

## Neogene benthic foraminifera from the southern Bering Sea (IODP Expedition 323)

Eiichi Setoyama and Michael A. Kaminski

### ABSTRACT

This study describes a total of 95 calcareous benthic foraminiferal taxa from the Pliocene–Pleistocene recovered from IODP Hole U1341B in the southern Bering Sea with illustrations produced with an optical microscope and SEM. The benthic foraminiferal assemblages are mostly dominated by calcareous taxa, and poorly diversified agglutinated forms are rare or often absent, comprising only minor components. Elongate, tapered, and/or flattened planispiral infaunal morphotypes are common or dominate the assemblages reflecting the persistent high-productivity and hypoxic conditions in the deep Bering Sea. Most of the species found in the cores are long-ranging, but we observe the extinction of several cylindrical forms that disappeared during the mid-Pleistocene Climatic Transition.

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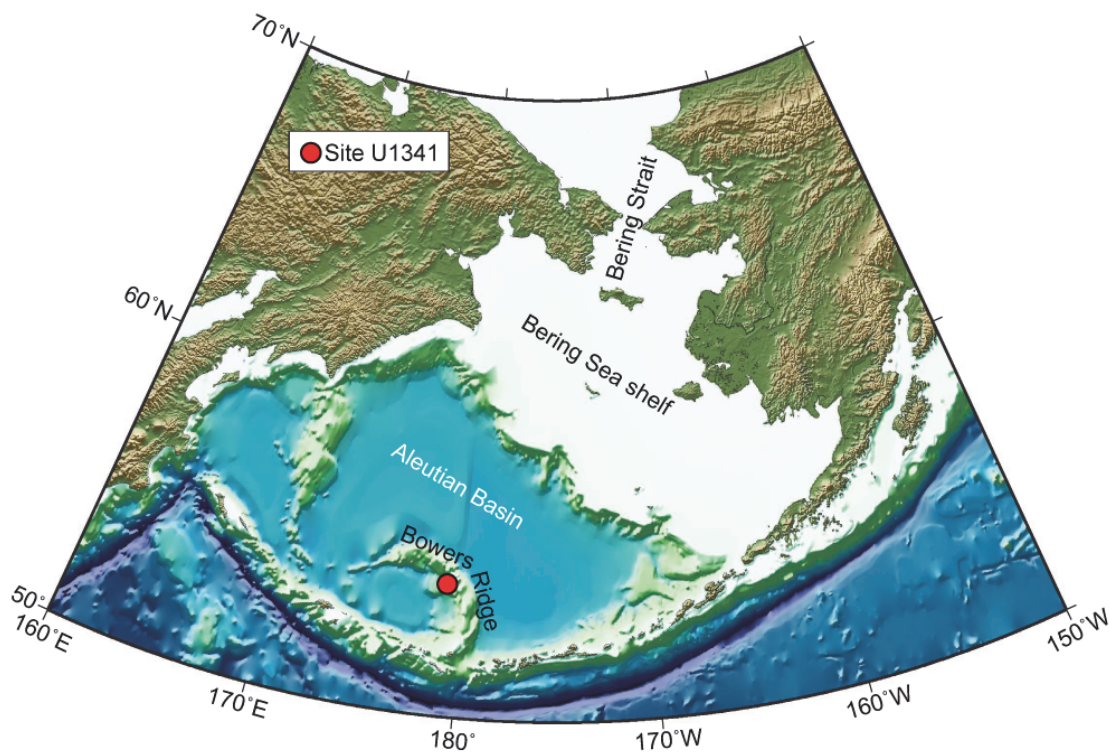
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### INTRODUCTION

The Bering Sea is a large, permanently hypoxic deep basin that has a well-developed oxygen-minimum zone (Takahashi et al., 2011). Despite being one of the largest marginal seas, whose dimensions are comparable to that of the Mediterranean, the fossil benthic foraminiferal assemblages of the Bering Sea have barely been studied. Drilling in the southern Bering Sea during Integrated Ocean Drilling Program (IODP) Expedition 323 has provided the first opportunity to study

the foraminiferal assemblages and palaeoceanographic proxies in continuously-cored sections in the deeper, southern part of the Bering Sea, with an aim toward assessing the effects of climate change on the benthic fauna.

Although benthic foraminifera have been studied from modern sea floor samples and from upper Quaternary sediments in short cores collected from the Bering Sea area (Anderson, 1963; Khusid et al., 2006), the only published record of the older Pleistocene and Neogene foraminiferal assem-



**FIGURE 1.** Location of Site U1341 in the Bering Sea. The map is adopted and modified from Expedition 323 scientists (2011).

blages of the Bering Sea remains that of Echols (1973) from Deep Sea Drilling Project Leg 19. Unfortunately, none of these reports provided adequate illustrations of the benthic foraminifera.

The purpose of this study is to provide a firmer taxonomic basis for further studies of the upper Neogene foraminifera in the Bering Sea and adjacent areas of the North Pacific. The agglutinated foraminifera from noncalcareous sediments in the deeper cored intervals of IODP Hole 1341B have been previously described by Kaminski et al. (2013). This study, therefore, focuses on the benthic foraminifera recovered from the stratigraphically younger intervals in Hole 1341B, some of which show excellent preservation of calcareous microfossils.

### GEOLOGICAL SETTING

Site U1341 is located just below the modern dissolved oxygen-minimum zone in the Bering Sea. Hole U1341B was drilled at a water depth of 2139.5 m on the western flank of the central part of Bowers Ridge (Figure 1), and recovered 594.98 m of cores in total. The bottom of Hole U1341B is estimated between 4.1 and 5.0 Ma (Onodera et al., 2013). Three lithological units were recognised,

with Unit III subdivided into two subunits. Unit I is composed of alternating diatom ooze and mixed diatom-siliciclastic lithologies, and Unit II consisting of mostly diatom ooze with an interval dominated by mixed diatom-siliciclastic lithologies. Subunit IIIA is mainly olive silty clay with some authigenic carbonates, and Subunit IIIB includes diatom ooze, diatom silty clay, and authigenic carbonate in an interval between Cores U1341B-62X and -64X. Thin, distinct, parallel laminations are only recorded in intervals in Unit I, whereas thickly laminated to thinly bedded intervals are found in all units.

### MATERIALS AND METHODS

Sediment samples, ca. 20cc, were collected during the postcruise sampling party from the interval between Cores U1341B-1H and -71X. The samples were gently disintegrated and washed over a 63- $\mu$ m sieve using only water. Foraminiferal specimens were picked and arranged in microslides after being air-dried. The number of specimens for each taxon is given in the Appendix. Optical microscope photographs were made using a Nikon digital camera Digital Sight DS-Fi 1 mounted on a Nikon-1500 stereomicroscope, and

SEM images were taken with JEOL JSM-5900 SEM at the Earth Sciences Department, King Fahd University of Petroleum & Minerals in Dhahran, Saudi Arabia. Optical microscopic photographs were processed using the focus stacking software CombineZP to combine images photographed at different depths of field to produce an image with a greater depth of field. Foraminiferal specimens are stored in faunal slides and deposited in the collections of Micropress Europe, AGH University of Science & Technology, in Kraków, Poland.

### FORAMINIFERAL ASSEMBLAGES

A total of 95 calcareous benthic taxa are recorded from the interval between Cores 1H and 71X in Hole 1341B. The benthic foraminiferal assemblages are wholly or mostly composed of calcareous forms, especially in the younger interval. Agglutinated foraminifera are often absent or comprise a very small portion. The impoverished agglutinated assemblages consisting mostly of *Karrerella* and *Martinottiella* in the upper half of the studied interval are taxonomically very similar to the assemblages described by Kaminski et al. (2013) from the lower portion of the cored section in Hole 1341B (see Expedition 323 Scientists, 2011). Throughout the studied interval, elongated, tapered, and/or flattened planispiral forms, such as *Ebuliminella*, *Globobulimina*, *Melonis*, and *Uvigerina*, which are, in general, infaunal and tolerant to oxygen-depleted conditions (see Corliss, 1985, 1991; Bernhard, 1986), are very common or dominate the Bering Sea assemblages. These forms are also reported to comprise a large portion of assemblages in high productivity areas (e.g., Fariduddin and Loubere, 1997; Koho et al., 2008; Caille et al., 2014). The composition of the assemblages from the studied interval, thus, indicates prevailing high productivity and hypoxic conditions in the study area (see Figure 2). The assemblages from the interval between Cores 1H and 11H, Assemblage I in Expedition 323 Scientists (2011), are relatively highly diversified and abundant. The specimens are well preserved in this interval. *Ebuliminella exilis*, *Rutherfordoides tenuis*, *Islandiella helenae*, *Melonis affinis*, and *Uvigerina senticosa* commonly occur, and several species including *E. exilis*, *Globocassidulina neomargareta*, *Nonionella digitata*, are confined to this interval. The interval between Cores 12H and 37H contains assemblages, which are generally less abundant, but similarly diversified to those from the top interval. Two samples from Core 36H are exceptional, and the assemblages contain more than 200 cal-

careous benthic individuals. *Hansenisca* sp. A, *I. helenae*, *M. affinis*, *Pullenia bulloides*, and *U. senticosa* occur commonly in samples where foraminiferal specimens are present. These assemblages belong to Assemblage II in Expedition 323 Scientists (2011). The samples from Cores 38H–45H (Assemblage III in Expedition 323 Scientists, 2011) are barren of calcareous microfossils. Below the barren interval, low diversity and impoverished assemblages are observed in Cores 46H–71X (Assemblage VI in Expedition 323 Scientists, 2011), and many of the samples contain only agglutinated foraminifera (Kaminski et al., 2013). The preservation of the specimens is variable, and *Hansenisca* sp. A, *Parrelloides healdi*, *Uvigerina proboscidea*, and *U. senticosa* are occasionally recorded in this interval.

### BIOSTRATIGRAPHY

There is a clear difference between the samples above Core 12H and those from deeper intervals of the core. The assemblages are more abundant and diversified, and the preservation state of the specimens is very good to excellent above Core 12H. Some species, such as *Takayanagia* cf. *Takayanagia cushmani*, *E. exilis*, and *N. digitata*, are also confined to this younger interval. Cylindrical forms, including *Epelistoma*, *Neugeborina*, *Siphonodosaria?*, and *Stilostomella*, that belong to the group which went extinct during the Last Global Extinction in the late Pliocene–middle Pleistocene (Hayward et al., 2012) disappear at or below Sample 13H-5, 146–148 cm. This level may well represent the onset of the mid-Pleistocene Climate Transition (1.2–0.55 Ma) because the peak of the global extinction is recorded during the mid-Pleistocene Climate Transition (Hayward et al., 2012). The proposed age of the interval between Samples 11H-CC and 12H-3, 144–146 cm is 0.9–1.0 Ma (Onodera et al., 2013) which falls within the time range of the climate transition. The first occurrences of some species, such as *Alabaminella weddelensis*, *Brizalina pacifica* and *Fursenkoina complanata*, are recorded in Sample 37H-3, 148–150 cm, just above Assemblage III, which is mostly barren.

### SYSTEMATICS

The suprageneric classification of this study is based on Loeblich and Tappan (1987) with modification following Pawlowski et al. (2013). The identification of species is primarily based on the monographs of McCulloch (1977) and Jones

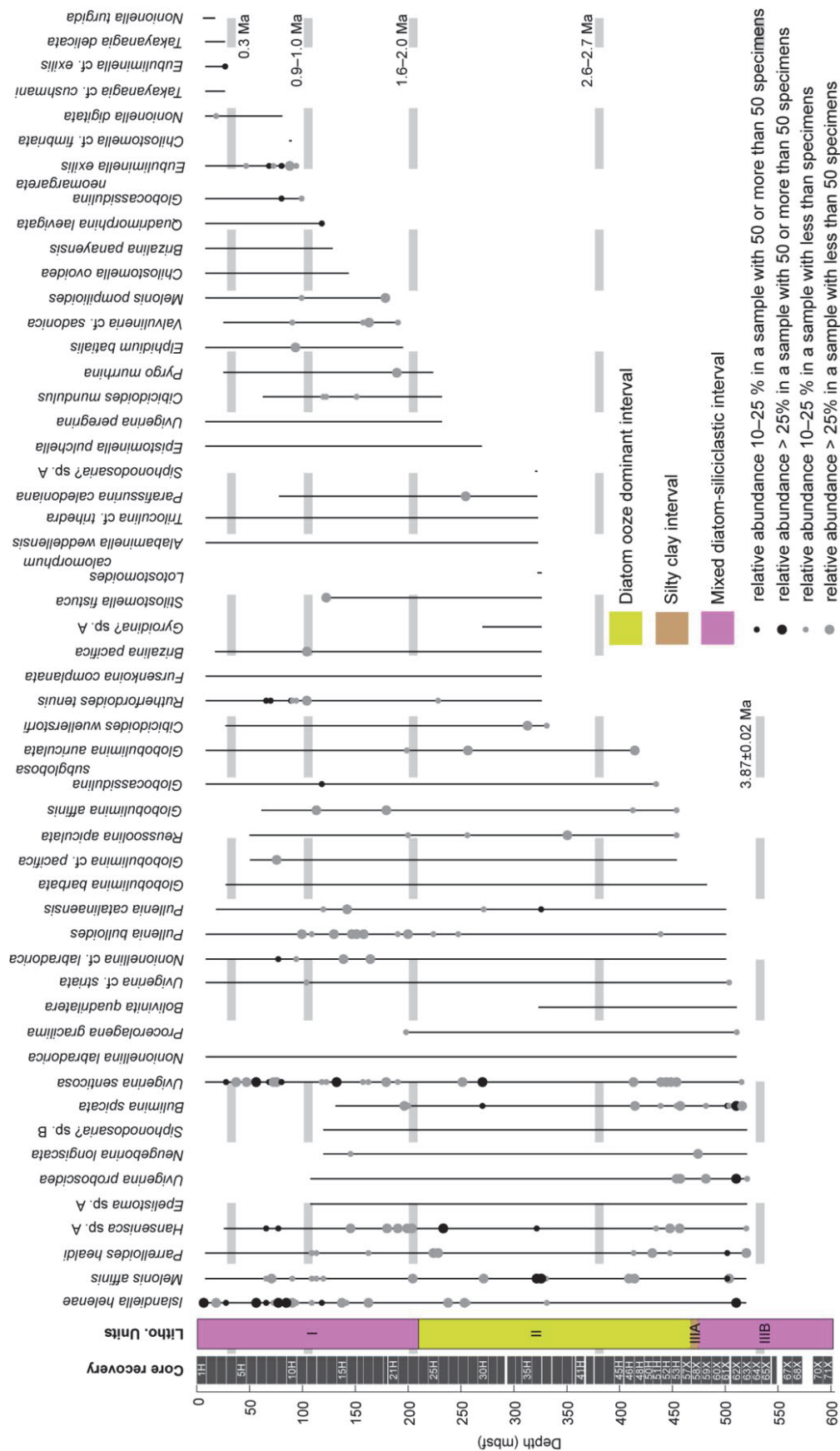


FIGURE 2. Stratigraphic ranges of selected species in Hole 1341B. The ages are based on bioevents of diatoms (Onodera et al., 2013).

(1994). Additional literature on foraminifera from the eastern Pacific (e.g., Matoba and Yamaguchi, 1982; Hermelin, 1989), California (Finger, 1990, 1992), and areas around Japan (e.g., Matoba, 1967; Kaiho, 1992) were consulted. Identified taxa are illustrated in Figures 3–8.

Phylum FORAMINIFERA (d'Orbigny, 1826)  
Class TUBOTHALAMEA Pawlowski, Holzmann  
and Tyszka, 2013

Order MILIOLIDA Delage and Hérouard, 1896

Family HAUERINIDAE Schwager, 1876

Subfamily MILIOLINELLINAE Vella, 1957

Genus PYRGO Defrance, 1824

*Pyrgo murrhina* (Schwager, 1866)

Figure 3.1a, b

1866 *Biloculina murrhina* Schwager: p. 203, pl. 4, fig. 15.

1884 *Biloculina depressa* var. *murrhina* Schwager; Brady, p. 146, pl. 2, figs. 10, 11.

1994 *Pyrgo murrhina* (Schwager); Jones, p. 18, pl. 2, figs. 10, 11, 15.

2013 *Pyrgo murrhina* (Schwager); Holbourn, Henderson and MacLeod, p. 458.

**Remarks.** Specimens greatly vary in size and shape as noted by Holbourn et al. (2013).

*Pyrgo* sp. A  
Figure 3.2a, b

1989 *Pyrgo* sp. 1: Hermelin, p. 37, pl. 3, figs. 1, 2.

**Description.** Test small, biloculine, oval in outline, subcircular in cross section with inflated chambers and a keeled periphery. Aperture rounded, terminal on a prominent apertural neck with a tooth.

**Remarks.** The specimens resemble *Pyrgo affinis* (d'Orbigny, 1846), but differ by possessing a clear apertural neck and its smaller size. It is also similar to juvenile forms of *Pyrgo nasutus* Cushman (1935), but the periphery is not as strongly keeled and serrated. It may well be a juvenile of *Pyrgo murrhina* as suggested by Hermelin (1989).

Genus TRILOCULINA d'Orbigny, 1826  
*Triloculina* cf. *Triloculina trihedra* Loeblich and  
Tappan, 1953  
Figure 3.3a, b

1953 *Triloculina trihedra* Loeblich and Tappan: p. 45, pl. 4, fig. 10.

**Remarks.** The specimens are more elongate and slender than the specimens illustrated by Loeblich and Tappan (1953) and Cole and Ferguson (1975).

Class GLOBOTHALAMEA Pawlowski, Holzmann,  
and Tyszka, 2013

Order ROTALIIDA (Delage and Hérouard, 1896)

Superfamily BOLIVINACEA Glaessner, 1937

Family BOLIVINIDAE Glaessner, 1937

Genus BOLIVINA d'Orbigny, 1839b

*Bolivina seminuda* Cushman, 1911

Figure 3.4

1911 *Bolivina seminuda* Cushman: p. 34, fig. 55.

1982 *Bolivina seminuda* Cushman; Matoba and Yamaguchi, p. 1036, pl. 1, fig. 14a, b.

**Remarks.** The specimens resemble *Bolivina seminuda* forma C described by Matoba and Yamaguchi (1982), which is less tapered and possesses a more circular cross section than the other two forms (A and B) described from the Pliocene–Holocene in the Gulf of California.

*Bolivina* sp. A

Figures 3.5a, 3.5b, 8.1

**Description.** Test small, elongated, tapered, biserial. Periphery slightly lobulated, bluntly angled. Chambers increasing in size gradually. Sutures depressed, sinuous, oblique. Wall rough. Aperture a basal, high arch.

*Bolivina* spp.

**Remarks.** Poorly preserved, small specimens are included.

Genus BRIZALINA Costa, 1856

*Brizalina pacifica* (Cushman and McCulloch, 1942)

Figures 3.6a, 3.6b, 8.2

1942 *Bolivina acerosa* Cushman var. *pacifica* Cushman and McCulloch: p. 185, pl. 21, figs. 2, 3.

1970 *Bolivina pacifica* (Cushman and McCulloch); Sliter, p. 168, pl. 7, fig. 5.

1981 *Brizalina pacifica* (Cushman and McCulloch); Finger and Lipps, p. 129, pl. 2, fig. 6.

2012 *Brizalina pacifica* (Cushman and McCulloch); Ishimura, p. 4364, figs. 2d, g, h, 3j.

**Description.** Test elongated, slender, oval in cross section with rounded periphery. Chambers increasing in size gradually. Sutures clear, very slightly depressed, oblique, slightly curved. Wall smooth, finely perforated. The upper part of each chamber is clear. Aperture a narrow loop at the base of the last chamber.

**Remarks.** It differs from *Brizalina earlandi* (Parr, 1950) by possessing more than twelve chambers of which the upper part is clear.

*Brizalina panayensis* McCulloch, 1977

Figures 3.7a, 3.7b, 8.3



**FIGURE 3.** All scale bars are 100  $\mu\text{m}$ . **1.** *Pyrgo murrhina*, 13H-3, 146–148 cm; a. lateral view; b. apertural view. **2.** *Pyrgo* sp. A, 13H-3, 146–148 cm; a. lateral view; b. apertural view. **3.** *Triloculina* cf. *Triloculina trihedra*, 9H-5, 146–148 cm; a. lateral view; b. apertural view. **4.** *Bolivina seminuda*, 3H-CC, lateral view. **5.** *Bolivina* sp. A, 36H-CC; a. lateral view; b. edge view showing the asymmetrically positioned aperture. **6.** *Brizalina pacifica*, 11H-5, 146–148 cm; a. lateral view; b. edge view. **7.** *Brizalina panayensis*, 1H-CC; a. lateral view; b. edge view. **8.** *Bolivinita quadrilatera*, 61X-5, 115–117 cm; a. lateral view; b. edge view showing the asymmetrically positioned aperture. **9.** *Takayanagia* cf. *Takayanagia cushmani*, 1H-CC; a. ventral view showing the tooth plate; b. dorsal view; c. edge view. **10.** *Rutherfordoides tenuis*, 10H-3, 146–148 cm; a. ventral view; b. dorsal view. **11.** *Globocassidulina neomargareta*, 9H-5, 146–148 cm; a. ventral view; b. apertural view showing the tooth plate; c. dorsal view; d. edge view. **12.** *Globocassidulina subglobosa*, 13H-3, 146–148 cm; a. ventral view; b. dorsal view; c. edge view. **13.** *Islandiella helenae*, 12H-3, 146–148 cm; a. ventral view; b. ventral view in immersion; c. dorsal view; d. edge view. **14.** *Globocassidulina* sp. A, 3H-CC; a. ventral side, b. dorsal side, c. edge view.

1977 *Bolivina panayensis* McCulloch: p. 257, pl. 105, fig. 15.

**Remarks.** The overall morphology of this species is similar to *Brizalina spathula* (Williamson, 1858) and *Brizalina argentea* (Cushman, 1926a), but it is different from the latter species by possessing clear costae. This form also resembles *Brizalina subaenariensis* (Cushman, 1922), but differs by possessing more costae and chambers and being more elongated.

Superfamily BOLIVINITACEA Cushman, 1927b

Family BOLIVINITIDAE Cushman, 1927b

Genus BOLIVINITA Cushman, 1927b

*Bolivinita quadrilatera* (Schwager, 1866)

Figure 3.8a, 3.8b

1866 *Textularia quadrilatera* Schwager: p. 253, pl. 7, fig. 103.

1884 *Textularia quadrilatera* Schwager; Brady, p. 358, pl. 42, figs. 8–12.

1977 *Bolivinita quadrilatera* (Schwager); McCulloch, p. 254, pl. 105, fig. 27.

1994 *Bolivinita quadrilatera* (Schwager); Jones, p. 47, pl. 42, figs. 8–12.

1996 *Bolivinita quadrilatera* (Schwager); Revets, p. 6, pl. 1, figs. 1–4.

**Description.** Test elongated, tapered, biserial with a quadrate cross-section. Chambers increasing in size gradually. Sutures thick, oblique, flush or slightly elevated. Wall finely perforated. Apertural face depressed. Aperture an oval opening asymmetrically positioned near the base of the final chamber.

Superfamily CASSIDULINACEA d'Orbigny, 1839a

Genus GLOBOCASSIDULINA Voloshinova, 1960

*Globocassidulina neomargareta* Finger and Lipps

in Finger et al. (1990)

Figure 3.11a–d

1990 *Globocassidulina neomargareta* Finger and Lipps: p. 38, pl. 8, figs. 26, 27.

1990 *Globocassidulina neomargareta* Finger and Lipps; Finger, p. 112, plate-figs. 1–8.

**Description.** Test small, lenticular with a rounded periphery, biserially arranged and planispirally enrolled. Chambers inflated, increasing in size gradually. Sutures oblique, depressed. Wall finely perforated, smooth. Aperture a basal oval opening with a toothplate.

**Remarks.** The known range of this species in California is from the Oligocene to the Miocene (Finger, 1990).

*Globocassidulina subglobosa* (Brady, 1881)

Figure 3.12a–c

1881 *Cassidulina subglobosa* Brady: p. 60.

1884 *Cassidulina subglobosa* Brady; Brady, p. 430, pl. 54, fig. 17.

1994 *Globocassidulina subglobosa* (Brady); Jones, p. 60, pl. 54, fig. 17.

2012 *Globocassidulina subglobosa* (Brady); Milker and Schmiedl, p. 86, figs. 13–14.

**Remarks.** This form is much larger than *Globocassidulina neomargareta* Finger and Lipps (1990).

*Globocassidulina* sp. A

Figure 3.14a–c

**Description.** Test very large, planispirally coiled with biserially arranged chambers, about five pairs of chambers in the final whorl. Periphery angled. Chambers elongate, increasing in size gradually. Sutures flash in the early part, slightly depressed later. Wall thick, finely perforated. Aperture a basal arch without a tooth plate.

**Remarks.** Only three specimens, only one of which is complete, are recorded. It differs from *Globocassidulina crassa* (d'Orbigny, 1839b) by the shape of the aperture.

Genus ISLANDIELLA Nørvang, 1959

*Islandiella helenae* Feyling-Hanssen and Buzas,

1976

Figures 3.13a–d, 5.2a–c, 8.6

1976 *Islandiella helenae* Feyling-Hanssen and Buzas: p. 155, figs. 1–4.

1980 *Islandiella helenae* Feyling-Hanssen and Buzas; Rodrigues, Hooper, and Jones, p. 49, pl. 1, figs. 1, 3, 5, pl. 4, figs. 3, 6, 9, pl. 6, figs. 1, 2.

1983b *Islandiella helenae* Feyling-Hanssen and Buzas; Nomura, p. 16, pl. 2, figs. 4a–c, 5a–c, pl. 7, figs. 11, 12, pl. 8, figs. 1, 2.

1999 *Planocassidulina helenae* (Feyling-Hanssen and Buzas); Nomura, p. 51, figs. 33-1a-c, -2a-c, 36-1, -2.

**Remarks.** The size and the convexity of test vary greatly among specimens. The identification criteria of the species in this study follow Nomura (1983b), and it is distinguished from *Islandiella norcrossi* (Cushman, 1933) by possessing rounded-rhomboid to oval chambers, but not triangular chambers in mature specimens, and the different position of the aperture. Although the species was transferred to the genus *Planocassidulina* Gudina (1966) emended by Nomura (1999) from *Islandiella* by Nomura (1999) based on the acute and sometimes almost keeled periphery of *I. helenae* and *I. norcrossi*, the angle of periphery often varies among specimens, and they do not possess a

proper keel. We therefore retain the species in the genus *Islandiella*.

Genus TAKAYANAGIA Nomura,  
1983a *Takayanagia delicata* (Cushman, 1927a)  
Figure 4.1a–c

1927a *Cassidulina delicata* Cushman: p. 168, pl. 6, fig. 5.

**Description.** Test small to medium, nearly circular in the side view, lenticular in the edge view, biserial, planispirally enrolled, with about four pairs of chambers in the final whorl, periphery angled. Chambers elongated, somewhat inflated, increasing in size gradually. Sutures clear, depressed. Wall finely perforate, smooth. Aperture a long slit along the base of the last chamber, without a tooth plate.

**Remarks.** This form may resemble *Takayanagia cushmani*, but differs in being more inflated and thicker in edge view and in the absence of a tooth plate.

*Takayanagia* cf. *Takayanagia cushmani* (Stewart and Stewart, 1930)  
Figures 3.9a–c, 8.4

1930 *Cassidulina cushmani* Stewart and Stewart: p. 71, pl. 9, figs. 5a, b.

1982 "*Islandiella*" *cushmani* (Stewart and Stewart); Matoba and Yamaguchi, p. 1045, pl. 2, fig. 1a,b.

**Remarks.** The original description of the species by Stewart and Stewart (1930) mentions the presence of a slight tooth plate, and our specimens also possess a tooth plate that varies in size (see figs. 3.9a, 8.4). It differs from *Takayanagia delicata* (Cushman, 1927a) by possessing a more acute periphery and possessing a tooth plate, and from *Cassidulina teretis* Tappan (1951) by lacking umbilical bosses. It also differs from the typical *Takayanagia cushmani* by possessing a clear tooth plate. A very similar form was reported as "*Islandiella cushmani*" by Matoba and Yamaguchi (1982), which also possesses a *Cassidulina*-type aperture with a tooth plate.

Superfamily TURRILINACEA Cushman, 1927b  
Family TURRILINIDAE Cushman, 1927b  
Subfamily TURRILINIDAE Cushman, 1927b  
Genus EUBULIMINELLA Revets, 1993  
*Eubuliminella exilis* (Brady, 1884)  
Figures 4.2, 8.7

1884 *Bulimina elegans* var. *exilis* Brady, p. 399, pl. 50, figs. 5, 6.

1958 *Bulimina exilis* Brady: Asano, p. 3, pl. 3, figs. 7a, 7b.

1993 *Eubuliminella exilis* (Brady): Revets, p. 141, pl. 1, figs. 1–7.

**Remarks.** Only the slender specimens with limbate sutures as noted by Revets (1993) are included.

*Eubuliminella* cf. *Eubuliminella exilis* (Brady, 1884)  
Figures 4.3, 8.8

1884 *Bulimina elegans* var. *exilis* Brady, p. 399, pl. 50, figs. 5, 6.

**Remarks.** This form differs from *E. exilis* by possessing much more inflated chambers which give a more lobulated outline and in lacking limbate sutures in the last chambers. Both *E. exilis* and this form coexist in the same samples, but the latter occurs only in two of the youngest samples, 1H-CC and 3H-CC.

Superfamily BULIMINACEA Jones, 1875  
Family BULIMINIDAE Jones, in Griffith and Henfrey, 1875

*Bulimina rostratiformis* McCulloch, 1977  
Figure 4.5a, b

1977 *Bulimina rostratiformis* McCulloch, p. 245, pl. 104, fig. 8.

**Remarks.** The specimens in this study are much smaller than the type specimen.

*Bulimina spicata* Phleger and Parker, 1951  
Figure 4.6

1951 *Bulimina spicata* Phleger and Parker: p. 16, pl. 7, figs. 25, 30.

**Remarks.** This species is different from *Bulimina mexicana* Cushman (1922) by its smaller size and less defined costae. It differs from *Globobulimina* cf. *Globobulimina spinescens* (Brady, 1884) in this study by its less elongated chambers and more stout and smaller test.

Genus GLOBOBULIMINA Cushman, 1927b  
*Globobulimina affinis* (d'Orbigny, 1839a)  
Figure 4.7

1839a *Bulimina affinis* d'Orbigny: p. 105, pl. 2, figs. 25, 26.

1992 *Globobulimina affinis* (d'Orbigny); Kaiho, pl. 4, figs. 6, 7.

2001 *Bulimina affinis* (d'Orbigny); Szarek, p. 128, pl. 18, fig. 1.

*Globobulimina auriculata* (Bailey, 1851)  
Figure 4.8

1851 *Bulimina auriculata* Bailey: p. 12, figs. 25–27, 67.

1958 *Globobulimina auriculata* (Bailey); Asano, p. 9, pl. 2, figs. 1–3.





**FIGURE 4.** All scale bars are 100  $\mu\text{m}$ . **1.** *Takayanagia delicata*, 1H-CC; a. ventral view; b. dorsal view; c. edge view. **2.** *Eubuliminella exilis*, 1H-CC, lateral view. **3.** *Eubuliminella* cf. *Eubuliminella exilis*, 1H-CC, lateral view. **4.** *Fursenkoina complanata*, 1H-CC, a. lateral view; b. edge view. **5.** *Bulimina rostratiformis*, 8H-3, 146–148 cm; a. lateral view; b. apertural view. **6.** *Bulimina spicata*, 62X-5, 146–148 cm, lateral view. **7.** *Globobulimina affinis*, 8H-CC, lateral view. **8.** *Globobulimina auriculata*, 25H-CC, lateral view. **9.** *Globobulimina barbata*, 8H-3, 146–148 cm; a. lateral view; b. apertural view. **10.** *Globobulimina barbata*, 52H-CC, lateral view. **11.** *Globobulimina* cf. *Globobulimina pacifica*, 8H-CC, lateral view. **12.** *Globobulimina* cf. *Globobulimina spinenscens*, 61X-5, 115–117 cm; a. lateral view; b. apertural view. **13.** *Globobulimina ovata*, 18H-3, 146–148 cm; a. lateral view; b. apertural view. **14.** *Globobulimina ovata*, 36H-5, 148–150 cm, lateral view. **15.** *Uvigerina peregrina*, 1H-CC; a. lateral view; b. apertural view. **16.** *Uvigerina peregrina*, 3H-CC; a. lateral view; b. apertural view. **17.** *Uvigerina proboscidea*, 12H-3, 146–148 cm; a. lateral view; b. apertural view. **18.** *Uvigerina proboscidea*, 14H-CC, lateral view. **19.** *Uvigerina senticosa*, 7H-CC, lateral view. **20.** *Uvigerina senticosa*, 14H-CC; a. lateral view; b. apertural view. **21.** *Uvigerina interruptacostata*, 3H-CC; a. lateral view; b. apertural view. **22.** *Uvigerina interruptacostata*, 8H-3, 146–148 cm, lateral view. **23.** *Rutherfordoides erectus*, 1H-CC; a. lateral view; b. edge view. **24.** *Siphonodosaria* sp. A, 36H-5, 148–150 cm, lateral view.

1989 *Globobulimina auriculata* (Bailey); Revets, pl. 6, figs. 1–4.

**Remarks.** This form differs from other species of *Globobulimina* by possessing a large auricular apertural tongue.

*Globobulimina barbata* (Cushman, 1927a)  
Figures 4.9a, 4.9b, 4.10

1927a *Bulimina barbata* Cushman: p. 151, pl. 2, fig. 11.

1960 *Globobulimina barbata* (Cushman); Uchio, pl. 6, fig. 6.

1992 *Bulimina barbata* (Cushman); Kaiho, pl. 4, fig. 8.

**Remarks.** This form differs from *Globobulimina spinescens* (Brady, 1884) by its more slender test and more prominent spines.

*Globobulimina ovata* (d'Orbigny, 1846)  
Figures 4.13a, 4.13b, 4.14

1846 *Bulimina ovata* d'Orbigny: p. 185, pl. 11, figs. 13, 14.

1985 *Praeglobobulimina ovata* (d'Orbigny); p. 67, pl. 21, fig. 3.

2006 *Globobulimina ovata* (d'Orbigny); Ortiz and Thomas, p. 118, pl. 6, figs. 4, 5.

**Description.** Test elongated, slender, triserial with either rounded or pointed ends. Chambers elongated, increasing in size rapidly. Sutures clear, depressed, oblique. Wall finely perforate, smooth. Aperture basal, loop-shaped, with a small apertural tongue.

**Remarks.** This form is more elongated and slender with the last two more embracing chambers, which comprise three quarters of the total length of the test, than *Globobulimina affinis*. It differs from *Globobulimina pacifica* by being more elongate and possessing more than three chambers externally visible. The specimens in this study resemble the Eocene specimen of *Globobulimina ovata* (d'Orbigny, 1846) illustrated by Ortiz and Thomas (2006, pl. 6, fig. 5a, b), but differ from the type specimen of *G. ovata* by its more overlapping and elongated chambers, less incised sutures, and possessing less chambers externally visible.

*Globobulimina* cf. *Globobulimina pacifica*  
Cushman, 1927b  
Figure 4.11

1927b *Globobulimina pacifica* Cushman: p. 67, pl. 14, fig. 12.

**Remarks.** This species is similar to *Globobulimina pacifica* in possessing three strongly overlapping chambers, but differs in its more elongated,

slender test. It differs from *Praeglobobulimina ovata* (d'Orbigny, 1846) by its more strongly overlapping chambers and possessing fewer chambers (about three) visible externally, and from *Globobulimina ovata* (d'Orbigny, 1839) in the more slender test with less inflated chambers.

*Globobulimina* cf. *Globobulimina spinescens*  
(Brady, 1884)  
Figure 4.12a, 4.12b, 8.10

1884 *Bulimina pyrula* d'Orbigny var. *spinescens* Brady: p. 400, pl. 50, figs. 11, 12.

1958 *Globobulimina spinescens* (Brady); Asano, p. 12, pl. 3, figs. 1, 2.

1980 *Bulimina* aff. *pyrula spinescens* Brady; Butt, pl. 8, fig. 22, pl. 9, fig. 30.

**Remarks.** The specimens in this study resemble the specimens illustrated by Asano (1958) and Butt (1980), which is more elongated and slender than the typical broad forms.

Family UVIGERINIDAE Haeckel, 1894  
Subfamily UVIGERININAE Haeckel, 1894  
Genus UVIGERINA d'Orbigny, 1826  
*Uvigerina interruptacostae* LeRoy, 1944  
Figures 4.21a, 4.21b, 4.22

1944 *Uvigerina interrupta-costae* LeRoy: p. 31, pl. 8, fig. 44.

1986 *Uvigerina interrupta-costae* LeRoy; Boersma, p. 990, pl. 20, fig. 7.

**Remarks.** The specimens in this study possess numerous fine costae with small pustules between. Costae are restricted to each chamber, and sometimes broken into segments. It differs from *Uvigerina peregrina* Cushman (1923) by its more numerous and finer costae.

*Uvigerina peregrina* Cushman, 1923  
Figures 4.15a, 4.15b, 4.16a, 4.16b

1923 *Uvigerina peregrina* Cushman: p. 166, pl. 42, figs. 7–10.

1950 *Uvigerina akitaensis* Asano: p. 14, pl. 14, figs. 60–62.

1984 *Uvigerina peregrina* Cushman; Boersma, p. 124, pl. 1, figs. 1–4.

1986 *Uvigerina peregrina* Cushman; Lutze, 1986, p. 32, figs. 1–6.

**Remarks.** Many of the specimens in this study are elongated and slender resembling *Uvigerina akitaensis* Asano (1950). It has been, however, shown that *U. peregrina* exhibits a high morphological plasticity based on morphological analysis (Van der Zwaan et al., 1986) and molecular phylogeny analysis (Schweizer et al., 2005), and thus we follow

the suggestion by Scott (Scott et al., 2000) and Schweizer (2006) that *U. akiataensis* is a synonym of *U. peregrina*.

*Uvigerina proboscidea* Schwager, 1866

Figures 4.17a, 4.17b, 4.18, 8.11

1866 *Uvigerina proboscidea* Schwager: p. 250, pl. 7, fig. 96.

1986 *Uvigerina proboscidea* Schwager; van Morkhoven, Berggren and Edwards, p. 28, pl. 6, figs. 1–4.

**Remarks.** Specimens with a hispid wall are included here, whereas individuals with the papillose wall are included in *Uvigerina senticosa* (Cushman, 1927a). The specimens resembles *Uvigerina auberiana* d'Orbigny (1826) with its hispid wall, but differs in its larger test size and lacking the truly biserial portion in the late growth stage.

*Uvigerina senticosa* Cushman, 1927a

Figures 4.19, 4.20a, 4.20b, 8.12

1927a *Uvigerina senticosa* Cushman: p. 159, pl. 3, fig. 14.

1980 *Uvigerina senticosa* Cushman; Thompson, pl. 8, fig. 11.

1992 *Uvigerina senticosa* Cushman; Kaiho, pl. 4, fig. 12.

**Remarks.** Specimens with a papillose and an only slightly papillose wall are included. Small, smooth-walled specimens with the papillose to hispid early part are also included here. These small specimens are probably juveniles, and almost confined to the uppermost part of the studied interval.

Family FURSENKOINIDAE Loeblich and Tappan, 1961

*Fursenkoina complanata* (Egger, 1893)

Figures 4.4a, 4.4b, 8.9

1884 *Virgulina schreibersiana* Čížek; Brady, p. 414, pl. 52, figs. 1–3.

1893 *Virgulina schreibersiana* Čížek var. *complanata* Egger: p. 292, pl. 8, figs. 91, 92.

1958 *Virgulina complanata* Egger; Asano, p. 14, pl. 3, fig. 8.

1994 *Fursenkoina complanata* (Egger); Jones, p. 56, pl. 52, figs. 1–3.

2012 *Stainforthia complanata* (Egger); Milker and Schmiedl, p. 86, fig. 20.16.

2013 *Fursenkoina complanata* (Egger); Holbourn, Henderson and MacLeod, p. 258.

**Remarks.** The specimens in this study possess a twisted, biserial early portion, not triserial.

Genus RUTHERFORDOIDES McCulloch, 1981

*Rutherfordoides erectus* (Cushman and Renz, 1941)

Figures 4.23a, 4.23b, 8.13

1941 *Cassidulinoides erecta* Cushman and Renz: p. 25, pl. 4, figs. 6, 7.

1985 *Rutherfordoides erecta* (Cushman and Renz); Kohl, p. 89, pl. 18, fig. 2.

1999 *Rutherfordoides erecta* (Cushman and Renz); Nomura, p. 56, figs. 29-9, -10, -11, -12, 30-12, 38, 39.

*Rutherfordoides tenuis* (Phleger and Parker, 1951)

Figures 3.10a, 3.10b, 8.5

1951 *Cassidulinoides tenuis* Phleger and Parker: p. 27, pl. 14, figs. 14–17.

1967 *Evolvocassidulina tenuis* (Phleger and Parker); Eade, p. 433, fig. 3.3, 4.

1985 *Rutherfordoides tenuis* (Phleger and Parker); Kohl, p. 89, pl. 18, fig. 5.

**Remarks.** Some mature specimens are as elongated as the type specimens. The specimens do not possess a prominent tooth plate. The early portions is only arched and not coiled fully as in the genus *Evolvocassidulina*. Juvenile forms of this species may resemble *Rutherfordoides erectus* (Cushman and Renz), but differ by its more rounded cross section, and chambers which are overlapping less and possess blunt rounded ends.

Superfamily STILOSTOMELLACEA Finlay, 1947

Family STILOSTOMELLIDAE Finlay, 1947

Genus SIPHONODOSARIA Silvestri, 1924

*Siphonodosaria?* sp. A

Figures 4.24, 8.14

**Description.** Test elongated, uniserial with several chambers. Chambers globular in the early part and more ovoid in the later part, inflated, increasing in size rapidly, not tightly arranged. Wall rough. Aperture on a neck with a lip.

**Remarks.** The apertural features are not visible in the specimens, thus it is not clear whether it belongs to the genus *Siphonodosaria* or *Strictocostella*. It is rare, and its last occurrence is observed in sample 36H-5, 148/150cm.

*Siphonodosaria?* sp. B

Figure 8.15

**Remarks.** This form is superficially similar to *Siphonodosaria bradyi* (Cushman, 1927b) with a row of spines, but the aperture is not visible. It is rare, and its last occurrence is observed in sample 13H-5, 146/148cm.

*Siphonodosaria?* spp.

**Remarks.** Broken specimens, often single-chambered, are included.

Genus STILOSTOMELLA Guppy, 1894  
*Stilostomella fistuca* (Schwager, 1866)  
 Figure 8.16

- 1884 *Nodosaria subtertenuata* Schwager; Brady, p. 507, pl. 62, figs. 7, 8.  
 1866 *Nodosaria fistuca* Schwager: p. 216, pl. 5, figs. 36, 37.  
 1994 *Stilostomella fistuca*: Jones, p. 73, pl. 62, figs. 7, 8, supplementary plate 2, figs. 12, 13.  
 2002 *Stilostomella fistuca* (Schwager): Hayward, p. 306, pl. 3, figs. 41–45.  
 2012 *Stilostomella fistuca* (Schwager): Hayward, Kawagata, Sagaa, Grenfell, van Kerckhoven, Johnson and Thomas, p. 183, pl. 20, figs 1–14.

**Remarks.** This species possesses ovoidal chambers which are loosely attached and a pustulose test surface. It is very rare, and its last occurrence is observed in Sample 13H-CC in Hole U1341B.

Superfamily DISCORBACEA Ehrenberg, 1838  
 Family BAGGINIDAE Cushman, 1927b  
 Subfamily BAGGININAE Cushman, 1927b  
 Genus VALVULINERIA Cushman, 1926a  
*Valvulineria* cf. *Valvulineria sadonica* Asano 1951  
 Figure 5.1a–c

- 1951 *Valvulineria sadonica* Asano; p. 8, figs. 55–57.  
 1963 *Valvulineria sadonica* Asano: Matsunaga, pl. 45, fig. 1.  
 2000 *Valvulinera sadonica* Asano: Scott, Takayanagi, Hasegawa, and Saito, p. 37, Fig. 14.273–275.

**Remarks.** It differs from *Valvulineria sadonica* by apertural flaps covering almost entirely the umbilicus which somehow resemble imbricated portici in planktic foraminifera (see Norris, 1992). It differs from *Valvulineria mexicana* Parker (1954) by its smaller flaps.

*Valvulineria* spp.

**Remarks.** Small specimens which may belong to the genus are included.

Family EPONIDIDAE Hofker, 1951  
 Subfamily EPONIDINAE Hofker, 1951  
 Genus ALABAMINELLA Saidova, 1975  
*Alabaminella weddellensis* (Earland, 1936)  
 Figure 5.3a–c

- 1936 *Eponides weddellensis* Earland: p. 57, pl. 1, figs. 65–67.

**Description.** Test very small, biconvex, low trochospiral, tightly coiled with five chambers in the final whorl. Umbilicus closed. Periphery subangular. Chambers elongated on the spiral side, triangular on the umbilical side, increasing in size gradually. Sutures clear, depressed, slightly curved on the spiral side, radial and straight on the umbilical side. Wall finely perforated. Aperture a basal arch near the peripheral edge, continuing as a basal slit to the umbilicus.

**Remarks.** The specimens in this study are also similar to *Eponides* (?) cf. *Eponides pusillus* (Parr) described by McCulloch (1977) which may actually belong to *Alabaminella weddellensis*.

Superfamily DISCORBINELLACEA Sigal, 1952  
 Family PARRELLOIDIDAE Hofker, 1956  
 Genus PARRELLOIDES Hofker, 1956  
*Parrelloides healdi* (Stewart and Stewart, 1930)  
 Figures 5.6a–c, 5.7a–c

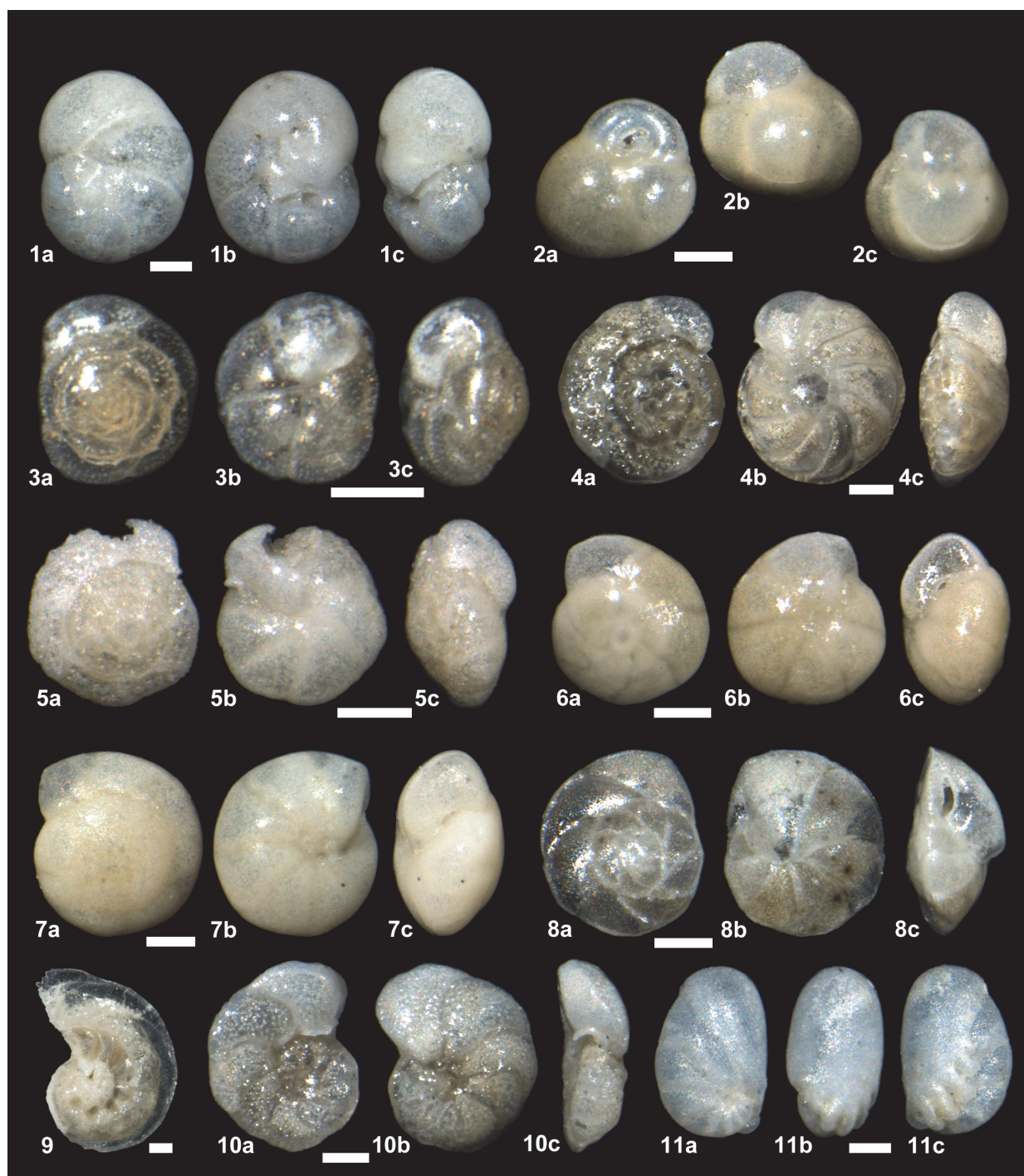
- 1930 *Eponides healdi* Stewart and Stewart: p. 70, pl. 8, fig. 8.  
 1990 *Gyroidina healdi* (Stewart and Stewart); Finger, 118, plate-figs. 1–9.  
 1992 *Gyroidina healdi* (Stewart and Stewart); Finger, p. 88, pl. 36, figs. 1–6.

**Description.** Test of medium size, low trochospiral, tightly coiled, biconvex, circular in outline, with seven and a half to nine chambers in the final whorl and a closed umbilicus. Periphery rounded to slightly pinched. Sutures flush, slightly curved backwards on the spiral side, straight on the umbilical side. A small basal pore-like aperture with a slight lip. The aperture is placed in the middle of the apertural face between the umbilicus and periphery and does not extend to or position at the periphery.

**Remarks.** This form is superficially similar to *Hansenisca* sp. A, but differs in possessing a closed umbilicus and only one aperture and being more biconvex. It also differs from *Parrelloides densus* Saidova (1975) in possessing sutures that are curved backwards and the more acute periphery. The known range of this species in California is from the Oligocene to the Pliocene (Finger, 1990).

Family PSEUDOPARRELLIDAE Voloshinova in Voloshinova and Dain, 1952  
 Subfamily PSEUDOPARRELLINAE Voloshinova in Voloshinova and Dain, 1952  
 Genus EPISTOMINELLA Husezima and Maruhasi, 1944

*Epistominella pulchella* Husezima and Maruhasi,



**FIGURE 5.** All scale bars are 100  $\mu\text{m}$ . **1.** *Valvulineria* cf. *Valvulineria sadonica*, 4H-CC; a. dorsal view; b. ventral view; c. edge view. **2.** juvenile form of *Islandiella helenae*?, 1H-CC; a. ventral view; b. dorsal view; c. edge view. **3.** *Alabaminella weddellensis*, 13H-3, 146–148 cm; a. dorsal view; b. ventral view; c. edge view. **4.** *Cibicoides mundulus*, 18H-3, 146–148 cm; a. ventral view; b. dorsal view; c. edge view. **5.** *Cibicoides simplex*, 1H-CC; a. ventral view; b. dorsal view; c. edge view. **6.** *Parrelloides healdi*, 1H-CC; a. dorsal view; b. ventral side view; c. edge view showing the pore-like aperture. **7.** *Parrelloides healdi*, 25H-5, 146–148 cm; a. spiral view; b. umbilical view; c. edge view showing the pore-like aperture. **8.** *Epistominella pulchella*, 4H-CC; a. spiral view; b. umbilical view; c. edge view showing the elongate arch aperture. **9.** *Laticarinina pauperata*, 52H-CC. **10.** *Cibicoides wuellerstorfi*, 10H-3, 146–148 cm; a. ventral view; b. dorsal view; c. edge view. **11.** *Nonionella digitata*, 9H-5, 146–148 cm; a. dorsal view; b. edge view; c. ventral side.

1944  
Figure 5.8a–c

1944 *Epistominella pulchella* Husezima and Maruhashi: p. 398, pl. 34, fig. 10.

1992 *Epistominella pulchella* Husezima and Maruhashi; Kato, p. 386, pl. 3, figs. 2–4.

**Description.** Test small to medium, low trochospiral with seven chambers in the final whorl. The umbilical side is more inflated than the spiral side, which is only slightly convex. Periphery acute. Umbilicus closed. Chambers increasing in size gradually. Sutures clear, depressed, curved backwards on the spiral side, less so on the umbilical side. Wall smooth, finely perforated. Aperture an elongate arch at the base of the last chamber. Apertural face somewhat dented.

**Remarks.** This species is very similar to *Epistominella smithi* (Stewart and Stewart, 1930) described from the lower Pliocene of California, but based on the definition the former differs from the latter by possessing more chambers in the final whorl (seven instead of five to six) and *E. smithi* seems to have a more prominent keel. It differs from *Epistominella exigua* (Brady, 1884) by its planoconvex test and less lobulated periphery.

Family DISCORBINELLIDAE Sigal in Piveteau, 1952

Subfamily DISCORBINELLINAE Sigal in Piveteau, 1952

Genus LATICARININA Galloway and Wissler, 1927

*Laticarinina pauperata* (Parker and Jones, 1865)  
Figures 5.9, 8.17

1865 *Pulvinulina repanda* Fichtel and Moll var. *menardii* d'Orbigny subvar. *pauperata* Parker and Jones: p. 395, pl. 16, figs. 50, 51.

1884 *Pulvinulina pauperata* Parker and Jones: Brady, p. 696, pl. 104, figs. 3–11.

1985 *Laticarinina pauperata* (Parker and Jones): Kohl, p. 77, pl. 26, fig. 1.

1994 *Laticarinina pauperata* (Parker and Jones): Jones, p. 104, pl. 104, figs. 3–11.

2013 *Laticarinina pauperata* (Parker and Jones): Holbourn, Henderson and MacLeod, p. 328, figs. 1, 2.

**Remarks.** The specimens in this study are biconvex and not as evolute as those illustrated by other studies. The keel is broader than the height of the final chambers, as depicted in the original illustrations by Parker and Jones.

Superfamily PLANORBULINACEA Schwager, 1877

Family CIBICIDIDAE Cushman, 1927b  
Genus CIBICIDOIDES Saidova, 1975

*Cibicoides mundulus* (Brady, Parker, and Jones, 1888) emend. Loeblich and Tappan, 1955  
Figure 5.4a–c

1884 *Truncatulina*, sp., intermediate form near *Truncatulina haidingerii* d'Orbigny; Brady, pl. 95, fig. 6.

1888 *Truncatulina mundula* Brady, Parker, and Jones: p. 228, pl. 45, fig. 25

1955 *Cibicoides mundula* (Brady, Parker, and Jones) emend. Loeblich and Tappan: p. 25, pl. 4, fig. 4.

1994 *Cibicoides mundulus* (Brady, Parker and Jones): Jones, p. 99, pl. 95, fig. 6.

1996 *Cibicoides mundulus* (Brady, Parker and Jones): Revets, p. 65, pl. 1, figs. 9–12.

2013 *Cibicoides mundulus* (Brady, Parker and Jones): Holbourn, Henderson and MacLeod, p. 196, figs. 1–8.

**Remarks.** The specimens in this study clearly resemble those illustrated by Loeblich and Tappan (1955) and Holbourn et al. (2013) in possessing an umbilical boss that was not illustrated by Brady et al. (1888). Although the genus *Cibicoides* is placed under the family Parrelloidae by Loeblich and Tappan (1987), it is assigned to the family Cibicididae in this study following Schweizer et al. (2009)

*Cibicoides simplex* McCulloch, 1977  
Figure 5.5a–c

1977 *Cibicoides* (?) *simplex* McCulloch: p. 447, pl. 152, fig. 12.

**Remarks.** This species is characterised by its biconvex test with a bluntly angled periphery, a prominently perforated wall and sutures which are flush to only slightly depressed. The specimens in this study are smaller than the type specimen described by McCulloch (1977).

*Cibicoides wuellerstorfi* (Schwager, 1866)  
Figure 5.10a–c

1866 *Anomalina wuellerstorfi* Schwager: p. 258, pl. 7, figs. 105, 107.

1884 *Truncatulina wuellerstorfi* (Schwager); Brady, p. 662, pl. 93, figs. 8, 9.

1963 *Planulina wuellerstorfi* (Schwager); Matsunaga, pl. 50, fig. 7.

1980 *Cibicides wuellerstorfi* (Schwager); Thompson, pl. 7, figs. 7, 8.

1994 *Cibicidoides wuellerstorfi* (Schwager); Jones, p. 98, pl. 93, figs. 8, 9.

1994 *Fontbotia wuellerstorfi* (Schwager); Loebllich and Tappan, p. 150, pl. 319, figs. 7–13.

2013 *Planulina wuellerstorfi* (Schwager); Holbourn, Henderson, and MacLeod, p. 416.

**Remarks.** This species has recently been assigned to three different genera. It is the type species of the genus *Fontbotia*, which was considered as a subjective synonym of the genus *Planulina* by Revets (1996). This species is assigned to the genus *Cibicidoides* in this study following the results of molecular phylogenetic studies by Schweizer (2006) and Schweizer et al. (2009, 2011).

Superfamily NONIONACEA Schultze, 1854

Family NONIONIDAE Schultze, 1854

Subfamily NONIONINAE Schultze, 1854

Genus NONIONELLA Cushman, 1926a

*Nonionella digitata* Nørvang, 1945

Figures 5.11a–c, 8.18

1945 *Nonionella turgida* (Williamson) var. *digitata* Nørvang: p. 29, text-fig. 4.

2007 *Nonionella digitata* Nørvang; Vázquez Riveiros and Patterson, p. 29, fig. 12.5.

**Remarks.** This form can be differentiated from the other species of *Nonionella* by its umbilical flap with long digitate extensions. The umbilical flap is much more prominent with longer extensions than that of *Nonionella stella* Cushman and Moyer (1930). The digitate flap can be observed with juveniles.

*Nonionella turgida* (Williamson, 1858)

1858 *Rotalina turgida* Williamson: p. 50, pl. 4, figs. 95–97.

1884 *Nonionina turgida* (Williamson); Brady, p. 731, pl. 109, figs. 17–19.

1994 *Nonionella turgida* (Williamson); Jones, p. 108, pl. 109, figs. 17–19.

**Remarks.** This form is quite rare in our samples, and only broken specimens are recorded. It differs from the other species by its smaller and thinner test with more numerous, elongated chambers.

*Nonionella* spp.

**Remarks.** Small specimens, probably juveniles of one of the species of *Nonionella* and *Nonionellina* identified in this study, are included here.

Genus NONIONELLINA Voloshinova, 1958

*Nonionellina labradorica* (Dawson, 1860)

Figures 6.1a, b, 8.19

1860 *Nonionina labradorica* Dawson: p. 191, text-fig. 4.

1963 *Nonion labradricum* (Dawson); Matsunaga, pl. 37, fig. 4.

1967 *Nonion labradricum* (Dawson); Matoba, pl. 29, fig. 7.

1980 *Nonion labradoricum* (Dawson); Keller, pl. 3, figs. 9, 10.

2007 *Nonionellina labradorica* (Dawson); Vázquez Riveiros and Patterson, p. 29, fig. 12.7.

2013 *Nonionellina labradorica* (Dawson); Holbourn, Henderson and MacLeod, p. 374.

**Remarks.** The outline of the specimens in this study is not lobulated as the specimen illustrated by Dawson (1860). They have a smooth outline as in the specimens from the Pacific illustrated by Matsunaga (1963), Matoba (1967) and Vázquez Riveiros and Patterson (2007), though a form with a lobulated outline has been recorded in the Pacific, e.g., in the Japan Trench area (Keller, 1980).

*Nonionellina* cf. *Nonionellina labradorica* (Dawson, 1860)

Figures 6.2a, b, 8.20

1860 *Nonionina labradorica* Dawson: p. 191, text-fig. 4.

**Remarks.** This form is smaller and thinner than *Nonionellina labradorica*. The chambers in this form increase in size more slowly than in *N. labradorica*. Both forms coexist, but in some samples only the small form is observed. It might be a juvenile of *N. labradorica*.

Subfamily ASTRONONIONINAE Saidova, 1981

Genus ASTRONONION Cushman and Edwards, 1937

*Astrononion stellatum* Cushman and Edwards, 1937

Figure 6.3a–c

1937 *Astrononion stellatum* Cushman and Edwards: p. 32, pl. 3, figs. 9–11.

**Description.** Test small, planispiral, involute, with seven chambers in the final whorl, lobulate in outline. Periphery rounded. Chambers inflated, increasing in size gradually, with a plate extending into the umbilicus. Sutures depressed. Wall smooth, finely perforate. Aperture an interiomarginal slit.

**Remarks.** It differs from *Astrononion stelligerum* (d'Orbigny, 1839a) by possessing fewer chambers in the final whorl.



**FIGURE 6.** All scale bars are 100  $\mu\text{m}$ . **1.** *Nonionellina labradorica*, 3H-CC; a. lateral left view; b. edge view. **2.** *Nonionellina* cf. *Nonionellina labradorica*, 15H-5, 146–148 cm; a. lateral left view; b. edge view. **3.** *Astrononion stellatum*, 10H-CC; a. lateral right view; b. lateral left view; c. edge view. **4.** *Melonis affinis*, 1H-CC; a. lateral left view; b. edge view. **5.** *Melonis affinis*, 9H-5, 146–148 cm. **6.** *Melonis pompilioides*, 1H-CC; a. lateral left view; b. edge view. **7.** *Pullenia bulloides*, 11H-3, 146–148 cm; a. lateral left view; b. apertural view. **8.** *Pullenia bulloides*, 12H-3, 146–148 cm; a. lateral left view; b. apertural view. **9.** *Pullenia* cf. *Pullenia catalinaensis*, 36H-CC; a. lateral left view; b. edge view. **10.** *Pullenia* cf. *Pullenia catalinaensis*, 9H-5, 146–148 cm; a. lateral left view; b. edge view. **11.** *Pullenia elegans*, 13H-3, 146–148 cm; a. lateral right view; b. edge view. **12.** *Pullenia elegans*, 13H-3, 146–148 cm; a. lateral left view; b. edge view. **13.** *Pullenia salisburyi*, 26H-5, 147–149 cm; a. lateral left view; b. edge view. **14.** *Chilostomella ovoidea*, 2H-CC, a. ventral view; b. dorsal view. **15.** *Chilostomella* cf. *Chilostomella fimbriata*, 10H-3, 146–148 cm; a. lateral right view; b. edge view.



## Subfamily PULLENIINAE Schwager, 1877

## Genus MELONIS de Montfort, 1808

*Melonis affinis* (Reuss, 1851)

Figures 6.4a, b, 6.5

- 1858 *Nonionina barleeana* Williamson: p. 32, pl. 3, figs. 68, 69.
- 1884 *Nonionina umbilicatula* (Montagu); Brady, p. 726, pl. 109, figs. 8, 9.
- 1994 *Melonis affinis* (Reuss); Jones, p. 107, pl. 109, figs. 8, 9.
- 1994 *Melonis barleeanus* (Williamson); Loeblich and Tappan, p. 157, pl. 347, figs. 1–5.
- 2001 *Melonis affinis* (Reuss); Szarek, p. 143, pl. 23, figs. 12–14.
- 2012 *Melonis affinis* (Reuss); Milker and Schmiedl, p. 115, fig. 26.9-10.
- 2012 *Melonis barleeenum* (Williamson); Milker and Schmiedl, p. 115, fig. 26.11-12.
- 2013 *Melonis barleeenum* (Williamson); Holbourn, Henderson, and MacLeod, p. 354.

**Remarks.** Most of the specimens found in this study are similar to *Melonis affinis* illustrated by Milker and Schmiedl (2012), who distinguished this species from *M. barleeenum* by its less prominent apertural lip. Based on molecular analysis, Schweizer (2006) synonymised *Melonis barleeanus* under *Melonis affinis*. The genus *Melonis* is suggested to belong to the family Cibicididae based on its closer relationship to cibicidids than to the genus *Pullenia* revealed by the molecular phylogenetic study by Schweizer et al. (2009). The genus *Melonis* is, however, retained in the subfamily Pulleniinae under the family Nonionidae because of its planispiral coiling mode, which does not agree with the morphological definition of the family Cibicididae.

*Melonis pompilioides* (Fichtel and Moll, 1798)

Figure 6.6a, b

- 1798 *Nautilus pompilioides* Fichtel and Moll: p. 31, pl. 2, figs. a–c.
- 1884 *Nonionina pompilioides* (Fichtel and Moll); Brady, p. 727, pl. 109, figs. 10, 11.
- 1976 *Melonis pompilioides* (Fichtel and Moll); Pflum and Frerichs, p. 122, pl. 7, figs. 7, 8.
- 1979 *Melonis pompilioides* (Fichtel and Moll); Corliss, p. 12, pl. 5, figs. 9, 10.
- 1994 *Melonis pompilioides* (Fichtel and Moll); Jones, p. 108, pl. 109, figs. 10, 11.

**Remarks.** This species differs from *Melonis affinis* by possessing a much thicker test with a broadly rounded periphery. The specimens in this study are

assigned to *Melonis pompilioides* rather than to *Melonis spheroides* (Voloshinova, 1958) following the remarks by Belanger and Berggren (1986) that *M. spheroides* is more involute and possesses narrower and shallower umbilici, indistinct sutures and larger pores. Van Morkhoven et al. (1986) regarded the two species to be synonymous.

## Genus PULLENIA Parker and Jones, in Carpenter, Parker and Jones 1862

*Pullenia bulloides* (d'Orbigny, 1846)

Figures 6.7a, 6.7b, 6.8a, 6.8b

- 1846 *Nonionina bulloides* d'Orbigny: p. 107, pl. 5, figs. 9, 10.
- 1884 *Pullenia sphaeroides* d'Orbigny; Brady, p. 615, pl. 84, figs. 12, 13.
- 1963 *Pullenia bulloides* (d'Orbigny); Matsunaga, pl. 49, fig. 9.
- 1985 *Pullenia bulloides* (d'Orbigny); Kohl, p. 92, pl. 32, fig. 5.
- 1994 *Pullenia bulloides* (d'Orbigny); Jones, p. 92, pl. 84, figs. 12, 13.

**Remarks.** Specimens with a broad periphery and four to five chambers in the final whorl are included.

*Pullenia* cf. *Pullenia catalinaensis* McCulloch, 1977

Figures 6.9a, b, 6.10a, b

- 1977 *Pullenia catalinaensis* McCulloch: p. 436, pl. 171, fig. 4.

**Description.** Test of medium size, planispiral, with five and a half to six and a half chambers in the final whorl. Umbilicus small. Periphery rounded, lobulated. Chambers increasing in size gradually. Sutures distinct, depressed, sinuous, or curved backwards. Wall finely perforated, smooth. Aperture a basal slit with a lip.

**Remarks.** The specimens in this study are smaller than the type specimen, which is ca. 1 mm in the maximum diameter, and appear to be more highly perforated. McCulloch depicts a specimen that appears to be shinier, without visible pores. The species differs from *Pullenia bulloides* in its more laterally compressed test, higher number of chambers, and curved sutures and from *Pullenia quinqueloba* (Reuss, 1851) by possessing a more rounded periphery and more than five chambers in the final whorl.

*Pullenia elegans* Cushman and Todd, 1943

Figures 6.11a, b, 6.12a, b

- 1943 *Pullenia elegans* Cushman and Todd: p. 23, pl. 4, fig. 11.

1973 *Pullenia elegans* Cushman and Todd; Lankford and Phleger, p. 125, pl. 6, fig. 9.

1977 *Pullenia elegans* McCulloch, p. 437, pl. 171, fig. 1.

**Remarks.** This form is laterally compressed and possesses a subarcuate and lobulate periphery, about seven chambers in the final whorl, and curved sutures. It differs from *Pullenia quinqueloba* by possessing more than five chambers.

*Pullenia salisburyi* Stewart and Stewart, 1930  
Figure 6.13a, b

1930 *Pullenia salisburyi* Stewart and Stewart: p. 72, pl. 8, fig. 2.

1973 *Pullenia salisburyi* Stewart and Stewart; Lankford and Phleger, p. 125, pl. 6, fig. 10.

**Remarks.** This form is different from *Pullenia elegans* by being smaller and possessing fewer chambers in the final whorl and a last chamber which is much larger than the previous chambers. It resembles *Pullenia quinqueloba* with five chambers in the final whorl, but differs in possessing a disproportionately large last chamber.

Superfamily CHILOSTOMELLACEA Brady, 1881  
Family CHILOSTOMELLIDAE Brady, 1881  
Subfamily CHILOSTOMELLINAE Brady, 1881  
Genus CHILOSTOMELLA Reuss in Čížek, 1849  
*Chilostomella ovoidea* Reuss, 1850  
Figure 6.14a, b

1850 *Chilostomella ovoidea* Reuss: p. 380, pl. 48, fig. 12.

1994 *Chilostomella ovoidea* Reuss; Loeblich and Tappan, p. 160, pl. 350, figs. 1–3.

**Remarks.** The specimens in this study are not as broad as the specimen illustrated by Reuss (1850), but not as elongated and slender as *Chilostomella oolina* Schwager (1878). They are similar to the specimen from the western Timor Sea illustrated by Loeblich and Tappan (1994).

Genus CHILOSTOMELLINA  
*Chilostomellina* cf. *Chilostomellina fimbriata*  
Cushman, 1926b  
Figure 6.15a, b

1926b *Chilostomellina fimbriata* Cushman: p.78, pl. 11, fig. 22.

1980 *Chilostomellina fimbriata* Cushman; Keller, pl. 2, figs. 6, 7.

**Remarks.** The only specimen in this study is broken, but possesses an apertural margin, which is more fimbriate than the specimens illustrated by Cushman (1926b, 1928) and Hoskin and Haskins

(1975). The form identified in this study resembles the specimen illustrated by Keller (1980).

Family QUADRIMORPHINIDAE Saidova, 1981  
Genus QUADRIMORPHINA Finlay, 1939  
*Quadriformina laevigata* (Phleger and Parker, 1951)  
Figure 7.1a–c

1951 *Valvulineria laevigata* Phleger and Parker: p. 25, pl. 13, figs. 11, 12.

1982 *Quadriformina laevigata* (Phleger and Parker); Matoba and Yamaguchi, p. 1048, pl. 4, fig. 2.

2000 *Quadriformina laevigata* (Phleger and Parker); Ohkushi, Thomas and Kawahata, p. 144, pl. 3, fig. 2.

**Description.** Test small, biconvex, trochospiral, circular, and slightly lobulate in outline, with four chambers in the final whorl. Chambers inflated especially in the final whorl, increasing in size rapidly. Sutures clear, incised, straight to slightly curved backwards on the spiral side, straight and radial on the umbilical side. Wall smooth, finely perforated. Aperture basal, with a large flap that covers the entire umbilicus.

Family ORIDORSALIDAE Loeblich and Tappan, 1984  
Genus ORIDORSALIS Andersen, 1961  
*Oridorsalis umbonatus* (Reuss, 1851)  
Figure 7.2a–c

1851 *Rotalina umbonata* Reuss: p. 75, pl. 5, fig. 35.

1884 *Truncatulina tenera* Brady: p. 99, pl. 95, fig. 11.

1982 *Oridorsalis umbonatus* (Reuss); Matoba and Yamaguchi, p. 1045, pl. 4, fig. 11.

1994 *Oridorsalis umbonata* (Reuss); Jones, p. 99, pl. 95, fig. 11.

2001 *Oridorsalis umbonatus* (Reuss); Szarek, p. 144, pl. 24, figs. 1, 2.

2013 *Oridorsalis umbonatus* (Reuss); Holbourn, Henderson, and MacLeod, p. 384.

**Remarks.** The specimens in this study possess six to seven chambers in the final whorl.

Family GAVELINELLIDAE Hofker, 1956  
Subfamily GAVELINELLINAE Hofker, 1956  
Genus *Gyroidina* d'Orbigny, 1826  
*Gyroidina?* sp. A  
Figures 7.3a–c, 7.4a–c

**Description.** Test small, trochospiral, tightly coiled with a flat spiral side and more convex umbilical



**FIGURE 7.** All scale bars are 100  $\mu\text{m}$ . **1.** *Quadrिमorphina laevigata*, 13H-3, 146–148 cm; a. dorsal view; b. ventral view; c. edge view. **2.** *Oridorsalis umbonatus*, 3H-CC; a. dorsal view; b. ventral view; c. edge view. **3.** *Gyroidina?* sp. A, 36H-5, 148–150 cm; a. dorsal view; b. ventral view; c. edge view. **4.** *Gyroidina?* sp. A, 36H-CC; a. dorsal view; b. ventral view; c. edge view. **5.** *Hansenisca* sp. A, 9H-3, 146–148 cm; a. dorsal view; b. ventral view; c. edge view showing a basal slit aperture. **6.** *Hansenisca* sp. A, 16H-3, 146–148 cm; a. dorsal view; b. ventral view; c. edge view showing a low arch aperture. **7.** *Epelistoma* sp. A, 63X-3, 146–148 cm, lateral view. **8.** *Lenticulina* sp. A, 26H-5, 147–149 cm; a. lateral left view; b. edge view. **9.** *Lenticulina* sp. B, 62X-5, 146–148 cm; a. lateral left view; b. edge view. **10.** *Hemirobulina* sp. A, 9H-5, 146–148 cm; a. lateral left view; b. edge view. **11.** *Reussoolina apiculata*, 28H-CC, lateral view. **12.** *Lagena* cf. *Lagena tagusensis*, 12H-3, 146–148 cm; a. lateral view; b. apertural view. **13.** *Lagena striata*, 10H-3, 146–148 cm; a. lateral view; b. apertural view. **14.** *Oolina squamosa*, 10H-3, 146–148 cm; a. lateral view; b. apertural view. **15.** *Glandulina ovula*, 36H-5, 148/150 cm, lateral view.

side, bluntly angled periphery and eight chambers in the final whorl. Umbilicus very small. Chambers increasing in size gradually. Sutures clear, straight, flush, or slightly depressed, radial on the umbilical side. Wall smooth or slightly rough, finely perforated. Aperture a basal slit or a low arch with a lip. It is not clear if there is a bipartitor.

**Remarks.** This form may be a juvenile of *Parrelloides* or *Hansenisca*, which are recorded in this study. The extent of the aperture varies among specimens, but the aperture and the lip do not extend clearly onto the spiral side so that it is not likely that they belong to the genus *Cibicidoides*. This particular form is found only in two samples.

Genus HANSENISCA Loeblich and Tappan, 1987

*Hansenisca* sp. A

Figures 7.5a–c, 7.6a–c

**Description.** Test of medium size, trochospiral, spiral side evolute and flat to slightly elevated, umbilical side involute and elevated, with an small open umbilicus with subangular shoulder, with nine to ten chambers in the final whorl. Periphery more angular than rounded. Chambers increasing in size gradually. Sutures flush or very slightly depressed, curved backwards on the spiral side, radial and straight on the umbilical side. Wall calcareous, very finely perforate, smooth. Aperture an interiomarginal small pore-like opening placed between the umbilicus and the periphery with a narrow lip. A second aperture is present at the umbilicus with a flap.

**Remarks.** This form resembles species of *Gyroidina*, such as *Gyroidina soldani* (d'Orbigny, 1826), but differs by possessing a second aperture at the umbilicus. The size of the umbilicus varies greatly, and it is almost closed in some specimens. A very similar form was reported as *Gyroidinoides* sp. A from the Izu-Bonin Arc (ODP Legs 125 and 126) by Kaiho (1992, pl. 8, fig. 8).

*Hansenisca* spp.

**Remarks.** Broken specimens with the aperture and the umbilicus that are often not observable. Specimens of *Parrelloides* might be included.

Family ELPHIDIIDAE Galloway, 1933

Subfamily ELPHIDIINAE Galloway, 1933

Genus ELPHIDIUM de Montfort, 1808

*Elphidium batialis* Saidova, 1961

Figure 8.21

1961 *Elphidium batialis* Saidova: p. 77, pl. 23, fig. 161.

1980 *Elphidium batialis* Saidova; Keller, pl. 4, fig. 4.

1980 *Elphidium batialis* Saidova; Thompson, pl. 7, figs. 3, 6.

**Remarks.** This species is commonly reported from the Pliocene–Recent of the northwest Pacific (e.g., Thompson, 1980; Khusid et al., 2005, 2006; Bubenshchikova et al., 2008). Hanagata (2008) reported it from the Oligocene of southern Hokkaido.

Incertae sedis order

Order LAGENIDA (Delage and Hérouard, 1896)

Superfamily NODOSARIACEA Ehrenberg, 1838

Family CHRYSALOGONIDAE Mikhalevich, 1993

Genus EPELISTOMA Hayward and Kawagata in

Hayward et al. (2012)

*Epelistoma* sp. A

Figure 7.7

**Remarks.** Only one specimen is found complete. Differs from *Nodosaria lamulifera* Thalmann (1950) by possessing twice as many costae (about 12), which do not extend the full length of the test, and some merge with each other. It also superficially resembles *Epelistoma crassitesta* (Schwager, 1866), but differs in being smaller and possessing fewer longitudinal costae (about 20–25 in *E. crassitesta*).

Genus LOTOSTOMOIDES Hayward and

Kawagata in Hayward et al. (2012)

*Lotostomoides calomorphum* (Reuss, 1866)

Figure 8.22

1866 *Nodosaria (Nodosaria) calomorpha* Reuss: p. 129, pl. 1, figs. 15–19.

1884 *Nodosaria calomorpha* Reuss; Brady, p. 497, pl. 61, figs. 23–27.

1994 *Glandulonodosaria calomorpha* (Reuss); Jones, p. 72, pl. 61, figs. 23–26, 27, supplementary plate 1, figs 10–11.

2012 *Lotostomoides calomorphum* (Reuss); Hayward, Kawagata, Sagaa, Grenfell, van Kerckhoven, Johnson and Thomas, p. 125, pl. 6, figs 24–29.

**Remarks.** Specimens with only two chambers are recorded in this study. The last chamber is smaller than the penultimate chamber in all the specimens in this study. The somewhat rough wall surface of the specimens in this study may be due to diagenesis.

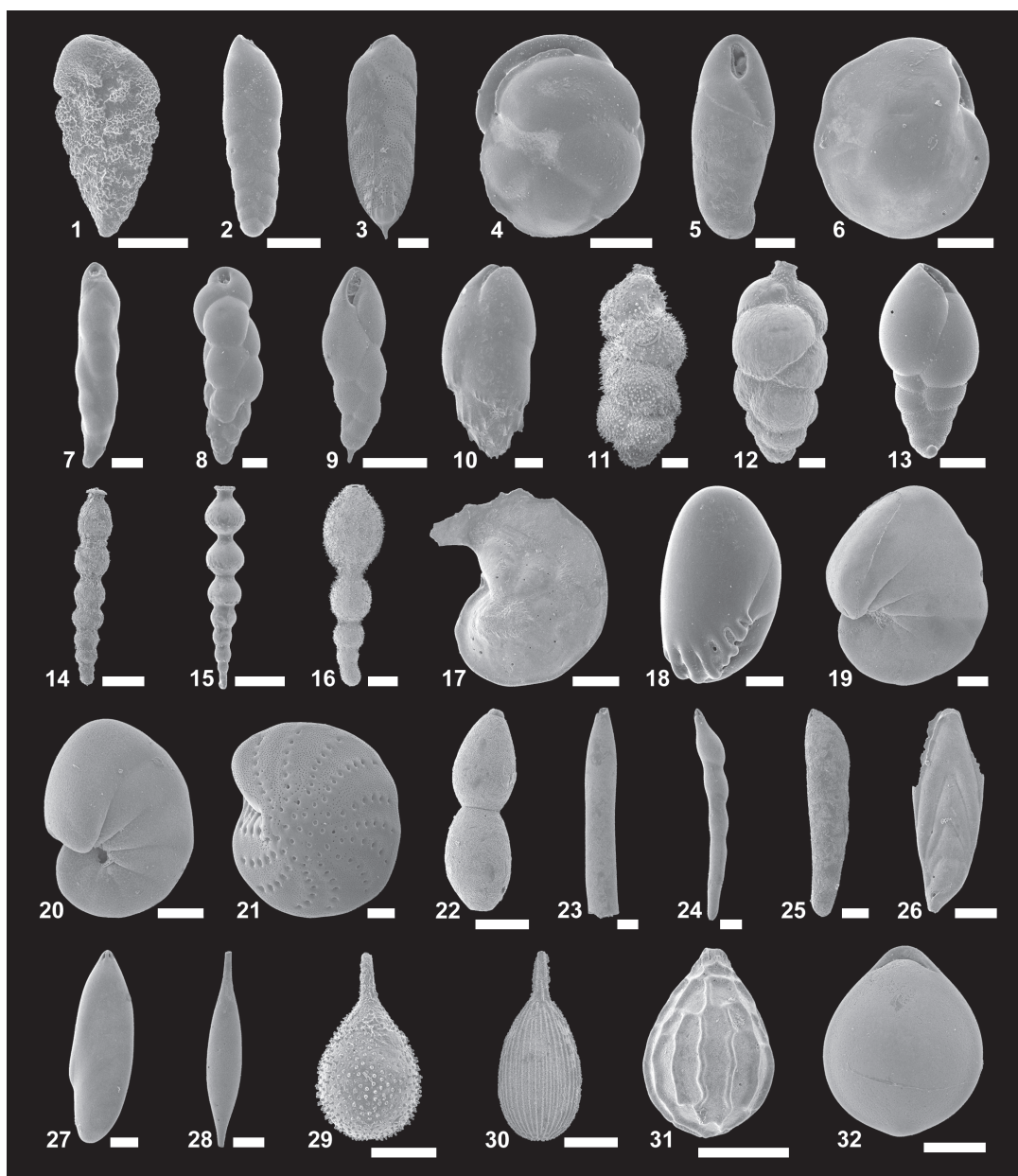
Family GLANDULONODOSARIIDAE Silvestri, 1901

Genus NEUGEBORINA Popescu in Cicha, Rögl,

Rupp, and Ctyroka, 1998

*Neugeborina longiscata* (d'Orbigny, 1846)

Figure 8.23



**FIGURE 8.** All scale bars are 100  $\mu\text{m}$ . **1.** *Bolivina* sp. A, 1H-CC, lateral view. **2.** *Brizalina pacifica*, 3H-CC, lateral view. **3.** *Brizalina panayensis*, 3H-CC, lateral view. **4.** *Takatanagia* cf. *Takayanagia cushmani*, 1H-CC, lateral view showing the apertural plate. **5.** *Rutherfordoides tenuis*, 16H-5, 146–148 cm, lateral view. **6.** *Islandiella helenae*, 13H-3, 146–148 cm, lateral view. **7.** *Eubuliminella exilis*, 1H-CC, lateral view. **8.** *Eubuliminella* cf. *Eubuliminella exilis*, 3H-CC, lateral view. **9.** *Fursenkoina complanata*, 3H-CC, lateral view. **10.** *Globobulimina* cf. *Globobulimina spinescens*, 61X-5, 115–117 cm, lateral view. **11.** *Uvigerina proboscidea*, 59X-3, 145–147 cm, lateral view. **12.** *Uvigerina senticosa*, 8H-5, 146–148 cm, lateral view. **13.** *Rutherfordoides erectus*, 1H-CC, lateral view. **14.** *Siphonodosaria?* sp. A, 36H-5, 148–150 cm, lateral view. **15.** *Siphonodosaria?* sp. B, 13H-5, 146–148 cm, lateral view. **16.** *Stilostomella fistuca*, 36H-CC, lateral view. **17.** *Laticarinina pauperata*, 61X-CC, lateral view. **18.** *Nonionella digitata*, 3H-CC, lateral view. **19.** *Nonionellina labradorica*, 3H-CC, lateral view. **20.** *Nonionellina* cf. *Nonionellina labradorica*, 3H-CC, lateral view. **21.** *Elphidium batialis*, 3H-CC, lateral view. **22.** *Lotostomoides calomorphum*, lateral view. **23.** *Neugeborina longiscata*, 16H-5, 146–148 cm, lateral view. **24.** *Laevidentalina californica*, 26H-CC, lateral view. **25.** *Laevidentalina* sp. A, 36H-5, 148–150 cm, lateral view. **26.** *Mucronina* sp. A, 61X-CC, lateral view. **27.** *Astacolus* sp., 22H-CC, lateral view. **28.** *Procerolagena gracillima*, 16H-5, 146–148 cm, lateral view. **29.** *Lagena hispidula*, 13H-5, 146–148 cm, lateral view. **30.** *Lagena striata*, 8H-3, 146–148 cm, lateral view. **31.** *Oolina squamosa*, 9H-5, 146–148 cm, lateral view. **32.** *Parafissurina caledoniana*, 8H-CC, lateral view.

1846 *Nodosaria longiscata* d'Orbigny: p. 32, pl. 1, figs. 10–12.

1998 *Neugeborina longiscata* (d'Orbigny); Cicha, Rögl, Rupp, and Ctyroka, p. 195, pl. 21, fig. 12.

2009 *Neugeborina longiscata* (d'Orbigny); Kender, Kaminski, and Jones, p. 515, pl. 19, fig. 6.

2012 *Neugeborina longiscata* (d'Orbigny); Hayward, Kawagata, Sagaa, Grenfell, van Kerckhoven, Johnson, and Thomas, p. 134, pl. 8, figs. 19–23.

**Remarks.** All the specimens are broken, and the aperture is not preserved.

Family NODOSARIIDAE Ehrenberg, 1838  
Subfamily NODOSARIINAE Ehrenberg, 1838  
Genus DENTALINA Risso, 1826  
*Dentalina* spp.

**Remarks.** Specimens which are elongate, arcuate, and uniserial with a terminal aperture are included. All of them are broken and incomplete, which hinders the species identification.

Genus LAEVIDENTALINA Loeblich and Tappan, 1986

*Laevidentalina californica* (Cushman and Gray, 1946)  
Figure 8.24

1946 *Dentalina californica* Cushman and Gray: p. 66, pl. 12, figs. 3–5.

1994 *Dentalina californica* (Cushman and Gray); Loeblich and Tappan, p. 64, pl. 115, fig. 4.

**Remark.** It resembles *Laevidentalina aphelis* Loeblich and Tappan (1986) in possessing a slender and arcuate test, but differs in its more oblique sutures and large proloculus. It differs from *Laevidentalina bradyensis* (Dervieux, 1894) by being more slender and possessing a long apertural neck. This form is less robust and much more slender than *Laevidentalina* sp. A.

*Laevidentalina* sp. A  
Figure 8.25

**Description.** Test elongated, tapered, arcuate. Chambers increasing gradually in size, not inflated. Sutures slightly oblique, distinct, limbate, only slightly depressed. Wall smooth, without ornamentation. Aperture rounded, terminal on a neck.

**Remarks.** It differs from *Laevidentalina sidebotomi* (Cushman, 1933) by its more tapered test with less inflated and more rapidly growing chambers.

*Laevidentalina* spp.

**Remarks.** Broken specimens with a uniserial, elongated, and arcuate tests are included.

Genus NODOSARIA Lamarck, 1812  
*Nodosaria* spp.

**Remarks.** Broken uniserial specimens with globular chambers are included.

Family PLECTOFRONDICULARIIDAE Montanaro-Gallitelli, 1957 after Cushman, 1927b  
Genus MUCRONINA Ehrenberg, 1839  
*Mucronina* sp. A  
Figure 8.26

**Description.** Test compressed, lanceolate, uniserial throughout, with an acute periphery without a keel. Chambers chevron-shaped, inflated, increasing in size rapidly. Sutures depressed. Wall smooth without ornamentation.

**Remarks.** The last chambers of all specimens are broken. Specimens may resemble *Mucronina spatulata* (Costa, 1855), but differ in lacking longitudinal striations.

*Mucronina* spp.

**Remarks.** Broken specimens of various sizes are included. They may also belong to *Mucronina* sp. A.

Family VAGINULINIDAE Reuss, 1860  
Subfamily LENTICULININAE Chapman, Parr and Collins, 1934  
Genus LENTICULINA Lamarck, 1804  
*Lenticulina* sp. A  
Figure 7.8a, b

**Description.** Test small, circular in outline, planispiral with five to six chambers in the final whorl and an acute periphery. Sutures thick, flush, radial, slightly curved backwards. Chambers increasing in size gradually. Wall smooth without ornamentation. Aperture terminal.

**Remarks.** It differs from *Lenticulina gibba* (d'Orbigny, 1839a) by being less elongated in outline and possessing sutures that are only slightly curved backwards and less chambers in the final whorl. It might be a juvenile of *Lenticulina* sp. B.

*Lenticulina* sp. B  
Figure 7.9a, b

**Description.** Test large, circular in outline, planispiral with seven and a half chambers in the final whorl and an acute periphery. Sutures thick or slightly elevated, curved backwards. Chambers increasing in size gradually. Wall smooth without ornamentation. Aperture terminal with striations.

*Lenticulina* spp.

**Remarks.** Broken specimens of various sizes and juveniles are included.

Subfamily MARGINULININAE Wedekind, 1937  
*Astaculus* spp.  
Figure 8.27

**Remarks.** Only three specimens were recorded.

Genus HEMIROBULINA Stache, 1864  
*Hemirobulina* sp. A  
Figure 7.10a, b

**Description.** Test elongate, with a circular cross section, uniserial, the early part of the test curved, with four chambers. Chambers overlapping, increasing in size gradually, except for the last chamber, which is much larger. Sutures flush, oblique. Wall smooth, without ornamentation. Aperture terminal, on a neck.

*Hemirobulina* spp.

**Remarks.** Specimens of the genus, some of which are broken, are included.

Family LAGENIDAE Reuss, 1862  
Genus *PROCEROLAGENA* Puri, 1953 (1954)  
*Procerolagena gracillima* (Seguenza, 1862)  
Figure 8.28

- 1862 *Amphorina gracillima* Seguenza: p. 51, pl. 1, fig. 37.  
1884 *Lagena gracillima* (Seguenza); Brady, p. 456, pl. 56, figs. 19–28.  
1994 *Procerolagena gracillima* (Seguenza); Jones, p. 62, pl. 56, figs. 19–22, 24–29.  
2012 *Hyalinonetrium gracillimum* (Costa); Milker and Schmiedl, p. 74, fig. 18.30.

**Remarks.** The specimens in the studied materials are slender and unornamented. Many of them are broken. This species is retained in *Procerolagena* following Jones (1994), who considered the genus *Hyalinonetrium* to be a junior synonym of *Procerolagena*. The publication date of Puri's original publication is October 10, 1953, but Loeblich and Tappan (1987) reported the publication date as 1954.

Genus REUSSOOLINA Colom, 1956  
*Reussoolina apiculata* (Reuss, 1851)  
Figure 7.11

- 1851 *Oolina apiculata* Reuss: p. 22, pl. 2, fig. 1.  
1993 *Reussoolina apiculata* (Reuss); Clark and Patterson, fig. 2.7.

**Description.** Test unilocular, ovate, with an aciculate base. Wall smooth, without ornamentation. Aperture terminal, rounded with radial grooves, on a slight neck.

Family ELLPISOLAGENIDAE Silvestri, 1923  
Subfamily OOLININAE Loeblich and Tappan, 1961  
Genus LAGENA Walker and Jacob, 1798  
*Lagena hispidula* Cushman, 1913  
Figure 8.29

- 1884 *Lagena laevis* Montagu; Brady, p. 455, pl. 56, 7–14, 30.  
1913 *Lagena hispidula* Cushman: p. 14, pl. 5, figs. 2, 3.  
1994 *Lagena hispidula* Cushman; Jones, p. 62, pl. 56, figs. 10, 11, 13.

**Remarks.** The specimens possess a hispid test, but spines seem to be more robust and less densely distributed than on the specimens illustrated by Cushman (1913) and Jones (1994). The specimens differs from the one illustrated by Milker and Schmiedl (2012, fig. 18.32) by possessing spines and lacking horizontal rings on the apertural neck.

*Lagena striata* (d'Orbigny, 1839b)  
Figures 7.13a, b, 8.30

- 1839b *Oolina striata* d'Orbigny: p. 21, pl. 5, fig. 12.

**Remarks.** This form differs from *Lagena sulcata* (Walker and Jacob, 1798) by possessing much finer and numerous costae which run from the apertural neck to the bottom of the chamber. The specimens in this study also differ from the one illustrated by Milker and Schmiedl (2012, fig. 18.33) by their costae which continue to the apertural neck, and the absence of horizontal rings on the neck.

*Lagena* cf. *Lagena tagusensis* McCulloch, 1977  
Figure 7.12a, b

- 1977 *Lagena tagusensis* McCulloch: p. 48, pl. 50, fig. 10.

**Remarks.** The specimens differ from the type specimen by lacking the phialine lip on the apertural neck and from *Lagena crenata* (Parker and Jones, 1865) by possessing a smooth apertural neck without ornamentation and much fewer ridges on the chamber.

*Lagena* spp.

**Remarks.** Different forms of the genus are included.

Genus OOLINA d'Orbigny, 1839b  
*Oolina squamosa* (Montagu, 1803)  
Figures 7.14a, b, 8.31

- 1803 *Vermiculum squamosum* Montagu: p. 526, pl. 14, fig. 2.

1884 *Lagena squamosa* (Montagu); Brady, p. 471, pl. 58, figs. 28–31.

1994 *Oolina squamosa* (Montagu); Jones, p. 66, pl. 58, figs. 28–32.

**Remarks.** Specimens with reticulate ornamentation only in the upper half of the test are included in this species. Such a form is illustrated as *Oolina* cf. *Oolina squamosa imperfecta* (Buchner) by McCulloch (1977).

*Oolina* spp.

**Remarks.** Different forms some of which are broken and could not be identified at the species level are included.

Subfamily ELLIPSOLAGENINAE Silvestri, 1923

Genus FISSURINA Reuss, 1850

*Fissurina* spp.

**Remarks.** Partially broken specimens of the genus are included. A few clearly possess some extended structures.

Subfamily PARAFISSURININAE Jones, 1984

*Parafissurina caledoniana* McCulloch, 1981

Figure 8.32

1981 *Parafissurina caledoniana* McCulloch: p. 111, pl. 36, figs. 4, 6, 9.

**Remarks.** *Parafissurina* sp. B of Kaiho (1992, pl. 2, fig. 19) may also belong to this species.

Family GLANDULINIDAE Reuss, 1860

Subfamily GLANDULININAE Reuss, 1860

Genus GLANDULINA d'Orbigny, 1839a

*Glandulina ovula* d'Orbigny, 1846

Figure 7.15a, b

1846 *Glandulina ovula* d'Orbigny: p. 29, pl. 1, figs. 6, 7.

1884 *Nodosaria* (*Gl.*) *rotundata* Reuss; Brady, p. 491, pl. 61, 17–19.

1994 *Glandulina ovula* d'Orbigny; Jones, p. 72, pl. 61, figs. 17–22.

**Remarks.** The specimens from the Bering Sea are not as tapered as the specimen illustrated by d'Orbigny (1846).

*Glandulina* spp.

**Remarks.** Broken specimens that may be assigned to *Glandulina ovula*, are included here.

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## APPENDIX

Counts of specimens. File in electronic format at: [palaeo-electronica.org/content/2015/1264-bering-benthic-forams](http://palaeo-electronica.org/content/2015/1264-bering-benthic-forams)