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# Middle Permian (Late Guadalupian) foraminifers from Dark Canyon, Guadalupe Mountains, New Mexico

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**ABSTRACT:** Late Capitanian foraminifers are described from two cores taken by Amoco on the north side of the entrance of Dark Canyon. The Amoco #1 core (400ft) penetrates proximal forereef debris of the Tansill Formation and bottoms in massive Capitan reefal limestone. The Amoco #2 core (468ft) penetrates proximal backreef lagoonal deposits of the upper Yates Formation and the Tansill Formation.

Foraminifers are very diverse and abundant in these cores. Based on the fusulinid distribution, the *Codonofusiella extensa* (upper part of the Yates Formation), *Yabeina texana*, *Paradoxiella pratti* and *Reichelina lamarensis* zones (lower and middle Tansill Formation) are present in the Amoco #2 core. Among small foraminifers, the first appearance of the genera *Sengoerina* and *Crescentia* are recorded at the base of the *Y. texana* Zone and they disappear at the top of the *P. pratti* Zone. The genus *Baisalina* appears at the base of the *R. lamarensis* Zone and disappears at the top of that zone. The Ocotillo Silt Member and upper dolomitized part of the Tansill Formation do not contain foraminifers. The Ocotillo Silt Member is present in the Amoco #2 core at a depth of from 88 to 112ft and, because of its regional dip of approximately six degrees, would possibly project below the base of the Amoco #1 core, thus correlating the Capitan and Tansill formations in the Amoco #1 core with the upper Tansill Formation of the Amoco #2 core. The lower part of the Amoco #1 core (from 110 to 370ft) contains fusulinacean species of the *Paraboultonia splendens* Zone. The assemblage of small foraminifers is dominated by species of nodosariids and hemigordiopsids. Four new genera and sixteen new species of foraminifers are described from both cores.

## INTRODUCTION AND STRATIGRAPHIC SETTING

The Guadalupe Mountains in southeastern New Mexico and West Texas is a northeasterly tilted tectonic block of Middle/Upper Permian strata exhumed in the Tertiary (Hayes 1964) and forms the classic shelf-to-basin exposures of the Middle Permian Capitan reef depositional system. The International Commission on Stratigraphy (ICS) recently published an International Standard for the Middle Permian Guadalupian Series consisting of the Roadian, Wordian and Capitanian stages, the stratotype sections of which were designated in the Guadalupe Mountains (Gradstein 2000, Gradstein et al. 2004, Wardlaw et al. 2004). The lower boundaries of these stages have been drawn based primarily on the first appearance of conodonts: for the Roadian - *Jinogondolella nankingensis*; the Wordian - *J. aserrata*; and the Capitanian - *J. postserrata* (Glenister et al. 1999, Wardlaw et al. 2004) (text-fig. 1). The boundary of the Guadalupian with the overlying Lopingian Series is based on the evolutionary transition of the conodont *Clarkina postbitteri hongshuiensis* into *C. postbitteri postbitteri* (Wardlaw et al. 2004). In a recent paper, Lambert et al. (2002) illustrated specimens of *C. p. hongshuiensis* from the western part of the Apache Mountains in West Texas that conclusively demonstrated that the Guadalupian Series is essentially complete in the type area.

Fusulinaceans are also present in abundance in Guadalupian strata of West Texas and have been used for many years in both regional and international correlations of the Permian System (Dunbar and Skinner 1937, Ross 1964, Wilde 1955, 1975, 1990, Skinner and Wilde 1954, 1955, Wilde and Rudine 2000, Yang and Yancey 2000). Large fusulinaceans of several genera, such as *Parafusulina*, *Skinnerin*a, and *Polydiexodina*, are present in the lower part of the Guadalupian, but not in the upper part. In the Guadalupe Mountains, the last appearance of the very large fusulinacean *Polydiexodina* appears to be in the middle part of the reefal Yates Formation (top of Yates B, middle Capitanian, Bebout and Kerans 1993) (text-fig. 1). The fusulinacean assemblage in the overlying upper part of the Yates Formation, Tansill (equivalent to basinal Lamar and "post-Lamar") Formation is dominated by small fusulinaceans such as *Codonofusiella*, *Yabeina*, *Reichelina,* and *Paraboultonia*. Wilde (1990) proposed a Zone of *Paraboultonia* for the last fusulinacean interval at the top of the Guadalupian. Recently, Wilde et al. (1999) formally introduced the name Reef Trail Member for the "post-Lamar" strata at the top of the Bell Canyon Formation and illustrated fusulinaceans from four successive fusulinacean zones: *Yabeina*, *Paradoxiell*a, *Reichelina*, and *Paraboultonia*. Unfortunately, in this paper (Wilde et al. 1999, fig. 3), the Guadalupian/Lopingian boundary was drawn with question in the lower part of the Reef Trail Member with the implication that the *Paraboultonia* Zone was entirely of Lopingian age. Although Wilde et al. (1999) discussed the fusulinacean succession in this interval as support for this conclusion, it was premature for Wilde to suggest the placement of this boundary in the Guadalupian stratotype because the conodont succession in the type section of the Reef Trail Member had not been completely documented. In a recent paper, Lambert et al. (2002) clearly documented the upper boundary of the Capitanian in an undisturbed section in the western part of the Apache Mountains to the south of the Guadalupe Mountains. In this section (Lambert et al. 2002, fig. 3), the last appearance of *Paraboultonia* is in bed E1, about two meters below the first beds of the Castile Formation and in the same bed with the first appearance of the conodont *Clarkina postbitteri hongshuiensis*

Henderson, Mei and Wardlaw. The base of the Lopingian has since been defined at the first appearance of the conodont *Clarkina postbitteri postbitteri* (Wardlaw et al. 2004). Thus, the Zone of *Paraboultonia* is entirely Late Guadalupian in age and there are no known Lopingian fusulinaceans in the West Texas succession. No evidence was documented in this study of small foraminiferal species in the Dark Canyon succession to dispute this conclusion.

A number of well known canyons, among them McKittrick, Big, Slaughter, Rattlesnake, and Walnut, cut the east facing scarp of the Guadalupe Mountains and expose various facies of the forereef, reef and backreef deposits of the Guadalupian. Dark Canyon, the northernmost of these canyons, trends east-west, and is located about 10 miles (15km) southwest of Carlsbad, New Mexico in the SW ¼ of Sec. 24, T23E, R25E, Eddy County, New Mexico (text-fig. 2).

The two Amoco research cores were taken on the north side of Dark Canyon near the entrance (text-figs. 3, 4) in the shallow-water backreef Capitanian facies where the upper Guadalupian (Capitanian) has been subdivided into three formations (in ascending order): the Seven Rivers, Yates and Tansill formations. In this paper, small foraminifers and fusulinaceans from the *Yabeina*, *Paradoxiella, Reichelina* and *Paraboultonia* zones are described from these two cores. The Amoco #1 core (no. 4492) was taken near the mouth of the canyon and penetrates 398ft (121.3m) of proximal forereef debris of the Tansill Formation and bottoms in massive Capitan reef facies. The Amoco #2 core (no. 4518) was taken approximately 4000ft (1220m) to the west and penetrates 468ft (142.6m) of mostly backreef lagoonal shelf deposits of the Tansill Formation and bottoms in the upper part of the underlying Yates Formation (Tyrrell et al. 1978, Ward 1988). Over 750 large (2"x3") thin sections were made every 2 inches (5cm) throughout the fossiliferous strata of the cores. Algae and bryozoans are also common to abundant in the many intervals of the cores, but have not yet been studied.

## PREVIOUS WORKS ON FORAMINIFERS

Non-fusulinacean small foraminifers are not well known in the Guadalupian of West Texas, although a few have been illustrated. In the earliest paper known, two equatorial sections of the genus *Abadehella* Okimura and Ishii (in Okimura et al. 1975) are illustrated from the Delaware Mountain Formation of the Apache Mountains, but it was mistakenly assigned to the alga genus *Anthracoporella* Pia 1920 (Johnson 1951, pl. 7, fig. 6-7). Later, Toomey and Cys (1977) presented a small list and one image of small foraminifers from Tansill transitional facies B at the entrance of Dark Canyon, and noted the presence of representatives of the genera *Geinitzina* Spandel 1901, *Tetrataxis* Ehrenberg 1854 (mistaken identification of the genus *Abadehella*), *Globivalvulina* Schubert 1921 and *Hemigordius* Schubert 1908. Recently, Wilde et al. (1999) illustrated several sections of small foraminifers attributed to *Abadehella* cf. *A. coniformis* Okimura and Ishii, from the Bell Canyon Formation at Seven Heart Gap in the Apache Mountains. Recently, Nestell and Nestell (in Lambert et al. 2002) illustrated specimens of several genera of small foraminifers, including *Pseudoammodiscus*, *Hemigordius*, *Rectocornuspira*, *Multidiscus*, *Calcitornella*, *Nodosaria*, *Ichthyolaria*, and *Abadehella*. These forms were recovered from insoluble residues from late Middle Permian strata in the western part of the Apache Mountains containing the conodonts *Jinogondolella xuanhanensis, J. altudaensis*, and *J. granti* (Lambert et al. 2002).

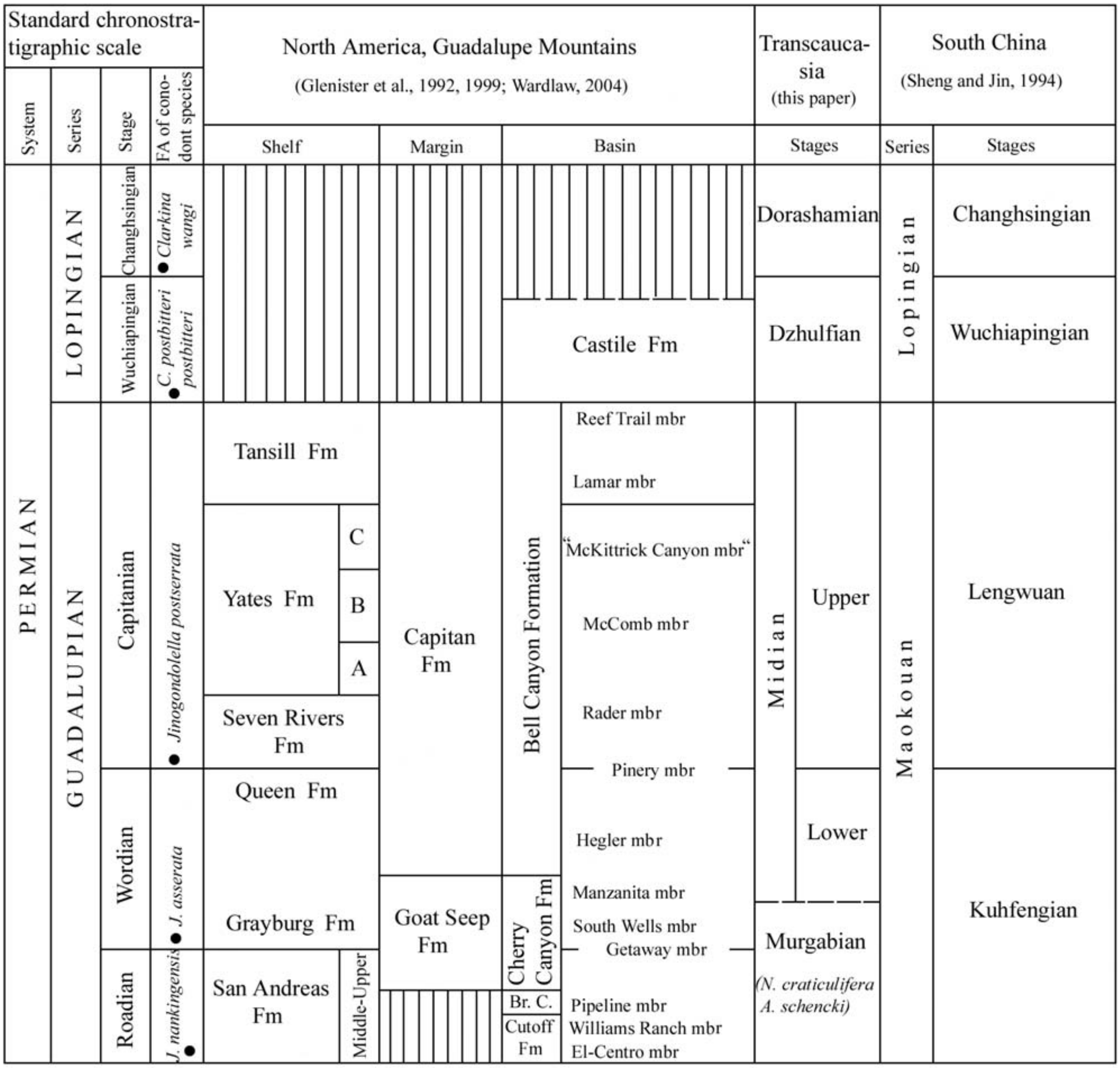
Only a few genera and species of fusulinaceans have been described from the upper Guadalupian (upper Yates/Tansill or the equivalent Lamar/Reef Trail) strata in West Texas. Wilde et al. (1999) presented a thorough discussion of the history of the discovery of many of these forms. Two interesting and controversial occurrences are the Tethyan form *Yabeina texana*, first reported from the McKittrick Canyon area by Skinner and Wilde (1955), and *Paraboultonia splendens*, first described from Seven Heart Gap in the Apache Mountains (Skinner and Wilde 1954). *Yabeina texana* is the only true verbeekinid found in North America, except for specimens from exotic terranes in the Pacific Northwest. Since its first discovery in the basal Lamar Limestone Member of the McKittrick Canyon area, *Yabeina texana* has also been reported from the Tansill Formation at the top of McKittrick Canyon (Tyrrell, personal communication, 2005) and near the entrance of Dark Canyon (Tyrrell 1962, 1969).

## DISTRIBUTION OF FORAMINIFERS IN THE CORE HOLES

The Amoco #1 core has 220ft of Tansill, 70ft of alternating Tansill/Capitan lithologies, and 110ft of massive Capitan (text-fig. 5). Small foraminifers in the cored section consist of 38 species belonging to 25 genera. The following species appear in the massive Capitan facies: *Tuberitina variabilis* n. sp., *Vachardella longiuscula* n. gen., n. sp., *Agathammina* sp. 1, *Nodosaria* cf. *N. novizkiana* Sosnina, *N.* cf. *N. partisana* Sosnina, *Geinitzina* sp. 1, *G.* sp. 4, *Tauridia* sp. 4, *Ichthyolaria* sp. 1, *Calvezina* sp. 1, *Globivalvulina* sp. 1, *Abadehella* sp. 2, and *Deckerella* sp. Almost all species continue into the overlying backreef Tansill facies, except for *Nodosaria* cf. *N. partisana*, *Geinitzina* sp. 1 and *G.* sp. 4. Only 25 species occur in the Tansill Formation. The most characteristic species are *Tansillites anfractuosus* n. gen., n. sp., *Pseudohemigordius incredibilis* n. gen., n. sp., *Graecodiscus praecursor* n. sp., *Polarisella lingulae* n. sp., *Neoendothyranella wildei* n. gen., n. sp., and *Aschemonella* sp.

Fusulinaceans present in the Amoco #1 core are represented by the species *Paraboultonia splendens* Skinner and Wilde, *Reichelina* aff. *R. changhsingensis* Sheng and Chang, *R.* cf. *R. lamarensis* Skinner and Wilde, *Parareichelina* sp., *Codonofusiella* (*Lantschichites*) *altudaensis* Wilde and Rudine, *Pseudokahlerina capitanensis* n. sp., and *Rauserella erratica* Dunbar (text-fig. 5). These species belong to the *Paraboultonia splendens* zone established by Wilde (1990).

The Amoco #2 core consists entirely of backreef facies, having 399ft of the Tansill Formation and 70ft of the underlying Yates Formation (text-fig. 6). Small foraminifers are very diverse and represented by 46 species belonging to 29 genera. *Tuberitina variabilis* n. sp., *Haplophragmina? infrequens* n. sp., *Vachardella longiuscula* n. gen., n. sp., *Palaeonubecularia marginata* n. sp., *Pseudohemigordius incredibilis* n. gen., n. sp., *Agathammina* sp. 1, *Graecodiscus* sp. 2, *Nodosaria capitanensis* n. sp., *Geinitzina aetheria* n. sp., *Howchinella* sp. 1, *Globivalvulina guadalupensis* n. sp., *Abadehella* ex gr. *A. coniformis* Okimura and Ishii, *Neoendothyranella wildei* n. gen., n. sp., and *Spireitlina* sp. appear in the upper part of the Yates Formation. Almost all species continue into the overlying Tansill Formation, except *Howchinella* sp. 1, and *Spireitlina* sp. The Tansill Formation is subdivided into four informal units: lower, middle, Ocotillo Silt Member, and upper (Tyrrell et al. 1978). In the lower Tansill, the species *Pseudolituotuba* (*Pseudospira*) sp. 1, *Agathammina pusilla* (Geinitz), *Nodosaria* cf. *N. novizkiana*



TEXT-FIGURE 1
Correlation chart for Middle and Upper Permian strata in the West Texas, Transcaucasia, and South China.

Sosnina, *Polarisella lingulae* n. sp., *Rectoglandulina lepida* (Wang), *Eomarginulinella* sp. 1, *E.* sp. 3, *Tauridia* sp. 1, *Pachyphloia* sp., *Robustopachyphloia*? sp., *Globivalvulina* sp. 1, *Crescentia migrantis* n. sp., *Dagmarita* sp., *Abadehella* sp. 2, *Spireitlina* sp. 2, *S*? sp., and *Deckerella* sp. appear for the first time. All but eight species continue into the middle Tansill. Only *Nodosaria* cf. *N. novizkiana*, *Polarisella lingulae* n. sp., *Eomarginulinella* sp. 1, *Spireitlina*? sp., and *Deckerella* sp. are characteristic for the lower Tansill. In the middle Tansill, the species *Calcitornella* sp., *Calcivertella* sp., *Tansillites anfractuosus* n. gen., n. sp., *Baisalina americana* n. sp., *Agathammina* ex gr. *A. rosella* G. Pronina, *A.* sp. 4, *A.* sp. 7, *Graecodiscus praecursor* n. sp., *Nodosaria* sp. 8, *Lingulina*? sp., *Tauridia* sp. 4, *Globivalvulina* sp. 4, and *Endothyra* sp. 1 appear at the first time.

In the upper part of the Yates Formation in the Amoco #2 core, fusulinaceans are represented by the species *Reichelina*? sp., *Codonofusiella extensa* Skinner and Wilde, and *Rauserella bengeensis* Wilde and Rudine (text-fig. 6). The first two noted species continue into the lower Tansill; *R. bengeensis* also extends into the middle Tansill. The first appearance of the distinctive species *Yabeina texana* Skinner and Wilde marks the base of the Tansill Formation. Abundant specimens of *Y. texana* are also present throughout several meters of the basal part of the Tansill Formation in a *Mizzia* grainstone in a surface outcrop at the base of the north wall of Dark Canyon about 250 meters to the southwest from the site of the Amoco #2 core and about 1500 meters from the mouth of Dark Canyon. *Codonofusiella* sp. and *Paradoxiella pratti* Skinner and Wilde appear above the last occurrence of *Y. texana* in the core, and

*Reichelina lamarensis* Skinner and Wilde marks approximately the base of the middle Tansill (text-fig. 6). No foraminifers were found in the Amoco #2 core in the Ocotillo Silt Member and the overlying dolomitic upper Tansill. The fusulinacean assemblages present in the Amoco #2 core follow Wilde (1990), Wilde et al. (1999), and Wilde and Rudine's (2000) proposed zonation of *Codonofusiella*, *Yabeina*, *Paradoxiella*, *Reichelina* for Late Capitanian age strata in the Guadalupe Mountains (text-figs. 6, 7).

The upper part of the Capitan and basal part of the Tansill formations in the Amoco #1 core can probably be correlated with the upper Tansill of the Amoco #2 core by the stratigraphic position and regional dip of the Ocotillo Silt Member. Parsley (1988, p. 35, fig. 15) showed the Ocotillo Silt Member as "pinching out" to the east in the direction of the position of Amoco #1 core. It is present in the Amoco #2 core at a depth of from 88ft to 112ft and, because of its regional dip of approximately six degrees, would project just below the base of the Amoco #1 core. Mazzullo (1999, p.108, fig. 2) noted the presence of the Ocotillo Silt Member (thickness about 33ft) as "commonly brecciated siltstones, silty dolomites and micritic limestones" and poorly exposed in the south wall of Dark Canyon just back from the entrance.

## ANALYSIS AND AGE OF FORAMINIFERAL ASSEMBLAGE

The assemblages of small foraminifers in both cores are very rich and diverse, but mostly only endemic species are represented. Only seven species are known from other regions, mostly in the Tethyan realm: *Rectoglandulina lepida* (Wang), *Nodosaria novizkiana* Sosnina, *N. grandecamerata* Sosnina, *N. partisana* Sosnina, *Agathammina pusilla* (Geinitz), *Agathammina rosella* G. Pronina, and *Abadehella coniformis* Okimura and Ishii. *Rectoglandulina lepida* is known in the Xarla Formation of Xizang, China that has been correlated with the Maokou Formation of South China (Wang 1986), and also in the *Pseudoammodiscus baissalensis* - *Reitlingeria vediensis* Zone of the lower Midian (= Wordian) of Transcaucasia (Pronina 1990). *Nodosaria novizkiana*, *N. grandecamerata* and *N. partisana* occur in the *Metadoliolina lepida* Zone of the Chandalaz Group of the upper Midian (= Capitanian) of South Primorye (Sosnina 1965, 1980). *Agathammina pusilla* is present in the lower Zechstein of Poland (Wolanska 1959), the Naujoji Akmene Formation of the Baltic area (Miklukho-Maklay and Ukharskaya 1975), the Khachik Formation of the upper Midian (= Capitanian) of Transcaucasia (Pronina 1990), and many other regions of the Tethyan realm. It is also reported from the Mantuan Productus Bed of the Peawaddy Formation of the Bowen Basin of Australia (Palmieri 1994). *Agathammina rosella* was described from the Khachik Formation of the upper Midian (= Capitanian) of Transcaucasia (Pronina 1988a). *Abadehella coniformis* is known from many regions of the Tethys.

We consider the genus *Pseudohemigordius* to be present in the lower Zechstein of Poland (Jurkiewicz 1966), but mistakenly identified there as *Glomospira* sp.

For the first time, representatives of the Tethyan genera *Graecodiscus* Vachard (in Vachard et al. 1993a), *Sengoerina* Altiner 1999, *Crescentia* Ciarapica, Cirilli, Martini and Zaninetti 1986, *Baisalina* Reitlinger 1965, *Dagmarita* Reitlinger 1965, *Eomarginulinella* Sosnina 1967 and *Partisania* Sosnina 1978 are reported herein from the Capitanian of West Texas. Representatives of the genus *Graecodiscus* are known from the lower Dzhulfian of Greece (Vachard et al. 1993a) and upper Changhsingian of the Northwestern Caucasus (Pronina-Nestell and Nestell 2001). The genus *Sengoerina* was established from a Midian olistholith in northwestern Anatolia, Turkey (Altiner 1999). The age range of that genus, according to that author, is limited to the Midian. Vachard (personal communication, 2005) stated that he has specimens of *Sengoerina* in the Murgabian (= Wordian) strata in the Hindu Kush Mountains of northern Afghanistan.

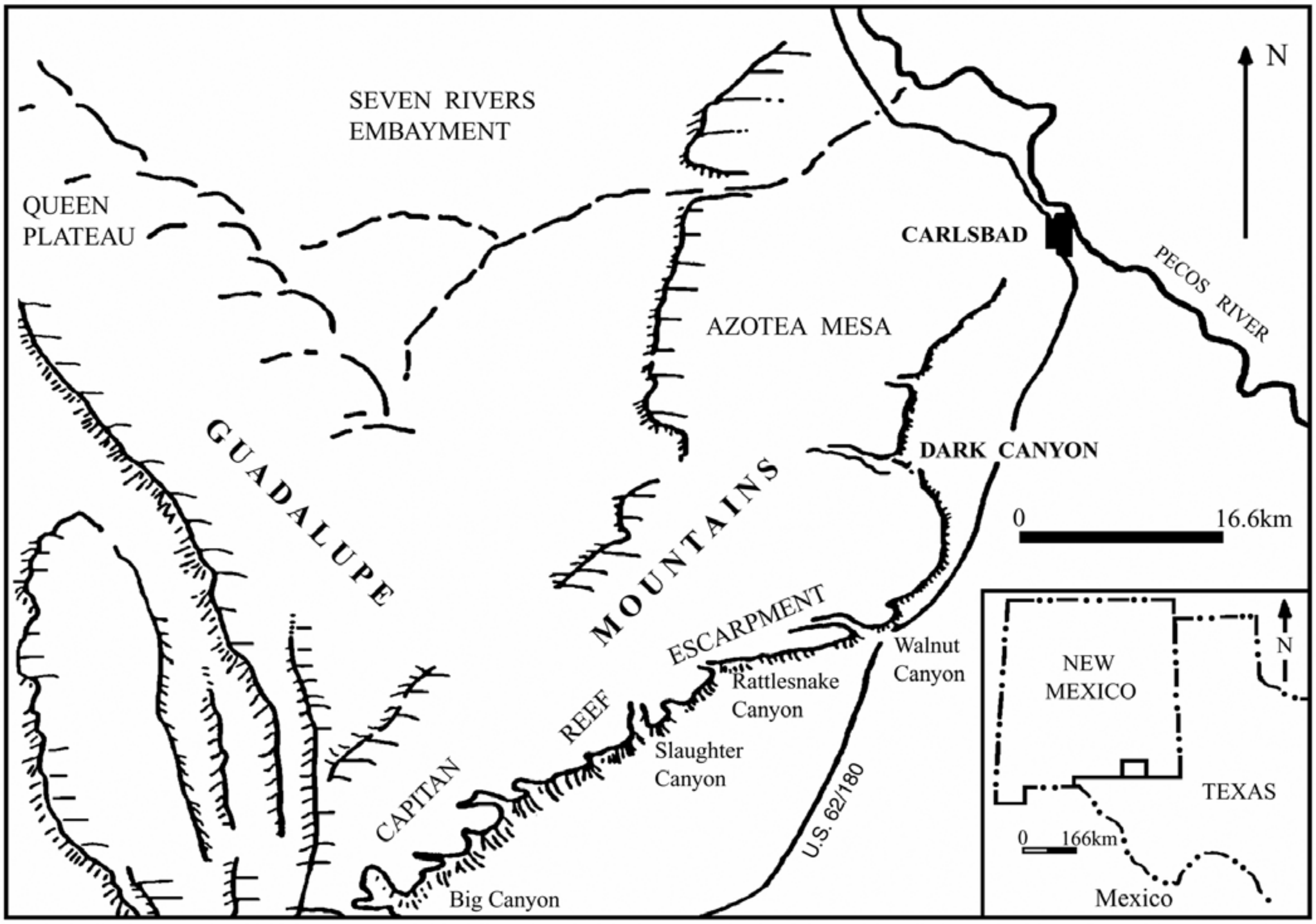
A representative of the genus *Crescentia* was described from a limestone lens of Permian age reworked into strata of the Triassic Monte Facito Formation in the western Lucania, Italy (Ciarapica et al. 1986). The age of this genus was established as Middle? and Late Permian by these authors.

The genus *Baisalina* is known from the late Midian to probably Dorashamian (= Changhsingian) in many regions of the Tethys. Nguyen Duc Tien (1986) on pl. 4, fig. 2 illustrated a specimen of a species identified as *Neoendothyra* cf. *N. bronnimanni* Bozorgnia from Sampou, Kampuchea. In our opinion, that form is a synonym of the new genus *Neoendothyranella* and species *Neoendothyranella wildei*, because it has plectogyroidal coiling of the first volutions, large size, and the initial part of the straight last chamber. In Kampuchea, this species occurs together with *Codonofusiella gubleri* Nguyen Duc Tien, *Pseudofusulina crassa* (Deprat), and *Lepidolina multiseptata multiseptata* (Deprat) indicating a late Midian (= Capitanian) age (Nguyen Duc Tien 1979). The distribution of the genus *Eomarginulinella* is limited to the late Midian (= Capitanian) (Sosnina 1967), and the range of the genus *Partisania* is from late Midian to Changhsingian. We have found one specimen of the genus *Dagmarita*, which extends its stratigraphic range from the uppermost part of the *Verbeekina grabaui* Zone (corresponding to the *Neoschwagerina simplex* Zone) of the Chihsian (Zheng 1986) to within the Changhsingian. Therefore, based on the presence of species and genera of small foraminifers that are mostly confined to the late Midian (= Capitanian) in many regions, we conclude that the age of the Tansill Formation in the Guadalupe Mountains is late Capitanian and should not be considered as Lopingian (in part) as suggested by Wilde et al. (1999). Unfortunately, no conodonts have been found as yet in the Tansill Formation, but the range of *Paraboultonia* in conodont - bearing strata in the Apache Mountains is limited to the late Guadalupian (Lambert et al. 2002).

The fusulinacean assemblages present in the Amoco cores are dominated by endemic forms such as *Paraboultonia splendens* Skinner and Wilde, and *Codonofusiella* (*Lantschichites*) *altudaensis* Wilde and Rudine, *Yabeina texana* Skinner and Wilde, *Paradoxiella pratti* Skinner and Wilde, *Rauserella bengeensis* Wilde and Rudine, and *Reichelina lamarensis* Skinner and Wilde. A few species such as *Rauserella erratica* Dunbar, *Codonofusiella* cf. *C. paradoxica* Dunbar and Skinner, *Codonofusiella extensa* Skinner and Wilde, and rare specimens of *Parareichelina* sp. and *Reichelina* aff. *R. changhsingensis* Sheng and Chang are known from other regions. An analysis of the distribution and age of each species is given in the remarks section of their systematic description.

## SYSTEMATIC DESCRIPTIONS

The authors use the system of higher protozoan taxa proposed by Cavalier-Smith (1998) and high foraminifer taxa (on the class and subclass level) proposed by V. Mikhalevich (1998,

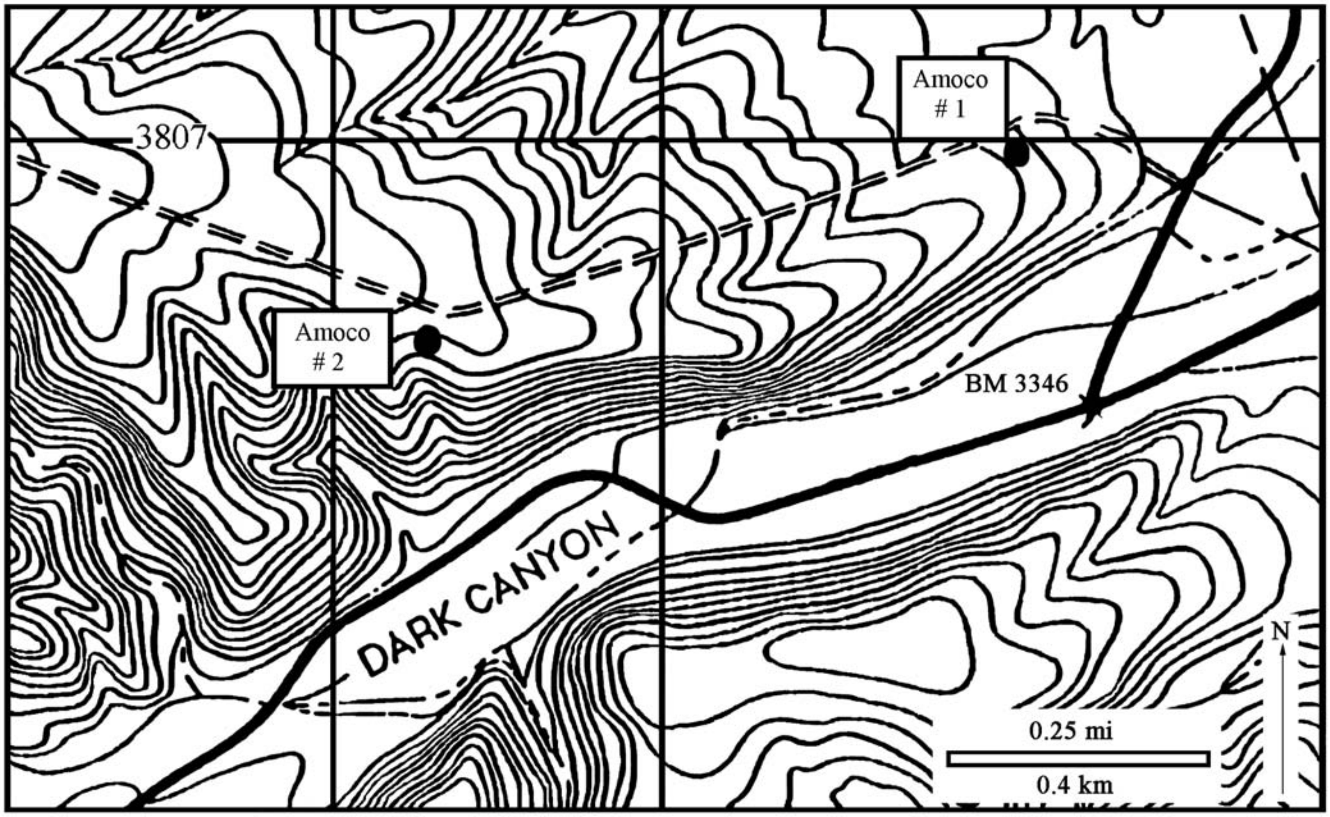


TEXT-FIGURE 2
Map of Guadalupe Mountains area (after Babcock 1977).

2000) for descriptions of new species. Within this framework, we have used several different workers' definitions for the scopes of the following orders: – Parathuramminida of Mikhalevich (1995), Tournayellida of Lipina and Reitlinger (1996), Hemigordiopsida of Pronina (1994) and partly (family Pseudolituotubidae) of Vdovenko et al. (1993), Biseriamminida, Endothyrida and superorder Fusulinoida of Rauser-Chernoussova et al. (1996) with some corrections of the present authors. Some data on classification of small foraminifers of Bozorgnia (1973), Loeblich and Tappan (1987), Mamet and Pinard (1992), and Vachard et al. (1994) were also taken into consideration. For descriptions of some new species we use the terminology: pseudocolonial test, pseudotubular chamber and pseudoinvolute test. Pseudocolonial tests are random aggregates of monothalamous (usually globular) tests that are not interconnected with apertures or openings (Rauser-Chernoussova and Fursenko 1959, p. 168). A pseudotubular chamber is a tube opened from the internal ventral side along the entire length of the test adjoined by the open part to the wall of the previous whorl (Rauser-Chernoussova and Fursenko 1959, p. 177). A pseudoinvolute test is a planispiral test in which secondary deposits fill not only the depressions between the whorls of the pseudotube, but also the umbonal depression, and by merging with the walls of the test, camouflage the evolute coiling of the whorls (Malakhova 1965, p. 159). Open nomenclature is used for a number of forms because properly oriented sections were not available. The holotypes and paratypes have been reposited in the Division of Invertebrate Paleontology of the Natural History Museum and Biodiversity Research Center of the University of Kansas (KUMIP) as specimens 2,506,729–2,506,999. The distribution of small foraminiferal species in the Amoco #1 and #2 cores are listed in the Appendix 1 according to depth. Measurements of all fusulinacean specimens are given in text-figure 8.

Kingdom PROTOZOA Goldfuss 1817; emend. Owen 1858
Subkingdom NEOZOA Cavalier-Smith 1993; emend. Cavalier-Smith 1997
Phylum FORAMINIFERA (d'Orbigny 1826) Eichwald 1830 stat. nov. Margulis 1974
Class ASTRORHIZATA Saidova 1981; emend. Mikhalevich 1998
Order PARATHURAMMINIDA Mikhalevich 1980 [= Parathuramminida Sabirov 1987]
Family TUBERITINIDAE A. Miklukho-Maklay 1958
Subfamily TUBERITININAE A. Miklukho-Maklay 1958 [nom. transl. Loeblich and Tappan 1961 ex Tuberitinidae A. Miklukho-Maklay 1958]
Genus *Tuberitina* Galloway and Harlton 1928

***Tuberitina variabilis*** Nestell and Nestell, **n**. **sp**.
Plate 1, figures 1-10



TEXT-FIGURE 3
Topographic map of east entrance of Dark Canyon and location of Amoco #1 and Amoco #2 cores (modified from USGS Kitchen Cove Quadrangle; scale 1:24,000; contour interval 20ft; after Parsley 1988).

*Description*: Test is pseudocolonial, attached, composed of one chamber or forms an accumulation of two-six chambers with flattened base. Test attaches to substratum by basal disk. Chambers are of semielliptical to ellipsoidal shape and increase very rapidly in height. Height of chamber in unilocular tests is 0.12-0.21mm; in bichambered tests, the height of the first chamber is 0.06-0.14mm, the second is 0.18-0.22mm. Width of chamber in unilocular tests is 0.17-0.22mm; in bichambered tests, the width of the first chamber is 0.1-0.2mm, the second is 0.18-0.21mm. Wall is calcareous, single layered, microgranular, from homogenous to slightly perforate. Thickness of wall in unilocular tests is 0.005-0.01mm; in bichambered tests, the wall thickness of the first chamber is 0.02mm, the second is 0.02-0.03mm. The shape of the chambers, and thickness and structure of the wall changes depending on the position of the section with respect to the center of the test. Triangular hickenings of the wall occur at the base of the test. An aperture is absent. Dimensions: total length of pseudocolony 0.72mm; diameter of base of chambers in a unilocular test 0.17-0.29mm; in bichambered, the first chamber is 0.13-0.22mm, second is 0.21-0.29mm.

*Designation of types*: The specimen illustrated on Plate 1, figure 1 is designated as the holotype (KUMIP 2,506,729). It is from the Dark Canyon Amoco #1 core, depth 80ft, Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From the Latin *variabilis* - variable.

*Material*: One hundred specimens of unilocular, bichambered and pseudocolonial tests.

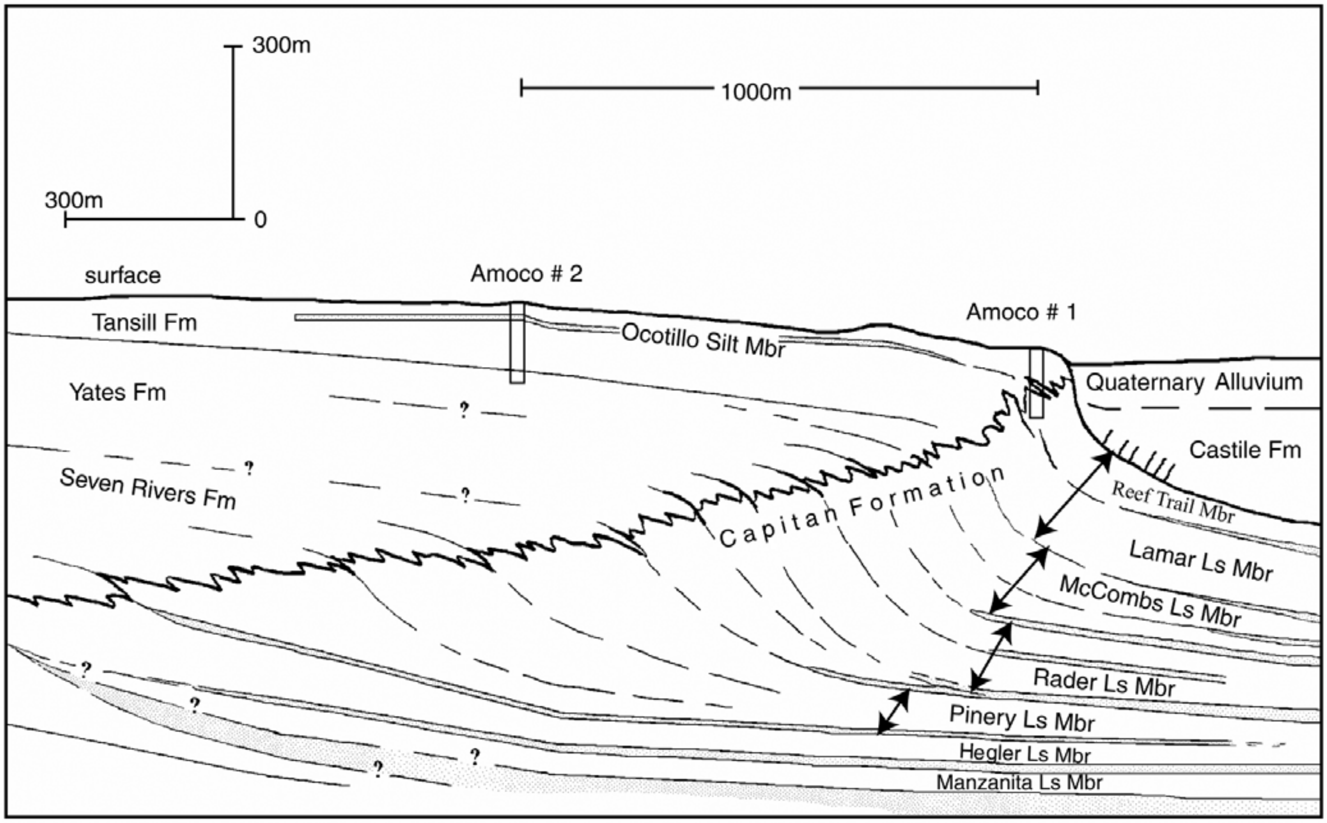
*Discussion*: Based on the nature of the growth of the chambers, *Tuberitina variabilis* n. sp. is similar to *T. collosa* (Reitlinger 1950, p. 89, pl. 19, fig. 7-9) from the Middle Carboniferous (= Early and Middle Pennsylvanian) of the Russian Platform, but differs by its pseudocolonial character, semielliptical to ellipsoidal chamber shape, thinner wall, homogenous to slightly perforate wall structure (in *T. collosa* wall structure is coarse perforate), and smaller size.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon; Amoco #1 core, upper part of the Capitan and Tansill formations, and the Amoco #2 core, upper part of the Yates and lower and middle part of the Tansill formations; Middle Permian (Capitanian).

Class SPIRILLINATA Maslakova 1990; emend. Mikhalevich 1998
Subclass AMMODISCANA Mikhalevich 1980
Order TOURNAYELLIDA Hohenegger and Piller 1975
Family CHERNYSHINELLIDAE Reitlinger 1958; emend. Lipina 1965 [nom. transl. Lipina and Reitlinger 1996 ex Chernyshinellinae Reitlinger 1958]
Subfamily MSTINIINAE Lipina 1989
Genus *Haplophragmina* Reitlinger 1950

***Haplophragmina*? *infrequens*** Nestell and Nestell, **n**. **sp**.
Plate 1, figures 11-13

*Description*: Test is free, large, elongate, appears to consist of two parts. Initial part is spiral?, later becomes straight, round in



TEXT-FIGURE 4
East - west profile of Guadalupian strata at the mouth of Dark Canyon showing approximate location of the two Amoco cores (modified after Tyrrell 2002).

equatorial section. In straight part there are four crescentiform chambers that gradually increase in height and width. Height of the first chamber is 0.08mm, last is 0.14-0.16mm, width of the first chamber is 0.15-0.18mm, last is 0.25-0.36mm. Wall is calcareous, single layered, dark, thick, coarsely granular. Wall thickness is 0.05-0.08mm. Septa in the straight part of test are of arcuate shape with thickness and structure analogous to the wall. A cribrate aperture occurs only in the last two chambers. Dimensions: length (L) of test 1.14-1.21mm, width (W) 0.45-0.54mm, thickness 0.46mm, ratio L/W 2.1-2.7.

*Designation of types*: The specimen illustrated on Pl. 1, fig. 11 is designated as the holotype (KUMIP 2,506,739). It is from the Dark Canyon Amoco #2 core, depth 324.55-324.7ft, lower part of the Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From the Latin *infrequens* – rare occurrence.

*Material*: 12 sections of different orientation.

*Discussion*: Based on the presence of a cribrate aperture in the last two chambers, *Haplophragmina*? *infrequens* n. sp. is similar to *H. potensa* Reitlinger (Reitlinger 1950, p. 29, pl. 4, fig. 9-10) from the Middle Carboniferous (= Early and Middle Pennsylvanian) of the Russian Platform, but differs by smaller test size, number of chambers in the straight part, crescentiform chambers, and much younger stratigraphical interval. This new species is assigned conditionally to the genus *Haplophragmina* because the known stratigraphical range of this genus is limited to Lower (= Mississippian) and Middle Carboniferous (= Early and Middle Pennsylvanian) (Loeblich and Tappan 1987; Lipina and Reitlinger 1996).

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #2 core, upper part of the Yates and lower part of the Tansill formations; Middle Permian (Capitanian).

Order HEMIGORDIOPSIDA Mikhalevich 1987 [nom. transl. G. Pronina 1990 ex Hemigordiopsina Mikhalevich 1987]
Suborder PSEUDOAMMODISCINA G. Pronina 1990
Family ORTHOVERTELLIDAE Mikhalevich 1988
Subfamily CALCIVERTELLINAE Loeblich and Tappan 1964

Genus ***Tansillites*** Nestell and Nestell, **n. gen.**
*Calcitornella*? (part.). – PANZANELLI-FRATONI et al. 1987, pl. 10, fig. 2.
*Palaeonubecularia*? (part). – CIARAPICA et al. 1986, pl. 3, fig. 5, 6.

*Type species*: *Tansillites anfractuosus* n. sp., USA, New Mexico, Guadalupe Mountains, Dark Canyon, Tansill Formation; Middle Permian (Capitanian).

*Description*: Test is probably attached, small, bichambered, evolute, with pseudotubular second chamber. Coiling is in two planes; initially the second chamber forms two volutions with a slight displacement relative to each other around the proloculus, and then changes the plane of coiling and spirals randomly. Wall is calcareous, single layered, microgranular, and very thin.

*Etymology*: After the Tansill Formation from which the genus is described.

*Composition of the genus*: Monotypic.

*Discussion*: Based on the type of coiling of the second chamber in the later stages, the genus *Tansillites* n. g. is similar to the genus *Baryshnikovia* Reitlinger from the Lower Carboniferous? (= Mississippian) and Lower Permian(= Cisuralian), Artinskian (in Vdovenko et al. 1993, p. 60, pl. 11, fig. 5-6), but differs from it by the type of coiling of its initial part and its thin microgranular wall.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Tansill Formation; Middle Permian (Capitanian); Italy, southern Apennines, limestone conglomerate of Permian age in the Triassic Monte Facito Formation.

*Range*: Middle Permian (Capitanian).

***Tansillites anfractuosus*** Nestell and Nestell, **n**. **sp**.
Plate 1, figures 26-29; plate 2, figures 1-5

*Description*: Test is probably attached, small, bichambered, with a pseudotubular second chamber and shows two stages of growth. Initially the second chamber forms two displaced volutions around the proloculus, and then changes the plane of coiling and spirals randomly. Total number of volutions of the test is 4-6. Proloculus is spherical, with diameter 0.026-0.04mm. The first two volutions are low, with height 0.01mm. Successive volutions quickly increase in height from 0.03mm in third volution to 0.06mm in last one. Wall is calcareous, single layered, microgranular, thin, thickness 0.01mm. Dimensions: test height 0.24-0.28mm, test diameter 0.18-0.28mm, thickness 0.09mm.

*Designation of types*: The specimen illustrated on plate 2, figure 5 is designated as the holotype (KUMIP 2,506,762). It is from the Dark Canyon Amoco #1 core, depth 106ft, Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From the Latin *anfractuosus* - winding.

*Material*: 73 sections of different orientation.

*Discussion*: The type species is the only known representative of this genus.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, Tansill Formation, and the Amoco #2 core, middle part of the Tansill Formation; Middle Permian (Capitanian).

Family PSEUDOLITUOTUBIDAE Conil and Longerstaey in Conil et al. 1980; emend. Reitlinger in Vdovenko et al. 1993
Genus *Palaeonubecularia* Reitlinger 1950

***Palaeonubecularia marginata*** Nestell and Nestell, **n**. **sp**.
Plate 2, figures 6-8

*Description*: Test is attached, large, irregular shape, consists of an accumulation of oriented chambers glomerately coiled around an elongate support. Proloculus not seen. Number of volutions is up to 19. Height of volutions is 0.052-0.1mm. Wall is calcareous, single layered, microgranular, thick, thickness up to 0.05mm. Dimensions: test diameter 0.73-4.21mm, width 0.57-1.19mm.

*Designation of types*: The specimen illustrated on plate 2, figure 6 is designated as the holotype (KUMIP 2,506,763). It is from the Dark Canyon Amoco #1 core, depth 10ft, Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From the Latin *marginatus* - bordered.

*Material*: 27 sections of different orientation.

*Discussion*: Based on the height of the volutions, *P. marginata* n. sp. is similar to *Palaeonubecularia dublicata* (Wang) (described as *Tolypammina dublicata* in Wang 1986, p. 135, pl. 1, fig. 22), but differs from the latter by larger test size and number of volutions, random coiling around a long support, and thicker wall.

*Remarks*: According to Loeblich and Tappan (1987), the genus *Palaeonubecularia* is probably algal, but it is classified as a foraminifer by Reitlinger (in Vdovenko et al. 1993). Although the systematic position of the genus is controversial, we follow Reitlinger and refer this new species to the family Pseudolituotubidae.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, Tansill Formation, and the Amoco #2 core, upper part of the Yates and lower and middle parts of the Tansill formations; Middle Permian (Capitanian).

Suborder HEMIGORDIOPSINA Mikhalevich 1987
Family HEMIGORDIOPSIDAE A. Nikitina 1969; emend. Brönnimann, Whittaker and Zaninetti 1978
Subfamily HEMIGORDIINAE Reitlinger in Vdovenko et al. 1993 [nom. transl. G. Pronina 1994 ex Hemigordiidae Reitlinger in Vdovenko et al. 1993]

Genus ***Pseudohemigordius*** Nestell and Nestell, **n. gen.**
*Glomospira* sp. – JURKIEWICZ 1966, pl. 1, fig. 9.

*Type species*: *Pseudohemigordius incredibilis* n. sp., USA, New Mexico, Guadalupe Mountains, Dark Canyon, Tansill Formation; Middle Permian (Capitanian).

*Description*: Test is free, bichambered, with pseudotubular second chamber, from lens-shaped to low conical, initial part is pseudoinvolute, one-two last volutions are evolute. Initially the second chamber forms one-two planispiral volutions, with subsequent volutions displaced relative to first volutions at small angle, and then the coiling becomes low trochospiral. Wall is calcareous, single layered, microgranular.

*Etymology*: On similarity with the genus *Hemigordius*.

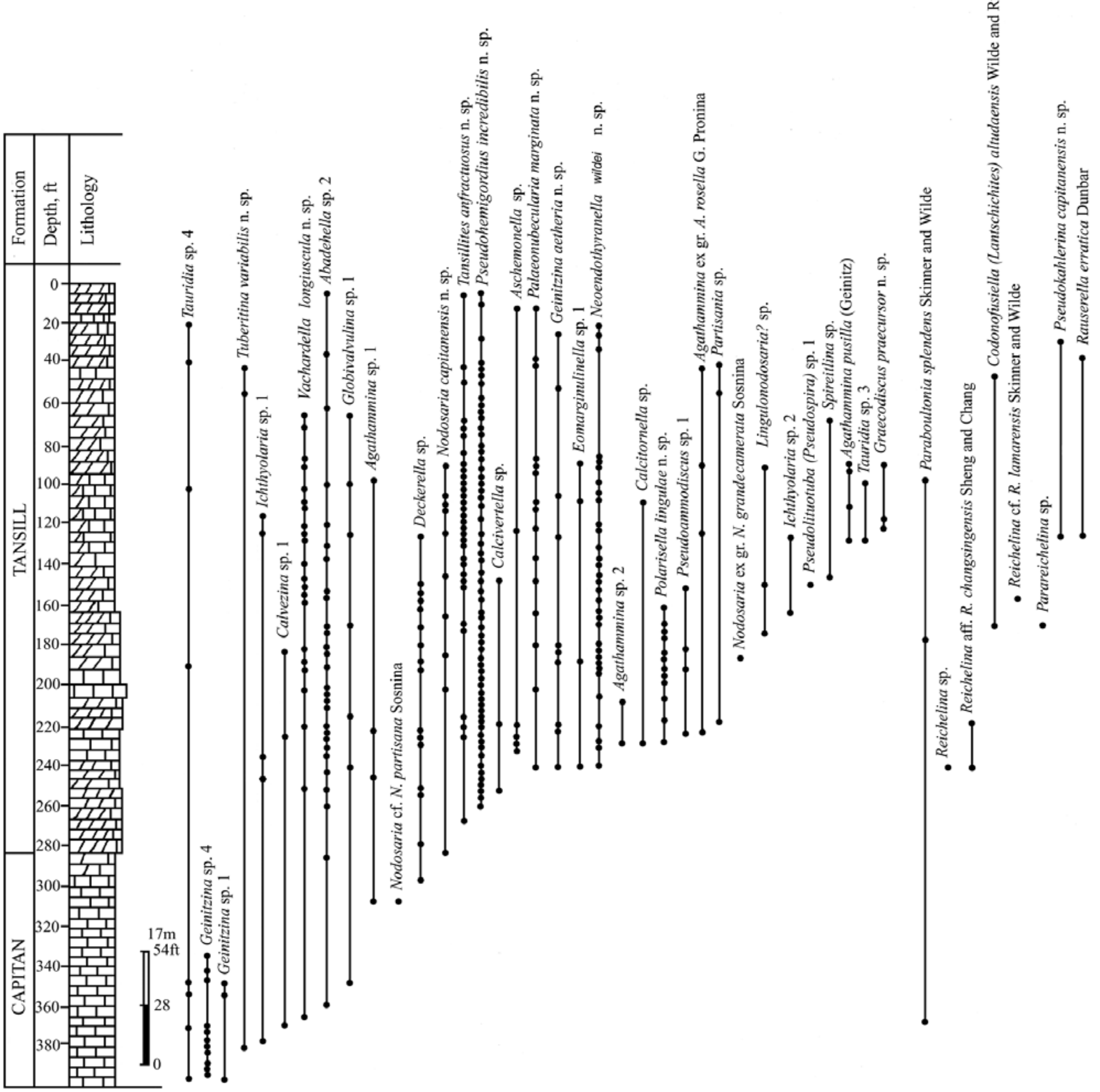
*Composition of the genus*: Monotypic.

*Discussion*: The new genus *Pseudohemigordius* differs from the genus *Hemigordius* Schubert 1908 by the low trochospiral coiling of the test.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, Tansill Formation, and the Amoco #2 core, upper part of the Yates and lower and middle part of the Tansill formations; Middle Permian (Capitanian); Poland, Galenzice, Core Holes no. 2 and 6; lower Zechstein, the *Ammodiscus* Zone.

*Range*: Middle Permian (Capitanian).

***Pseudohemigordius incredibilis*** Nestell and Nestell, **n**. **sp**.
Plate 2, figures 10-27



TEXT-FIGURE 5
Distribution of foraminifers in the Amoco #1 core (Section modified from Parsley 1988).

*Description*: Test is free, bichambered, with pseudotubular second chamber, from lens-shaped to low conical, initial part is pseudoinvolute, one-two last volutions are evolute. Proloculus is spherical, diameter 0.03-0.05mm. Number of volutions is 4-6. Initially the second chamber forms one-two planispiral volutions, with subsequent volutions displaced relative to first volutions at a small angle (pl. 2, fig. 12), then the coiling becomes low trochospiral. Height of volutions gradually increases from 0.01mm in first volution to 0.04mm in last one. Wall is calcareous, microgranular, thickness 0.01-0.02mm. Dimensions: test diameter 0.22-0.43mm, height 0.18-0.25mm, and thickness 0.1-0.19mm.

*Variability*: Size of tests is greatly variable, and the nature of the coiling varies from low (pl. 2, fig. 19, 20, 21) to relatively high trochospiral (pl. 2, fig. 17, 22, 23).

*Designation of types*: The specimen illustrated on plate 2, figure 18 is designated as the holotype (KUMIP 2,506,775), and the specimen on plate 2, figure 23 as the paratype (KUMIP 2,506,780). They are from the Dark Canyon Amoco #1 core, depth 42ft, Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From the Latin *incredibilis* - incredible.

*Material*: 170 sections of various orientations.

*Discussion*: Given in the description of the genus.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, Tansill Formation, and the Amoco #2core, upper part of the Yates and lower and middle parts of the Tansill formations; Middle Permian(Capitanian).

Family BAISALINIDAE Loeblich and Tappan 1986

Subfamily BAISALININAE Loeblich and Tappan 1986 [nom. transl. G. Pronina 1994 ex Baisalinidae Loeblich and Tappan 1986]

Genus *Baisalina* Reitlinger 1965

***Baisalina americana*** Nestell and Nestell, **n**. **sp**.
Plate 2, figures 28-36

*Description*: Test is free, bichambered, involute, of oval-shape, compressed on both sides, with a rounded periphery, and with a pseudotubular second chamber subdivided into pseudochambers by rare septa. Number of volutions is 5-7. The proloculus is spherical, diameter 0.06-0.08mm. First two-four volutions are streptospirally coiled, last two volutions are planispiral. First volutions are low with height of 0.01-0.02mm, last 2-3 volutions sharply increase in height (from 0.04 to 0.07mm in last). Wall is calcareous, single layered, microgranular, thickness 0.03-0.04mm. Septa are rare, short, and triangular in shape. Aperture is at base of apertural face, slit or oval shaped? Dimensions: greatest test diameter 0.52-0.71mm, width 0.37-0.49mm.

*Designation of types*: The specimen illustrated on Pl. 2, fig. 31 is designated as the holotype (KUMIP 2,506,788). It is from the Dark Canyon Amoco #2 core, depth 177.1-177.25ft, middle part of the Tansill Formation, Middle Permian (Capitanian).

*Etymology*: It is the first species of the genus *Baisalina* found in America.

*Material*: 80 sections of different orientation.

*Discussion*: *B. americana* n. sp. is similar to *Baisalina globosa* (Wang 1982, p. 15, pl. 3, fig. 15) based on the planispiral coiling of the two last volutions but differs by the 2.5 times smaller test size, and rare location of septa.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #2 core, middle part of the Tansill Formation, Middle Permian (Capitanian).

Family AGATHAMMINIDAE Ciarapica, Cirilli and Zaninetti 1987 [nom. transl. G. Pronina 1994 ex Agathammininae Ciarapica, Cirilli and Zaninetti 1987]

Subfamily AGATHAMMININAE Ciarapica, Cirilli and Zaninetti 1987

Genus *Agathammina* Neumayr 1887; emend. Wolanska 1959

***Agathammina pusilla*** (Geinitz 1848)
Plate 3, figures 1-5

*Serpula pusilla* GEINITZ 1848, pl. 3, fig. 3-6; 1861, p. 39, pl. 10, fig. 15-21.

*Trochammina pusilla* JONES, PARKER and KIRKBY 1869, p. 390, pl. 13, fig. 2-6, 15.

*Glomospira pusilla* PAALZOW 1935, p. 30, pl. 3, fig. 8.

*Agathammina pusilla* WOLANSKA 1959, p. 47, pl. 1, fig. 1-3; pl. 2, fig. 1-55. – SCHERP 1962, p. 304, pl. 5, fig. 1-10. – JURKIEWICZ 1966, pl. 2, fig. 9-13. – MIKLUKHO-MAKLAY and UKHARSKAYA 1975, p. 50, pl. 6, fig. 11-13; pl. 14, fig. 9-11. – PRONINA 1988a, pl. 3, fig. 5, 6. – PRONINA 1988b, pl. 1, fig. 25-26. – PALMIERI 1994, p. 31-32, pl. 29, fig. 12-13. – LEVEN and OKAY 1996, pl. 8, fig. 11.

*Discussion*: Our specimens are very similar to *A. pusilla* (Geinitz) described by Miklukho-Maklay (Miklukho-Maklay and Ukharskaya 1975, p. 50, pl. 6, fig. 11-13, pl. 14, fig. 9-11) from the Naujoji Akmene Formation of the Zechstein in the Baltic Area, but differs by smaller test size.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, Tansill Formation, and the Amoco #2 core, lower and middle parts of the Tansill Formation; Middle Permian (Capitanian); the lower and middle Zechstein of Germany; the *Agathammina pusilla* Zone of the lower Zechstein in Poland; the Naujoji Akmene Formation of the Zechstein in the Baltic area; the Khachik Formation of the upper Midian in Transcaucasia; the Mantuan Productus Bed of the Peawaddy Formation of the Bowen Basin in Australia; the Karakaya Complex (Hodul Unit) in northwestern Turkey.

Genus *Graecodiscus* Vachard in Vachard et al. 1993a

***Graecodiscus praecursor*** Nestell and Nestell, **n**. **sp**.
Plate 4, figures 1-2

*Description*: Test is free, large, globular in center and discoidal on periphery, bichambered. The pseudotubular second chamber forms two stages of growth. Proloculus is spherical, its diameter 0.06mm. Total number of volutions is 6-8.5. Initial part of test is coiled as in *Quinqueloculina* and resembles an equatorial section of *Agathammina*, consists of four - six volutions. Last stage is planispiral with 2-2.5 volutions. The height of volutions gradually increases from 0.05mm in first volution to 0.14mm in last. Wall is calcareous, single layered, micrograular. Thickness of the wall is 0.03mm in the first volution and 0.07mm in the last one. Dimensions: test length (L) 1.29-1.79mm, length of initial part 0.75mm, cross diameter of initial part 0.78mm, width (W) of planispiral part 0.58mm; ratio L/cross diameter 1.7-2.3.

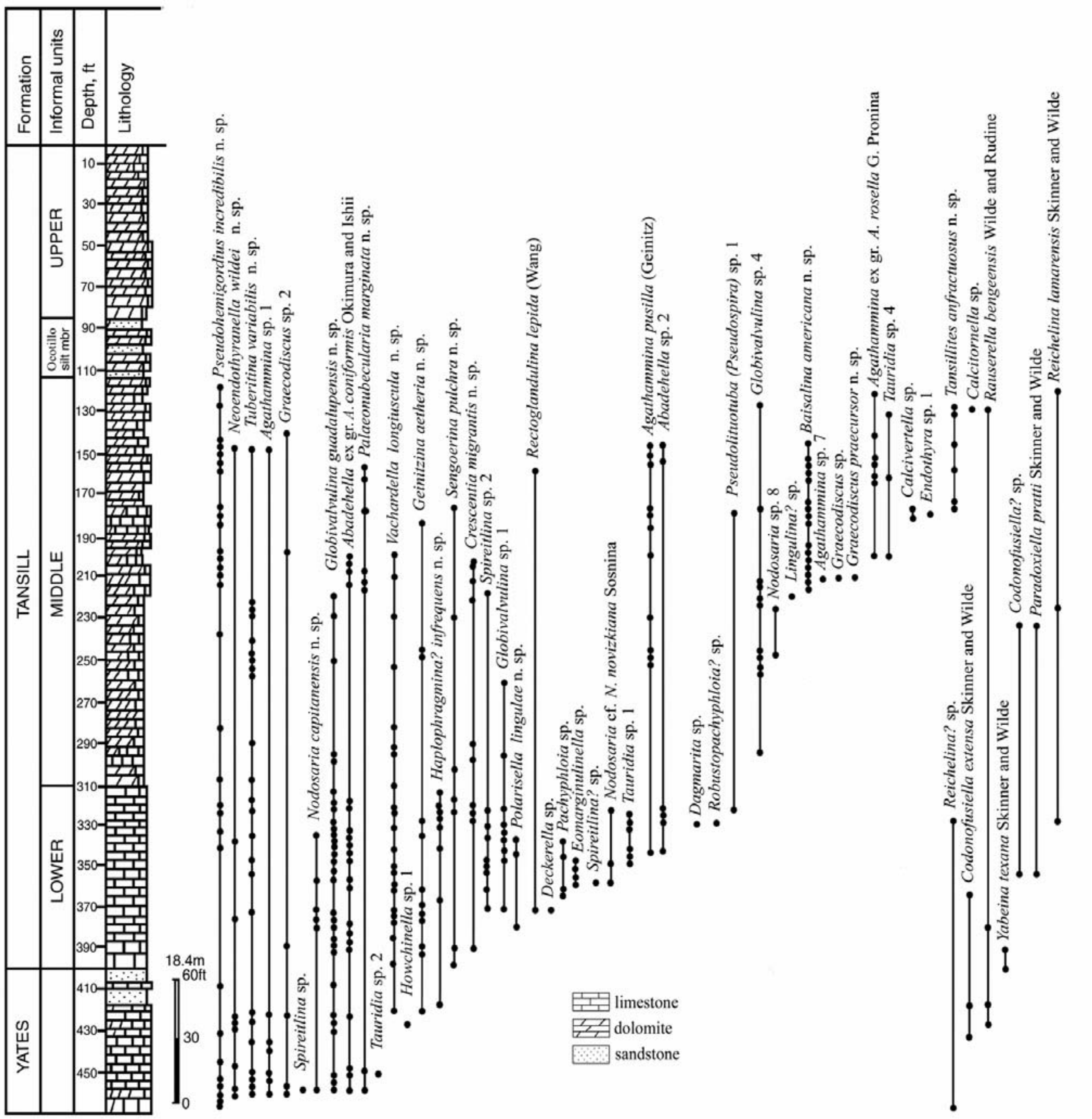
*Designation of types*: The specimen illustrated on plate 4, figure 1 is designated as the holotype (KUMIP 2,506,808); the specimen on plate 4, figure 2 is designated as the paratype (KUMIP 2,506,809). They are from the Dark Canyon Amoco #1 core: the holotype - depth 120ft, paratype - depth 90ft, Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From the Latin *praecursor* - predecessor.

*Material*: 2 axial and 2 oblique sections.

*Discussion*: Based on the two stages of growth, *G. praecursor* n. sp. is similar to *G. teresae* Vachard (in Vachard et al. 1993a, p. 227, pl. 6, fig. 2) but differs by having fewer volutions in the initial part, by quinqueloculine - like coiling that is not streptospiral in the initial part, and by having a smaller test size.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, Tansill Formation, and the Amoco #2 core, middle part of the Tansill Formation; Middle Permian (Capitanian).



TEXT-FIGURE 6
Distribution of foraminifers in the Amoco #2 core (Section modified from Parsley 1988). Informal units after Tyrrell et al. 1978.

Class NODOSARIATA Mikhalevich 1992
Subclass NODOSARIANA Mikhalevich 1992
Order NODOSARIIDA Calkins 1926 [= Lagenida Fursenko 1958, Nodosariida Güvenc 1967]
Family NODOSARIIDAE Ehrenberg 1838 [= Protonodosariidae Mamet and Pinard 1992]
Subfamily NODOSARIINAE Ehrenberg 1838
Genus *Nodosaria* Lamarck 1812

***Nodosaria capitanensis*** Nestell and Nestell, **n**. **sp**.
Plate 4, figures 4-6

*Description*: Test is small, from tongue-shaped to rectangular-oval in shape, from weakly to moderate elongate, rounded in transverse section. Number of chambers is 3-5. Proloculus is oval, weakly projected, with maximum diameter 0.045mm and minimum diameter 0.02-0.06mm. Successive chambers are rectangular, of moderate height, very slowly increasing in height and of almost constant width. Height of the second chamber 0.015-0.03mm, last is 0.015-0.04mm, width of second chamber 0.05mm, last is 0.05-0.07mm. Wall is calcareous, monolamellar, radial, and thin, its thickness 0.007-0.015mm. Attachment of chambers is simple. Sutures are simple, straight, not excavated. Septa are straight, of similar structure as the wall, thinner than the wall, and with very well developed thickenings near the apertural border of septa, their height is 0.02mm. Dimensions: test length (L) 0.13-0.17mm, width (W) 0.06-0.075mm, ratio of L/W 1.7-2.7.

*Designation of types*: The specimen illustrated on Pl. 4, fig. 4 is designated as the holotype (KUMIP 2,506,811). It is from the Dark Canyon Amoco #2 core, depth 358.1-358.25ft, lower part of the Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From the El Capitan Peak in the Guadalupe Mountains National Park, West Texas, USA.

*Material*: 17 axial sections.

*Discussion*: Based on the test shape and oval shape of proloculus, *Nodosaria capitanensis* n. sp. is similar to *N. doraschamensis* (Pronina 1989, p. 32, pl. 1, fig. 27-31) but differs by larger test size, weakly projected proloculus and simple attachment of chambers.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, Tansill Formation, and the Amoco #2 core, upper part of the Yates and lower and middle parts of the Tansill formations; Middle Permian (Capitanian).

Genus *Polarisella* Mamet and Pinard 1992

***Polarisella lingulae*** Nestell and Nestell, **n**. **sp**.
Plate 4, figure 13

*Description*: Test is small, tongue-shaped, moderate to very elongate, with a rounded peripheral end, and is rounded in transverse section. Number of chambers is 5-9. Proloculus not seen, but is probably projected. Successive chambers are of trapeziform shape, low, last chamber is crescentiform in shape. Chambers gradually increase in height (from 0.02mm in the second chamber to 0.04mm in the last one), sharply increase in width in the first four chambers (from 0.06mm in the second to 0.13mm in the sixth chamber), and remain constant (0.13mm) in the last two chambers. Chambers overlap one another insignificantly in the first four chambers and weakly in the last chambers. Sutures are excavated in the last two chambers. Wall is calcareous, monolamellar, radial, with thickness 0.015-0.045mm. Aperture is terminal, central, and appears rounded. Attachment of chambers is simple. Septa are box-shaped in early chambers and thinner than wall, successive septa arcuate and with the same thickness as the wall. Dimensions: test length (L) 0.32-0.42mm, width (W) 0.10-0.12mm, ratio of L/W 3.0-3.5.

*Designation of types*: The specimen illustrated on Pl. 4, fig.13 is designated as the holotype (KUMIP 2,506,818). It is from the Dark Canyon Amoco #1 core, depth 198ft, Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From the Latin *lingula* – small tongue.

*Material*: 10 axial and 11 oblique sections.

*Discussion*: Based on the size of the test, *P. lingulae* n. sp. is similar to *P. angjieshanensis* (Wang) (Wang 1986, p. 136, pl. 2, fig. 4) but differs from the latter by its rounded periphery, crescentiform shape of the last chamber, and deepened sutures in the last two chambers.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, Tansill Formation, and the Amoco #2 core, lower part of the Tansill Formation; Middle Permian (Capitanian).

Family GEINITZINIDAE Bozorgnia 1973
Genus *Geinitzina* Spandel 1901; emend. Sellier de Civrieux and Dessauvagie 1965 [= *Geinitzella* Spandel 1898]

***Geinitzina aetheria*** Nestell and Nestell, **n**. **sp**.
Plate 4, figures 26-31

*Description*: Test is small, of triangular shape, weakly elongate**,** flattened, and oval in transverse section. Initial end is mucronate, terminal end is widely rounded with a depression in the middle. Number of chambers is 5-10. Proloculus is small, spherical, with diameter 0.02mm. Following chambers are very low, sinus-shaped, very slowly increasing in height and very rapidly in width. Height of the second chamber is 0.01-0.02mm, width 0.03mm; height of the last chamber 0.023-0.03mm, width is 0.15mm. Wall is calcareous, monolamellar, radial, thin, with a thickness of 0.01mm. Aperture is terminal, oval in shape. Overlapping of chambers is significant. Septa are sinus-shaped, with the same thickness and structure as the wall, and without thickenings near the apertural border of septa. Dimensions: test length (L) 0.17-0.25mm, width (W) 0.11-0.16mm, thickness 0.06-0.08mm, ratio of L/W 1.5-1.6.

*Designation of types*: The specimen illustrated on Pl. 4, fig. 27 is designated as the holotype (KUMIP 2,506,836). It is from the Dark Canyon Amoco #1 core, depth 172ft, Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From the Latin *aetherius* - ethereal.

*Material*: 33 sections of different orientation.

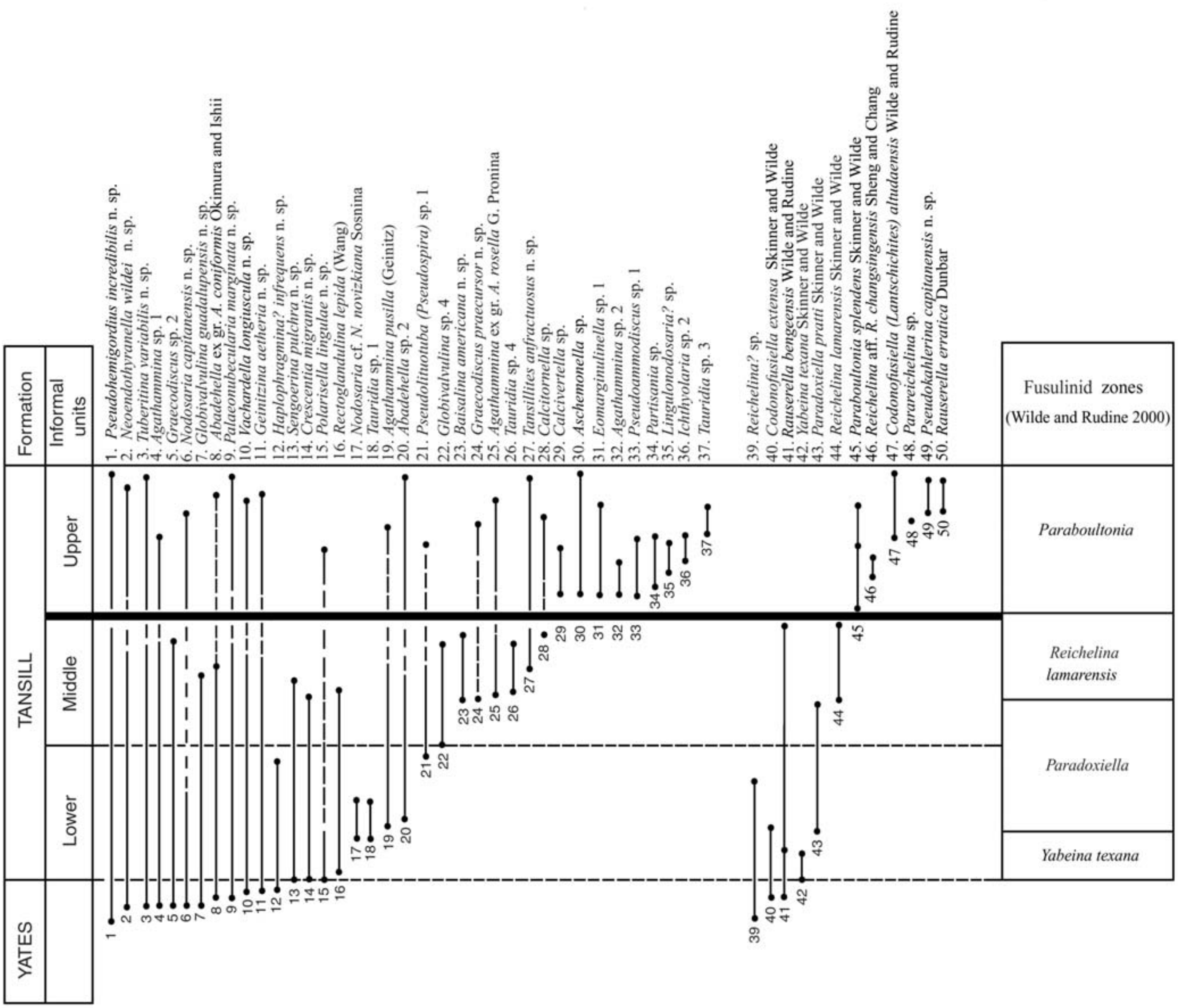
*Discussion*: *Geinitzina aetheria* n. sp. is similar to *G. araxensis* (Pronina 1989, p. 34, pl. 2, fig. 1-2) based on the low chambers, but differs by triangular shape of the test and absence of thickenings near the apertural border of the septa.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, Tansill Formation, and the Amoco #2 core, upper part of the Yates and lower and middle parts of the Tansill formations; Middle Permian (Capitanian).

Class ROTALIATA Mikhalevich 1980
Subclass TEXTULARIANA Mikhalevich 1980
Order BISERIAMMINIDA Mikhalevich 1981
Family GLOBIVALVULINIDAE Reitlinger 1950
Genus *Globivalvulina* Schubert 1921

***Globivalvulina guadalupensis*** Nestell and Nestell, **n**. **sp**.
Plate 5, figures 14-25

*Description*: Test is free, large, of oval shape, involute, biserial, with planispiral coiling. Number of volutions is two; number of chambers in two volutions is 8-10. Proloculus is large, spherical, diameter 0.06mm. Following chambers are of subglobular shape, gradually increasing in height (from 0.05mm in the second chamber to 0.1-0.12mm in the sixth chamber). The last chamber very rapidly increases in height and width, and in lateral sections is mushroom-shaped (pl. 5, fig. 14, 18). Height of the last chamber is 0.3-0.35mm, width is 0.42-0.67mm. Wall is calcareous, microgranular, and thick, thickness in the last



TEXT-FIGURE 7
Range chart of foraminiferal species in Amoco cores. Black horizontal line denotes Ocotillo Silt Member. Missing number 38 signifies space between small foraminifers and fusulinaceans.

volution is 0.03-0.04mm. Septa are curved, thick, with three layers in the initial chambers: external and internal layer of microgranular structure, intermediate layer of coarse-radial structure, and in the last volutions with one layer of microgranular structure. Thickness of the microgranular layer in the initial chambers is 0.02mm, coarse-radial layer is 0.02-0.03mm. Dimensions: larger test diameter 0.54-0.92mm, smaller 0.38-0.60mm.

*Designation of types*: The specimen illustrated on Pl. 5, fig. 18 is designated as the holotype (KUMIP 2,506,868); the specimens illustrated on Pl. 5, fig. 14 (KUMIP 2,506,864), Pl. 5, fig. 20 (KUMIP 2,506,870), Pl. 5, fig. 25 (KUMIP 2,506,875) are designated as the paratypes. They are from the Dark Canyon Amoco #2 core, the holotype: depth 324.2-324.35ft, paratypes: fig. 14 - depth 326.45-326.6ft, fig. 20 - depth 343.9-344.05ft, fig. 25 - depth 326.75-326.9ft, lower Tansill Formation; Middle Permian (Capitanian).

*Etymology*: From Guadalupe Peak, Guadalupe Mountains National Park, West Texas, USA.

*Material*: 101 sections of different orientation.

*Discussion*: Based on the large size of the test, *G. guadalupensis* n. sp. is similar to *G. vonderschmitti* (Reichel 1946, p. 556, fig. 37a-e), but differs by the last chamber rapidly increasing in height, and the absence of a radial layer of the wall in the last chamber.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #2 core, upper part of the Yates, lower and middle Tansill formations; Middle Permian (Capitanian).

| Species | Reg. No. | Figure | Length | Width | F. R. | Di. Prol. | Radius vector | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| *Codonofusiella* cf. *C. paradoxica* | 2,506,925 | Pl. 8, fig.1 | 1.268 | 0.812 | | 0.054 | 0.09 | 0.164 | 0.253 | 0.497 | | | |
| *C.* (*Lantschichites*) *altudaensis* | 2,506,926 | Pl. 8, fig.2 | | 0.818 | | 0.049 | 0.066 | 0.125 | 0.209 | 0.574 | | | |
| *Paraboultonia splendens* | 2,506,928 | Pl. 8, fig.3 | 1.695 | 0.398 | | 0.046 | 0.094 | 0.142 | 0.238 | | | | |
| *Pseudokahlerina capitanensis* | 2,506,921 | Pl. 7, fig. 24 | 0.463 | 0.976 | | 0.093 | 0.149 | 0.232 | 0.467 | 0.584 | | | |
| *Pseudokahlerina capitanensis* | 2,506,920 | Pl. 7, fig. 23 | 0.492 | 0.788 | | 0.082 | 0.127 | 0.193 | 0.284 | 0.421 | | | |
| *Pseudokahlerina capitanensis* | 2,506,923 | Pl. 7, fig. 26 | | 0.891 | | 0.074 | 0.114 | 0.138 | 0.211 | 0.341 | | | |
| *Pseudokahlerina capitanensis* | 2,506,922 | Pl. 7, fig. 25 | 0.414 | 0.998 | | 0.073 | 0.133 | 0.251 | 0.489 | | | | |
| *Paraboultonia splendens* | 2,506,929 | Pl. 8, fig.5 | | 0.629 | | 0.058 | 0.093 | 0.125 | 0.203 | | | | |
| *Rauserella erratica* | 2,506,938 | Pl. 8, fig.4 | | 0.872 | | 0.041 | 0.078 | 0.171 | 0.298 | | | | |
| *Pseudokahlerina capitanensis* | 2,506,924 | Pl. 7, fig. 27 | 0.453 | 0.563 | | 0.087 | 0.128 | 0.206 | 0.341 | | | | |
| *Paraboultonia splendens* | 2,506,930 | Pl. 8, fig.6 | 3.171 | 0.663 | | 0.054 | 0.082 | 0.118 | 0.162 | 0.0232 | 0.0365 | | |
| *C.* (*Lantschichites*) *altudaensis* | 2,506,927 | Pl. 8, fig.7 | 2.295 | 0.708 | | 0.061 | 0.073 | 0.124 | 0.221 | 0.447 | | | |
| *Parareichelina* sp. | 2,506,939 | Pl. 8, fig.8 | 0.074 | 0.873 | 12,9 | | | | | | | | |
| *Paraboultonia splendens* | 2,506,931 | Pl. 8, fig.9 | 2.743 | 0.628 | | 0.077 | 0.094 | 0.142 | 0.223 | 0.344 | | | |
| *Paraboultonia splendens* | 2,506,932 | Pl. 8, fig.10 | 3.242 | 0.728 | | 0.078 | 0.083 | 0.126 | 0.177 | 0.251 | 0.426 | | |
| *Paraboultonia splendens* | 2,506,933 | Pl. 8, fig.11 | 3.041 | 0.751 | | 0.076 | 0.098 | 0.134 | 0.192 | 0.289 | 0.434 | | |
| *Paraboultonia splendens* | 2,506,934 | Pl. 8, fig.12 | 2.553 | 0.583 | | 0.054 | 0.093 | 0.148 | 0.194 | 0.316 | | | |
| *Paraboultonia splendens* | 2,506,937 | Pl. 8, fig.15 | | 0.841 | | 0.052 | 0.096 | 0.144 | 0.219 | 0.318 | 0.446 | | |
| *Paraboultonia splendens* | 2,506,935 | Pl. 8, fig.13 | 2.388 | 0.496 | | 0.446 | 0.057 | 0.096 | 0.164 | 0.294 | | | |
| *Reichelina* aff. *R. changsingensis* | 2,506,940 | Pl. 8, fig.16 | 0.119 | 0.936 | 24 | | | | | | | | |
| *Paraboultonia splendens* | 2,506,936 | Pl. 8, fig.14 | 2.351 | 0.579 | | 0.062 | 0.066 | 0.127 | 0.196 | 0.321 | | | |
| *Paraboultonia splendens* | 2,506,941 | Pl. 9, fig. 1 | bkn | 0.597 | | 0.048 | 0.088 | 0.112 | 0.207 | 0.341 | | | |
| *Paraboultonia splendens* | 2,506,942 | Pl. 9, fig. 2 | | 0.682 | | 0.063 | 0.088 | 0.116 | 0.168 | 0.295 | | | |
| *Paraboultonia splendens* | 2,506,943 | Pl. 9, fig. 3 | 1.692 | 0.363 | | 0.047 | 0.092 | 0.123 | 0.192 | | | | |
| *Paraboultonia splendens* | 2,506,944 | Pl. 9, fig. 4 | 1.934 | 0.473 | | 0.042 | 0.088 | 0.172 | 0.274 | | | | |
| *Reichelina* aff. *R. changsingensis* | 2,506,948 | Pl. 9, fig. 6 | | 0.421 | | 0.035 | | | | | | | |
| *Paraboultonia splendens* | 2,506,945 | Pl. 9, fig. 5 | 1.408 | 0.482 | | 0.048 | 0.069 | 0.098 | 0.164 | 0.268 | | | |
| *Paraboultonia splendens* | 2,506,946 | Pl. 9, fig. 7 | | 1.133 | | 0.044 | 0.067 | 0.097 | 0.172 | 0.271 | 0.477 | | |
| *Paraboultonia splendens* | 2,506,947 | Pl. 9, fig. 8 | | 0.668 | | 0.061 | 0.084 | 0.118 | 0.192 | 0.338 | | | |
| *Reichelina lamarensis* | 2,506,949 | Pl. 9, fig. 9 | | 1.141 | | 0.027 | | 0.044 | 0.091 | 0.152 | 0.227 | 0.761 | |
| *Rauserella bengeensis* | 2,506,959 | Pl. 9, fig. 10 | 0.591 | 0.328 | | 0.036 | 0.036 | 0.046 | 0.097 | 0.187 | | | |
| *Rauserella bengeensis* | 2,506,960 | Pl. 9, fig. 11 | 0.618 | 0.351 | | 0.038 | | 0.042 | 0.116 | 0.196 | | | |
| *Rauserella bengeensis* | 2,506,961 | Pl. 9, fig. 12 | | 0.397 | | 0.032 | 0.047 | 0.086 | 0.132 | 0.233 | | | |
| *Rauserella bengeensis* | 2,506,962 | Pl. 9, fig. 13 | | 0.453 | | 0.051 | 0.054 | 0.097 | 0.144 | 0.297 | | | |
| *Rauserella bengeensis* | 2,506,963 | Pl. 9, fig. 14 | 0.622 | 0.341 | | 0.036 | 0.03 | 0.035 | 0.107 | 0.295 | | | |
| *Rauserella bengeensis* | 2,506,964 | Pl. 9, fig. 15 | 0.538 | 0.318 | | 0.037 | 0.041 | 0.062 | 0.097 | 0.157 | | | |
| *Reichelina lamarensis* | 2,506,950 | Pl. 9, fig. 16 | 0.429 | 0.654 | | 0.039 | 0.039 | 0.072 | 0.126 | 0.297 | 0.393 | | |
| *Reichelina lamarensis* | 2,506,951 | Pl. 9, fig. 17 | | 0.619 | | | 0.037 | 0.038 | 0.088 | 0.188 | 0.343 | | |
| *Reichelina lamarensis* | 2,506,952 | Pl. 9, fig. 18 | 0.349 | 0.612 | | 0.041 | 0.053 | 0.104 | 0.162 | 0.293 | | | |
| *Reichelina lamarensis* | 2,506,953 | Pl. 9, fig. 19 | 0.398 | 1.313 | | 0.037 | 0.046 | 0.069 | 0.112 | 0.153 | 0.296 | 0.853 | |
| *Reichelina lamarensis* | 2,506,954 | Pl. 9, fig. 20 | | 0.583 | | 0.04 | 0.041 | 0.064 | 0.111 | 0.178 | 0.349 | | |
| *Reichelina lamarensis* | 2,506,955 | Pl. 9, fig. 21 | 0.348 | 0.672 | | 0.042 | 0.039 | 0.076 | 0.126 | 0.214 | 0.371 | | |
| *Reichelina lamarensis* | 2,506,956 | Pl. 9, fig. 22 | 0.379 | 1.324 | | | | | | | | | |
| *Reichelina lamarensis* | 2,506,957 | Pl. 9, fig. 23 | 0.319 | 1.122 | | 0.038 | 0.046 | 0.083 | 0.142 | 0.243 | 0.769 | | |
| *Reichelina lamarensis* | 2,506,958 | Pl. 9, fig. 24 | 0.422 | 1.018 | | 0.033 | 0.052 | 0.084 | 0.156 | 0.284 | 0.641 | | |
| *Reichelina lamarensis* | 2,506,965 | Pl. 10, fig. 1 | 0.388 | 0.837 | | 0.036 | 0.036 | 0.061 | 0.108 | 0.197 | 0.543 | | |
| *Reichelina lamarensis* | 2,506,966 | Pl. 10, fig. 2 | 0.481 | 0.821 | | 0.037 | 0.047 | 0.087 | 0.137 | 0.236 | 0.511 | | |
| *Reichelina lamarensis* | 2,506,967 | Pl. 10, fig. 3 | 0.398 | 1.029 | | 0.033 | 0.026 | 0.074 | 0.219 | 0.653 | | | |
| *Reichelina lamarensis* | 2,506,968 | Pl. 10, fig. 4 | 0.388 | 0.687 | | 0.028 | 0.044 | 0.117 | 0.191 | 0.456 | | | |
| *Reichelina lamarensis* | 2,506,969 | Pl. 10. fig. 5 | 0.437 | 0.964 | | | | | | | | | |
| *Reichelina lamarensis* | 2,506,970 | Pl. 10, fig. 6 | | 0.847 | | | | | | | | | |
| *Reichelina* sp. | 2,506,971 | Pl. 10, fig. 7 | | 0.767 | | | | | | | | | |
| *Paradoxiella pratti* | 2,506,972 | Pl. 10, fig. 8 | | 1.768 | | | | | | | | | |
| *Paradoxiella pratti* | 2,506,973 | Pl. 10, fig. 9 | | 1.449 | | 0.087 | 0.074 | 0.133 | 0.249 | 0.567 | | | |
| *Codonofusiella extensa* | 2,506,974 | Pl. 10, fig. 10 | 2.992 | 0.742 | | 0.052 | | | | | | | |
| *Rauserella bengeensis* | 2,506,977 | Pl. 10, fig. 11 | | 0.496 | | 0.034 | | | | | | | |
| *Codonofusiella extensa* | 2,506,975 | Pl. 10, fig. 12 | 1.507 | 0.538 | | 0.076 | 0.064 | 0.111 | 0.193 | 0.309 | | | |
| *Yabeina texana* | 2,506,979 | Pl. 10, fig. 13 | 1.782 | 1.238 | | 0.098 | 0.093 | 0.144 | 0.219 | 0.296 | 0.386 | 0.594 | 0.642 |
| *Yabeina texana* | 2,506,980 | Pl. 10, fig. 14 | | 1.083 | | 0.073 | 0.049 | 0.102 | 0.164 | 0.234 | 0.324 | 0.424 | 0.548 |
| *Yabeina texana* | 2,506,981 | Pl. 10, fig. 15 | | 1.533 | | | | | | | | | |
| *Codonofusiella extensa* | 2,506,976 | Pl. 10, fig. 16 | 2.838 | 0.694 | | 0.058 | 0.069 | 0.098 | 0.143 | 0.218 | 0.374 | | |
| *Rauserella bengeensis* | 2,506,978 | Pl. 10, fig. 17 | 0.567 | 0.737 | | 0.079 | | | | | | | |
| *Codonofusiella extensa* | 2,506,982 | Pl. 11, fig. 1 | 2.134 | 1.309 | | 0.068 | 0.064 | 0.113 | 0.181 | 0.278 | 0.557 | | |
| *Rauserella bengeensis* | 2,506,997 | Pl. 11, fig. 2 | 0.352 | 0.472 | | 0.081 | 0.083 | 0.152 | 0.237 | | | | |
| *Codonofusiella extensa* | 2,506,983 | Pl. 11, fig. 3 | 3.146 | 0.771 | | 0.076 | 0.059 | 0.103 | 0.179 | 0.277 | 0.432 | | |
| *Codonofusiella extensa* | 2,506,984 | Pl. 11, fig. 4 | | 1.593 | | 0.068 | 0.059 | 0.106 | 0.167 | 0.271 | 0.417 | | |
| *Rauserella erratica* | 2,506,999 | Pl. 11, fig. 6 | 1.969 | 0.652 | | | | | | | | | |
| *Codonofusiella extensa* | 2,506,985 | Pl. 11, fig. 5 | | 1.282 | | 0.068 | 0.059 | 0.088 | 0.152 | 0.251 | 0.403 | | |
| *Rauserella bengeensis* | 2,506,998 | Pl. 11, fig. 7 | 0.326 | 0.223 | | 0.089 | 0.082 | 0.139 | 0.218 | | | | |
| *Codonofusiella extensa* | 2,506,986 | Pl. 11, fig. 8 | 2.688 | 1.294 | | 0.056 | 0.044 | 0.074 | 0.106 | 0.171 | 0.248 | 0.938 | |
| *Codonofusiella extensa* | 2,506,987 | Pl. 11, fig. 9 | 2.124 | 0.616 | | 0.053 | 0.088 | 0.128 | 0.226 | 0.353 | | | |
| *Codonofusiella extensa* | 2,506,988 | Pl. 11, fig. 10 | | 2.159 | | 0.063 | 0.084 | 0.169 | 0.252 | 0.339 | | | |
| *Codonofusiella extensa* | 2,650,989 | Pl. 11, fig. 11 | 2.653 | 0.652 | | 0.072 | 0.041 | 0.062 | 0.118 | 0.216 | 0.379 | | |
| *Codonofusiella extensa* | 2,506,990 | Pl. 11, fig. 12 | 1.849 | 0.635 | | 0.059 | 0.046 | 0.077 | 0.134 | 0.211 | 0.352 | | |
| *Codonofusiella extensa* | 2,506,991 | Pl. 11, fig. 13 | | 1.571 | | 0.062 | 0.054 | 0.082 | 0.119 | 0.296 | 0.348 | | |
| *Codonofusiella extensa* | 2,506,992 | Pl. 11, fig. 14 | | 0.569 | | 0.073 | 0.059 | 0.072 | 0.114 | 0.195 | 0.321 | | |
| *Codonofusiella extensa* | 2,506,993 | Pl. 11, fig. 15 | 3.132 | 0.688 | | 0.042 | 0.029 | 0.054 | 0.094 | 0.141 | 0.233 | 0.377 | |
| *Codonofusiella extensa* | 2,506,994 | Pl. 11, fig. 16 | | 1.695 | | | 0.038 | 0.081 | 0.177 | 0.333 | | | |
| *Codonofusiella extensa* | 2,506,995 | Pl. 11, fig. 17 | | 1.842 | | 0.053 | 0.047 | 0.092 | 0.193 | 0.325 | | | |
| *Codonofusiella extensa* | 2,506,996 | Pl. 11, fig. 18 | | 1.993 | | 0.064 | | | | | | | |

TEXT-FIGURE 8
Measurements of the fusulinacean specimens in the Amoco cores. All measurements in mm, F. R. denotes form ratio, Di. Prol. - diameter of proloculus.

| Wall thickness | | | | | | | Half length | | | | | | | Septal count | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0.014 | 0.016 | 0.021 | 0.028 | 0.029 | | | 0.066 | 0.148 | 0.343 | 0.689 | | | | | | | | | | |
| 0.011 | 0.014 | 0.018 | 0.023 | 0.026 | | | 0.073 | 0.122 | 0.273 | 0.711 | 1.569 | | | | | | | | | |
| 0.009 | 0.012 | 0.017 | 0.022 | | | | 0.064 | 0.121 | 0.357 | 0.698 | | | | | | | | | | |
| 0.009 | 0.011 | 0.019 | 0.028 | 0.032 | | | 0.056 | 0.091 | 0.171 | 0.228 | 0.232 | | | | | | | | | |
| 0.009 | 0.012 | 0.024 | 0.016 | 0.023 | | | 0.054 | 0.062 | 0.103 | 0.193 | 0.246 | | | | | | | | | |
| 0.009 | 0.011 | 0.012 | 0.016 | 0.014 | | | | | | | | | | | 4 | 5 | | | | |
| 0.008 | 0.016 | 0.021 | 0.032 | | | | 0.049 | 0.078 | 0.104 | 0.266 | | | | | | | | | | |
| 0.009 | 0.011 | 0.014 | 0.016 | | | | | | | | | | | | | | | | | |
| 0.008 | 0.011 | 0.014 | 0.016 | | | | | | | | | | | | | | | | | |
| 0.009 | 0.013 | 0.024 | 0.026 | | | | 0.048 | 0.074 | 0.134 | 0.168 | | | | | | 7 | 8 | | | |
| 0.008 | 0.009 | 0.012 | 0.014 | 0.016 | 0.022 | | 0.059 | 0.092 | 0.239 | 0.479 | 1.042 | 1.676 | | | | | | | | |
| 0.008 | 0.009 | 0.012 | 0.014 | 0.016 | 0.021 | | 0.056 | 0.114 | 0.298 | 0.678 | 1.327 | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 0.008 | 0.009 | 0.012 | 0.015 | 0.021 | | | 0.096 | 0.254 | 0.496 | 1.091 | 1.512 | | | | | | | | | |
| 0.009 | 0.011 | 0.012 | 0.013 | 0.016 | 0.021 | | 0.068 | 0.068 | 0.187 | 0.444 | 1.342 | 1.688 | | | | | | | | |
| 0.009 | 0.011 | 0.011 | 0.012 | 0.014 | 0.021 | | 0.058 | 0.086 | 0.292 | 0.585 | 1.373 | 1.732 | | | | | | | | |
| 0.009 | 0.009 | 0.011 | 0.013 | 0.016 | | | 0.074 | 0.141 | 0.368 | 1.032 | 1.276 | | | | | | | | | |
| 0.009 | 0.009 | 0.01 | 0.0112 | 0.015 | 0.016 | | | | | | | | | 14 | 17 | 22 | 27 | 40 | | |
| 0.008 | 0.009 | 0.01 | 0.011 | 0.013 | 0.016 | | 0.042 | 0.071 | 0.188 | 0.676 | 1.224 | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 0.008 | 0.011 | 0.012 | 0.013 | 0.014 | | | 0.056 | 0.074 | 0.196 | 0.706 | 1.191 | | | | | | | | | |
| 0.008 | 0.011 | 0.012 | 0.014 | 0.018 | | | 0.064 | 0.086 | 0.248 | 0.679 | 0.906 | | | | | | | | | |
| 0.007 | 0.008 | 0.009 | 0.012 | 0.015 | | | | | | | | | | | 6 | 15 | 18 | 25 | | |
| 0.007 | 0.008 | 0.009 | 0.011 | | | | 0.057 | 0.203 | 0.663 | 0.932 | | | | | | | | | | |
| 0.008 | 0.009 | 0.011 | 0.014 | | | | 0.087 | 0.196 | 0.577 | 1.168 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 0.006 | 0.008 | 0.011 | 0.013 | 0.016 | | | 0.041 | 0.074 | 0.148 | 0.338 | 0.749 | | | | | | | | | |
| 0.007 | 0.01 | 0.011 | 0.013 | 0.015 | 0.018 | | | | | | | | | | 5 | 12 | 18 | 23 | 33 | |
| 0.008 | 0.008 | 0.01 | 0.014 | 0.017 | | | | | | | | | | | 4 | 15 | 21 | 31 | | |
| | 0.014 | 0.018 | 0.021 | 0.025 | 0.032 | | | 9 | 13 | 18 | 26 | | | | | | | | | |
| 0.007 | 0.009 | 0.011 | 0.015 | | | | 0.049 | 0.087 | 0.137 | 0.293 | | | | | | | | | | |
| | 0.009 | 0.012 | 0.014 | | | | | 0.041 | 0.122 | 0.286 | | | | | | | | | | |
| 0.007 | 0.008 | 0.011 | 0.012 | | | | | | | | | | | | 4 | 6 | 8 | | | |
| 0.007 | 0.008 | 0.009 | 0.014 | | | | | | | | | | | | 5 | 7 | | | | |
| 0.008 | 0.008 | 0.01 | 0.015 | | | | 0.041 | 0.079 | 0.131 | 0.248 | | | | | | | | | | |
| 0.007 | 0.008 | 0.011 | 0.016 | | | | 0.041 | 0.077 | 0.133 | 0.286 | | | | | | | | | | |
| 0.009 | 0.012 | 0.014 | 0.018 | 0.022 | | | 0.022 | 0.042 | 0.076 | 0.143 | 0.223 | | | | | | | | | |
| | 0.013 | 0.014 | 0.015 | 0.017 | | | | | | | | | | | 12 | 17 | 20 | | | |
| 0.009 | 0.013 | 0.016 | 0.019 | | | | 0.041 | 0.061 | 0.092 | 0.146 | | | | | | | | | | |
| 0.007 | 0.008 | 0.009 | 0.012 | 0.012 | 0.017 | | 0.022 | 0.028 | 0.066 | 0.097 | 0.139 | 0.181 | | | | | | | | |
| 0.007 | 0.009 | 0.012 | 0.015 | 0.017 | | | | | | | | | | 8 | 12 | 15 | 20 | | | |
| 0.008 | 0.01 | 0.011 | 0.014 | 0.018 | | | 0.025 | 0.041 | 0.082 | 0.132 | 0.176 | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 0.008 | 0.009 | 0.012 | 0.014 | 0.017 | | | 0.028 | 0.043 | 0.082 | 0.121 | 0.153 | | | | | | | | | |
| 0.007 | 0.009 | 0.012 | 0.015 | 0.018 | | | 0.031 | 0.048 | 0.079 | 0.118 | 0.183 | | | | | | | | | |
| 0.008 | 0.009 | 0.012 | 0.016 | 0.019 | | | 0.031 | 0.041 | 0.066 | 0.123 | 0.198 | | | | | | | | | |
| 0.009 | 0.011 | 0.015 | 0.017 | 0.019 | | | 0.035 | 0.057 | 0.088 | 0.154 | 0.241 | | | | | | | | | |
| 0.011 | 0.013 | 0.016 | 0.017 | | | | | | | | | | | | | | | | | |
| 0.008 | 0.011 | 0.014 | 0.0116 | | | | 0.048 | 0.071 | 0.124 | 0.286 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 0.007 | 0.008 | 0.012 | 0.021 | | | | | | 16 | 25 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 0.009 | 0.012 | 0.014 | 0.016 | | | | 0.071 | 0.163 | 0.338 | 0.748 | | | | | | | | | | |
| 0.011 | 0.013 | 0.016 | 0.016 | 0.015 | 0.016 | 0.21 | 0.098 | 0.144 | 0.217 | 0.336 | 0.468 | 0.622 | 0.823 | | 9 | 11 | 14 | 17 | 22 | 29 |
| 0.009 | 0.01 | 0.012 | 0.014 | 0.016 | 0.018 | 0.022 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 0.009 | 0.01 | 0.013 | 0.014 | 0.016 | | | 0.067 | 0.104 | 0.196 | 0.368 | 1.477 | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 0.008 | 0.009 | 0.013 | 0.015 | 0.016 | | | 0.079 | 0.157 | 0.326 | 0.582 | 1.156 | | | | | | | | | |
| 0.007 | 0.009 | 0.012 | | | | | 0.072 | 0.084 | 0.191 | | | | | | | | | | | |
| 0.009 | 0.01 | 0.012 | 0.014 | 0.016 | | | 0.086 | 0.169 | 0.328 | 0.556 | 1.562 | | | | | | | | | |
| 0.009 | 0.01 | 0.013 | 0.015 | 0.016 | | | | | | | | | | | | 10 | 18 | 27 | | |
| | | | | | | | | | | | | | | | | | | | | |
| 0.009 | 0.01 | 0.011 | 0.012 | | | | | | | | | | | | | | | | | |
| 0.006 | 0.008 | 0.01 | 0.013 | 0.014 | | | 0.047 | 0.068 | 0.098 | | | | | | 7 | 15 | 22 | 28 | | |
| 0.007 | 0.008 | 0.009 | 0.01 | 0.012 | 0.015 | 0.019 | 0.036 | 0.074 | 0.122 | 0.274 | 0.471 | 1.376 | | | | | | | | |
| 0.008 | 0.01 | 0.012 | 0.015 | | | | 0.049 | 0.148 | 0.362 | 1.456 | | | | | | | | | | |
| 0.007 | 0.008 | 0.01 | 0.01 | | | | | | | | | | | | 7 | 15 | 21 | | | |
| 0.007 | 0.008 | 0.01 | 0.012 | 0.016 | 0.019 | | 0.054 | 0.097 | 0.166 | 0.386 | 1.262 | | | | | | | | | |
| 0.006 | 0.008 | 0.011 | 0.014 | 0.016 | 0.022 | | 0.048 | 0.079 | 0.151 | 0.334 | 0.881 | | | | | | | | | |
| 0.007 | 0.008 | 0.01 | 0.012 | 0.016 | 0.019 | | | | | | | | | | | 12 | 15 | 23 | | |
| 0.007 | 0.008 | 0.01 | 0.015 | 0.018 | | | 0.066 | 0.097 | 0.182 | 0.389 | 0.773 | | | | | | | | | |
| 0.007 | 0.008 | 0.009 | 0.012 | 0.014 | 0.016 | | 0.051 | 0.092 | 0.154 | 0.242 | 0.479 | 1.534 | | | | | | | | |
| 0.009 | 0.011 | 0.014 | 0.016 | | | | | | | | | | | | | | | | | |
| 0.008 | 0.011 | 0.013 | 0.018 | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |

TEXT-FIGURE 8
*Continued.*

Genus *Sengoerina* Altiner 1999

***Sengoerina pulchra*** Nestell and Nestell, **n. sp.**
Plate 6, figures 3-6

*Description*: Test is large, elongate, biserial, with a planispiral initial part and short uncoiled last part. Initial part consists of one volution with six rounded chambers. Proloculus is spherical, with a diameter of 0.04-0.06mm. Successive chambers rapidly increase in height and width. Height of the second chamber is 0.04mm, third is 0.10mm, fourth is 0.14mm, fifth is 0.18mm, width of the third chamber is 0.15mm, fourth is 0.17mm, fifth is 0.28mm. Short uncoiled part consists of two rounded chambers in each row gradually increasing in height and width. Height of the first chamber is 0.16-0.18mm, width is 0.22mm, the height of the second chamber is 0.20-0.25mm, width is 0.40mm. Wall is calcareous, single layered, microgranular, with a thickness of 0.03mm. Septa are curved, with the same structure as the wall, and thinner than the wall. Thickness of the septa is 0.015mm. Septa have an extra small plate (oral projection) that appears in the last chamber and covers the aperture. Precise shape of the aperture is unknown. Dimensions: test height 0.65-0.80mm, diameter 0.39-0.57mm, and thickness 0.43mm.

*Designation of types*: The specimen illustrated on plate 6, figure 5 is designated as the holotype (KUMIP 2,506,880), the specimen on Pl. 6, fig. 3 as the paratype (KUMIP 2,506,878). They are from the Dark Canyon Amoco #2 core, the holotype: depth 391.55-391.7ft, paratype: - depth 178.3-178.45ft; the holotype – lower and paratype – middle part of the Tansill Formation; Middle Permian (Capitanian).

*Etymology*: From the Latin *pulcher* - beautiful.

*Material*: 6 sections of different orientation.

*Discussion*: *Sengoerina pulchra* n. sp. differs from *S. argandi* (Altiner 1999, p. 215, pl. 1, fig. 1-10) by larger size of the test, rounded chambers, and single layered wall without a radial layer on the septa.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #2 core, lower and middle part of the Tansill Formation, Middle Permian (Capitanian).

Family DAGMARITIDAE Bozorgnia 1973
Genus *Crescentia* Ciarapica, Cirilli, Martini and Zaninetti 1986

***Crescentia migrantis*** Nestell and Nestell, **n. sp.**
Plate 6, figures 7-12

*Description*: Test is free, large, biserial, with a planispiral initial part and short uncoiled last part, and with spinose outgrowths in place of the attachment of the chambers. The initial part forms one volution with 4-6 chambers in it. Proloculus is large, spherical, with diameter 0.06-0.08mm. Successive chambers gradually increase in height from 0.05mm to 0.11mm. Uncoiled part consists of 1-3 chambers of crescentiform shape in each row, gradually increasing in height and very slowly in width. Height of the first chamber is 0.14-0.16mm, width is 0.14-0.19mm, height of the last chamber 0.16mm, width is 0.20mm. Wall is calcareous, single layered, microgranular, with a thickness of 0.05mm. Septa are curved, three layered, with intermediate radial layer (thickness 0.015mm) and microgranular external layer (thickness 0.020mm) and a thin internal layer. Septa have an extra plate in the last chamber that covers the aperture. Dimensions: test height 0.58-1.03mm, diameter of spiral part 0.51-0.56mm, and test width 0.5-0.56mm.

*Designation of types*: The specimen illustrated on Pl. 6, fig. 11 is designated as the holotype (KUMIP 2,506,886), the specimen on Pl. 6, fig. 8 as the paratype (KUMIP 2,506,883). They are from the Dark Canyon Amoco #2 core, the holotype: depth 199.85-200.0ft, paratype - depth 213.7-213.85ft, middle Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From the Latin *migrans* - emigrant.

*Material*: 21 sections of different orientation.

*Discussion*: From the only representative of the genus *Crescentia*, *C. vertebralis* Ciarapica, Cirilli, Martini and Zaninetti (Ciarapica et al. 1986, p. 208, pl. 1, fig. 1, 2), *Crescentia migrantis* n. sp. differs by larger size of the test, slightly longer uncoiled part, and thicker intermediate radial layer on the septa.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #2 core, lower and middle part of the Tansill Formation, Middle Permian (Capitanian).

Order ENDOTHYRIDA Fursenko 1958
Family ENDOTEBIDAE Vachard, Martini, Rettori and Zaninetti 1994

Genus ***Vachardella*** Nestell and Nestell, **n. gen.**
*Type species*: *Vachardella longiuscula* n. sp., USA, New Mexico, Guadalupe Mountains, Dark Canyon, the lower parts of the Tansill Formation; Middle Permian (Capitanian).

*Description*: Test is large, elongate, with two stages of growth: initial planispiral part and rectilinear later part. Planispiral part has one to one and a half voluions. Septa are straight and short in this part. Straight part contains 2-8 chambers. Septa of this part are almost horizontal or with a slight inclination to the axis, and are thick; they are similar to the wall in structure. Wall is calcareous, single layered, coarsely granular, and thick. The wall consists of large grains of calcite that create the impression of an agglutinated wall. The calcareous composition of these grains was confirmed by examining the wall structure with polarized light. Aperture is terminal and simple.

*Etymology*: Named after Dr. D. Vachard for his contributions to the study of the Paleozoic foraminifers.

*Discussion*: The new genus *Vachardella* is similar to the genus *Granuliferelloides* McKay and Green 1963 from the lowermost Carboniferous (Tournaisian) of Canada (McKay and Green 1963) on the basis of two stages of growth, but differs from it by the planispiral volution in the coiled part, crescentiform shape of the chambers in the straight part, and much younger stratigraphic interval. From the Triassic genus *Endotebanella* Vachard, Martini, Rettori and Zaninetti (Vachard et al. 1994), the new genus differs by the larger size of the test, different type of coiling in the initial spiral part of the test and its very smaller development, longer straight part and more coarsely granular structure of the wall.

*Remarks*: The wall of our new genus is calcareous, single layered, coarsely granular, and thick. It consists of large grains of calcite that create the impression of an agglutinated wall and resembles the morphology of the genus *Ammobaculites* Cushman 1910. According to Bender (1995), *Ammobaculites* has an agglutinated wall with an inner and outer organic layer. Our new genus, known only in thin section, appears to have neither an inner nor outer organic layer, and the wall consists of calcitic grains floating in calcareous cement.

Our new genus could have the same controversial status as the genus *Miliammina* (Cretaceous - Holocene) by having the morphological features of two foraminiferal groups, the miliolids and textulariids. Based on test morphology, *Miliammina* has been assigned to the Miliolida (Haynes 1981). Based on its agglutinated wall, it has been assigned to the Textulariida (Loeblich and Tappan 1987). In a recent paper on actin phylogeny of foraminifers, Flakowski et al. (2005) concluded that genus *Miliammina* belongs to the Miliolida and not to the Textulariida.

*Occurrence*: USA, New Mexico, Gaudalupe Mountains, Dark Canyon; the upper part of the Yates and Tansill formations.

*Range*: Middle Permian (Capitanian).

***Vachardella longiuscula*** Nestell and Nestell, **n**. **sp**.
Plate 1, figures 14-19

*Description*: Test is large, elongate, with two stages of growth: initial planispiral part and straight later part. Proloculus is spherical, with a diameter of 0.04mm. Planispiral part has one volution with 5 chambers in it. Septa are straight and short in this part. Straight part contains 2-8 chambers of crescentiform shape gradually increasing in height and very slowly in width: height of the first chamber is 0.04-0.05mm, width is 0.04-0.09mm, last one is 0.078-0.104mm and 0.15mm. Septa of this part are almost horizontal or with a slight inclination to the axis, and thick; they are analogous to the wall in structure. Wall is calcareous, single layered, coarsely granular, and thick, with a thickness of 0.026-0.052mm. The wall consists of large grains of calcite that creates the impression of an agglutinated wall. The calcareous composition of these grains was confirmed by examining the wall structure with polarized light. Aperture is terminal and simple. Dimensions: test height 0.49-1.258mm, width 0.18-0.44mm, and diameter of the spiral part 0.16-0.31mm.

*Designation of types*: The specimen illustrated on Pl. 1, fig. 15 is designated as the holotype (KUMIP 2,506,743). It is from the Dark Canyon Amoco #2 core, depth 389.35-389.5ft, lower part of the Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From the Latin *longiusculus* - long.

*Material*: 56 sections (37 axial longitudinal and 24 oblique).

*Discussion*: Given in the description of the genus.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, Capitan and Tansill formations, and the Amoco #2 core, upper part of the Yates and lower and middle Tansill formations; Middle Permian (Capitanian).

Family ENDOTHYRANOPSIDAE Reitlinger 1958; emend. Reitlinger 1981
Subfamily NEOENDOTHYRINAE Reitlinger in Rauser-Chernoussova et al. 1996

Genus ***Neoendothyranella*** Nestell and Nestell, **n**. **gen**.
*Neoendothyra* (part.). – NGUYEN DUC TIEN 1986, pl. 4, fig. 2.

*Type species*: *Neoendothyranella wildei* n. sp., USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Tansill Formation; Middle Permian (Capitanian).

*Description*: Test is free, large, elongate, consists of two parts: initial part as in the genus *Neoendothyra*; last part is straight and uniserial. Coiling is plectogyroidal in the initial 2-2.5 volutions. Strong secondary deposits cover the base of each volution and fill up the lateral sides. Uniserial part is cylindrical with 4-6 chambers. Aperture is terminal and central in uniserial part. In the initial part, septa are oblique, thin, with small bulges at ends. Septa are thick in the straight part, with mace-shape thickenings near apertural border of septa.

*Etymology*: Name by similarity with the genus *Neoendothyra*.

*Discussion*: Based on the type of test structure, *Neoendothyranella* n. gen. is similar to *Endothyranella* Galloway and Harlton 1930 (in Galloway and Ryniker 1930), but differs by its carinate periphery, plectogyroidal coiling, and the presence of secondary deposits in the initial part of the test.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon; Kampuchea at the locality Sampou.

*Range*: Middle Permian (Capitanian).

***Neoendothyranella wildei*** Nestell and Nestell, **n**. **sp**.
Plate 6, figures 14-22

*Neoendothyra* cf. *N. bronnimanni* NGUYEN DUC TIEN 1986, pl. 4, fig. 2.

*Description*: Test is large, elongate, composed of two parts: the initial part as in the genus *Neoendothyra*; last part is straight and uniserial. Coiling of the initial part is plectogyroidal with 2-2.5 volutions. Volutions rapidly increase in height. Height of the first volution is 0.19-0.25mm, second is 0.51-0.65mm. Number of chambers in all volutions is 17. Septa are oblique in the initial part of the test, with small bulges at the ends. Secondary deposits are developed at the base of the volutions. Straight part is cylindrical, consists of 4-5 rounded-rectangular chambers, slowly increasing in height and width. Height of the first chamber 0.09-0.11mm, width is 0.14-0.35mm; height of fourth chamber is 0.15-0.21mm, width is 0.33-0.42mm. Septa are straight, with mace-shape thickenings at apertural border of septa. Height of thickenings is 0.05-0.06mm. Wall is calcareous, single layered, microgranular, thickness in the initial part and in the uniserial part is 0.02-0.035mm. Dimensions: test height 1.62-1.97mm, great diameter of initial part 0.74- 0.87mm, small diameter of initial part 0.27-0.33mm, height of uniserial part 0.85-1.21mm, and width 0.39-0.46mm.

*Designation of types*: The specimen illustrated on plate 6, figure 22 is designated as the holotype (KUMIP 2,506,897), the specimen on Pl. 6, fig. 21 as the paratype (KUMIP 2,506,896). They are from the Dark Canyon Amoco #1 core, the holotype: depth 220ft, paratype: - depth 231.5ft, Tansill Formation, Middle Permian (Capitanian).

*Etymology*: After the late Dr. Garner Wilde who has contributed very much information about fusulinacean distribution and taxonomy, especially in the Permian rocks of West Texas.

*Material*: 51 sections of different orientation.

*Discussion*: Only type species is known.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, Tansill Formation, and the Amoco #2 core, upper part of the Yates and lower and middle parts of the Tansill formations; Middle Permian (Capitanian); Kampuchea, locality Sampou; Middle Permian.

Superorder FUSULINOIDA Fursenko 1958 [nom. transl. Rauser-Chernoussova and Solovieva in Rauser-Chernoussova et al. 1996 ex Fusulinida Fursenko 1958]

Order OZAWAINELLIDA Solovieva 1980 [nom. transl. Solovieva and Reitlinger in Rauser-Chernoussova et al. 1996 ex Ozawainellinae Thompson and Foster 1937]

Family OZAWAINELLIDAE Thompson and Foster 1937 [nom. transl. A. Miklukho-Maklay, Rauser-Chernoussova and

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## PLATE 1

1-10 – *Tuberitina variabilis* Nestell and Nestell, n. sp.

1 KUMIP 2,506,729, holotype, pseudocolony of tuberitinas, ×90, Amoco #1 core, depth: 80ft;

2 KUMIP 2,506,730; pseudocolony of tuberitinas, ×90, Amoco #2 core, depth: 257.95-258.1ft;

3 KUMIP 2,506,731, axial section of three chambered specimen, ×90, Amoco #1 core, depth: 194ft;

4 KUMIP 2,506,732, axial section of bichambered specimen, ×90, Amoco #1 core, depth: 80ft;

5 KUMIP 2,506,733, axial section of unilocular specimen, ×90, Amoco #1 core, depth: 286ft;

6 KUMIP 2,506,734, axial section of bichambered specimen, ×90, Amoco #2 core, depth: 464.55-464.7ft;

7 KUMIP 2,506,735, tangential section, ×90, Amoco #1 core, depth: 252ft;

8 KUMIP 2,506,736, axial section of bichambered specimen, ×90, Amoco #1 core, depth: 172ft;

9 KUMIP 2,506,737, axial section of unilocular specimen, ×90, Amoco #1 core, depth: 270ft;

10 KUMIP 2,506,738, axial section of unilocular specimen, ×90, Amoco #1 core, depth: 226ft.

11-13. *Haplophragmina*? *infrequens* Nestell and Nestell, n. sp.

11 KUMIP 2,506,739, holotype, close to axial section, ×64, Amoco #2 core, depth: 324.55-324.7ft;

12 KUMIP 2,506,740, transverse section, ×64, Amoco #2 core, depth: 327.3-327.45ft;

13 KUMIP 2,506,741, close to axial section, ×64, Amoco #2 core, depth:329.05-329.2ft

14-19 – *Vachardella longiuscula* Nestell and Nestell, n. gen., n. sp.

14 KUMIP 2,506,742, axial section, ×64, Amoco #2 core, depth:347.65-347.8ft;

15 KUMIP 2,506,743, holotype, axial section, ×64, Amoco #2 core, depth: 389.35-389.5ft;

16 KUMIP 2,506,744, close to axial section, ×64, Amoco #1 core, depth: 204ft;

17 KUMIP 2,506,745, axial section, ×64, Amoco #1 core, depth: 122ft;

18 KUMIP 2,506,748, equatorial section of the initial part, ×64, Amoco #2 core, depth: 213.05-213.2ft;

19 KUMIP 2,506,747, equatorial section of the initial part, ×90, Amoco #2 core, depth: 285.2-285.35ft.

20 – *Vachardella* sp. 1, KUMIP 2,506,746, axial section, ×64, Amoco #2 core, depth 298.0-298.15ft.

21-22 – *Pseudoammodiscus* sp. 1.

21 KUMIP 2,506,749, axial section, ×90, Amoco #1 core, depth: 192ft;

22 KUMIP 2,506,750, equatorial section, ×90, Amoco #1 core, depth: 226ft.

23 – *Calcitornella* sp., KUMIP 2,506,751, axial section, ×90, Amoco #1 core, depth 230ft.

24-25 – *Calcivertella* sp..

24 KUMIP 2,506,752, close to axial section, ×90, Amoco #2 core, depth 178.3-178.45ft;

25 KUMIP 2,506,753, equatorial section, ×90, Amoco #1 core, depth 146ft.

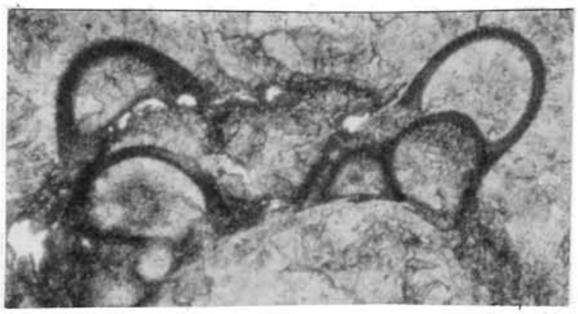
26-29 – *Tansillites anfractuosus* Nestell and Nestell, n. gen., n. sp.

26 KUMIP 2,506,754, equatorial section, ×90, Amoco #2 core, depth: 129.95-130.1ft;

27 KUMIP 2,506,755, equatorial section, ×90, Amoco #1 core, depth: 90ft;

28 KUMIP 2,506,756, lateral section, ×90, Amoco #1 core, depth: 72ft;

29 KUMIP 2,506,757, close to axial section, ×90, Amoco #2 core, depth: 145.1-145.25ft.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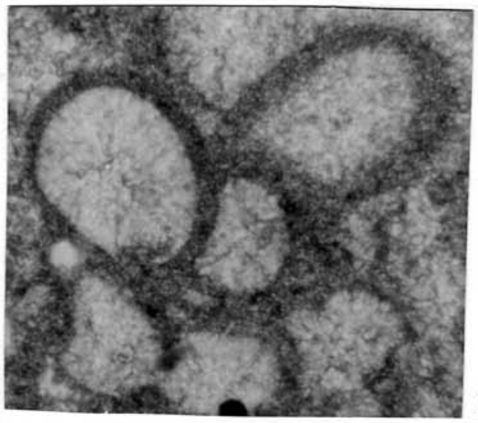
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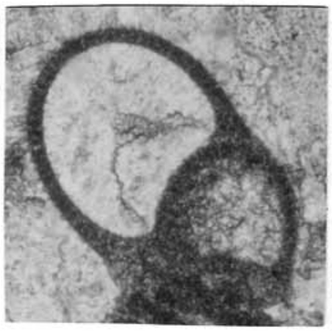
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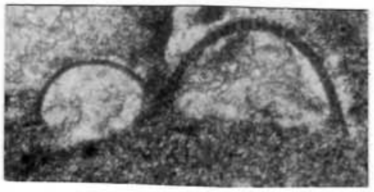
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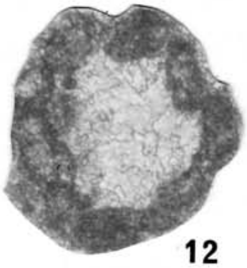
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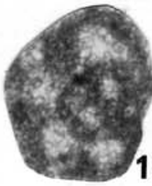
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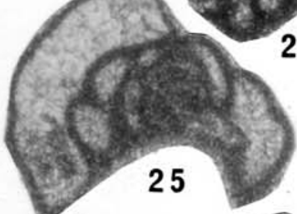
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## PLATE 2

1-5 – *Tansillites anfractuosus* Nestell and Nestell, n. gen., n. sp.

1 KUMIP 2,506,758, axial section, ×90, Amoco #1 core, depth: 76ft;

2 KUMIP 2,506,759, axial section, ×90, Amoco #1 core, depth: 72ft;

3 KUMIP 2,506,760, equatorial section, ×90, Amoco #1 core, depth: 90ft;

4 KUMIP 2,506,761, axial section, ×90, Amoco #2 core, depth: 177.3-177.45ft;

5 KUMIP 2,506,762, holotype, axial section, ×90, Amoco #1 core, depth: 106ft.

6-8 – *Palaeonubecularia marginata* Nestell and Nestell, n. sp.

6 KUMIP 2,506,763, holotype, axial section, ×32, Amoco #2 core, depth: 177.85-178.0ft;

7 KUMIP 2,506,764, axial section, ×32, Amoco #1 core, depth: 148ft;

8 KUMIP 2,506,765, axial section, ×32, Amoco #1 core, depth: 10ft.

9 – *Pseudolituotuba* (*Pseudospira*) sp. 1, KUMIP 2,506,766, close to axial section, ×56, Amoco #1 core, depth 154ft.

10-27 – *Pseudohemigordius incredibilis* Nestell and Nestell, n. gen., n. sp.

10 KUMIP 2,506,767, juvenile specimen, axial section, ×90, Amoco #1 core, depth: 108ft;

11 KUMIP 2,506,768; juvenile specimen, equatorial section, ×90, Amoco #1 core, depth: 108ft;

12 KUMIP 2,506,769, axial section, ×90, Amoco #1 core, depth: 88ft;

13 KUMIP 2,506,770, equatorial section, ×90, Amoco #2 core, depth: 298.0-298.15ft;

14 KUMIP 2,506,771, axial section, ×90, Amoco #1 core, depth: 262ft;

15 KUMIP 2,506,772, axial section, ×90, Amoco #1 core, depth: 262ft;

16 KUMIP 2,506,773, equatorial section, ×90, Amoco #1 core, depth: 90ft;

17 KUMIP 2,506,774, lateral section, ×90, Amoco #1 core, depth: 220ft;

18 KUMIP 2,506,775, holotype, lateral section, ×90, Amoco #1 core, depth: 42ft;

19 KUMIP 2,506,776, lateral section, ×90, Amoco #1 core, depth: 42ft;

20 KUMIP 2,506,777, lateral section, ×90, Amoco #2 core, depth: 155.5-155.65ft;

21 KUMIP 2,506,778, axial section, ×90, Amoco #1 core, depth: 42ft;

22 KUMIP 2,506,779, lateral section, ×90, Amoco #2 core, depth: 342.45-342.6ft;

23 KUMIP 2,506,780, paratype, lateral section, ×90, Amoco #1 core, depth: 42ft;

24 KUMIP 2,506,781, tangential section, ×90, Amoco #1 core, depth: 106ft;

25 KUMIP 2,506,782, tangential section, ×90, Amoco #1 core, depth: 106ft;

26 KUMIP 2,506,783, lateral section, ×90, Amoco #2 core, depth: 216.3-216.45ft;

27 KUMIP 2,506,784, lateral section, ×90, Amoco #2 core, depth: 285.2-285.35ft.

28-36. *Baisalina americana* Nestell and Nestell, n sp.

28 KUMIP 2,506,785, lateral section, ×64, Amoco #2 core, depth: 150.8-150.95ft;

29 KUMIP 2,506,786, equatorial section, ×64, Amoco #2 core, depth: 177.3-177.45ft;

30 KUMIP 2,506,787, lateral section, ×64, Amoco #2 core, depth: 150.8-150.95ft;

31 KUMIP 2,506,788, holotype, axial section, ×64, Amoco #2 core, depth: 177.1-177.25ft;

32 KUMIP 2,506,789, equatorial section, ×64, Amoco #2 core, depth: 150.8-150.95ft;

33 KUMIP 2,506,790, close to axial section, ×64, Amoco #2 core, depth: 148.65-148.8ft;

34 KUMIP 2,506,791, lateral section, ×64, Amoco #2 core, depth: 213.05-213.2ft;

35 KUMIP 2,506,792, equatorial section, ×64, Amoco #2 core, depth: 177.3-177.45ft ;

36 KUMIP 2,506,793, equatorial section, ×64, Amoco #2 core, depth: 177.45-177.6ft.


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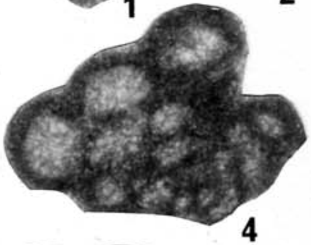
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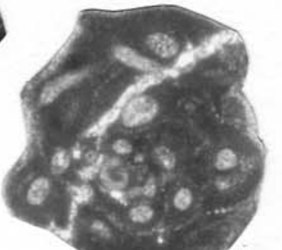
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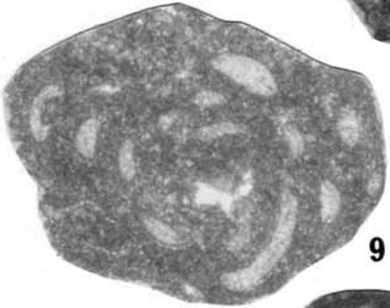
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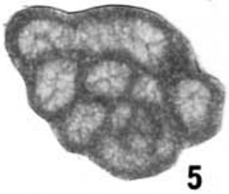
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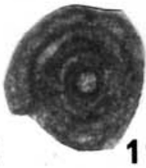
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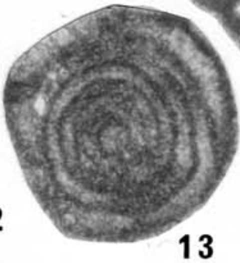
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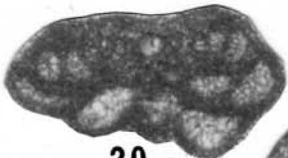
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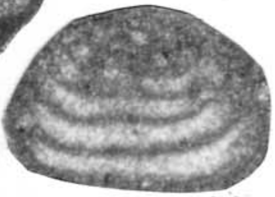
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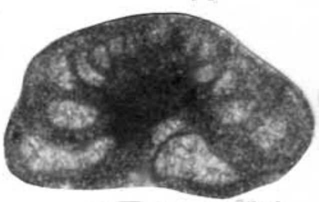
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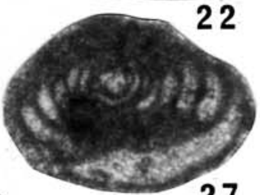
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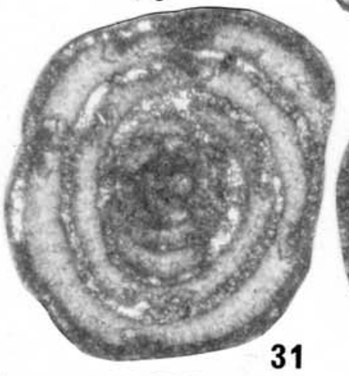
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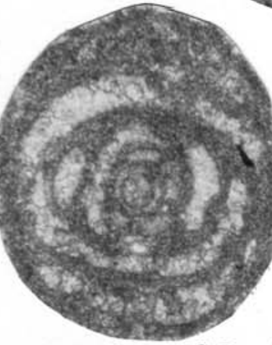
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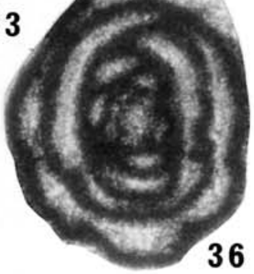
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Rozovskaya 1958 ex Ozawainellinae Thompson and Foster 1937]

Subfamily REICHELININAE A. Miklukho-Maklay 1959

Genus *Reichelina* Erk 1942; emend. K. Miklukho-Maklay 1954

***Reichelina lamarensis*** Skinner and Wilde 1955

Plate 9, figures 16-24; Plate 10, figures 1-6

*Reichelina lamarensis* SKINNER and WILDE 1955, p. 927-940, pl. 89, figs. 1-9. – YANG and YANCEY 2000, pl. 9-2, figs. 1-16. – WILDE and RUDINE 2000, p. 347-348, pl. 15-2, figs. 1-5, pl. 15-3, figs. 1-11, pl. 5-4, figs. 1-9, pl. 15-5, figs. 1-3.

*Reichelina bengensis* YANG and YANCEY 2000, p. 198-199, pl. 9-2, figs. 17-20.

*Reichelina birdensis* YANG and YANCEY 2000, p. 198-199, pl. 9-2, figs. 21-27.

*Description*: Test is minute, inner volutions coiled discoidally; much of the last or outer volution uncoiled from the inner coils in an axial section, with up to 7 septal divisions in the uncoiled part of an axially oriented specimen. Mature specimens generally have about 5 volutions, although a few specimens reach 7 volutions. Diameter (D) and length (L) reach 1.32mm and 0.42mm in mature specimens, respectively (L/D = 3.14). Spirotheca is very thin, ranges from 0.007mm in the first volution to about 0.017mm in the last volutions, and consists of a tectum and possibly recrystallized diaphanotheca. Septa are strongly convex and unfluted, septal pores are common. Proloculus varies from very tiny in probable microspheric specimens and averages about 0.4mm in megalospheric specimens. Tunnel is low, narrow, and indistinct in some specimens. Chomata low and broad, and extend laterally to the polar region and join across the tunnel floor.

*Material*: 17 oriented specimens.

*Discussion*: The genus *Reichelina* was first described by Erk (1942) from late Middle Permian strata near Bursa, Turkey. Skinner and Wilde (1955) described *Reichelina lamarensis*, the first species of this genus to be found in North America. It was originally found in the Lamar Limestone Member of the Bell Canyon Formation from a locality known as Buck Hill (located on private property) on the south side of the road into McKittrick Canyon in Guadalupe Mountains National Park. Skinner and Wilde (1955) noted that sporadic specimens occur throughout the Lamar. This species has been recently described from similar age strata in the northern part of the Del Norte Mountains and western part of the Glass Mountains in West Texas (Wilde and Rudine 2000). Yang and Yancey (2000) also noted this same species and described three new species, *R. bengensis*, *R. birdensis*, and *R. haneefi* from the same area. They also referred *Ozawainella delawarensis* Dunbar and Skinner 1937 to the genus *Reichelina*. Skinner and Wilde (1955) had previously suggested the latter referral with question. The present authors take a conservative approach to the speciation of American forms of this genus and consider that the species *R. bengensis* and *R. birdensis* are population variants of *R. lamarensis*. This conclusion is based on numerous oriented sections of *R. lamarensis* made from strata at the south side of the mouth of Dark Canyon in which a great variation of morphology can be seen in a single sample. We consider that *R. haneefi* possibly constitutes a different species from *R. lamarensis.*

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #2 core. *Reichelina lamarensis* occurs in the Dark Canyon Amoco #2 core at various levels ranging from 110.85ft to a depth of 216.45ft. The species is common to abun-

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## PLATE 3

1-5 – *Agathammina pusilla* (Geinitz).

1 KUMIP 2,506,794, equatorial section, ×40, Amoco #1 core, depth: 116ft;

2 KUMIP 2,506,795, axial lateral section, ×40,Amoco #1 core, depth: 116ft;

3 KUMIP 2,506,796, axial section, ×64, Amoco #2 core, depth: 231.75-231.9ft;

4 KUMIP 2,506,797, equatorial section, ×64, Amoco #2 core, depth: 183.9-184.05ft;

5 KUMIP 2,506,798, tangential lateral section, ×64, Amoco #1 core, depth: 128ft.

6-7 – *Agathammina* sp. 7

6 KUMIP 2,506,799, equatorial section, ×64, Amoco #2 core, depth: 216.3-216.45ft;

7 KUMIP 2,506,800, axial section, ×64, Amoco #2 core, depth: 216.3-216.45ft.

8-11 – *Agathammina* ex gr. *A. rosella* G. Pronina

8 KUMIP 2,506,801, equatorial? section, ×40, Amoco #2 core, depth: 153.6-153.75ft;

9 KUMIP 2,506,802, axial? section, ×64, Amoco #2 core, depth: 202.25-202.4ft;

10 KUMIP 2,506,803, equatorial? section, ×64, Amoco #1 core, depth: 126ft;

11 KUMIP 2,506,804, axial? section, ×64, Amoco #1 core, depth: 120ft.

12 – *Agathammina* sp. 1, KUMIP 2,506,805, axial lateral section, ×90, Amoco #2 core, depth 465.0-465.15ft.

13 – *Graecodiscus* sp., KUMIP 2,506,806, close to axial section, ×55, Amoco #1 core, depth 154ft.

14 – *Agathammina* sp. 2, KUMIP 2,506,807, close to axial section, ×55, Amoco #1 core, depth 208ft.


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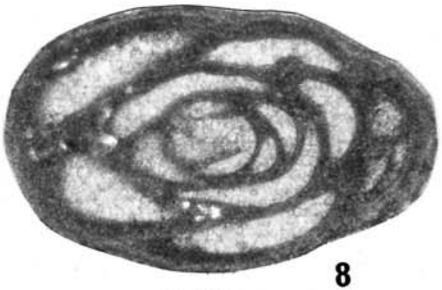
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## PLATE 4

1-2 – *Graecodiscus praecursor* Nestell and Nestell, n. sp.
- 1 KUMIP 2,506,808, holotype, close to axial section, ×40, Amoco #1 core, depth: 120ft
- 2 KUMIP 2,506,809, paratype; close to axial section, ×40, Amoco #1 core, depth: 90ft.

3 – *Graecodiscus* sp. 2, KUMIP 2,506,810, close to axial section, ×64, Amoco #2 core, depth 465.0-465.15ft.

4-6 – *Nodosaria capitanensis* Nestell and Nestell, n. sp.
- 4 KUMIP 2,506,811, holotype, axial section, ×90, Amoco #2 core, depth: 358.1-358.25ft;
- 5 KUMIP 2,506,812, axial section, ×90, Amoco #1 core, depth: 186ft;
- 6 KUMIP 2,506,813, axial section, ×90, Amoco #2 core, depth: 463.65-463.8ft.

7 – *Nodosaria* cf. *N. novizkiana* Sosnina, KUMIP 2,506,814, close to axial section, ×90, Amoco #2 core, depth 329.75-329.9ft.

8 – *Nodosaria* sp. 8, KUMIP 2,506,815, axial section, ×90, Amoco #2 core, depth 231.75-231.9ft.

9 – *Nodosaria* ex gr. *N. grandecamerata* Sosnina, KUMIP 2,506,816, tangential section, ×64, Amoco #1 core, depth 190.5ft.

10 – *Nodosaria* cf. *N. partisana* Sosnina, KUMIP 2,506,817, close to axial section, ×90, Amoco #1 core, depth 310.1ft.

11 – *Robustopachyphloia*? sp., KUMIP 2,506,849, axial section, ×90, Amoco #2 core, depth 332.25-332.4ft.

12 – *Lingulina*? sp., KUMIP 2,506,819, tangential axial section, ×90, Amoco #2 core, depth 221.7-221.85ft.

13 – *Polarisella lingulae* Nestell and Nestell, n. sp., KUMIP 2,506,818, holotype, close to axial section, ×90, Amoco #1 core, depth 198ft.

14 – *Rectoglandulina lepida* (Wang), KUMIP 2,506,820, close to axial section, ×90, Amoco #2 core, depth 155.0-155.15ft.

15, 18 – *Eomarginulinella*? sp.
- 15 KUMIP 2,506,823, lateral section, ×90, Amoco #2 core, depth: 360.85-361.0ft;
- 18 KUMIP 2,506,824, lateral section, ×90, Amoco #2 core, depth: 358.95-359.1ft.

16-17 – *Eomarginulinella* sp. 1
- 16 KUMIP 2,506,821, close to axial section, ×64, Amoco #1 core, depth: 88ft;
- 17 KUMIP 2,506,822, close to axial section, ×64, Amoco #1 core, depth: 110ft.

19-20 – *Calvezina* sp. 1.
- 19 KUMIP 2,506,825, transverse section, ×90, Amoco #1 core, depth 372ft;
- 20 KUMIP 2,506,826, close to axial section, ×90, Amoco #1 core, depth 372ft.

21-22 – *Lingulonodosaria*? sp.
- 21 KUMIP 2,506,828, axial lateral section, ×90, Amoco#1 core, depth: 174ft.
- 22 KUMIP 2,506,827, axial section, ×90, Amoco #1 core, depth: 88ft.

23-25 – *Geinitzina* sp. 1.
- 23 KUMIP 2,506,847, transverse section, ×90, Amoco #1 core, depth: 356ft;
- 24 KUMIP 2,506,848, tangential axial section, ×90, Amoco #1 core, depth: 350ft;
- 25 KUMIP 2,506,844, lateral section, ×90, Amoco #1 core, depth: 374ft.

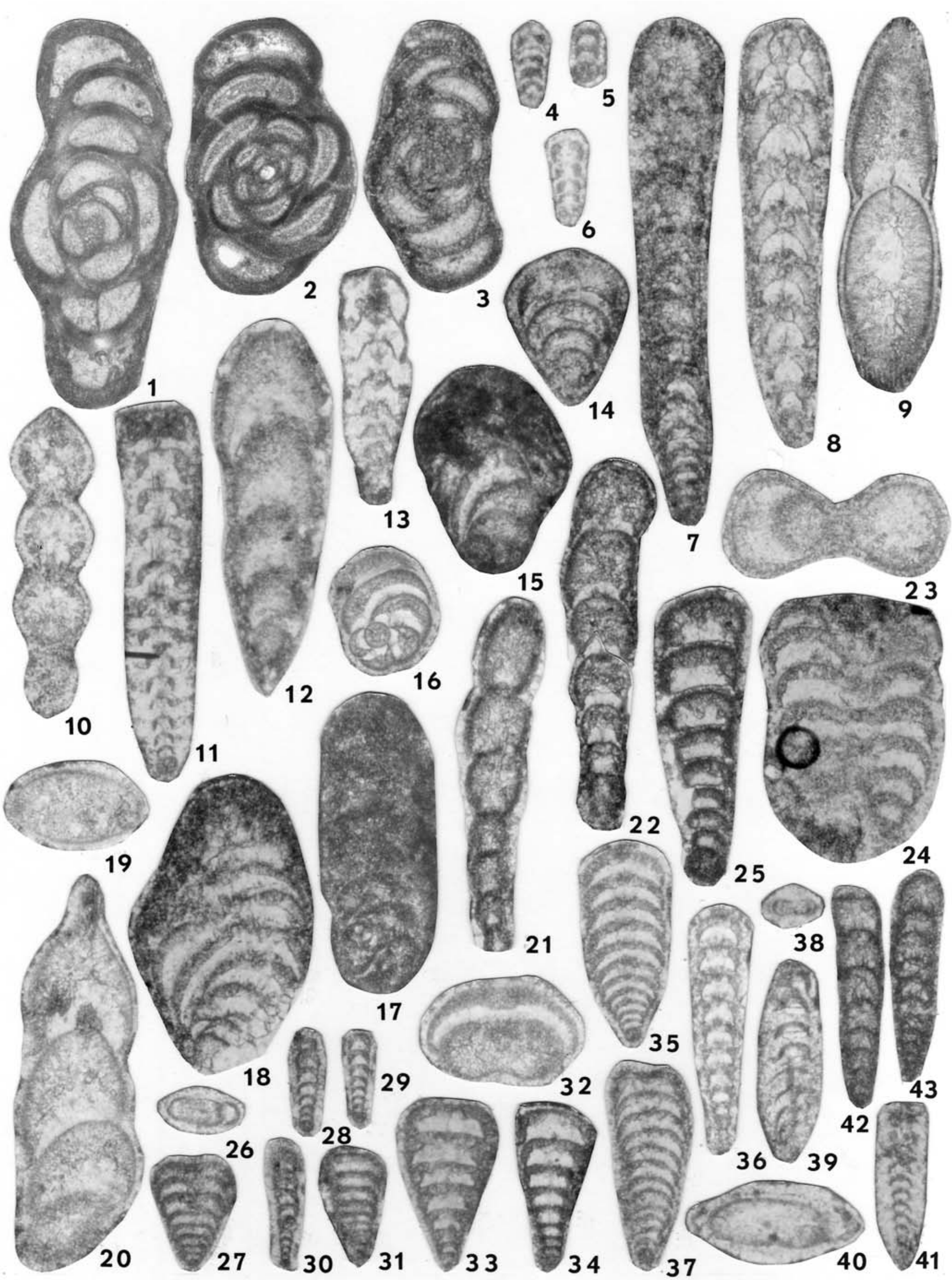
Fig. 26-31– *Geinitzina aetheria* Nestell and Nestell, n. sp., x 90.
- 26 KUMIP 2,506,835, transverse section, ×90, Amoco #1 core, depth: 176ft;
- 27 KUMIP 2,506,836, holotype, axial section, ×90, Amoco # 1 core, depth: 172ft;
- 28 KUMIP 2,506,837, lateral section, ×90, Amoco #1 core, depth: 226ft;
- 29 KUMIP 2,506,839, lateral section, ×90, Amoco #1 core, depth: 102ft;
- 30 KUMIP 2,506,838, lateral section, ×90, Amoco #1 core, depth: 172ft;
- 31 KUMIP 2,506,840, close to axial section, ×90, Amoco #1 core, depth: 186ft.

32-34 – *Geinitzina* sp. 4
- 32 KUMIP 2,506,841, tangential transverse section, ×90, Amoco #1 core, depth: 336.5ft;
- 33 KUMIP 2,506,842, close to axial section, ×90, Amoco #1 core, depth: 378ft;
- 34 KUMIP 2,506,843, lateral section, ×90, Amoco #1 core, depth: 396ft.

35-37 – *Tauridia* sp. 1
- 35 KUMIP 2,506,831, axial section, ×90, Amoco #2 core, depth: 344.05-344.2ft;
- 36 KUMIP 2,506,830, axial lateral section, ×90, Amoco #2 core, depth: 343.5-343.65ft;
- 37 KUMIP 2,506,829, axial section, ×90, Amoco #2 core, depth: 324.2-324.35ft.

38-41 – *Pachyphloia* sp.
- 38 KUMIP 2,506,852, transverse section, ×90, Amoco #2 core, depth: 343.5-343.65ft;
- 39 KUMIP 2,506,851, tangential lateral section, ×90, Amoco #2 core, depth: 365.5-365.65ft;
- 40 KUMIP 2,506,850, transverse section, ×90, Amoco #2 core, depth: 365.5-365.65ft;
- 41 KUMIP 2,506,853, lateral axial section, ×90, Amoco #2 core, depth: 366.5-366.65ft.

42-43 – *Ichthyolaria* sp. 1
- 42 KUMIP 2,506,855, lateral section, ×90, Amoco #1 core, depth: 238ft;
- 43 KUMIP 2,506,854, lateral section, ×90, Amoco #1 core, depth: 378ft.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dant in the depth interval from 199.65 to 211.05ft. One specimen from a depth of 322.75ft is questionably referred to *Reichelina lamarensis*.

***Reichelina*** aff. ***R. changhsingensis*** Sheng and Chang 1958
Plate 8, figure 16; plate 9, figure 6

*Description*: Test is minute, inner volutions discoidal, outer volution significantly uncoiled on one side of the inner coils in an axial section, with 24 septal divisions in the uncoiled part of axially oriented specimen. Diameter (D) and length (L) are 0.936mm and 0.119mm, respectively (L/D = 0.127). The equatorial specimen has a diameter of 0.421mm, proloculus diameter of 0.035mm and 10 septal divisions in the uncoiled part.

*Discussion*: Only one poorly oriented axial specimen of this variant of *Reichelina* that exhibits a significant uncoiling of the last chamber was seen in the collection. It is questionably referred to *R. changhsingensis.* One other equatorial specimen is also referred to this species with question. The species *R. changhsingensis* is well known from many localities in late Middle and Upper Permian strata in the Tethys.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, depth 222ft (axial specimen) and 244ft (equatorial specimen), Tansill Formation, Middle Permian (Capitanian).

Genus *Parareichelina* Miklukho-Maklay in Rauser-Chernoussova and Fursenko 1959

***Parareichelina*** sp.
Plate 8, figure 8

*Description*: Test is minute, inner volutions coiled, slightly inflated discoid, outer volution uncoiled in a flare that can be seen on opposite sides of the inner coils in an axial or oriented equa-

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## PLATE 5

1-2 – *Tauridia* sp. 3
1 KUMIP 2,506,833, axial section, ×90, Amoco #1 core, depth: 98ft;
2 KUMIP 2,506,832, transverse section, ×90, Amoco #1 core, depth: 126ft.

3 – *Tauridia* sp. 2, KUMIP 2,506,834, lateral section, ×90, Amoco #2 core, depth 453.1-453.25ft.

4-5 – *Tauridia* sp. 4
4 KUMIP 2,506,846, close to axial section, ×90, Amoco #1 core, depth: 108ft;
5 KUMIP 2,506,845, lateral section, ×90, Amoco #1 core, depth: 192ft.

6 – *Howchinella* sp. 1, KUMIP 2,506,856, close to axial section, ×90, Amoco #2 core, depth 429.15-429.3ft.

7-8 – *Ichthyolaria* sp. 2
7 KUMIP 2,506,857, transverse section, ×90, Amoco #1 core, depth: 166ft;
8 KUMIP 2,506,858, tangential axial section, ×90, Amoco #1 core, depth: 128ft.

9 – *Partisania* sp., KUMIP 2,506,859, tangential section, ×64, Amoco #1 core, depth 42ft.

10-13 – *Globivalvulina* sp. 4
10 KUMIP 2,506,861, tangential section, ×64, Amoco #2 core, depth: 213.05-213.2ft;
11 KUMIP 2,506,860, axial section, ×64, Amoco #2 core, depth: 213.05-213.2ft;
12 KUMIP 2,506,862, lateral section, ×64, Amoco #2 core, depth: 375.0-375.15ft;
13 KUMIP 2,506,863, close to axial section, ×64, Amoco #2 core, depth: 230.0-230.15ft.

14-25 – *Globivalvulina guadalupensis* Nestell and Nestell, n. sp.
14 KUMIP 2,506,864, paratype, lateral section, ×64, Amoco #2 core, depth: 326.45-326.6ft;
15 KUMIP 2,506,866, tangential lateral section, ×64, Amoco #2 core, depth: 318.0-318.15ft;
16 KUMIP 2,506,865, axial section, ×64, Amoco #2 core, depth: 452.1-452.25ft;
17 KUMIP 2,506,867, axial section, ×64, Amoco #2 core, depth: 375.95-376.1ft;
18 KUMIP 2,506,868, holotype, axial section, ×64, Amoco #2 core, depth: 324.2-324.35ft;
19 KUMIP 2,506,869, tangential section, ×64, Amoco #2 core, depth: 382.8-382.95ft;
20 KUMIP 2,506,870, paratype, axial section, ×64, Amoco #2 core, depth: 343.9-344.05ft;
21 KUMIP 2,506,871, axial section, ×64, Amoco #2 core, depth: 342.45-342.6ft;
22 KUMIP 2,506,872, tangential lateral section, ×64, Amoco #2 core, depth: 344.05-344.2ft;
23 KUMIP 2,506,873, axial section, ×64, Amoco #2 core, depth: 430.8-430.95ft;
24 KUMIP 2,506,874, tangential lateral section, ×64, Amoco #2 core, depth: 346.85-347.0ft;
25 KUMIP 2,506,875, paratype, tangential section, ×64, Amoco #2 core, depth: 326.75-326.9ft.


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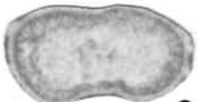
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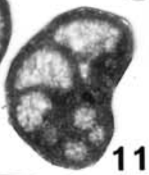
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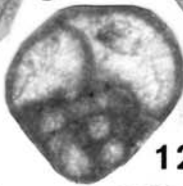
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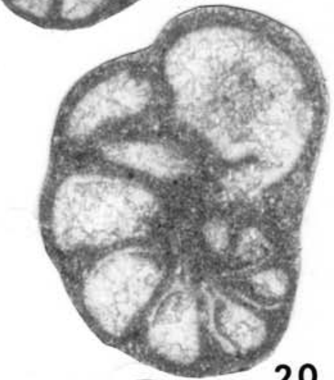
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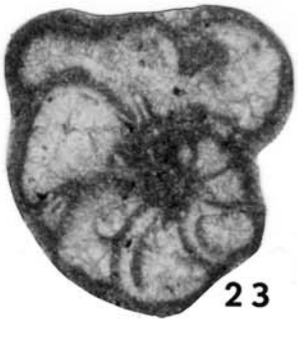
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torial section, with 9 and 12 septal divisions, respectively. Diameter (D) and length (L) are 0.873mm and 0.074mm, respectively L/D = 0.085.

*Discussion*: Only one tangential section of this form was seen in the collection. As the specimen clearly exhibits a flare in two opposite directions in an axial section, it is referred to *Parareichelina*. This fusulinacean genus is known from several localities in the Tethys including the Northwestern Caucasus (K. Miklukho-Maklay 1954, Pronina-Nestell and Nestell 2001), Sikhote-Alin (Sosnina 1968) and the Koryak (Davydov et al. 1996) area of eastern Siberia, Himalayas (Ladakh) (Lys et al. 1980), China (Sheng 1963), and Northern California (Stevens et al. 1991).

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, depth 174ft, Tansill Formation, Middle Permian (Capitanian).

Genus *Rauserella* Dunbar 1944

***Rauserella erratica*** Dunbar 1944
Plate 8, figure 4, plate 11, figure 6

*Rauserella erratica* DUNBAR 1944, p. 37-38, pl. 9, figs. 1-8; ROSS 1964, p. 315, pl. 50, figs. 1, 2. – TELLEZ-GIRON and NESTELL 1983, pl. 10, fig. 3;
VACHARD et al. 1993b, pl. 6, fig. 12, pl. 8, figs. 15, 16. – YANG and YANCEY 2000, p. 197, pl. 9-1, figs. 1-7.

*Description*: Test is highly irregularly fusiform, consisting of 4-7 volutions, of which the inner ones are very tightly coiled planispirally, generally highly skew to the axis of coiling of the last several volutions. The direction of axis of coiling shifts during growth so the tests are very irregular in appearance. Test length is generally les than 1.5mm and width less than 0.5mm. Spirotheca thin, ranging from about 0.007mm in the inner volutions to about 0.017mm in the last volution, consisting of a tectum and diaphanotheca. Proloculus is spherical, minute, 0.041mm in the specimen illustrated on Pl. 8, fig. 4. Tunnel is narrow and not well developed. Septa are generally planar to slightly fluted in the outer volutions.

*Discussion*: *Rauserella erratica* is a robust species of the genus that exhibits a few skewed coils in the inner volutions followed by somewhat regular elongate fusiform coiling. This genus and species were first described from Middle Permian strata at Las

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**PLATE 6**

1-2 – *Globivalvulina* sp. 1
1 KUMIP 2,506,876, tangential axial section, ×64, Amoco #1 core, depth: 128ft;
2 KUMIP 2,506,877, tangential lateral section, ×64, Amoco #2 core, depth: 342.9-343.05ft.

3-6 – *Sengoerina pulchra* Nestell and Nestell, n. sp.
3 KUMIP 2,506,878, paratype, axial section, ×64, Amoco #2 core, depth: 178.3-178.45ft;
4 KUMIP 2,506,879, tangential section, ×64, Amoco #2 core, depth: 407.35-407.5ft;
5 KUMIP 2,506,880, holotype, lateral section, ×64, Amoco #2 core, depth: 391.55-391.7ft;
6 KUMIP 2,506,881, axial section, ×64, Amoco #2 core, depth: 344.05-344.2ft.

7-12 – *Crescentia migrantis* Nestell and Nestell, n. sp.
7 KUMIP 2,506,882, close to axial section, ×64, Amoco #2 core, depth: 324.4-324.55ft;
8 KUMIP 2,506,883, paratype, lateral section, ×64, Amoco #2 core, depth: 213.7-213.85ft;
9 KUMIP 2,506,884, tangential lateral section, ×64, Amoco #2 core, depth: 303.5-303.65ft;
10 KUMIP 2,506,885; tangential lateral section, ×64, Amoco #2 core, depth: 323.9-324.05ft;
11 KUMIP 2,506,886, holotype, axial section, ×64, Amoco #2 core, depth: 199.85-200.0ft;
12 KUMIP 2,506,887; equatorial section of the initial part, ×64, Amoco #2 core, depth: 324.55-324.7ft.

13 – *Endothyra* sp., KUMIP 2,506,888, equatorial section, ×64, Amoco #2 core, depth 178.3-178.45ft.

14-22 – *Neoendothyranella wildei* Nestell and Nestell, n. gen., n. sp.
14 KUMIP 2,506,889, tangential lateral section of the initial part, ×64, Amoco #2 core, depth: 427.4-427.55ft;
15 KUMIP 2,506,890, tangential lateral section of the initial part, ×64, Amoco #1 core, depth: 170ft;
16 KUMIP 2,506,891, tangential axial section of the initial part, ×64, Amoco #1 core, depth: 22ft;
17 KUMIP 2,506,892, tangential lateral section of the initial part, ×64, Amoco #1 core, depth: 108ft;
18 KUMIP 2,506,893, tangential lateral section of the initial part, ×64, Amoco #1 core, depth: 152ft;
19 KUMIP 2,506,894, close to axial section of the initial part, ×64, Amoco #1 core, depth: 172ft;
20 KUMIP 2,506,895, close to axial section of the initial part, ×64, Amoco #1 core, depth: 90ft;
21 KUMIP 2,506,896, paratype, lateral section, ×64, Amoco #1 core, depth: 231.5ft;
22 KUMIP 2,506,897, holotype, lateral section, ×64, Amoco #1 core, depth: 220ft.


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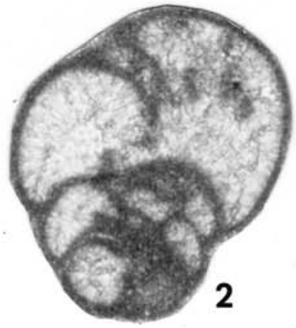
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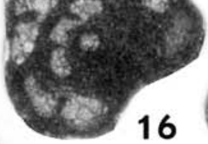
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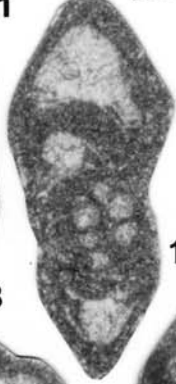
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Delicias, Coahuila, Mexico (Dunbar 1944, Tellez-Giron and Nestell 1983). It is also common in coeval strata in the Glass, Del Norte (Yang and Yancey 2000), and Guadalupe Mountains of West Texas, and near Olinalá in the Mexican State of Guerrero (Vachard et al. 1993b). It is also known in the eastern Tethys in China in the Maokou Formation in Guizhou Province (Yang 1985), the Qixia Formation in Jiangsu Province (Zhang et al. 1988), the Permian of the Nadanhada Range in northeastern China (Han 1985) and possibly at other localities. Sosnina (1968) also described a new subspecies, *R. erratica ussuriensis*, from the Southern Primorye area that we consider to probably be conspecific with *R. erratica*.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, the depth 128ft (pl. 8, fig. 4), Tansill Formation, and the Amoco #2 core, the depth 425.2-426ft, upper part of the Yates Formation; Middle Permian (Capitanian). Only two specimens referred to this species are illustrated although other poorly oriented specimens were seen in both cores that could possibly be referred to this species.

***Rauserella bengeensis*** Wilde and Rudine 2000
Plate 9, figures 10-15, Plate 10, figures 11, 17, Plate 11, figures 2, 7

*Rauserella bengeensis* WILDE and RUDINE 2000, p. 348, pl. 15-1, figs. 1-9, pl. 15-2, figs. 6-10.

*Discussion*: *Rauserella bengeensis* is a very tiny member of the genus *Rauserella* and was first described from Middle Permian strata exposed in the Glass and Del Norte mountains of West

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## PLATE 7

1 – *Dagmarita* sp., KUMIP 2,506,898, lateral section, ×90, Amoco #2 core, depth 331.9-332.05ft.

2-7 – *Abadehella* ex gr. *A. coniformis* Okimura and Ishii
- 2 KUMIP 2,506,899, axial section, ×64, Amoco #2 core, depth: 202.1-202.25ft;
- 3 KUMIP 2,506,900, lateral section, ×64, Amoco #2 core, depth: 197.95-198.1ft;
- 4 KUMIP 2,506,901, axial section, ×64, Amoco #2 core, depth: 380.85-381.0ft;
- 5 KUMIP 2,506,902, transverse section, ×64, Amoco #2 core, depth: 378.4-378.55ft;
- 6 KUMIP 2,506,903, axial section, ×64, Amoco #2 core, depth: 215.95-216.1ft;
- 7 KUMIP 2,506,904, axial section, ×64, Amoco #1 core, depth: 38ft.

8-11 – *Abadehella* sp. 2
- 8 KUMIP 2,506,905, close to axial section, ×64, Amoco #2 core, depth: 330.5-330.65ft;
- 9 KUMIP 2,506,906, close to axial section, ×64, Amoco #2 core, depth: 346.85-347.0ft;
- 10 KUMIP 2,506,907, close to axial section, ×64, Amoco #1 core, depth:180ft;
- 11 KUMIP 2,506,908, close to axial section, ×64, Amoco #1 core, depth: 138ft.

12 – *Spireitlina* sp. 2, KUMIP 2,506,909, close to axial section, ×90, Amoco #2 core, depth 324.55-324.7ft.

13 – *Spireitlina* sp., KUMIP 2,506,910, close to axial section, ×64, Amoco #2 core, depth 465.0-465.15ft.

14 – *Spireitlina*? sp., KUMIP 2,506,911, axial section, ×90, Amoco #2 core, depth 358.1-358.25ft.

15-16 – *Deckerella* sp.
- 15 KUMIP 2,506,912, close to axial section of young specimen, ×32, Amoco #1 core, depth: 255.5ft
- 16 KUMIP 2,506,913, tangential axial section of adult specimen, ×32, Amoco #1 core, depth: 282ft.

17-22 – *Aschemonella* sp.
- 17 KUMIP 2,506,914, axial section, ×64, Amoco #1 core, depth: 228ft;
- 18 KUMIP 2,506,915, tangential section, ×64, Amoco #1 core, depth: 238ft;
- 19 KUMIP 2,506,916, close to axial section, ×64, Amoco #1 core, depth: 230ft;
- 20 KUMIP 2,506,917, tangential section, ×64, Amoco #1 core, depth: 231.5ft;
- 21 KUMIP 2,506,918; close to axial section, ×64, Amoco #1 core, depth: 224ft;
- 22 KUMIP 2,506,919, axial? section of the apertural end, ×64, Amoco #1 core, depth: 126ft.

23-27 – *Pseudokahlerina capitanensis* Nestell and Nestell, n. sp.
- 23 KUMIP 2,506,920, axial section, ×40, Amoco #1 core, depth: 116ft;
- 24 KUMIP 2,506,921, holotype, axial section, ×40, Amoco #1 core, depth: 110ft;
- 25 KUMIP 2,506,922, axial section, ×40, Amoco #1 core, depth: 120ft;
- 26 KUMIP 2,506,923, axial section, ×40, Amoco #1 core, depth: 120ft;
- 27 KUMIP 2,506,924, axial section, ×40, Amoco #1 core, depth: 128-128.15ft.


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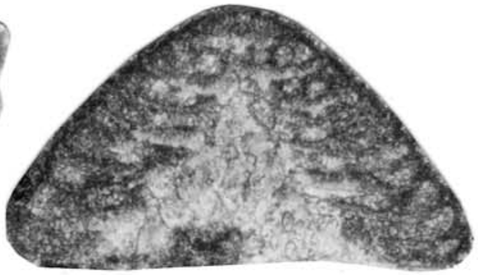
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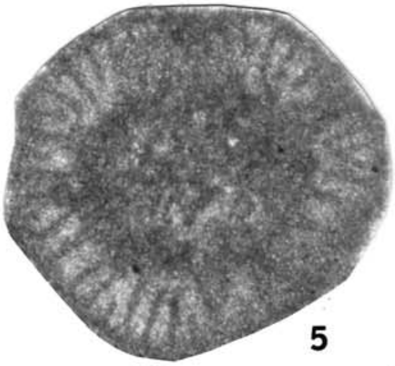
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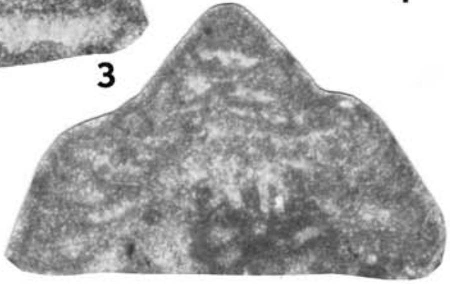
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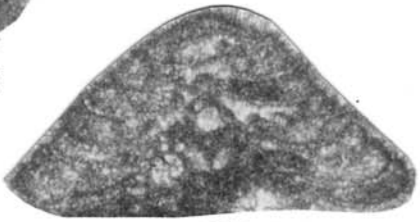
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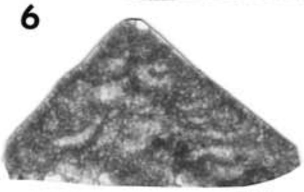
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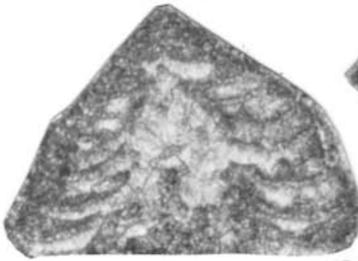
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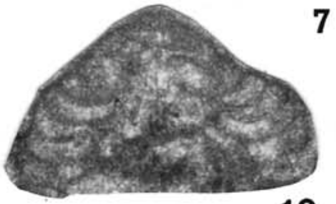
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Texas (Wilde and Rudine 2000). We have a number of very small specimens that resemble this species at several levels in both cores. Some are not well oriented. As many of our specimens seem to closely agree with the type material, we refer these forms to the *R. bengeensis*.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, the depth 128ft (pl. 8, fig. 4), Tansill Formation, and the Amoco #2 core, depth 372.95-373.1ft, 423.8-423.95ft, Yates Formation, and depth 142.2-144.35ft, 145.85-146.0ft, 424.35-424.5ft, 425.85-426.0ft, Tansill Formation; Middle Permian (Capitanian).

Order SCHUBERTELLIDA Skinner 1931 [nom. transl. Chediya in Rauser-Chernoussova et al. 1996 ex Schubertellidae A. Miklukho-Maklay, Rauser-Chernoussova and Rozovskaya 1958]
Family BOULTONIIDAE Skinner and Wilde 1954
Genus *Paraboultonia* Skinner and Wilde 1954

***Paraboultonia splendens*** Skinner and Wilde 1954
Plate 8, figures 3, 5, 6, 9-15; Plate 9, figures 1-5, 7, 8

*Lantschichites splendens* (Skinner and Wilde) in SHENG 1963, pl.12, figs. 16-22. – YANG and YANCEY 2000, p. 202-203, pl. 9-3, figs. 1-6, 11. – WILDE and RUDINE 2000, p. 348-349, pl. 15-8, figs. 1-11, pl. 15-9, figs. 1-7.

*Discussion*: A number of well-oriented specimens of this species are present in the two cores. It is unnecessary to give a detailed description as this species was recently thoroughly discussed by Wilde and Rudine (2000). The taxonomic position of *Paraboultonia splendens* Skinner and Wilde in the fusulinacean world has been the subject of some disagreement for a number of years. Tumanskaya (1953) described the subgenus *Lantschichites* of the genus *Codonofusiella* with type species *C.* (*L.*) *maslennikovi*, a form that is very similar to the genus *Paraboultonia* with type species *P. splendens* erected by Skinner and Wilde (1954). This genus was also considered as a synonym of *Lantschichites* by Miklukho-Maklay et al. with no comment (in Rauser-Chernoussova and Fursenko 1959). Later, Sheng (1963) elevated *Lantschichites* to generic status and since that time, most fusulinacean workers have suppressed *Paraboultonia* in favor of *Lantschichites*. The basic difference between the two genera is in the uncoiled last volution. The last whorl expands in *Paraboultonia*, but the septa continue to touch the floor of the previous whorl, whereas the last whorl is significantly uncoiled in *Lantschichites*, and the septa in the uncoiled part are attached to the previous septal face, as in the genus *Codonofusiella.* Whether or not this difference is of generic character is a matter of opinion and disagreement continues. Both points of view are discussed in two recent papers in the same symposium volume (Yang and Yancey 2000, Wilde and Rudine 2000), where species of both genera are described from the Glass and Del Norte Mountains in West Texas. We tend to agree with Wilde and Rudine (2000) and consider *Paraboultonia* to be a separate genus based on sections made of topotype material recently collected in the Apache Mountains. In samples collected in Seven Heart Gap (Skinner and Wilde 1954) from the “six inch limestone bed about 40ft below the top of the Bell Canyon Formation near the east end of the Apache

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## PLATE 8

1 – *Codonofusiella* cf. *C. paradoxica* Dunbar and Skinner, KUMIP 2,506,925, axial section, ×40, Amoco #1 core, depth 44ft.

2, 7 – *Codonofusiella* (*Lantschichites*) *altudaensis* Wilde and Rudine

2 KUMIP 2,506,926, oblique section, ×32, Amoco #1 core, depth: 44-45ft;

7 KUMIP 2,506,927, axial section, ×32, Amoco #1 core, depth: 172ft.

3, 5, 6, 9-15 – *Paraboultonia splendens* Skinner and Wilde

3 KUMIP 2,506,928, axial section, ×40, Amoco #1 core, depth: 98ft;

5 KUMIP 2,506,929, equatorial section, ×40, Amoco #1 core, depth: 128ft;

6 KUMIP 2,506,930, axial section, ×40, Amoco #1 core, depth: 156ft;

9 KUMIP 2,506,931, axial section, ×32, Amoco #1 core, depth: 178ft;

10 KUMIP 2,506,932, axial section, ×32, Amoco #1 core, depth: 196-197ft;

11 KUMIP 2,506,933, axial section, ×32, Amoco #1 core, depth: 196-197ft;

12 KUMIP 2,506,934, axial section, ×40, Amoco #1 core, depth: 202ft;

13 KUMIP 2,506,935, equatorial section, ×40, Amoco #1 core, depth: 208-209ft;

14 KUMIP 2,506,936, ×40, Amoco #1 core, depth: 228ft;

15 KUMIP 2,506,937, axial section, ×40, Amoco #1 core, depth: 202ft.

4 – *Rauserella erratica* Dunbar, KUMIP 2,506,938, equatorial section, ×40, Amoco #1 core, depth 128ft.

8 – *Parareichelina* sp., KUMIP 2,506,939, axial section, ×64, Amoco #1 core, depth 174ft.

16 – *Reichelina* aff. *R. changhsingensis* Sheng and Chang, KUMIP 2,506,940, parallel axial section, ×64, Amoco #1 core, depth 222ft.


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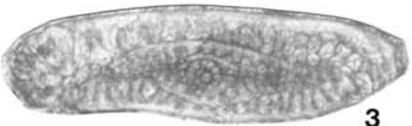
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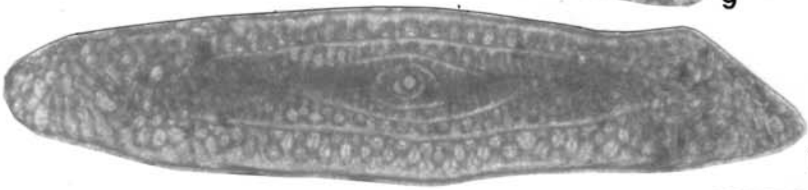
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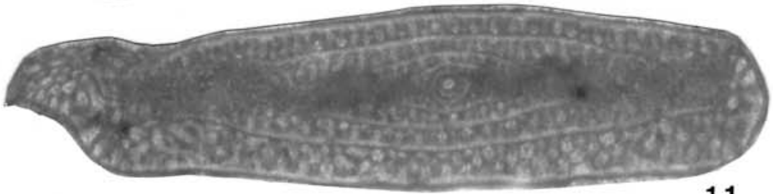
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Mountains, southern Culberson County, Texas", there are no specimens that show a significant uncoiled portion of the test. For that reason, the generic identity of *Paraboultonia* is considered valid and is used in this paper. Only two of the forms illustrated from the Amoco cores appear to have a significant uncoiled portion and they are referred below to *C*. (*L*). *altudaensis* Wilde and Rudine. *Paraboultonia splendens* also ocurs in the Guadalupe Mountains in the upper part of the Lamar Limestone and Reef Trail Member of the Bell Canyon Formation in the McKittrick Canyon area (Wilde et al. 1999). It is also common in surface collections made by the authors in the transitional Capitan to Tansill limestone at the mouth of Dark Canyon where the Amoco #1 core was taken.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, illustrated specimens in the interval from the depth 98-228ft, Tansill Formation; Middle Permian (Capitanian). Specimens possibly referable to *P. splendens* were seen in the Amoco #1 core from the depth 10–366ft, but some poorly oriented specimens seen in the upper part of the core show uncoiling typical of *C.* (*L.*) *altudaensis*.

Family PALAEOFUSULINIDAE A. Miklukho-Maklay 1963; emend. Leven 1987 [nom. transl. Chediya in Rauser-Chernoussova et al. 1996 ex Palaeofusulininae A. Miklukho-Maklay 1963]
Genus *Codonofusiella* Dunbar and Skinner 1937
Subgenus *Lantschichites* Tumanskaya 1953

***Codonofusiella (Lantschichites) altudaensis*** Wilde and Rudine 2000
Plate 8, figures 2, 7

*Description*: Two specimens, only one of which is well oriented, appear to slightly uncoil and are referred to this species. Test is minute, polar regions are blunt and cylindrical. Diameter (D) 0.708mm, length (L) 2.296mm, L/D = 3.2. There are five volutions, the last volution is slightly uncoiled, septa are intensely fluted from pole to pole, high septal folds are squared

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## PLATE 9

1-5, 7, 8 – *Paraboultonia splendens* Skinner and Wilde

1 KUMIP 2,506,941, axial section, ×40, Amoco #1 core, depth: 230ft;

2 KUMIP 2,506,942, equatorial section, ×40, Amoco #1 core, depth: 230ft;

3 *KUMIP 2,506,943, axial section, ×40, Amoco #1 core, depth: 231.5ft;

4 KUMIP 2,506,944, axial section, ×40, Amoco #1 core, depth: 242ft;

5 KUMIP 2,506,945, axial section, ×40, Amoco #1 core, depth: 246ft;

7 KUMIP 2,506,946, equatorial section, ×40, Amoco #1 core, depth: 297-298ft;

8 KUMIP 2,506,947, equatorial section, ×40, Amoco #1 core, depth: 362ft.

6 – *Reichelina* aff. *R. changhsingensis* Sheng and Chang, KUMIP 2,506,948, equatorial section, ×64, Amoco #1 core, depth 244ft.

9, 16-24 – *Reichelina lamarensis* Skinner and Wilde

9 KUMIP 2,506,949, equatorial section, ×64, Amoco #2 core, depth: 110.85-111.0ft;

16 KUMIP 2,506,950, axial section, ×64, Amoco #2 core, depth: 177.3-177.45ft;

17 KUMIP 2,506,951, equatorial section, ×64, Amoco #2 core, depth: 178.5-178.65ft;

18 KUMIP 2,506,952, axial section, ×64, Amoco #2 core, depth: 199.65-199.8ft;

19 KUMIP 2,506,953, axial section, ×64, Amoco #2 core, depth: 202.1-202.25ft;

20 KUMIP 2,506,954, equatorial section, ×64, Amoco #2 core, depth: 202.25-202.4ft;

21 KUMIP 2,506,955, axial section, ×64, Amoco #2 core, depth: 202.25-202.4ft;

22 KUMIP 2,506,956, axial section, ×64, Amoco #2 core, depth: 207.15-207.3ft;

23 KUMIP 2,506,957, axial section, ×64, Amoco #2 core, depth: 209.3-209.45ft;

24 KUMIP 2,506,958, axial section, ×64, Amoco #2 core, depth: 210.9-211.05ft.

10-15 – *Rauserella bengeensis* Wilde and Rudine

10 KUMIP 2,506,959, axial section, ×90, Amoco #2 core, depth: 144.2-144.35ft;

11 KUMIP 2,506,960, axial section, ×90, Amoco #2 core, depth: 144.2-144.35ft;

12 KUMIP 2,506,961, equatorial section, ×90, Amoco #2 core, depth: 145.85-146.0ft;

13 KUMIP 2,506,962, equatorial section, ×90, Amoco #2 core, depth:145.85-146.0ft;

14 KUMIP 2,506,963, axial section, ×90, Amoco #2 core, depth:145.85-146.0ft;

15 KUMIP 2,506,964, axial section, ×90, Amoco #2 core, depth: 145.85-146.0ft.


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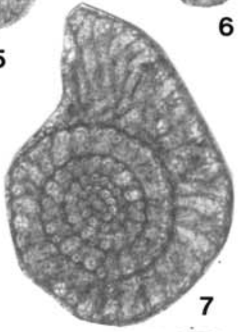
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off at the top in the last volution. Spirotheca is very thin (from 0.008mm in the first volution to 0.021mm in the 6th), consists of tectum and diaphanotheca. Proloculus is minute, outside diameter is 0.061mm.

*Discussion*: As noted above in the discussion of *Paraboultonia*, Wilde and Rudine (2000) present a through discussion of the controversial status of the genus *Codonofusiella* with subgenus *Lantschichites*. We basically agree with their conclusions regarding the status of this form and do not feel that this paper is the proper place to discuss this problem further. Both of the specimens illustrated here appear to begin to uncoil in the last volution.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, illustrated specimens (pl. 8, fig. 2) from a depth of 44-45ft, and (pl. 8, fig. 7) from a depth of 172ft, Tansill Formation, Middle Permian (Capitanian).

***Codonofusiella*** cf. ***C. paradoxica*** Dunbar and Skinner 1937
Plate 8, figure 1

*Codonofusiella paradoxica* DUNBAR and SKINNER 1937, p. 607-609, pl. 45, figs 1-9. – SHENG 1963, p.47, pl. 6, figs. 21-24. – YANG and YANCEY 2000, p. 202, pl. 9-3, figs. 7-9.

*Description*: Only one specimen of theis species with five volutions was noted in the cores. Length (L) 1.268mm, diameter (D) 0.812mm, L/D = 1.56. Wall thickness is from 0.004mm in the first volution to 0.021mm in the fifth volution, with tectum and diaphanotheca. Septa are intensely fluted with high and narrow septal folds. Proloculus is tiny, 0.054mm. Tunnel is poorly developed in the first two normally coiled volutions.

*Discussion*: *Codonofusiella paradoxica* Dunbar and Skinner is a small form of this genus with a reduced flare. It is known from the Glass and Del Norte Mountains (Yang and Yancey 2000), and in the Chinati Mountains (Skinner 1940) to the south of the Guadalupe Mountains in West Texas. It has also been reported from the eastern Tethys in the Wujiaping Limestone, Guizhou Province, in China (Sheng 1963).

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, depth 44ft, Tansill Formation, Middle Permian (Capitanian).

***Codonofusiella extensa*** Skinner and Wilde 1955
Plate 10, figures 10, 12, 16; Plate 11, figures 1, 3-5, 8-18

*Codonofusiella extensa* SKINNER and WILDE 1955, p. 930-934, pl. 89, fig. 10, pl. 90, figs. 1-5, pl. 91, figs. 1-6. – VACHARD et al. 1993b, pl. 6, figs. 18-21, pl. 7, figs. 1-9. – YANG and YANCEY 2000, p. 202, pl. 9-3, figs. 10.

*Description*: Test is small, with coiled inner part of four to five fusiform volutions and an uncoiled thin flare that expands laterally in a slightly concave manner along the entire test. The septa of the flare increase in length and do not reach back to the main part of the test in the later part of the flare. The coiling of the innermost volutions is often skewed to the later ones. Half width

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## PLATE 10

1-6 – *Reichelina lamarensis* Skinner and Wilde
1 KUMIP 2,506,965, axial section, ×64, Amoco #2 core, depth: 213.05-213.2ft;

2 KUMIP 2,506,966, axial section, ×64, Amoco #2 core, depth: 213.05-213.2ft;

3 KUMIP 2,506,967, axial section, ×64, Amoco #2 core, depth: 215.55-215.7ft;

4 KUMIP 2,506,968, axial section, ×64, Amoco #2 core, depth: 215.95-216.1ft;

5 KUMIP 2,506,969, axial section, ×64, Amoco #2 core, depth: 216.3-216.45ft;

6 KUMIP 2,506,970, equatorial section, ×64, Amoco #2 core, depth: 216.3-216.45ft.

7 – *Reichelina* sp., KUMIP 2,506,971, equatorial section, ×64, Amoco #2 core, depth: 322.75-322.9ft.

8-9 – *Paradoxiella pratti* Skinner and Wilde
8 KUMIP 2,506,972, oblique section, ×40, Amoco #2 core, depth: 330.1-330.25ft;

9 KUMIP 2,506,973, equatorial section, ×40, Amoco #2 core, depth: 330.5-330.65ft.

10, 12, 16 – *Codonofusiella extensa* Skinner and Wilde
10 KUMIP 2,506,974, axial section, ×32, Amoco #2 core, depth: 333.0-333.15ft;

12 KUMIP 2,506,975, axial section, ×40, Amoco #2 core, depth: 390.05-390.2ft;

16 KUMIP 2,506,976, axial section, ×32, Amoco #2 core, depth: 423.5-423.9ft.

11, 17 – *Rauserella bengeensis* Wilde and Rudine
11 KUMIP 2,506,977, axial section, ×90, Amoco #2 core, depth: 372.95-373.1ft;

17 KUMIP 2,506,978, oblique equatorial section, ×90, Amoco #2 core, depth: 423.8-423.95ft.

13-15 – *Yabeina texana* Skinner and Wilde
13 KUMIP 2,506,979, oblique section, ×40, Amoco #2 core, depth: 391.55-391.7ft;

14 KUMIP 2,506,980, equatorial section, ×40, Amoco #2 core, depth: 392.5-392.65ft;

15 KUMIP 2,506,981, equatorial section showing development of axial septulae, ×40, Amoco #2 core, depth: 392.5-392.65ft.


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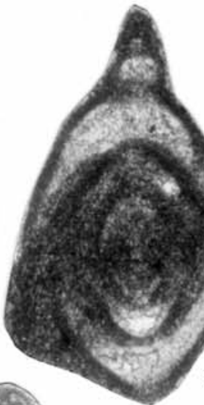
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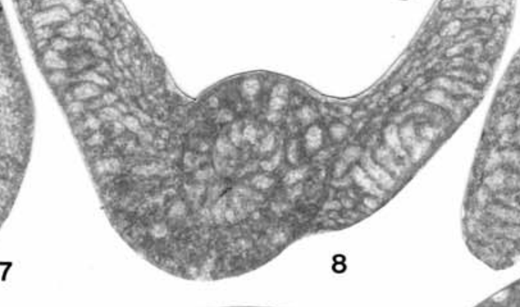
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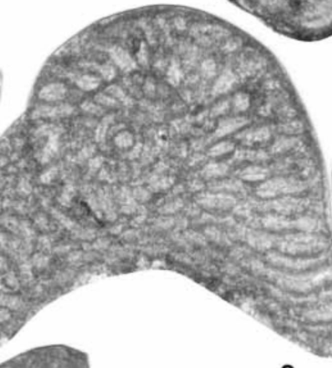
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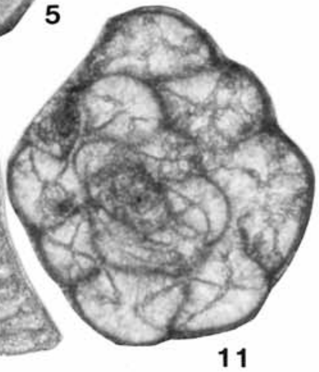
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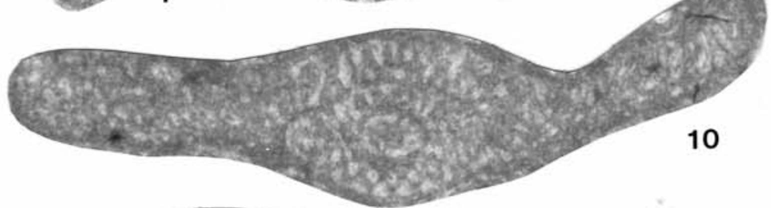
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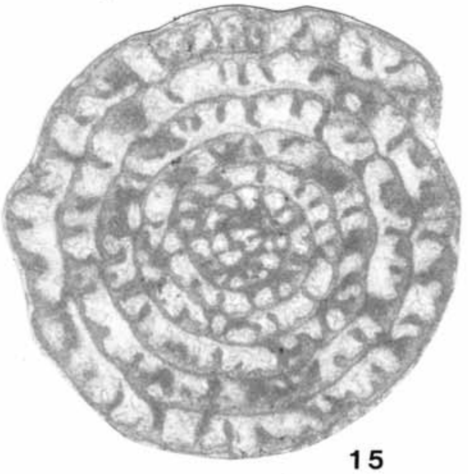
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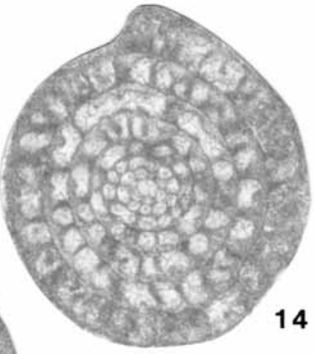
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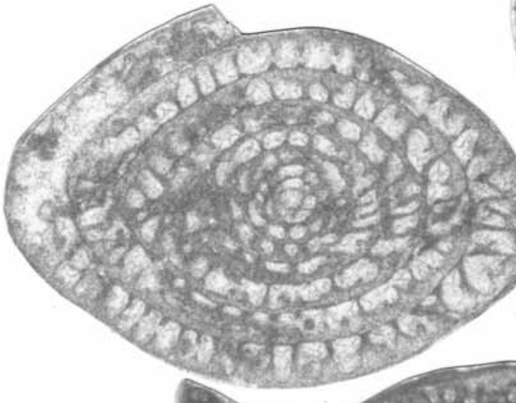
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ranges from 0.041mm in the first volution to 0.379mm in the unflared portion of the fifth volution. Half width of flared test (pl. 11, fig. 8) is 0.938mm. Half-length ranges from 0.036mm in the first volution to 1.562mm in the fifth or sixth volution. Spirotheca is thin, ranging from 0.006mm in the first volution to 0.022mm in the seventh volution, with a tectum and diaphanotheca. Septa are intensely fluted with high and narrow septal folds. Proloculus tiny, diameter ranges from 0.042mm to 0.076mm. Tunnel is narrow, bordered by weak chomata in the inner volutions.

*Discussion*: This distinctive species is very abundant in a few-meter interval of calcite spar grainstone in the Amoco #2 core just preceding the appearance of *Yabeina texana*.

It is difficult to assign poorly oriented specimens to this genus unless the flare is shown. It was originally described from the McCombs Limestone Member of the Bell Canyon Formation in a small exposure of this limestone near the mouth of McKittrick Canyon, Guadalupe Mountains, West Texas. It is also present in the basal Lamar Limestone in Bear Canyon at the type locality of *Yabeina texana*, where it occurs with this genus. It has also been reported from the Glass and Del Norte Mountains (Yang and Yancey 2000) and from near Olinalá in the Mexican state of Guerrero (Vachard et al. 1993b).

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #2 core, depth 420.0-434.45ft, upper part of the Yates Formation. This species is abundant in grainstone several meters thick in this interval that is immediately below quartz sandstone at the top of the Yates Formation in the core. Specimens possibly referable to this species also occur in the core as deep as 466ft and in the intervals 410-407ft, 396-387.5ft, 360-361ft, and 333ft.

Genus *Paradoxiella* Skinner and Wilde 1955

***Paradoxiella pratti*** Skinner and Wilde 1955
Plate 10, figures 8, 9

*Paradoxiella pratti* SKINNER and WILDE 1955, p. 934-937, pl. 91, fig. 7-9, pl. 92, fig. 1-10, pl. 93, fig. 1.

*Description*: Test is small, almost disk-shaped with inflated center portion. The coiled part of the test typically consists of three volutions, followed by an uncoiled flare of two volutions that expands rapidly so that the chambers of the flare are extended laterally with sharply recurved ends that terminate against the test. Spirotheca is thin, consisting of a tectum and diaphanotheca. Thin septa are intensely fluted. The spherical proloculus is minute, about 50 microns. Tunnel is low, narrow, and bordered by weakly developed chomata in the coiled part of the test. Only one equatorial section (pl. 10, fig. 9) of four volutions is well oriented, width 1.449mm, diameter of

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## PLATE 11

1, 3-5, 8-18 – *Codonofusiella extensa* Skinner and Wilde
- 1 KUMIP 2,506,982, axial section, ×40, Amoco #2 core, depth: 423.9-424.6ft;
- 3 KUMIP 2,506,983, axial section, ×32, Amoco #2 core, depth: 424.8-425.2ft;
- 4 KUMIP 2,506,984, equatorial section, ×40, Amoco #2 core, depth: 424.8-425.2ft;
- 5 KUMIP 2,506,985, equatorial section, ×40, Amoco #2 core, depth: 425.2-426.0ft;
- 8 KUMIP 2,506,986, axial section, ×32, Amoco #2 core, depth: 426.7-428.0ft;
- 9 KUMIP 2,506,987, axial section, ×40, Amoco #2 core, depth: 427.4-427.55ft;
- 10 KUMIP 2,506,988, equatorial section, ×40, Amoco #2 core, depth: 427.4-427.55ft;
- 11 KUMIP 2,506,989, axial section, ×32, Amoco #2 core, depth: 428.4-428.55ft;
- 12 KUMIP 2,506,990, axial section, ×40, Amoco #2 core, depth: 428.4-428.55ft;
- 13 KUMIP 2,506,991, equatorial section, ×40, Amoco #2 core, depth: 428.75-428.9ft;
- 14 KUMIP 2,506,992, axial section, ×40, Amoco #2 core, depth: 431.05-431.2ft;
- 15 KUMIP 2,506,993, axial section, ×32, Amoco #2 core, depth: 431.05-431.2ft;
- 16 KUMIP 2,506,994, equatorial section, ×40, Amoco #2 core, depth: 431.05-431.2ft;
- 17 KUMIP 2,506,995, equatorial section, ×40, Amoco #2 core, depth: 434.3-434.45ft;
- 18 KUMIP 2,506,996, equatorial section, ×40, Amoco #2 core, depth: 434.3-434.45ft;

2, 7 – *Rauserella bengeensis* Wilde and Rudine
- 2 KUMIP 2,506,997, equatorial section, ×90, Amoco #2 core, depth: 424.35-424.5ft;
- 7 KUMIP 2,506,998, oblique section, ×90, Amoco #2 core, depth: 425.85-426.0ft.

6 – *Rauserella erratica* Dunbar, KUMIP 2,506,999, parallel axial section, ×32, Amoco #2 core, depth 425.2-426ft.


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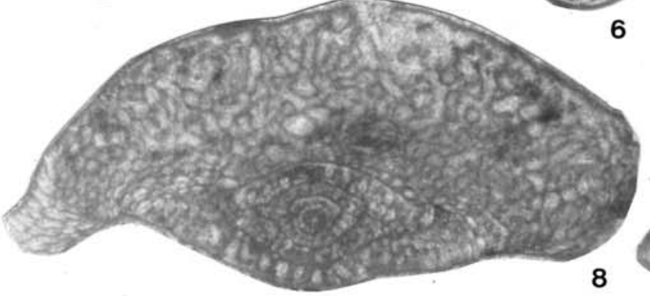
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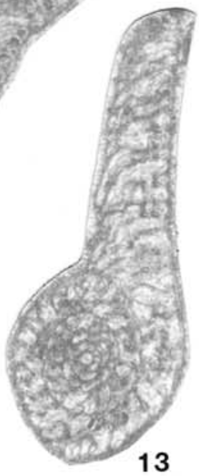
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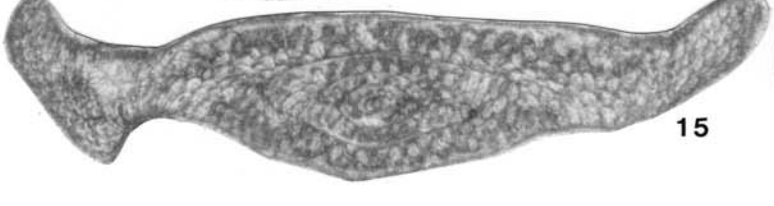
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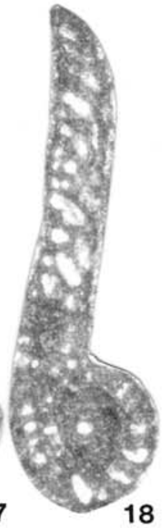
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proloculus is 0.087mm, half widths are 0.074, 0.133, 0.249, and 0.567mm in the fourth volution, and wall thickness increases from 0.007mm in the first volution to 0.021mm in the fourth volution, septa 16 in the second volution to 25 in the third volution. The other section (pl. 10, fig. 8) is slightly oblique, of three volutions and with diameter 1.768mm.

*Discussion*: *Paradoxiella* was first described from a locality known as Buck Hill (located on private property), on the east side of the road into McKittrick Canyon in Guadalupe Mountains National Park. It is common in an interval from 15 to 30ft above the base of the Lamar Limestone Member of the Bell Canyon Formation. The genus *Paradoxiella* has also been reported in West Texas from the Glass Mountains and from "float" in the Apache Mountains (Wilde et al. 1999, p. 73, Wilde and Rudine 2000). It is also reported from the Tethys in the Akasaka Limestone (Sada and Skinner 1977), in reworked pebbles in the Kwanto Massif (Ishii and Takahashi 1960) in Japan, in the Akiyoshi Limestone Group, southwest Japan (Sakamoto et al. 2000), questionably (poorly oriented specimens) in an exotic block of Lamayuru, Himalayas (Ladakh) (Lys et al. 1980) and in Greece (Vachard et al. 1993c).

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #2 core, depth 258.55-248.5ft, middle Tansill Formation where it is common. Specimens referable to this genus are possibly present above and below this interval, but without seeing the distinctive recurved flare of the later volutions this species is difficult to differentiate from *Codonofusiella*.

Order STAFFELLIDA A. Miklukho-Maklay 1949 [nom. transl. Rauser-Chernoussova in Rauser-Chernoussova et al. 1996 ex Staffellinae A. Miklukho-Maklay 1949]
Family KAHLERINIDAE Leven 1963 [nom. transl. Rauser-Chernoussova in Rauser-Chernoussova et al. 1996 ex Kahlerininae Leven 1963]
Genus *Pseudokahlerina* Sosnina 1968

***Pseudokahlerina capitanensis*** Nestell and Nestell, **n. sp.**
Plate 7, figures 23-27

*Description*: Test is disc-shaped, strongly compressed along the axis of coiling with straight or slightly compressed sides. Umbilical depressions are wide but not deep, periphery narrowly rounded. The ratio of length to width is 0.474 in the holotype. Initial chamber is small, spherical, its diameter 0.093mm. Spiral is narrow in the initial two volutions and rapidly increases in height in the following ones. Diameters of volutions (in mm): in the first 0.149, in the second 0.232, in the third 0.467 and the fourth 0.584. Wall in the initial volutions is thin and indistinct, 0.009mm in the first volution to 0.032mm in the 5th volution. Diaphanotheca porous and weakly developed. Septa are plane, thin in the initial volutions, straight and slightly curved, long, arcuate and curved, noticeably thickened at the ends. Chomata are indistinct.

*Designation of types*: The specimen illustrated on plate 7, figure 24 is designated as the holotype (KUMIP 2,506,921). It is from the Dark Canyon Amoco #1 core, depth 110ft, Tansill Formation, Middle Permian (Capitanian).

*Etymology*: From El Capitan Peak of the Guadalupe Mountains.

*Material*: Five axial sections.

*Discussion*: Specimens of the genus *Pseudokahlerina* are very similar to *Kahlerina* Kochansky-Devidé and Ramovs 1955 but are separated based on the external outline of the test, size, wall structure and weak development of chomata. *Kahlerina* has a small test with a thick wall of finely perforate structure and is compressed along the axis of coiling. However, *Pseudokahlerina* has a less massive test, strongly compressed along the axis of coiling, a thinner wall with less distinct perforate (porous) structure, a more rapidly untwisted spiral, and long arcuate and curved septa in the last volution.

Sosnina (1968) introduced the new genus *Pseudokahlerina* and described five new species from the late Midian (*Metadoliolina lepida* Zone) of the South Primorye. Chediya (in Kotlyar et al. 1989) described (based on one axial section) *Pseudokahlerina porrecta* from the Transcaucasia in the late Midian Khachik Horizon, the *Chusenella minuta* Zone, and Stevens et al. (1997) illustrated *Pseudokahlerina*? sp. as a tangential section. Our new species does not resemble these species and especially differs in the very irregular type of coiling in some specimens (juveniles) and the large proloculus.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #1 core, depth 128.15–110ft, Tansill Formation, Middle Permian (Capitanian).

Order NEOSCHWAGERNINIDA Minato and Honjo 1966
Family NEOSCHWAGERINIDAE Dunbar and Condra 1927 [nom. transl. Dunbar in Cushman 1948 ex Neoschwagerininae Dunbar and Condra 1927]
Subfamily NEOSCHWAGERININAE Dunbar and Condra 1927
Genus *Yabeina* Deprat 1914

***Yabeina texana*** Skinner and Wilde 1955
Plate 10, figures 13-15

*Yabeina texana* SKINNER and WILDE 1955, p. 937-940, pl. 93, fig. 2-4, pl. 94, fig. 1-4, pl. 95, fig. 1-4.

*Description*: Test is small, inflated, ellipsoidal, with 8-10 volutions in mature specimens, first two or three are sometimes skewed to the axis of coiling. Spirotheca is thin with tectum and finely alveolar keriotheca. Septa are irregularly spaced and generally curved. Parachomata are present throughout test, low and thick in inner whorls, and high and narrow in outer whorls. Pendent shaped primary transverse septula connect with the parachomata to form a box - like chamberlet with elliptical openings on the sides. One or two transverse secondary septula and up to four or five axial septula are present in mature tests. Proloculus is small and spherical. Three typical specimens of this genus are illustrated. Only one equatorial section (pl. 10, fig. 14) of seven volutions is well oriented, width 1.083mm, diameter of proloculus 0.073mm, half width of successive chambers 0.049, 0.102, 0.164, 0.234, 0.324, 0.424, and 0.548mm, wall thickness increases from 0.009mm in the first volution to 0.022mm in the seventh volution, septa increase from 8 in the first volution to 27 in the seventh volution. The slightly oblique axial section illustrated (pl. 10, fig. 13) of eight volutions has diameter of 1.238mm and length of 1.782mm, diameter of proloculus 0.098mm. The other equatorial specimen (pl. 10, fig. 15) of eight volutions has diameter of 1.533mm.

*Discussion*: *Yabeina texana* was originally described from Bear Canyon in what is now Guadalupe Mountains National Park, located about 55 kilometers to the southwest of Dark Canyon. At the type locality it ranges through the basal 15ft of the Lamar Limestone Member of the Bell Canyon Formation. It has also been reported in the basal part of the Tansill Formation from the third spur northeast of McKittrick Canyon (Tyrrell 1962) and occurs in a surface outcrop in the base of the north wall of Dark Canyon at the base of the Tansill Formation about 1500 meters from the mouth of the canyon. The correlation of the basal Lamar Limestone Member in the forereef to the basal Tansill Formation in the backreef is based in part on the presence of this genus. We have also recently found this species in the Apache Mountains at Seven Heart Gap in the upper part of the Bell Canyon Formation in the top of a debris flow and about a meter below the stratum typicum of *Paraboultonia splendens*. Recently, a form identified as *Yabeina texana* was reported from the Akiyoshi Limestone Group in southwest Japan (Sakamoto et al. 2000), but in our opinion the forms illustrated in that paper as *Yabeina texana* and the conclusion of the authors that the fauna discussed is of Dzhulfian age are both questionable.

*Occurrence*: USA, New Mexico, Guadalupe Mountains, Dark Canyon, the Amoco #2 core, depth 387.5-396.5ft, basal part of Tansill Formation, and top of the Yates Formation at 399ft. This species is common to abundant in the noted interval and also in a similar interval in the base of the Tansill Formation in basal part of the outcrop in the north wall of Dark Canyon just to the south of the corehole.

## CONCLUSIONS

Four new genera (*Tansillites*, *Pseudohemigordius*, *Vachardella*, and *Neoendothyranella*) and sixteen new species of foraminifers are described from late Guadalupian strata in the two Amoco cores in Dark Canyon. The small foraminifers present in the cores are diverse, but are represented mostly by what appear to be endemic forms with only a few species known from the Tethyan realm (e.g., South China, Transcaucasia, South Primorye, and Cambodia), and the Zechstein of Poland and the Baltic area, and Australia. Many of the fusulinacean species are also endemic with a few species known in the Tethyan realm, but most of them are known in North America in autochthonous late Guadalupian age rocks only in West Texas and Mexico. A few genera such as *Reichelina*, *Codonofusiella*, and *Yabeina* are also known from allochthonous rocks of the same age in accreted terranes of the Pacific Northwest.

None of the small foraminifers and fusulinaceans studied in the two Dark Canyon cores indicates to us a post-Guadalupian age for these strata and we do not agree with Wilde's suggestion that the *Paraboultonia* Zone is possibly Lopingian in age (Wilde et al. 1999, fig. 3). Lambert et al. (2002) recently established that the uppermost Guadalupian strata in the nearby Apache Mountains contain the conodont *Clarkina postbitteri hongshuiensi* where the last occurrence of the fusulinacean species *Paraboultonia splendens* is approximately 2m below the last occurrence of that conodont. Thus, within the current status of the placement of the uppermost Guadalupian boundary, the foraminifers in the Dark Canyon cores would be late middle Permian.

## ACKNOWLEDGMENTS

We especially thank Greg Wahlman and John Groves, formerly of Amoco Production Company for arranging the loan of the thin-sections used in this study. We had many useful and lively discussions with Garner Wilde about foraminiferal taxonomy and fusulinacean zonation of the Guadalupian of West Texas. Daniel Vachard (University of Lille), Greg Wahlman (BP America), Calvin Stevens (San Jose State University) and Michael Kaminski (University College London) made useful suggestions to improve the manuscript. We also thank Willis Tyrrell for his information on the occurrences of *Yabeina* in the Guadalupe Mountains Permian sections. Bruce Wardlaw aided in the construction of the Permian correlation chart.

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## APPENDIX 1

## A LIST OF THE DISTRIBUTION OF THE SMALL FORAMINIFERS IN AMOCO CORES

*Tuberitina variabilis* Nestell and Nestell, n. sp.: Amoco #1 core, depth: 46, 58, 64, 66, 68, 70, 72, 74, 76, 78, 80, 88, 92, 93.6, 98, 108, 110, 112, 166, 168, 170, 172, 174, 176, 178, 180, 184, 186, 188, 190.5, 194, 196, 198, 200, 202, 204, 208, 220, 222, 224, 226, 228, 230, 231.5, 235, 240, 242, 244, 246, 248, 250, 252, 254, 255.5, 260, 268, 270, 286, 344, 344.9, 348, 350, 354, 364, 366, 380, 386ft; Amoco #2 core, depth: 148.85-149.0, 216.3-216.45, 227.75-229.9, 228.5-228.65, 230.0-230.15, 230.85-231.0, 243.0-243.15, 243.85-244.0, 248.5-248.65, 249.85-250.0, 250.3-250.45, 251.2-251.35, 255.35-255.5, 256.05-256.21, 257.0-257.15, 257.95-258.1, 258.55-258.7, 293.6-293.75, 309.9-310.05, 318.35-318.5, 322.0-322.15, 337.4-337.5, 349.65-349.8, 354.7-354.85, 355.95-356.1, 375.0-375.15, 424.35-424.5, 425.25-425.4, 425.85-426.0, 427.1-427.25, 440.8-440.95, 453.25-453.4, 459.65-459.8, 462.55-462.7, 463.05-463.2, 463.65-463.8ft.

*Haplophragmina? infrequens* Nestell and Nestell, n. sp.: Amoco #2 core, depth: 314.05-314.2, 323.9-324.05, 324.55-324.7, 326.45-326.6, 327.3-327.45, 327.95-328.1, 329.05-329.2, 330.5-330.65, 331.9-332.05, 374.3-374.45, 423.8-423.95ft.

*Pseudoammodiscus* sp. 1: Amoco #1 core, depth: 154, 182, 192, 226ft.

*Calcitornella* sp.: Amoco #1 core, depth: 114, 230ft; Amoco #2 core, depth 124.95-125.1ft.

*Calcivertella* sp.: Amoco #1 core, depth: 146, 220, 254ft; Amoco #2 core, depth: 177.85-178.0, 178.3-178.45ft.

*Tansillites anfractuosus* Nestell and Nestell, n. gen., n. sp.: Amoco #1 core, depth: 4, 46, 52, 68, 72, 76,82, 88, 90, 92, 93.6, 98, 100, 102, 104, 106, 108, 112, 116, 118, 120, 122, 124, 126, 128, 130, 138, 140, 146, 148, 150, 174, 176, 218, 222, 226, 270ft; Amoco #2 core, depth: 129.0-129.15, 129.95-130.1, 145.1-145.25, 156.5-156.65, 177.3-177.45ft.

*Palaeonubecularia marginata* Nestell and Nestell, n. sp.: Amoco #1 core, depth: 10, 42, 44, 88, 90, 104, 108, 110, 112, 122, 138, 148, 166, 180, 184, 202, 244ft; Amoco #2 core, depth: 152.0-152.15, 154.25-154.4, 177.85-178.0, 210.0-210.15, 211.75-211.9, 213.05-213.2, 216.3-216.45, 464.05-464.2ft.

*Pseudolituotuba* (*Pseudospira*) sp. 1: Amoco #1 core, depth 154ft; Amoco #2 core, depth: 178.05-178.2, 178.3-178.45, 210.0-210.15, 326.45-326.6, 326.75-326.9ft.

*Pseudohemigordius incredibilis* Nestell and Nestell, n. gen., n. sp.: Amoco #1 core, depth: 4, 10, 32, 42, 44, 70, 72, 76, 78, 90, 92, 93.6, 98, 102, 104, 106, 108, 110, 112, 114, 118, 120, 122, 126, 138, 140, 146, 148, 152, 154, 156, 158, 160, 162, 166, 170, 172, 174, 176, 178, 180, 184, 186, 188, 190.5, 194, 196, 198, 200, 202, 204, 206, 208, 218, 220, 226, 228, 230, 231.5, 235, 240, 242, 244, 246, 248, 252, 255.5, 262ft; Amoco #2 core, depth: 119.55-119.7, 129.0-129.15, 129.45-129.6, 145.1-145.25, 145.85-146.0, 148.85-149.0, 150.8-150.95, 151.7-151.85, 153.6-153.75, 154.0-154.15, 155.5-155.65, 156.5-156.65, 156.95-157.1, 160.05-160.2, 177.1-177.25, 177.3-177.45, 177.45-177.6, 178.3-178.45, 182.8-182.95, 198.2-198.35, 199.65-199.8, 199.85-200.0, 200.65-200.8, 202.1-202.25, 202.25-202.4, 202.7-202.85, 203.0-203.15, 206.0-206.15, 208.25-208.4, 209.15-209.3, 209.3-209.45, 215.55-215.7, 216.3-216.45, 216.85-217.0, 240.4-240.55, 285.2-285.35, 309.9-310.05, 322.75-322.9, 323.5-323.65, 323.9-324.05, 324.2-324.35, 324.55-324.7, 325.95-326.1, 326.3-326.45, 326.45-326.6, 326.75-326.9, 327.95-328.1, 329.05-329.2, 329.75-329.9, 330.7-330.8, 331.9-332.05, 335.65-335.8, 342.45-342.6, 342.9-343.05, 351.85-352.0, 353.6-353.75, 354.7-354.85, 360.85-361.0, 362.0-362.15, 365.5-365.65, 370.95-371.1, 372.95-373.1, 373.6-373.75, 373.95-374.1, 374.3-374.45, 375.0-375.15, 375.8-375.95, 377.65-377.8, 378.0-378.15, 378.4-378.55, 378.7-378.85, 379.0-379.15, 390.05-390.2, 396.0-396.15, 409.2-409.35, 434.3-434.45, 447.4-447.55, 449.3-449.45, 453.25-453.4, 454.2-454.35, 463.65-463.8, 464.05-464.2, 468.5-468.65ft.

*Baisalina americana* Nestell and Nestell, n. sp.: Amoco #2 core, depth: 144.2-144.35, 148.65-148.8, 148.85-149.0, 149.25-149.4, 149.65-149.8, 150.8-150.95, 151.1-151.25, 151.7-151.85, 152.0-152.15, 152.75-152.9, 153.6-153.75, 154.0-154.15, 154.25-154.4, 155.5-155.65, 155.9-156.05, 156.15-165.3, 156.5-156.65, 156.95-157.1, 157.4-157.55, 160.05-160.2, 160.5-160.65, 163.9-164.05, 164.75-164.9, 165.25-165.4, 166.55-166.7, 174.0-174.15, 177.1-177.25, 177.3-177.45, 177.45-177.6, 177.6-177.75, 177.85-178.0, 178.05-178.2, 178.3-178.45, 178.5-178.65, 182.05-182.2, 183.35-183.5, 183.9-184.05, 196.25-196.4, 197.95-198.1, 198.2-198.35, 198.9-199.05, 199.65-199.8, 199.85-200.0, 200.65-200.8, 201.1-201.25, 201.5-201.65, 202.1-202.25, 202.25-202.4, 202.7-202.85, 203.0-203.15, 206.0-206.15, 208.25-208.4, 209.15-209.3, 209.3-209.45, 210.0-210.15, 210.9-211.05, 211.75-211.9, 212.85-213.0, 213.05-213.2, 213.7-213.85, 214.15-214.3, 214.65-214.8, 215.55-215.7, 215.95-216.1, 216.3-216.45ft.

*Agathammina pusilla* (Geinitz): Amoco #1 core, depth: 90, 92, 116, 128ft; Amoco #2 core, depth: 144.2-144.35, 149.25-149.4, 152.0-152.15, 177.6-177.75, 178.02-178.2, 183.9-184.05, 199.85-200.0, 231.75-231.9, 249.85-250.0, 250.3-250.45, 348.85-349.0ft.

*Agathammina* sp. 7: Amoco #2 core, depth 216.3-216.45ft.

*Agathammina* ex gr. *A. rosella* G. Pronina: Amoco #1 core, depth: 46, 88, 126, 230ft; Amoco #2 core, depth: 119.55-119.7, 139.8-139.95, 152.0-152.15, 153.6-153.75, 159.8-159.95, 160.35-160.5, 202.25-202.4ft.

*Agathammina* sp. 1: Amoco #1 core, depth: 98, 222, 246, 310.1ft; Amoco #2 core, depth: 145.1-145.25, 427.1-427.25, 440.8-440.95, 443.9-444.05, 453.1-453.25, 465.0-465.15ft.

*Agathammina* sp. 2: Amoco #1 core, depth: 208, 231.5ft.

*Graecodiscus* sp.: Amoco #1 core, depth: 154ft; Amoco #2 core, depth 215.95-216.1ft.

*Graecodiscus praecursor* Nestell and Nestell, n. sp.: Amoco #1 core, depth: 90, 120, 126ft; Amoco #2 core, depth 210.0-210.15ft.

*Graecodiscus* sp. 2: Amoco #2 core, depth: 144.2-144.35, 199.85-200.0, 394.85-395.0, 426.7-426.85, 427.1-427.25, 428.4-428.55, 428.75-428.9, 450.15-450.3, 462.55-462.7, 463.65-463.8, 465.0-465.15ft.

*Nodosaria capitanensis* Nestell and Nestell, n. sp.: Amoco #1 core, depth: 90, 106, 112, 116, 126, 146, 166, 186, 204, 286ft; Amoco #2 core, depth: 338.4-338.5, 358.1-358.25, 373.95-374.1, 378.0-378.15, 381.0-381.15, 463.65-463.8ft.

*Nodosaria* cf. *N. novizkiana* Sosnina: Amoco #1 core, depth 341.9ft; Amoco #2 core, depth: 329.75-329.9, 354.7-354.85ft.

*Nodosaria* sp. 8: Amoco #2 core, depth: 231.75-231.9, 252.0-252.15ft.

*Nodosaria* ex gr. *N. grandecamerata* Sosnina: Amoco #1 core, depth 190.5ft.

*Nodosaria* cf. *N. partisana* Sosnina: Amoco #1 core, depth 310.1ft.

*Polarisella lingulae* Nestell and Nestell, n. sp.: Amoco #1 core, depth: 160, 172, 176, 178, 184, 186, 188, 192, 196, 208, 220, 228ft; Amoco #2 core, depth: 333.85-334.0, 347.65-347.8, 379.0-379.15ft.

*Lingulina?* sp.: Amoco #2 core, depth 221.7-221.85ft.

*Rectoglandulina lepida* (Wang): Amoco #2 core, depth: 155.0-155.15, 375.95-376.1ft.

*Eomarginulinella* sp. 1: Amoco #1 core, depth: 88, 110, 190.5, 242ft.

*Eomarginulinella?* sp.: Amoco #2 core, depth: 354.7-354.85, 358.95-359.1, 360.85-361.0, 363.75-363.9ft.

*Calvezina* sp. 1: Amoco #1 core, depth: 184, 226, 372ft.

*Lingulonodosaria?* sp.: Amoco #1 core, depth: 88, 150, 174ft.

*Tauridia* sp. 1: Amoco #2 core, depth: 324.2-324.35, 324.55-324.7, 332.75-332.9, 333.35-333.5, 343.5-343.65, 344.05-344.2, 347.65-347.8, 354.7-354.85ft.

*Geinitzina aetheria* Nestell and Nestell, n. sp.: Amoco #1 core, depth: 32, 50, 90, 102, 104, 128, 144, 166, 170, 172, 176, 180, 184, 186, 188, 190.5, 222, 226, 242ft; Amoco #2 core, depth: 178.3-178.45, 248.5-248.65, 249.85-250.0, 251.2-251.35, 334.35-334.5, 338.4-338.55, 365.5-365.65, 366.5-366.65, 373.6-373.75, 374.3-374.45, 375.95-376.1, 378.0-378.15, 392.5-392.65, 425.25-425.4ft.

*Geinitzina* sp. 4: Amoco #1 core, depth: 336.5, 344.9, 348, 372, 374, 378, 380, 382, 386, 394, 396ft.

*Geinitzina* sp. 1: Amoco #1 core, depth: 350, 356, 398ft.

*Pachyphloia* sp.: Amoco #2 core, depth: 343.5-343.65, 365.5-365.65, 366.5-366.65ft.

*Robustopachyphloia*? sp.: Amoco #2 core, depth 332.25-332.4ft.

*Howchinella* sp. 1: Amoco #2 core, depth 429.15-429.3ft.

*Ichthyolaria* sp. 1: Amoco #1 core, depth: 114, 128, 238, 255.5, 378ft.

*Ichthyolaria* sp. 2: Amoco #1 core, depth: 128, 166ft.

*Tauridia* sp. 3: Amoco #1 core, depth: 98, 126ft.

*Tauridia* sp. 2: Amoco #2 core, depth 453.1-453.25ft.

*Tauridia* sp. 4: Amoco #1 core, depth: 20, 46, 108, 192, 356, 398ft; Amoco #2 core, depth: 129.0-129.15, 160.5-160.65, 208.25-208.4ft.

*Partisania* sp.: Amoco #1 core, depth: 42, 54, 220ft.

*Globivalvulina* sp. 4: Amoco #2 core, depth: 124.95-125.1, 178.5-178.65, 213.05-213.2, 215.55-215.7, 222.85-223.0, 230.0-230.15, 233.85-234.0, 249.85-250.0, 250.3-250.45, 255.35-255.5, 257.0-257.15, 297.35-297.5ft.

*Globivalvulina guadalupensis* Nestell and Nestell, n. sp.: Amoco #2 core, depth: 224.8-224.95, 232.2-232.35, 251.2-251.35, 297.35-297.5, 298.0-298.15, 318.0-318.15, 324.7-324.85, 325.95-326.1, 330.5-330.65, 332.75-332.9, 333.0-333.15, 333.35-333.5, 333.85-334.0, 334.35-334.5, 335.65-335.8, 336.05-336.2, 336.35-336.5, 337.4-337.5, 340.2-340.3, 340.35-340.5, 340.5-340.65, 341.0-341.15, 342.45-342.6, 342.9-343.05, 343.5-343.65, 343.9-344.05, 344.05-344.2, 346.0-346.15, 346.85-347.0, 347.65-347.81, 348.65-348.8, 349.65-349.8, 350.85-351.0, 352.5-352.65, 352.8-352.95, 353.6-353.75, 354.7-354.85, 358.1-358.25, 358.95-359.1, 359.15-359.3, 360.85-361.0, 362.0-362.15, 375.0-375.15, 375.8-375.95, 375.95-376.1, 378.7-378.85, 382.8-382.95, 389.65-389.8, 390.95-391.1, 391.4-391.55, 391.55-391.7, 394.4-394.55, 394.85-395.0, 409.2-409.35, 426.7-426.85, 428.75-428.9, 429.15-429.3, 429.35-429.5, 430.05-430.2, 431.05-431.2, 431.5-431.65, 452.1-452.25, 455.1-455.25, 459.4-459.55, 461.7-461.85, 463.05-463.2ft.

*Globivalvulina* sp. 1: Amoco #1 core, depth: 66, 100, 128, 172, 218, 242, 350ft; Amoco #2 core, depth: 258.55-258.7, 297.6-297.75, 324.4-324.55, 329.75-329.9, 330.1-330.25, 330.7-330.8, 331.9-332.05, 336.05-336.2, 338.4-338.55, 342.9-343.05, 343.5-343.65, 348.85-349.0, 373.6-373.75ft.

*Sengoerina pulchra* Nestell and Nestell, n. sp.: Amoco #2 core, depth: 178.3-178.45, 232.2-232.35, 302.0-302.15, 318.0-318.15, 324.4-324.55, 344.05-344.2, 391.55-391.7, 407.35-407.5ft.

*Dagmarita* sp.: Amoco #2 core, depth 331.9-332.05ft.

*Crescentia migrantis* Nestell and Nestell, n. sp.: Amoco #2 core, depth: 199.85-200.0, 202.25-202.4, 213.7-213.85, 221.7-221.85, 293.6-293.75, 303.5-303.65, 322.75-332.9, 323.5-323.65, 323.9-324.05, 324.4-324.55, 324.55-324.7, 326.3-326.45, 326.45-326.6, 327.3-327.45, 392.5-392.65ft.

*Endothyra* sp.: Amoco #2 core, depth 178.3-178.45ft.

*Vachardella longiuscula* Nestell and Nestell, n. gen., n. sp.: Amoco #1 core, depth: 66, 72, 88, 92, 104, 110, 112, 122, 126, 128, 140, 146, 148, 154, 158, 184, 190.5, 192, 204, 220, 254, 366ft; Amoco #2 core, depth: 197.95-198.1, 198.2-198.35, 199.85-200.0, 213.05-213.2, 213.4-213.55, 232.2-232.35, 257.95-258.1, 285.2-285.35, 297.35-297.5, 298.0-298.15, 312.75-312.9, 323.5-323.65, 323.9-324.05, 324.2-324.35, 324.4-324.55, 324.55-324.7, 326.3-325.45, 326.45-326.6, 332.25-332.4, 332.75-332.9, 347.65-347.8, 352.0-352.15, 354.7-354.85, 363.9-364.05, 365.5-365.65, 373.95-374.1, 375.0-375.15, 375.95-376.1, 377.65-377.8, 379.0-379.15, 389.35-389.5, 389.65-389.8, 407.35-407.5, 423.8-423.95ft.

*Vachardella* sp. 1: Amoco #2 core, depth 298.0-298.15ft.

*Neoendothyranella wildei* Nestell and Nestell, n. gen., n. sp.: Amoco #1 core, depth: 22, 26, 36, 88, 90, 92, 98, 104, 108, 124, 126, 134, 138, 140, 144, 146, 148, 152, 158, 162, 166, 168, 170, 172, 180, 184, 188, 192, 196, 198, 208, 220, 222, 230, 231.5, 240ft; Amoco #2 core, depth: 148.85-149.0, 317.75-317.9, 342.45-342.6, 349.65-349.8, 377.65-377.8, 425.85-426.0, 427.1-427.25, 427.4-427.55, 427.8-427.95, 429.15-429.3, 430.05-430.2, 449.15-449.3, 462.55-462.7, 463.05-463.2ft.

*Abadehella* ex gr. *A. coniformis* Okimura and Ishii: Amoco #1 core, depth 38ft; Amoco #2 core, depth: 197.95-198.1, 198.2-198.35, 199.85-200.0, 201.1-201.25, 202.1-202.25, 202.25-202.4, 202.7-202.85, 208.25-208.4, 215.95-216.1, 322.0-322.15, 322.75-322.9, 323.5-323.65, 323.9-324.05, 327.95-328.1, 329.75-329.9,338.4-338.55, 340.5-340.65, 341.0-341.15, 347.65-347.8, 348.65-348.8, 348.85-349.0,350.85-351.0, 360.85-361.0, 362.9-363.05, 363.9-364.05, 365.5-365.65, 366.5-366.65, 370.95-371.1, 371.85-372.0, 372.95-373.1, 373.6-373.75, 374.3-374.45, 375.0-375.15, 375.95-376.1, 377.65-377.8, 378.0-378.15, 378.4-378.55, 378.7-378.85, 379.0-379.15, 380.4-380.55, 380.55-380.7, 380.85-381.0, 381.55-381.7, 384.95-385.1, 388.0-388.15, 391.4-391.55, 392.5-392.65, 394.4-394.55, 394.85-395.0, 427.1-427.25, 427.8-427.95, 453.25-453.4, 459.4-459.55ft.

*Abadehella* sp. 2: Amoco #1 core, depth: 4, 38, 100, 122, 132, 138, 156, 158, 170, 174, 180, 182, 190.5, 202, 204, 206, 208, 220, 222, 224, 231.5, 235, 242, 252, 260, 286, 360ft; Amoco #2 core, depth: 144.2-144.35, 325.95-326.1, 326.75-326.9, 330.5-330.65, 344.05-344.2, 346.85-347.0ft.

*Spireitlina* sp.: Amoco #1 core, depth: 66, 148ft; Amoco #2 core, depth 465.0-465.15ft.

*Spireitlina* sp. 2: Amoco #2 core, depth: 216.85-217.0, 324.55-324.7, 333.35-333.5, 336.05-336.2, 351.85-352.0, 352.5-352.65, 354.7-354.85, 363.75-363.9, 373.6-373.75ft.

*Spireitlina*? sp.: Amoco #2 core, depth 358.1-358.25ft.

*Deckerella* sp.: Amoco #1 core, depth: 126, 152, 156, 158, 160, 172, 180, 188, 192, 222, 228, 230, 254, 255.5, 282, 298ft; Amoco #2 core, depth 374.3-374.45ft.

*Aschemonella* sp.: Amoco #1 core, depth: 10, 126, 224, 228, 230, 231.5, 238ft.

APPENDIX 2
## A LIST OF DESCRIBED TAXA

*Tuberitina variabilis* Nestell and Nestell, n. sp.
Plate 1, figs. 1-10

*Haplophragmina*? *infrequens* Nestell and Nestell, n. sp.
Plate 1, figs. 11-13

*Tansillites* Nestell and Nestell, n. gen.

*Tansillites anfractuosus* Nestell and Nestell, n. sp.
Plate 1, figs. 26-29; Plate 2, figs. 1-5

*Palaeonubecularia marginata* Nestell and Nestell, n. sp.
Plate 2, figs. 6-8

*Pseudohemigordius* Nestell and Nestell, n. gen.

*Pseudohemigordius incredibilis* Nestell and Nestell, n. sp.
Plate 2, figs. 12-27

*Baisalina americana* Nestell and Nestell, n. sp.
Plate 2, figs. 28-36

*Agathammina pusilla* (Geinitz 1848)
Plate 3, figs. 1-5

*Graecodiscus praecursor* Nestell and Nestell, n. sp.
Plate 4, figs. 1-2

*Nodosaria capitanensis* Nestell and Nestell, n. sp.
Plate 4, figs. 4-6

*Polarisella lingulae* Nestell and Nestell, n. sp.
Plate 4, fig. 13

*Geinitzina aetheria* Nestell and Nestell, n. sp.
Plate 4, figs. 26-31

*Globivalvulina guadalupensis* Nestell and Nestell, n. sp.
Plate 5, figs. 14-25

*Sengoerina pulchra* Nestell and Nestell, n. sp.
Plate 6, figs. 3-6

*Crescentia migrantis* Nestell and Nestell, n. sp.
Plate 6, figs. 7-12

*Vachardella* Nestell and Nestell, n. gen.

*Vachardella longiuscula* Nestell and Nestell, n. sp.
Plate 1, figs. 14-19

*Neoendothyranella* Nestell and Nestell, n. gen.

*Neoendothyranella wildei* Nestell and Nestell, n. sp.
Plate 6, figs. 14-22

*Reichelina lamarensis* Skinner and Wilde 1955
Plate 9, figs. 16-24; Plate 10, figs. 1-6

*R*. aff. *R. changhsingensis* Sheng and Chang 1958
Plate 8, fig. 16, Plate 9, fig. 6

*Parareichelina* sp.
Plate 8, fig. 8

*Rauserella erratica* Dunbar 1944
Plate 8, fig. 4, Plate 11, fig. 6

*Rauserella bengeensis* Wilde and Rudine 2000
Plate 9, figs. 10-15; Plate 10, figs. 11, 17; Plate 11, figs. 2, 7

*Paraboultonia splendens* Skinner and Wilde 1955
Plate 8, figs. 3, 5, 6, 9-15; Plate 9, figs. 1-5, 7, 8

*Codonofusiella* (*Lantschichites*) *altudaensis* Wilde and Rudine 2000
Plate 8, figs. 2, 7

*C*. cf. *C. paradoxica* Dunbar and Skinner 1937
Plate 8, fig. 1

*C. extensa* Skinner and Wilde 1955
Plate 10, figs. 10, 12, 16; Plate 11, figs. 1, 3-5, 8-18

*Paradoxiella pratti* Skinner and Wilde 1955
Plate 10, figs. 8, 9

*Pseudokahlerina capitanensis* Nestell and Nestell, n. sp.
Plate 7, figs. 23-27

*Yabeina texana* Skinner and Wilde 1955
Plate 10, figs. 13-15

# *Velatomorpha,* a new healdioidean ostracode genus from the early Pennsylvanian Joggins Formation, Nova Scotia, Canada

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**ABSTRACT:** Internal features of the smooth, traditionally nonmarine ostracode "*Carbonita*" *altilis* (Jones and Kirkby 1879) are reported in detail for the first time. Based on the 26-28 stigmata within the adductor muscle scar (AMS) field, a ridge and groove contact margin, and an adont hinge, we establish the new genus *Velatomorpha*. Included within this genus are taxa previously assigned to *Carbonita, Healdia*?, and *Microcheilinella*. The characters diagnosed for this new genus warrant placement in the Suborder Metacopina, Superfamily Healdioidea. The associated biota and sedimentary facies indicate that *Velatomorpha* lived in a mixed freshwater-marine (brackish) estuarine environment. The implication of our taxonomic revision for *Velatomorpha altilis* underscores the necessity to carefully evaluate the internal features of smooth, podocopid and metacopine ostracodes reported from Paleozoic strata before making taxonomic assignments and generalized paleoecological inferences.

## INTRODUCTION

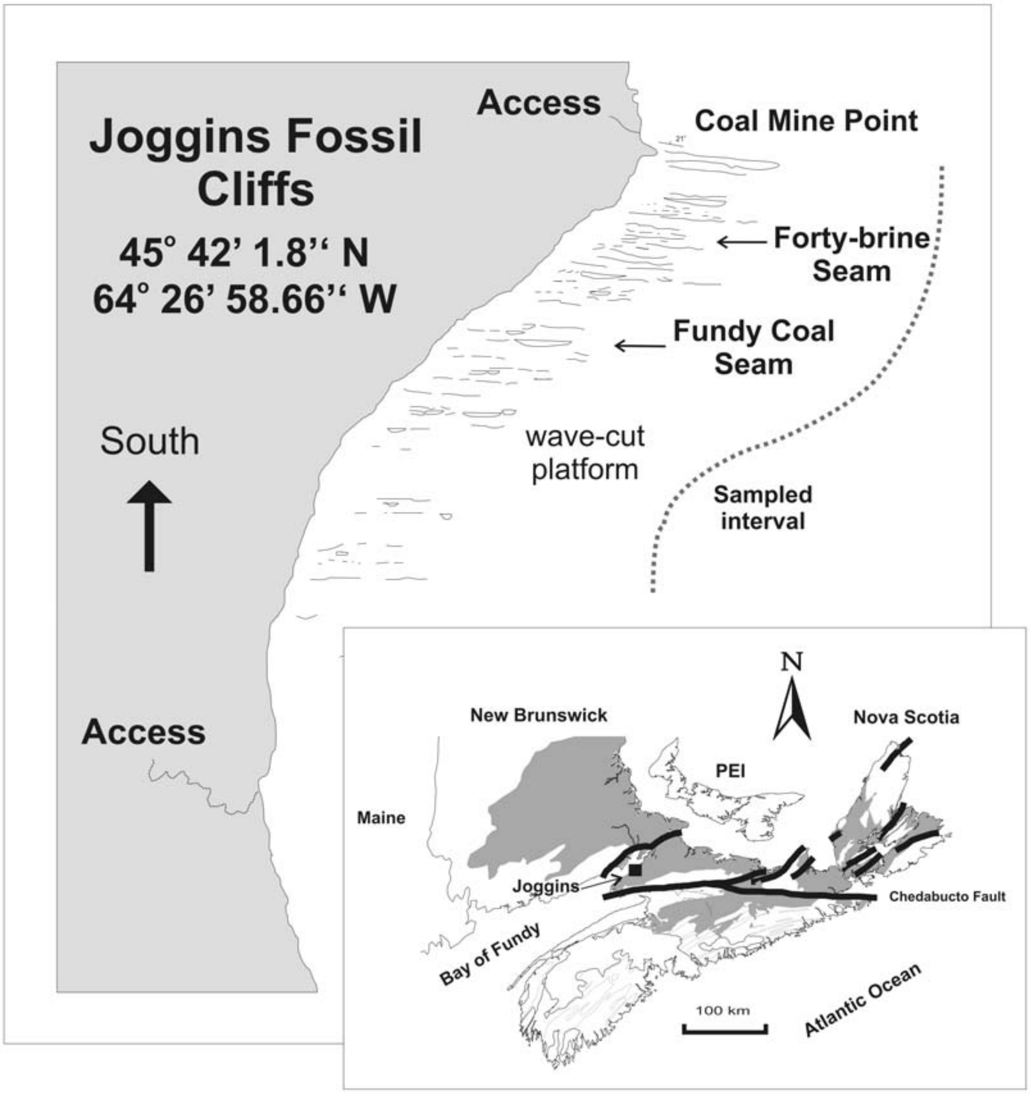
The Late Paleozoic ostracode *Carbonita* Strand (1928) is enigmatic with respect to both its systematic position within the Ostracoda and its paleoecological tolerances (Carbonel et al. 1988; Holmes and Horne 1999; Horne 2003). The taxonomic confusion regarding the diagnosis of "*Carbonia*" Jones 1870 began soon after the renaming of the genus to *Carbonita* Strand 1928 when several new genera of smooth, nonmarine ostracodes were proposed from North American localities: *Whipplella* Holland 1934; *Pruvostina* Scott and Summerson 1943; *Hilboldtina* Scott and Summerson 1943; and *Gutschickia* Scott 1944. The distinctions between these genera were based on differences in external morphology rather than any profound understanding of their internal morphologies. In the decades to follow, European researchers adopted a very broad concept of *Carbonita* as a genus that encompassed most of the presumed nonmarine taxa identified from both North America and Europe (Pollard 1966; Anderson 1970; Bless and Pollard 1973) where variation in shape was attributed to ecophenotypic variability. Sohn (1977a, 1985) challenged this all-encompassing *Carbonita* concept when he argued that distinct differences between internal features (e.g., AMS) justified taxonomic partitioning of the genus. Sohn (1985) subsequently proposed a new superfamily Carbonitacea (= Carbonitoidea) to encompass these problematic genera.

Two shortcomings exist in the broad and inclusive interpretation of taxa assigned to *Carbonita*. First, we agree with Sohn's (1985) assessment that there is distinct morphologic variability of AMS, hingement, and contact margins between species of *Carbonita, Whipplella,* and *Gutschickia* illustrated from Nova Scotia, Virginia, Pennsylvania, and Illinois, which on its own merit warrants the removal of the North American taxa from synonymy of *Carbonita*. Second, the generalization that taxa assigned to *Carbonita* are "freshwater" is presumptuous and frequently misleading. There is ample evidence to suggest that some species assigned to *Carbonita* also lived in marginal marine environments where they are associated with marine and brackish ostracodes including representatives from the superfamilies Paraparchitoidea, Kloedenelloidea, and Bairdioidea (Scott and Summerson 1943; Cooper 1946; Bless and Pollard 1973; Peterson and Kaesler 1980; Sohn 1985; Tibert and Scott 1999).

Upon the initial examination of new material of "*Carbonita*" *altilis* (Jones and Kirkby 1879) collected from Joggins, Nova Scotia, we realized a potential for confusion given the current state of carbonitoidean ostracode taxonomy. To resolve the issue, approximately 1200 specimens from two dozen samples were examined and this ultimately led us to a detailed description of the internal features including the AMS field, hingement, and contact margin. The new data suggest that *C. altilis* does not belong to the genus *Carbonita,* and belongs within the Healdioidea. Moreover, these results emphasize the need for a comprehensive taxonomic investigation of the type specimens assigned to this contentious genus and allied taxa to determine the true phyletic relationships and affinities of the Carbonitoidea and the taxa currently contained therein.

## COMPARATIVE MATERIAL

Comparative material was examined from the National History Museum collections of the Carbonitoidea published in Sohn (1977a, 1985) that include: (1) *Carbonita* (USNM 365113–365116); (2) *Darwinula* (USNM 365126, 365456); (3) *Gutschickia* (USNM 365117–365118, 365133; 168122, 168124–168126); (4) *Whipplella* (USNM 365123, 365125); and (4) *Pruvostina* (USNM 365124). We have also examined type material of *Carbonita* deposited in the Natural History Museum in London that include: (1) the type of *Carbonia agnes* Jones 1870 designated by Bassler and Kellet 1934 as the



TEXT-FIGURE 1
Location of the samples acquired from the Joggins Formation adjacent to the Bay of Fundy. Detailed map of the coastal outcrop showing the sampling interval and position of the coal seams (modified from Davies and Gibling 2003).

lectotype (BM 43512); (2) the types of *Carbonita agnes* (Jones 1870) in the Adams Collection No. 2 (BM 43513) and specimen marked number 6 selected by Anderson as the lectotype (*in* Pollard 1966); and (3) the lectotype BM. I. 2446 A and paralectotypes of *Carbonita altilis* (Jones and Kirkby 1889) listed as specimens BM. I. 2446 B and C all from the T.R. Jones Collection. Finally, we have examined the type material for *Gutschickia* and *Whipplella* from the Carnegie Museum in Pittsburg, Pennsylvania that include: (1) the holotype *Whipplella cuneiformis* Holland 1934 (CM 6493); and (2) the holotype *Gutschickia* Scott 1944 = *Whipplella ninevehensis* Holland 1934 (CM 6483).

## GEOLOGIC LOCALITY

The Carboniferous Joggins Formation crops out on the Bay of Fundy in Cumberland County Nova Scotia (text-fig. 1). The strata comprise approximately 1400m of mudrock, sandstone, coal, and sparse limestone (Gibling 1987). Davies and Gibling (2003) recognized three primary sedimentary facies associations that include open water, poorly drained, and well-drained floodplain. Microfossil samples were collected from the entire interval with a focus on the limestone beds that lay between the Fundy and Forty-brine coal seams in the vicinity of Coal Mine Point (text-fig. 2). The strata are assigned to the Cumberland Group and this corresponds to the early Pennsylvanian (text-fig. 3) (Gibling 1987). Rogers (1965) identified the bivalves *Naiadites carbonarius*, *Naiadites longus*, *Curvirimula*? *ovalis* and *Anthraconaia*? sp. from the Joggins Formation and coeval deposits and these taxa are assigned to the stratigraphic interval spanning the *modularis* Biozone-to *similis-pulchra* Biozone in the United Kingdom (Westphalian A to lower Westphalian C).

The Joggins section has received much attention with respect to the abundant terrestrial plant, invertebrate, and vertebrate fossils identified in the coal measures (e.g., Lyell 1871; Dawson 1868, 1897; Copeland 1957; Carroll et al. 1972; Ferguson 1975;

Vasey 1984, 1994; Brand 1994; Calder 1998; Falcon-Lang 1999, 2003a, b; Falcon-Lang et al. 2004; Hebert and Calder 2004). The Joggins aquatic biota are generally regarded as a low salinity association and recent reports of foraminifera indicates that the environment was a mixed freshwater/marine, low gradient, coastal plain (Archer et al. 1995).

Ostracodes from Nova Scotia are well-documented in the brackish and marine strata underlying the Joggins Formation (Dewey 1987, 1988, 1989; Dewey and Fahraeus, 1987; Tibert & Scott 1999). The ostracodes from the Joggins Formation were described in detail by Copeland (1957) and reported by Duff and Walton (1973) and Vasey (1984) where the environment was inferred to be freshwater and/or brackish.

## SYSTEMATIC PALEONTOLOGY

Suborder and superfamily assignments follow the classification scheme of Horne (2004). Discussions regarding the systematic position of taxa above the suborder are beyond the scope of this paper; therefore, we follow the subclass and order scheme presented in Benson et al. (1961).

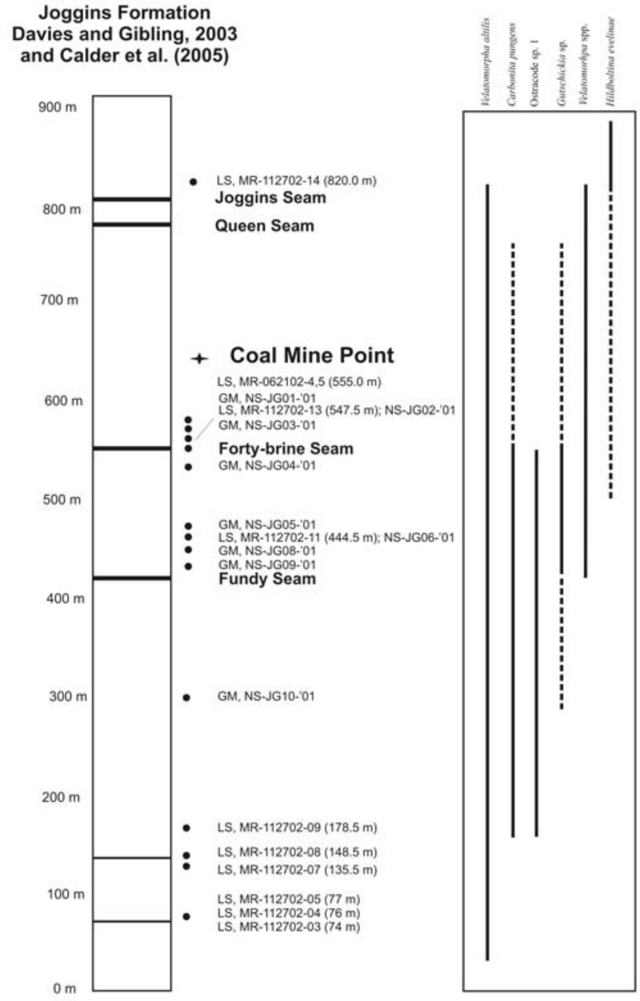
Subclass OSTRACODA Latreille 1806
Order PODOCOPIDA Müller 1894
Suborder DARWINULOCOPINA Sohn 1988

Superfamily **DARWINULOIDOIDEA** Molostovskaya 1979

*Remarks:* Smooth-shelled, ovate podocopid ostracodes with the greatest height in the posterior, right over left valve overlap, a well-developed calcified inner lamella, and a small, conservative central aggregate AMS field of 10-12 stigmata such as reported for *Darwinuloides* Mandelstam 1956 (Molostovskaya 2000). *Whipplella* and *Pruvostina* were recently assigned to the Superfamily Darwinuloidoidea (Sohn and Swain, 1999) on the basis of their biserial aggregate of individual stigmata and the presence of frontal scars (text-fig. 4F); the AMS fields match reasonably well the diagnosis for the genus *Darwinuloides* (Benson et al., 1961). Examination of the type material for *Whipplella cuneiformis* Holland 1934 (CM 6493) confirms the biserial array of 10-12 stigmata.

Superfamily **CARBONITOIDEA** Sohn 1985

*Remarks:* The characters for the family include right over left valve overlap with a calcified inner lamella, a prominent dorsal swelling (overreach), a small sub-central AMS pit (text-fig. 4B), and a generally elongate, suboval shape of the thinly calcified carapace. Sohn (1985) proposed the Carbonitoidea to encompass most of the nonmarine genera reported from North America. *Pruvostina* and *Whipplella* have been re-assigned to the Darwinuloidea (Sohn and Swain 1999) and it is plausible that *Gutschickia* is closely allied to the Healdioidea (see below). Whether *Hilboldtina* is a carbonitoidean, also remains a point of contention given that the only true distinct characters are lateral ridges and these may be environmentally cued (Carbonel et al., 1988). Until we can observe additional diagnostic characters for these problematic taxa (e.g., contact margin, frontal muscle scar patterns, and hingement), these genera remain tentatively assigned to the Carbonitoidea.

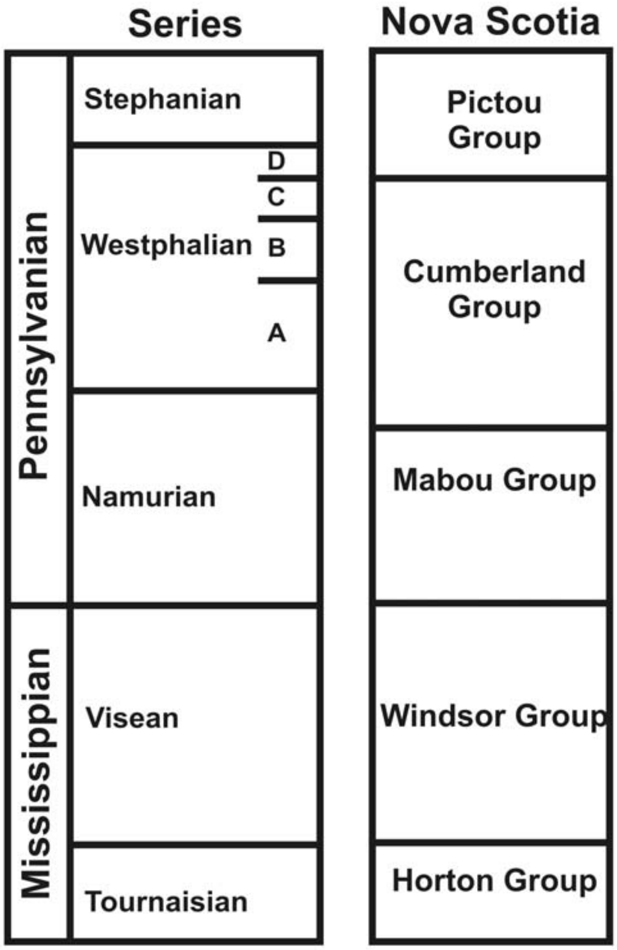


TEXT-FIGURE 2
Stratigraphic section showing position of the major coals and the samples analyzed for this study. This section is modified from Calder et al. (2005) and the lower 600m corresponds to the published section in Davies and Gibling (2003). The solid vertical bars indicate known occurrences from this study. The hatched bars indicate distributions reported from Copeland (1957), Duff and Walton (1973), and Vasey (1984). GM = grey mudstone, LS = limestone.

We draw attention to the AMS field for *Carbonita* (text-fig. 4B) presented by Anderson (1970, fig. 1g) and reproduced by Sohn (1977a, fig. 1b). A sub-central pit is clearly present in taxa that also exhibit, thin, elongate, and relatively small carapace size including the type species *Carbonita agnes* (Jones 1870), *C. scalpellus* (Jones and Kirkby 1879), and *C. pungens* (Jones and Kirkby 1879); representatives of these three taxa have been examined by the authors including the lectotype of *C. agnes* (BM 43512). Considering that AMS fields are useful for supra-generic classification (Gramm 1987), those observed for the type species of the carbonitoidean genera should bear significant similarities for the superfamily as a whole. Therefore, the polyphyletic nature of the Carbonitoidea can be demonstrated by 3 distinct AMS patterns within the group as follows:

(1) *Carbonita* pattern displaying a circular aggregate of 11 stigmata surrounding 4 central pits (text-fig. 4B);

(2) *Darwinula* pattern displaying a biserial array of 12 or more elongated stigmata (text-fig. 4D); and



TEXT-FIGURE 3
Stratigraphy of the Carboniferous Maritimes Basin, Atlantic Canada (modified from Tibert and Gibling, 1999).

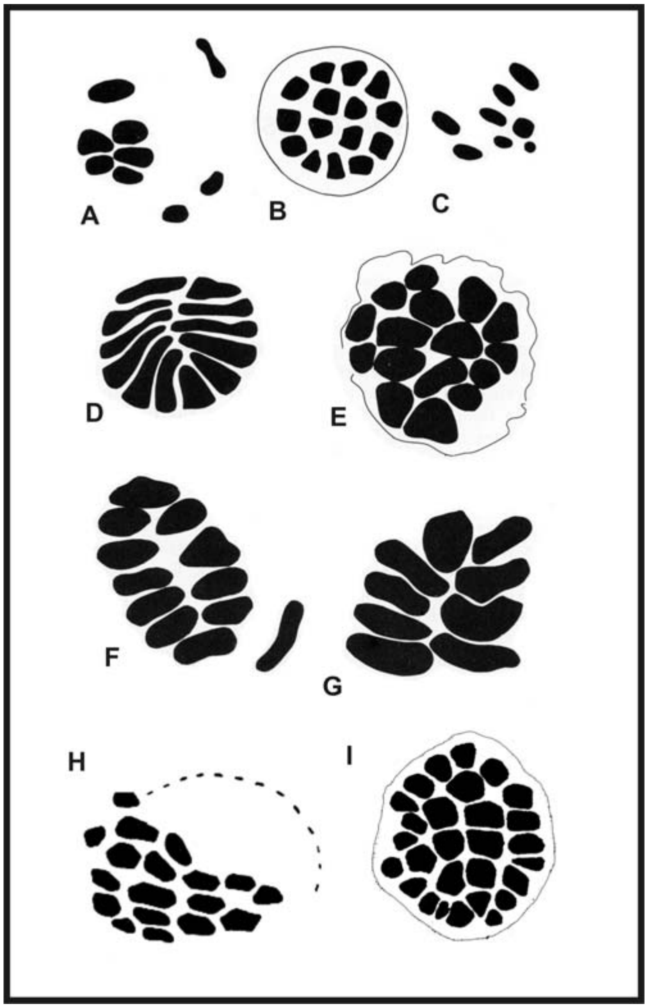
(3) *Gutschickia* pattern displaying a large muscle field of 4-8 central stigmata surrounded by 15-24 arranged in a general oblique pattern (= "modified healdiid" Sohn 1977a) (text-fig. 4E).

Family **CARBONITIDAE** Sohn 1985

*Remarks:* Sohn (1985) described the family as straight hinged, smooth, with an aggregate AMS and a calcified inner lamella. Although both Carbonitidae and Healdiidae have aggregate AMS fields, Carbonitidae differ in the presence of a calcified inner lamella, a simple hinge, and an absence of external spikes and spines.

Genus ***Carbonita*** Strand 1928

*Remarks:* The diagnostic characters for *Carbonita* (Anderson 1970, fig. 1) are apparently representative from several species. Consequently, there is much confusion regarding the breadth of the generic concept. For example the angular shape of both *Gutschickia* and *Carbonita* prompted Anderson (1970) to include the following taxa within the synonymy of *Carbonita altilis*: *Gutschickia* (*Whipplella*) *ninevehensis* (Holland, 1934), *Whipplella deltoidea* Holland 1934, ?*Pruvostina wanlessi* Scott and Summerson, 1943, and *Gutschickia subangulata* (Jones and Kirkby 1879 in Cooper 1946). The original basis for differentiating between *Gutschickia* and *Pruvostina*, as outlined by Sohn (1977a, 1985), was an incised hinge and a pronounced overlap for the latter. *Hilboldtina* is differentiated on the basis of lateral striations observed on the external surface of the carapace (Anderson 1970; Sohn 1985).



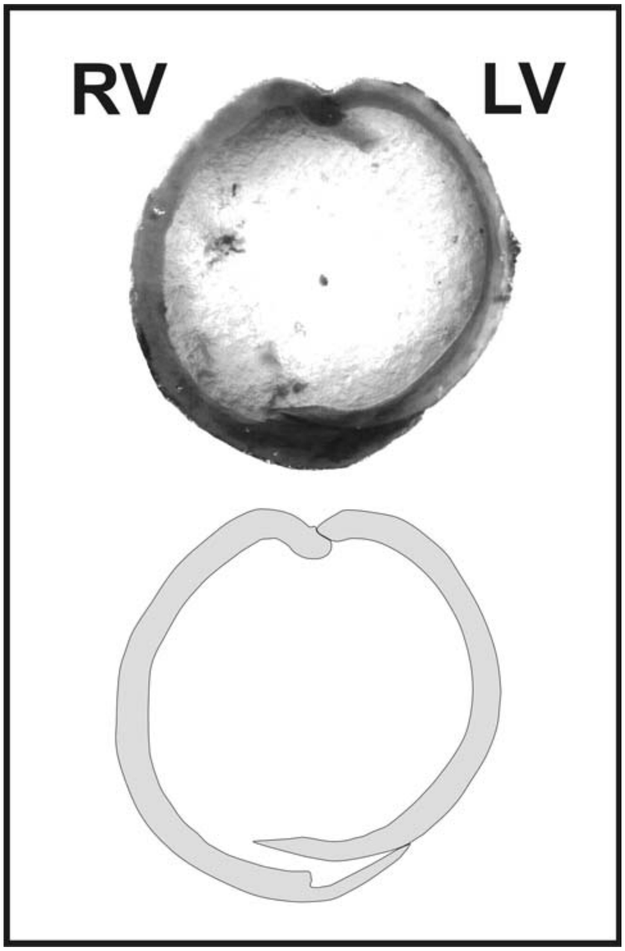
TEXT-FIGURE 4
Adductor muscle scar fields for the Carbonitoidea and allied genera (modified from Sohn, 1977a). A. *Candona*, B. *Carbonita* (lectotype), C. *Cypridopsis*, D. *Darwinula*, E. *Gutschickia*, F. *Whipplella*, G. *Suchonella*, H. *Microcheilinella* (Gramm, 1977), I. *Healdia*? *obtusa* Abushik (modified from Gramm 1987).

Suborder METACOPINA Bradley 1960

Superfamily **HEALDIOIDEA** Harlton 1933

*Remarks:* The Healdiidae Harlton 1933 best represent this superfamily of smooth metacopine ostracodes that demonstrate left over right valve overlap, lack a calcified inner lamella (see Benson et al. 1961, fig. 277), and yield a large, central aggregate AMS field. Healdioideans possess contact margins characterized by a ridge and groove on the left valve that is especially prominent in the anterior and posterior areas (Pozner 1951).

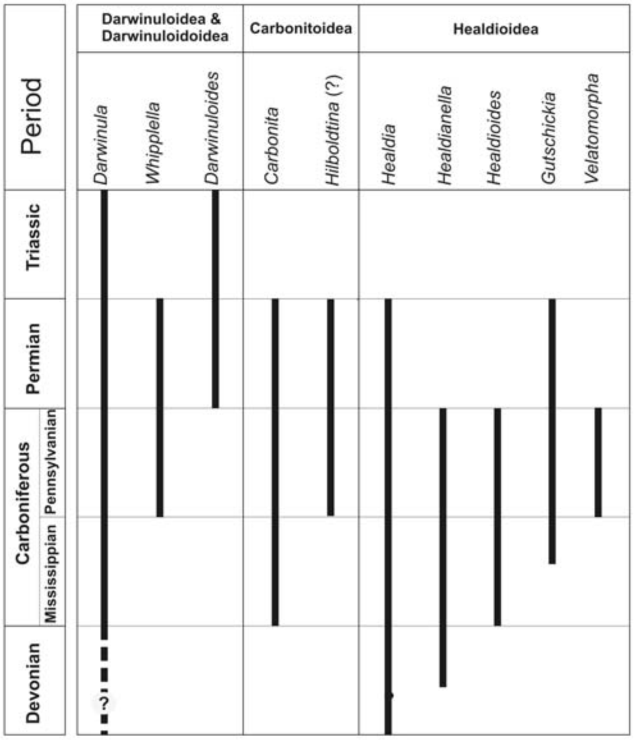
*Healdia* exhibits posterior spines or thickened ridges. The genus *Healdianella* Pozner 1951, described from the Lower Carbonif-



TEXT-FIGURE 5
Transverse polished section of *Velatomorpha altilis*. The lower image is a line tracing to illustrate the overlap. Note there is no positive evidence for a calcified inner lamella in this image or in other polished sections. Note the ridge and groove architecture of the right valve and the beveled edge of the left valve. This specimen is laterally compressed.

erous of Russia (*Healdianella darwinulinoides*), was created to encompass those smooth metacopine ostracodes with healdiid adductor muscle scar fields (see fig. 284, 4 *in* Benson et al. 1961). *Healdioides* Coryell and Rozanski 1942, described from upper Mississippian strata in Illinois, is distinct by virtue of its thickened posterior ridge; there are few taxa assigned to this genus and most occurrences are restricted south central United States (Sohn 1977b; Hoare and Mapes 2000).

To resolve uncertainty surrounding the smooth healdiids, Gramm et al. (1972) compared the AMS field of *Healdia sensu stricto* (comprising ~32-48 stigmata) to those AMS fields known for the smooth, nonspinose forms that included *Bairdiocyproidea*, *Healdia*?, and *Healdianella*. They noted a reduction of stigmata and an observed rearward-curving arch in all genera. Gramm (1982) also described the AMS field for *Healdianella darwinuloides* in order to validate its taxonomic position within the Metacopina. Finally, Gramm (1987) illustrated the unornamented species *Healdia*? *obtusa*, which exhibits a distinct cluster of inner spots (~6) surrounded by a group of peripheral spots (22-24) (text-fig. 4I). This bi-arcuate, oblong array, although more conservative with respect to total number of stigmata, is similar to those illustrated for *Healdia* and *Healdianella*.



TEXT-FIGURE 6
Stratigraphic ranges of genera assigned to Darwinuloidea, Darwinuloidoidea, Carbonitoidea, and Healdioidea. Ranges inferred from Benson et al. (1961) and from recent data presented in Table 2. Solid lines indicate known occurrences. Hatched lines indicate uncertain temporal distributions.

Family **HEALDIIDAE?** Harlton 1933

R*emarks:* We question the familial position of the newly proposed genus herein until allied taxa (e.g., *Gutschickia* and *Pruvostina*) can be studied in more detail in as much that a new family may be warranted.

Genus ***Velatomorpha*** Tibert and Dewey **n. gen.**

*Type species*: *Carbonia fabulina* var. *altilis* JONES AND KIRKBY 1889, p. 269, figs. 1-4.

*Included species*: We believe that the following species should be included in this genus:

*Carbonia fabulina* varieties – JONES AND KIRKBY 1884, p. 358, pl. 12, figs. 9a-e.
*Carbonia fabulina* var. *altilis* (Jones and Kirkby) – JONES AND KIRKBY 1889, p. 269, figs. 1-4.
*Microcheilinella intumescens* – POZNER 1951, p. 81, figs. 4a-b.
*Carbonita altilis* (Jones and Kirkby) – COPELAND 1957, p. 25, pl. 1, figs. 1-3.
*Carbonita inflata* (Jones and Kirkby 1879) – COPELAND 1957, p. 26, pl. 1, figs. 12-14, pl. 2, figs. 18-19.
*Carbonita agnes* (Jones 1870) – COPELAND 1957, p. 25, pl. 1, figs. 19-21.
*Carbonita elongata* (Jones and Kirkby 1884) – COPELAND 1957, p. 25, figs. 22-25.

*Healdia*? *obtusa* Abushik – GRAMM 1987, p. 64, fig. 1c-e.

*Etymology*: Named *velato* Latin for concealed and *morpha* Greek for morphology; referring to internal characters that are not easily identified (e.g., contact margin, AMS field, and hingement).

*Deposited material*: The hypotype material described herein is deposited at the Royal Ontario Museum. *Velatomorpha altilis* (Jones and Kirkby 1889) figured on Plate 1E is the best representative for the genus (ROM 57271). The other 6 specimens illustrated in this paper are designated as follows: Plate 1 (F) ROM 57272, (G) ROM 57273, (H) ROM 57274; Plate 2, (A-C) ROM 57275, (D) ROM 57276, (E) ROM 57277.

*Diagnosis*: Sub-ovate; strong right over left valve overlap; greatest height at the anterior; gentle sloping posterior; 6-8 inner stigmata surrounded by 19-20 stigmata; AMS field is bi-arcuate with a rearward facing convex arch; contact margin is a ridge and groove on the left valve most prominent at anterior and posterior areas; adont hinge as described for the Superfamily Healdioidea.

*Remarks*: *Healdia* and *Healdioides* have posterior ornamentation in the form of thickened ridges and/or spines. *Healdianella* can be differentiated from *Velatomorpha* because it demonstrates greatest height in the posterior, a gentle anterior slope, less pronounced overlap, and a more ovate AMS field comprising 10-12 additional outer stigmata of true healdiid fashion. We acknowledge a similar AMS field for *Gutschickia*, illustrated in Sohn (1977a, 1985). Both *Gutschickia* and *Velatomorpha* express right over left valve overlap and this has been confirmed by the frontal scars illustrated in Sohn (1977a, fig. 4.7). The two genera are differentiated on the basis that *Gutschickia* has a knife edge dorsal incision, more acute cardinal angles, and the greatest height is posterior of the AMS (Table 1). *Whipplella* and *Carbonita* demonstrate sub-equal valves with a small circular AMS field is located anterior of the median position, clearly differentiating *Velatomorpha* from these taxa.

Included within the proposed new genus is *Microcheilinella intumescens* based on its overlap and the subovate outline. Pozner (1951, pl. 17, figs 4a, 4b) illustrated the type specimen with right over left overlap, which contradicts the diagnosis for *Microcheilinella* (Geis, 1932, p. 181) and we assume this to be an error based on recent illustrations of the type material (Gramm 1982).

*Age and distribution*: Laurasia, Mississippian–Pennsylvanian. All taxa previously assigned to *Carbonita* are from North America. *Healdia? obtusa* Abushik (Gramm 1987) and *Microcheilinella intumescens* Pozner 1951 are reported from Carboniferous strata in Russia.

**Velatomorpha altilis** (Jones and Kirkby 1889)
Plate 1, figs. A-H, Plate 2, figs. A-I

*Cytherella inflata* DAWSON 1868, p. 206, fig. 48b-c.
*Carbonia fabulina* and varieties JONES AND KIRKBY 1884, p. 358, pl. 12, fig. 9a-e.
*Carbonia fabulina* var. *altilis* JONES AND KIRKBY 1889, p. 269, figs. 1-4.
*Carbonita altilis* (Jones and Kirkby). – COPELAND 1957, p.25, pl. I, figs. 1-3. – ANDERSON 1970, p. 82, pl. 14, figs. 25-31.

*Lectotype*: Anderson (*in* Pollard 1966) designated and illustrated a lectotype specimen from the T. R. Jones Collection in the British Museum labeled BM I 2446 (= BM I 22446 *in* Anderson, 1970, p. 82, pl. 14, fig. 27). This specimen is illustrated herein on Plate 1A-C. An additional specimen from the G. J. Hinde Collection labeled BM I. 19484 is also illustrated in Anderson (1970, pl. 14, fig. 29); this specimen was collected from south Joggins, Nova Scotia.

*Type Locality:* Mabou Coalfield, Inverness County, Cape Breton, Nova Scotia.

*Collection locality this study*: Joggins, Cumberland County, Nova Scotia, Canada, Latitude 45º42'1.8"N, Longitude 64º26' 58.66" W. The samples collected correspond to the 0-900 m stratigraphic interval (text-fig. 2, modified from Davies and Gibling 2003; Calder et al. 2005). The majority of the material was collected from the stratigraphic interval between the Fundy and Forty-brine coal seams where two, organic-rich, limestone beds are exposed on the wave-cut platform (text-figs. 1, 2).

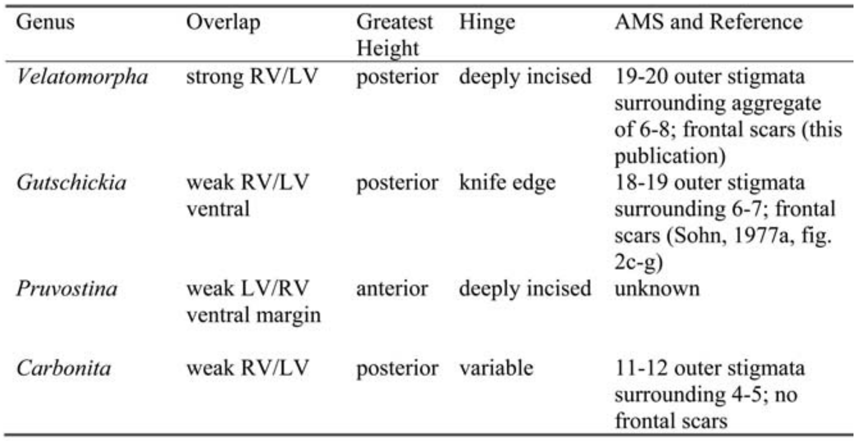
*Material*: Approximately1200 specimens.

*Measurements*: Lectotype, BM. I. 2446A (Plate 1A,B,D): L = 926µm, H = 630µm, W = 617µm; Paralectotype BM. I. 2446C (Plate 1C): L = 856µm; W = 555µm; ROM 57271 (Plate 1E): L = 906µm, H = 624µm; ROM 57272 (Plate 1F): L = 1054µm, H = 655µm; ROM 57273 (Plate 1G): L = 944µm, W = 521µm; ROM 57274 (Plate 1H): L = 985µm, W = 553µm; ROM 57275 (Plate 2A,B,C): L = 947µm, H = 606µm, W = 605µm; ROM 57276 (Plate 2D): L = 865µm, H = 562µm; ROM 57277 (Plate 2E,F): L = 862µm, H = 560µm.

*Description*: *Velatomorpha altilis* is a robust species of Healdioidea with a pronounced marginal overlap along the entire free margin that is especially prominent along the mid-ventral area. The right valve exhibits a broad ridge and groove that accommodates the left valve (Plate 2G); this is especially evident at the posterior end. In ventral view, the maximum overlap occurs posterior of the median position. The greatest height is posterior of the median position. Females are short, stout, and swollen in the posterior position. Males are more elongate with a prominent angularity of the right valve observed from the left aspect (Plate 1F). The bi-arcuate AMS field is oblique to the vertical axis and it is elongated where 19-21 stigmata surround a central array of 6-8 (Plate 2C, F) (see fig. 284, 4 *in* Benson et al. 1961). The carapace is often coarsely punctate. The pores are simple with a pit and central pore and no sieve plate (Type A of Puri 1974). Pustules are common. The hinge comprises a short, thickened bar observed on the left valve (Plate 2H, I) that maintains the approximate position of the incised area (L: 407µm; W: 35µm); the terminal ends of the bar form a thickened, flange-like projection with crenulations (?), and this bar is accommodated by the right valve in the approximate area of dorsal incision.

*Remarks*: The first informal reports for the conspecific material from Nova Scotia include *Cytherella inflata* (Dawson 1868, p. 206, fig. 48b-c) and *Carbonia fabulina* and varieties (Jones and Kirkby 1884, p. 358, pl. 12, fig. 9a-e). Jones and Kirkby (1889) formally illustrated *Carbonita altilis* using a specimen collected from the Mabou coalfields on Cape Breton Island Nova Scotia; this section is comparable in both age and depositional environment to the Joggins Formation. Several illustrated specimens of *Carbonita altilis* (in Anderson 1970, pl. 15, figs. 38-40), in our opinion, resemble *Gutschickia* in both shape and hingement.

TABLE 1
Characteristics for genera related to *Velatomorpha*.



| Genus | Overlap | Greatest Height | Hinge | AMS and Reference |
|---|---|---|---|---|
| *Velatomorpha* | strong RV/LV | posterior | deeply incised | 19-20 outer stigmata surrounding aggregate of 6-8; frontal scars (this publication) |
| *Gutschickia* | weak RV/LV ventral | posterior | knife edge | 18-19 outer stigmata surrounding 6-7; frontal scars (Sohn, 1977a, fig. 2c-g) |
| *Pruvostina* | weak LV/RV ventral margin | anterior | deeply incised | unknown |
| *Carbonita* | weak RV/LV | posterior | variable | 11-12 outer stigmata surrounding 4-5; no frontal scars |

Our specimens closely resemble *Carbonita humilis* (Jones and Kirkby 1879) and *Cytherella foveoloata* Wright 1830 as illustrated and discussed in Anderson (1970, pl. 15, figs. 32-36) and Bless and Pollard (1973). Bless and Pollard (1973, 1975) demonstrated a wide variety of morphologic expression for *Carbonita humilis*. They concluded that there are three ecologically determined "species-groups" within the genus *Carbonita:* (1) *C. humilis* group; (2) *C. pungens-secans* group; and (3) *C. salteriana* group. Bless and Pollard (1973) illustrated numerous specimens of *C. humilis* that lack a calcified inner lamella, maintain a rather prominent right over left valve overlap, and exhibit large normal pores where pustules are not uncommon. Some of the illustrated material for *Carbonita humilis* may in fact be junior synonyms of *Velatomorpha altilis*, but we will forego this conclusion until the appropriate type material can be observed.

*Age and distribution*: Maritimes Basin, North America, Lower Pennsylvanian (Westphalian A-C; mid-Langsettian). *Velatomorpha altilis* has been reported from the Westphalian coal measures of Joggins and Mabou, Nova Scotia (Copeland, 1957) and potential synonyms occupy coeval coal measures in western Europe (Pollard 1966; Anderson 1970; Bless and Pollard 1973, 1975).

## DISCUSSION

### Taxonomic Implications

Our pursuit for the best generic assignment for *Carbonita altilis* has inevitably led us to a detailed discussion of the darwinulocopine superfamily Carbonitoidea and metacopine superfamily Healdioidea. The following opinions result from our investigations of the North American literature and type material deposited and illustrated by Bradfield (1935), Cooper (1941), Coryell and Rozanski (1942), Scott and Summerson (1943), Scott (1944), Copeland (1957), and Sohn (1977a, 1985). Table 2 summarizes the age and distribution of the type material and select taxa relevant to this discussion. We recognize three primary superfamilies into which most of the smooth, Paleozoic carbonitoidean taxa can be assigned. The distribution of these genera is shown in text-figure 5 and their relevance will be discussed here.

### *On the suprageneric position of Velatomorpha*

Adductor muscle scar patterns are useful for suprageneric classifications, but they are by no means conclusive. For example, the platycopes and metacopes both possess a central aggregate AMS pattern. Gramm (1985), in his detailed account of the AMS fields of the Cavellinidae, established that the biserial aggregate AMS validated the partitioning of Paleozoic platycope and metacopes. The Sigillioidea and Paraparchitoidea also possess aggregate AMS fields. Consequently, the origins of the *Carbonita* and its kin must rely on additional characteristics for suprageneric diagnoses. Additional characteristics include the nature of overlap, hingement, and contact margin.

Healdiid ostracodes have left over right valve overlap (Benson et al. 1961). Darwinulocopine (*Darwinula*, *Darwinuloides*, and *Carbonita*) and platycopine (e.g. *Cavellina* and *Cytherella*) demonstrate right over left overlap. Our material clearly shows right over left valve overlap and dorsal over reach. *Velatomorpha* resembles Healdia in all aspect except the direction of overlap; thus, we are left to infer that either this taxon is an example of reversal of overlap (common in the ostracoda) that was manifested by geographic isolation of a marine taxon in the marginally marine waters during the Pennsylvanian. Alternatively, the hinge and contact margin of our material does bear close resemblance to kloedenellid platycopes (= hemisolenic) which would imply that this form may have ancestral roots with the Platycopida (Adamczak 2003a,b).

The hingement for the Carbonitoidea is simple (Anderson 1970). The Healdiids, have well developed adont hinges comprising a prominent bar on the right valve, and an opposing groove in the left, where the anterior and posterior position of the bar is often thickened. Crenulations are also visible on some of the better preserved material (Gramm 1982). Mesozoic healdiids, such as *Hungarella*, yield additional crenulations along the entire free contact margin (Benson et al. 1961). *Velatomorpha altilis* has a healdiid style adont hinge indicated by a hinge bar on the left valve (Plate 2H) and, although poorly preserved, faint crenulations have been observed on the terminal hinge elements (Plate 2I).

The contact margin is an important characteristic that supports our healdioidean assignment for *Velatomorpha altilis*. In his description of the Carbonitoidea, Sohn (1985, p. 51) comments that "*Carbonita* differs from that of the Healdioidea in the pres-

TABLE 2
Age, authors, location information for genoholotypes material and select representative taxa from the Carbonitoidea, Sigillioidea, Healdioidea, and Darwinuloidea.

| **Superfamily and associated genera** | **Type species (* = type material examined )** | **Authors (genotype and select taxa from North America)** | **Location** | **Age** |
|---|---|---|---|---|
| **Carbonitoidea** | | | | |
| *Carbonita*<br>Strand 1928 | **Carbonia agnes* LT - BMNH 43513 | Jones 1870 | United Kingdom | Mississipian |
| | **Carbonia fabulina* var. *altilis* LT – BMNH 2446 | Jones and Kirkby 1889 | Atlantic Canada | Mississippian-Pennsylvanian |
| | *Carbonita altilis* | Copeland 1957 | Atlantic Canada | Lower Pennsylvanian |
| | **Carbonita* spp. | Sohn 1977a, 1985 | West Virginia | Pennsylvanian |
| | *C. scalpellus* | Tibert and Scott 1999 | Atlantic Canada | Lower Mississippian |
| | *C. pungens* | Tibert unpublished | Pennsylvania | Pennsylvanian |
| | *Carbonita* spp. | Retrum and Kaesler | Kansas | Permian |
| *Hilboldtina*<br>Scott and Summer son 1943 | *Hilboldtina multiplicata* GHT - Univ. Illinois x-1703 | Scott and Summerson 1943 | Tennessee | Lower Pennsylvanian |
| | *Carbonia evelinae LT - BMNH 56370* | Jones 1870 | United Kingdom | Mississippian |
| | *Hildboldtina evelinae* | Sohn 1977a, 1985 | West Virginia | Pennsylvanian |
| | *Carbonita evelinae* | Tibert unpublished | Atlantic Canada | Lower Pennsylvanian |
| | *Carbonita evelinae* | Retrum and Kaesler | Kansas | Permian |
| *Whipplella*<br>Holland 1934 | **W. cuneiformis* Carnegie 6493 | Holland 1934 | West Virginia | Permian |
| | *Whipplella carbonaria* | Scott 1944 | Illinois | Permian |
| | **Whipplella* spp. | Sohn 1977a, 1985 | West Virginia | Pennsylvanian |
| *Gutschickia*<br>Scott 1944 | **Whipplella ninehevensis* HT - Carnegie 6483 | Holland 1934 | Pennsylvania | Permian |
| | *Gutschickia ninehevensis* | Scott 1944 | Illinois | Permian |
| | *G. levis*; *G. ovata* | Cooper 1946 | Illinois | Middle Pennsylvanian |
| | *G. bretonensis* | Copeland 1957 | Atlantic Canada | Lower Pennsylvanian |
| | **Gutschickia* spp. | Sohn 1977a, 1985 | West Virginia | Pennsylvanian |
| *Pruvostina*<br>Scott and Summerson 1943 | *Pruvostina wanlessi* GHT: Univ. Illinois x-1705 | Scott and Summerson 1943 | Illinois | Lower Pennsylvanian |
| | **Pruvostina* sp. | Sohn 1977a, 1985 | West Virginia | Pennsylvanian |

TABLE 2
*Continued.*

| | | | | |
|---|---|---|---|---|
| **Healdioidea** | | | | |
| *Healdia* Roundy 1926 emended Harlton 1929 | **Healdia simplex*<br>GHT: USNM 119718 | Roundy 1926 | Texas | Upper Pennsylvanian |
| | *H. ovata* | Bradfield 1935 | Oklahoma | Upper Pennsylvanian |
| | *Healdia* spp. | Dewey and Fahareus 1987 | Atlantic Canada | Upper Mississippian |
| | *Healdia* spp. | Hoare and Merrill 2004 | Texas | Mississippian-Pennsylvanian |
| *Healdianella* Pozner 1951 | *Healdianella darwinuloides*<br>GHT: Leningrad 109-85 | Pozner 1951 | Moscow Basin | Upper Mississippian |
| | *Healdianella darwinulinoides* | Gramm 1982 | Moscow Basin | Upper Mississippian |
| *Healdioides* Coryell and Rozanski 1942 | *Healdioides diversus*<br>HT – Columbia Univ. | Coryell and Rozanski 1942 | Illinois | Upper Mississippian |
| | **Healdiodes* spp. | Sohn 1977b | Arkansas | Pennsylvanian |
| | *H. retusus, H. commensuratus* | Hoare and Mapes 2000 | Arkansas | Mississippian |
| **Sigilloidea** | | | | |
| *Microcheilinella* Geis 1932 emended Geis 1933 | *Microcheilus distortis*<br>HT – Univ. Illinois 366 | Geis 1932 | Indiana | Middle Mississippian |
| | *M. cordata*; *M. tumida* | Cooper 1941 | Illinois | Upper Mississippian |
| | *M. acuminata* | Coryell and Rozanski 1942 | Illinois | Upper Mississippian |
| | *Microcheilinella mendelgrammi* | Olempska 2001 | Europe & China | Devonian-Mississippian |
| **Darwinuloidoidea & Darwinuloidea** | | | | |
| *Darwinuloides* Mandelstam | *Darwinuloides oviformis* | Mandelstam | Siberian Platform | Permian-Triassic |
| | **Whipplella* sp. | Sohn and Swain 1999 | West Virginia | Mississippian |
| *Darwinula* Brady and Robertson 1885 | *Polycheles stevensoni* | Brady and Robertson 1870 | Europe | Recent |
| | *Darwinula* sp. | Swain 1962 | New York | Middle Ordovician |
| | **Darwinula* sp. | Sohn 1977a, 1985 | West Virginia | Mississippian |

ence of radial pore canals that are associated with a calcified inner lamella…" a characteristic which ultimately helped to validate the new superfamily. In contrast, the superfamily Healdioidea do not exhibit calcified inner lamellae (Benson et al., 1961) and more recently, Gramm (1982) illustrated the contact margin of *Healdianella* as a wide ridge and groove on the left valve in which the margin of the right nestles (a stop ridge). Our cross-sectional analysis of *Velatomorpha altilis* did not yield evidence for a calcified inner lamella (text-fig. 5). Plate 2G illustrates a ridge and groove architecture in the anterior position of the contact margin.

Considering the diagnostic characters for the superfamilies (see above), we conclude that *Velatomorpha altilis* has strong healdioidean affinities based on:

(1) A central aggregate AMS field;

(2) A thickened bar on the right valve that is accommodated by an opposing groove on the left (adont hinge *sensu* Benson et al. 1961);

(3) A contact margin comprising a ridge and groove on the left valve that is most pronounced in anterior and posterior regions.

Why do we not simply assign "*Carbonita*" *altilis* to *Healdia*, *Healdianella*, or *Healdioides*? First, *Velatomorpha altilis* is unique in that the number of stigmata in the AMS fields are more conservative than the healdiid kin (see systematics above). Second, the right over left overlap for *V. altilis* contradicts a Healdioidean diagnosis and this will require further consideration. Finally, *Healdia* and *Healdioides* are known to have thickened posterior ridges and spines which *Velatomorpha* does not. The external morphologic differences between *Velatomorpha* and other healdiid genera may be attributed to environmental influences. Ostracodes that occupy shallow, normal marine environments typically demonstrate external ornament that include spines and/or ridges (Benson et al. 1961). The spines and ridges were apparently not expressed in the ancestor to *Velatomorpha* that invaded the organic-rich, low salinity, coastal water bodies during the Pennsylvanian.

### *On the suprageneric position of* Carbonita

Based on our examination of type, published, and unpublished material (e.g., Tibert and Scott 1999; Retrum and Kaesler, unpublished material), we regard *Carbonita* as a distinct taxon. Is there an alternative suprageneric placement of *Carbonita*? In a recent review of ostracode evolutionary trends, Horne (2003) proposed that the Carbonitoidea, although potentially related to Paleozoic Sigillioidea (text-fig. 6), is a polyphyletic group. Our propositions regarding *Velatomorpha* herein certainly support the latter notion. The fact remains that the Carbonitoidea are probably podocopid ostracodes as originally proposed by Sohn (1985). The question arises, to which sub-order are they most closely allied? In the context of the taxonomic scheme of Horne (2004), there are two likely possibilities of podocopid suborders: Sigilliocopina and Darwinulocopina.

Included in the diagnostic criteria for the Paleozoic Sigillioidea (Gramm 1977; Olempska 2001) is left over right overlap, a central aggregate AMS, and a well-developed calcified inner lamella. The prominent Paleozoic sigillioid genus *Microcheilinella* also exhibits strongly crenulated merodont hinge elements (Olempska 2001). The overlap and hingement contrasts that diagnosed for the Carbonitoidea. *Darwinula* is a genus that exhibits a conservative central aggregate AMS, right over left valve overlap, and simple hingement. These features are encapsulated in the diagnosis for *Carbonita* Strand (see Anderson 1970). It therefore seems reasonable to us, to assign the Carbonitoidea to the Darwinulocopina.

### Paleoecological implications

Ostracodes reported from the Joggins locality (Copeland 1957; Duff and Walton 1973) include *Carbonita* c.f. *salteriana*, *Carbonita bairdioides* (= *Gutschickia* sp.), *Carbonita pungens*, *Carbonita elongata*, and *Carbonita evelinae* (= *Hilboldtina evelinae*). Nearly all samples included in this study contained an association of *Velatomorpha altilis* and sparse (<5%) *Carbonita pungens*. Most remarkable is the oligospecific domination of *Velatomorpha altilis* (95-100%) in nearly all of the samples collected from Joggins (excluding only JG-09 and MR-112702-14). Furthermore, the *V. altilis* dominated assemblages contain mostly articulated late instar and adult carapaces that indicate mass mortality events (see Tibert and Scott 1999). The associated specimens of *Carbonita pungens* are disarticulated which indicates that they accumulated as a post-mortem death assemblage washed in from adjacent nonmarine sources (see Tibert and Scott 1999). The synthesis of the paleoecological information suggests to us that the environment of deposition for the Joggins Formation was proximal marginal marine that recorded environmental alternations between fresh and brackish waters.

At both Joggins and Port Hood, the bivalves *Naiadites*, *Anthraconaia*, and *Carbonicola* co-occur in relative abundance with *Velatomorpha altilis* (Copeland 1957; Vasey 1984). Spirorbids and the arthropods *Euproops* sp. and *Bellinurus* sp. are also common. Vertebrate remains include fish scales (*Rhizodopsis* sp. and *Rhabdoderma* sp., Duff and Walton 1973) and dental elements of the chondrichthyes fish *Ageleodus cristatus* (Dawson 1868). All of the above fossil groups are similar in their paleoecological affinities where they and many of their descendants are typically associated with mixed freshwater and marine (brackish) deposits.

The paleoecological interpretations for the Carbonitoidea range from nonmarine through brackish (e.g., Pollard 1966; Anderson 1970; Bless and Pollard 1973; Bless 1983; Peterson and Kaesler 1980; Tibert and Scott 1999; Watabe and Kaesler 2004). The occurrence of *Velatomorpha altilis* in the Joggins Formation supports a marginal marine, estuarine interpretation for the genus. The paleontological richness of the Joggins flora and fauna and the observed variability within the ostracode assemblages indicate that a nonmarine paleoecological inference should not be made on the presence of *Carbonita* alone. It is likely that species of *Velatomorpha* and *Carbonita* probably represent marginally marine taxa that occupied lagoons, estuaries, and coastal lakes during the Carboniferous. *Velatomorpha* or *Carbonita* found in association with brackish and/or marine ostracode superfamilies (Paraparchitoidea, Kloedenelloidea, and Healdioidea) provides a strong testament for marine influence (Tibert and Scott 1999; Dewey 2001). In contrast, *Carbonita* found in association with *Darwinula* and/or nonmarine bivalves and conchostracans indicates oligohaline (0-5 ‰ salinity) conditions closer to true nonmarine (Sohn 1985). What is compelling to us, are the rich assemblages of Permian *Carbonita* that progressively increase their relative abundance and frequency throughout the Upper Paleozoic which signifies their successful occupation of nonmarine environments (Peterson and Kaesler 1980; Lethiers and Damotte 1993). *Velatomorpha* was apparently excluded from isolated terrestrial aquatic environments and this ultimately led to their demise by late Pennsylvanian times (text-fig. 6).

## CONCLUSIONS

We contend that species assigned to the genus *Carbonita* belong to one of the following superfamilies (Table 3):

1) Darwinuloidoidea – Those taxa that demonstrate right over left valve overlap and a *Darwinula* style biserial rosette AMS field should be placed within the Darwinuloidoidea (see Sohn and Swain 1999). Taxa previously assigned to the Carbonitoidea include *Whipplella* and *Pruvostina.*

2) Carbonitoidea – Paleozoic ostracodes that have thinly calcified, small-to medium sized, sub-equal carapaces that exhibit right over left valve overlap where the degree of overlap is minimal, an AMS field that comprises a small, circular sub-central pit of 10-15 stigmata oriented around 1-4 inner stigmata, and sexual dimorphism. *Carbonita* is a distinct genus that includes the lectotype *Carbonita agnes* (BM 43513 examined by CD), *Carbonita scalpellus*, and *Carbonita pungens*. Those thinly calcified, striated taxa should remain as *Hilboldtina* (e.g., *H. evelinae*) until the type material can be examined.

3) Healdioidea – Species assigned to the Healdioidea possess a bi-arcuate healdiid AMS field, a contact margin with ridge and groove architecture, an adont hinge, and strong valve overlap. *Velatomorpha* new genus and *Gutschickia* both exhibit healdioidean characteristics and taxa assigned to both are subsequently removed from the Carbonitoidea.

*Velatomorpha altilis* is derived from the marine superfamily Healdioidea. The phylogenetic origin of the remaining Carbonitoidea, however, remains uncertain although the podocopid Darwinulocopina, given their similar aggregate AMS fields, are considered likely ancestors.

*Velatomorpha altilis* exhibited opportunistic behavior in a marginal marine environment that alternated between brackish and freshwater coastal water bodies during the early Pennsylvanian in the Maritimes Basin, Atlantic Canada.

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TABLE 3
Model for superfamily placement of species currently assigned to the Carbonitoidea.

| Superfamily | Overlap | AMS | Contact Margin | Examples |
|---|---|---|---|---|
| ***Suborder Darwinulocopina*** | | | | |
| *Darwinuloidoidea* | RV/LV | Biserial aggregate of 10-12 stigmata; frontal scars | Calcified inner lamella | *Whipplella*, *Darwinuloides* |
| *Carbonitoidea* | RV/LV | Central aggregate of 10-15 stigmata oriented around 1-4 inner stigmata | Calcified inner lamella | *Carbonita pungens*, *Carbonita agnes*, *Carbonita scalpellus*, *Hilboldtina evelinae* *Gutschickia* spp. |
| ***Suborder Metacopina*** | | | | |
| *Healdioidea* Family Healdiidae | Strong LV/RV | 20-30 outer rounded stigmata surrounding aggregate of 6-8; frontal scars | No visible calcified inner lamella | *Healdia*, *Healdianella*, *Healdioides*, |
| *Healdioidea* Family (?) | Strong RV/LV | 19-20 outer rounded stigmata surrounding aggregate of 6-8; frontal scars | No visible calcified inner lamella | *Velatomorpha*, *Gutschickia* |

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## PLATE 1

*Velatomorpha altilis*

A-B left and right lateral view of an adult carapace from Mabou Mines, Nova Scotia (BM. I. 2446A, illustrated figs. 25 and 27 *in* Anderson, 1970),

C lateral view of a right valve (BM. I. 2446C),

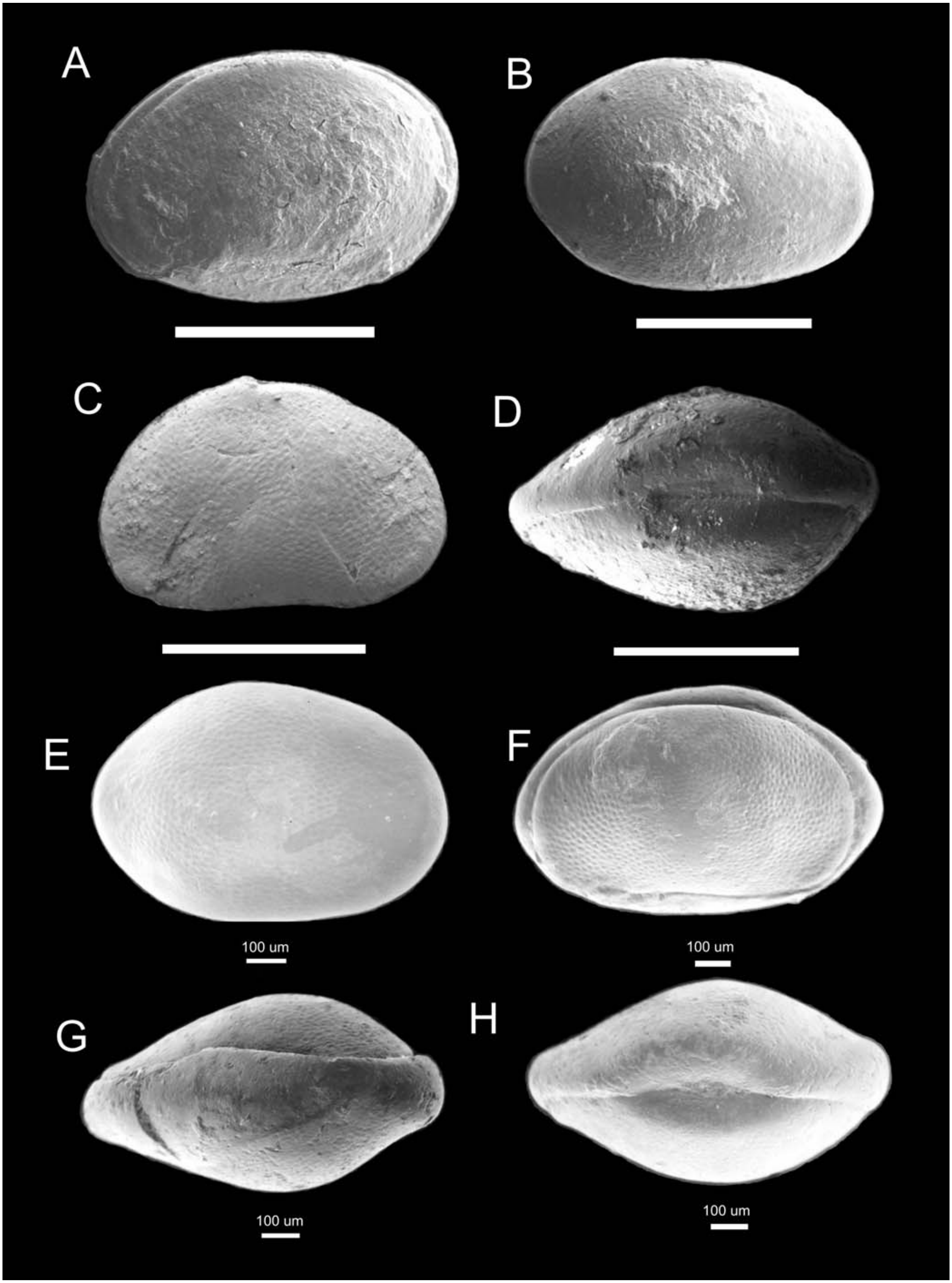
D dorsal view of BM. I. 2446A,

E right lateral view adult (ROM 57271),

F left lateral view adult (ROM 57272),

G view of adult valve, illustrating the ventral overlap (ROM 57273),

H dorsal view of adult female, illustrating the deeply incised hinge area and dorsal over reach (ROM 57274).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## PLATE 2

*Velatomorpha altilis*

A right lateral view of an adult adult carapace with AMS preserved on internal mold (FS = Frontal scars) (ROM 57275),

B ventral view of A tilted to illustrate the right valve overlap and the position of the FS (ROM 57275),

C inset enlargement from A-B illustrating the AMS field and lower frontal scar (ROM 57275),

D right view of adult female (ROM 57276),

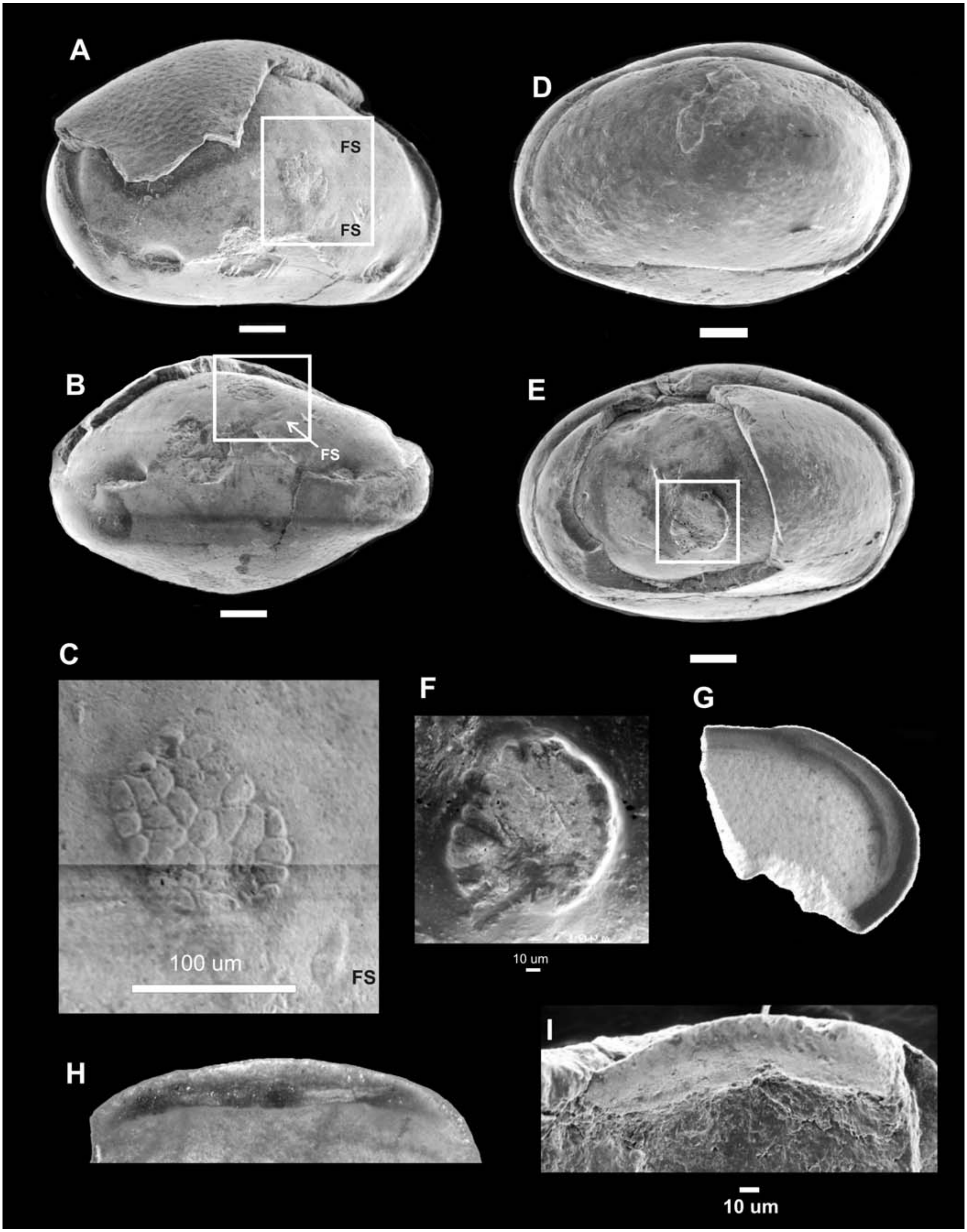
E right view of adult female with shell removed to illustrate AMS field (ROM 57277),

F inset enlargement of E viewed perpendicular to the image to illustrate variation in the AMS,

G internal view of the contact margin of a right valve fragment. Note the ridge and groove to accommodate the opposing right margin,

H hinge of a left valve fragment (posterior to left),

I hinge element (?) of a valve fragment. Note the beveled edge and the faint crenulations.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# Benthic foraminifera from a relict flood tidal delta along the Virginia/North Carolina Outer Banks

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**ABSTRACT:** Examination of benthic foraminifera from six vibracores collected from a relict flood tidal delta near the Virginia/North Carolina border documents the assemblages associated with a former inlet and provides geologic evidence of this former inlet that once defined the boundary between Virginia and North Carolina along the Outer Banks. Three distinct foraminiferal assemblages were identified. The oldest assemblage contained abundant and diverse forms, dominated by *Elphidium excavatum* and several other calcareous species typical of shallow nearshore areas. Sediment immediately below and above this diverse calcareous assemblage was barren or nearly barren of foraminifera. A medium-salinity agglutinated marsh assemblage characterized mainly by *Trochammina inflata* with fewer *Tiphotrocha comprimata* overlies the uppermost barren unit. The core top assemblage was dominated by low-salinity marsh species *Jadammina macrescens*, *Miliammina petila* and *Miliammina fusca*.

A comparison of these vertically-stacked assemblages with the modern geographic distribution of assemblages in the Outer Banks estuarine system and on the nearby continental shelf reveals a succession of depositional environments proceeding from estuarine and flood tidal delta to medium salinity marsh to lower salinity marsh. These changes in depositional environments reflect a rapid and dramatic increase in salinity caused by the opening of an inlet followed by a gradual decrease in salinity due to inlet shoaling and eventual marsh colonization of the flood tidal delta. These changes cannot be determined through sedimentological studies alone; micropaleontological analysis is required.

We conclude this distinctive trend of changing depositional environments constitutes paleontological evidence of the origin and evolution of Old Currituck Inlet that breached the barrier spit prior to 1585AD, actively built a flood tidal delta for more than 145 years, and then closed in 1731AD allowing the flood tidal delta to become colonized by marsh species.

## INTRODUCTION

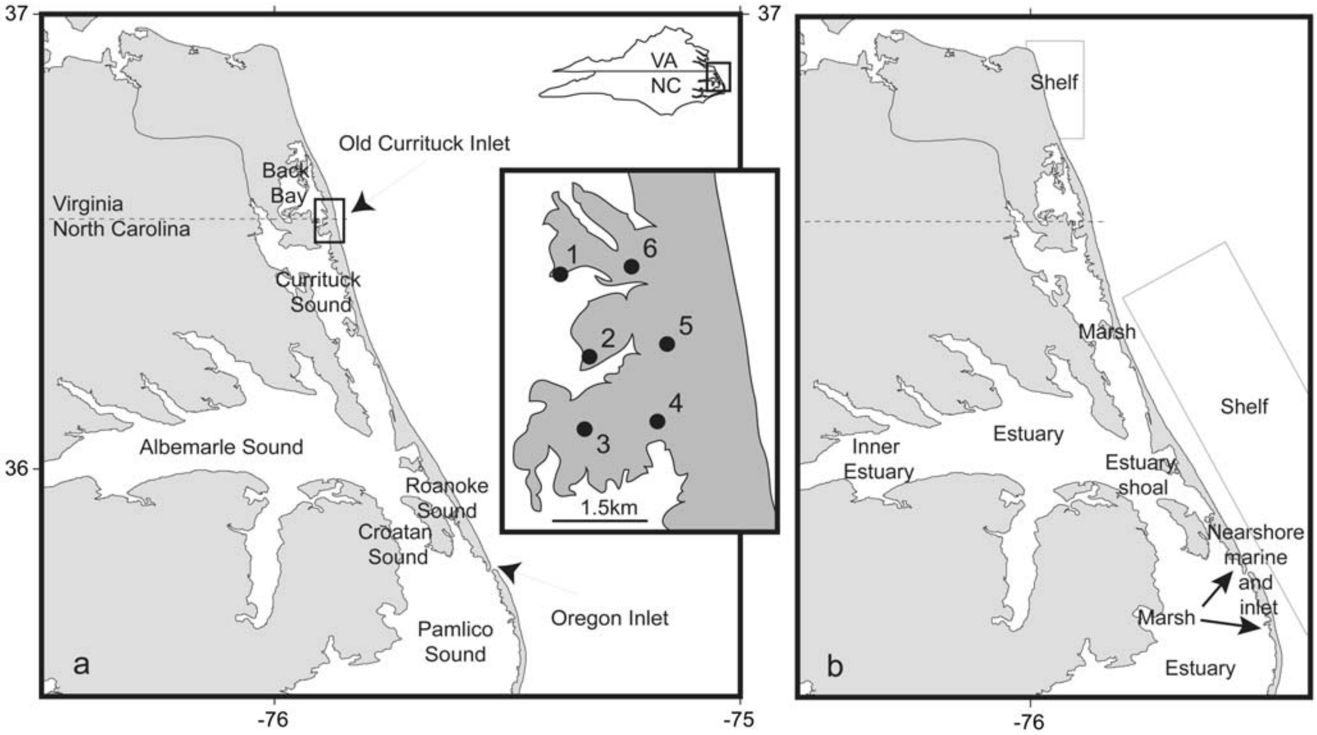
The Outer Banks of Virginia and North Carolina, along the US eastern seaboard, is a string of wave-dominated barrier islands and long linear sandy spits, interrupted by few active inlets that are successive, highly mobile and short-lived (Nummendal et al. 1977, Hayes 1994, Moslow and Heron 1994, McBride 1999). The Outer Banks has a distinctive shape that protrudes eastward into the Atlantic Ocean, reflecting the antecedent topography of the region (Riggs et al. 1995) that led to the development of an extensive estuarine system in which salinities range from fresh where rivers flow into the sounds to normal ocean water near inlets (Caldwell 2001). Water depth, type of substrate and amount of organic matter also vary throughout the Outer Banks system and are influenced by the position of inlets that commonly open during extreme storm events, migrate laterally in the direction of net littoral drift, and eventually close.

In this study, microfossils from cores collected from a relict flood tidal delta were examined with two objectives. First, the benthic foraminiferal assemblages were compared to modern distributions throughout the Outer Banks estuarine system and on the proximal continental shelf to reconstruct the environmental change recorded in down-core sediments. Secondly, the vertical sequence of depositional environments observed in the cores was compared to the historical record of Old Currituck Inlet in order to establish a microfossil signature that can serve as evidence of former inlet activity.

### Old Currituck Inlet, Virginia/North Carolina

Old Currituck Inlet was open along Currituck Spit in the northern Outer Banks, ~80km north of Oregon Inlet, North Carolina, in 1585 when the first coastal surveys were conducted, and closed in 1731 (Fisher 1962, 1977). Today, Oregon Inlet is the only active tidal inlet along the northern stretch of the Outer Banks, but Fisher (1962, 1977) documented the existence of 11 historical inlets that were active over the past ~400 years between Cape Henry and Cape Hatteras by recognizing persistent geomorphic features of inlets that remain preserved or partially preserved along the bay side of barrier islands and spits. A large, well-developed relict flood tidal delta marks the former position of Old Currituck Inlet (McBride and Robinson 2003). In addition, the inlet location is well documented, as the northern shoreline of Old Currituck Inlet served as the original state boundary between Virginia and North Carolina.

The relict flood tidal delta of Old Currituck Inlet, now capped by marsh, separates Back Bay to the north from Currituck Sound to the south (text-figure 1a). These shallow bays, removed from direct contact with the ocean, experience no astronomical tides but are subject to bi-directional wind-induced water flow, or "wind tides" (Caldwell 2001). Currituck Sound and Back Bay have a complex history of fluctuating salinity that can be attributed to both natural causes and human activity. Although modern salinities range between ~1 and 4ppt, the barrier islands have been overwashed during extreme storm events that



TEXT-FIGURE 1
The Outer Banks of Virginia/North Carolina. (a) Locations of cores 1 through 6 on the relict flood tidal delta of Old Currituck Inlet (inset) separating Back Bay from Currituck Sound. (b) Modern distributions of biofacies in southern Pamlico, Albemarle, Roanoke and Croatan Sounds (Culver and Horton 2005, Vance et al. 2006), Pamlico Sound (Abbene et al. in press), the Virginia continental shelf (Cronin et al. 1998) and the North Carolina continental shelf (Schnitker 1971).

elevated past annual salinities to near 10ppt (Robinson and McBride 2003).

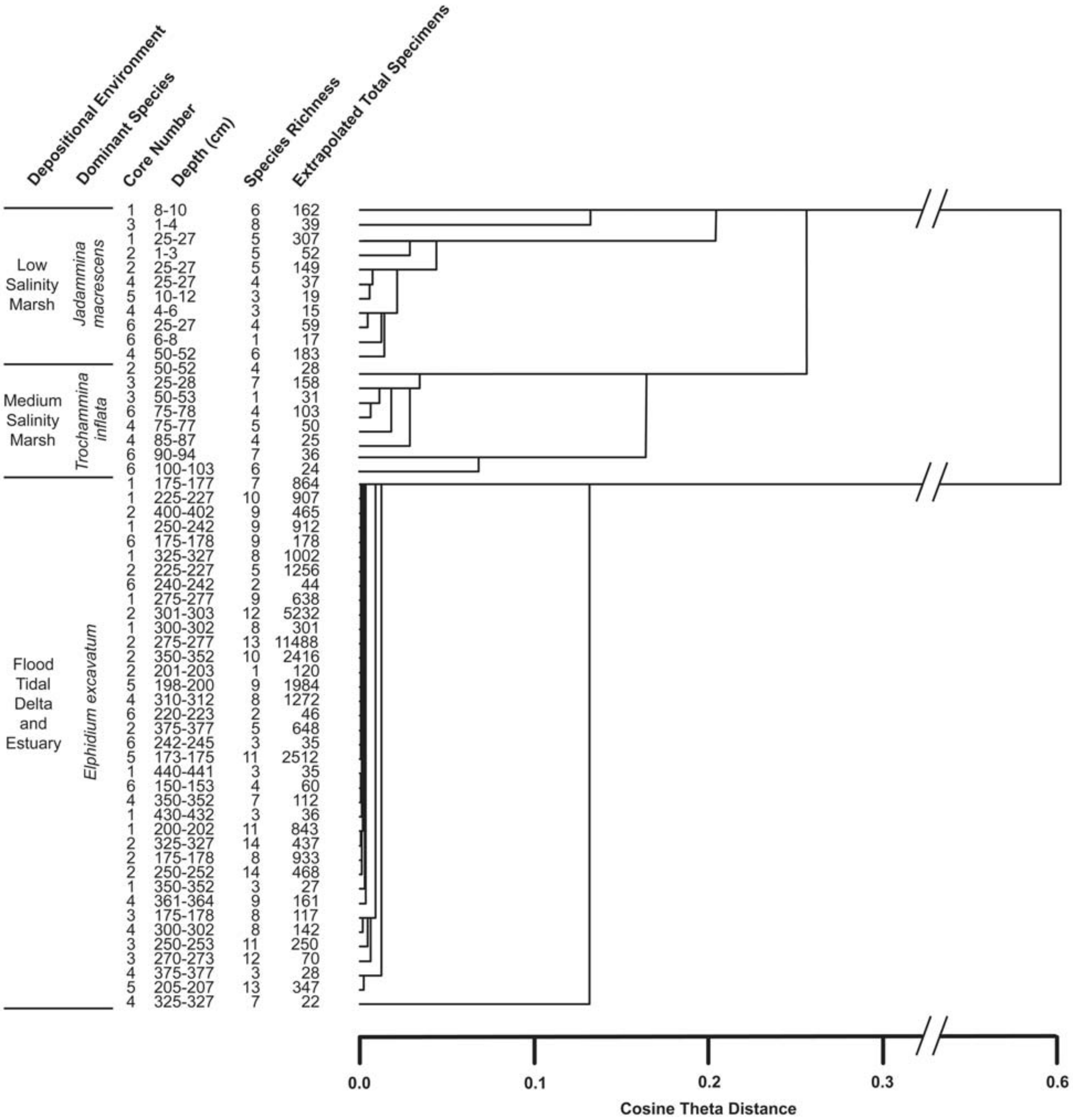
**Previous Studies**

Previous studies have established modern distributions of foraminifera along the Atlantic coast, linking assemblages to specific environments on the continental shelves (Murray 1969, Schnitker 1971, Culver and Buzas 1980, and included references, Culver and Snedden 1996, Cronin et al. 1998), in brackish lagoons and bays (Ronai 1955, Collins et al. 1995, Collins 1996), in estuaries (Buzas 1969, Nichols and Norton 1969, Ellison and Nichols 1970, Collins et al. 1995, Collins 1996, Ishman et al. 1999, Cronin et al. 2000) and in marshes (Parker and Athearn 1959, Phleger 1965, Scott and Medioli 1980, Goldstein 1988, Scott et al. 1991, Goldstein and Harben 1993, Collins et al. 1995, Collins 1996). These studies paired with those specific to barrier island systems (Byrnes 1988, Culver et al. 1996, Woo et al. 1997) and active flood tidal deltas (Luck 1934, Grossman and Benson 1967) are key to paleoenvironmental interpretations of coastal deposits.

While Culver and Buzas (1980) compiled hundreds of sources of distribution data for foraminiferal assemblages off the entire North American Atlantic Coast, Cronin et al. (1998) and Schnitker (1971) provided detailed assemblage data for the Virginia and North Carolina continental shelves, respectively (text-figure 1b). Both report a dominance of *Elphidium excavatum* in surface samples. Table 1 summarizes these assemblage data as well as those from the studies briefly discussed below. Culver and Horton (2005), Vance et al. (2006), and Horton and Culver (in press) documented modern distributions in southern Currituck Sound as well as in nearby Albemarle, Croatan, and Roanoke Sounds (text-figure 1b). Grossman and Benson (1967), Smith (2004), Abbene et al. (in review) studied foraminiferal distributions in Pamlico Sound. These estuarine and marsh assemblages are highly variable in their species dominance and species richness and in the proportion of calcareous to agglutinated forms.

Vance et al. (2006) included several sites on either side of Oregon Inlet, while Abbene et al.(in press) studied four sites near Ocracoke and Hatteras Inlets (text-figure 1b). These nearshore marine and inlet sites were dominated by *Elphidium excavatum*.

In the first known effort to establish the sedimentary nature of an active flood tidal delta, Luck (1934) described the assemblage of benthic foraminifera found in flood tidal delta sediments of Barnegat Inlet, New Jersey. While Luck (1934) included a plate of many of the species identified, he unfortunately did not publish any quantitative foraminiferal assemblage data. Grossman and Benson (1967) published more useful descriptions of Pamlico Sound sediments including those from the flood tidal deltas of Ocracoke and Drum Inlets, the ebb tidal delta of Ocracoke Inlet, and Cape Lookout Bight. In general the tidal delta assemblage they describe is characterized by a mixing of brackish and marine species of benthic foraminifera but can be subdivided into a flood tidal delta assemblage of more brackish forms and an ebb tidal delta assemblage of more marine forms.



TEXT-FIGURE 2
Cluster analysis diagram showing three distinct groups: low salinity marsh dominated by *Jadammina macrescens* and *Miliammina petila*, medium salinity marsh dominated by *Trochammina inflata* and *Arenoparella mexicana*, and estuarine and flood tidal delta dominated by *Elphidium excavatum*.

Finally, Culver and Horton (2005) and Horton and Culver (in press) described six distinct marsh assemblages in Pamlico and southern Currituck Sounds representing both higher and lower marshes in three different salinity regimes.

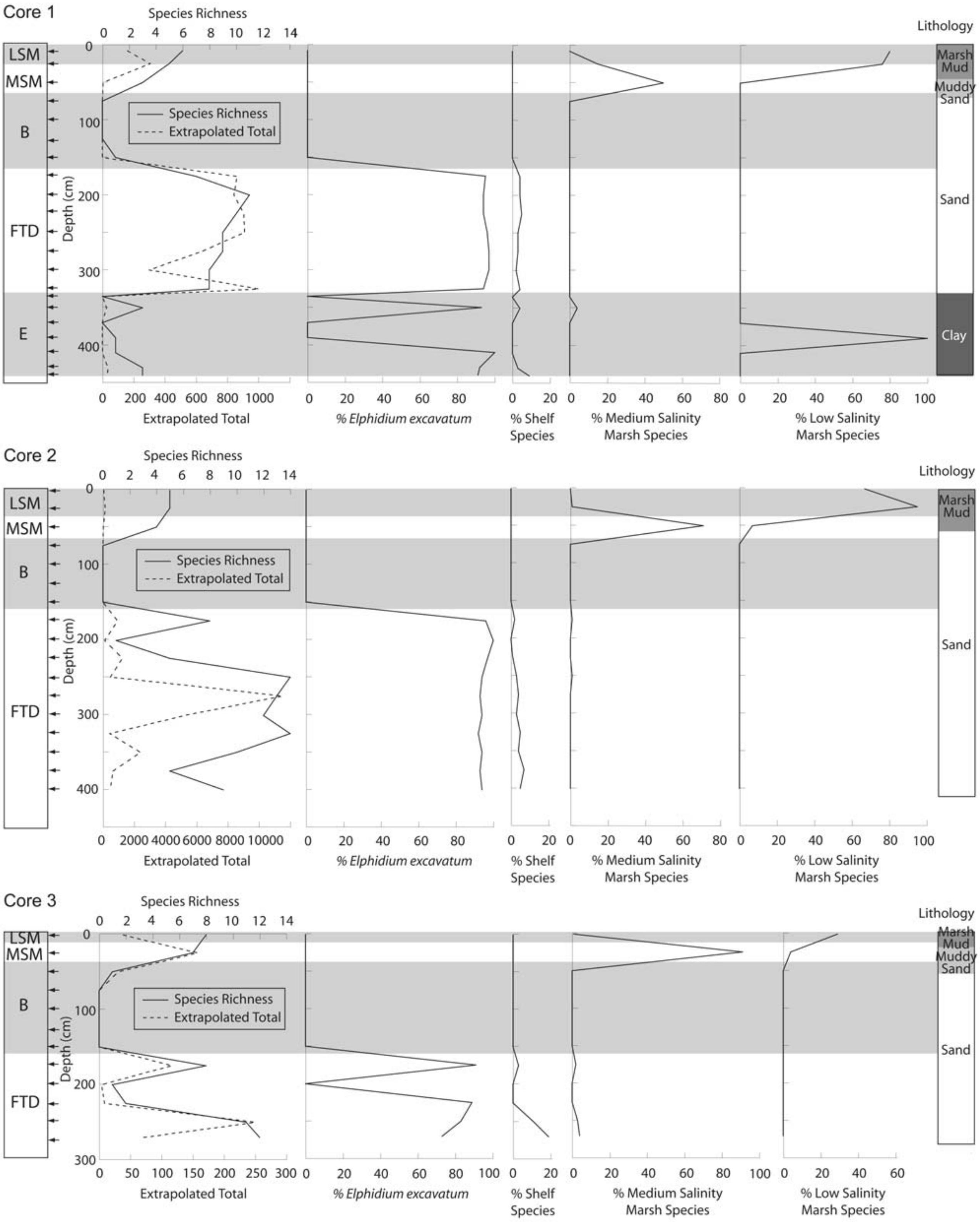
Foraminiferal assemblages from sediment cores have been useful in reconstructing changes between oceanic and estuarine influences (Cann et al. 2000; Cann and Cronin 2004), but few previous studies have been successful in relating downcore changes in foraminiferal assemblages to former tidal inlet dynamics along barrier islands (Collins et al. 1999, Scott et al. 2003).

## METHODS

### Field and Laboratory

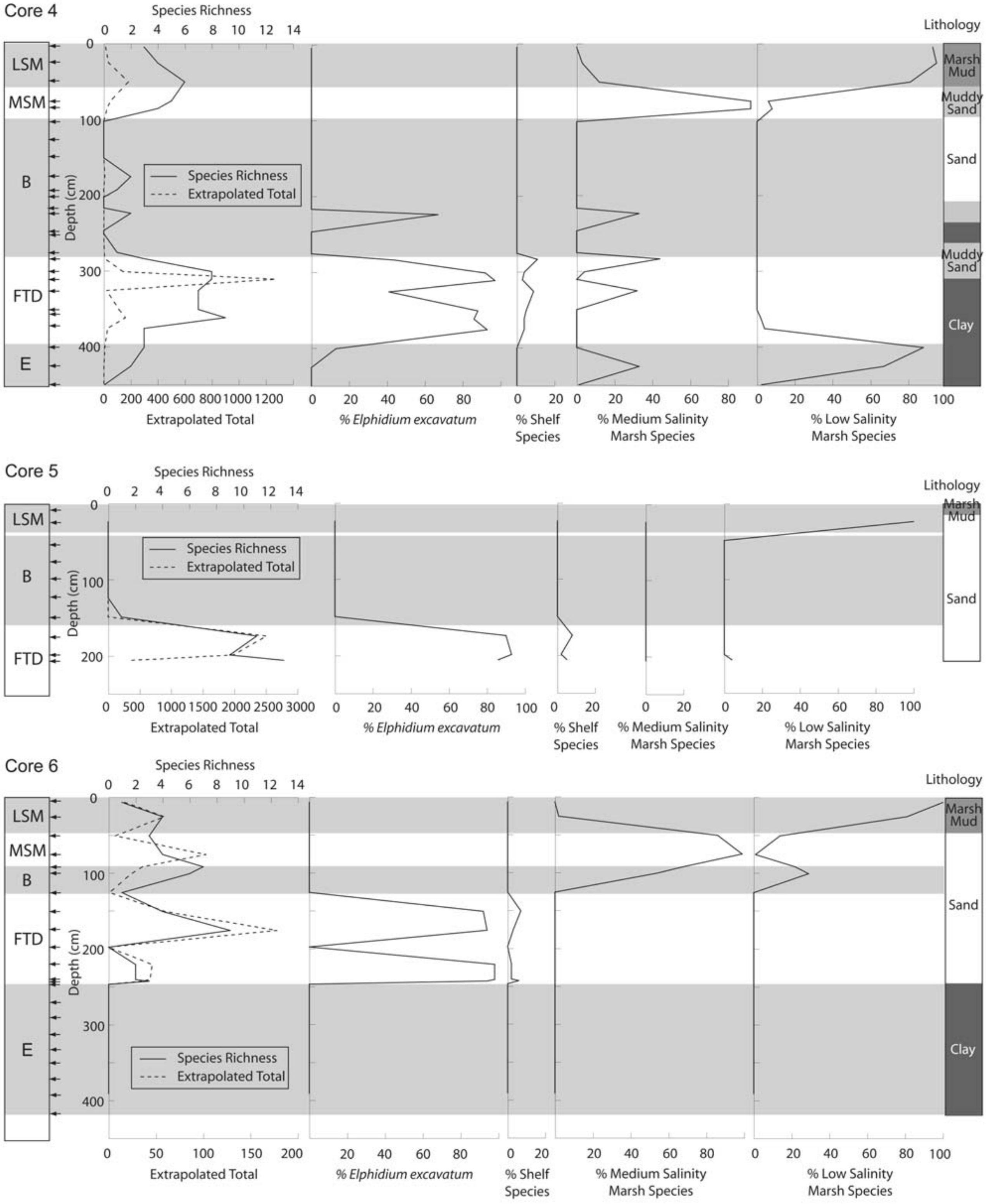
Six vibracores were collected from the relict flood tidal delta of Old Currituck Inlet (See text-figure 1a and Table 2 for core locations). These cores were opened, described, and sampled at ~25cm intervals for micropaleontological analyses. Additional samples were collected immediately below and above sedimentologic contacts and at other horizons of stratigraphic interest.

Sediment samples of ~10cm$^3$ were processed using standard procedures in which bulk samples are dried in an oven at ≤50°C



TEXT-FIGURE 3

Depositional environment designation, species richness, extrapolated total, relative fractional abundance of diagnostic species, and lithology in Cores 1, 2 and 3 of the Old Currituck Inlet flood tidal delta. Shelf species include *Ammonia parkinsoniana, Buccella frigida, Cibicides lobatulus, Elphidium galvestonense, Elphidium exicanum, Elphidium subarcticum, Guttulina lactea, Hanzawaia strattoni* and four *Quinqueloculina* species. Medium salinity marsh species include *Trochammina inflata, Arenoparrella mexicana* and *Tiphotrocha comprimata*. Low salinity marsh species include *Jadammina macrescens* and *Miliammina petila*. E = estuary; FTD = flood tidal delta; B = barren; MSM = medium salinity marsh; LSM = low salinity marsh. Small arrows indicate sample locations.



TEXT-FIGURE 4

Depositional environment designation, species richness, extrapolated total, relative fractional abundance of diagnostic species, and lithology in Cores 4, 5 and 6 of the Old Currituck Inlet flood tidal delta. Shelf species include *Ammonia parkinsoniana, Buccella frigida, Cibicides lobatulus, Elphidium galvestonense, Elphidium mexicanum, Elphidium subarcticum, Guttulina lactea, Hanzawaia strattoni* and four *Quinqueloculina* species. Medium salinity marsh species include *Trochammina inflata, Arenoparrella mexicana* and *Tiphotrocha comprimata*. Low salinity marsh species include *Jadammina macrescens* and *Miliammina petila*. E = estuary; FTD = flood tidal delta; B = barren; MSM = medium salinity marsh; LSM = low salinity marsh. Small arrows indicate sample locations.

TABLE 1
Descriptions of modern assemblages from selected previous studies within and around the Outer Banks, North Carolina.

| **Continental Shelf** | **Location** | **Dominant Species*** | **Other Characteristic Species**** |
|---|---|---|---|
| Schnitker, 1971 | North Carolina coast | *Elphidium clavatum*[1] | *Hanzawaia concentrica*[2], *Reophax atlantica, Webbinella concava, Guttulina lactea* |
| Cronin et al., 1998 | Virginia coast | *Elphidium excavatum* | *Quinqeloculina seminula, Ammonia parkinsoniana, Buccella frigida, Florilus atlanticus, Hanzawaia concentrica*[2], *Eggerella advena* |
| **Inlet** | | | |
| Vance et al. 2006 | Oregon Inlet, NC | *Elphidium excavatum* | *Hanzawaia strattoni, Elphidium subarcticum, Ammonia parkinsoniana, Ammonia tepida* |
| Abbene et al. in press | Ocracoke and Hatteras Inlets, NC | *Elphidium excavatum* | *Cibicides lobatulus, Cibicides refulgens, Elphidium subarcticum, Quinqueloculina lamarckiana, Quinqueloculina seminula* |
| **Flood Tidal Delta** | | | |
| Grossman and Benson, 1967 | Ocracoke and Drum Inlets, NC | *Elphidium exavatum* | *Quinqueloculina* spp., *Triloculina* sp., *Cibicides lobatulus, Hanzawaia concentrica*[2] |
| **Estuary** | | | |
| Abbene et al. in press | Pamlico Sound, NC | *Ammotium salsum* | *Ammonia parkinsoniana, Elphidium excavatum* |
| Abbene et al. in press | Pamlico Sound, NC | *Elphidium excavatum* | *Ammotium salsum, Ammonia parkinsoniana* |
| **Marsh** | | | |
| Abbene, 2004; Abbene et al. in review | Outer Banks, NC | None | *Ammonnia parkinsoniana, Ammotium salsum, Trochammina inflata, Haplophragmoides wilberti* |
| Culver and Horton, 2005 | High salinity high marsh | *Trochammina inflata, Haplophragmoides wilberti* | *Arenoparrella mexicana, Miliammina petila, Siphotrochammina lobata, Trochammina* sp., *Haplophragmoides bonplandi* |
| Culver and Horton, 2005 | High salinity low marsh | *Miliammina fusca, Ammotium cf. Ammotium salsum* | |
| Culver and Horton, 2005 | Medium salinity high marsh | None | *Tiphotrocha comprimata, Trochammina inflata, Jadammina macrescens, Arenoparrella mexicana* |
| Culver and Horton, 2005 | Medium salinity low marsh | None | *Trochammina inflata, Arenoparrella mexicana, Tiphotrocha comprimata, Jadammina macrescens* |
| Culver and Horton, 2005 | Low salinity high marsh | *Jadammina macrescens* | *Miliammina petila* |
| Culver and Horton, 2005 | Low salinity low marsh | *Jadammina macrescens, Ammobaculites subcatenulatus, Miliammina fusca, Ammotium salsum* | *Trochamminita irregularis, Haplophragmoides bonplandi, Trochammina* sp. |

*Dominant species comprise greater than or equal to 65% of the total population.
**Characteristic species are listed in order of decreasing abundance.

[1] *Elphidium excavatum* of this study
[2] *Hanzawaia Strattoni* of this study

then disaggregated in a beaker with warm tap water and ~2ml of dilute Calgon solution (5g Calgon to 1L water). The samples were agitated on a shaker, washed through a 63µm sieve, and dried. In sandy samples the foraminifera were concentrated by the soap floating technique described in Harris and Sweet (1989). A split of 300 to 350 benthic foraminifer specimens was sought from the >125µm size fraction. Though many samples contained fewer than 300 individuals, several samples required multiple splitting. Specimen identifications were confirmed by comparison with type and figured specimens in the Cushman Collection, National Museum of Natural History, Smithsonian Institution, Washington, D.C. Foraminiferal census data are given in Tables 3 through 8, and the original reference for each taxon is given in Appendix 1. Some of the most diagnostic taxa are illustrated on Plate 1.

Annual surveys of salinity were conducted at the core locations and at an additional 38 sites surrounding the relict flood tidal delta throughout Back Bay and Currituck Sound on a single day in August of 2002, 2003 and 2004 to establish the natural variability in salinity. Table 2 provides the salinity data for each year at each core location. Also listed in Table 2 are salinity values for Back Bay and Currituck Sound for each year, represented by the averaged salinity values from the additional sites surrounding the flood tidal delta.

### Quantitative Analytical Procedures

Benthic foraminiferal census data (Tables 3-8) were reduced by removing samples with less than ten individuals (< 0.1% of entire combined data set) and taxa that never exceeded unit abundance in any sample and accounted for less than ten individuals in the entire combined data set; thus, rare species were excluded. Species abundances were standardized by transforming actual specimen counts into percent data.

All multivariate analyses were done using Aabel (Gigawiz Ltd. Co., Aabel, version 1.5.8) following the methods described by Davis (2002) and Hair et al. (1998). A hierarchical cluster analysis of the percent abundance data was conducted using a weighted pair group method average-linkage, with cosine-theta distance measurement.

Measures of diversity calculated on all samples include species richness and extrapolated total number of specimens.

## RESULTS

The six flood tidal delta cores yielded 39 species of benthic foraminifera (Appendix 1). Tables 3 through 8 show the species counts, number of specimens per sample and species richness for each sample from the six cores. These statistics vary greatly between samples within individual cores. For example, each core has a zone of barren samples that separates samples rich in *Elphidium* species and high in numbers of specimens, below the barren zone, from samples rich in agglutinated species and low in number of specimens above the barren zone. Another near barren zone below the *Elphidium*-rich samples is observed in the three longest cores (Cores 1, 4 and 6).

A cluster analysis (text-figure 2) revealed three definitive groups that reflect total number of specimens per sample, species richness, and species dominance. The lower cluster represents all samples dominated by *Elphidium excavatum*. The two smaller clusters represent distinct marsh assemblages that are recognized on the basis of species dominance: *Trochammina inflata* or *Jadammina macrescens*. The cluster analysis divided each core into vertical zonations following the stratigraphic sequence shown in the cluster diagram: an *Elphidium excavatum*-dominated assemblage overlain by a *Trochammina inflata*-dominated and then *Jadammina macrescens*-dominated assemblage.

A further subdivision of the *Elphidium exacavatum*-dominated cluster group was warranted based on accessory species in the individual samples, specimen count, the interspersal of barren samples not evaluated in the cluster analysis, and lithology of the samples. A low specimen count subdivision occurs in the lower portion of the *Elphidium excavatum*-dominated zone in the longest cores (Cores 1, 4 and 6). This oldest unit exists entirely in clay and contains no more than 36 specimens, and often 0 specimens, per sample. These few specimens are either *Elphidium excavatum* or assorted agglutinated species including *Jadammina macrescens, Arenoparrella mexicana, Miliammina petila*, and *Tiphotrocha comprimata*, with less than four species represented per sample.

In contrast, a second subdivision, usually occurring in laminated sand, contains high specimen counts and high species richness, contains no barren samples, and represents the most abundant unit in each core. This increase in the number of specimens and species richness is most obvious in Core 2 where extrapolated totals yield an average of 2346 individual foraminifera specimens per sample. Species richness is also greatest in this core with 33 species represented in this subdivision. *Elphidium excavatum* percent abundance exceeds 86% in all samples. Other species, in order of abundance, include *Buccella frigida, Ammonia parkinsoniana, Buccella inusitata, Hanzawaia strattoni, Elphidium mexicanum, Elphidium subarcticum, Ammonia tepida, Haynesina germanica* and *Elphidium galvestonense*. *Eponides repandus*, *Guttulina lactea, Nonionella atlantica, Planulina mera*, and four *Quinqueloculina* species are also present.

Above the *Elphidium excavatum*-dominated zone, a nearly barren unit in bioturbated sand is distinguished by very low numbers of specimens and by very low faunal richness. The samples in this unit were not evaluated by the cluster analysis because most samples are barren of benthic foraminifera. Of the non-barren samples, no more than 9 specimens were found.

The uppermost two units contain only agglutinated species and are usually found in rooted mud or muddy sand. A change in species dominance is evident moving up-core and distinguishes the two units in the cluster analysis. The penultimate unit is characterized mainly by *Trochammina inflata* with *Tiphotrocha comprimata* as the second most abundant species, whereas the uppermost unit is dominated by *Jadammina macrescens* followed by *Miliammina petila* and *Miliammina fusca*.

TABLE 2
Core localities and salinities at core sites for 2002, 2003 and 2004.

| Core | Latitude | Longitude | Length (cm) | Salinity (ppt)<br>2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|
| CI-FTD-01-1 | 36°33'12" | 75°53'59" | 441 | 4.0 | 0.9 | 0.8 |
| CI-FTD-01-2 | 36°32'19" | 75°53'41" | 410 | 4.1 | 0.8 | 0.9 |
| CI-FTD-01-3 | 36°31'44" | 75°53'46" | 275 | 4.1 | 0.8 | 0.9 |
| CI-FTD-01-4 | 36°32'07" | 75°52'53" | 455 | 4.1 | 0.6 | 0.6 |
| CI-FTD-01-5 | 36°32'23" | 75°52'59" | 207 | 3.9 | 0.7 | 0.7 |
| CI-FTD-01-6 | 36°33'18" | 75°53'07" | 411 | 4.2 | 0.7 | 0.8 |
| | | | Average Salinity for Back Bay: | 3.9 | 0.8 | 0.7 |
| | | | Average Salinity for Currituck Sound: | 5.4 | 0.8 | 1.2 |

## DISCUSSION

Though the cluster analysis revealed only three clusters based on species dominance, closer examination distinguished two subdivisions within the *Elphidium excavatum*-dominated cluster. A comparison of these four assemblage groups with modern benthic foraminiferal distributions yielded four environments of deposition: estuary, flood tidal delta, medium salinity marsh, and low salinity marsh. When depositional environments are assigned to each sample and projected onto the appropriate core and depth, a stratigraphic sequence emerges that is repeated in each core (text-figures 3 and 4), though only Cores 1, 4 and 6 penetrate the oldest depositional environment. The boundaries associated with these environmental changes can be correlated to Old Currituck Inlet's paleo-inlet activity through comparison with historical records. These environmental divisions are not necessarily coincidental with lithologic boundaries (See Core 4 on text-figure 4).

### Estuary

The *Elphidium excavatum*-dominated cluster includes samples with agglutinated estuarine species as well as those with calcareous nearshore marine and inlet species. The overwhelming dominance of *Elphidium* in these samples precluded the cluster analysis from making this more subtle distinction between samples. Therefore, samples from both estuarine and flood tidal delta environments grouped together. In benthic foraminiferal distribution studies of the Outer Banks region (Table 1), modern estuarine assemblages are generally characterized by a wide range of species richness and number of specimens, reflecting the variations in salinity, and often include many barren samples. The proportion of agglutinated to calcareous species, the presence or absence of diagnostic accessory species usually found on the continental shelf, and the sample lithology (clay or sand) separate the estuarine from the inlet assemblages. We separated the samples within the *Elphidium excavatum*-dominated cluster into an estuarine subgroup and a flood tidal delta subgroup using these criteria.

Samples in the estuarine sub-group also contain *Ammonia parkinsoniana* and the agglutinated species *Arenoparrella mexicana, Jadammina macrescens, Trochammina inflata, Trochammina compacta, Miliammina petila* and *Tiphotrocha*

TABLE 3
Core 1 Benthic foraminiferal assemblages.

| Depth (cm) | *Ammonia parkinsoniana* | *Ammonia tepida* | *Arenoparrella mexicana* | *Buccella frigida* | *Buccella hannai* | *Buccella inusitata* | *Cibicides lobatulus* | *Cribrostomoides crassimargo* | *Elphidium crispum* | *Elphidium excavatum* | *Elphidium galvestonense* | *Elphidium gunteri* | *Elphidium mexicanum* | *Elphidium subarcticum* | *Eponides repandus* | *Guttulina lactea* | *Hanzawaia strattoni* | *Haplophragmoides bonplandi* | *Haplophragmoides manilaensis* | *Haplophragmoides wilberti* | *Haynesina germanica* | *Jadammina macrescens* | *Miliammina fusca* | *Miliammina petila* | *Nonionella atlantica* | *Planulina mera* | *Pseudothurammina limnetis* | *Quinqueloculina impressa* | *Quinqueloculina jugosa* | *Quinqueloculina lata* | *Quinqueloculina seminula* | *Siphotrochammina lobata* | *Tiphotrocha comprimata* | *Triloculina oblonga* | *Trochammina compacta* | *Trochammina inflata* | *Trochammina lobata* | *Trochamminita irregularis* | *Trochamminita salsa* | Indeterminate | Total | Species richness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 12 | 20 | 118 | - | - | 8 | - | - | - | - | - | - | - | - | - | - | 1 | 3 | - | 162 | 6 |
| 25-27 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 157 | 24 | 76 | - | - | - | - | - | - | - | - | 47 | - | - | - | - | - | 3 | - | 307 | 5 |
| 50-52 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | 4 | 3 |
| 75-77 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 100-102 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 125-127 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 150-152 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| 175-177 | 1 | - | - | 10 | - | 1 | - | - | - | 306 | 1 | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 322 | 7 |
| 200-202 | 2 | 2 | - | 4 | - | - | - | - | - | 296 | - | - | 2 | - | 2 | 1 | 2 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 3 | - | - | - | - | 1 | - | - | - | - | 316 | 11 |
| 225-227 | 2 | - | - | 9 | 1 | 3 | - | - | 1 | 318 | 1 | - | 1 | - | - | - | 3 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 340 | 10 |
| 250-252 | 2 | 1 | - | 5 | - | 2 | - | - | - | 327 | - | - | - | - | - | 1 | 1 | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 342 | 9 |
| 275-277 | 1 | - | - | 2 | - | 2 | 1 | - | - | 309 | - | - | 1 | 2 | - | - | 1 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 320 | 9 |
| 300-302 | 1 | - | - | 1 | - | 2 | 1 | - | - | 291 | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 301 | 8 |
| 325-327 | 3 | 1 | - | 7 | - | 3 | - | - | - | 293 | - | - | 1 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | 311 | 8 |
| 335-337 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 350-352 | - | - | 1 | - | - | - | - | - | - | 25 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 27 | 3 |
| 370-372 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 390-392 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| 410-412 | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 1 |
| 430-432 | 1 | - | - | - | - | - | - | - | - | 33 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | 36 | 3 |
| 440-441 | 2 | - | - | 1 | - | - | - | - | - | 32 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 35 | 3 |

TABLE 4
Core 2 Benthic foraminiferal assemblages.

| Depth (cm) | *Ammonia parkinsoniana* | *Ammonia tepida* | *Arenoparrella mexicana* | *Buccella frigida* | *Buccella hannai* | *Buccella inusitata* | *Cibicides lobatulus* | *Cribrostomoides crassimargo* | *Elphidium crispum* | *Elphidium excavatum* | *Elphidium galvestonense* | *Elphidium gunteri* | *Elphidium mexicanum* | *Elphidium subarcticum* | *Eponides repandus* | *Guttulina lactea* | *Hanzawaia strattoni* | *Haplophragmoides bonplandi* | *Haplophragmoides manilaensis* | *Haplophragmoides wilberti* | *Haynesina germanica* | *Jadammina macrescens* | *Miliammina fusca* | *Miliammina petila* | *Nonionella atlantica* | *Planulina mera* | *Pseudothurammina limnetis* | *Quinqueloculina impressa* | *Quinqueloculina jugosa* | *Quinqueloculina lata* | *Quinqueloculina seminula* | *Siphotrochammina lobata* | *Tiphotrocha comprimata* | *Triloculina oblonga* | *Trochammina compacta* | *Trochammina inflata* | *Trochammina lobata* | *Trochamminita irregularis* | *Trochamminita salsa* | Indeterminate | Total | Species richness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 10 | - | - | 23 | 6 | 12 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 52 | 5 |
| 25-27 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 119 | 5 | 23 | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 149 | 5 |
| 50-52 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | 6 | 4 | - | - | 16 | - | - | - | - | 28 | 4 |
| 75-77 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 100-103 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 125-127 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 150-152 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 175-177 | 4 | - | - | 3 | - | 1 | - | - | - | 345 | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 2 | 1 | - | - | - | 358 | 8 |
| 201-203 | - | - | - | - | - | - | - | - | - | 120 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 120 | 1 |
| 225-227 | - | - | - | 4 | - | 2 | - | - | - | 305 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 313 | 5 |
| 250-252 | 3 | 2 | 1 | 1 | - | 1 | - | - | - | 331 | 1 | 1 | 4 | 2 | 1 | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 351 | 14 |
| 275-277 | 1 | 4 | - | 3 | - | 2 | 3 | - | 1 | 335 | - | - | - | 1 | 2 | - | 4 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | - | - | - | - | - | - | 359 | 13 |
| 301-303 | 2 | 3 | - | 3 | 1 | - | - | - | 1 | 307 | - | - | 3 | 2 | 3 | - | 1 | - | - | - | 1 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 328 | 12 |
| 325-327 | - | 1 | - | 4 | 1 | 3 | - | - | - | 304 | 4 | 2 | 3 | - | - | 2 | 2 | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | - | 1 | - | - | - | - | 330 | 14 |
| 350-352 | 2 | - | - | 3 | 1 | 3 | - | - | - | 284 | - | 1 | 3 | - | - | - | 3 | - | - | - | - | - | - | - | - | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 302 | 10 |
| 375-377 | 3 | - | - | 13 | - | - | - | - | - | 301 | - | - | 3 | - | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 324 | 5 |
| 400-402 | 2 | - | - | 14 | - | 3 | - | - | - | 437 | 1 | - | 3 | 1 | - | 1 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 465 | 9 |

*comprimata*. Estuarine samples exhibit a higher percentage of agglutinated forms and fewer total numbers of specimens than flood tidal delta samples and more closely resemble the Abbene et al. (in press) Estuarine B assemblage that currently surrounds Ocracoke and Hatteras Inlets than any other documented Outer Banks modern assemblage.

The estuarine assemblage (E in text-figures 3 and 4) occurs only in clay deposits in the deeper samples of the longest three cores (Cores 1, 4 and 6) and represents a pre-inlet environment of deposition.

### Flood Tidal Delta

Samples in the flood tidal delta sub-division of the *Elphidium excavatum*-dominated cluster are nearly entirely calcareous and contain *Ammonia parkinsoniana, Buccella frigida, Cibicides lobatulus, Elphidium galvestonensis, Elphidium mexicanum, Elphidium subarcticum, Hanzawaia strattoni*, and *Quinqueloculina seminula*. These species are found on the Virginia and North Carolina continental shelf (Schnitker 1971; Cronin et al. 1998) and are characteristic of modern active inlet assemblages (Abbene 2004, Abbene et al., in review).

The flood tidal delta samples contained within the *Elphidium excavatum*-dominated assemblage are comparable to the flood tidal delta assemblages of Grossman and Benson (1967) in that species richness is high, representing a mixture of brackish and marine species, and includes four species of *Quinqueloculina* as well as *Triloculina oblonga, Cibicides lobatulus, Planulina mera* and *Hanzawaia strattoni*. Twelve samples within the flood tidal delta subdivision contain agglutinated marsh species. Mixing of species from different environments could indicate an overwash component in the evolution of Old Currituck Inlet.

The flood tidal delta samples occur above the estuarine samples in the three longest cores and at the base of the three shorter cores (FTD in text-figures 3 and 4). This transition from an estuarine environment to a flood tidal delta marks the opening

TABLE 5
Core 3 Benthic foraminiferal assemblages.

| Depth (cm) | *Ammonia parkinsoniana* | *Ammonia tepida* | *Arenoparrella mexicana* | *Buccella frigida* | *Buccella hannai* | *Buccella inusitata* | *Cibicides lobatulus* | *Cribrostomoides crassimargo* | *Elphidium crispum* | *Elphidium excavatum* | *Elphidium galvestonense* | *Elphidium gunteri* | *Elphidium mexicanum* | *Elphidium subarcticum* | *Eponides repandus* | *Guttulina lactea* | *Hanzawaia strattoni* | *Haplophragmoides bonplandi* | *Haplophragmoides manilaensis* | *Haplophragmoides wilberti* | *Haynesina germanica* | *Jadammina macrescens* | *Miliammina fusca* | *Miliammina petila* | *Nonionella atlantica* | *Planulina mera* | *Pseudothurammina limnetis* | *Quinqueloculina impressa* | *Quinqueloculina jugosa* | *Quinqueloculina lata* | *Quinqueloculina seminula* | *Siphotrochammina lobata* | *Tiphotrocha comprimata* | *Triloculina oblonga* | *Trochammina compacta* | *Trochammina inflata* | *Trochammina lobata* | *Trochamminita irregularis* | *Trochamminita salsa* | Indeterminate | Total | Species richness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-4 | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 25 | 1 | 7 | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 8 | 62 | - | 109 | 8 |
| 25-28 | - | - | 9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | 5 | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | 134 | - | - | - | 5 | 158 | 7 |
| 50-53 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 31 | - | - | - | - | 31 | 1 |
| 75-78 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 100-103 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 125-128 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 150-153 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 175-178 | - | - | - | 1 | - | - | - | - | - | 107 | - | 1 | - | 1 | - | - | 2 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | 2 | 117 | 8 |
| 200-203 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | - | - | - | 4 | 1 |
| 225-228 | - | - | - | - | - | - | - | - | - | 8 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 9 | 2 |
| 250-253 | 1 | - | - | 2 | - | - | - | - | - | 208 | 13 | - | - | - | - | 4 | 8 | - | 1 | - | 2 | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 7 | - | - | - | 3 | 250 | 11 |
| 270-273 | 1 | - | 1 | 1 | - | - | - | - | - | 51 | 4 | 1 | 1 | - | - | 1 | 5 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 2 | - | - | 1 | - | 70 | 12 |

TABLE 6
Core 4 Benthic Foraminiferal Assemblages.

| Depth (cm) | *Ammonia parkinsoniana* | *Ammonia tepida* | *Arenoparrella mexicana* | *Buccella frigida* | *Buccella hannai* | *Buccella inusitata* | *Cibicides lobatulus* | *Cribrostomoides crassimargo* | *Elphidium crispum* | *Elphidium excavatum* | *Elphidium galvestonense* | *Elphidium gunteri* | *Elphidium mexicanum* | *Elphidium subarcticum* | *Eponides repandus* | *Guttulina lactea* | *Hanzawaia strattoni* | *Haplophragmoides bonplandi* | *Haplophragmoides manilaensis* | *Haplophragmoides wilberti* | *Haynesina germanica* | *Jadammina macrescens* | *Miliammina fusca* | *Miliammina petila* | *Nonionella atlantica* | *Planulina mera* | *Pseudothurammina limnetis* | *Quinqueloculina impressa* | *Quinqueloculina jugosa* | *Quinqueloculina lata* | *Quinqueloculina seminula* | *Siphotrochammina lobata* | *Tiphotrocha comprimata* | *Triloculina oblonga* | *Trochammina compacta* | *Trochammina inflata* | *Trochammina lobata* | *Trochamminita irregularis* | *Trochamminita salsa* | Indeterminate | Total | Species richness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 13 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 15 | 3 |
| 25-27 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 28 | 1 | 7 | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 37 | 4 |
| 50-52 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 142 | 11 | 6 | - | - | - | - | - | - | - | - | 20 | - | - | 2 | - | - | 2 | - | 183 | 6 |
| 75-77 | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | 3 | - | - | 41 | - | 1 | - | - | 50 | 5 |
| 85-87 | - | - | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 15 | - | - | - | - | 25 | 4 |
| 102-104 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 125-127 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 150-152 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 175-177 | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | - | - | - | - | 9 | 2 |
| 192-194 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | 1 |
| 202-204 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 216-218 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 223-225 | - | - | 1 | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 2 |
| 246-248 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 250-252 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 275-277 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | - | - | - | - | 5 | 1 |
| 283-285 | - | - | - | - | - | - | - | - | - | 4 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | - | - | - | 9 | 3 |
| 300-302 | 2 | - | 1 | 3 | - | - | - | - | - | 131 | - | - | - | 1 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | 2 | - | - | - | - | 143 | 8 |
| 310-312 | 4 | - | 1 | 3 | - | - | 1 | - | - | 307 | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 320 | 8 |
| 325-327 | 1 | - | 2 | - | - | - | - | - | - | 9 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 4 | - | - | 2 | - | 20 | 7 |
| 350-352 | 2 | 2 | - | 1 | - | - | - | - | - | 99 | - | 2 | - | 3 | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 112 | 7 |
| 361-364 | 2 | 5 | - | - | - | 1 | - | - | - | 139 | - | 2 | - | 3 | - | 1 | - | - | - | - | 7 | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 163 | 9 |
| 375-377 | - | - | - | - | - | - | - | - | - | 26 | - | - | - | 1 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 28 | 3 |
| 400-402 | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 6 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 8 | 3 |
| 425-427 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 3 | 2 |
| 450-452 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |

of Old Currituck Inlet at some date prior to 1585 and is recorded in Cores 1, 4 and 6.

### Medium Salinity Marsh

The cluster analysis reveals two distinct marsh assemblages. An assemblage dominated by *Trochammina inflata* and containing *Arenoparella mexicana, Tiphotrocha comprimata* and *Jadammina macrescens* exists immediately below the present assemblage (MSM in text-figures 3 and 4) and resembles modern marsh assemblages in the medium salinity low marshes described by Culver and Horton (2005) and Horton and Culver (in press).

The colonization of the flood tidal delta sediment by marsh followed the closing of Old Currituck Inlet in 1731. The barren interval (B in text-figures 3 and 4) separating the flood tidal delta deposits from the medium salinity marsh sediments represents the gradual shoaling of the inlet.

### Low Salinity Marsh

The relict flood tidal delta investigated in this study is currently covered by a thick vegetated marsh that experiences salinities ranging from ~1ppt to ~4ppt (Table 2). The uppermost species assemblage is dominated by *Jadammina macrescens* with *Miliammina petila* as the second-most occurring taxon and closely resembles the low salinity high marsh in southern Currituck Sound described in Culver and Horton (2005) and Horton and Culver (in press).

The clear transition in marsh assemblages from medium salinity marsh to low salinity marsh (LSM in text-figures 3 and 4) reflects a further freshening of Back Bay and Currituck Sound unrelated to the closing of Old Currituck Inlet.

## CONCLUSIONS AND SUMMARY

A comparison of benthic foraminiferal assemblages from six relict flood tidal delta cores with the modern distribution of benthic foraminifera throughout the Outer Banks system has re-

TABLE 7
Core 5 Benthic Foraminiferal Assemblages.

| Depth (cm) | *Ammonia parkinsoniana* | *Ammonia tepida* | *Arenoparrella mexicana* | *Buccella frigida* | *Buccella hannai* | *Buccella inusitata* | *Cibicides lobatulus* | *Cribrostomoides crassimargo* | *Elphidium crispum* | *Elphidium excavatum* | *Elphidium galvestonense* | *Elphidium gunteri* | *Elphidium mexicanum* | *Elphidium subarcticum* | *Eponides repandus* | *Guttulina lactea* | *Hanzawaia strattoni* | *Haplophragmoides bonplandi* | *Haplophragmoides manilaensis* | *Haplophragmoides wilberti* | *Haynesina germanica* | *Jadammina macrescens* | *Miliammina fusca* | *Miliammina petila* | *Nonionella atlantica* | *Planulina mera* | *Pseudothurammina limnetis* | *Quinqueloculina impressa* | *Quinqueloculina jugosa* | *Quinqueloculina lata* | *Quinqueloculina seminula* | *Siphotrochammina lobata* | *Tiphotrocha comprimata* | *Triloculina oblonga* | *Trochammina compacta* | *Trochammina inflata* | *Trochammina lobata* | *Trochamminita irregularis* | *Trochamminita salsa* | Indeterminate | Total | Species richness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10-12 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 13 | 3 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 19 | 3 |
| 25-27 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 48-50 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 75-77 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 98-100 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 123-125 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 148-150 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| 173-175 | - | 1 | - | 4 | 2 | - | 1 | - | - | 295 | - | - | 13 | 4 | - | - | 4 | - | - | - | - | - | - | - | - | 2 | - | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | 328 | 11 |
| 198-200 | 2 | 2 | - | - | 5 | 4 | - | - | - | 296 | - | - | - | - | - | 1 | 4 | - | - | - | 1 | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | 317 | 9 |
| 205-207 | 2 | - | - | 2 | 1 | 7 | - | - | - | 262 | 7 | - | - | 3 | - | - | - | - | - | - | 1 | 9 | 3 | 4 | 1 | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 303 | 13 |

vealed a succession of four distinct environments of deposition that occurred at each of the core locations: estuary, flood tidal delta, medium salinity marsh and low salinity marsh.

This sequence indicates that an estuary in what is now Back Bay, Virginia, and Currituck Sound, North Carolina, was transformed by the breaching of Currituck Spit and an increase in salinity through the addition of ocean water. The inlet built the flood tidal delta and eventually closed, followed by marsh colonization of the flood tidal delta shoals and a decrease in salinity. Salinity continued to decrease as evidenced by the change in marsh assemblages. We conclude this distinctive trend of changing depositional environments constitutes geologic evidence of the origin and evolution of Old Currituck Inlet that breached the barrier spit prior to 1585, actively built a flood tidal delta for more than 145 years, and then closed in 1731.

The compilation of modern foraminiferal assemblages from the Outer Banks estuarine system and along the Virginia and North Carolina shelf yields a comprehensive snapshot of species distributions under modern conditions. Foraminifera assemblages near open inlets (Oregon, Ocracoke and Hatteras Inlets) are distinct from assemblages in lower salinity estuarine waters farther from access to the ocean and from marsh assemblages along the backside of barrier islands within the Sounds. This study, limited to a small geographic area where an inlet is known to have opened, remained open for at least 145 years, and eventually closed documents how these assemblages respond to a changing regime along a wave-dominated barrier island system and details the resulting upcore sequence of assemblages representing distinct depositional environments. This inlet signature preserved in the relict flood tidal delta sediments is a diagnostic tool, one that is only available through micropaleontological study, that can be used to locate the position of other former inlets along the Outer Banks and other wave-dominated barrier islands worldwide in both modern and ancient sediments.

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TABLE 8
Core 6 Benthic foraminiferal assemblages.

| Depth (cm) | *Ammonia parkinsoniana* | *Ammonia tepida* | *Arenoparrella mexicana* | *Buccella frigida* | *Buccella hannai* | *Ruccella inusitata* | *Cibicides lobatulus* | *Cribrostomoides crassimargo* | *Elphidium crispum* | *Elphidium excavatum* | *Elphidium galvestonense* | *Elphidium gunteri* | *Elphidium mexicanum* | *Elphidium subarcticum* | *Eponides repandus* | *Guttulina lactea* | *Hanzawaia strattoni* | *Haplophragmoides bonplandi* | *Haplophragmoides manilaensis* | *Haplophragmoides wilberti* | *Haynesina germanica* | *Jadammina macrescens* | *Miliammina fusca* | *Miliammina petila* | *Nonionella atlantica* | *Planulina mera* | *Pseudothurammina limnetis* | *Quinqueloculina impressa* | *Quinqueloculina jugosa* | *Quinqueloculina lata* | *Quinqueloculina seminula* | *Siphotrochammina lobata* | *Tiphotrocha comprimata* | *Triloculina oblonga* | *Trochammina compacta* | *Trochammina inflata* | *Trochammina lobata* | *Trochamminita irregularis* | *Trochamminita salsa* | Indeterminate | Total | Species richness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6-8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 17 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 17 | 1 |
| 25-27 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 45 | 10 | 3 | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 59 | 4 |
| 50-53 | - | - | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 7 | 3 |
| 75-78 | - | - | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 95 | - | - | - | - | 103 | 4 |
| 90-94 | - | - | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 8 | - | - | - | - | - | - | - | - | - | - | 9 | - | 1 | 11 | 1 | - | 1 | - | 36 | 7 |
| 100-103 | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | 7 | 1 | - | - | - | - | - | - | - | - | 1 | 5 | - | - | 5 | - | - | - | - | 24 | 6 |
| 125-128 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| 150-153 | 3 | - | - | 1 | - | 1 | - | - | - | 55 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 60 | 4 |
| 175-178 | 1 | - | - | 3 | - | 2 | - | - | 1 | 167 | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 178 | 9 |
| 197-200 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 220-223 | 1 | - | - | - | - | - | - | - | - | 45 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 46 | 2 |
| 240-242 | - | - | - | 1 | - | - | - | - | - | 43 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 44 | 2 |
| 242-245 | - | - | - | 1 | - | - | - | - | - | 33 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 35 | 3 |
| 246-249 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 270-273 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 290-293 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 310-313 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 330-334 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 350-353 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 370-373 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 390-393 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 409-412 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |

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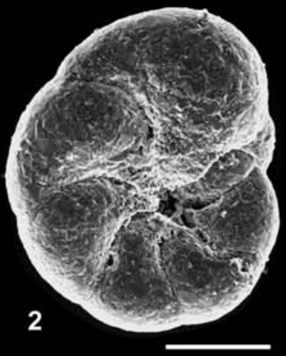
## PLATE 1

Scale bar = 100μ**m.**

1 *Arenoparrella mexicana* (Kornfeld)
2 *Tiphotrocha comprimata* (Cushman and Brönnimann)
3,4 *Siphotrochammina lobata* Saunders
5 *Jadammina macrescens* (Brady)
6 *Miliammina fusca* (Brady)
7 *Miliammina petila* Saunders
8 *Trochammina inflata* (Montagu)
9 *Trochamminita salsa* (Cushman and Brönnimann)
10 *Ammonia parkinsoniana* (d'Orbigny)
11 *Buccella frigida* (Cushman)
12 *Elphidium excavatum* (Terquem)
13,14 *Cibicides lobatulus* (Walker and Jacob)
15,16 *Hanzawaia strattoni* (Applin)


1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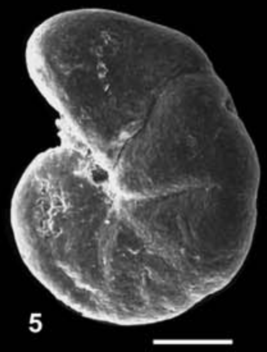
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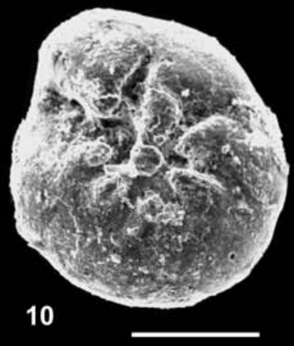
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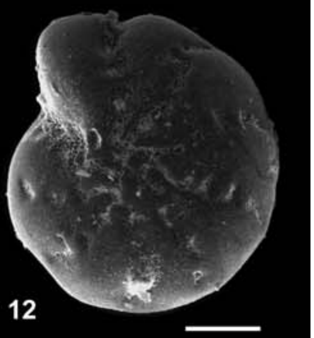
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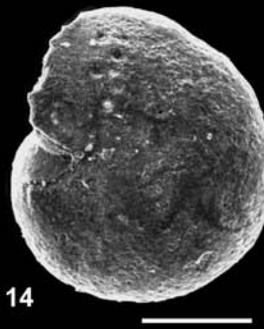
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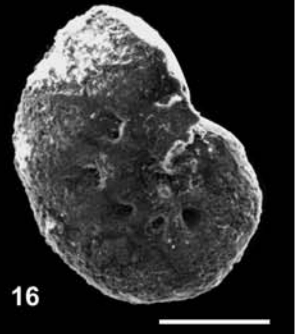
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## APPENDIX 1

Foraminiferal taxa observed in the flood tidal delta deposits of Old Currituck Inlet

*Ammonia parkinsoniana* (d'Orbigny) 1839
*Ammonia tepida* (Cushman) 1926
*Arenoparrella mexicana* (Kornfeld) 1931
*Buccella frigida* (Cushman) 1922
*Buccella hannai* (Phleger and Parker) 1951
*Buccella inusitata* Andersen 1952
*Cibicides lobatulus* (Walker and Jacob), in Kanmacher 1798
*Cribrostomoides crassimargo* (Norman) 1892
*Elphidium crispum* (Linné) 1758
*Elphidium excavatum* (Terquem) 1875
*Elphidium galvestonense* Kornfeld 1931
*Elphidium gunteri* Cole 1931
*Elphidium mexicanum* Kornfeld 1931
*Elphidium subarcticum* Cushman 1944
*Eponides repandus* (Fichtel and Moll) 1798
*Guttulina lactea* (Walker and Jacob), in Kanmacher 1798
*Hanzawaia strattoni* (Applin)1925
*Haplophragmoides bonplandi* Todd and Brönnimann 1957
*Haplophragmoides manilaensis* Andersen 1953
*Haplophragmoides wilberti* Andersen 1953
*Haynesina germanica* (Ehrenberg) 1840
*Jadammina macrescens* (Brady) 1870
*Miliammina fusca* (Brady) 1870
*Miliammina petila* Saunders 1958
*Nonionella atlantica* Cushman 1947
*Planulina mera* Cushman 1944
*Pseudothurammina limnetis* (Scott and Medioli) 1980
*Quinqueloculina impressa* Reuss 1851
*Quinqueloculina jugosa* Cushman 1944
*Quinqueloculina lata* Terquem 1876
*Quinqueloculina seminula* (Linné) 1758
*Siphotrochammina lobata* Saunders 1957
*Tiphotrocha comprimata* (Cushman and Brönnimann) 1948b
*Triloculina oblonga* (Montagu) 1803
*Trochammina compacta* Parker 1952
*Trochammina inflata* (Montagu) 1808
*Trochammina lobata* Cushman 1944
*Trochamminita irregularis* Cushman and Brönnimann 1948a
*Trochamminita salsa* (Cushman and Brönnimann) 1948a

## *Short Note*

# *Reticulofenestra circus* var. *lata* n.var.: a large reticulofenestrid (Coccolithophoridae) from the Early Oligocene

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**ABSTRACT:** *Reticulofenestra circus* var. *lata* is described from the Early Oligocene of North Atlantic Deep Sea Drilling Project (DSDP) Site 558. The taxon is a large variety of *Reticulofenestra circus*, a medium-sized subcircular reticulofenestrid (8-10 micron in size). The outline of the new variety and the shape of the central area are identical to those of *R. circus*. Nonetheless it can be easily differentiated with the light microscope by the thicker collar and the considerable larger size (12-14µm) of the coccolith. The quantitative distribution pattern shows that the taxon has a shorter stratigraphic range compared to that of *R. circus*, ranging from the uppermost part of Zone NP22 to the lower part of Zone NP23, within Chron C12r. The ages of the FO and of the LO of *Reticulofenestra circus* var. *lata* at Site 558 have been estimated at 32.46 and 31.71 Ma respectively, based on the available magnetostratigraphy. The LO is located slightly below the LO of *Sphenolithus akropodus*, whose biochronological age has been here calculated at 31.31 Ma. *Reticulofenestra circus* var. *lata* may represent a new Early Oligocene biostratigraphic marker.

## INTRODUCTION

The genus *Reticulofenestra* Hay, Mohler and Wade 1966 is a major component of the calcareous nannofossil assemblages from the Eocene to the Recent. Size variation of the placoliths has been studied in detail, mainly in the Neogene record, and successfully applied in the species differentiation within the group (Backman 1980, Pujos 1985, Driever 1988, Young 1990, Takayama 1993). Moreover, the periodic occurrence of circular morphotypes during the geological record, such as *Reticulofenestra reticulata* in the Eocene, *Reticulofenestra circus* in the Early Oligocene, *Reticulofenestra rotaria* in the Late Miocene, *Reticulofenestra cisnerosi* in the Early Pliocene, *Reticulofenestra asanoi* in the Early Pleistocene, appears also to be a distinctive pattern of this genus; they all have a rather short stratigraphic range and have been frequently used as biostratigraphic markers.

During high resolution quantitative biostratigraphic analyses on Early Oligocene cores from the North Atlantic DSDP Site 558 an undescribed subcircular reticulofenestrid has been observed. The taxon fits quite well within the overall concept of *R. circus* but can be easily differantiated with the light microscope and has a more restricted stratigraphic range. In this note the taxon is formally described as a new variety of *R. circus* and its potential biostratigraphic usefulness is discussed.

## MATERIAL AND METHOD

The new variety described herein has been observed from the Early Oligocene sediments of North Atlantic DSDP Leg 82, Site 558 (latitude 34°46'N, longitude 37°21'W, 3754m) (Bougault et al. 1985) from the upper part of core 26 to core 25. The dominant lithologies in the investigated interval is represented by marly forams and nannofossil chalk. The studied interval belongs to the upper part of Zone NP22 and the lower part of Zone NP23 (text-fig. 1). Qualitative calcareous nannofossil biostratigraphic studies on the Oligocene record at Site 558 can be found in Miller et al. (1985).

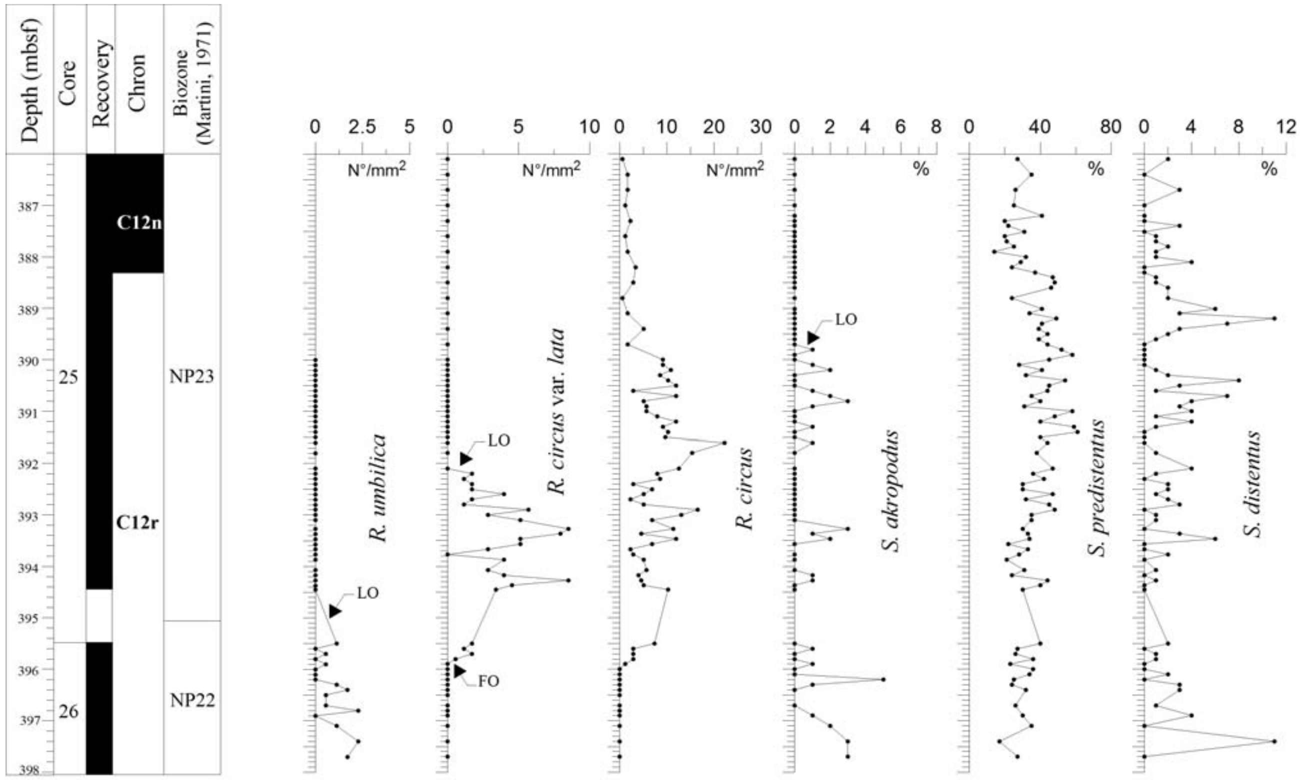
Smear slides were prepared from unprocessed samples using standard methodologies (Bown and Young 1988) and analysed under a polarized light microscope at 1000x magnification. Sampling resolution is about 1 sample/10 cm equivalent to approximately 1 sample/20 ky. The distributions of *Reticulofenestra circus*, of *R. circus* var. *lata* and of *R. umbilica*, have been obtained by counting the investigated taxa within 100 fields of views, containing about 500-600 coccoliths. A counting of 100 sphenoliths has been also performed in order to evaluate the abundance patterns within the genus, which represents a major component of the investigated interval. Quantitative distribution of the taxa have been correlated to the available magnetostratigraphy of Khan et al. (1985). Age assignment of the recognized bioevents has been proposed by means of interpolation within Chron C12r following geomagnetic polarity time scale of Berggren et al. (1995) and Cande and Kent (1995).

## SYSTEMATIC DESCRIPTION

Genus *Reticulofenestra* Hay, Mohler and Wade 1966

*Reticulofenestra circus* de Kaenel and Villa 1996
Plate 1, figures 1-8

The species has been described from deep-sea cores of the northeastern Atlantic Ocean, as a subcircular reticulofenestrid, 8-9 micron in diameter, having a quadrate central opening which represents 25% to 30% of the total length of the coccolith. At Site 558 the species is easily distinguishable among reticulofenestrids, it is about 8-10 micron in size and has been recognized throughout most of the investigated interval (text-fig. 1). According to de Kaenel and Villa (1996), the lowest and rare occurrences of *Reticulofenestra circus* are recorded from Zone NP21 or NP22 at different sites, while the highest occurrences fall within Zone NP23. In the Southern Ocean, the FO of the species is recorded within Zone NP 21 and Chron C13n from Marino and Flores (2002) and dated at 33.39 Ma (Marino and Flores 2002) or at 33.35 Ma (Channell et al. 2003). No biochronological data are available on the LO of the species.



TEXT-FIGURE 1
Abundance patterns of selected calcareous nannofossil taxa at Site 558 and related magnetostratigraphy. FO: first occurrence; LO: last occurrence. Magnetostratigraphy from Khan et al. (1985).

At Site 558 the lowest occurrence of *Reticulofenestra circus* falls within the upper part of Zone NP22, and within Chron C12r. However, this datum is in disagreement with biomagnetostratigraphic correlation of Marino and Flores (2002) and Channell et al. (2003) which may suggest that the event is strongly diachronous or that it has a low reliability since the species is rare and scattered in the lower part of the range. Therefore the event need to be further investigated and no biochronological data are here provided.

***Reticulofenestra circus*** var. ***lata*** Maiorano **n. var.**
Plate 1, figures 9-16

*Diagnosis:* A large subcircular variety of *R. circus*, over 12 micron in size.

*Description:* A large placoliths having a circular to subircular outline, a quadrate central opening which represents about 25% of the total length of the coccolith and a prominent collar.

*Differentiation: Reticulofenestra circus* var. *lata* differs from *R. circus* by having a thicker collar and significantly larger size. The outline of *Reticulofenestra circus* var. *lata* and the shape of the central opening are indistinguishable from those of *R. circus* (pl. 1, figs. 1-8). For these reasons it is considered a variety of *R. circus* rather than a separate species. *Reticulofenestra circus* var. *lata* is differentiated from *Cyclicargolithus abisectus* >10μm by its larger, quadrate central opening.

*Size:* About 12-14 micron long.

Derivation of name: from latin latus, large which refers to the large size of the coccolith.

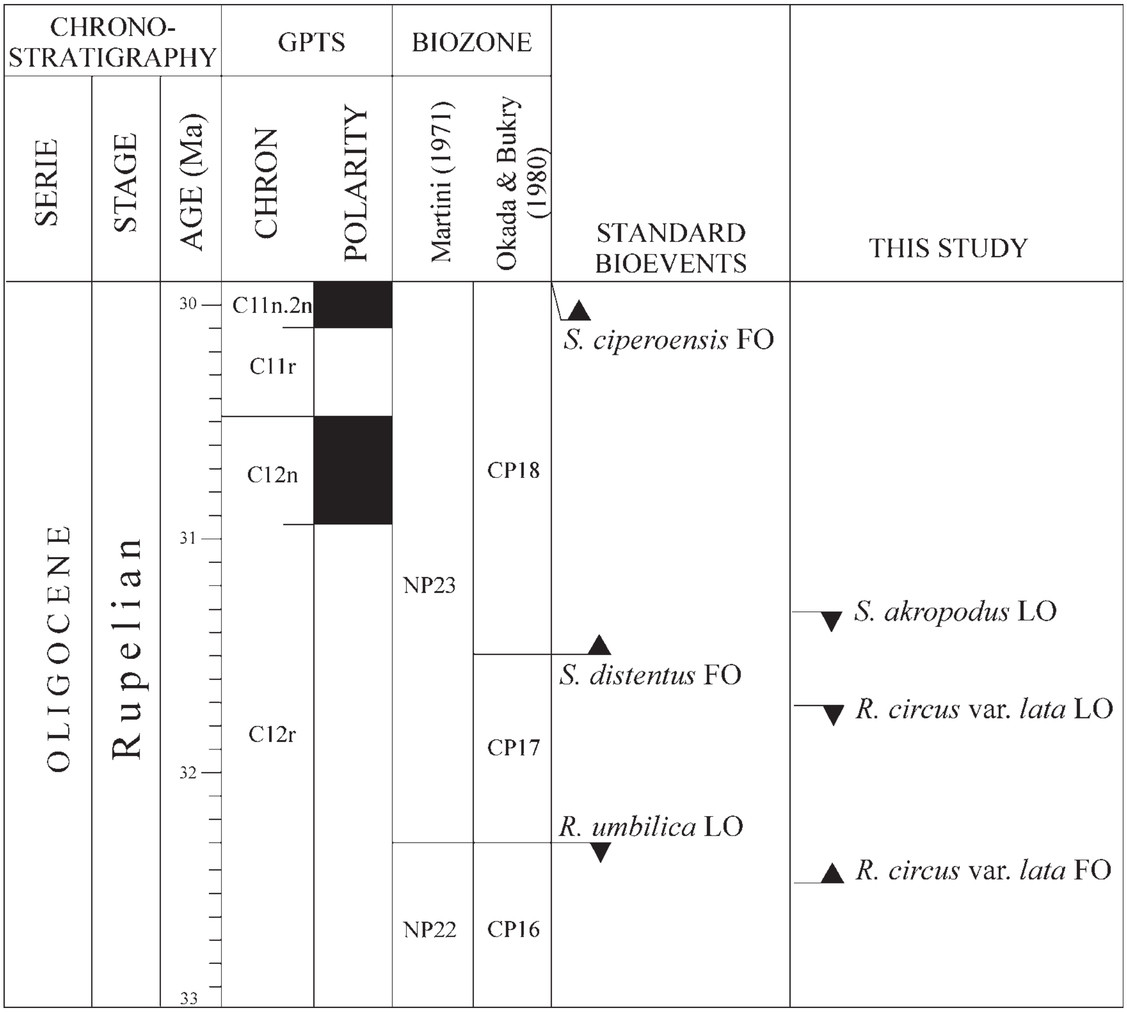
*Holotype:* Plate 1, fig. 11, DSDP Site 558, sample 25-6, 70cm.

*Type locality:* DSDP Site 558, North Atlantic Ocean.

*Range:* from the upper part of Zone NP22 to the lower part of Zone NP23. Restricted to Chron C12r.

### New Early Oligocene biostratigraphic markers

*Reticulofenestra circus* var. *lata* has a short stratigraphic distribution, ranging from the uppermost part of Zone NP22 to the lower part of Zone NP23. The biostratigraphic resolution of this interval is considerably low as most of the Oligocene record (text-fig. 2). Actually the Zone NP23 is defined by the LO of *Reticulofenestra umbilica* and the FO of *Sphenolithus ciperoensis* dated at 32.3 and 29.9 Ma, respectively (Berggren et al. 1995). The FO of *Sphenolithus distentus*, which is a standard biohorizon in the zonation of Okada and Bukry (1980) (text-fig. 2), does not really improve the biostratigraphic resolution of this interval, since it has been often documented as a low reli-



TEXT-FIGURE 2
Correlation of the bioevents to GPTS of Berggren et al. (1995) and Cande and Kent (1995) through the Zones NP22 and NP23. Calibration of the zonal bioevents refer to Berggren et al. (1995); position of additional bioevents is also shown according to the present study.

able biovent both in the open ocean and in the Mediterranean sea (Fornaciari et al. 1990, Olafsson and Villa 1992, Catanzariti et al. 1997). At Site 558 scattered and rare occurrences of *S. distentus* have been recorded below the LO of *R. umbilica* (text-fig. 1), in agreement with what has been reported by Miller et al. (1985), confirming the low reliability of the event for the recognition of CP17/CP18 zonal boundary. De Kaenel and Villa (1996) has recently proposed new bioevents within Zone NP22 and NP23 from deep-sea cores of the Iberia Abyssal Plain, represented by the FO and LO of *R. circus* and the LO of *Sphenolithus akropodus*. Quantitative results at Site 558 and their correlation to magnetostratigraphy (text-fig. 1) allow to monitor the distribution pattern of *Reticulofenestra circus* var. *lata* as well as of *R. circus* and of *Sphenolithus akropodus*. The FO and LO of the new variety fall within Chron C12r, with an estimated age of 32.46 Ma (mbsf 395.9 /395.8) and 31.71 Ma (mbsf 392.2/392.1), respectively. The LO of *Reticulofenestra circus* var. *lata* slightly precedes the LO of *S. akropodus* whose age is here estimated at 31.31 Ma (mbsf 389.8/389.7). No previous biochronological data are available on the LO of *S. akropodus*. It is noteworthy that the LO of *Reticulofenestra circus* var. *lata* and the LO of *S. akropodus* have been also recognized in few Mediterranean on-land sections from central Italy (Maiorano and Monechi in prep.) where their stratigraphic distribution appears comparable with those observed at Site 558, thus suggesting their potential utility for stratigraphic correlation.

## CONCLUSION

A large variety of *Reticulofenestra circus* from the Early Oligocene NP22 and NP23 zonal interval is here described as *Reticulofenestra circus* var. *lata*. It is a subcircular reticulofenestrid, about 12-14µm in size, with a quadrate central area and a prominent collar. The outline of the coccolith and the shape of the central opening are identical to those of *R. circus*. However, the significantly larger size and the thicker collar are diagnostic features of the taxon. The FO of the taxon (32.46 Ma) is recorded within Zone NP22; conversely, the LO of *Reticulofenestra circus* var. *lata* (31.71 Ma) is recorded within Zone NP23, slightly below the LO of *S. akropodus* whose age has been estimated at 31.31 Ma. *Reticulofenestra circus* var. *lata* is easily distinguishable in the light microscope and may represent a new biostratigraphic marker for the subdivision of NP22 and NP23 biozones.

## TAXONOMIC LIST

Calcareous nannofossils cited in the paper are listed by alphabetical order of generic epithets.

*Cyclicargolithus* Bukry 1971
*Cyclicargolithus abisectus* (Müller 1970) Wise 1973
*Reticulofenestra* Hay, Mohler and Wade 1966
*Reticulofenestra circus* de Kaenel and Villa 1996
*Reticulofenestra cisnerosi* (nomen nudum, Lancis and Flores 2004)
*Reticulofenestra reticulata* (Gartner and Smith 1967) Roth and Thierstein 1972
*Reticulofenestra rotaria* Theodoridis 1984
*Reticulofenestra umbilica* (Levin 1965) Martini and Ritzkowski 1968
*Sphenolithus* Deflandre in Grassé1952
*Sphenolithus akropodus* de Kaenel and Villa 1996
*Sphenolithus ciperoensis* Bramlette and Wilcoxon 1967
*Sphenolithus distentus* (Martini 1965) Bramlette and Wilcoxon 1967
*Sphenolithus predistentus* Bramlette and Wilcoxon 1967

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## PLATE 1

Light microscope photographs of selected calcareous nannofossil species. XP - crossed polarized light, PL - parallel light.

1-2 *Reticulofenestra circus* de Kaenel and Villa. 1 XP, 2 PL, DSDP Site, 558, 25-2, 100.

3-4 *Reticulofenestra circus* de Kaenel and Villa. 3 XP, 4 PL, DSDP Site, 558, 25-3, 70.

5-6 *Reticulofenestra circus* de Kaenel and Villa. 5 PL, 6 XP, DSDP Site, 558, 25-4, 70.

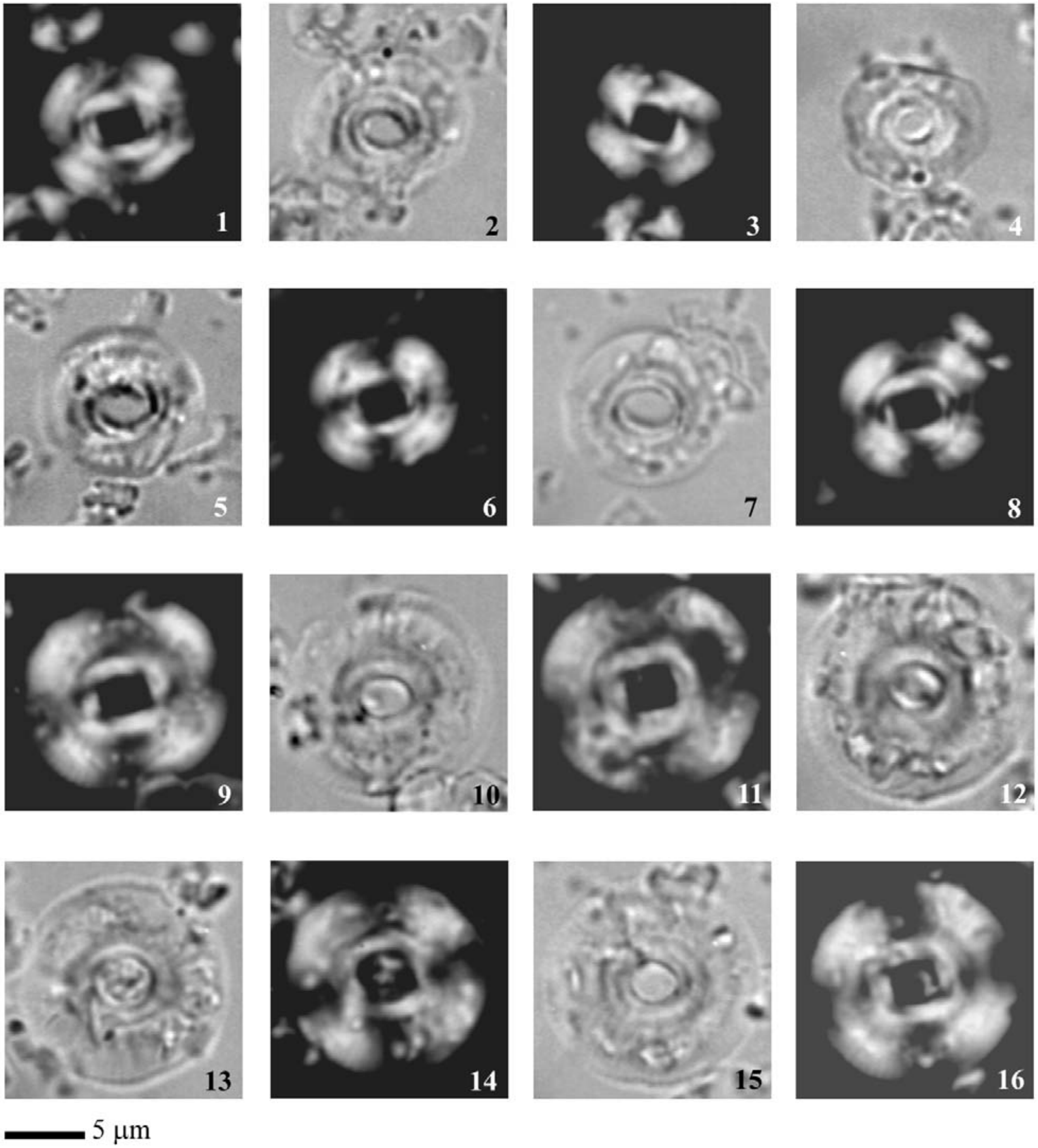
7-8 *Reticulofenestra circus* de Kaenel and Villa. 7 PL, 8 XP, DSDP Site, 558, 25-4, 70.

9-10 *Reticulofenestra circus* var. *lata* n. var. 9 XP, 10 PL, DSDP Site, 558, 25-5, 70.

11-12 *Reticulofenestra circus* var. *lata* n. var. 11 XP, 12 PL, DSDP Site, 558, 25-6, 70.

13-14 *Reticulofenestra circus* var. *lata* n. var. 13 PL, 14 XP, DSDP Site, 558, 25-5, 100.

15-16 *Reticulofenestra circus* var. *lata* n. var. 15 PL, 16 XP, DSDP Site, 558, 25-6, 128.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# *Dictyotidium senticogremium* sp. nov., a new prasinophyte (Chlorophyta) phycoma from the Upper Devonian of northern Iran

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**ABSTRACT:** A new, morphologically distinctive, murornate prasinophyte phycoma, *Dictyotidium senticogremium* sp. nov., is described from Upper Devonian strata of the Geirud Formation, Alborz Mountains, northern Iran. It is characterized by a small, near-circular vesicle, the surface of which is regularly divided by low membranous muri into few relatively large polygonal lacunae; central parts of the latter bear prominent granulate sculpture. *Dictyotidium senticogremium* sp. nov. occurs in a relatively diverse acritarch, prasinophyte, and miospore assemblage collectively indicating an early Late Devonian (Frasnian) age.The species is persistent, relatively common and has a presumably short stratigraphic range; therefore it is a potentially useful biostratigraphic index fossil for inter-basinal correlation across Iran.

## INTRODUCTION

Little detailed research has been published on acritarch palynofloras from Iranian Upper Devonian strata (e.g., Coquel et al. 1977, Kimyai 1979, Hashemi and Playford 1998). One reason for this scarcity of data is that one can determine the age of rock units from abundant, diverse, and biostratigraphically useful invertebrate faunas generally known from these strata (Stöcklin 1972, Bozorgnia 1973, Alavi and Bolourchi 1973). More importantly, since commencement of Devonian palynological research in Iran in the early 1970s (for summary of such studies up to mid-1996 see Hashemi and Playford 1998, pp. 118-119) there have not been many Iranian acritarch workers and foreign palynologists also have not shown any interest in acritarchs from this area.

During routine palynological investigations of Upper Devonian strata from several localities in northern Iran, the authors encountered a distinctive, hithero undescribed murornate prasinophyte phycoma, which is detailed herein as *Dictyotidium senticogremium* sp. nov. This species has been recorded from Upper Devonian (Frasnian) sediments cropping out at two localities in the central Alborz Mountains, northern Iran, i.e., southwest of Damghan and north of Tehran (text-fig. 1). The species is relatively common and its evidently short stratigraphic range suggests its potential as a biostratigraphic index.

## GEOLOGICAL SETTING AND STRATIGRAPHY

Stöcklin (1968) recognized several distinct tectonostratigraphic units in Iranian geology. Of these, the Alborz (a.k.a. Elburz) Mountains, with approximate east-west trend, constitute the spectacular ranges of northern Iran, with peaks more than 5600m high.

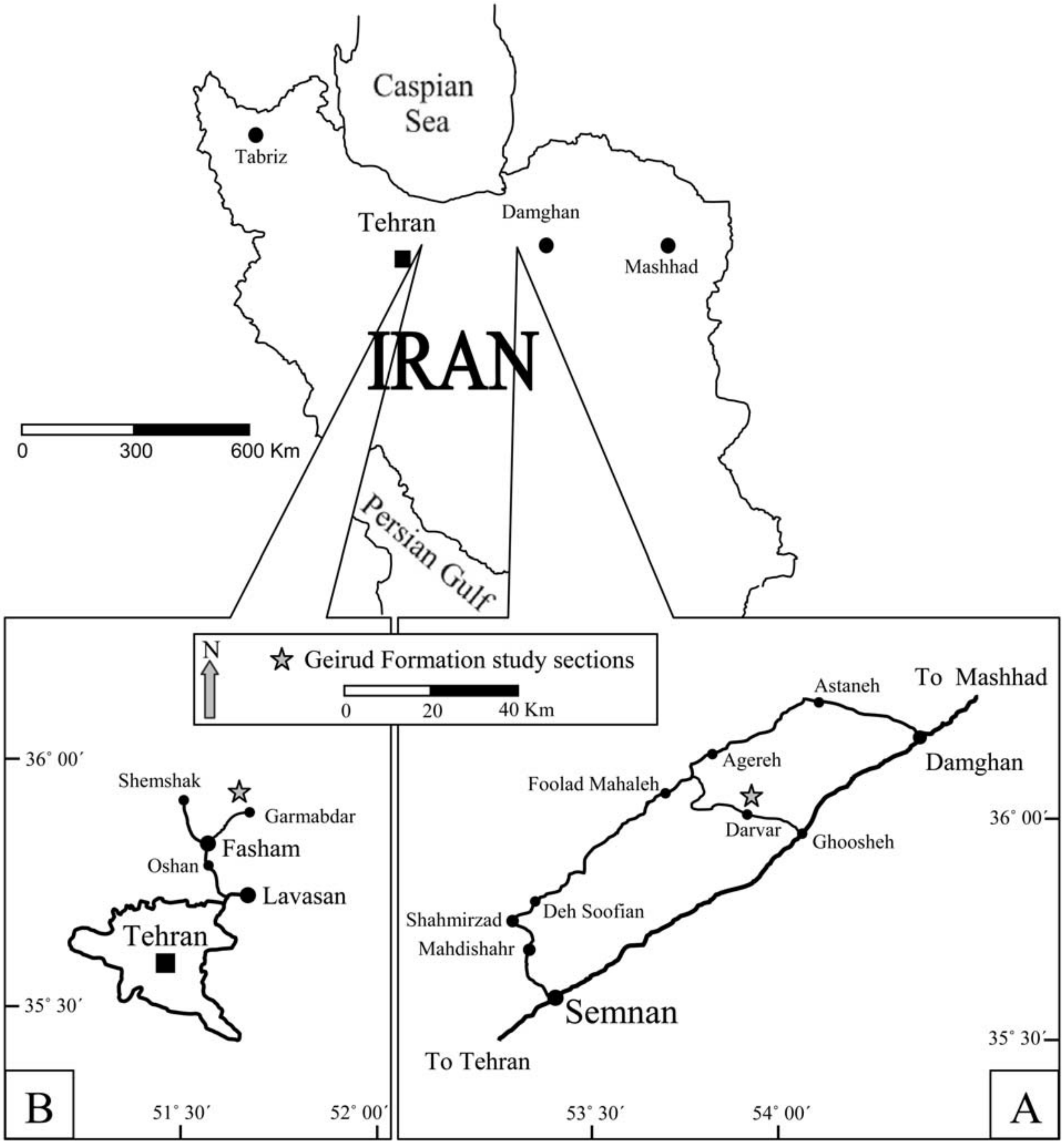
The platform nature of the Alborz Basin compares closely with that characterizing other parts of Iran during the Paleozoic (Stöcklin 1968). The basin contains a varied sequence spanning, with notable interruptions, the Precambrian through Quaternary interval and reaching several thousand meters in thickness. In general, the sequence is dominated mainly by marine Paleozoic and Mesozoic formations, followed by Paleogene rocks (predominantly pyroclastics) and mostly non-marine Quaternary deposits (Stöcklin 1972). Devonian (notably Upper Devonian) strata featuring lateral lithofacies changes, are well developed in northern Iran (see Stöcklin 1972, Bozorgnia 1973, Alavi and Bolourchi 1973 for lithostratigraphic subdivision and terminology).

In the central Alborz Mountains, the Geirud Formation (Assereto 1963) is a relatively thick succession of conglomerate, sandstone, dolostone, shale, and limestone. It disconformably overlies either the Lower Ordovician Lashkarak Formation or the Upper Cambrian Mila Formation, and is disconformably succeeded by black fossiliferous limestone intercalated with grey-black shale of the Lower Carboniferous Mobarak Formation (text-fig. 2). Palynomorphs, including organic-walled microphytoplankton, have previously been recorded (Kimyai 1972, Ghavidel-syooki 1994, 1995) and described (Kimyai 1979; Masoudi 2005) from the Geirud Formation.

## MATERIAL AND METHODS

This study is based upon samples collected from two measured exposures of the Geirud Formation in the central Alborz Mountains (text-fig. 1).

At the Darvar section, southwest of Damghan and north of Darvar (text-fig. 1-A), the Geirud Formation consists of a thick basal red conglomerate and sandstone unit followed by brachiopodal limestone with intercalations of grey-black shale (text-fig. 2-A). At the Garmabdar section, west of Garmabdar and north of Tehran (text-fig. 1-B), the Geirud Formation comprises basal grey sandstone and quartzite followed by alternating fossiliferous limestone and black shale and capped by thick basalt (text-fig. 2-B).

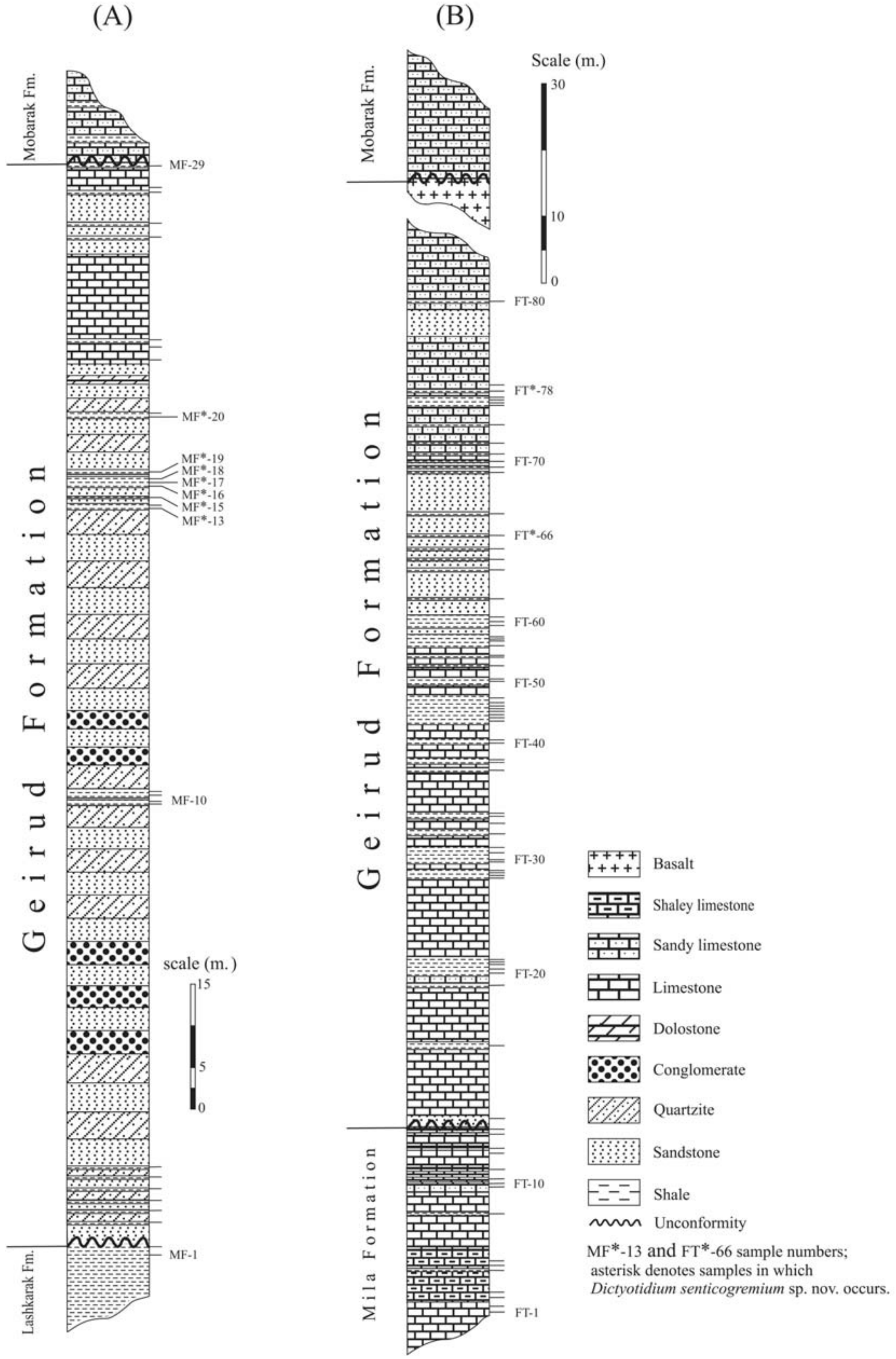


TEXT-FIGURE 1
Sketch maps showing the localities where *Dictyotidium senticogremium* sp. nov. has been recorded from the Geirud Formation, central Alborz Mountains, northern Iran.
A- location map of the Geirud Formation at the Darvar stratigraphic section, north of Darvar, 35km southwest of Damghan.
B- location map of the Geirud Formation at the Garmabdar stratigraphic section, west of Garmabdar, 35km north of Tehran.

Conventional palynological laboratory procedures, as detailed by Phipps and Playford (1984), were employed for extraction and concentration of the palynomorphs. Of the study samples (text-fig. 2), those of grey-black shale yielded the more diverse and better preserved palynofloras (miospores, acritarchs, and prasinophytes).

In the Darvar section (text-fig. 2-A), *Dictyotidium senticogremium* sp. nov. initially appears 80m above the base (MF*-13) and last occurs in MF*-20; thus persisting through 10m of strata. In the Garmabdar section (text-fig. 2-B), it first occurs in FT*-66 (88.4m above the base) and extends stratigraphically for 21.5m, its last occurrence being in FT*-78.

Slide locations of the type and other figured specimens are specified in table 1 as follows: sample number (e.g., MF-12, FT-78), preparation/slide number (e.g., Mf5/2, Ft13/2), mechanical stage coordinates per standard "England Finder" slide (e.g.,

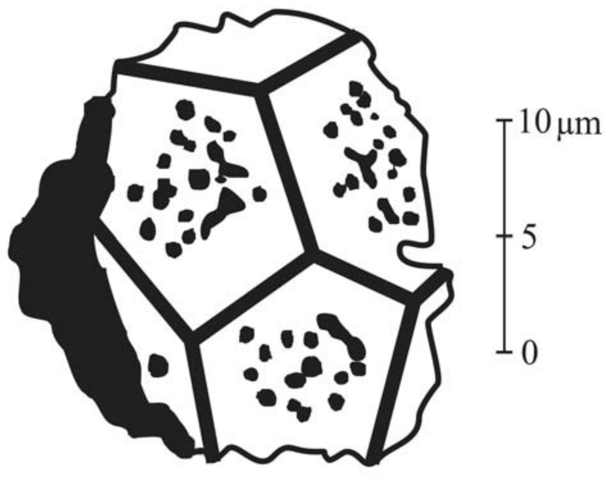


TEXT-FIGURE 2

Generalized stratigraphy of the Paleozoic succession (in part) in the central Alborz Mountains, showing lithology, palynological sampling horizons, and samples from which *Dictyotidium senticogremium* sp. nov. has been retrieved.

A- columnar stratigraphic section of the Geirud Formation, north of Darvar, southwest of Damghan, central Alborz Mountains (for location see text-figure 1A).

B- columnar stratigraphic section of the Geirud Formation, west of Garmabdar, north of Tehran, central Alborz Mountains (for location see text-figure 1B).



TEXT-FIGURE 3
Line drawing of the holotype of *Dictyotidium senticogremium* sp. nov. Note the pentagonal lacunae sculptured with grana characteristically clustered in central area of lacunae and locally conjoined to form short irregular ridges.

L43/2), and registered specimen number (prefixed TTU). The latter refers to the official catalogue of the type collections of the Department of Geology, Teacher Training University, Tehran, where the material (including all rock samples and residues) is permanently housed.

## SYSTEMATIC PALAEONTOLOGY

A moderately diverse and fairly well-preserved palynomorph assemblage, comprising miospores, prasinophyte cysts (phycomata), and algae *incertae sedis* (acritarchs *sensu stricto*) occur in the Geirud Formation. The systematics, distribution, and stratigraphic significance of the palynomorph assemblage will be presented in a separate paper.

Morphological terminology used hereunder follows Williams et al. (2000) and Playford (2003).

Division CHLOROPHYTA Pascher 1914
Class PRASINOPHYCEAE Christensen 1962
Family CYMATIOSPHAERACEAE Mädler 1963

Genus ***Dictyotidium*** Eisenack emend. Staplin 1961
1955 *Dictyotidium* EISENACK , p. 179.
1961 *Dictyotidium* STAPLIN , p. 417.

For additional synonymy see Tappan and Loeblich (1971, p. 396).

Type species: *Dictyotidium dictyotum* (Eisenack) Eisenack 1955; by original designation.

***Dictyotidium senticogremium*** Hashemi **n. sp.**
Plate 1, figs. 1-12; text-fig. 3

*Diagnosis*: Vesicle originally spherical, circular to subcircular in outline; rarely with large-scale arcuate compression fold ± paralleling vesicle margin. Eilyma 0.5-1.2μm thick; surface fairly regularly divided into 5-8 large pentagonal lacunae by low (0.5-1.5μm high), narrow (0.5-1μm wide), straight, psilate muri. Lacunae 6-10μm in diameter, sculptured with grana up to 1μm high, 0.5-1.5μm in basal diameter; grana concentrated in central parts of lacunae, mostly discrete (0.5-3μm apart), locally fused to form short irregular ridges (1.5-3μm long). No excystment structure observed.

*Dimensions* (25 specimens): Vesicle diameter 16 (19) 23μm.

*Holotype*: Preparation Mf5/2, Q35/4; Plate 1, figs. 1a, b. Vesicle subcircular in outline, diameter 19μm; eilyma 0.7μm thick, with low (0.7μm high), narrow (0.8μm wide), membranous, psilate muri encompassing pentagonal lacunae 9-10μm in diameter; lacunae sculptured with grana up to 0.7μm high, 0.5-1μm wide at base, and 0.5-2μm apart where discrete, uncommonly fused to form short ridges 2.5-3μm long. No excystment structure evident.

*Type locality*: Northern Iran, central Alborz Mountains, 35km southwest of Damghan, north of Darvar, Lat. 36°01'57½" N, Long. 53°54'26½" E, Geirud Formation, 83.3m above base.

*Name derivation*: Latin, *senticosus*, thorny, rough; Latin *gremium*, middle, centre; referring to granulate sculpture concentrated ± centrally in lacunae.

*Remarks and comparison*: The combined features of diminutive vesicle, relatively few lacunae delimited by low muri, and grana clustered ± centrally within the lacunae appear to segregate *Dictyotidium senticogremium* sp. nov. from previously described species.

Two Iranian Upper Devonian (Frasnian) species, featuring sculptured lacunae, differ from the present species as follows: *D. araiomegaronium* Hashemi and Playford 1998 (p. 133, 134; pl. 2, figs. 7-11; pl. 3, fig. 8; text-fig. 6), recorded herein in association with *D. senticogremium* sp. nov., features predominantly psilate lacunae; and *D.* sp. C of Hashemi and Playford 1998 (p. 136; pl. 3, figs. 7a, b) has a larger vesicle with a variety of sculptural modifications, i.e., verrucae or a single spina.

## ASSOCIATED PALYNOFLORAL ASSEMBLAGES AND BIOSTRATIGRAPHIC SIGNIFICANCE

In the study material, *Dictyotidium senticogremium* is consistently associated with abundant and reasonably diverse microphytoplankton and miospore assemblages. Quantitatively important among the co-occurring palynomorph taxa are the following: *Dictyotidium araiomegaronium* Hashemi and Playford 1998, *D. craticulum* (Wicander and Loeblich) Wicander and Playford 1985, *Deltotosoma intonsum* Playford in Playford and Dring 1981, *Gorgonisphaeridium* spp., *Maranhites perplexus* Wicander and Playford 1985, *Stellinium micropolygonale* (Stockmans and Willière) Playford 1977, *Tornacia sarjeantii* Stockmans and Willière 1966, *Cymbosporites catillus* Allen 1965, *Ancyrospora* spp., *Geminospora lemurata* Balme emend. Playford 1983, *Calamospora* spp., *Grandispora* spp., and *Retusotriletes* spp.

Co-occurring species of particular stratigraphic significance include *Cymatiosphaera perimembrana* Staplin 1961, *Chomotriletes vedugensis* Naumova 1953, *Daillydium pentaster* (Staplin) emend. Playford in Playford and Dring 1981, *Deltotosoma intonsum* Playford in Playford and Dring 1981, *Gorgonishaeridium plerispinosum* Wicander 1974, *Maranhites perplexus* Wicander and Playford 1985, *Papulogabata annulata* Playford in Playford and Dring 1981, *Tornacia sarjeantii* Stockmans and Willière 1966, *Unellium lunatum* (Stockmans and Willière) Eisenack, Cramer and Díez 1979, *U. piriforme*

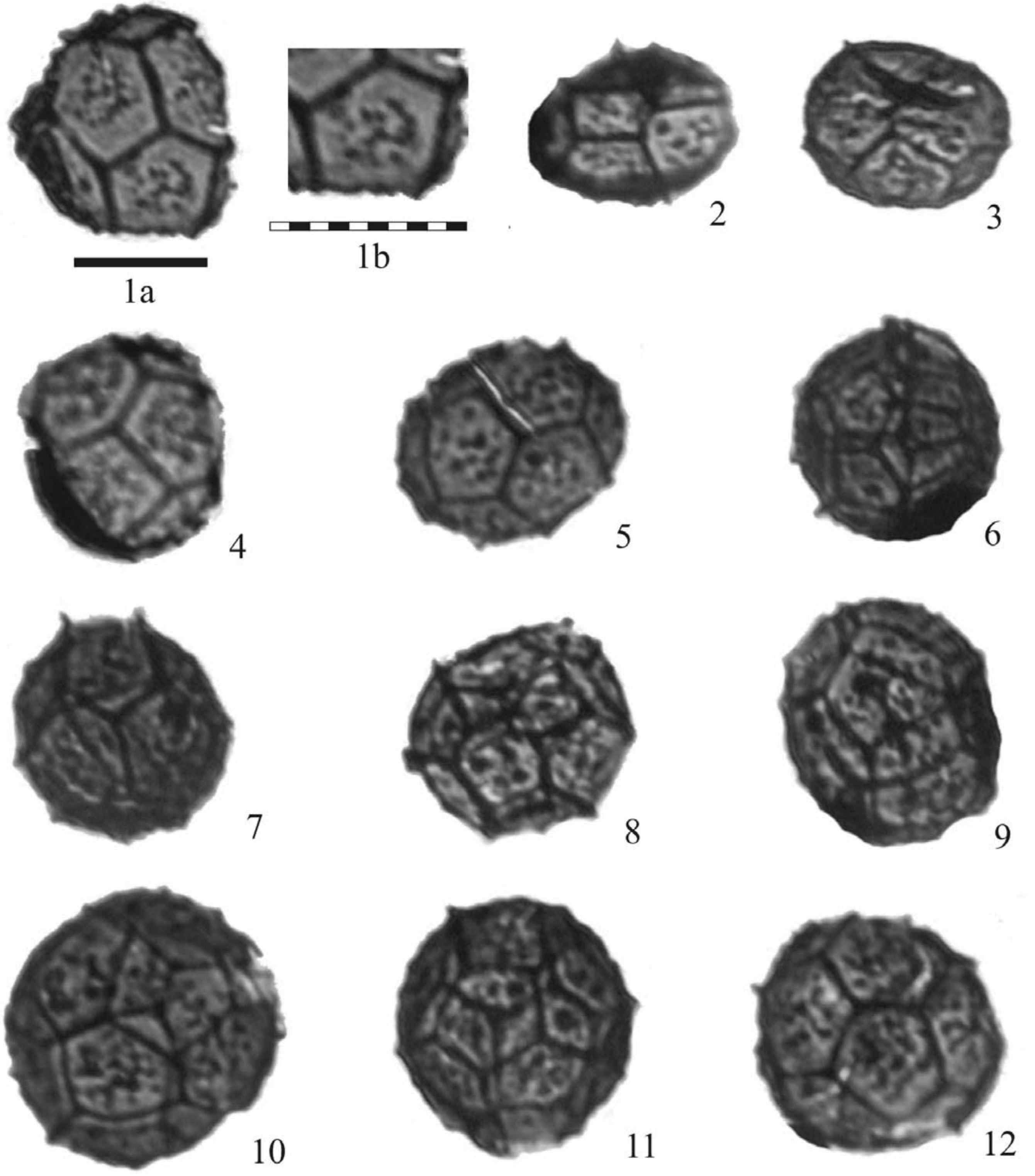


**PLATE 1**
*Dictyotidium senticogremium* sp. nov.

All specimens are from the Darvar section, except that depicted in figure 2, which is from the Garmabdar section. The scale bar in figure 1a represents 10μm in length and applies to all figures except figure 1b in which the scale bar is also 10μm long. Figure 1 (a, b; TTU 345; England Finder Q35/4) is the holotype; The remainder of figures are topotypes except of figure 2 which is a paratype.

TABLE 1
List of illustrated specimens.
All specimens are from the Darvar section, except that depicted in figure 2, which is from the Garmabdar section (see text-figs. 1 and 2 for details). Abbreviations are as follows: S = microscope slide made of "sink"; TTU = Teacher Training University.

| Pl./fig. | Sample no. | Prep./slide no. | England Finder | TTU Type No. |
|---|---|---|---|---|
| 1/1a, b | MF-19 | Mf5/2 | Q35/4 | P. 345 |
| 1/2 | FT-78 | Ft13/2 | R51/3 | P. 346 |
| 1/3 | MF-18 | Mf19/1 | J50/4 | P. 347 |
| 1/4 | MF-15 | Mf13/2 | J21/1 | P. 348 |
| 1/5 | MF-18 | Mf19/1 | G36/2 | P. 349 |
| 1/6 | MF-19 | Mf5/14 | G23/4 | P. 350 |
| 1/7 | MF-18 | Mf19/1 | C26/4 | P. 351 |
| 1/8 | MF-20 | Mf6/1 | X30 | P. 352 |
| 1/9 | MF-19 | Mf5/33 | R49/4 | P. 353 |
| 1/10 | MF-15 | Mf13/5 | Q57 | P. 354 |
| 1/11 | MF-16 | Mf11/S | P42/4 | P. 355 |
| 1/12 | MF-18 | Mf19/1 | L43/2 | P. 356 |

Rauscher 1969*, Geminospora lemurata* Balme emend. Playford 1983*, Grandispora cornuta* Higgs 1975, and *Retusotriletes rugulatus* Riegel 1973. These species collectively signify an early Late Devonian (Frasnian) age according to data presented by such authors as Wicander (1974), Playford and Dring (1981), Wicander and Playford (1985), Playford and McGregor (1993), Hashemi and Playford (1998) and Le Hérissé et al. 2000.

The absence in the associated palynofloras of the globally ubiquitous latest Devonian miospore species *Retispora lepidophyta* (Kedo) Playford 1976 is particularly noteworthy. However, this distinctive species makes its first appearance slightly higher in both study sections, and it is inferred that *Dictyotidium senticogremium* is stratigraphically confined to the Frasnian portion of the study sections.

There is currently no other independent biostratigraphic evidence of the age for the study intervals. Detailed investigation of invertebrates (mostly brachiopods) recovered from the study intervals that would provide additional data is yet to be undertaken.

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