Placopsilina* n.sp. (R)
        - *Acruliammina longa* (UC) (Fig. 7I)
    - Textulariidae
      - Spiroplectammininae
        - *Quasispiroplectammina longa* (R)
        - *Q. alexanderi* (R)
        - *Haimasiella wintoi* (R)
        - *Textulariopsis rioensis* (UC) (Fig. 9A)
        - *T. washitensis* (R)

Miliolina
Miliolacea
Nubeculariidae
Nubeculariinae
Nubecularia depressa (R)
Nodobacullariinae
Nodophythalnidium pyriforme (R)
Miliolidae
Quinqueloculininae
Quinqueloculina minima (R) (Fig. 7D)
Rotaliina
Nodosariacea
Nodosariidae
Nodosariinae
Nodosaria barkeri (R)
N. n.sp. A (UC)
N. n.sp. B (R)
N. ?oklahomensis (R)
?Pseudoglandulina scotti (R)
Dentalina communis (UC) (Fig. 8F)
D. debilis (R)
D. aff. *D. hammensis* (UC)
D. aff. *D. cylindroides* (R)
D. ?n.sp. (R)
Dentalinopsis n.sp. (R) (Fig. 9B)
Marginulina tenuissima (UC) (Fig. 9C)
Lagena apiculata (R)
L. sulcata (UC) (Fig. 9F)
Citherina kochii (R)
C. striolata (R) (Fig. 9I)
Palmula howei (R)
Lenticulina cyprina (UC)
L. gaultina (UC) (Fig. 7B)
L. lenticulinoidea (R)
Saracenaria aff. *S. callitoechia* (R) (Fig. 7G)
Polymorphinidae
Polymorphininae
Globulina excerta (UC) (Fig. 7C)
Webinellinae
?Webinella sp. (R)
Bullopora n.sp. (R)
**Histopomphus redriverensis*
H. aff. *H. ceruicarnis* (R)
?Washitella roanokensis (R) (Fig. 7E)
Glandulinidae
Glandulininae
Tristix n.sp. aff. *T. acutangulatia* (UC) (Fig. 9H)
Buliminacea
Turrilinidae
Turrilininae
Neobulimina minima (C) (Fig. 9G)
Discorbacea
Discorbidae
Discorbinae
Discorbis minima (R)
Spirillinacea
Spirillinidae
Spirillininae
Spirillina minima (R)
S. n.sp. (R)
Turispirillina subconica (R)
Patellininae
Patellina subcretacea (R)
Globigerinacea
Heterohelicidae
Guembelitriinae
Gumbelitria harrisi (R)
Rotaliporidae
Hedbergellinae
Hedbergella planispira (UC) (Fig. 9E)
H. n.sp. (R)
Crassidulinacea
Caucasinidae
Fursenkoininae
Fursenkoina croneisi (R)
F. minuta (R)
Alabamidae
?Gyroidina loetterlei (C) (Fig. 8E)
G. n.sp. (R)
Anomalinidae
Anomalininae
Gavelinella plummeri (C) (Fig. 8D)
Lingulogavelinella asterinoides (UC) (Fig. 8B)
Robertinacea
Certobuliminidae
Epistomininae
Hoeglundina ?limbata (R)

Ostracoda
Platycopa
Cytherellidae
Cytherella obovata (VC) (Fig. 7A)
C. n.sp. (C)
Cytherelloidea reticulata (C) (Fig. 6A–B)
C. obliquirugata (UC) (Fig. 6G)
Podocopa
Bairdiidae
?Bythocypris sp. (R)
Cyprididae
Paracypridinae
Paracypridinae
Paracypris dentonensis (UC) (Fig. 6C)
Cytheridae
Trachyleberidinae
Trachyleberis paupera (UC) (Fig. 5B)
Cythereis n.sp. aff. *C. eaglefordensis* (C) (Fig. 5A)
C. ?howleyi (UC)
C. nuda (UC) (Fig. 6F)
Isocythereis worthensis (UC) (Fig. 5D)
I. mahonae (R) (Fig. 6D)
Protocythere sandidgei (VC) (Fig. 5C)
Progonocytherinae
Centrocythere ?concentrica (UC) (Fig. 6E)
Cytherideinae
Haplocytheridae washitaensis (VC)
Shuleridea oliverensis (UC) (Fig. 5E)
Cytherurinae
Eocytheropteron howelli (UC) (Fig. 5H)
E. bicornutum (UC) (Fig. 5F)
E. acutolatum (UC) (Fig. 5G)
Family uncertain
n.gen. and sp. (R)

CORRELATION

The microfauna of the Tucumcari Shale is dominated by species previously reported from the Washita Group of Texas and Oklahoma. Brooks (1959) suggested correlation of the Tucumcari with the Duck Creek and the underlying Kiamichi Formations of Texas. Scott (1970b), using macrofossils, considered the Tucumcari Shale to correlate with the Duck Creek, Fort Worth and Denton Formations of the Washita Group, but indicated the Tucumcari could, locally, correlate as well with the Kiamichi Formation. Brand and Mattox (1972), also using macrofossils, considered the Tucumcari Shale to contain elements of both the Kiamichi and Duck Creek Formations. These authors relied heavily on the presence in the Tucumcari Shale of the Kiamichi ammonite *Craginites* aff. *C. serratescens*, and the two Duck Creek ammonites *Eopachydiscus* aff. *E. laevicaniculatum* Roemer and *Pervinquieria* [now *Mortoniceras*] *equidistans*.

Lozo (1943) studied the Kiamichi–Washita boundary in Texas using microfossils. He considered the boundary best defined by ostracodes, although foraminiferans are also quite useful in defining the boundary. Lozo considered the Kiamichi–Duck Creek boundary to correspond to the boundary between the middle Albian *Oxytropidocera* zone and the upper Albian *Mortoniceras* zone. Bishop (1967), using lithologic criteria, considered the Kiamichi Formation to belong to the Washita Group, rather than the Fredricksburg Group where it was previously placed. The group placement of the Kiamichi Formation is not relevant to the correlation of the Tucumcari Shale with that formation.

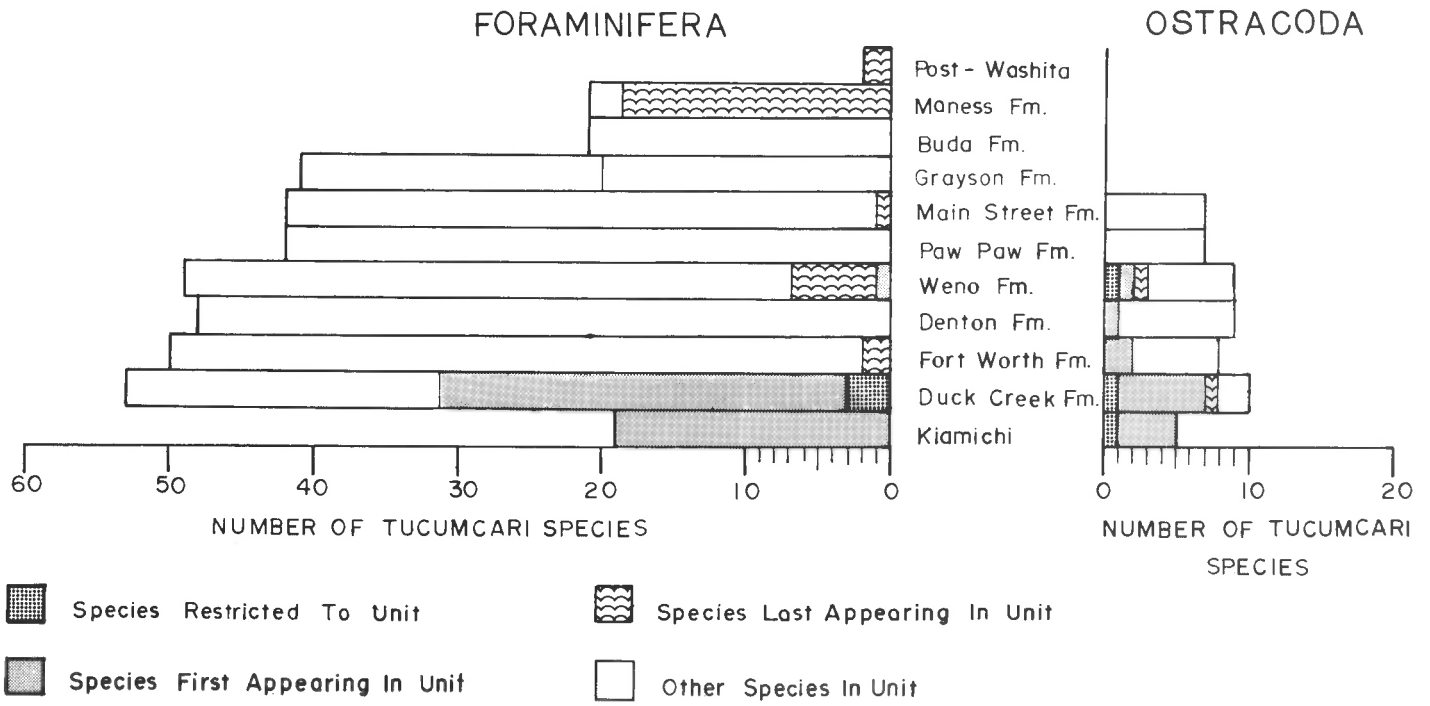


FIGURE 2. Correlation of Tucumcari Shale Foraminifera and Ostracoda with the formations of the Washita Group in Texas.

Present studies of the microfauna from Pyramid Mountain (Fig. 2) indicate that it clearly should not be correlated with the Kiamichi Formation. The foraminiferan fauna contains 66 species, of which only 19 species (28.7%) are also known from the Kiamichi Formation, and none of these species are restricted to the Kiamichi—they are known to range upward into the Duck Creek Formation. The Tucumcari ostracodes total 19 species, of which 5 species (26%) are shared with the Kiamichi Formation. One ostracode species, *Schuleridea? oliverensis* (Fig. 5E), has not previously been reported from the Duck Creek. Lozo (1943) did not report this species from his samples, but it may have a spotty distribution extending into the lower Duck Creek.

Correlation with specific Washita Group formations overlying the Kiamichi is difficult due to lack of restricted species and the lack of microfaunal studies on certain key formations (e.g., Fort Worth, Paw Paw, Main Street and Buda). The Tucumcari foraminiferan fauna (Fig. 2) shows the strongest correlation with that of the Duck Creek Formation, with which it shares 53 species (80.3% of the Tucumcari fauna). Four species—*Saracenaria* aff. *S. callitoecha* (Fig. 7G), *Nubecularia depressa* (Fig. 10F), *Lenticulina lenticuloidea* and *Marginula raristriata*—are restricted to the Duck Creek. Moreover, the Tucumcari foraminiferan fauna has 32 species (48.5%) which first appear in the Duck Creek Formation. Progressing up the Washita section, the number of species shared with the Weno Formation drops to 49 (74.2%). Species shared with the Grayson Formation decreases to 42 (63.6%). The Maness Formation, at the top of the Washita Group, has only 21 species (31.8%) in common with the Tucumcari, and only two Tucumcari species (3%) extend into units above the Washita Group. The Tucumcari foraminferan fauna has 9 species (13.6%) that are restricted to units below the Weno Formation. *Palmula howei* and *Triplasia* cf. *T. goodlandensis* (Fig. 7H) do not range above the Fort Worth Formation. *Patellina subcretacea, Turrispirillina subconica, Quinloculina minima* (Fig. 7D), *Discorbis minima, Fursenkoina croneisi, Globulina excerta* (Fig. 7C) and *Nodosaria ?oklahomensis* do not occur above the Weno Formation. The foraminiferan evidence thus indicates that the Tucumcari Shale at Pyramid Mountain correlates best with the lower Washita Group, most probably with the Duck Creek Formation.

Kessinger (1967), in studies of the Foraminifera from outliers of the Llano Estacado, considered *Gavelinella plummerae* (Fig. 8D), *Textulariopsis washitensis, Gyroidina loetterlei* and *Citherina kochii,* all of which are found in the Tucumcari Shale, to be restricted to the Washita Group in northern Texas. An examination of the range charts and tables in the same reference indicates that some of the foraminiferans are found in both the Duck Creek and the Kiamichi (e.g., *Textulariopsis washitensis*), and some are restricted to the Kiamichi (e.g., *Gavelinella plummerae*). This formation does not significantly clarify the placement of the Tucumcari Shale in relation to the Kiamichi–Duck Creek boundary, but suggests a more pronounced Kiamichi element in the Texas outliers of the Llano Estacado.

When the Tucumcari foraminiferans are compared to European faunas, such as those studied by Carter and Hart (1977), several things become apparent. Planktonic foraminiferans, uncommon in the Tucumcari Shale, are the same even at the species level (e.g., *Hedbergella planispira:* Fig. 9E), whereas the benthonic Foraminifera differ on the species level but converge on the generic level. Recovery of better planktonic foraminiferan faunas from the Tucumcari should allow better correlation with the European Albian faunas.

The Ostracoda (Fig. 2) do not provide as much biostratigraphic information as the Foraminifera. The Tucumcari ostracode fauna has 10 species (50%) in common with the Duck Creek Formation, of which one species, *Paracypris dentonensis* (Fig. 6C), is restricted to that unit. The Tucumcari shares 11 species (55%) with the Weno Formation, of which one species (*Cythereis ?howleyi*) is restricted to the Weno. The Grayson Formation has only 7 species in common with the Tucumcari, and the ostracode faunas of the units above the Grayson have not been studied. A few Tucumcari ostracodes are restricted to units below the Weno Formation. *Cytherelloidea reticulata* (Figs. 6A–B) does not extend above the Weno. *Eocytheropteron howelli* (Fig. 5H), *Cytheropteron bicornutum* (Fig. 5F) and *Isocythereis mahoni* (Fig. 6D) do not extend above the Duck Creek Formation. *Isocythereis worthensis* (Fig. 5D) and *Protocythereis sandidgei* (Fig. 5E) have not been reported below the Fort Worth Formation in Texas. The ostracode fauna thus supports a correlation of the Tucumcari Shale with the lower Washita Group, specifically the Duck Creek to Weno interval. The foraminiferan and ostracode evidence from the *Texigryphaea* horizon of the Tucumcari Shale thus suggests correlation with the upper Duck Creek Formation of the Washita Group.

TABLE 1. Characteristics of Tucumcari Shale macrofaunal communities, modified from Scott (1974). Asterisk indicates possible position of Pyramid Mountain, Tucumcari Shale microfauna.

Community	Environment	Feeding Type
Arenicolites	Upper shoreface	Infaunal susp.
Scabrotrigonia/ Turritella	Mid-shoreface	Infaunal susp.
Corbula/Breviarca	Lower shoreface	Infaunal susp.
*Texigryphaea/ Lopha	Lower shoreface (Biostrome)	Epifaunal susp.
Nucula/Nuculana	Open Bay	Infaunal detritus & susp.

PALEOECOLOGY

General characteristics

Scott (1970, 1974) studied the paleoecology of the Tucumcari Shale based on macrofaunas and sedimentology and recognized five faunal associations in the Lower Cretaceous of New Mexico and adjacent Colorado, Oklahoma and Kansas. The characteristics of these communities are shown in Table 1.

The microfauna from the Tucumcari Shale at Pyramid Mountain coexisted with a dense assemblage of macrofossils dominated by *Texigryphaea*. Scott (1974) assigned such assemblages to a *Texigryphaea–Lopha* biostrome community, said to have occupied the lower shoreface environment. This environment was also occupied by the *Corbula–Breviarca* community, with patches and elongate banks of the *Texigryphaea–Lopha* community. Scott (1974) noted that such banks in the Kiowa Formation "apparently occupied sandy bottoms within the wave zone where salinity was nearly normal marine." It is significant that Scott (1970b) considered the *Inoceramus bellvuensis* zone, with which the Tucumcari Shale may correlate, to mark a period of maximum transgression for the upper Albian. The *Texigryphaea* horizon at Pyramid Mountain differs from many others of the *Texigryphaea–Lopha* type in that it is thinner, the enclosing sediment is finer-grained, and the fauna shows limited evidence of transport. Sandy, well-indurated shell conglomerates are more typical of these communities in the Tucumcari Shale elsewhere in east-central New Mexico. This suggests that the Pyramid Mountain texigryphaeas may have occupied deeper, farther offshore, less agitated waters than the typical, lower-shoreface biostromes.

TABLE 2. Relationship of plankton/benthonic foraminiferan ratios to water depth, modified from Tipworth et al. (1966). Asterisk indicates depth indicated by the Pyramid Mountain foraminiferan fauna.

	Percentage Planktonic/Benthic Ratio	Depth (m)	Environment
*	0 - 10	0 - 70	Inner-middle shelf
	10 - 20	0 - 70	Inner-middle shelf
	20 - 30	60 - 120	Middle-outer shelf
	30 - 40	100 - 600	Outer shelf/upper slope
	40 - 50	100 - 600	Outer shelf/upper slope
	50 - 60	550 - 700	Upper-lower slope
	60 - 70	680 - 825	Upper-lower slope
	70 - 80	700 - 1100	Upper-lower slope
	80 - 90	900 - 1200	Upper-lower slope
	90 -100	1200 - 2000	Upper-lower slope

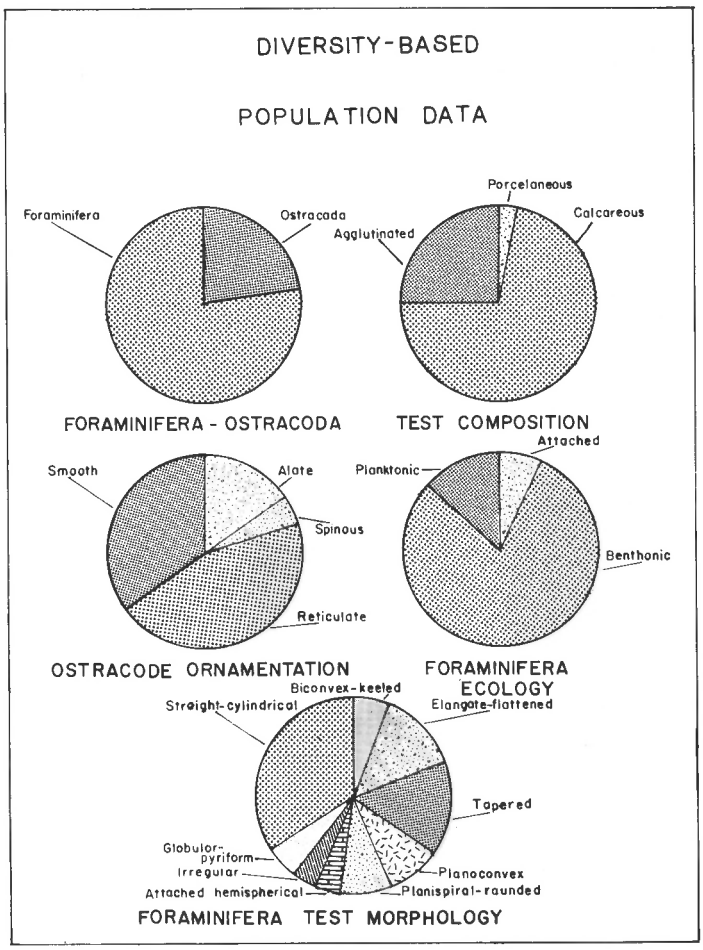


FIGURE 3. Diversity-based population characteristics of the Foraminifera and Ostracoda from the Tucumcari Shale.

The microfauna of the Tucumcari Shale indicates a high-diversity, high-density fauna characterized by benthonic Foraminifera (Fig. 3). Douglas (1979) used three foraminiferan-fauna trends to estimate paleodepths and shoreline relationships. These trends are: planktonic–benthonic ratios, test composition ratios and diversity trends. Tipworth et al. (1966) established the relationship between percentage planktonic/benthonic ratios and approximate water depth (Table 2). The Tucumcari Foraminifera have a planktonic/benthonic ratio of 5.8, indicating a water depth of less than 70 m. Albers et al. (1966) also established a relationship between planktonic/benthonic ratios and depth (Table 3). This relationship indicates a depth of about 20 m within the inner-shelf/inner-neritic-shelf environment.

Diversity of the benthonic foraminiferans was used by Walton (1964) to describe a general trend of increasing diversity with increasing depth. The benthonic foraminiferans of the Tucumcari Shale have an absolute diversity of 65 species, compared with a diversity of 114 species for the Duck Creek Formation (Tappan, 1943), 41 species for the Weno Formation (Traux, 1980) and 52 species for the Grayson Formation (Mancini, 1982). Traux (1980) estimated the depth of deposition of the Weno Formation to be about 100 to 600 m.

Absolute diversity is not the best measure of diversity, since in most cases the greater the number of specimens, the greater the diversity of that assemblage. This effect was considered by Fisher et al. (1943) when they developed the Fisher Alpha Index to measure diversity. Murray (1973) constructed a nanogram (Fig. 4) to calculate the alpha

TABLE 3. Relationship of plankton/benthonic foraminiferan ratios to water depth, modified from Albers et al. (1966). Asterisk indicates depth indicated by the Pyramid Mountain Tucumcari Shale foraminiferan fauna.

Percentage Planktonics	Depth	Environment
None	-	None/marginal marine
*Rare	20	Inner shelf/neritic
10	20-100	Middle shelf/neritic
50	100-200	Outer shelf/neritic
>50	200-500	Upper slope/bathyal
>>50	500-2000	Lower slope/bathyal
100	>2000	Abyssal

index with the number of specimens and number of species. The Tucumcari fauna has an alpha index of 12. Murray (1973) considered an alpha index of 5 to separate normal-marine from abnormal-marine environments with values greater than 10 typical of, but not restricted to, bathyal and deeper environments. Douglas (1979) considered an alpha index of 7 or 8 to separate better normal- from abnormal-marine environments. The Tucumcari fauna is well within the range of a normal-marine environment and could represent a relatively deep-water environment based on its alpha index.

Test composition ratios are usually based on the relative proportions of agglutinated, calcareous and porcelaneous species. Agglutinated tests are typical of faunas in marginal-marine environments and those below the CCD (carbonate-compensation depth), whereas porcelaneous tests are typical of faunas from the continental shelf and particularly hypersaline environments (Murray, 1973). Porcellaneous tests also characterize warm-water, reef environments (Douglas, 1979). Hyaline, calcareous faunas dominate the shelf and bathyal environments. Sliter and Baker (1972) noted that calcareous agglutinated species of the textularid and verneuilinid types, and nodosariids, are typical of Cretaceous outer-continental-shelf environments rather than marginal-marine environments (100–200 m). These groups are common in the Tucumcari Shale fauna from Pyramid Mountain. These authors consider the polymorphids, another group of attached foraminifera common in the Tucumcari Shale, to be typical of the inner-shelf environment (0–100 m), suggesting a depth of about 100 m. The Tucumcari Shale foraminiferan fauna has a ratio of 8/1/21.5 for agglutinated/porcelaneous/calcareous Foraminifera. Todd and Bronnimann (1957) studied Recent foraminiferan faunas from Trinidad and found the percentage of agglutinated Foraminifera decreased from about 32% for onshore faunas to about 15% for offshore faunas. This would indicate the Tucumcari fauna (35%) is an onshore fauna. This analogy may be flawed because the large, agglutinated Foraminifera (e.g., *Cribrotina texana*) are strongly associated with *Lopha* and oyster spat (Scott, 1974), and may not be typical of the environment as a whole.

Severin (1983) has recently suggested using foraminiferan-test morphology as a method of discriminating biofacies. He defined six morphotypes: straight cylindrical, plano-convex, elongate flattened, biconvex keeled, tapered and round planispiral. The Tucumcari fauna (Fig. 3) does not easily fit into Severin's morphotypes, and I have added three additional morphotypes: irregular (including attached), hemispherical attached and pyriform. The Nodosariinae and representatives of *Reophax* are transitional between straight cylindrical and tapered types, but were placed in the former group. Another problem with the Tucumcari fauna involves species with differing initial (juvenile) and later morphology. In these cases, the final (adult) morphology was used to arrive at the morphology used in the figure.

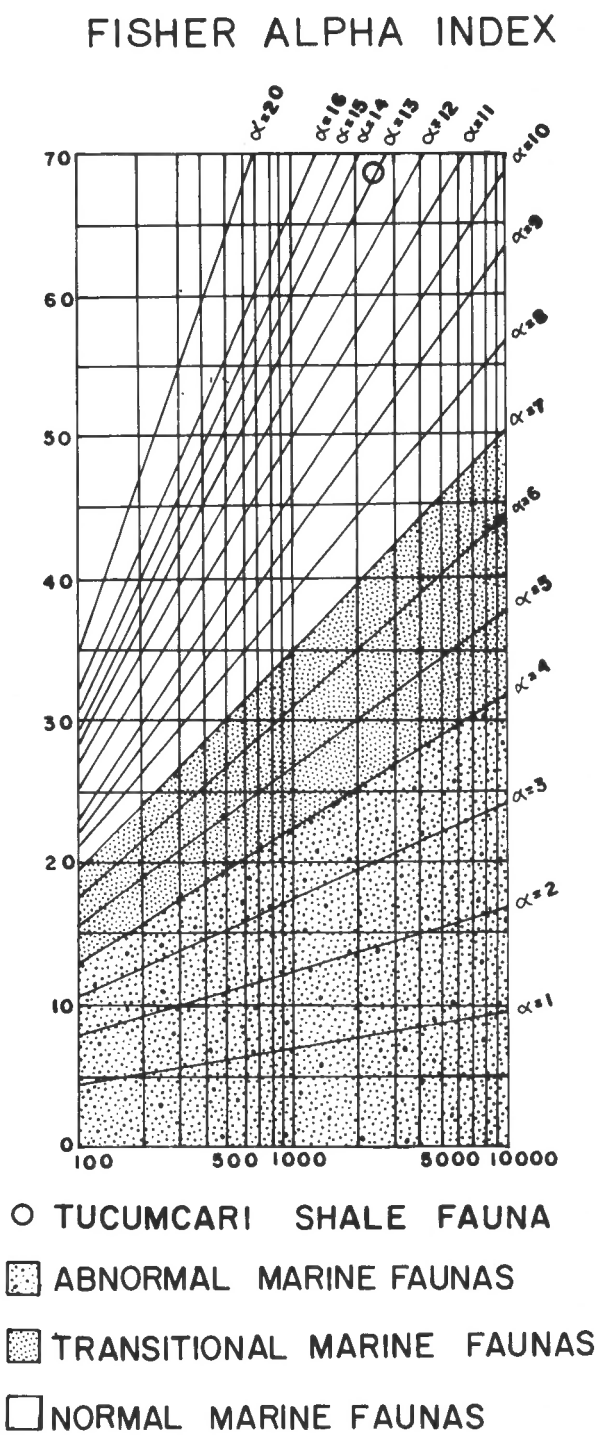


FIGURE 4. Position of the Tucumcari Shale Foraminifera on the Fisher Alpha Index.

Severin (1983) observed that the straight-cylindrical morphotype is most abundant in bays, while the elongate-flattened, biconvex-keeled and tapered morphotypes are most abundant in deeper (60–110 m), offshore areas. The abundance of both straight-cylindrical and tapered morphotypes in the Tucumcari Shale could be caused by several factors. The problem of classification of the nodosariids and *Reophax* (*sensu lato*) has already been mentioned. A second possibility is that the material from Pyramid Mountain represents a transported and mixed fauna. This possibility is considered unlikely, since even ornamented Foraminifera do not show evidence of abrasion or size sorting. A final possibility is that the Tucumcari Shale environment combined the char-

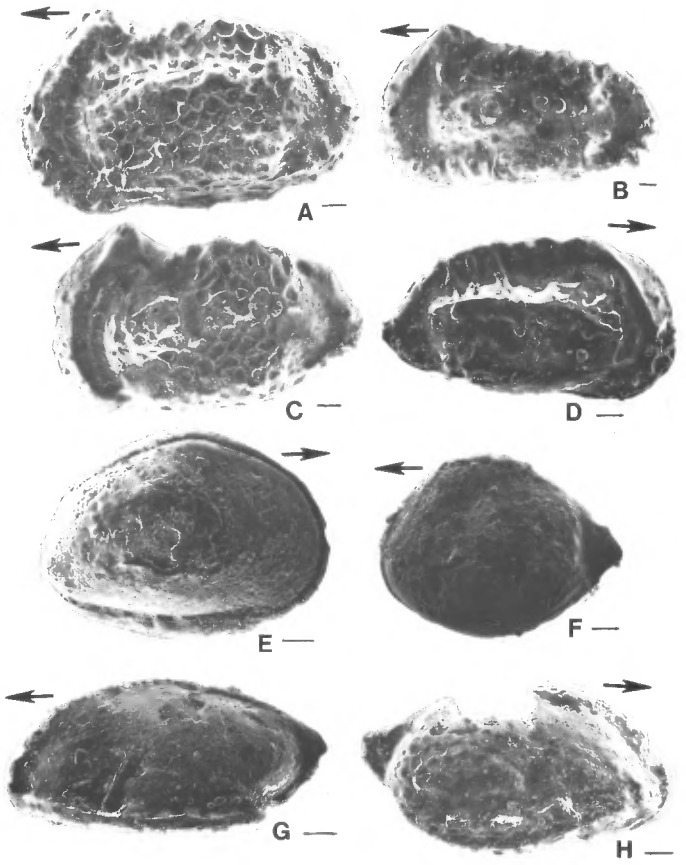


FIGURE 5. Ostracoda from the Tucumcari Shale. A, *Cythereis* n.sp. aff. *C. eaglefordensis*. B, *Trachyleberis paupera*. C, *Protocythereis sandidgei*. D, *Isocythereis worthensis*. E, *Schuleridea*? *oliverensis*. F, *Eocytheropteron bicornutum*. G, *Eocytheropteron acutolatum*. H, *Eocytheropteron howelli*. The bars represent 50 μ, the arrows indicate anterior.

acteristics of both bay and open-ocean environments. This is certainly possible, considering the paleogeographic reconstructions presented by Scott (1970b). Indeed, Scott (1974) refers to the environment as a bay–shoreface, yet the water depth is rather great for a typical bay and is more like the deep-water environment typical of the open ocean. Thus, the deep waters combined with a bay-like circulation pattern might explain the morphotypes encountered in the Tucumcari Shale. Finer tuning of the morphotypes, perhaps in the sense of Brasier (1982), might allow better discrimination of ecological preferences in the foraminiferan faunas of the Cretaceous. The above information suggests the Tucumcari Shale fauna from Pyramid Mountain was deposited in an offshore, normal-marine environment of about 20–70 m depth.

The attached foraminiferans

Attached Foraminifera from the Tucumcari Shale are common when proper substrates (e.g., bivalve fragments) are available. Four attached foraminiferan groups are present in the Pyramid Mountain *Texigryphaea* assemblage: the agglutinated Tolypamminae (Ammodiscidae), the agglutinated Placopsilininae (Lituolidae), the porcelaneous Nubeculariinae (Nubeculariidae) and the hyaline, calcareous Webinellinae (Polymorphinidae). The study of the Pyramid Mountain assemblage provided an opportunity to examine the attached Foraminifera in detail, yielding much new information on substrate and site preference for individual foraminiferan species. The following systematic section summarizes the detailed information, but a few generalizations can be made here. Foraminiferans are not characteristically substrate specialists, but occupy whatever substrate is available. In the Tucumcari Shale they tended to occupy dead and often fragmented shells, as indicated by their relative proportions on the interior and exterior of shells and shell fragments. Furthermore, they tend towards "communal" occupancy of substrates, with multiple occupancy being the rule rather than the exception. Bivalve fragments were the most common substrate, and hence the one most often colonized by foraminiferans. However, Tucumcari Shale foraminiferans also occupied ?echinoid fragments, other foraminiferans (Fig. 10F) and even other epizoans (serpulid-worm tubes). Some attached forms were found loose in the sample, indicating either that they were dislodged or were originally attached to soft-bodied hosts.

SYSTEMATICS OF ATTACHED FORAMINIFERA

The systematics, detailed descriptions and paleoecology of the attached Foraminifera from the Tucumcari Shale at Pyramid Mountain are described below. The attached foraminiferans that are not illustrated were those found only on macrofaunal elements and thus not available for SEM illustration at this time. Not included in this study are some species, such as ?*Washitella roanokensis* (Fig. 7E), which generally lived unattached, but occasionally attached themselves to sand grains.

Foraminifera
Ammodiscacea
Ammodiscidae
Tolypammininae
Lituotuba spp.

Description—*Lituotuba* spp. consist of iron-stained, very finely agglutinated tubes which irregularly cover some valves of *Texigryphaea tucumcarii*. Since these tubes vary considerably in size, more than a single species may be present. The tubes often show constrictions resulting from the tapering nature of the tube sections. In a few specimens, the initial portion of the tube shows some tendency to form a loose coil about the minute proloculus. Measurements for *Lituotuba* are shown in Table 4.

Discussion—*Lituotuba* is a conservative, long-ranging genus (Silurian to Recent), and descriptions of new species should await a detailed review of the genus. *Lituotuba* spp. are common on some *Texigryphaea* specimens where they occupy both the interior and exterior of both valves. They often colonized the posterior margins. This genus has not been recovered from the microfossil residues.

?Ammodiscella n.sp.

Description—?*Ammodiscella* n.sp. is minute, consisting of a proportionately large, raised proloculus followed by a minute, regularly coiled, unseptate second chamber. The walls are finely arenaceous and iron-stained. The coiled portion consists of three to four coils. The aperture is at the end of the coiled portion. Measurements are given in Table 5.

Discussion—?*Ammodiscella* n.sp. was found in the interior of a single, broken, left valve of *Texigryphaea tucumcarii*. A total of 13 specimens occupy this valve, evenly distributed over the interior surface. These specimens are associated with a serpulid and a ?bryozoan colony. The colonization pattern suggests occupation following the death of the bivalve. This species was not found in the microfossil samples.

TABLE 4. Measurements (in mm) of *Lituotuba* sp. from the Tucumcari Shale.

Specimen Number	Number Coils	Proloculus Diameter	Coil Diameter	Length	Width
1	2	?0.1	1.8	9.5	0.9
2	?	-	-	8.5	0.8
3	4	?	0.8	4.6	0.5
4	+ 2	-	-	6.0	0.4
5	5	0.2	1.2	7.2	?
6	2	0.2	1.8	+1.8	?

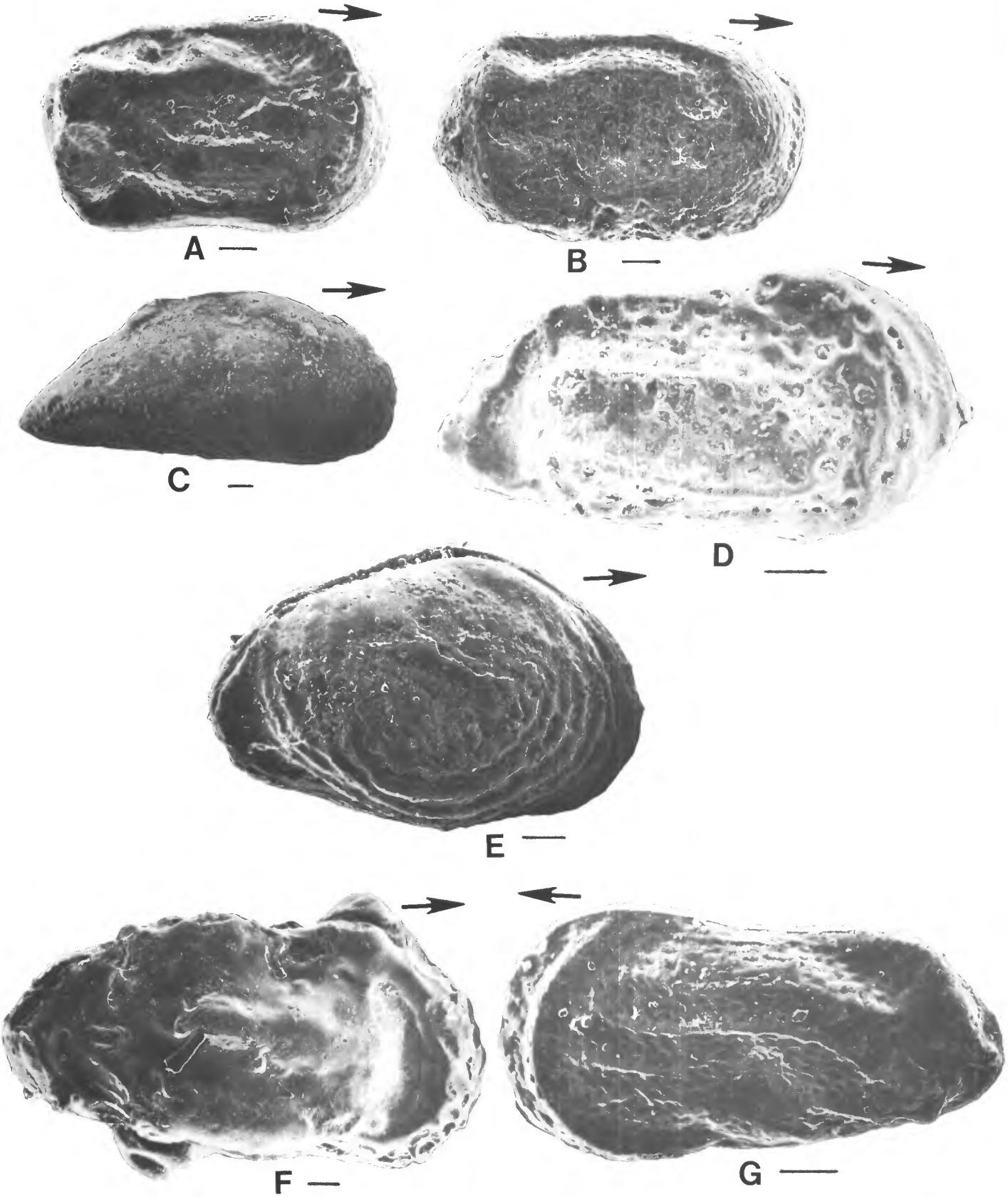


FIGURE 6. Ostracoda from the Tucumcari Shale. A, *Cytherelloidea reticulata* (female). B, *Cytherelloidea reticulata* (male). C, *Paracypris dentonensis*. D, *Isocythereis mahonae*. E, *Centrocythere ?concentrica*. F, *Cythereis nuda*. G, *Cytherelloidea obliquirugata*. The bars represent 50 μ, the arrows indicate anterior.

TABLE 5. Measurements (im mm) of ?*Ammodiscella* n.sp. from the Tucumcari Shale.

Specimen Number	Number of Coils	Test Diameter	Proloculus Diameter
1	4	1.5	0.2
2	4	1.5	0.2
3	4	1.3	0.2
4	4	1.5	0.2
5	4	1.3	0.2
6	3	0.9	0.2
7	4	1.3	0.2
8	4	1.4	0.2
9	3	1.5	0.2
10	4	1.5	0.2
11	3	1.4	0.2
12	4	1.4	0.2
13	3	1.5	0.2

TABLE 6. Measurements (in mm) of *Placopsilina* n.sp. from the Tucumcari Shale.

Specimen Number	Coil Number	Proloculus Diameter	Coil Diameter	Chamber Number	Length
1	1	?	1.6	+10	12.3
2	1	0.5	1.5	10	5.3
3	1	?	?1.8	+5	15.8
4	1	?	1.4	+6	9.9
5	1	0.6	2.3	7	13.8

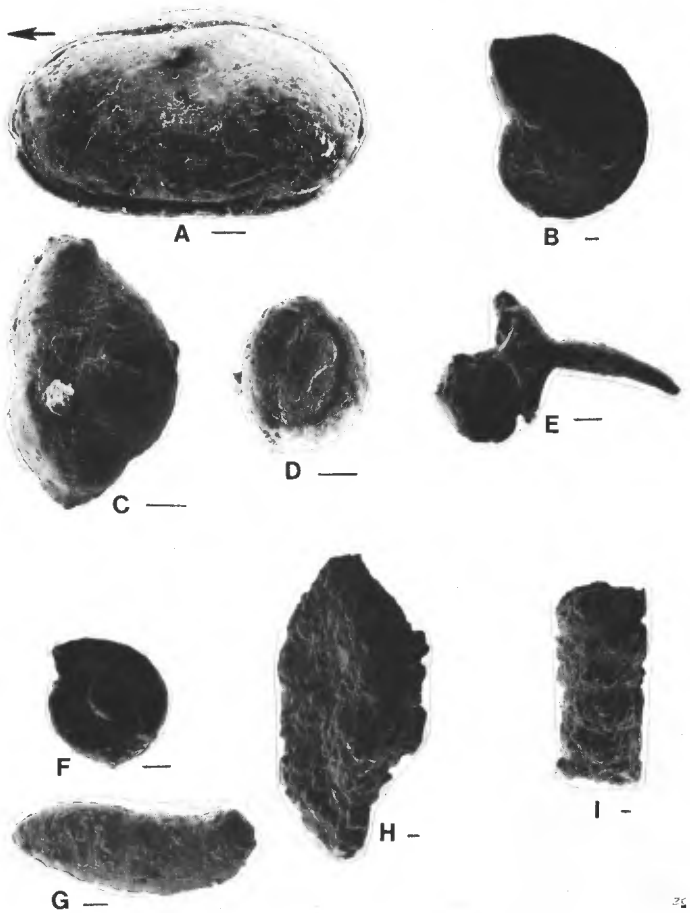


FIGURE 7. Ostracoda and Foraminifera from the Tucumcari Shale. A, *Cytherella obovata*. B, *Lenticulina gaultina*. C, *Globulina excerta*. D, *Quinqueloculina minima*. E, ?*Washitella roanokensis*. F, *Glomospira gaultina*. G, *Saracenaria* aff. *S. callitoechia*. H, *Triplasia* cf. *T. goodlandensis*. I, *Acruliammina longa* (unattached portion). The bar represents 50 μ, the arrow indicates anterior.

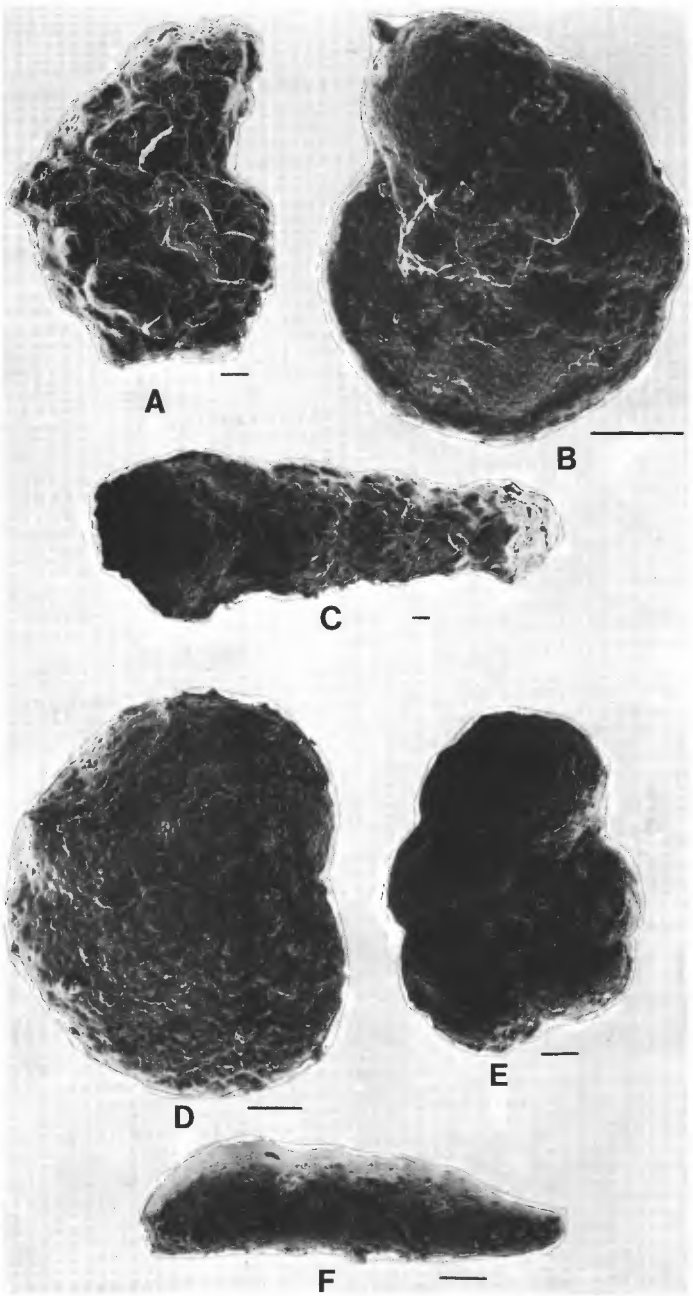


FIGURE 8. Foraminifera from the Tucumcari Shale. A, *Ammobaculites goodlandensis*. B, *Lingulogavelinella asterinoides*. C, *Cribratina texana*. D, *Gavelinella plummeri*. E, ?*Gyroidina loetterlei*. F, *Dentalina communis*. The bars represent 50 μ.

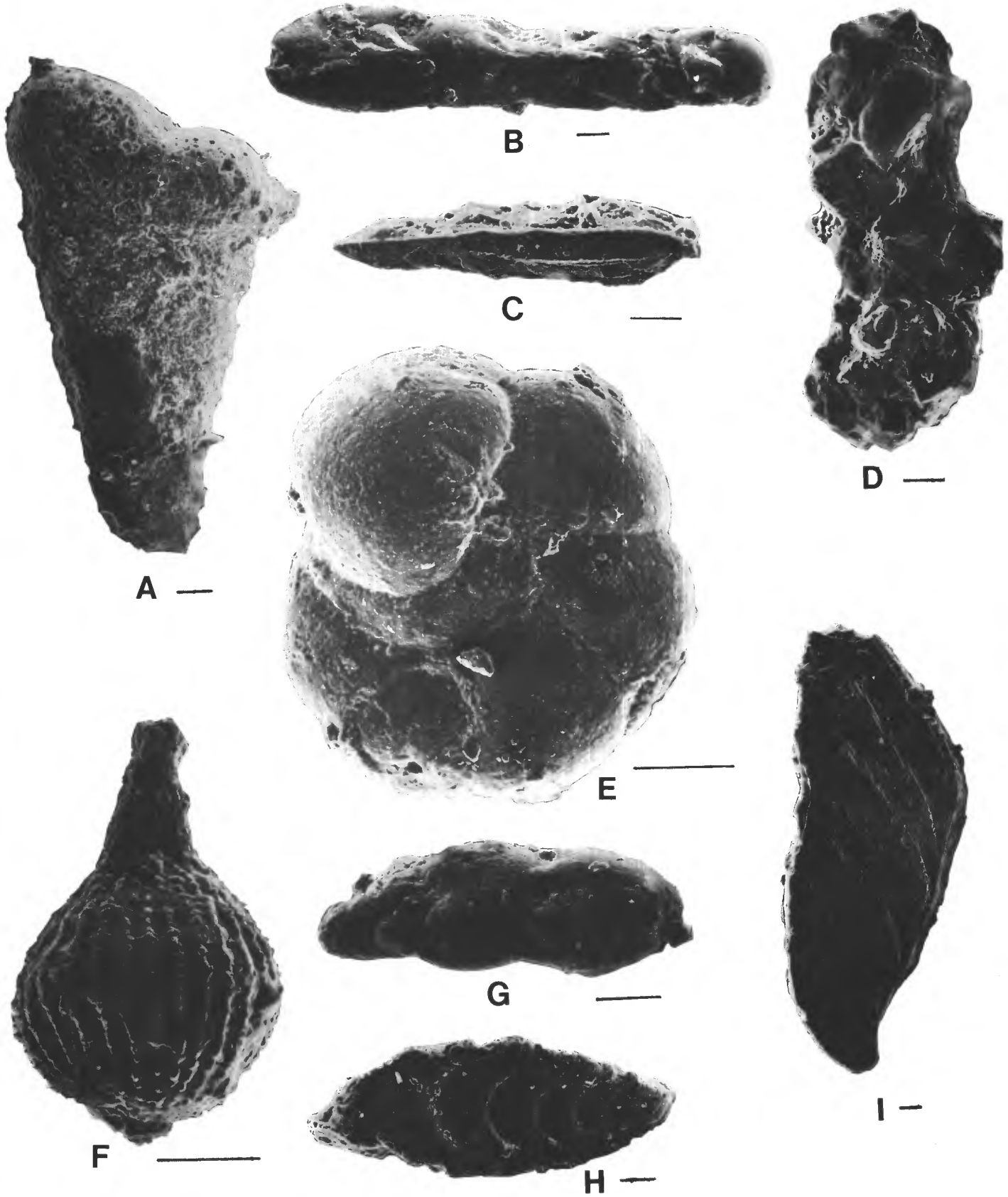


FIGURE 9. Foraminifera from the Tucumcari Shale. A, *Textulariopsis rioensis*. B, *Dentalinopsis* n.sp. C, *Marginulina tenuissima*. D, *Ammobaculites variablis*. E, *Hedbergella planispira*. F, *Lagena sulcata*. G, *Neobulimina minima*. H, *Tristix* n.sp. aff. *T. acutangulatia*. I, *Citherina striolata*. The bars represent 50 μ.

Ammodiscella has previously been reported only from the Late Pennsylvanian (*A. virgilensis*) (Loeblich and Tappan, 1964), and, thus, assignment of the Tucumcari specimens to this genus is provisional. ?*Ammodiscella* n.sp. differs from *A. virgilensis* in its much smaller diameter and very even coiling.

Lituolidae
Placopsilininae
Placopsilina n.sp.
Fig. 10C

Description—The test is small, finely arenaceous, attached, with an early coiled stage containing a proloculus succeeded by three to four chambers, followed by a uniserial, somewhat winding uncoiled stage with up to eight, poorly defined, rectangular chambers which may vary slightly in size. The wall is very thin and finely arenaceous, consisting of very fine sand and coarse silt with much cement. The chambers are poorly expressed on the exterior of the test. The aperture is terminal, consisting of a simple semicircular opening against the attachment surface. Measurements are given in Table 6.

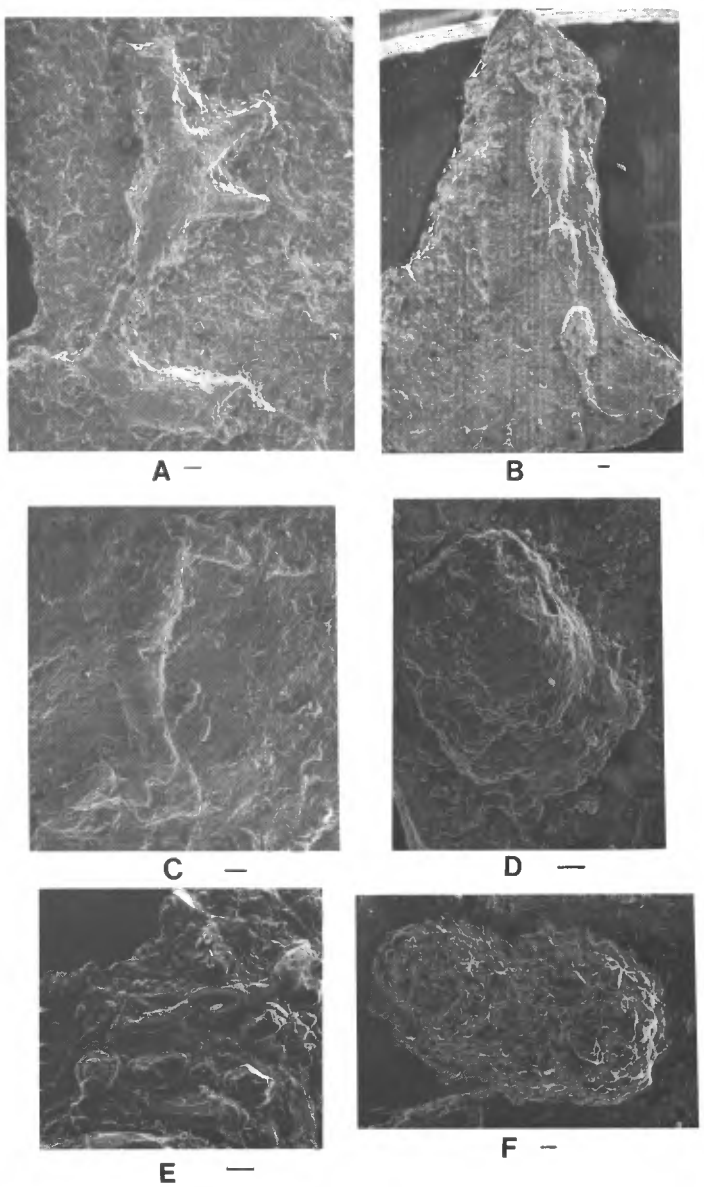


FIGURE 10. Attached Foraminifera from the Tucumcari Shale. A, *Histopomphus* aff. *ceruicarnis*. B, *Bullopora* n.sp. C, *Placopsilina* n.sp. D, ?*Webinella* sp. E, *Acruliammina longa*. F, *Nubecularia depressa*. The bars represent 50 μ.

Discussion—*Placopsilina* n.sp. resembles *P. minima* Tappan, from which it is distinguished by having rectangular chambers of uneven size, a better defined, tightly coiled initial stage and a more even, finely arenaceous wall.

Placopsilina ranges from Jurassic to Recent, with a tendency to become less regular in more recent species. The genus has very few Early Cretaceous species since most former species have been transferred to other genera by later workers. Tappan (1943) described *P. expansa* from the Albian of Texas, but this species has rapidly expanding chambers in the uniserial portion, quite unlike the species from the Tucumcari Shale.

Placopsilina n.sp. is a rare element in the Tucumcari fauna of attached foraminifera, with only eight specimens recovered from the sample. Six of the eight specimens (75%) occur on the exterior of shell fragments, the remaining specimens on the interior. This suggests either the bivalve valves and fragments lay on the sea floor with their exteriors preferentially exposed, or colonization of living as well as dead bivalves by *Placopsilina* and, hence, greater numbers on the exterior of the valves. Four of the six specimens attached to the shell exterior occur on the same fragment. *Placopsilina* n.sp. has been recovered only on smooth bivalve (e.g., *Texigryphaea*) fragments. One specimen was found on the exterior of right valve of a very small individual of *Texigryphaea,* suggesting early colonization. The only other epizoan found associated with *Placopsilina* n.sp. was a single bryozoan on one fragment.

Placopsilina is considered to be representative of the middle-shelf (30–100 m) environment of modern oceans (Uchio, 1960). A similar environment has been suggested for Cretaceous species by Sliter and Baker (1972), who considered this genus to be an inner-shelf (0–100 m) inhabitant.

Acruliammina longa Tappan, 1940
Figs. 7I, 10E

Description—The test is medium-sized, arenaceous and attached in part. It consists of an early coiled stage composed of a proloculus and two to four, rarely eight, chambers, followed by a uniserial, rectilinear, uncoiled stage consisting of two to fifteen attached chambers and two unattached cylindrical chambers. The coiled stage has a large, well-defined "umbilical plug" over the proloculus, typical of the genus but often broken off. Lozo (1944) notes that this "umbilical plug" is, in reality, the outer covering of the proloculus. Coiling is either clockwise or counterclockwise, without apparent preference. The uniserial attached stage occasionally twisted back on itself when it reached the edge of the attachment surface. At other times, the specimen continued to grow over the edge of the fragment to the other side. The wall is arenaceous and composed of cement and small quartz grains with a scattering of coarser quartz grains. The separation of the chambers in the coiled portion of the test is obscure, but in the attached and unattached uniserial stage they are distinct. The aperture is cribrate with a dividing medial septum in the late uniserial attached stage, and cribrate and terminal in the unattached stage. The unattached stage is almost always broken, but sometimes includes a small part of the attached stage. Measurements are given in Table 7.

Discussion—*Acruliammia longa* was originally described as *Placopsilina longa* from the Albian Grayson Formation, Washita Group, of Texas (Tappan, 1940). Its range was later extended downward to the Denton and Duck Creek Formations (Washita Group) of Texas and Oklahoma (Tappan, 1943). Lozo (1944) also reports this species from the marly facies of the Kiamichi in north Texas.

The paleoecology of *Acruliammina longa* is poorly known. Tappan (1940) noted that the species in the Grayson of Texas is fairly common, frequently being attached to pelecypod fragments. Study of 23 specimens from the Tucumcari Shale indicates this species is most commonly (88%) attached to smooth bivalve fragments (e.g., *Texigryphaea*), but also occurs on ribbed or spiney bivalve fragments (11%). Single specimens were found on an ?echinoid fragment and on a sepulid-worm tube. About equal numbers occur on the inner (48%) and outer (39%) surfaces of fragments, suggesting colonization following the death of the bivalve. Some specimens occur on the broken edges of fragments,

TABLE 7. Measurements (in mm) of attached specimens of *Acruliammina longa* from the Tucumcari Shale.

Specimen Number	Coil Diameter	Proloculus Diameter	Chamber Number	Length	Width
1	5.8	0.9	+10	+7.9	3.8
2	5.1	?	+5	+6.1	4.3
3	7.6	3.0	+5	+8.9	?
4	6.1	?	+8	+9.8	4.6
5	?4.2	?	+5	+13.7	?
6	7.6	?	+10	+22.9	3.6
7	5.1	2.0	+3	+7.6	4.1
8	5.6	1.8	7	11.9	4.7
9	4.2	1.8	13	+8.9	6.5
10	3.0	?	+6	+23.7	3.3
11	2.8	?	+11	21.5	4.4
12	-	-	+5	+9.8	3.7
13	3.3	2.0	+15	+36.6	7.1
14	-	-	+4	+16.0	8.4
15	2.8	1.8	+9	+12.4	4.6
16	5.1	2.0	?11	24.6	4.3
17	3.7	?	13	18.8	5.3
18	2.3	?	+6	17.5	4.8
19	-	?	+9	+24.1	5.1
20	+3.8	?	12	22.6	+3.6
21	5.1	1.6	+6	+8.1	3.6
22	3.8	?	?10	23.4	5.3
23	6.6	?	7	12.7	5.6
24	3.6	?1.0	10	9.1	5.6

suggesting colonization of broken bivalve shells. *Acrulimmina longa* also tends to occur on fragments previously occupied by other individuals of its species. In most cases (three specimens), one individual occupied one side of a fragment, another individual the other side. In one case, a fragment was occupied by five individuals, some overlapping previous tenants. Other epizoans associated with *Acrulimmina* include *Bulopora* n.sp., *Histopomphus* aff. *H. cervicornis, Histopomphus redriverensis* and a bryozoan.

Miliolina
Miliolacea
Nubeculariidae
Nubeculariinae
Nubecularia depressa
Fig. 10F

Description—The test is minute, consisting of a globular proloculus surrounded by a miliolinid single coil consisting of two chambers. Later chambers are uniserial, in a somewhat arcuate arrangement, individually pyrform in outline, with the base slightly and asymmetrically rounded and tapering toward the aperture. The single Tucumcari specimen has three uniserial chambers, a proloculus diameter of 0.4 mm and a coiled-portion diameter of about 0.6 mm. The largest uniserial chamber is 1.5 mm long and 0.5 mm wide. The total length of the uniserial portion is 3.4 mm.

Discussion—This species is very rare in the Tucumcari fauna, being represented by a single specimen attached to the exterior of an agglutinated foraminiferan test, possibly *Cribratina texana*. The type specimen of this species was described from the Gault Formation (Albian) of England, and the species is also recorded from the Duck Creek Formation of Texas and Oklahoma (Tappan, 1943).

Rotaliina
Polymorphinidae
Webbinellinae
?Webbinella sp.
Fig. 10D

Description—The test is minute, low and slightly oval. Walls are poorly preserved, but appear to be calcareous and of the polymorphine type. Poor preservation has obscured the nature of the initial chambers and the aperture. Measurements of *?Webbinella* sp. are given in Table 8.

Discussion—Tucumcari Shale specimens tentatively placed in this genus are rare and poorly preserved, and could as easily represent spat of *Histopomphus* or *Bullopora*. A larger collection of better preserved material would help clarify the true nature of this species. The genus ranges from Early Cretaceous to Recent and has a cosmopolitan distribution (Loeblich and Tappan, 1964).

The two specimens of *?Webbinella* from the Tucumcari Shale occur on the interior of smooth bivalve fragments, suggesting colonization of dead bivalves. The environmental significance of *Webbinella* is unknown. However, modern Polymorphidae are characteristic of the 0–30-m inner shelf (Parker, 1954; Resig, 1958) or the 30–100-m middle shelf (Natland, 1933; Walton, 1955; Uchio, 1960).

Bulopora n.sp.
Fig. 10B

Description—The test is medium-sized, calcareous and attached, occurring as a series of oval, hemispherical, tapering chambers connected by a tapering, stoloniform neck. The chambers usually number from one to four and, in some specimens (?microspheric forms), increase slowly in size. Most specimens (?megalospheric forms) have chambers of about equal size, which wind in a uniserial series over the surface of the attachment site. The initial attached chamber has one end rounded and the proloculus extending above the surface of the first attached chamber. The wall is calcareous, perforate, rather thin and often collapsed in larger chambers. The aperture is a small opening at the end of the tapering neck of the final chamber. Measurements are given in Table 9.

Discussion—*Bullopora* n.sp. resembles *B. rostrata* (Quenstedt) from which it differs in being more elongate and tapering at both ends, rather than only at the aperturate end. *Bullopora* n.sp. differs from *B. breoni* (Terquem) and *B. irregularis* in having a distinct stoloniform neck and in being more elongate.

Bullopora n.sp. is fairly common in the Tucumcari Shale, being represented by nine specimens in the microfossil samples. Four specimens occur on the interior of fragments, four on the exterior and one

TABLE 8. Measurements (in mm) of *?Webbelina* sp. from the Tucumcari Shale.

Specimen No.	Length	Width
1	4.3	2.8
2	5.6	2.8

TABLE 9. Measurements (in mm) of *Bullopora* n.sp. from the Tucumcari Shale.

Specimen Number	Chamber Number	Chamber Length	Chamber Width	Length
1	1	4.3	2.3	4.3
2	1	3.8	1.8	3.8
3	1	2.9	1.1	2.9
4	1	4.2	3.0	4.2
5	1	+3.9	2.7	+3.9
6	+3	2.8	2.2	+6.4
7	2	7.1	2.8	+10.7
8	1	3.8	1.8	3.8
9	7	11.6	3.8	70.0
10	1	7.9	2.7	7.9
11	+2	6.1	2.4	6.1
12	5	6.9	2.4	26.2
13	3	8.9	5.6	31.9
14	+3	2.6	1.2	6.0
15	3	6.9	4.4	17.5
16	2	10.4	4.1	16.5
17	3	+7.9	3.6	+17.3
18	+4	9.1	3.8	+30.5

on a fragment edge. This suggests occupation following bivalve death and fragmentation. Seven specimens (78%) occur on spat or small individuals. Three individuals (33%) were present on ribbed bivalve fragments. On one fragment, *Bullopora* n.sp. had grown between the ribs and parallel to them. Only two specimens were observed occupying the same fragment. One specimen was found associated with *Histopomphus* aff. *H. cervicornis*.

Histopomphus redriverensis

Description—The test is large, attached and calcareous, with an elongate, ovate primary chamber and an elongate, thin, bifurcating series of later chambers, which are open in aperturate chambers and bluntly closed in unused chambers. The wall is calcareous, smooth, finely perforate and is sometimes slightly iron-stained. The initial chamber is poorly preserved in the Tucumcari specimens, but is reported (Loeblich and Tappan, 1964) to be multilocular, with three or more separate chambers. Measurements are given in Table 10.

Discussion—This species differs from the holotype described by Tappan (1943) in being more elongate, but is otherwise similar. As noted by Tappan, this species is not likely to be confused with other possibly related species.

The genus *Histopomphus* is restricted to the Early Cretaceous of North America, having been reported from the Duck Creek Formation of Texas by Tappan (1943). Lozo (1944) described this species from the Goodland and Kiamichi Formations of Texas under the name *Bullopora irregularis*. The species has also been reported from the Walnut Formation of Oklahoma (Loeblich and Tappan, 1949).

Two specimens from the Tucumcari Shale were found on the interior of a *Texigryphaea* fragment that also contained two specimens of *Aculiammina longa* and one specimen of *Histopomphus* aff. *H. cervicornis* on the exterior of the fragment. This species colonized dead and perhaps fragmented bivalves. Lozo (1944) noted this species is mostly found on pectens and gryphaeas in the the upper Washita, oysters and echinoids in the lower Washita and mainly on echinoids in the Fredricksburg.

TABLE 10. Measurements (in mm) of *Histopomphus redriverensis* from the Tucumcari Shale.

Specimen Number	Chamber Number	Chamber Length	Chamber Width	Neck Number	Length
1	?3	9.4	0.5	4	17.0
2	?1	5.8	0.5	3	5.8

Histopomphus aff. *H. cervicornis* (Chapman)

Fig. 10A

Description—The test is medium to large, attached, and consists of a round, multilocular polymorphine proloculus resting on an initial, irregular, attached first chamber with many projecting, tapering, rounded, stoloniform, radiating necks around its periphery. There are often additional chambers connected by one of the necks. The wall is calcareous, perforate and rather thick and smooth on the outside. The apertures occur at the ends of the stoloniform necks and consist of a low opening in actively used necks that is closed off in unused necks. Measurements are given in Table 11.

Discussion—*Histopomphus* aff. *H. cervicornis* differs from the hypotype of *H. cervicornis* described by Tappan (1943) in having larger central chambers and shorter necks. The species at hand also resembles a species described by Tappan (1940) as *Bullopora* sp. (?=*H.* sp.), but differs in being slightly less elongate and in having more than a single chamber.

The placement of this species in *Histopomphus* is based on the presence of a multilocular polymorphine stage, rather than the unilocular early stage typical of *Vitriwebbina*. This feature is present in four of the seventeen specimens examined from the Tucumcari Shale. Tappan (1943) did not mention the polymorphine stage of *Histopomphus cervicornis*. However, Loeblich and Tappan (1949) noted the polymorphine early portion in specimens from the Walnut Creek Formation of Oklahoma.

Histopomphus cervicornis was originally described from the Albian of England, and has also been reported from Germany (Eichenberg, 1934). In the United States, the species is known from the Grayson Formation (Washita Group) of Texas (Tappan, 1940), from the Duck Creek Formation of Texas and Oklahoma (Tappan, 1943) and from the Walnut Creek Formation of Oklahoma (Loeblich and Tappan, 1949).

Histopomphus is considered by Sliter and Baker (1972) to occupy Cretaceous inner-shelf environments (0–100 m). In modern oceans, the Polymorphidae are typical of either the 0–30-m inner shelf (Parker, 1954; Resig, 1958) or the 30–100-m middle shelf (Natland, 1933; Walton, 1955; Uchio, 1960).

CONCLUSIONS

The present study indicates the *Texigryphaea* horizon in the basal Tucumcari Shale at Pyramid Mountain developed in a normal-marine environment. Foraminiferan benthonic/planktonic ratios, diversity, test composition, and gross morphology suggest a depth range of about 20–70 m. This environment was probably not subject to normal wave activity, but some agitation due to bottom currents may have occurred sporadically, as indicated by the development of local shell conglomerates in the basal Tucumcari.

The Foraminifera and Ostracoda both support correlation of the *Texigryphaea* horizon with the lower Washita Group (Duck Creek to Weno Formations) of Texas and Oklahoma. There is little evidence of endemics indicating open access to these areas. The most likely correlation is with the upper Duck Creek Formation interval because this also represents the period of maximum transgression in other areas.

TABLE 11. Measurements (in mm) of *Histopomphus* aff. *H. cervicornis* from the Tucumcari Shale.

Specimen Number	Number of Chambers	Chamber Length	Chamber Width	Number of Necks	Total Length
1	1	4.7	3.1	4	4.7
2	3	6.1	6.0	5	20.1
3	1	+6.1	3.8	?3	+6.1
4	2	4.3	+2.7	3	11.1
5	2	3.9	5.1	3	8.6
6	+3	10.2	2.7	3	23.8
7	2	8.8	5.7	6	14.1
8	2	8.4	5.1	?4	15.8
9	2	5.8	3.9	3	11.9
10	1	5.6	3.3	3	5.6
11	3	11.3	6.6	5	26.0
12	2	9.1	12.7	5	18.5
13	1	9.9	5.1	4	9.9
14	?3	?8.9	5.3	4	22.9
*15	2	7.7	3.9	4	13.8
16	1	14.9	7.9	5	14.9
17	?2	13.7	+2.7	?5	22.9
18	?1	7.9	9.9	8	7.9
19	2	8.1	10.2	4	16.3
20	2	4.8	11.9	6	8.1

The attached Foraminifera found in the Tucumcari Shale horizon were not host-specific, although the *Texigryphaea* valves and valve fragments were most often used because they were most abundant. These foraminiferans preferred dead, often fragmented bivalves as substrates. The attached Foraminifera seem to have had some preference for previously occupied substrates in the sense that, once a substrate was occupied, other Foraminifera of the same or different species would "follow the leader" in substrate utilization. This tendency has been documented in modern epizoans and shown to be caused by a response of the larvae to chemical signals from other attached specimens.

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REFERENCES

Albers, C. C., Bane, M. R., Dorman, J. H., Dunlap, J. B., Jr., Lampton, J. M., Macomber, D., Martin, G. B., Parrott, B. S., Skinner, H. C., Sylvester, R. K. and Ventress, W. P. S. (New Orleans Paleontological Committee), 1966, Foraminiferal ecological zones of the Gulf Coast: Gulf Coast Association of Geological Societies, Transactions, v. 16, pp. 345–348.

Alexander, C. I., 1929, Ostracoda of the Cretaceous of north Texas: University of Texas, Bulletin 2907, 137 pp.

Alexander, C. I., 1933, Shell structure of the ostracode genus *Cytheropteron*, and fossil species from the Cretaceous of Texas: Journal of Paleontology, v. 7, pp. 181–214.

Benson, R. H., Berdan, J. M., Bold, W. A., Hanai, T., Hessland, I., Howe, H. V., Kesling, R. V., Levinson, S. A., Reyment, R. A., Moore, R. C., Scott, H. W., Shaver, R. H., Sohn, I. G., Stover, L. E., Swain, F. M., Sylvester-Bradley, P. C. and Wainwright, J., 1961, Crustacea, Ostracoda; *in* Moore, R. C. and Pitrat, C., eds., Treatise on Invertebrate Paleontology, Part Q, Arthropoda 3: Geological Society of America and University of Kansas Press, New York, 442 pp.

Bishop, B. A., 1967, Stratigraphic study of the Kiamichi Formation of the Lower Cretaceous of Texas; *in* Hendricks, L., ed., Comanchean (Lower Cretaceous) stratigraphy and paleontology of Texas: Permian Basin Section, Society of Economic Paleontologists and Mineralogists, Midland, pp. 155–180.

Brand, J. P. and Mattox, R. B., 1972, Pre-Dakota Cretaceous Formations of northwestern Texas and northeastern New Mexico: New Mexico Geological Society, Guidebook 23, pp. 98–104.

Brasier, M. D., 1982, Architecture and evolution of the foraminiferid test—a theoretical approach; *in* Banner, F. T. and Cord, A. R., eds., Aspects of micropaleontology, George Allen and Unwin, London, pp. 1–41.

Brooks, L. C., 1959, Biostratigraphy of the Purgatoire Formation, west-central Quay County, New Mexico [M.S. thesis]: Texas Technological College, Lubbock, 123 pp.

Carter, D. J. and Hart, M. B., 1977, Aspects of mid-Cretaceous stratigraphical micropaleontology: British Museum (Natural History), Bulletin, Geology Series, v. 29, no. 1, 135 pp.

Chamney, T. P., 1976, Foraminiferal morphology symbol for paleoenvironmental interpretation of drill cutting samples: Arctic America; *in* Schafer, C. T. and Pelletier, B. R., eds., First international symposium on benthonic Foraminifera of continental margins, part B, paleoecology and biostratigraphy: Maritime Sediments, Special Publication 1, Halifax, pp. 585–624.

Fisher, R.A., Corbet, A. S. and Williams, C. B., 1943, The relation between the number of species and the number of individuals in random samples of an animal population: Journal of Animal Ecology, v. 12, pp. 42–58.

Frizzell, D. L., 1954, Handbook of Cretaceous Foraminifera of Texas: University of Texas, Bureau of Economic Geology, Report of Investigations 22, 232 pp.

Jenkins, D. G. and Murrey, J. W., 1981, Stratigraphical atlas of fossil Foraminifera: British Micropalaeontological Society, London, 310 pp.

Kessinger, W. P., Jr., 1967, Cretaceous (Kiamichi and Duck Creek) Foraminifera from Lynn, Terry, Hockley, and Lamb Counties, Texas; *in* Hendricks, L., ed., Comanchean (Lower Cretaceous) stratigraphy and paleontology of Texas: Permian Basin Section, Society of Economic Paleontologists and Mineralogists, pp. 300–308.

Howe, H. V. and Laurencich, L., 1958, Introduction to the study of Cretaceous Ostracoda: Louisiana State University Press, Baton Rouge, 536 pp.

Kues, B. S., 1985, Early geological explorations in northeastern and east-central New Mexico: New Mexico Geological Society, Guidebook 36.

Kues, B. S. and Kietzke, K. K., 1985, Supplemental road log 3, to Mesa Quemado and Pyramid Mountain: New Mexico Geological Society, Guidebook 36.

Kues, B. S., Lucas, S. G., Kietzke, K. K. and Mateer, N. J., 1985, Synopsis of Tucumcari Shale, Mesa Rica Sandstone and Pajarito Shale paleontology, Cretaceous of east-central New Mexico: New Mexico Geological Society, Guidebook 36.

Loeblich, A. R., Jr., 1946, New Washita Foraminifera: Journal of Paleontology, v. 20, pp. 238–258.

Loeblich, A. R., Jr. and Tappan, H., 1949, Foraminifera from the Walnut Formation (Lower Cretaceous) of northern Texas and southern Oklahoma: Journal of Paleontology, v. 23, pp. 245–266.

Loeblich, A. R., Jr. and Tappan, H., 1950, Foraminifera from the type Kiowa Shale, Lower Cretaceous, of Kansas: University of Kansas, Paleontological Contributions, Protozoa, art. 3, pp. 1–15.

Loeblich, A. R., Jr. and Tappan, H., 1964, Sarcodina chiefly "Thecamoebians" and Foraminifera; *in* Moore, R. C., ed., Treatise on Invertebrate Paleontology, Part C, Protista 2(1) and 2(2): Geological Society of America and University of Kansas Press, New York, 900 pp.

Loeblich, A. R., Jr. and Tappan, H., 1982, A revision of mid-Cretaceous textularian foraminifers from Texas: Journal of Micropaleontology, v. 1, pp. 55–69.

Lozo, F. E., Jr., 1943, Bearing of Foraminifera and Ostracoda on Lower Cretaceous Kiamichi–Washita boundary of north Texas: American Association of Petroleum Geologists, Bulletin, v. 27, pp. 1060–1080.

Lozo, F. E., Jr., 1944, Biostratigraphic relations of some north Texas Trinity and Kiamichi (Comanchean) Foraminifera: American Midland Naturalist, v. 31, pp. 513–582.

Mancini, E. A., 1982, Foraminiferal population changes in a shallow, epicon-

tinental marine carbonate–claystone sequence; Main Street–Grayson interval (Cretaceous), north-central Texas: Third North American Paleontological Convention, Proceedings, v. 2, pp. 353–358.
Marcou, J., 1858, Geology of North America, with two reports on the prairies of Arkansas and Texas, the Rocky Mountains of New Mexico, and the Sierra Nevada of California, originally made for the United States government: Zürcher, Zürich, 144 pp.
Markhoven, F. P. C. M., 1963, Post-Paleozoic Ostracoda: their morphology, taxonomy, and economic use. Volume II, generic descriptions: Elsevier Publishing Company, Amsterdam, 478 pp.
Murray, J. W., 1973, Distribution and ecology of living benthonic foraminiferids: Crane, Russals and Co., New York, 274 pp.
Natland, M. L., 1933, The temperature- and depth-distribution of some Recent and fossil Foraminifera in the southern California region: California University, Scripps Institute Oceanography, Bulletin, Technological Series, v. 3, pp. 225–230.
Parker, F. L., 1954, Distribution of the Foraminifera in the northeastern Gulf of Mexico: Harvard University, Museum of Comparative Zoology, Bulletin 111, pp. 453–588.
Resig, J. M., 1958, Ecology of Foraminifera of the Santa Cruz Basin, California: Micropaleontology, v. 4, pp. 287–308.
Scott, R. W., 1970a, Paleoecology and paleontology of the Lower Cretaceous Kiowa Formation, Kansas: University of Kansas, Paleontological Contributions, art. 52 (Cretaceous 1), 94 pp.
Scott, R. W., 1970b, Stratigraphy and sedimentary environments of Lower Cretaceous rocks, southern Western Interior: American Association of Petroleum Geologists, Bulletin, v. 54, pp. 1225–1244.
Scott, R. W., 1974, Bay and shoreface benthonic communities in the Lower Cretaceous: Lethaia, v. 7, pp. 315–330.
Severin, K. P., 1983, Test morphology of benthonic Foraminifera as a discriminator of biofacies: Marine Micropaleontology, v. 8, pp. 65–76.
Sliter, W. V. and Baker, 1972, Cretaceous bathymetric distribution of benthonic Foraminifera: Journal of Foraminiferal Research, v. 2, pp. 167–183.
Tappan, H., 1940, Foraminifera from the Grayson Formation of northern Texas: Journal of Paleontology, v. 14, pp. 93–126.
Tappan, H., 1943, Foraminifera from the Duck Creek Formation of Oklahoma and Texas: Journal of Paleontology, v. 17, pp. 476–517.
Tipsworth, H. L., Setzer, F. M. and Smith, F. L., Jr., 1966, Interpretation of depositional environment in Gulf Coast petroleum exploration from paleoecology and related stratigraphy: Gulf Coast Association of Geological Societies, Transactions, v. 16, pp. 119–130.
Todd, R. and Bronniman, P., 1957, Recent Foraminifera and Thecamoebina from the eastern Gulf of Paria: Cushman Foundation for Foraminiferal Research, Special Publication 3, 43 pp.
Truax, S., III, 1980, Foraminiferal distribution and paleoecology of the Weno Formation (Lower Cretaceous) along Sycamore Creek, Tarrant County, Texas [M.S. thesis]: University of Southwest Louisiana, Lafayette, 129 pp.
Uchio, T., 1960, Ecology of living benthonic Foraminifera from the San Diego, California, area: Cushman Foundation for Foraminiferal Research, Special Publication 5, 72 pp.
Vieaux, G. G., 1941, New Foraminifera from the Denton Formation in northern Texas: Journal of Paleontology, v. 15, pp. 624–628.
Walton, W. R., 1955, Ecology of living benthonic Foraminifera, Todos Santos Bay, Baja California: Journal of Paleontology, v. 29, pp. 952–1018.

APPENDIX

The following list presents Foraminifera and Ostracoda identified by Brooks (1959) from the Tucumcari Shale in Quay County, New Mexico, with taxonomic revisions and suggested corrections.

Brooks (1959)	Present Study
FORAMINIFERA	
Reophax echernex	*Reophax echernex*
R. minuta	*R. deckeri*
R. goodlandensis	*R. goodlandensis*
R. aff. *R. cylindricacea*	*R.* aff. *R. cylindricacea*
R. aff. *R.* sp. A Kessinger	*R.* aff. *R.* sp. A Kessinger
Haplostiche texana	*Cribratina texana*
Ammodiscus gaultinus	*Glomospira gaultinus*
A. kiowensis	*G. gaultinus*
Lituotuba sp. A	*Litutuba* sp. A
Ammobaculites subcretaceus	*Ammobaculites subcretaceus*
A. goodlandensis	*A. goodlandensis*
Triplasia acutocarinata	*Triplasia goodlandensis*
T. goodlandensis	*T. goodlandensis*
Lituola subgoodlandensis	*Lituola subgoodlandensis*
Textularia conica	*Textulariopsis conica*
T. rioensis	*T. rioensis*
T. washitensis	*T. washitensis*
T. aff. *T.* sp. A Kessinger	*T.* aff. *T.* sp. A Kessinger
T. (?) sp. A	*T.*(?) sp. A
Trochammina depressa	*Trochammina depressa*
T. krumensis	*T. krumensis*
T. obliqua	*T. obliqua*
T. truncata	*T. truncata*
Acruliammina longa	*Acruliammina longa*
Robulus munsteri	*Robulus munsteri*
R. aff. *R.* sp. A Kessinger	*R.* aff. *R.* sp. A Kessinger
R. n.sp. A	*R.* n.sp. A
Lenticulina gaultina	*Lenticulina gaultina*
L. washitensis	*L. washitensis*
L. aff. *L. gunderbookaensis*	*L.* aff. *L. gunderbookaensis*
L. aff. *L. warregoensis*	*L.* aff. *L. warregoensis*
L. n.sp. A	*L.* n.sp. A
Planularia dissona	*Planularia dissona*
Saracenaria cushmani	*Saracenaria cushmani*
Marginulina tenuissima	*Marginulina tenuissima*
Dentalina communis	*Dentalina communis*
Nodosaria barkeri	*Nodosaria barkeri*
N. bifurcata	*N. bifurcata*
N. harrisi	*N. harrisi*
N. n.sp. A	*N. harrisi*
Lingulina nodosaria	*Lingulina nodosaria*
Vaginulina tripleura	*Vaginulina tripleura*
Citharina intumescens	*Citharina striolata*
C. kochii	*C. kochii*
Neoflabellina howei(?)	*Palmula howei*
Lagena apiculata	*Lagena apiculata*
L. striatifera	*L. striatifera*
L. sulcata	*L. sulcata*
L. n.sp. A	*L.* n.sp. A
Tristix chapparsi	*Tristix chapparsi*
Discorbis minima	*Discorbis minima*
Valvulineria asterigerinoides(?)	*Valvulineria asterigerinoides*(?)
Gyroidina loetterlei	*Gyroidina loetterlei*
Anomalina petita	*Gavelinella plummerae*
A. plummerae	*G. plummerae*
A. n.sp. A	*G.* n.sp. A
OSTRACODA	
Cytherella ovata	*Cytherella ovata*
C. commanchensis	*C.* n.sp.
Cytherelloidea obliquirugata	*Cytherelloidea obliquirugata*
C. reticulata	*C. reticulata*
C. williamsoniana var. *stricta*	*C. reticulata*
C. aff. *C.* n.sp. Anderson	*C. reticulata*
Bairdia roundyi	*Bairdia roundyi*
Paracypris dentonensis	*Paracypris dentonensis*
P. siliqua	*P. siliqua*
Cytheridea amygdaloides	*Cytheridea amygdaloides*
C. amygdaloides var. *brevis*	*C. amygdaloides*
C. goodlandensis	*C. goodlandensis*
C. oliverensis	*Schuleridea oliverensis*
C. washitensis	*Haplocytheridea washitensis*
C. n.sp. A	*Cytheridea* n.sp. A
Cythere concentrica	*Centrocythere concentrica*
C. n.sp. A	*C.* n.sp. A
Cythereis dentonensis	*Protocythere sandidgei*
C. fredricksburgensis	*Cythereis fredricksburgensis*
C. krumensis	*C. krumensis*
C. mahonae	*C. mahonae*
C. nuda	*C. nuda*
C. paupera	*Trachyleberis paupera*
C. worthensis	*Isocythereis worthensis*
Cytheropteron acutolatum	*Cytheropteron acutolatum*
C. bilobatum	*C. bicornutum*
C. howelli	*C. howelli*
C. paenorbiculatum	*C. paenorbiculatum*
C. pirum	*C. bicornutum*
C. jugosum	*C. paenorbiculatum*
C. tumidum	*C. tumidum*