

## Miocene deep water agglutinated foraminifera from Viosca Knoll, offshore Louisiana (Gulf of Mexico)

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### ABSTRACT

An exploration well from the Gulf of Mexico, Amoco Viosca Knoll-915, has been studied in order to document the Neogene foraminiferal assemblages. Ditch cuttings samples from the Amoco V.K. 915 well yielded diverse assemblages of agglutinated and calcareous benthic foraminifera over a stratigraphic interval of 2940 m. Three species associations can be identified in the studied interval; the stratigraphical location of these associations is evident when total agglutinated species abundance for each sampling interval is plotted. In this study we use a combination of morphotype habitat preference and test functional morphology to interpret depositional environments. The associations indicate a change from a well-ventilated water column, to the development of a strong oxygen minimum zone characterised by alveolar foraminifera. The species composition of the lowermost association indicates a depositional environment dominated by fine-grained overbank fines and channel levee deposits, in agreement with sedimentological data. Colour plates of key agglutinates species are presented, created using digital image manipulation techniques (Palaeovision Technique, NHM).

### INTRODUCTION

The offshore Gulf of Mexico (see fig. 1 for location) has been the major oil producing regions in United States since the early 1950s<sup>1</sup>. By the early 1990s production had shifted to deeper water as shelf reservoirs became less economical<sup>1</sup>. The endeavour to maximise deep water production has provoked oil companies to explore alternative approaches for the reconstruction of outer shelf to bathyal palaeoenvironments. Benthic foraminifera show a measured response to specific environmental parameters, including productivity, oxygenation, and water depth (e.g., Gooday, 1996, Loubere, 1994, Bandy, 1967). These responses allow them to be used as palaeoenvironmental proxies.

In bathyal Miocene sediment located off the continental shelf of Louisiana, calcareous microfossils are often not present owing to dissolution, or are abraded suggesting they are not *in situ*. Commonly, the agglutinated benthic foraminifera are the only autochthonous microfossils present in sufficient numbers to be of use for palaeoenvironmental interpretations.

The samples used in this study originate from off the continental shelf of Louisiana (Amoco, Viosca Knoll 915, OCS 6894). The ultimate goal of this project is to better understand the response of Neogene deep water benthic foraminifera to low oxygen conditions through the study of additional material from similar environments. This paper serves to document and illustrate the Neogene agglutinated taxa present in the Amoco V.K. 915 well as a contribution to more fully documenting the Neogene deep-water agglutinated foraminifera (DWAF) present in the Gulf of Mexico.

### Background to the Study

The majority of previous foraminiferal studies carried out in the Gulf of Mexico have concentrated on their affinity with water masses and palaeobathymetry; (e.g., Pflieger, 1951; Pflieger & Parker, 1951, Pflieger, 1960; Pflum & Frerichs, 1976; Van Morkhoven *et al.*, 1986; Denne & Sen Gupta, 1991, 1993) Much of this research focused upon documenting upper depth limits and bathymetrical trends in the abundance of index species. Poag (1981) conducted a thorough analysis which attempted to integrate the environmental factors that influence benthic foraminiferal distributions. In his study, both agglutinated and calcareous taxa were considered, thus providing a better understanding of the relationships between benthic foraminiferal associations and their environment. Poag did not, however, carry out detailed studies of DWAF in the Gulf of Mexico.

Up to now, the majority of published studies on Neogene benthic foraminifera in the Gulf of Mexico have dealt with shallow water and neritic palaeoenvironments. Although a small number of studies have examined the Holocene DWAF in the Gulf region (Cushman, 1918, 1919; Poag, 1981; Schröder, 1987), very little work has been carried out on the Miocene. Much of what we know about Miocene DWAF comes from studies in the Caribbean (Cushman & Renz, 1941; Cushman & Stainforth, 1945; Cushman & Todd, 1945; Renz, 1949; Bermúdez, 1949; Brönnimann, 1952; Preece, 1999). Only a few recent studies have examined Neogene bathyal benthic foraminifera in the offshore Gulf of Mexico (Van Morkhoven *et al.*, 1986; Katz & Miller, 1993). Most recently, the Gulf Coast Taxonomic Equivalency Project (Picou *et al.*, 1999) has published a taxonomic

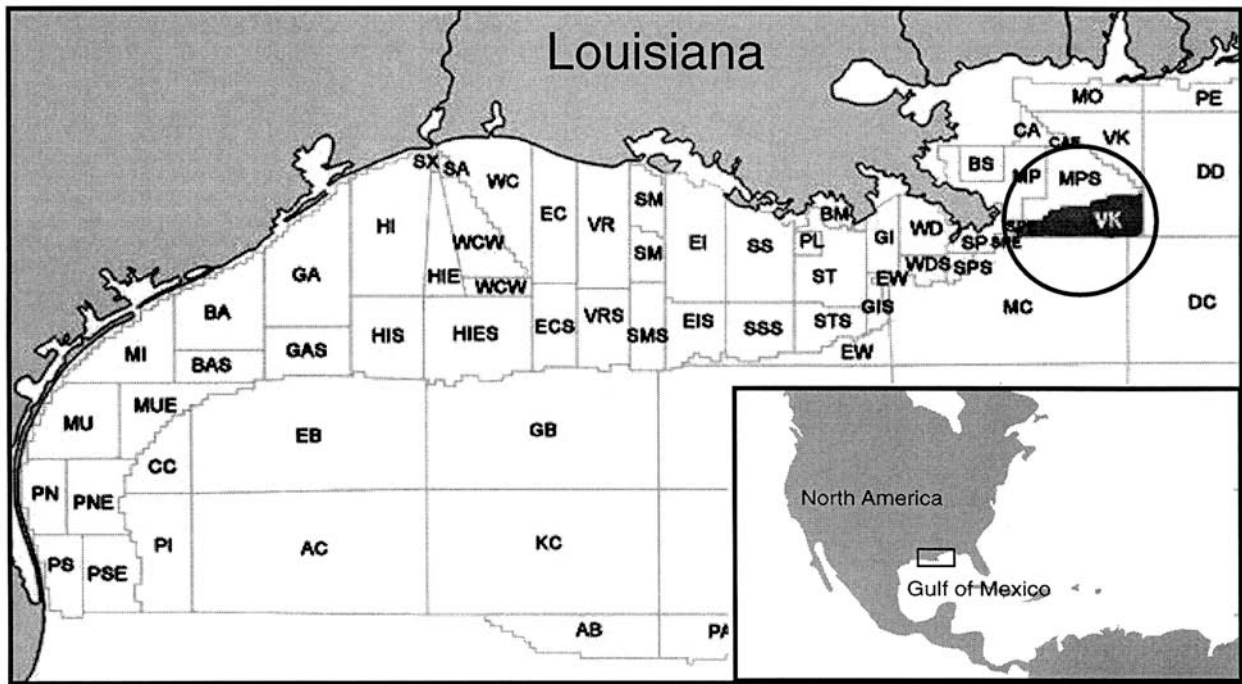


Figure 1. Location of Viosca Knoll 915 indicated by circle, inset map showing global context.

synopsis of the Oligocene to Miocene index foraminifera, with the goal of standardising the various in-house names used by the oil industry. This work is a useful reference for the mostly shallow-water marker species, but only a few DWAF species were included in this publication. There is therefore a need to expand upon this work, and describe the taxonomy of the Neogene DWAF in greater detail.

## METHODS

A total of 90 ditch cuttings samples from the Amoco V.K. 915 well, with an average spacing of 30ft, were studied for their foraminiferal content. The samples provided had been washed over a 63  $\mu\text{m}$  sieve to remove the silt and clay fractions; the entire residue was picked for its foraminiferal content. Following this, samples were passed through a nest of four sieves (500  $\mu\text{m}$ , 250  $\mu\text{m}$ , 125  $\mu\text{m}$  and 63  $\mu\text{m}$ ) corresponding to the size boundaries for coarse sand, medium sand, fine sand and shaken for 10 seconds. Each was then weighed using a set of Slater analogue scales (0.1 g accuracy); the weight of each sieve was then subtracted, leaving the resultant weight of sediment within each size fraction.

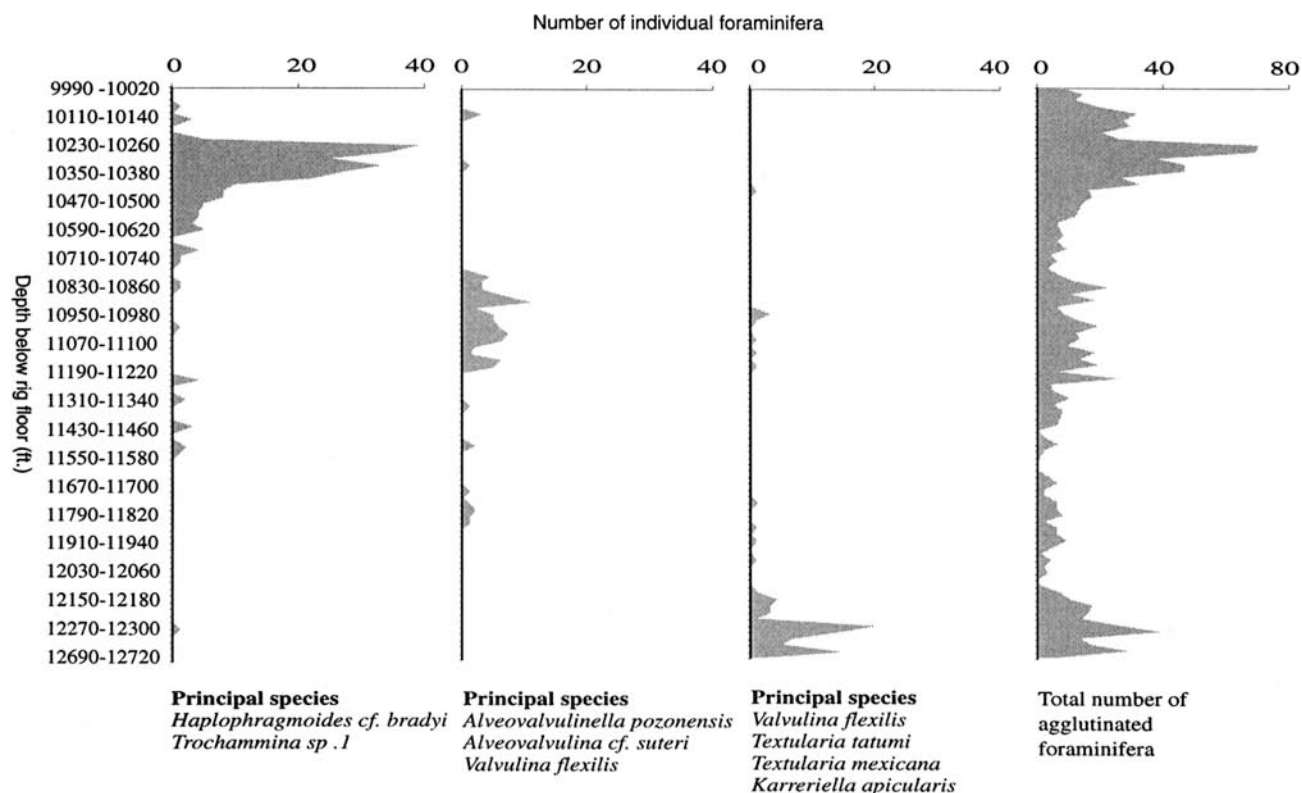
Both calcareous and agglutinated foraminifera were picked and mounted onto cardboard micro-palaeontological slides, however, the calcareous taxa were not included in this study. Planktonic foraminifera were examined to constrain the chronostratigraphy of the well, using the zonation and biochronology of Berggren *et al.* (1995).

To document the external morphology of the agglutinated benthic foraminifera, one or more specimens of each species was digitally photographed in reflected light. Electron micrographs are capable of producing sharp high magnification images but do not fully illustrate features used in identification of agglutinated foraminifera.

Digital composite photographs were produced using the following methodology: a reflected light photograph of the specimen is taken with the microscope focused on the uppermost section of the fossil. The focus is then moved down to the next 'layer' through the fossil ensuring that there is some degree of overlap between the two focal planes. This process is continued until the entire thickness of the specimen has been photographed. The 'in focus' sections of each photograph are then combined using Adobe® Photoshop® to create a composite image of the specimen with uniform focal clarity.

## RESULTS

The investigated samples from the Amoco VK 915 well yielded a low diversity assemblage of agglutinated foraminifera composed of 21 genera and 45 species. Agglutinated foraminiferal abundance was low throughout the majority of the well, with several horizons being barren of foraminifera. Preservation is generally good although compression of specimens was often a problem, with many genera regularly displaying severe deformation. The species abundance varies markedly between each interval (Appendix 1). Nevertheless, the data reveal that three separate species associations are responsible for each of the three abundance maxima. The numerical dominance of the associations can be delineated by comparing the downhole plots of the three associations with the total agglutinated foraminiferal abundance plot in Figure 2. The total weight of each sample remains fairly constant down well, with a noticeable increase in total weight beginning from 11790 ft. The interval below this depth is characterised by larger volumes of sediment, combined with a greater variation in total sediment weight. The sample sediment is dominated by the 250-125  $\mu\text{m}$  and 125-63  $\mu\text{m}$  fractions, the greatest variability is observed within the >500  $\mu\text{m}$  and 500-250  $\mu\text{m}$  size fractions.



**Figure 2.** Abundance of foraminifera within the three main associations, with principal species listed, shown against total foraminiferal abundance downhole.

The variation of individual size fractions between individual samples can be observed in fig. 3. These sedimentary variations display a degree of correlation with the total foraminiferal abundance. It appears that higher foraminiferal abundances in Amoco V.K. 915 are preceded larger amounts of coarser (>500  $\mu\text{m}$ ) and medium (500-250  $\mu\text{m}$ ) sand.

The stratigraphical position of the various assemblages can be determined through the use of rare planktonic foraminifera present in the samples. Planktonic foraminifera are very poorly preserved, occurring mainly as pyritised steinkerns. However, several samples in the studied well yielded planktonic index species that allowed stratigraphic age assignments for the assemblages. To date no other microfossil groups have been studied to confirm the defined planktonic foraminiferal zones. The three DWF assemblages are described below (also see fig. 2):

#### *Haplophragmoides cf. bradyi*, *Trochammina sp. 1* assemblage:

Interval: 10200 to 10680 ft.

The age of this interval is constrained by the occurrence of *Globoturborotalita nepenthes* at 10410 ft (last occurrence = top of Zone PL 1, 4.18Ma). The DWF in this interval are well-preserved, mostly unabraded, but with noticeable signs of deformation. The assemblage is dominated in by *Haplophragmoides cf. bradyi* and *Trochammina sp. 1*. The subdominant taxa include *Subreophax sp.*, *Cribrostomoides sp.*, *Recurvoides spp.*, *Haplophragmoides carinatus*, *H. pseudolatidorsatus*, *Reticulophragmium rotundidorsatum*, and some tubular astrorhizids mostly represented by *Rhabdammina* fragments. This interval also contains

rare specimens of some additional cyclamminids, including *Reticulophragmium acutidorsatum* and *Cyclammina cancellata*. The abundance of this assemblage reaches a maximum of 59% at 10,260 ft. The last occurrence (LO) of *Haplophragmoides cf. bradyi* is observed at 10,230 ft, and the LO of *H. pseudolatidorsatus* occurs at 10,260 ft.

*Haplophragmoides* as a genus that has been interpreted as being indicative of low oxygen environments (Kuhnt & Kaminski, 1990); *Trochammina* are also thought to inhabit lower oxygen conditions (Koutsoukos, *et al.*, 1990), whilst also displaying a preference for high organic content (Bandy, 1963).

#### *Alveovalvulina*, *Alveovalvulinella*, *Valvulina flexilis* assemblage:

Interval: 10,830 to 11,190 ft.

This assemblage displays lower abundance and poorer preservation than the previous one. Despite the absence of planktonic zonal marker species, the stratigraphic position of this assemblage relative to the other two indicates that it is of late Miocene age.

Many of the DWF specimens in the samples are crushed and fragmented. The assemblage is dominated by key elements of the so-called "Agua Salada Fauna" (Renz, 1948), which includes *Valvulina flexilis* and numerous taxa with complex internal structure such as *Alveovalvulina suteri*, *Alveovalvulinella pozonensis*, and cyclamminids. This assemblage exhibits a relative abundance maximum of 54% between 10,730 and 11,370 ft. Within this interval, the LO of *Alveovalvulinella pozonensis* is observed at 10,830 ft., and the Last Common Occurrence of *Alveovalvulina suteri* was found at 10,890 ft. Subdomi-

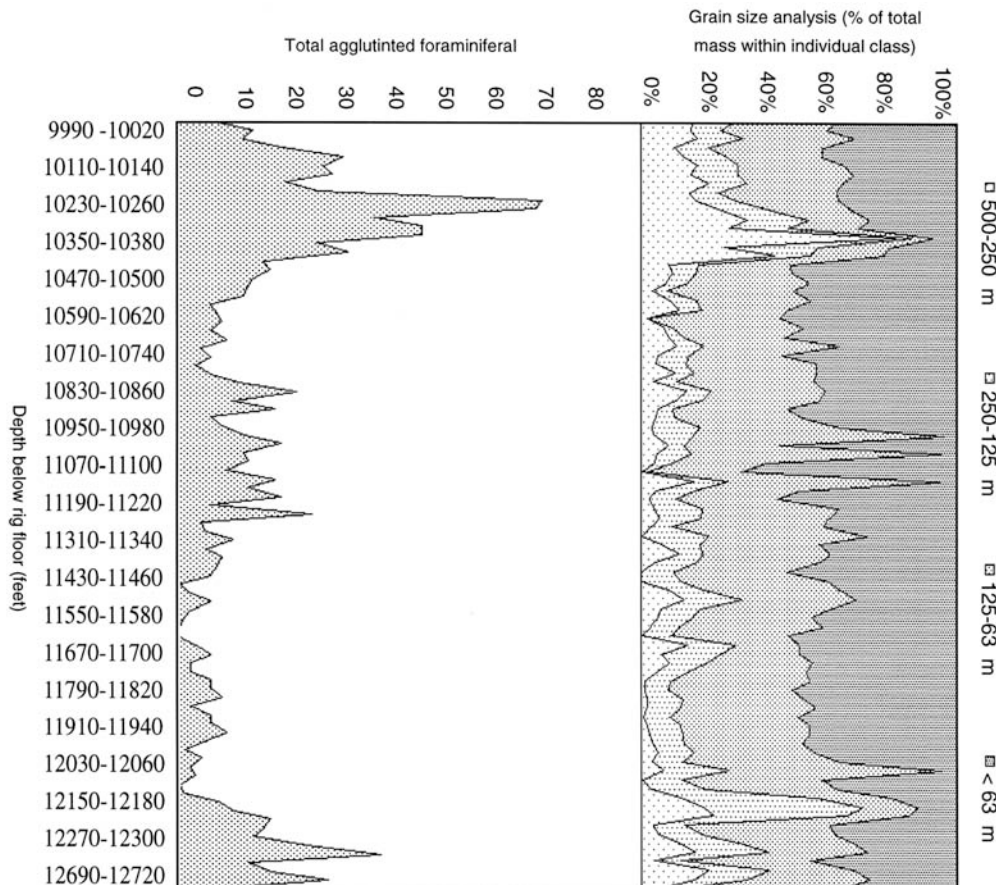


Figure 3. The relationship between total foraminiferal abundance down hole and sediment grain size.

nant forms include various species of *Haplophragmoides* and rare specimens of taxa that occur in the overlying assemblage.

With the exception of *Valvulina flexilis*, itself a low oxygen indicator species (Preece, 1999), all of the dominant genera in this assemblage possess alveolar wall structure. The dominant morphotype in the interval consists of tapered-elongated (infaunal) forms, which are typical of modern low oxygen environments (Kaminski *et al.*, 1995).

#### *Valvulina flexilis*, *Textularia* assemblage:

Interval: 12,300 to 12,930 ft.

The lowermost studied interval in the well contains an assemblage characterised by *Valvulina* and *Textularia* spp., although no single species clearly dominates. The interval occurs beneath a sandy, virtually barren interval between 11,640 and 12,300 ft. The DWAF assemblage displays lower abundance relative to the overlying two assemblages. The numerical dominance of this association reaches a maximum of 38% between 12,790 and 12,820 ft. The LO of *Globorotalia fohsi robusta* is observed at 12,630 ft. placing this association within planktonic foraminiferal Zone M9b (> 11.9Ma).

The DWAF assemblage contained in this shaley interval includes the distinctive species *Textularia mexicana* and *Textularia tatumi*, both of which have been documented from the Harang wedge of Louisiana (Pope & Smith, 1948). The so-called "Harang Fauna" is indicative of shale or mud rich facies (Pope

& Smith, 1948), apparently associated with channel overbank or levee deposits. *Karrerulina apicularis* is consistently present, as well as three species of *Textularia* which are still retained in open nomenclature (*Textularia* sp. 1; *Textularia* sp. 1; *Textularia* sp. 3; ?*Textularia* sp. 4, and *Textularia* sp. 5).

#### DISCUSSION

Deep sea environments are relatively stable with respect to temperate and salinity, both of which play a large role in determining the distributions of shallower water foraminifera (Pfleger, 1960). The response of foraminifera to environmental stimuli in the deep sea (eg., Gooday & Rathburn, 1999) is strongly influenced by seasonal fluctuations in the physiochemical properties of the water. Moreover, within oxygen minimum zones, the sea-water oxygen content and the oxygenation state of the bottom sediment are perhaps the dominant environmental parameters effecting the biota (Kaiho, 1991, 1994). Seasonal fluctuation of the sediment oxygen content can be produced by upwelling, leading to increased surface water productivity and export production. This leads to high oxygen consumption at the sediment-water interface. Sporadic events, such as turbidity currents or storm induced bottom currents, may not only disturb the bottom sediment, but also decimate the benthic community (Kaminski, 1985). Turbidity currents can also redistribute large amounts of organic matter (D'ufsky & Walton, 1965).

During the early to middle Miocene deep waters of the world ocean were warmer and marked by a lower oxygen content than today (Kaiho, 1991), and locally organic-rich biosiliceous sediments were deposited in the various low-latitude upwelling zones (Kennett, 1982). The Neogene assemblages recovered from Amoco V.K. 915 well are indicative of an environmentally stressed depositional setting. The occurrence of many species contained within the oldest assemblage were originally described from the Harang Wedge of Louisiana (Pope & Smith, 1948) and have been associated with channel levee deposits (Picu *et al.*, 1999). Between 11,640 and 12,300 ft there is an influx of channel sands, that demarks the upper stratigraphical boundary of this association. The large volume of compositionally and texturally mature quartz sand in the upper middle Miocene section of the well both dilutes foraminiferal abundance, and possibly formed a substrate unsuitable for foraminiferal colonisation. There no observations of any typical "recolonisation" assemblages that are known to occur in modern disturbed deep-sea depositional settings (e.g., Kaminski, 1985; Hess *et al.*, 2001).

The upper Miocene *Alveovalvulina-Alveovalvulinella-Valvulina flexilis* assemblage does not appear to have been affected by channel disturbance. The occurrence of low oxygen-adapted, alveolar foraminifera belonging to the infaunal morphogroup indicates that a pronounced oxygen minimum zone (OMZ) existed in the region. The strong OMZ off Louisiana during the Neogene could either be the result of an upwelling system or fluctuations in relative sea level. The inferred fluctuation in the intensity of the OMZ is reflected in the varying relative abundance of alveolar and infaunal taxa.

When the size fraction data for each interval is compared with the total foraminiferal abundance (Fig. 3) a degree of correlation between the two is evident. The correlation can be interpreted in one of two ways; Firstly it is possible that that foraminifera within V.K. 915 favour substrate containing high volumes of coarser sand; alternatively, the response of the foraminifera could be related to fluctuations in sea level. The offset between the influx of coarser sand and the foraminiferal response is too great to be controlled by the substrate. This insinuates that sea level fluctuation is also capable of affecting foraminiferal abundance in V.K. 915. The coarse and medium sand could possibly originate from redistribution of shelf sands during times of lower sea level and consequent incision of submarine channels. A subsequent rise in sea level could have lead to higher surface productivity and expansion of the OMZ resulting from increased shelf area, finer substrate and leaching of nutrients from the shelf (Erbacher & Thurow, 1996); therefore stimulating higher foraminiferal abundances. Thus it is plausible that the fluctuations in OMZ intensity inferred from the foraminifera species composition are a result of the changes in sea level implied by the sedimentological data.

#### SYSTEMATIC TAXONOMY

We present an annotated taxonomy for all the agglutinated species present in the Amoco VK 915 well.

The suprageneric classification follows the new scheme of Kaminski (this volume).

Class FORAMINIFERA d'Orbigny, 1826  
Order ASTORHIZIDA Lankester, 1885  
Suborder ASTORHIZINA Lankester, 1885  
Family RHABDAMMINIDAE Brady, 1884  
Subfamily RHABDAMMININAE Brady, 1884  
Genus *Rhabdammina* M. Sars in Carpenter, 1869

#### *Rhabdammina annulata* Grzybowski, 1896

Plate 1, Fig. 2

*Rhabdammina annulata* Rzehak. –Grzybowski, 1896, p. 276, pl. 8, fig. 8-9.

Finely agglutinated straight-sided tube having regularly spaced constrictions along its length. Generally flattened and fragmented specimens, normally not more than four constrictions long.

#### *Rhabdammina* spp.

Plate 1, Fig. 1

Medium to coarse agglutinated fragments of tubes, rarely more than 200 µm in length; found throughout the well.

Subfamily BATHYSIPHONINAE Avinimelech, 1952  
Genus *Bathysiphon* Sars, 1872

#### *Bathysiphon* sp.

Large tubular fragments, finely agglutinated thick wall.

**Occurrence.** Occasional small fragments found throughout the well.

Suborder SACCAMMININA Lankester, 1885  
Superfamily SACCAMMINACEA Brady, 1884  
Family SACCAMMINIDAE Brady, 1884  
Subfamily SACCAMMININAE Brady, 1884  
Genus *Saccammina* Carpenter, 1869

#### *Saccammina grzybowskii* (Schubert, 1902)

*Reophax difflugiformis* Brady. –Grzybowski, 1898, p. 277, pl. 10, figs 11-12.

*Reophax grzybowskii* Schubert, 1902, p. 20, pl. 1, fig. 13.

*Saccammina grzybowskii* (Schubert). –Hemleben & Troester, 1984, p. 522, pl. 1, fig. 14.. –Kaminski & Geroch, 1993, p. 248, pl. 2, figs 1a-4b.

Small test subcircular, single finely agglutinated chamber.

**Occurrence.** Low abundance concentrated in the top third of the well.

#### *Saccammina* aff. *sphaerica* Sars, 1872

*Saccammina sphaerica* Sars, 1872, p. 532, fig. 272 (fide Ellis & Messina 1940, et. seq.)

*Saccammina sphaerica* Sars. –Cushman & Stainforth, 1945, pl. 1, fig. 5. –Charnock & Jones, 1990, pl. 1, fig. 7, pl. 13, fig. 5.

Specimens small, deformed, with necked aperture poorly preserved.

**Occurrence.** Two specimens at 10,290 & 10,440 ft.

Order LITUOLIDA Lankester, 1885  
Suborder HORMOSININA Mikhalevich, 1980  
Superfamily HORMOSINELLACEA Rauser &

Reitlinger, 1986  
 Family HORMOSINELLIDAE Rauser & Reitlinger, 1986  
 Genus *Subreophax* Saidova, 1975

*Subreophax* sp.

Constricted finely agglutinated wall, size of chambers increases gradually.

**Occurrence.** Present exclusively in fragmentary form restricted to the upper 1/3 of the well.

Suborder LITUOLINA Lankester, 1885  
 Superfamily LITUOLACEA de Blainville, 1827  
 Family HAPLOPHRAGMOIDIDAE Maync, 1952  
 Genus *Haplophragmoides* Cushman, 1910

*Haplophragmoides* cf. *bradyi* (Robertson, 1891)

Plate 1, Figs 5–7

cf. *Trochammina bradyi* Robertson, 1891, p. 388.  
*Haplophragmoides bradyi* (Robertson). –Parker, 1954, pl. 1, fig. 16. –Schröder, 1986, p. 637, pl. 3, fig. 4.

**Description.** There is sufficient variability within this species to form a group of species which includes all specimens with the following characteristics. Test small, planispiral 4 1/2 to five triangular chambers, size of chambers increases gradually, chambers in last whorl are of similar size, giving segmented appearance to test due to their triangular shape combined with depressed sutures. Aperture indistinct due to small size of specimens, wall finely agglutinated. Specimens compressed leading to distinctive collapse of inflated chambers.

**Occurrence.** Highest abundance between 10,260 & 10,680 ft, present throughout.

*Haplophragmoides carinatus* Cushman & Renz, 1941

Plate 1, Fig. 8

*Haplophragmoides carinatus* Cushman & Renz, 1941, pl. 1, fig. 1.

*Haplophragmoides carinatum* (Cushman & Renz). –Cushman & Stainforth, 1945, pl. 1, fig. 18

*Haplophragmoides carinatus* Cushman & Renz. –Diaz de Gamero, 1977, pl. 3, fig. 1. –Cicha *et al.*, 1998, p. 106, pl. 3, figs 1-2.

Test small planispirally coiled with eight chambers in last whorl, subcircular outline with acute periphery, possessing a rounded narrow keel. Sutures flush with test, slightly darker colouration, radial, umbilical region depressed. Aperture a slit at base of last chamber, extends over entire width, test smoothly agglutinated. Tests often deformed resulting in severely compressed specimens.

**Occurrence.** Low abundance in top half of well.

**Remarks.** Cushman & Renz (1941) originally described this species from the lower to middle Miocene of the Agua Salada Group. Diaz de Gamero (1977) subsequently reported it from the upper Oligocene of the Falcon district of Venezuela. Specimens in the Cushman Collection are from the upper Oligocene St. Croix beds of Trinidad and from the lower Oligocene Ciperó Marl. Unfortunately, Cushman did not separate *H. carinatus* from the stratigraphically older species *Haplophragmoides*

*walteri* (Grzybowski 1898), and subsequent citations of this species by Cushman & Renz (1948) from older strata must be viewed with caution. *Haplophragmoides carinatus* differs from *H. walteri* in its more lenticular cross-section.

*Haplophragmoides compressus* LeRoy, 1939

*Haplophragmoides compressa* (fide Ellis & Messina 1940, et seq.)

Planispiral with 8 chambers, earlier ones in final whorl somewhat indistinct, inflated, with broadly depressed sutures. Periphery subacute with a thickened stubby keel, overall morphology is moderately compressed. Aperture peripheral, located in a small depression at the base of the last chamber. Test agglutinated, with a granular finish.

**Occurrence.** Single specimen found at 11550 ft.

*Haplophragmoides latissimisuteralis* Smith, 1971

Plate 2, Fig. 1

*Haplophragmoides latissimisuteralis* Smith 1971, p. 89, pl. 1, fig. 6

Small to medium, planispiral subcircular in outline, with 8 chambers in final whorl of the specimens found, sutures thick and raised compared with the often collapsed chambers, sutures become increasingly limbate with growth. Aperture is a very narrow slit at the base of the last chamber, indistinct in most specimens. Test wall finely agglutinated. Distinctive darker colouration of chambers contrasts with sutures, present in most specimens. Outline is irregular due to collapsed chambers

**Occurrence.** Occasional occurrence throughout the well.

*Haplophragmoides* cf. *indentatus* Voloshinova, 1961

Plate 2, Fig. 2

*Haplophragmoides indentatus* Voloshinova 1961 p. 190, figs 1,2.

Test medium, planispiral, semi-involute, umbilicate, undulating subcircular outline, periphery is broad and flattened; 8 chambers, inflated with broadly depressed sutures, aperture low thin slit on apertural face, often poorly preserved due to the irregular nature of the face. Wall agglutinated, coarse relative to the size of the specimens. Specimens are nonsymmetrical, skewed to one side, however we are not certain whether this is a relict of the easily deformed test or is an original test characteristic.

**Occurrence.** Moderate abundance between 10290 & 11490 ft.

**Remarks.** Specimens found closely resemble the type illustrated by Voloshinova in her fig. 2, but less so fig. 1.

*Haplophragmoides* aff. *pseudolatidorsatum* Smith, 1948

Plate 2, Fig. 3

*Haplophragmoides pseudolatidorsatum* Smith, 1948, p. 69, pl. 10, figs 7-8.

Small, planispirally coiled, subcircular outline, five chambers in last whorl, size increases rapidly, all

slightly inflated, sutures slightly depressed, subacute rounded periphery. Aperture situated at base of last chamber in depression, wall finely agglutinated. Differs from *H. pseudolatidorsatum* in that the periphery is slightly acute, combined with the presence of slight ornamentation on final chamber in the form of small rounded bosses.

**Occurrence.** Rare.

*Haplophragmoides* aff. *wilsoni* Smith, 1948

Plate 2, Figs 4, 5

*Haplophragmoides wilsoni* Smith, 1948, p. 67, pl. 9, figs 11-12. aff. *Budashevaella wilsoni* (Smith). –Cicha *et al.*, 1998, p. 86, pl. 3, fig. 13.

Medium size, circular to oval in outline, planispiral, moderately to deeply umbilicate, nine chambers in final whorl increasingly gradually in size. Sutures thick only slightly narrower than chambers, flush with test, generally of a darker colour than the chambers. Outside edge of chambers flattened giving a quadrate appearance to the cross-section. Aperture indistinct, narrow, located at the base of the apertural face. Test finely agglutinated, with large quantities of cement giving a polished appearance.

*Haplophragmoides* sp. 1

Plate 2, Fig. 6

Test small agglutinated, four similarly sized slightly inflated chambers in last whorl, sutures straight, moderately depressed, umbilical region slightly depressed. Outline circular-lobate, aperture on single recovered specimen indistinct.

**Occurrence.** Single specimen at 10,200 ft.

Genus *Veleroninoides* Saidova, 1981

*Veleroninoides veleronis* (Cushman & McCulloch, 1939)

Plate 2, Fig 7

*Haplophragmoides veleronis* Cushman & McCulloch, 1939, p. 82.

*Veleroninoides* Saidova, 1981, p. 17.

Test medium in size, evolute, open umbilicus, with the majority of earlier whorls visible in well preserved specimens. Minimum of four triangular similarly sized chambers in the last whorl, periphery broad, sutures depressed, test wall medium to finely agglutinated, with a glossy finish.

**Occurrence.** Rare.

Family SPHAERAMMINIDAE Cushman, 1933

Genus *Praesphaerammina* Kaminski & Filipescu, 2000

*Praesphaerammina subgaleata* (Va%iaek, 1947)

Plate 3, Fig. 1

*Sphaerammina subgaleata* Va%iaek, 1947, pl. 1, fig. 15.

*Praesphaerammina subgaleata* (Va%iaek). –Kaminski & Filipescu, 2000, p. 355, pl. 1, figs 1-6; pl. 2, figs 1-7.

Subspherical finely agglutinated, with final chamber encompassing approximately 60% of previous chambers. Aperture interio-areal to areal, ovate, displaying a slight lip.

**Remarks:** From the exterior, this species resembles a large specimen of *Saccammina*. However, broken specimens reveal that it is in fact multichambered, with the final chamber embracing previous chambers. This species is known from the Eocene of the Carpathian flysch, and this is the first record of it in the Miocene of the Gulf of Mexico.

Family LITUOLIDAE de Blainville, 1827

Subfamily AMMOMARGINULININAE Podobina, 1978

Genus *Ammobaculites* Cushman, 1910

*Ammobaculites* sp. 1

Plate 3, Fig. 2

Medium to large, planispiral in early chambers, becoming uniserial, last few chambers slightly curved, sutures indistinct in early section, becoming increasing depressed as chambers increase in size, later chambers slightly inflated, simple terminal aperture, wall agglutinated with medium size particles, all specimens flattened.

**Occurrence.** Low abundance in very top of well.

*Ammobaculites* sp. 2

Plate 3, Fig. 3

Only one fragment of this species found, initial planispiral portion of test present but poorly preserved, later uniserial segment only partially present.

**Occurrence.** Single specimen recovered from 10,110 ft.

*Ammobaculites?* sp. 3

Plate 3, Fig. 4

Finely agglutinated medium to large initial planispiral segment of test if obscured by deformation of test. Later uniserial section has suffered less deformation, aperture large circular terminal.

Superfamily RECURVOIDACEA Alekseychik-Mitskevich, 1973

Family AMMOSPHAEROIDINIDAE Cushman, 1927

Subfamily AMMOSPHAEROIDININAE Cushman, 1927

Genus *Ammosphaeroidina* Cushman, 1910

*Ammosphaeroidina pseudopauciloculata* (Mjatliuk, 1966)

Plate 5, Fig. 3

*Cystamminella pseudopauciloculata* Mjatliuk, 1966, p. 264, pl. 1, figs 5-7; pl. 2, fig. 6; pl. 3, fig. 3.

*Ammosphaeroidina pseudopauciloculata* (Mjatliuk). –Kaminski *et al.*, 1988, p. 193, pl. 8, figs 3-5.

Medium sized streptospirally coiled test, subcircular lobate outline, acute rounded periphery, chambers triangular, three visible in the final whorl, with the earlier streptospiral coil visible on one side of the test, the chambers have fine suture like lines cutting across them, less well developed than the sutures themselves. Sutures are depressed, aperture is a low interomarginal arch, test wall smoothly finished, with



a glossy cement plastering.

**Occurrence.** Rare in the studied section.

*Ammosphaeroidina* spp.

Fragments of indeterminate species affiliation.

Family AMMOSPHAEROIDINIDAE Cushman, 1927

Subfamily RECURVOIDINAE Alekseychik-Mitskevich, 1973

Genus *Cribrostomoides* Cushman, 1910

*Cribrostomoides* sp. 1

Plate 1, Figs 3,4

**Description.** Test medium size, planispirally coiled, open umbilical region, periphery broad, flattened, 7-9 chambers in the last whorl. Sutures limbate, slightly raised, majority of chambers are collapsed, giving the impression of raised sutures. Chambers increase gradually in size, producing a low broad apertural face. Aperture situated at base of last chamber, elongate slit with constrictions, in many cases aperture displays classic cribrations. Test is medium to finely agglutinated with smooth, well cemented finish. A variation on this species is a form that possesses a thickened lip on the last chamber.

**Occurrence.** Moderate abundance throughout the well.

Genus *Recurvoides* Earland, 1934

*Recurvoides azuaensis* Bermúdez, 1949

Plate 3, Fig. 6

*Recurvoides azuaensis* Bermúdez 1949, pl. 1, figs 35-37.

Test large, robust, moderately coarsely agglutinated, test well cemented.

**Occurrence.** Very few specimens constrained to the very top of the well.

**Remarks.** This species is distinguished by its involute coiling, few chambers, and large dimensions (>1.6 mm). The holotype is from the upper Oligocene Trincher Formation of the Dominican Republic.

*Recurvoides* sp. 1

Plate 3, Fig. 5

Test medium in size, streptospiral, low chambers increasing rapidly in width, finely agglutinated, aperture located at base of final chamber.

**Occurrence.** Single specimen found at 10110 ft.

*Recurvoides* sp. 2

Medium to fine agglutinated test small test, streptospirally coiled, sutures slightly incised, five chambers visible, increase gradually in size.

**Occurrence.** Two specimens recovered at 10110 ft.

Suborder TROCHAMMININA Saidova, 1981

Superfamily TROCHAMMINACEA Schwager, 1877

Family TROCHAMMINIDAE Schwager, 1877

Subfamily TROCHAMMININAE Schwager, 1877

Genus *Trochammina* Parker & Jones, 1859

*Trochammina* sp. 1.

Plate 5, Figs 1, 2

**Description.** Test small, low trochospiral, with at least seven chambers in the spiral side and four to six chambers on the umbilical side. Periphery subacute and rounded, chambers triangular in shape, producing a subcircular periphery. Chambers overlap on average 1/10<sup>th</sup> with the previous chamber, size increases gradually in final whorl. Sutures clear and slightly depressed. Chambers of roughly 1/2 specimens present are collapsed, producing a distinctive raised edge to the chambers. There is often a roughly agglutinated, relatively depressed region following the final chamber. Majority of specimens have undergone some degree of deformation.

**Occurrence.** Abundant between 10,320 ft and 10,680 ft.

*Trochammina* sp. 2

Test large, trochospiral, inflated chambers with depressed sutures, single specimen is deformed, initial trochospiral portion of test obscured.

**Occurrence.** Single specimen found at 10170 ft.

Suborder VERNEUILININA Mikhalevich & Kaminski, this volume

Superfamily VERNEUILINACEA Cushman, 1911

Family PROLIXOPLECTIDAE Loeblich & Tappan, 1985

*Karrerulina apicularis* (Cushman, 1911)

*Gaudryina apicularis* Cushman, 1911, textfig. 110.

*Karrerella apicularis* (Cushman). -Pflum & Frerichs, 1976, pl. 1, fig. 2.

*Karrerulina apicularis* (Cushman). -Murray & Alve, 1994, pl. 1, fig. 13. -Bender, 1995, p. 46, pl. 6, fig. 1; pl. 11, fig. 2.

All specimens flattened, test small, dark brown, sutures and chambers difficult to differentiate. Internal structure partially visible when viewed in transmitted light; majority of specimens are fragments of the initial triserial portion of the test.

**Occurrence.** Common below 12,790 ft

Order LOFTUSIIDA Kaminski & Mikhalevich, this volume

Suborder LOFTUSIINA Kaminski & Mikhalevich, this volume

Superfamily LOFTUSIACEA Brady, 1884

Family CYCLAMMINIDAE Marie, 1941

Subfamily ALVEOLOPHRAGMIINAE Saidova, 1981

Genus *Reticulophragmium* Maync, 1955

*Reticulophragmium* cf. *venezuelanum*

Text small, planispiral, subangular/circular outline, acute periphery, resembles *R. venezuelanum* however is rare, and all specimens are poorly preserved.

*Reticulophragmium rotundidorsatum* (von Hantken, 1875)

Plate 3, Fig. 7

*Haplophragmoides rotundidorsatum* von Hantken, 1875, p. 12,



pl. 1, fig. 2.

*Cyclammina* sp. Samuel, 1977, p. 48, pl. 7, fig. 5.

*Cyclammina rotundidorsata* (von Hantken). –Gradstein & Berggren, 1981, p. 256, pl. 7, figs 9-12.. –Morgiel & Olszewska, 1981, p. 14, pl. 4, fig. 15. –Geroch & Nowak, 1984, pl.3, figs 1-3, pl. 6, figs 14-16.

*Cyclammina* (*Reticulophragmium*) *rotundidorsata* (von Hantken). –Charnock & Jones, 1990, pl.7, figs 13-15, pl. 19, fig. 1.–Charnock & Jones, 1997, pl. 6, fig. 5, pl. 8, figs 1 - 2. *Reticulophragmium rotundidorsatum* (von Hantken). –Cicha, et. al. 1998, pl. 5. fig. 5.

Test small to medium, involute planispiral, periphery broad, rounded, width to length ratio nearly 1:1 giving a subspherical shape. Chambers increase in size more rapidly in the last three chambers, final chamber is extremely wide and obscures umbilical depression. Sutures are very narrow and very slightly depressed. Multiple apertures located along the base of the final chamber. Wall agglutinated, fine-grained, alveoles visible as pale spots closely and evenly spaced over the entire test.

**Remarks.** Hantken (1875) described it from lower Oligocene epicontinental deposits in Hungary, and it is known from the middle Eocene to Oligocene in the Carpathians, Labrador Margin, and North Sea, and in the Miocene of the Norwegian-Greenland Sea. Diaz de Gamero (1977) reported it from the basal Pecaya Formation (lowermost Miocene) of the Falcon Basin, Venezuela.

Subfamily CYCLAMMININAE Marie, 1941

Genus *Cyclammina* Brady, 1879

*Cyclammina acutidorsata* (von Hantken, 1868)

Plate 4, Fig. 1

*Haplophragmium acutidorsatum* von Hantken, 1868, p. 82, pl. 1, fig. 1.

*Cyclammina placenta* (Reuss). –Gradstein & Berggren, 1981 (part), p. 252, pl.7, fig. 7.

*Cyclammina acutidorsata* (von Hantken). –Diaz de Gamero 1977, pl. 3, fig. 3. –Verdenius & van Hinte, 1983, p. 194, pl. 5, fig. 10, pl. 6, figs 2-3.

*Reticulophragmium acutidorsatum* (von Hantken). –King, 1989, p. 458, pl. 9.2, fig. 15.

Test small to medium, involute planispiral outline flattened subcircular. 12 chambers in last whorl, size of chambers increases gradually, sutures narrow and slightly depressed, aperture is a low arch at base of last chamber. Alveoles distributed evenly over entire test, visible in areas where outer wall of test is absent. Wall agglutinated and fine grained.

**Occurrence.** Singular specimens distributed throughout.

**Remarks.** *Cyclammina acutidorsata* was described from the upper Oligocene of Hungary, and it is common in the Miocene of the Alpine-Carpathian foredeep basin throughout central Europe. Diaz de Gamero (1977) reported it from the mid Oligocene (P. opima Zone) to the lower Miocene (C. dissimilis Zone) in the Falcon Basin of Venezuela.

*Cyclammina* cf. *acutidorsata*

Plate 4, Fig. 2

**Description.** Rounded quadrate outline, planispirally coiled with at least 10 chambers in the last whorl.

Sutures slightly depressed, indistinct in some places leading to difficulty in distinguishing chambers. Distinctive inflated region forming a wide lip on the last chamber, encroaches somewhat into the umbilical region, covering the umbilicus in-part. Periphery moderately acute, with rounded apex. Aperture multiple, situated centrally at the base of the apertural face, nest of small rounded bosses indicates the presence of multiple apertures. Test possesses evenly spaced covering of small subcircular depressions indicating the presence of an alveolar inner structure. **Occurrence.** Single specimen at 12690 ft.

*Cyclammina cancellata* Brady, 1879

Plate 4, Figs 3, 4

*Cyclammina cancellata* Brady, 1879, p. 62.. –Kohl, 1985, p. 28, pl. 1, figs 4a-b.

Test medium sized, involute, planispiral, 11 chambers visible in final whorl, chambers wedge shaped, increase gradually in size, circular alveolar internal structure visible in places where outer layer of wall is missing. Subacute periphery, oval outline, sutures thin, flush with test. Depressed umbilical region, final two chambers encroach into this depression. Apertural face flat with aperture located towards the base, surrounded by multiple apertures concentrated around the primary aperture. Wall agglutinated, medium grained, well cemented, with a granular finish.

**Occurrence.** Occasional throughout the studied interval.

*Cyclammina* cf. *orbicularis*?

**Description.** Heavily alveolar form possessing 12 chambers, size increases steadily in the final whorl, sutures moderately depressed, umbilical regions clear. Test has regularly spaced, closely packed covering of circular depressions, indicating the location of alveolar structures. Outline subangular to circular, broad rounded periphery. Apertural face is broad and moderately high, possessing a raised region in centre, apparently composed from multiple alveoles.

**Occurrence.** Single specimen at 11400 ft.

Suborder ATAXOPHRAGMIINA Fursenko, 1958

Superfamily ATAXOPHRAGMIACEA Schwager, 1877

Family GLOBOTEXTULARIIDAE Cushman, 1927

Subfamily LIEBUSELLINAE Saidova, 1981

Genus *Jarvisella* Brönnimann, 1953

*Jarvisella karamatensis* Brönnimann, 1953

Plate 5, Fig. 4

*Jarvisella karamatensis* Brönnimann, 1953, p. 88, pl. 15, fig. 7.

Test ovate in outline, somewhat flattened, early chambers trochospirally enrolled, triserial in the adult, sutures much depressed and crenulated as a result of internal structure; wall finely agglutinated with much cement, dimpled surface texture, thin, imperforate, and readily compressed and distorted; aperture an interiomarginal arch, slightly depressed.

**Occurrence.** Two complete specimens found at 11460

ft and 12630 ft.

**Remarks.** Few complete specimens found, however, a large volume of fragmentary material appears to originate from *J. karamatensis*.

Family TEXTULARIELLIDAE Grönhagen & Luterbacher, 1966

Genus *Alveovalvulina* Brönnimann, 1951

*Alveovalvulina suteri* Brönnimann, 1951

Plate 5, Figs 5, 6

*Alveovalvulina suteri* Brönnimann, 1951, p. 102, pl. 11, fig. 5.

Test with early trochospiral stage of three or more chambers per whorl, later reduced to triserial, chambers strongly overlapping those of earlier whorls; wall agglutinated, with alveolar structure; aperture a low interiomarginal arch

Genus *Alveovalvulinella* Brönnimann, 1953

*Alveovalvulinella* Brönnimann, 1953, p. 90. –Loeblich & Tappan, 1964, p. C298, fig. 204, 5-7

Having compared the type figures for both *Guppyella* and *Alveovalvulinella*, we disagree with the synonymy of the two genera proposed by Loeblich & Tappan, 1988. *Alveovalvulinella* is herein reinstated, adhering to the description of Loeblich & Tappan, 1964, who described the genus as follows: "Test elongate, early chambers trochospiral, later triserial, biserial and finally uniserial; interior of chambers peripherally subdivided by traverse and longitudinal plates, forming alveoles, as in *Alveovalvulina*; wall agglutinated; aperture terminal, rounded in adult."

There are numerous valid morphological differences between *Guppyella* and *Alveovalvulinella* that warrant their being two separate genera. *Guppyella* is described as having 4-5 chambers in its initial trochospiral section, where as in the initial trochospire of *Alveovalvulinella* is indistinct, preventing an accurate determination of the number of chambers present. The wall of *Guppyella* is considerably thicker than that of *Alveovalvulinella*, with the majority of the chambers infilled with internal structure; the chamber walls of *Alveovalvulinella* contain complex internal structure, they however remain discrete; in the case of *Guppyella* the alveoles are sufficiently dense to interconnect chambers, they impinge through into the axial cavity. The uniserial section of *Alveovalvulinella* is restricted to the last 1-2 chambers, *Guppyella* becomes uniserial more rapidly in ontogeny, with over 1/2 the test being uniserial; *Guppyella*'s uniserial chambers are low broad and subcircular in section, *Alveovalvulinella*'s chambers are generally higher and ovate in section; The aperture of *Guppyella* is terminal, *Alveovalvulinella* is areal to terminal, only becomes terminal in adult; *Guppyella* is recorded from shallow water facies where as *Alveovalvulinella* is recorded as deep water.

*Alveovalvulinella pozonensis* (Cushman & Renz, 1941)

Plate 6, Figs 1, 2

*Liebusella pozonensis* Cushman & Renz, 1941, p. 9, pl. 2, figs

1, 2. –Renz, 1948, p. 144, pl. 2, figs 21, 22.

*Alveovalvulinella pozonensis* (Cushman & Renz). –

Brönnimann 1953, p. 91, pl. 15, fig. 3, textfigs 3e, 4a,b, 5a-d, 6g,h, 7.

**Occurrence.** Common in lower section of well.

**Remarks.** The majority of specimens of this species occur as fragments of the later, uniserial stages. Many of the specimens found appear to be juveniles and can be distinguished from *Alveovalvulina* due to the presence of a lip surrounding the more depressed aperture of *Alveovalvulinella*.

Order TEXTULARIIDA Delage & Herouard, 1896

Suborder TEXTULARIINA Delage & Herouard, 1896

Superfamily EGGERELLACEA Cushman, 1937

Family EGGERELLIDAE Cushman, 1937

Subfamily DOROTHIINAE Balakhmatova, 1972

?*Dorothia* sp. 1

Plate 6, Fig. 3

Finely agglutinated test, noncalcareous wall, initially trochospiral, three to four chambers per whorl, becoming biserial. Chambers inflated, last six increase gradually in size through ontogeny, aperture an interiomarginal slit in an arched reentrant of the ultimate chamber.

**Occurrence.** Single specimen found at 12,820 ft.

Subfamily EGGERELLINAE Cushman, 1937

Genus *Eggerella* Cushman, 1935

*Eggerella bradyi* Cushman, 1911

*Verneuilina bradyi* Cushman, 1911, p. 54.

Test large, high trochospire initially with 5 chambers per whorl, later stages have three. Only a single specimen found, poorly preserved, a pyrite infilling with remnants of the calcareous test still present.

*Eggerella* spp.

Several fragments occur throughout which closely resemble chambers of *Eggerella*.

Genus *Martinottiella* Cushman, 1933

*Martinottiella communis* (d'Orbigny, 1846)

*Clavulina communis* d'Orbigny, 1846, pl. 12, figs 1,2. –

Cushman & Barbat, 1932, pl. 5, figs 15, 16.

*Martinottiella communis* (d'Orbigny). –Bender, 1995, p. 46, pl. 6, fig. 16.

**Comments.** Found in fragmentary form, mostly the uniserial section of the test is preserved, no complete specimens found.

*Martinottiella aff. antillarum* (Cushman, 1936)

Plate 6, Fig. 4

*Listerella antillarum* Cushman, 1936, p. 41, pl. 6, fig. 12. –

Cushman, 1937, p. 152, pl. 17, figs 29, 30.

*Schenckiella antillarum* (Cushman). –Bermúdez, 1949, p. 92, pl. 5, figs 45, 46.

Initial portions of test appears to be trochospiral, becoming triserial, chambers increase rapidly in size, stabilises by the time the test is triserial, last three chambers comprise majority of length, are uniserial

with broadly depressed sutures. Aperture a rounded oblong slit situated terminally, small neck mounted on a raised area. Wall moderately coarsely agglutinated, glossy due to volume of cement.

**Occurrence.** Two specimens found at 12,660 ft. and 12,720 ft

**Remarks.** Differs from the specimen figured in Bermúdez (1949) in that the wall does not possess the 'spines' illustrated. The test wall of one of the specimens does have an irregular surface due to the arrangement of angular grains.

Family VALVULINIDAE Berthelin, 1880

Subfamily VALVULININAE Berthelin, 1880

Genus *Valvulina* d'Orbigny, 1826

*Valvulina flexilis* Cushman & Renz, 1941

Plate 7, Figs 4, 5, 6,

*Valvulina flexilis* Cushman & Renz, 1941, figs 16-17. – Cushman & Stainforth, 1945, p. 17, pl. 2, fig. 4. – Cushman & Renz, 1948, p. 177, pl. 2, figs 12a-c. – Renz, 1948, pl. 2, figs 11-12. – Brönnimann, 1953, textfig. 15. – Diaz de Gamero, 1977, pl. 3, fig. 13.

Text initially triserial, becoming biserial in adult stage. Chambers are frequently severely deformed resulting in a wide range of morphologies, very few specimens closely resemble Cushman's original description. Few specimens display any form of fracture, suggesting that the tests are prone to plastic deformation. Specimens placed into this species all possess the distinctive arrangement of the ultimate and penultimate chambers.

**Occurrence.** Common throughout the well.

**Remarks.** First described from the upper Oligocene "lower Agua Salada Formation" by Cushman & Renz (1941), it is regarded to be the index species for the "Agua Salada Fauna" (Renz, 1948). Its range in Trinidad was reported as upper Oligocene to middle Miocene by Brönnimann (1953). Blow (1959) recorded it from the Miocene upper Tocuyo and Pozon Formations of eastern Falcon, Venezuela. Diaz de Gamero (1977) established an uppermost Oligocene *V. flexilis* Zone in the Falcon Basin of Venezuela. It has also been observed in the lower Miocene of the Sirte Basin, Libya, offshore Cabinda, and in the Miocene of Transylvania (Preece, 1999).

*Valvulina* spp.

Plate 7, Figs 7, 8

Included within this category are all species of *Valvulina* that have been severely deformed, but still retain the chamber arrangement characteristic of *Valvulina*.

**Occurrence.** Common, especially towards the lower section of the well.

Superfamily TEXTULARIACEA Ehrenberg, 1838

Family TEXTULARIIDAE Ehrenberg, 1838

Subfamily TEXTULARIINAE Ehrenberg, 1838

Genus *Textularia* DeFrance, 1824

*Textularia mexicana* Cushman, 1922

Plate 6, Fig. 5

*Textularia mexicana* Cushman, 1922, p.17, pl. 2, fig. 9. – Diaz de Gamero, 1977, pl. 3, fig. 6. – Kohl, 1985, p. 117, pl. 2, fig. 3. – Picou *et al.* 1999, data sheet 136.

Medium sized, biserial throughout, chamber size increases regularly producing a lanceolate outline, periphery rounded acute. Chambers are oblong, angled downwards where the two sets join producing a 'zig zag' median ridge. Sutures straight, limbate and raised in relation to the chambers, at least 18 chambers visible. Final two chambers also depressed relative to sutures, aperture a low arch at base of apertural face, located in suture between penultimate and final chambers. Test finely agglutinated with a degree of cement plastering.

**Occurrence.** Low abundance between 12660 ft and 12750 ft.

*Textularia tatumi* Cushman & Ellisor, 1939

Plate 6, Fig. 6

*Textularia tatumi* Cushman & Ellisor, 1939, p. 2, pl. 1, fig. 2. – Picou *et al.*, 1999, data sheet 148.

Test small, biserial, chambers elongate, curved some slightly depressed, sutures flush, curved, absence of distinct median ridge, outline squat triangular, inflated rhomboidal cross section. Final chamber inflated producing an apertural depression at base of apertural face, wall fine to medium grained irregularly agglutinated with cement plastering.

**Occurrence.** Occasional between 12,630 ft and 12,930 ft.

**Remarks.** The species was first described from the Miocene of Ameranda Oil Co. well no. 1, St. Charles Parish LA, 9074-79'.

*Textularia* sp. 1

Plate 6, Fig. 7

**Description.** Test large, highly inflated biserial, 20 elongate chambers with a chisel shape where they meet forming a high amplitude, short wavelength 'zig zag' median ridge, sutures slightly raised. Specimen is 1/2 as wide as it is long, smooth lanceolate outline, blunt-acute periphery, domed last chamber creating incised arched aperture in base of apertural face. Wall agglutinated with fine granular surface.

**Occurrence.** Single specimen at 11,340 ft.

*Textularia* sp. 2

Plate 6, Fig. 8

**Description.** Medium size, biserial rounded lanceolate outline rounded acute periphery, chambers depressed, rounded margins, joining at broad slightly raised median suture, sutures themselves are slightly raised, width to length ratio is 1:2, aperture located at the base of the apertural face, a thin elongate straight slit, no distinct suture between the final two chambers. Test agglutinated, medium grained, with a granular surface.

**Occurrence.** Single specimen found at 12630 ft.

*Textularia* sp. 3

Plate 7, Fig. 1

**Description.** Test large, biserial, chambers become curved and overlap across the median line forming a chevron pattern, 14 chambers, Test 1/4 as wide as it is long, periphery subacute, outline is ribbed. Chambers slightly inflated, protrude above the sutures, are of a yellow/brown colour where as the sutures are brown. The periphery of each chamber is rounded acute in side view, creating a distinctive relief in comparison to the depressed sutures. Each suture appears as if it in-fills the space between the chambers, finished with cement plastering. Aperture situated at base of apertural face, elongate rectangular slit, flanked by raised region. Test fine grained agglutinated, smooth plastered finish, especially in sutures.

**Occurrence.** Single specimen found at 12,790ft.

#### ?*Textularia* sp. 4

Plate 7, Fig. 2

**Description.** Small to medium size, biserial test, early chambers increase rapidly in size forming an a sharply angled initial portion, later chambers of similar size approximately 18 chambers. Chambers are depressed and roughly twice as wide as sutures. Sutures slightly raised limbate, forming a 'zig zag' medial line, chambers meet at low angle in along median line. Outline is lanceolate with some serration created by abnormally wide chambers. Terminal chamber forms a saddle shaped depression flanked by two limbate sutures on the periphery of the test. Aperture situated at the base of apertural depression, in the form of an indistinct slit.

**Occurrence.** Two specimens recovered at 12,660 ft and 12,720 ft.

**Discussion.** The initial chambers are fragile and are therefore missing on the specimens present; it appears that these initial chambers may be planispirally arranged, thus placing this species in the genus *Spirorutilus*.

#### *Textularia* sp. 5

Plate 7, Fig. 3

Very small, biserial, 12 chambers, chambers severely flattened with the exception of final two chambers, sutures rounded limbate, same thickness as chambers, especially robust on last two chambers. Median ridge is raised and rounded producing a 'backbone', becoming increasingly prominent with compression. Rounded acute periphery, compressed lanceolate outline, aperture located at base of apertural face bordered by robust limbate rim or lip.

**Occurrence.** Two specimens found at 12,030 ft and 12,090 ft.

### CONCLUSIONS

We report the occurrence of 45 species of deep-water agglutinated foraminifera from the V.K. 915 well, offshore Louisiana. Several of species described from the Palaeogene of Central Europe are reported for the first time in the Neogene of the Gulf of Mexico. The stratigraphic succession and abundance of certain species associations result in the determination of three stratigraphic assemblages in the well:

1. *Haplophragmoides* cf. *bradyi*-*Trochammina* sp. 1 assemblage from 10,200 to 10,680 ft.
2. *Alveovalvulina*-*Alveovalvulinella*-*Valvulina flexilis* assemblage from 10,830 to 11,190 ft.
3. *Valvulina flexilis*-*Textularia* spp. assemblage from 12,300 to 12,930 ft.

In general, the assemblages indicate slope (probably upper bathyal) environments under the influence of an oxygen minimum zone. Evidence for this is the occurrence of numerous organically-cemented taxa with complex alveolar inner structures (perhaps to facilitate gas exchange), as well as the dominance of tapered-cylindrical morphotypes that were probably mobile infaunal detritivores according to the morphotype classification of Corliss and co-workers (Corliss & Chen, 1988). These infaunal organisms tend to be opportunistic and dominate in dysaerobic environments (Kaminski *et al.*, 1995). The correlation between coarse grain size and increased foraminiferal abundance appears to be related to sea level variations affecting surface productivity.

Several of the species have been suggested to exhibit an environmental preference for soft (muddy) substrate, often associated with oxygen minimum zones. It is possible that the 'Harang fauna' recorded from the lower interval of the well were able to inhabit such a substrate during periods of higher sediment oxygenation.

The indication that intensity of the OMZ fluctuated throughout the Neogene is corroborated by changes in species composition and variations in sediment grain size downwell. The presence of an infaunal, low-oxygen-adapted fauna dominated by *Valvulina flexilis* and *Reticulophragmium rotundidorsatum* succeeding the epifaunal *Haplophragmoides* cf. *bradyi*, *Trochammina* sp. 1. assemblage is indicative of a return to deposition below the OMZ.

### ACKNOWLEDGEMENTS

We gratefully acknowledge AMOCO (now BP exploration) for donating the sample material, and we thank Brian O'Niell and Sorin Filipescu for reviewing a draft of this paper. RCG was supported by a NERC-CASE Industrial Studentship award, cosponsored by TIMETRAX Ltd (with special thanks to Janice Weston). We also thank Jim Davy and the technical staff at UCL for their assistance, and Andy Henderson (NHM) for advice on photographic procedures. This is contribution nr. 71 of the Deep-Water Agglutinated Foraminiferal Project.

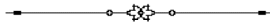
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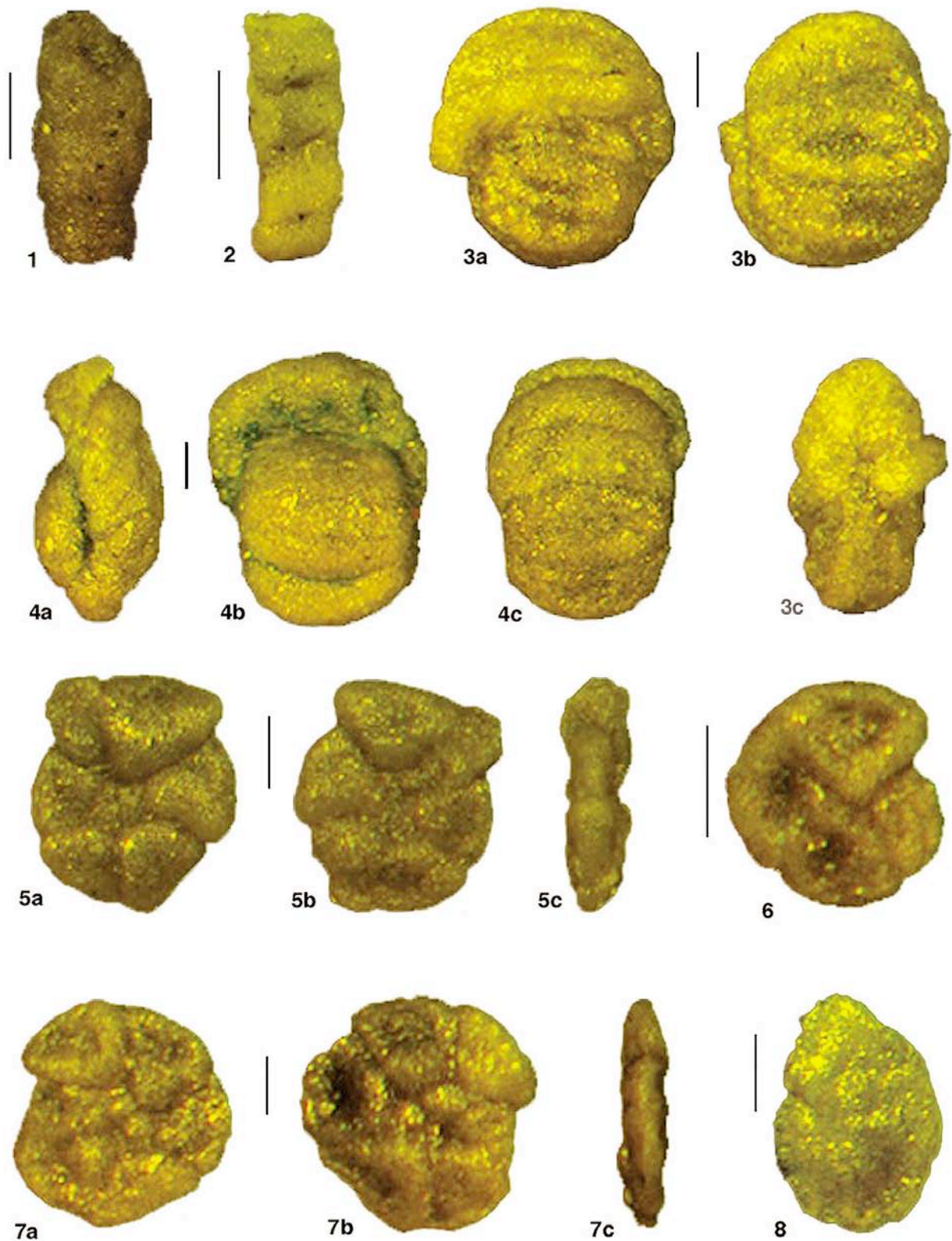






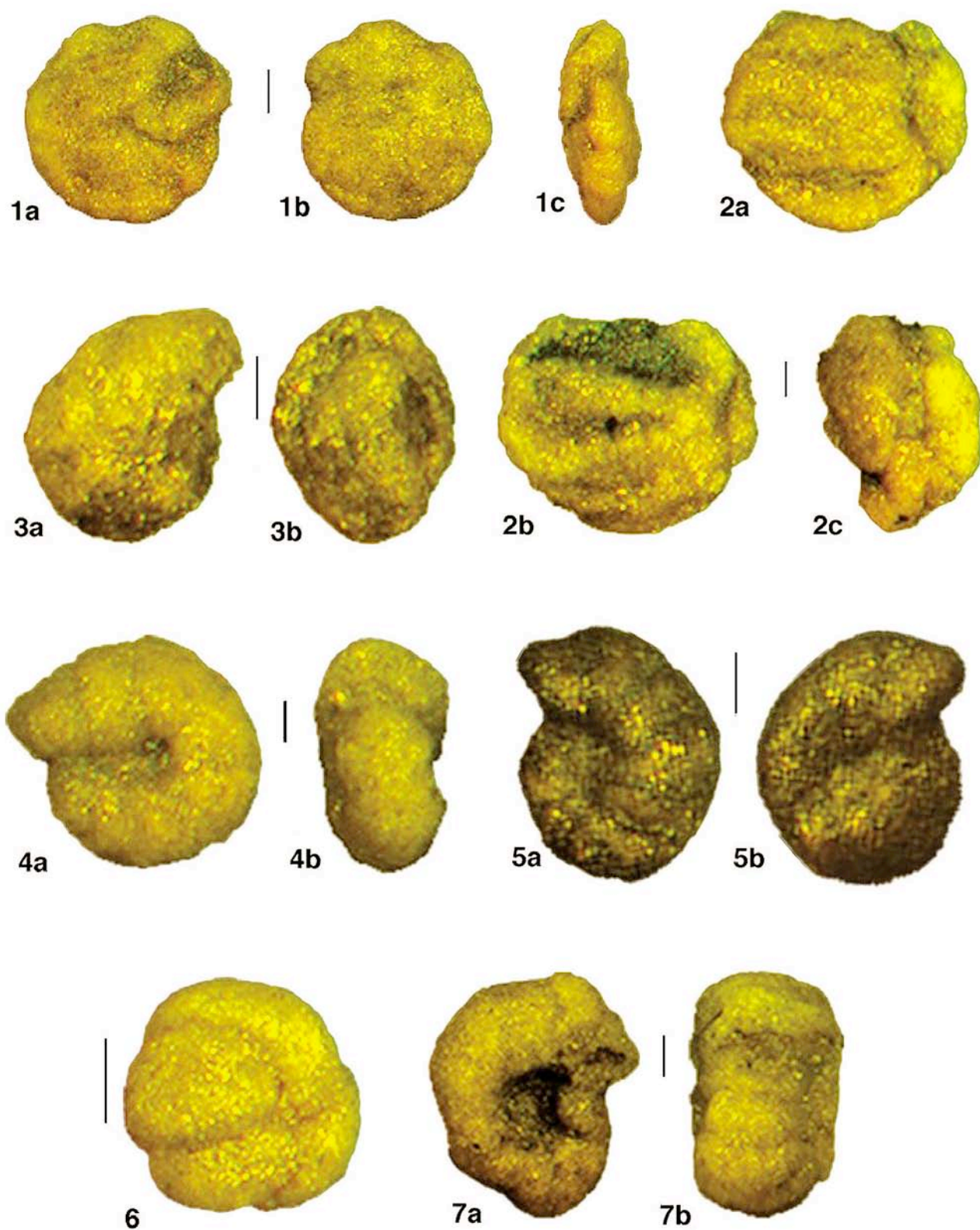




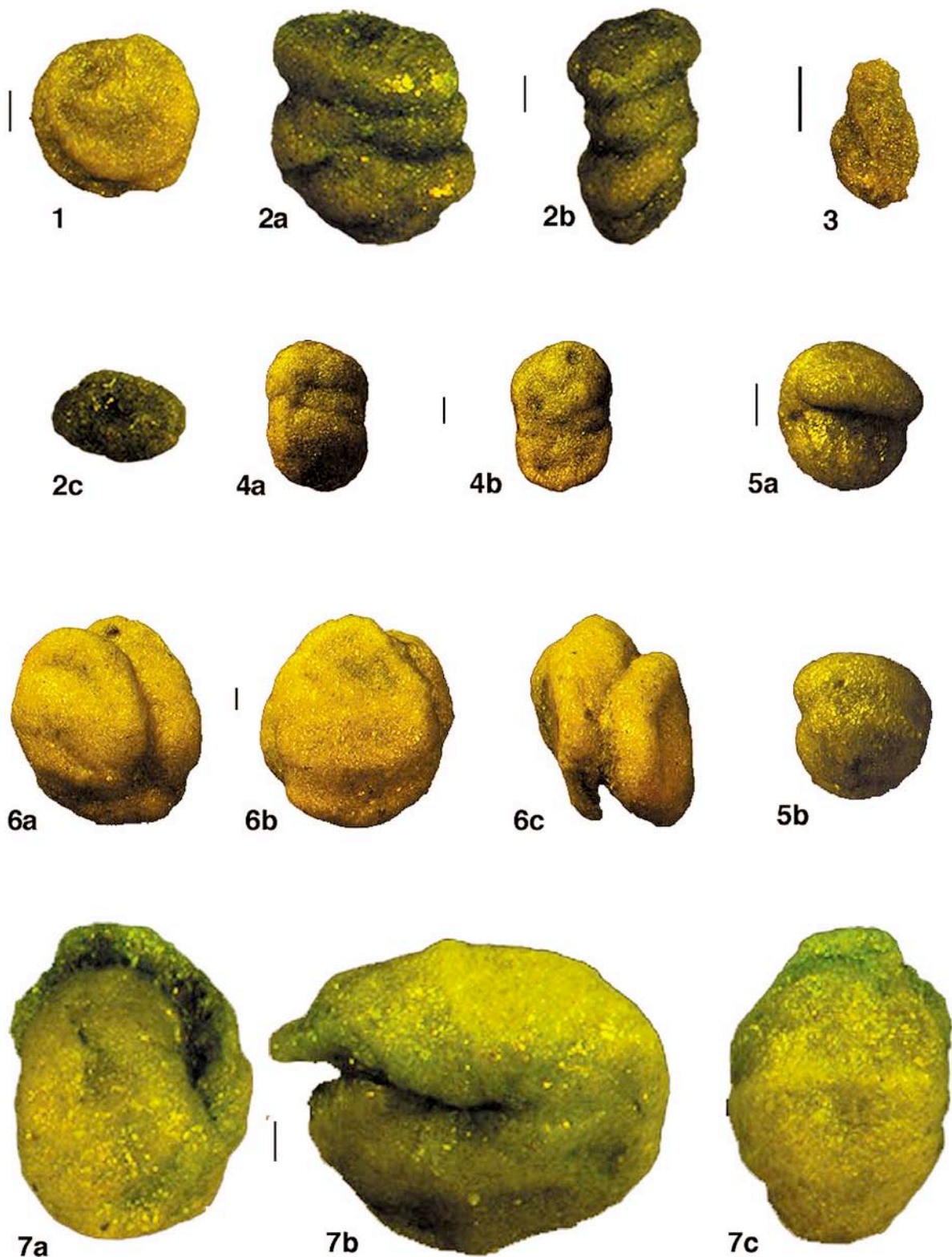


**Plate 1.** 1. *Rhabdammina* sp., 10,140 ft. 2. *Rhabdammina annulata* Grzybowski, 10,560 ft. 3. *Cribrostomoides* sp. 1., 10,350 ft. a. apertural view, b. dorsal view, c. lateral view. 4. *Cribrostomoides* sp. 1., 10,590 ft. a. lateral view, b. apertural view, c. dorsal view. 5. *Haplophragmoides* cf. *bradyi* (Robertson), 10,290 ft. a,b. lateral views, c. apertural view. 6-7. *Haplophragmoides* cf. *bradyi* (Robertson), 11,550 ft. a,b. lateral view, c. apertural view. 8. *Haplophragmoides carinatus* Cushman & Renz, 10,200 ft. All scale bars 100  $\mu$ m.



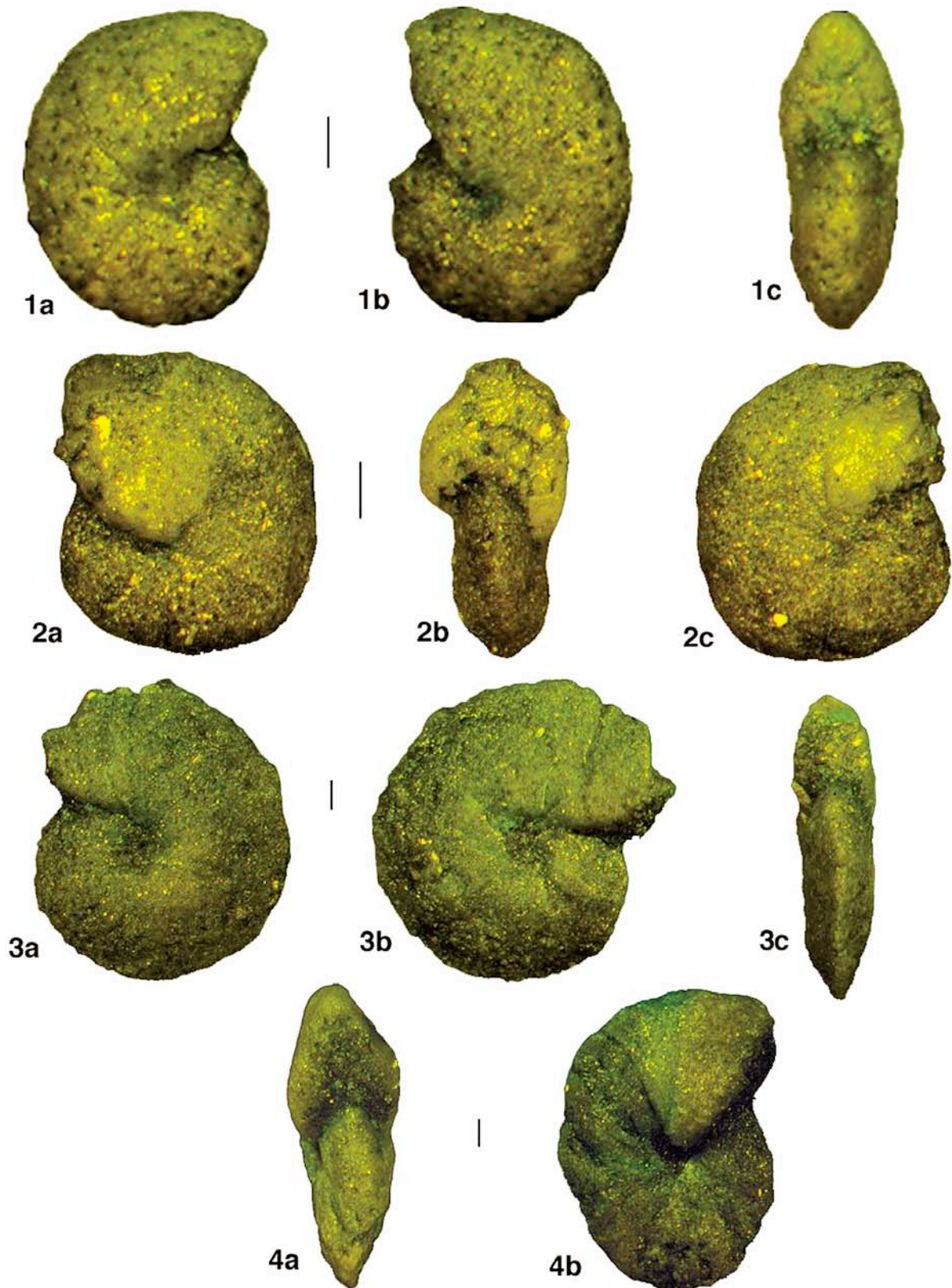


**Plate 2.** 1. *Haplophragmoides latissimisuteralis* Smith, 10,500 ft. a,b. lateral views, c. apertural view. 2. *Haplophragmoides* cf. *indentatus* Voloshinova, 10,680 ft. a,b. lateral views, c. apertural view. 3. *Haplophragmoides* aff. *pseudolatidorsatum* Smith, 10,770 ft. a. lateral view, b. apertural view. 4-5. *Haplophragmoides* aff. *wilsoni* Smith, 4. 10,260 ft., 5. 11,130 ft. a. lateral view, b. apertural view. 6. *Haplophragmoides* sp. 1. 10,200 ft. 7. *Veleroninoides veleronis* (Cushman & McCulloch), 11,430 ft. a. lateral view, b. apertural view. Scale bars = 100  $\mu$ m.

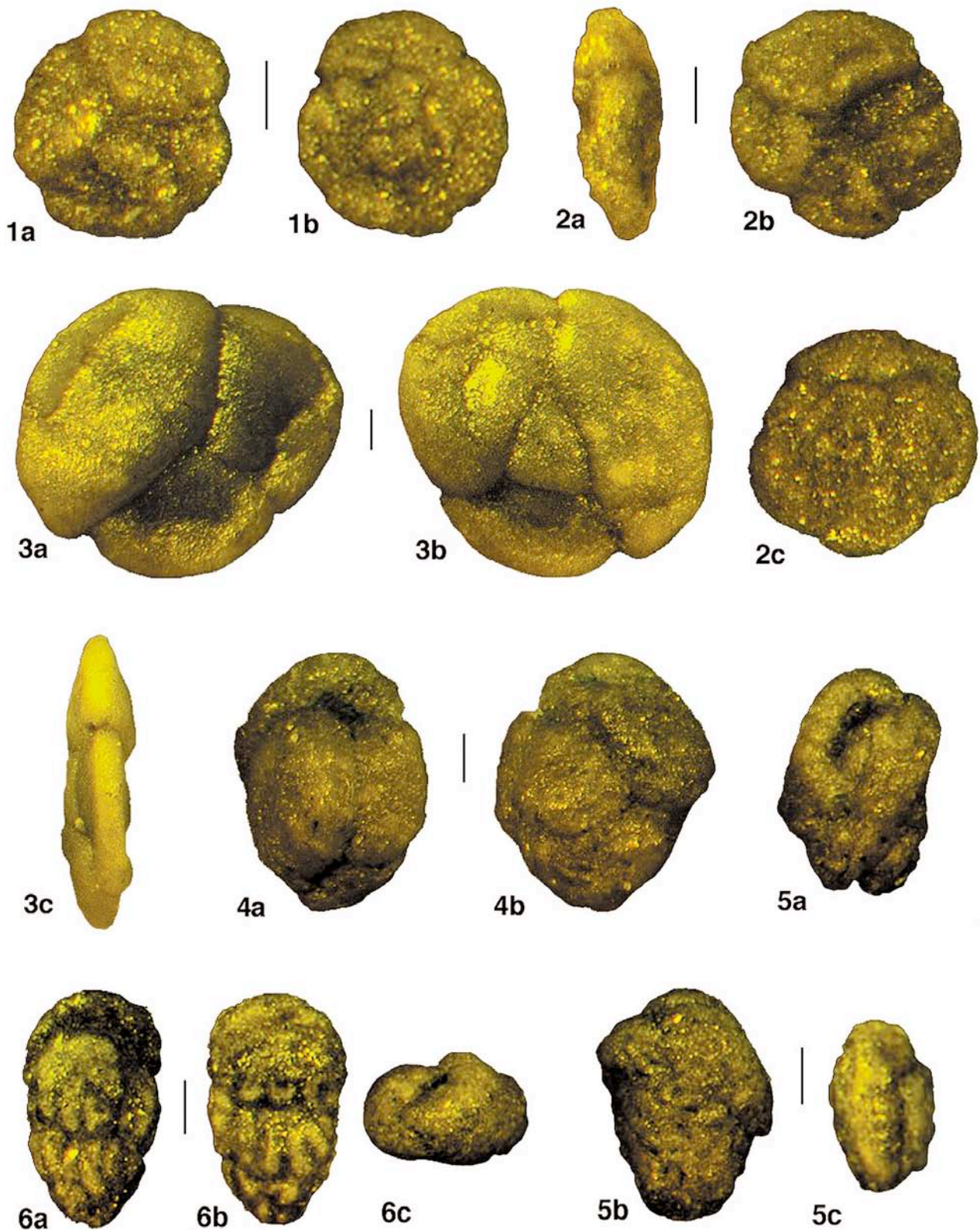


**Plate 3.** 1. *Praesphaerammina subgaleata* (Valko), 10,080 ft.; 2. *Ammobaculites* sp. 1, 10,110 ft.; a,b. lateral views, c. apertural view; 3. *Ammobaculites* sp. 2, 10,050 ft.; 4. *Ammobaculites?* sp. 10,170 ft. lateral views; 5. *Recurvoides* sp. 1. a. apertural view, b. dorsal view; 6. *Recurvoides azuaensis* Bermúdez, 10,230 ft. a. apertural view, b. dorsal view, c. lateral view; 7. *Reticulophragmium rotundidorsatum* (von Hantken), 10,110 ft. a. apertural view, b. lateral view, c. dorsal view. Scale bars = 100  $\mu$ m.





**Plate 4.** 1. *Cyclammina acutidorsata* (von Hantken), 10,980 ft. a,b. lateral views, c. apertural view; 2. *Cyclammina* cf. *acutidorsata*, 11,400 ft. a,c. lateral views, b. apertural view; 3-4. *Cyclammina cancellata* Brady, 12,750 ft. a,b. lateral views, c. apertural view. Scale bars = 100  $\mu$ m.

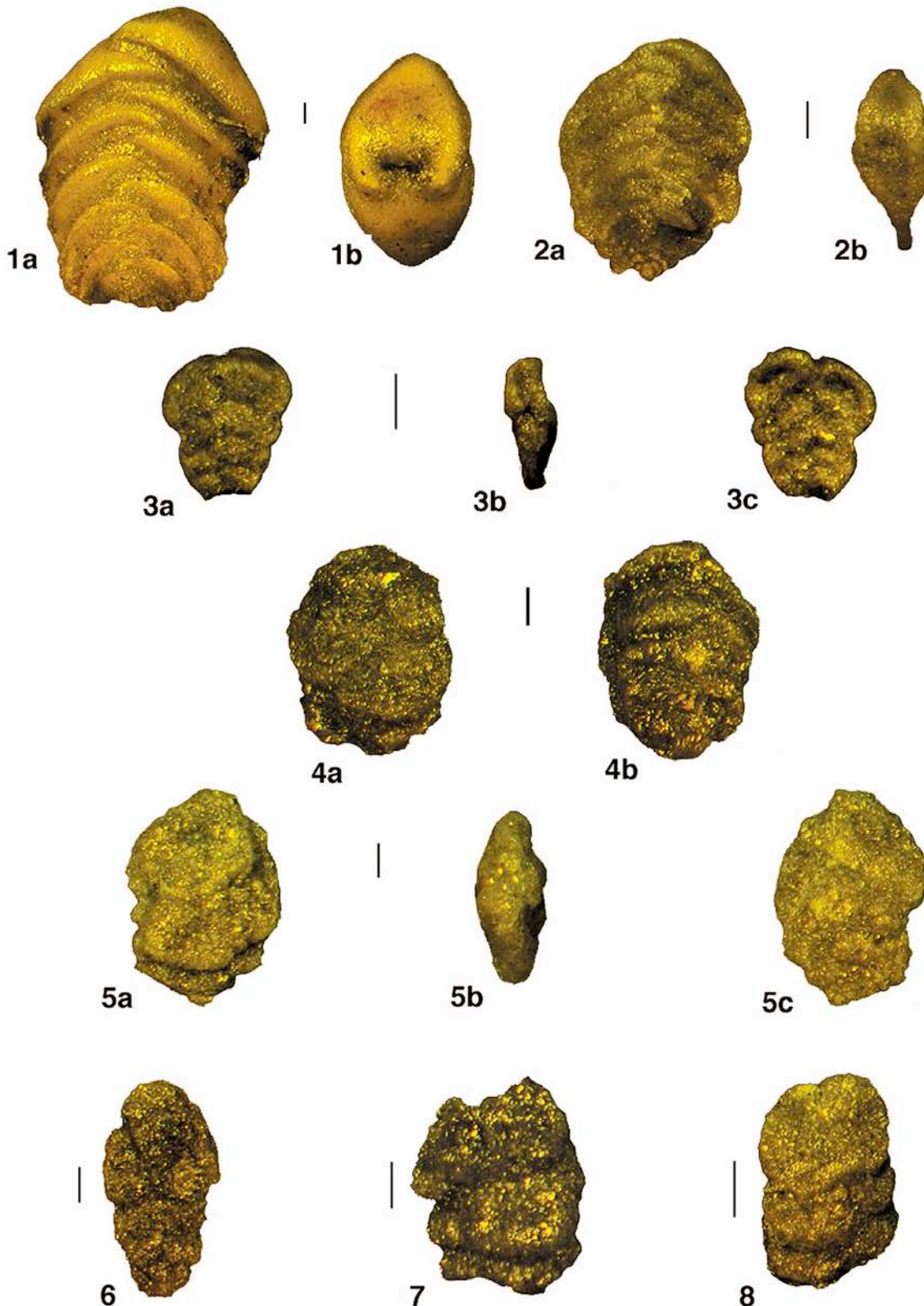


**Plate 5.** 1. *Trochammina* sp. 1. 10,410 ft. a. ventral view, b. dorsal view; 2. *Trochammina* sp. 1. a. edge view, b. ventral view, c. dorsal view; 3. *Ammosphaeroidina pseudopauciloculata* (Mjatliuk), 11,340 ft. a. ventral view, b. dorsal view, c. edge view; 4. *Jarvisella karamantensis* Brönnimann, 11,460 ft. lateral views; 5-6. *Alveovalvulina suteri* Brönnimann, 5. 10,830 ft. 6. 10,470 ft. a,b. lateral views, c. apertural view.





**Plate 6.** 1. *Alveovalvulinella pozonensis* (Cushman & Renz), 11,220 ft. a,b. lateral views, c. apertural view; 2. *Alveovalvulinella pozonensis* (Cushman & Renz), 11,490 ft. a,c. lateral views, b. apertural view. 3. *Dorothyia* sp. 12,820 ft. a,b. lateral views, c. apertural view; 4. *Martinotiella antillarum* (Cushman), 12,720 ft. a. lateral view, b. apertural view; 5. *Textularia mexicana* Cushman, 12,720 ft. a. lateral view, b. apertural view; 6. *Textularia tatumi* Cushman & Ellisor, 12,690 ft. a. lateral view, b. apertural view; 7. *Textularia* sp. 1, 11,340 ft. a. lateral view, b. apertural view; 8. *Textularia* sp. 2, 12,630 ft. a. lateral view, b. apertural view. Scale bars = 100  $\mu$ m.



**Plate 7.** 1. *Textularia* sp. 3. 12,790 ft. a. lateral view, b. apertural view; 2. *Textularia* sp. 4. 12,660 ft. a. lateral view, b. apertural view; 3. *Textularia* sp. 5. 12,030 ft. a, c. lateral views, b. apertural view; 4-6. *Valvulina flexilis* Cushman & Renz, 4. 10,920 ft. a lateral view showing aperture, b. lateral view, 5. 11,110 ft., a, c. lateral views, b. apertural view, 6. 10,830 ft., lateral view; 7, 8. *Valvulina* spp. (possibly *V. flexilis*) specimens showing characteristic deformation. Scale bars = 100  $\mu$ m.