

7. DATA REPORT: PALEOCENE/EOCENE BENTHIC FORAMINIFERS, ODP LEG 199 SITES 1215, 1220, AND 1221, EQUATORIAL CENTRAL PACIFIC OCEAN¹

Ritsuo Nomura² and Hiroyuki Takata³

ABSTRACT

Benthic foraminifers from Ocean Drilling Program Leg 199 Holes 1215A, 1220B, and 1221C were examined across the Paleocene/Eocene boundary. Assemblages were studied in 240 samples. The benthic foraminiferal extinction event that correlates with the Paleocene/Eocene epoch boundary was recognized at these sites. Benthic assemblages before the event are characterized by high diversity, but those after the event are low in diversity. An assemblage of agglutinated foraminifers without carbonate cement was recognized at Sites 1220 and 1221. These assemblages were typically found after the event. The discovery of such agglutinated assemblages has never been reported before at this boundary.

INTRODUCTION

The benthic foraminiferal extinction event across the Paleocene/Eocene boundary has been recognized in both deep-ocean and terrestrial sections in diverse locations (Thomas, 1998). However, biostratigraphic studies that identify detailed assemblage changes before and after the event are still too low in resolution. Previous studies suggest that the event occurred in a very short chronostratigraphic interval (Kennett and Stott, 1991; Thomas and Shackleton, 1996).

¹Nomura, R., and Takata, H., 2005. Data report: Paleocene/Eocene benthic foraminifers, ODP Leg 199 Sites 1215, 1220, and 1221, equatorial central Pacific Ocean. *In* Wilson, P.A., Lyle, M., and Firth, J.V. (Eds.), *Proc. ODP, Sci. Results*, 199, 1–34 [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/199_SR/VOLUME/CHAPTERS/223.PDF>. [Cited YYYY-MM-DD]

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Biostratigraphic studies of this event have mostly been performed on sections from the oceanic ridges at upper-bathyal to mid-bathyal paleodepths. Little information has been reported from abyssal paleodepths. Thus, the benthic assemblages at Sites 1215, 1220, and 1221 are particularly significant because these sites were located in an abyssal zone at ~3000 m paleodepth (Shipboard Scientific Party, 2002).

METHODS

A total of 238 sediment samples from Leg 199 Holes 1215A, 1220B, and 1221C were analyzed for benthic foraminifers at the following intervals:

Hole 1215A: 103 samples

- 1–2 cm (Samples 199-1215A-8X-3, 0–1 cm, to 8X-3, 111–112 cm, and 8H-4, 14–15 cm, to 8H-4, 40–41 cm)
- 1 cm (Samples 199-1215A-8X-3, 113–114 cm, to 8X-4, 12–13 cm)

Hole 1220B: 65 samples

- 2 cm (Samples 199-1220B-20X-2, 0–2 cm, to 20X-2, 46–48 cm)
- 1 cm (Samples 199-1220B-20X-2, 48–49 cm, to 20X-2, 88–89 cm)

Hole 1221C: 72 samples

- 3–20 cm (Samples 199-1221C-11X-1, 3–5 cm, to 11X-3, 28–30 cm, and 11X-3, 113–115 cm, to 12X-1, 18–20 cm)
- 2 cm (Samples 199-1221C-11X-3, 40–42 cm, to 11X-3, 108–110 cm)

Sediment samples (1–2 cm³) were dried at 80°C overnight and then weighed. Dried sediment samples were treated with 3% hydrogen peroxide solution overnight and washed through a 63- μ m sieve. Foraminifers were picked from an aliquot of the >149- μ m size fraction. A minimum of 200 specimens were picked, but because of limited sample volume and poor preservation in some sections, the number of foraminifers picked was sometimes <200.

Major systematic sources for this study are Ellis and Messina (1940), Cushman (1935, 1946, 1951), Tjalsma and Lohmann (1983), Loeblich and Tappan (1987), Nomura (1991), Speijer (1994), and Widmark (1997).

RESULTS

Site 1215

A total of 99 benthic foraminiferal taxa were recognized at this site (Table T1). In general, benthic foraminifers at Site 1215 were well preserved. Some forms such as *Abyssamina quadrata* show very good preservation, which retains the original calcareous crystalline structure of test walls. The number of specimens per gram of sediment ranges from 1.1 to 99.7; Sample 199-1215A-8H-3, 130–131 cm, contains the fewest foraminifers, and Sample 8H-3, 60–61 cm, contains the most foraminifers. These foraminiferal counts are low compared to those from the other two sites (see “Site 1220” and “Site 1221” below). The number of foraminifers decreases in several stratigraphic intervals, particularly in nine

T1. Distribution of benthic foraminifers, Hole 1215A, p. 11.

samples in the interval from 199-1215A-8H-3, 127–128 cm, to 8H-3, 135–136 cm, a black layer of nannofossil clay (Fig. F1).

Primary species recognized include *A. quadrata*, *Anomalinoidea praeacutus*, *Globocassidulina globosa*, *Nuttallides truempyi*, *Pullenia subcarinata*, *Quadriformina profunda*, *Tappanina selmensis*, *Paralabamina elevata*, *Globorotalites micheliniana*, *Gavelinella beccariiformis*, and buliminids. Agglutinated foraminifers are rare at this site.

Site 1220

A total of 111 benthic foraminiferal taxa were recognized at this site (Table T2). In contrast to the other sites, foraminifers were poorly preserved with recrystallized walls. Preservation is particularly poor in the interval from Sample 199-1220B-20X-2, 46–48 cm, to 20X-2, 78–79 cm, which correlates to an interval of multicolored layers. The maximum of 318 specimens/g is found in Sample 199-1220B-20X-2, 2–4 cm, and the minimum of 0 specimens/g is found in Samples 20X-2, 51–52 cm, 58–59 cm, 61–62 cm, and 67–69 cm.

Agglutinated foraminifers with no calcareous cement dominated in multicolored sediment layers. Because carbonate-free and cylindrical agglutinated forms such as *Saccorhiza* and *Rhabdammina* are found in the modern deeper ocean below the calcium carbonate compensation depth, we suggest that carbonate-corrosive bottom water covered the site during the time of deposition.

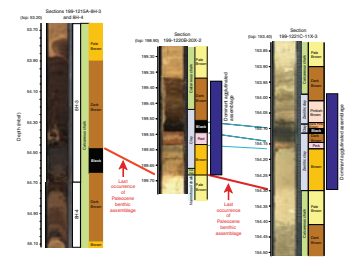
Primary species identified in lower Eocene sediments include *A. quadrata*, *A. praeacutus*, *Bulimina bradburyi*, *Bulimina trihedra*, *G. globosa*, *N. truempyi*, *Oridorsalis umbonatus*, *Pleurostomella paleocenica*, *P. subcarinata*, *Q. profunda*, *T. selmensis*, and *Valvalabamina* spp. Primary species identified in the uppermost Paleocene sediments include *Bulimina* cf. *denticulata*, *Buliminella beaumonti*, *Cibicoides eocaenus*, *G. beccariiformis*, *G. micheliniana*, *Neoepionides hillebrandti*, *P. elevata*, and *Valvalabamina* spp. Paleocene assemblages are characterized by high diversity, and Eocene assemblages are characterized by high abundance of individuals of the primary species but are less diversified.

Site 1221

A total of 139 taxa were recognized at this site (Table T3). The benthic assemblages at this site are similar to those at Site 1220 except that the hyaline calcareous foraminifers are well preserved. Agglutinated foraminifers were developed in the multicolored interval of zeolitic clay (Fig. F1), but preservation is as poor as at Site 1220. The test walls are typically deformed.

Very high foraminiferal numbers (400–700 specimens/g) were found in the calcareous chalk layers above the multicolored interval from 199-1221C-11X-3, 28–30 cm, to 11X-3, 56–58 cm. However, the diversity of foraminifers in these assemblages is low and dominated by few species such as *A. quadrata*, *A. praeacutus*, *G. globosa*, and *N. truempyi*. The assemblages below the multicolored interval are characterized by both high foraminiferal numbers and high diversity. Some calcareous forms such as *C. eocaenus*, *Globorotalites conicus*, *Gyroidinoides globosus*, *O. umbonatus*, and *Osangularia plummerae*, are characterized by large tests with thick walls.

F1. Benthic extinction event and the lithostratigraphic color units, p. 10.



T2. Distribution of benthic foraminifers, Hole 1220B, p. 12.

T3. Distribution of benthic foraminifers, Hole 1221C, p. 13.

PALEOCENE/EOCENE BOUNDARY

An abrupt decrease in diversity and foraminiferal number occurs in Samples 199-1220B-20X-2, 78–79 cm, and 199-1221C-11X-3, 88–90 cm, and 11X-3, 90–92 cm. This stratigraphic level represents the benthic extinction event. Most Paleocene taxa, such as *G. beccariiiformis*, *G. conicus*, *N. hillebrandti*, and *Pullenia coryelli*, disappear at the same stratigraphic level in each section, but some Paleocene taxa were observed above this level. The individual numbers of such Paleocene taxa, however, are very low, suggesting reworking. This evidence clearly suggests that the benthic event is represented by the abrupt change in the Paleocene assemblages. At Sites 1220 and 1221 this extinction event is correlated with the base of a brown layer, marked by massive zeolitic chalk, which is devoid of distinct bioturbation. At Site 1215, the event is less distinct compared to the other two sites. However, the last occurrence of typical Paleocene taxon *G. beccariiiformis* is found in Sample 199-1215A-8H-3, 126–127 cm. Many Paleocene foraminifers became extinct by this stratigraphic level. Thus, the benthic Paleocene/Eocene boundary event is placed between Sample 199-1215A-8H-3, 126–127 cm, and 8H-3, 125–126 cm, at Site 1215.

It is well known that the abrupt decrease in the Paleocene assemblages correlates with a shift to lower values in the oxygen and carbon isotope records (i.e., Kennett and Stott, 1991). [Nunes and Norris](#) (this volume) show that the shift in $\delta^{13}\text{C}$ occurs in Sample 199-1221C-11X-3, 58–60 cm, ~30 cm above the benthic event. This result conflicts with the previous concept of synchronous biostratigraphy and chemostratigraphy events. We will discuss this discrepancy between the isotopic record and the benthic assemblage evidence elsewhere.

ACKNOWLEDGMENTS

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APPENDIX

Faunal Reference List

Faunal examples are presented in Plates P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12, P13, P14, P15, P16, P17, P18, P19, P20, and P21.

Abyssamina quadrata Schnitker and Tjalsma, 1980.

Alabamina dissonata (Cushman and Renz) = *Pulvinulinella atlantisae* Cushman
var. *dissonata* Cushman and Renz, 1948.

Agglutinated Forms

Alabamina sp.

Alabamina sp. 1

Alabamina sp. 3

Alabamina sp. 4

Alabamina sp. 5

Allomorphina minuta Cushman, 1944.

Ammoglobigerina sp.

Anomalinooides praeacutus (Vasilenko) = *Anomalina praeacuta* Vasilenko, 1950.

Anomalinooides sp.

Aragonina aragonensis (Nuttall) = *Textularia aragonensis* Nuttall, 1930.

Aragonina ouezzanensis (Rey) = *Bolivinooides ouezzanensis* Rey, 1955.

Aragonina sp.

Astacolus spp.

Botellina sp.

Bulimina bradburyi Martin, 1943.

Bulimina denticulata Cushman and Parker, 1936.

Bulimina cf. *denticulata* Cushman and Parker, 1936.

Bulimina impendens Parker and Bermudez, 1937.

Bulimina jarvisi Cushman and Parker, 1936.

Bulimina midwayensis Cushman and Parker = *Bulimina arkadelphiana* Cushman
and Parker *midwayensis* Cushman and Parker, 1936.

Bulimina cf. *midwayensis* Cushman and Parker.

Bulimina proluxa Cushman and Parker, 1935.

Bulimina sp.

Bulimina sp. 1

Bulimina sp. 2

Bulimina spp.

Bulimina triangularis Cushman and Parker, 1935.

Bulimina trihedra Cushman, 1926.

Bulimina tuxpamensis Cole, 1928.

Bulimina velascoensis (Cushman) = *Gaudryina velascoensis* Cushman, 1925.

Buliminella beaumonti Cushman and Renz, 1946.

Buliminella cf. *grata* Parker and Bermudez, 1937 = cf. *Buliminella grata* Parker and
Bermudez, 1937.

Buliminella sp. 1

Buliminella sp.

Cibicoides eocaenus = *Rotalia eocaena* Gümbel, 1868.

Cibicoides cf. *dayi* (White) = cf. *Planulina dayi* White, 1928.

Cibicoides grimsdalei (Nuttall) = *Cibicides grimsdalei* Nuttall, 1930.

Cibicoides cf. *pseudoperlucidus* (Bykova) = cf. *Cibicides (Gemellides) pseudoperluci-*
du Bykova, 1954.

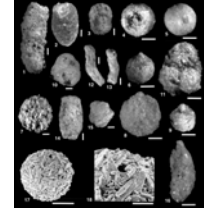
Cibicoides sp.

Cibicoides sp. 2

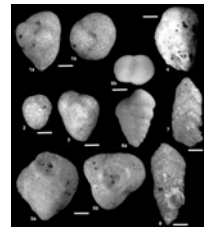
Cibicoides sp. 3

Cibicoides spp.

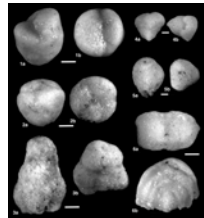
P1. *Rhabdammina*, *Hippocrepinella*, *Haplophragmoides*, *Saccamina*, *Hormosina*, *Placentamina*, *Ammobigerina*, *Saccorhiza ramosa*, *Botellina*, p. 14.



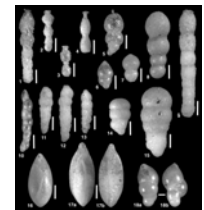
P2. *Eggerella*, *Tritaxia*, *Spiroplectammina*, p. 15.



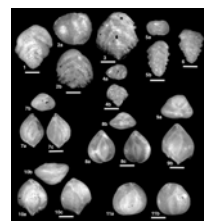
P3. *Marssonella*, *Tritaxia*, *Vulvulina*, p. 16.



P4. *Stilostomella*, *Nodosaria*, *Pleurostomella*, *Orthokarsteina*, *Pyrulinooides*, *Sigmomorphina*, p. 17.

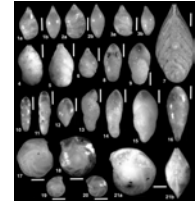


P5. *Aragonina*, *Tappanina*, *Falsoguttulina*, p. 18.

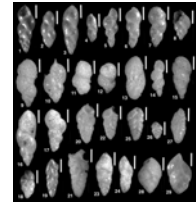


Cibicoides subcarinatus (Cushman and Deaderick) = *Cibicides subcarinatus* Cushman and Deaderick, 1944.
Coryphostoma crenulata (Cushman) = *Bolivina crenulata* Cushman, 1936.
Coryphostoma incrassata (Reuss) = *Bolivina incrassata* Reuss, 1851.
Coryphostoma cf. *midwayensis* (Cushman) = cf. *Bolivina midwayensis* Cushman, 1936.
Coryphostoma sp.
Dentalina inornata d'Orbigny, 1846.
Dentalina spp.
Dentalina wilcoxensis Cushman, 1944.
Dorothia bulletta (Carsey) = *Gaudryina bulletta* Carsey, 1926.
Eggerella spp.
Ellipsosonodosaria paleocenica Cushman and Todd, 1946.
Ellipsoglandulina labiata (Schwager) = *Glandulina labiata* Schwager, 1866.
Ellipsoglandulina plummerae (Cushman) = *Ellipsosonodosaria plummerae* Cushman, 1940.
Ellipsoglandulina spp.
Ellipsoglandulina velascoensis Cushman, 1926.
Ellipsoidella pleurostomelloides Heron-Allen and Earland, 1910.
Ellipsoidella spp.
Ellipsoidina ellipsoides Seguenza, 1859.
Ellipsoidina spp.
Ellipsopolymorphina fornasini Galloway, 1933.
Ellipsopolymorphina spp.
Eouvigerina sp.
Falsoguttulina sp. 1
Falsoguttulina wolburgi Bartenstein and Brand, 1949.
Fursenkoina sp.
Gavelinella beccariiiformis (White) = *Rotalia beccariiiformis* White, 1928.
Globimorphina trochoidea (Reuss) = *Globigerina trochoides* Reuss, 1845.
Globocassidulina globosa (Hantken) = *Cassidulina globosa* Hantken, 1875.
Globocassidulina sp.
Globocassidulina sp. 1
Globorotalites conicus (Boomgaard) = *Eponides conicus* Boomgaard, 1949.
Globorotalites micheliniana (d'Orbigny) = *Rotalina (Rotalina) micheliniana* d'Orbigny, 1840.
Globulina? sp.
Gubkinella asiatica Suleymanov, 1955.
Gyroidinoides beisseli (White) = *Gyroidina beisseli* White, 1928.
Gyroidinoides cf. *girardanus* (Nuttall) = cf. *Rotalina girardana* Reuss, 1851.
Gyroidinoides girardanus (Reuss) = *Rotalina girardana* Reuss, 1851.
Gyroidinoides globosus (Hagenow) = *Nonionia globosa* Von Hagenow, 1842.
Gyroidinoides cf. *globosus* (Hagenow).
Gyroidinoides goudkoffi (Trujillo) = *Eponides goudkoffi* Trujillo, 1960.
Gyroidinoides nitidus (Reuss) = *Rotalina nitida* Reuss, 1844.
Gyroidinoides octocameratus (Subbotina) = *Eponides octocameratus* Subbotina, 1960.
Gyroidinoides subangulatus (Plummer) = *Rotalia soldanii* (d'Orbigny) var. *subangulata* Plummer, 1927.
Gyroidinoides sp. 1
Gyroidinoides spp.
Haplophragmoides sp.
Haplophragmoides? sp.
Hemirobulina cf. *arcuatula* (Stache) = *Cristellaria (Hemirobulina) arcuatula* Stache, 1864.
Heronallenia sp.
Hippocrepinella sp.
Hormosina sp.
Hyperammina? sp.
Lenticulina insulsus (Cushman) = *Robulus insulsus* Cushman, 1947.
Lenticulina spp.

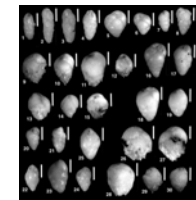
P6. *Hemirobulina*, *Astacolus*, *Saracenaria*, *Neoflabellina*, *Pleurostomella*, *Lenticulina*, p. 19.



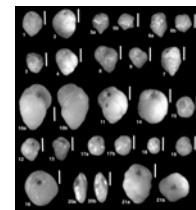
P7. *Paleopleurostomella*, *Coryphostoma*, p. 20.



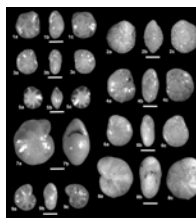
P8. *Bulimina*, p. 21.



P9. *Praebulimina*, *Bulimina*, *Globimorphina*, *Buliminella*, *Globocassidulina*, *Fursenkoina*, *Quadratobuliminella*, p. 22.

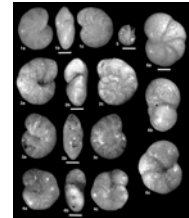


P10. *Alabamina*, *Nonion*, p. 23.

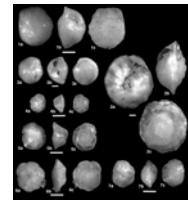


Lenticulina whitei Tjalsma and Lohmann, 1983.
Linaresia semicribrata (Beckmann) = *Anomalina pompilioides* Galloway and Hem-
inway var. *semicribrata* Beckmann, 1954.
Marssonella oxycona (Reuss) = *Gaudryina oxycona* Reuss, 1860.
Marssonella trochoides (d'Orbigny) = *Textularia trochoides* d'Orbigny, 1852.
Neoeponides haidingerii (d'Orbigny) = *Eponides haidingerii* (d'Orbigny) of Cush-
man, 1931.
Neoeponides hillebrandti Fisher, 1969.
Neoeponides infrequens (Plummer) = *Discorbis infrequens* Plummer, 1927.
Neoeponides spp.
Neoflabellina rugosa (d'Orbigny) = *Flabellina rugosa* d'Orbigny, 1840.
Nodosarella spp.
Nodosaria affinis (Reuss) = *Nonionina affinis* Reuss, 1851.
Nodosaria aspera Reuss, 1845.
Nodosaria monile Hagenow, 1842.
Nodosarella paleocenica Cushman and Todd, 1946.
Nodosaria spp.
Nonion havanense Cushman and Bermudez, 1937.
Nonion sp. 1
Nonion spp.
Nuttallides truempyi (Nuttall) = *Eponides truempyi* Nuttall, 1930.
Nuttallides sp. 1
Nuttallides sp. 2
Oridorsalis plummerae (Cushman) = *Eponides plummerae* Cushman, 1948.
Oridorsalis sp.
Oridorsalis umbonatus (Reuss) = *Rotalina umbonata* Reuss, 1851.
Orthokarstenia brevispinosa (Cushman) = *Siphogenerinoides brevispinosa* Cushman,
1939.
Orthokarstenia cf. *brevispinosa* (Cushman) = cf. *Siphogenerinoides brevispinosa*
Cushman, 1939.
Orthokarstenia clarki (Cushman and Campbell) = *Siphogenerinoides clarki* Cush-
man and Campbell, 1936.
Osangularia plummerae Brotzen, 1940.
Osangularia spp.
Paleopolymorphina pleurostomelloides (Franke) = *Polymorphina pleurostomelloides*
Franke, 1928.
Paralabamina elevata (Plummer) = *Truncatulina elevata* Plummer, 1927.
Paralabamina lunata (Brotzen) = *Eponides lunata* Brotzen, 1948.
Paralabamina sp. 1
Paralabamina sp. 4
Placentammina sp.
Pleurostomella clavata Cushman, 1926.
Pleurostomella paleocenica Cushman, 1947.
Pleurostomella rimosa Cushman and Bermudez, 1937.
Pleurostomella subnodosa Reuss, 1860.
Pleurostomella velascoensis Cushman, 1926.
Pleurostomella spp.
Polymorphina sp.
Praebulimina reussi (Morrow) = *Bulimina reussi* Morrow, 1934.
Pseudoglandulina spp.
Pseudonodosaria spp.
Pullenia cf. *eocenica* Cushman and Siegfus, 1939.
Pullenia coryelli White, 1929.
Pullenia cretacea Cushman, 1936.
Pullenia jarvisi Cushman, 1936.
Pullenia sp.
Pullenia subcarinata (d'Orbigny) = *Nonionina subcarinata* d'Orbigny, 1839.
Pyrulinoidea acuminatus (d'Orbigny) = *Pyrulina acuminata* d'Orbigny, 1840.
Pyrulina sp.
Quadratobuliminella pyramidalis Klasz, 1953.
Quadratobuliminella spp.

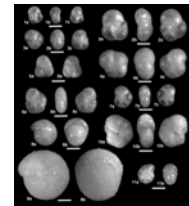
P11. *Valvalabamina, Linaresia*,
p. 24.



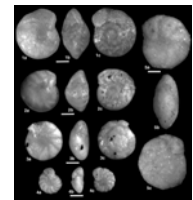
P12. *Globorotalites, Paralabamina*,
p. 25.



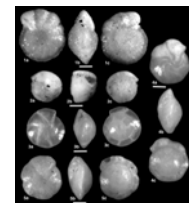
P13. *Quadriformina, Abyssamina,*
Allomorphina, Pullenia, p. 26.



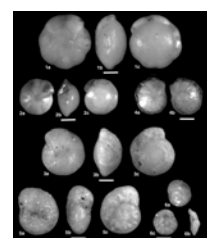
P14. *Cibicidoides*, p. 27.



P15. *Cibicidoides, Oridorsalis*, p. 28.

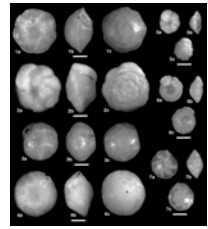


P16. *Oridorsalis, Osangularia, Gav-*
elinella, Heronallenia, p. 29.

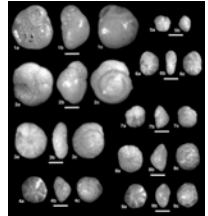


Quadriformina profunda Schnitker and Tjalsma, 1980.
Rhabdammina sp.
Saccamina sp.
Saccorhiza ramosa (Brady) = *Hyperammina ramosa* Brady, 1879.
Saracenaria midwayensis Kline, 1943.
Scheibnerova? sp.
Sigmomorphina sp.
Sigmomorphina terquemiana (Fornasini) = *Sigmomorphina semitecta* (Reuss) var. *terquemiana* (Fornasini) of Cushman and Ozawa, 1930.
Spiroplectammina jarvisi Cushman, 1939.
Spiroplectammina sp.
Spiroplectammina spectabilis (Grzybowski) = *Spiroplecta spectabilis* Grzybowski, 1898.
Spiroplectammina subglabra (Cushman) = *Textularia subglabra* Cushman, 1926.
Stilostomella paleocenica (Cushman and Todd) = *Ellipsonodosaria paleocenica* Cushman and Todd, 1946.
Stilostomella plummerae (Cushman) = *Ellipsonodosaria plummerae* Cushman, 1940.
Stilostomella rugosa Guppy, 1894.
Stilostomella sp.
Tappanina selmensis (Cushman) = *Bolivina selmensis* Cushman, 1933.
Tritaxia globulifera (ten Dam and Sigal) = *Pseudoclavulina globulifera* ten Dam and Sigal, 1950.
Tritaxia paleocenica Tjalsma and Lohmann, 1983.
Tritaxia pyramidata (Cushman) = *Gaudryina laevigata* Franke var. *pyramidata* Cushman, 1926.
Tritaxia sp.
Unilocular forms
Valvalabamina depressa (Cushman and Church) = *Gyroidina depressa* Cushman and Church, 1929.
Valvalabamina sp. 1
Valvalabamina sp. 2
Valvalabamina sp. 3
Valvalabamina sp. 4
Valvulineria spp.
Vulvulina spinosa Cushman, 1927.

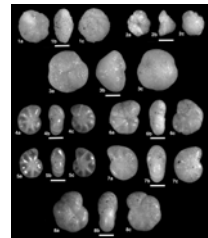
P17. *Nuttallides*, p. 30.



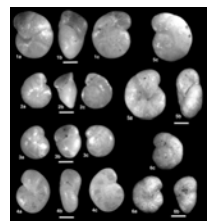
P18. *Paralabamina*, p. 31.



P19. *Paralabamina*, *Nonion*, *Valvalabamina*, p. 32.



P20. *Gyroidinoides*, *Valvalabamina*, p. 33.



P21. *Gyroidinoides*, *Neoeponides*, *Cibicidoides*, *Gubkinella*, *Lenticulina*, *Saracenaria*, *Eouvigerina*, p. 34.

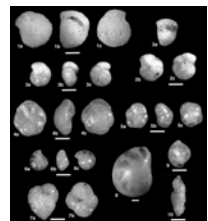


Figure F1. Stratigraphic level of the benthic foraminiferal extinction event and the lithostratigraphic color units at Sites 1215, 1220, and 1221.

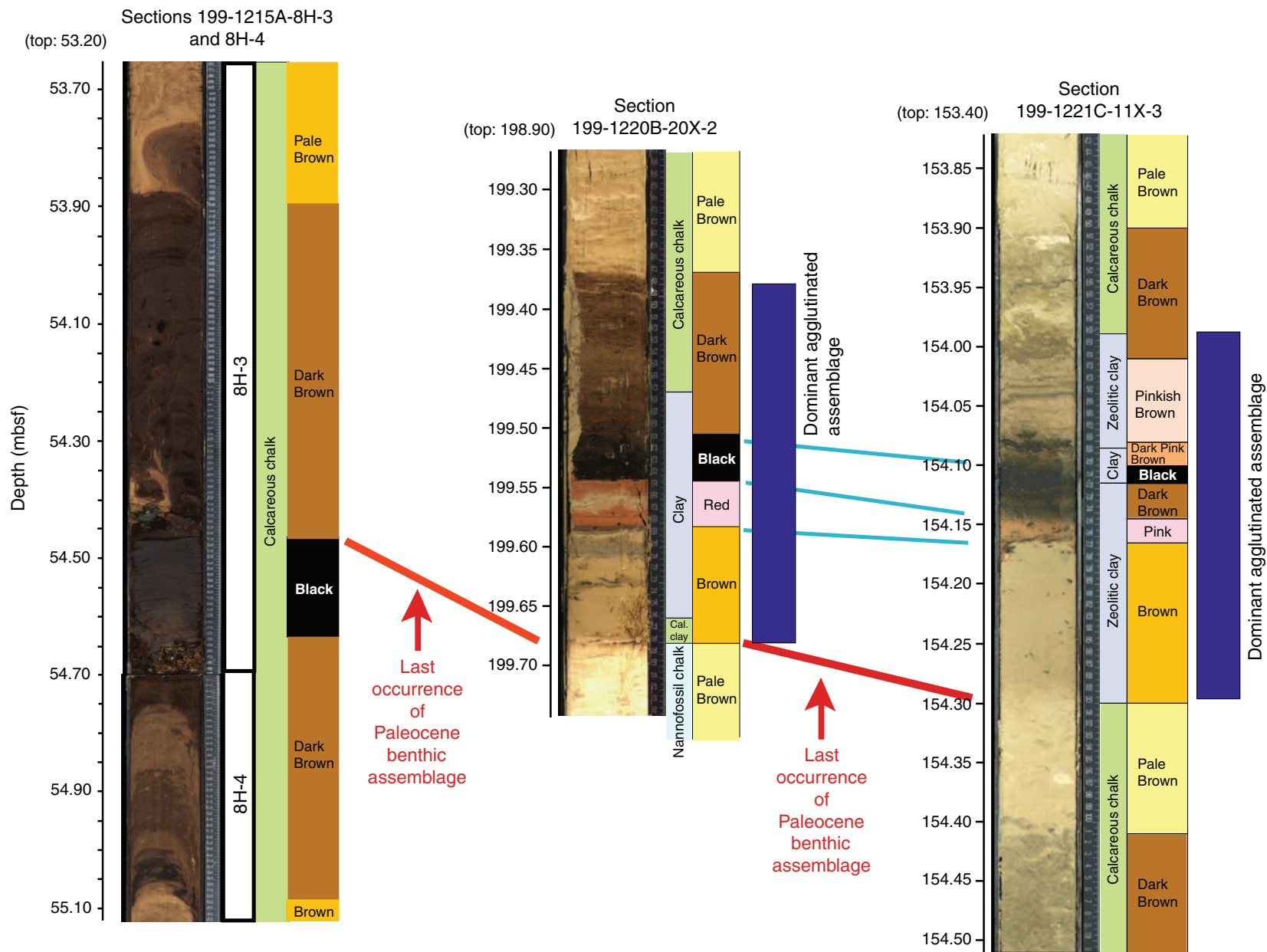


Table T1. Distribution of benthic foraminifers, Hole 1215A. (This table is available in an [oversized format](#).)

Table T2. Distribution of benthic foraminifers, Hole 1220B. (This table is available in an [oversized format](#).)

Table T3. Distribution of benthic foraminifers, Hole 1221C. (This table is available in an [oversized format](#).)

Plate P1. Scale bar = 100 μm except figures 17 and 18. 1. *Rhabdammina* sp. (Sample 199-1220B-20X-2, 69–70 cm). 2. *Hippocrepinella* sp. (Sample 199-1220B-20X-2, 67–68 cm). 3. *Haplophragmoides* sp. (Sample 199-1220B-20X-2, 59–60 cm). 4, 5. *Saccamina* sp. (Sample 199-1221C-11X-3, 70–72 cm). 6, 8, 9. *Hormosina* sp.; (6) Sample 199-1220B-20X-2, 70–71 cm, (8) Sample 199-1220B-20X-2, 77–78 cm, (9) Sample 199-1221C-11X-3, 94–96 cm. 7. *Placentamina* sp. (Sample 199-1221C-11X-3, 86–88 cm). 10, 11. *Ammobigerina* sp.; (10) Sample 199-1220B-20X-2, 64–65 cm, (11) Sample 199-1220B-20X-2, 69–70 cm. 12, 13. *Saccorhiza ramosa* (Brady) (Sample 199-1220B-20X-2, 77–78 cm). 14. *Botellina* sp. (Sample 199-1221C-11X-2, 58–60 cm). 15. *Haplophragmoides*? sp. (Sample 199-1220B-20X-2, 67–68 cm). 16. *Hyperammina*? sp. (Sample 199-1220B-20X-2, 70–71 cm). 17. Scanning electron microphotograph of *Saccamina* sp., showing recrystallized test walls (scale bar = 50 μm). 18. Close-up of figure 17, showing small aperture and crystals (scale bar = 17.6 μm).

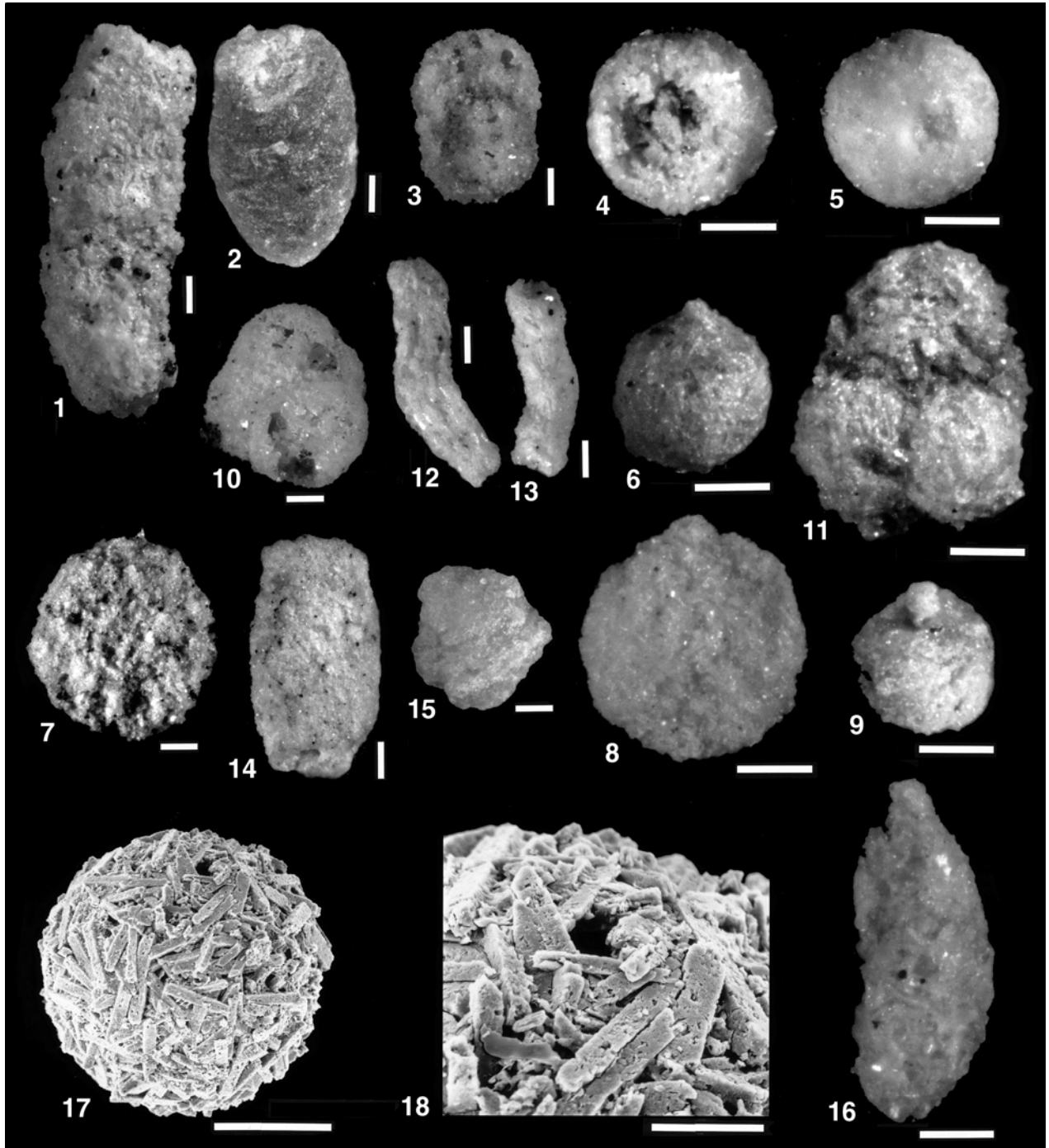


Plate P2. Scale bar = 100 μ m. 1. *Eggerella* sp. (Sample 199-1215A-8H-4, 7–8 cm). 2, 3. *Tritaxia paleocenica* Tjalsma and Lohmann; (2) Sample 199-1221C-11X-2, 73–75 cm, (3) Sample 199-1221C-11X-3, 104–106 cm. 4, 5. *Tritaxia globulifera* (ten Dam and Sigal); (4) Sample 199-1221C-11X-3, 108–110 cm, (5) Sample 199-1215A-8H-3, 126–127 cm. 6. *Spiroplectammina subglabra* (Cushman) (Sample 199-1221C-11X-1, 23–25 cm). 7. *Spiroplectammina spectabilis* (Grzybowski) (Sample 199-1220B-20X-2, 85–86 cm). 8. *Spiroplectammina jarvisi* Cushman. (Sample 199-1220B-20X-2, 79–80 cm).

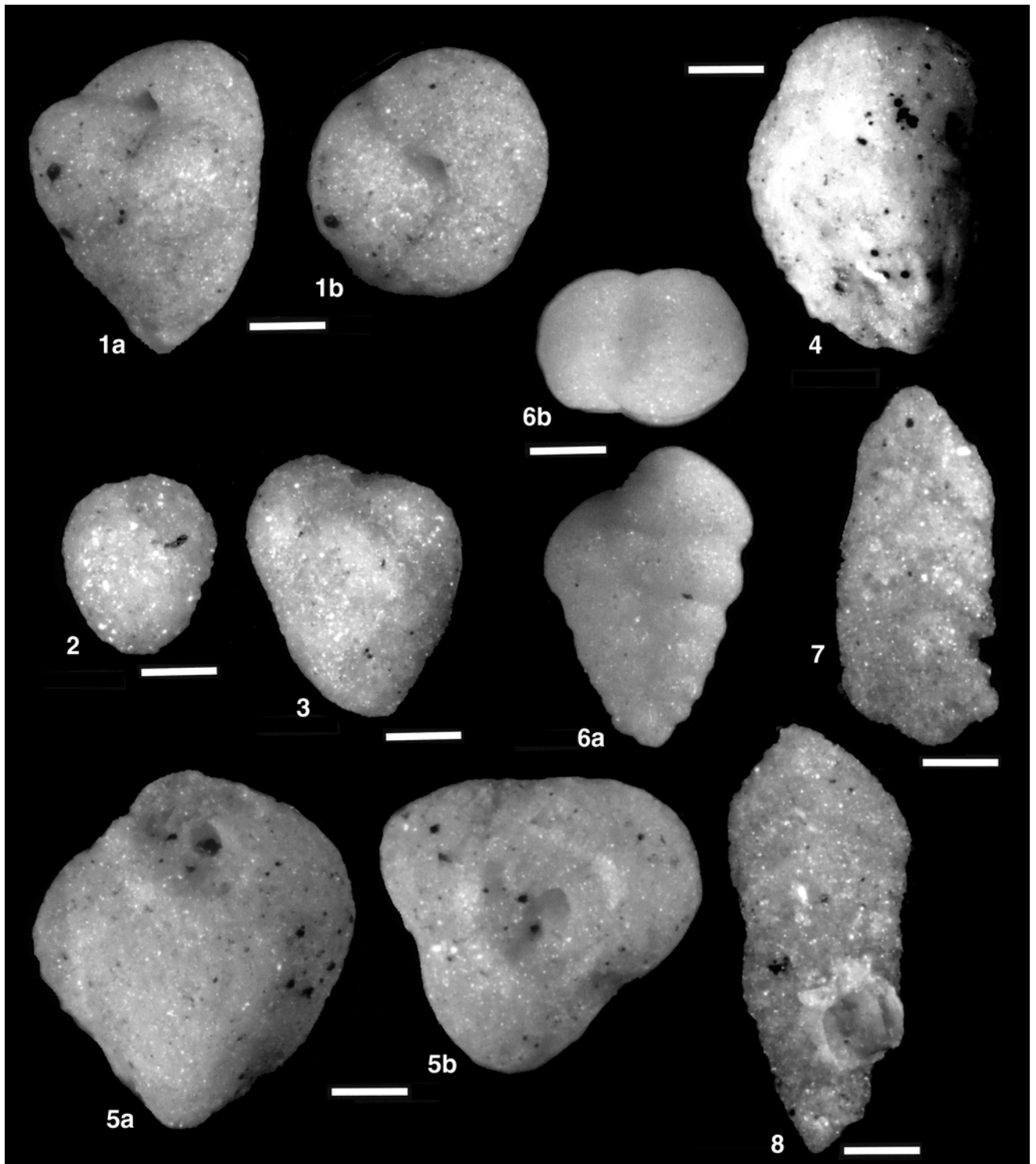


Plate P3. Scale bar = 100 μ m. 1. *Marssonella oxycona* (Reuss) (Sample 199-1215A-8H-4, 7–8 cm). 2. *Marssonella trochoides* (Marsson) (Sample 199-1221C-11X-3, 96–98 cm). 3, 5. *Tritaxia globulifera* (ten Dam and Sigal); (3) Sample 199-1221C-11X-3, 90–92 cm, (5) Sample 199-1220B-20X-2, 84–85 cm. 4. *Tritaxia pyramidata* Cushman (Sample 199-1220B-20X-2, 82–83 cm). 6. *Vulvulina spinosa* Cushman (Sample 199-1221C-12X-1, 18–20 cm).

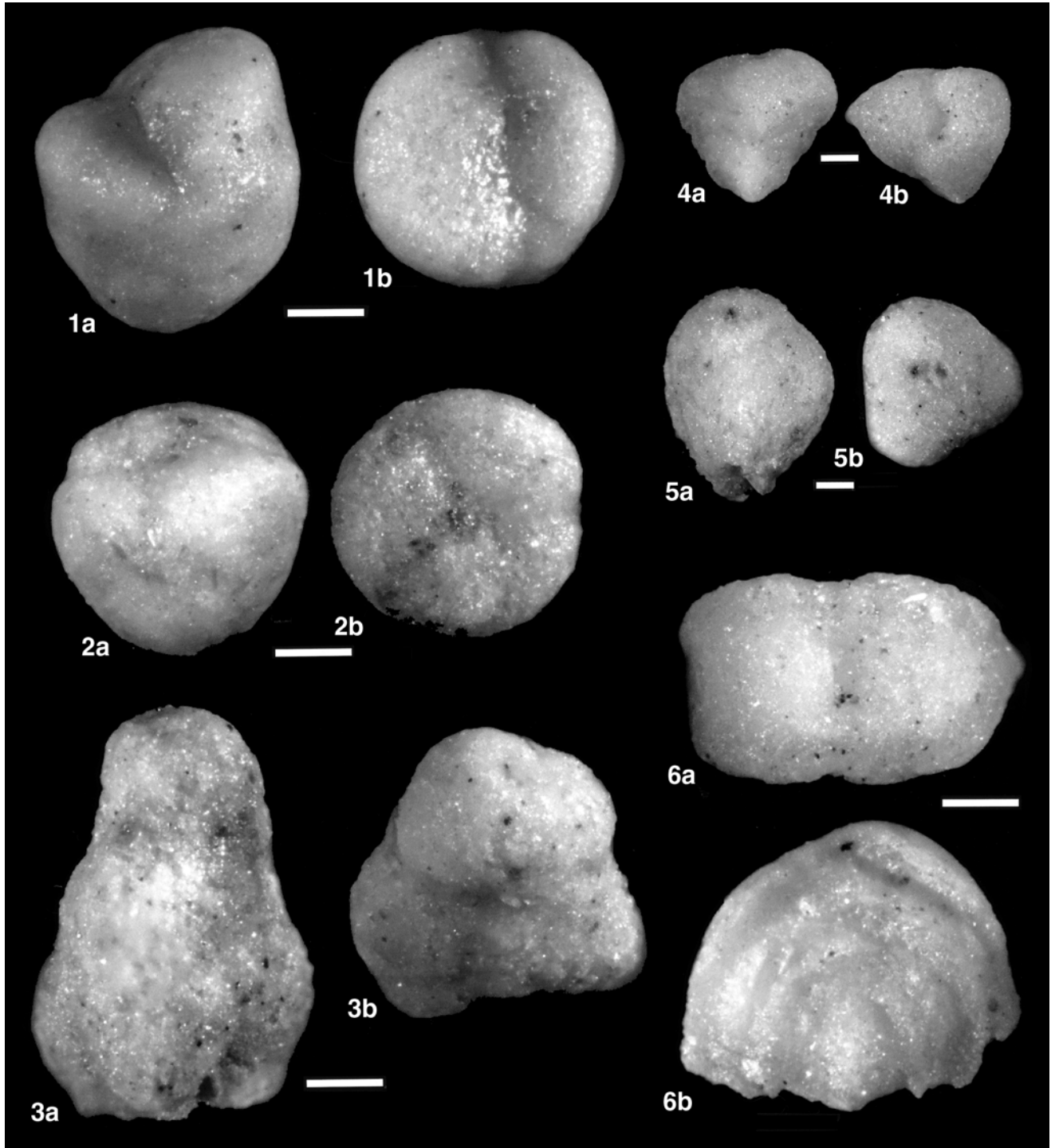


Plate P4. Scale bar = 100 μm . 1–3. *Stilostomella plummerae* (Cushman); (1) Sample 199-1220B-20X-2, 88–89 cm, (2) Sample 199-1221C-11X-3, 123–125 cm, (3) Sample 199-1215A-8H-4, 0–1 cm. 4. *Stilostomella paleocenica* (Cushman and Todd) (Sample 199-1221C-11X-1, 23–25 cm). 5, 6. *Stilostomella rugosa* Guppy; (5) Sample 199-1215A-8H-4, 11–12 cm, (6) Sample 199-1215A-8H-4, 8–9 cm. 7, 8. *Nodosaria monile* Hagenow; (7) Sample 199-1215A-8H-4, 10–11 cm, (8) Sample 199-1220B-20X-2, 18–20 cm. 9. *Nodosaria* sp. (Sample 199-1220B-20X-2, 78–79 cm). 10. *Pleurostomella subnodosa* Reuss (Sample 199-1215A-8H-3, 51–52 cm). 11–13. *Orthokarstenia brevispinosa* (Cushman); (11, 12) Sample 199-1220B-20X-2, 84–85 cm, (13) Sample 199-1221C-11X-3, 108–110 cm. 14, 15. *Orthokarstenia clarki* (Cushman and Campbell) (Sample 199-1221C-11X-2, 128–130 cm). 16. *Pyrulinooides acuminatus* (d'Orbigny) (Sample 199-1215A-8H-4, 10–11 cm). 17. *Sigmomorphina semitecta* var. *terquemiana* (Fornasini) (Sample 199-1221C-11X-3, 88–90 cm). 18. *Pleurostomella velascoensis* Cushman (Sample 199-1215A-8H-4, 40–41 cm).

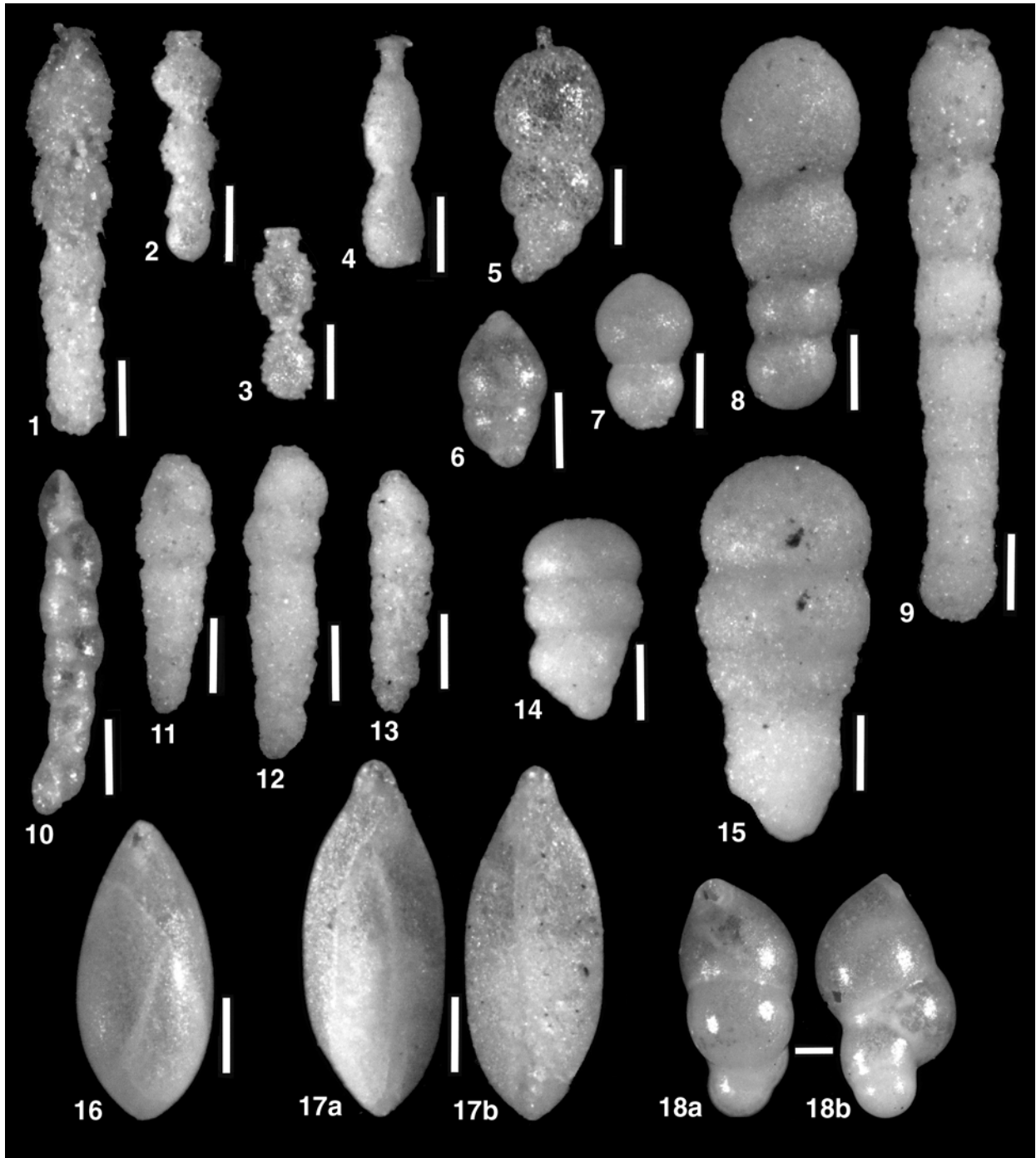


Plate P5. Scale bar = 100 μ m. 1. *Aragonina aragonensis* (Nuttall) (Sample 199-1221C-11X-1, 23–25 cm). 2–4. *Aragonina ouezzanensis* (Rey); (2) Sample 199-1215A-8H-4, 10–11 cm, (3) Sample 199-1221C-11X-3, 118–120 cm, (4) Sample 199-1215A-8H-4, 0–1 cm. 5, 6. *Tappanina selmensis* (Cushman); (5) Sample 199-1215A-8H-3, 9–10 cm, (6) Sample 199-1220B-20X-2, 4–6 cm. 7, 9, 10. *Falsoguttulina* sp. 1; (7) Sample 199-1215A-8H-4, 32–33 cm, (9) Sample 199-1215A-8H-4, 12–13 cm, (10) Sample 199-1221C-11X-3, 118–120 cm. 8, 11. *Falsoguttulina wolburgi* Bartenstein and Brand; (8) Sample 199-1215A-8H-4, 11–12 cm, (11) Sample 199-1221C-11X-3, 118–120 cm.

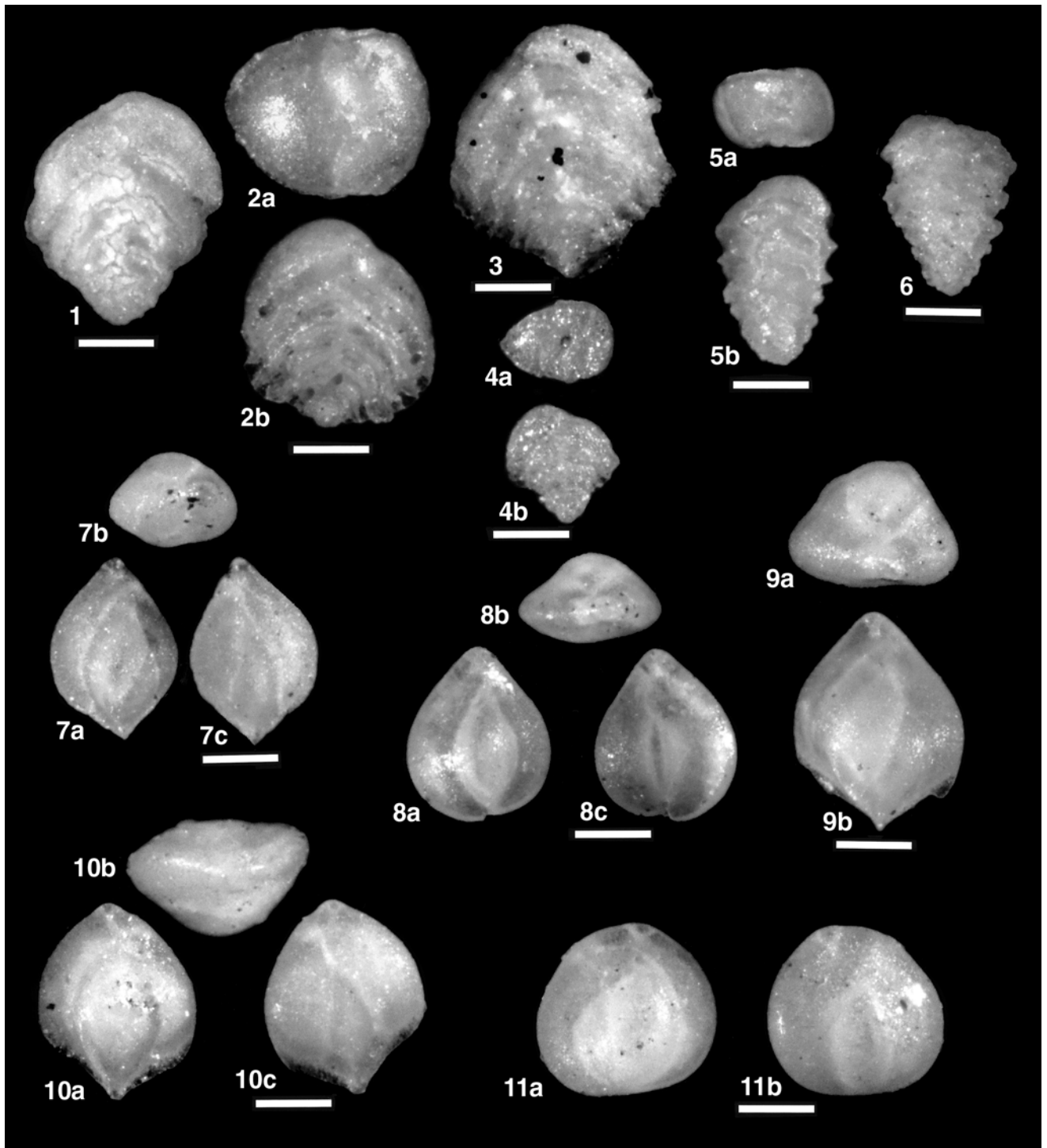


Plate P6. Scale bar = 100 μ m. 1–3. *Hemirobulina* cf. *arcuatula* (Stache); (1) Sample 199-1215A-8H-3, 113–114 cm, (2) Sample 199-1215A-8H-3, 27–28 cm, (3) Sample 199-1215A-8H-3, 36–38 cm. 4, 5. *Astacolus* *cretacea* (Cushman); (4) Sample 199-1221C-11X-2, 18–20 cm, (5) Sample 199-1221C-11X-3, 123–125 cm. 6. *Saracenaria* *midwayensis* Klein (Sample 199-1220B-20X-2, 12–14 cm). 7. *Neoflabellina* *rugosa* (d'Orbigny) (Sample 199-1215A-8H-4, 11–12 cm). 8, 9. *Pleurostomella* *rimosa* Cushman and Bermudez; (8) Sample 199-1220B-20X-2, 2–4 cm, (9) Sample 199-1220B-20X-2, 34–36 cm. 10, 11. *Pleurostomella* *paleocenica* Cushman; (10) Sample 199-1215A-8H-3, 27–28 cm, (11) Sample 199-1221C-11X-3, 42–44 cm. 12, 15, 16. *Pleurostomella* *clavata* Cushman; (12) Sample 199-1215A-8H-4, 11–12 cm, (15) Sample 199-1221C-11X-1, 23–25 cm, Sample (16) 199-1215A-8H-4, 16–17 cm. 13. *Pleurostomella* *velascoensis* Cushman (Sample 199-1220B-20X-2, 20–22 cm). 14. *Pleurostomella* *subnodosa* Reuss (Sample 199-1220B-20X-2, 0–2 cm). 17, 19–21. *Lenticulina* *insulsus* Cushman of Plummer; (17, 19) Sample 199-1215A-8H-4, 32–33 cm, (20) Sample 199-1215A-8H-4, 10–11 cm, (21) Sample 199-1221C-11X-3, 133–135 cm. 18. *Lenticulina* *whitei* Tjalsma and Lohmann (Sample 199-1215A-8H-4, 12–13 cm).

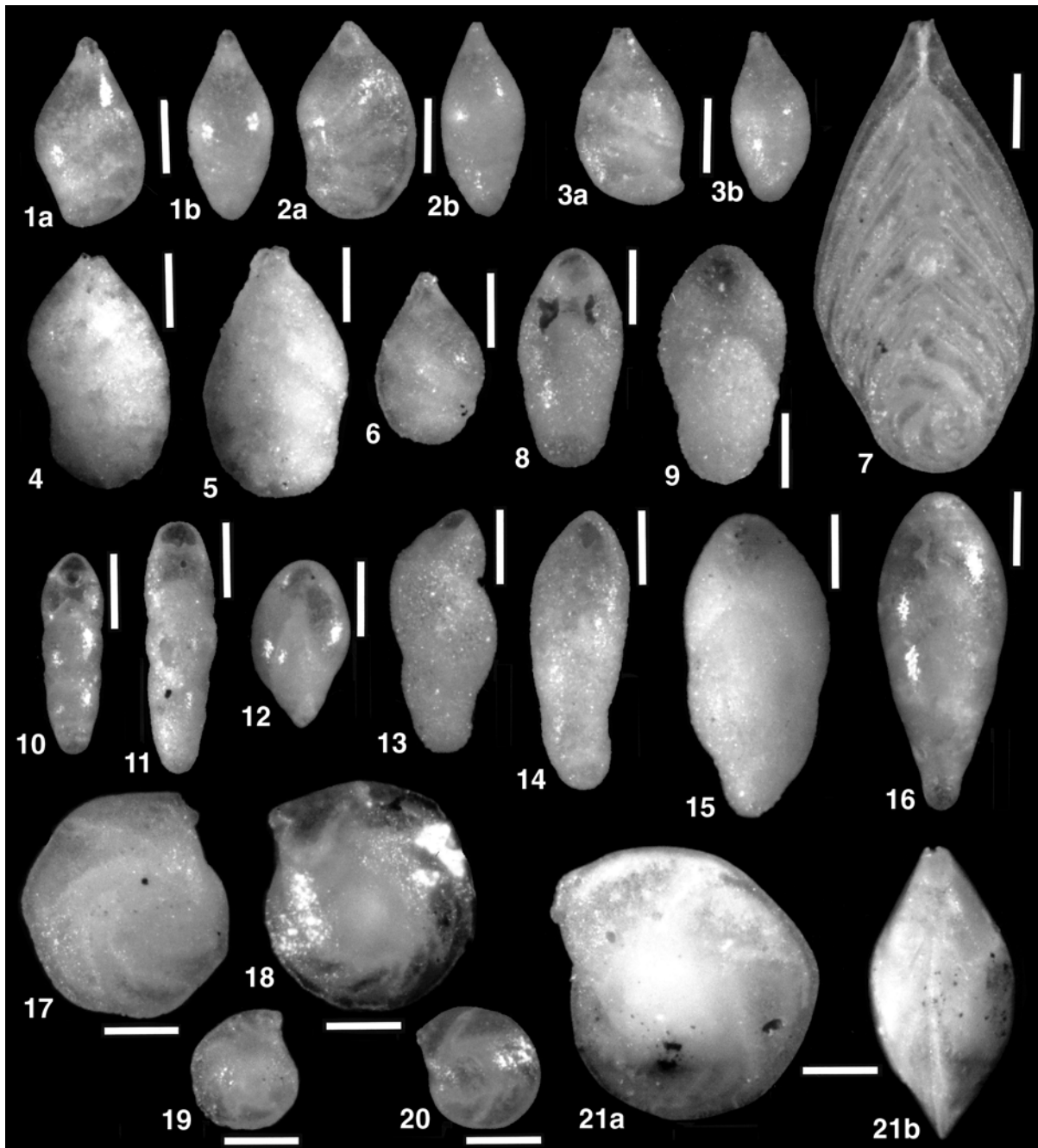


Plate P7. Scale bar = 100 μm . 1–17. *Paleopleurostomella pleurostomelloides* (Franke); (1) Sample 199-1215A-8H-4, 14–15 cm, (2) Sample 199-1215A-8H-3, 36–37 cm, (3) Sample 199-1215A-8H-4, 38–39 cm, (4) Sample 199-1215A-8H-3, 77–78 cm, (5) Sample 199-1215A-8H-3, 42–43 cm, (6) Sample 199-1215A-8H-3, 57–58 cm, (7) Sample 199-1215A-8H-3, 24–25 cm, (8) Sample 199-1215A-8H-3, 142–143 cm, (9) Sample 199-1220B-20X-2, 28–30 cm, (10) Sample 199-1220B-20X-2, 12–14 cm, (11, 13) Sample 199-1220B-20X-2, 83–84 cm, (12, 14, 15) Sample 199-1220B-20X-2, 16–18 cm, (16) Sample 199-1221C-11X-2, 113–115 cm, (17) Sample 199-1221C-11X-1, 103–105 cm. 18. *Coryphostoma* sp. (Sample 199-1220B-20X-2, 0–2 cm). 19. *Coryphostoma* cf. *midwayensis* (Cushman) (Sample 199-1220B-20X-2, 2–4 cm). 20–27. *Coryphostoma crenulata* (Cushman); (20) Sample 199-1215A-8H-3, 6–7 cm, (21) Sample 199-1220B-20X-2, 4–6 cm, (22) Sample 199-1215A-8H-3, 71–72 cm, (23, 24) Sample 199-1221C-11X-1, 123–125 cm, (25) Sample 199-1220B-20X-2, 10–12 cm, (26) Sample 199-1215A-8H-3, 117–118 cm, (27) Sample 199-1220B-20X-2, 12–14 cm. 28, 29. *Coryphostoma in-crassata* (Reuss); (28) Sample 199-1220B-20X-2, 83–84 cm, (29) Sample 199-1215A-8H-4, 30–31 cm [29]).

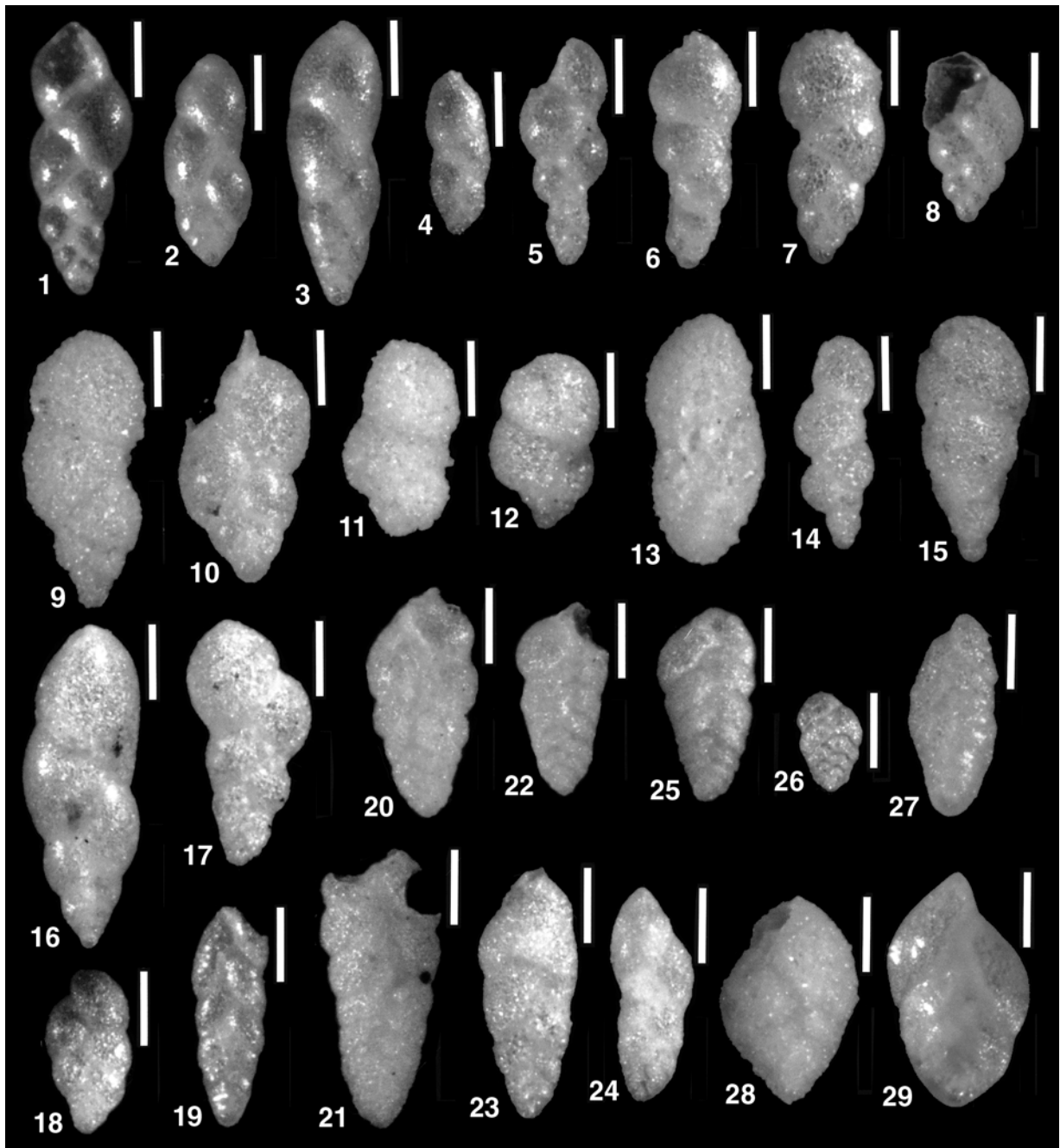


Plate P8. Scale bar = 100 μ m. 1–4. *Bulimina prolixa* Cushman and Parker; (1) Sample 199-1220B-20X-2, 26–28 cm, (2, 3) Sample 199-1220B-20X-2, 84–85 cm, (4) Sample 199-1221C-11X-3, 118–120 cm. 5, 6. *Bulimina bradburyi* Martin (Sample 199-1220B-20X-2, 4–6 cm). 7, 8. *Bulimina jarvisi* Cushman and Parker (Sample 199-1220B-20X-2, 2–4 cm). 9–14. *Bulimina midwayensis* Cushman and Parker; (9) Sample 199-1220B-20X-2, 14–16 cm, (10, 12) Sample 199-1215A-8H-4, 11–12 cm, (11) Sample 199-1215A-8H-4, 2–3 cm, (13) Sample 199-1221C-11X-3, 96–98 cm, (14) Sample 199-1221C-11X-3, 118–120 cm. 15. *Bulimina denticulata* Cushman and Parker (Sample 199-1221C-11X-1, 43–45 cm). 16–19. *Bulimina tuxpamensis* Cole; (16, 17) Sample 199-1220B-20X-2, 0–2 cm, (18, 19) Sample 199-1221C-11X-1, 23–25 cm. 20. *Bulimina* sp. (Sample 199-1220B-20X-2, 14–16 cm). 21. *Bulimina triangularis* Cushman and Parker (Sample 199-1221C-11X-2, 113–115 cm). 22–25. *Bulimina trihedra* Cushman; (22, 23) Sample 199-1220B-20X-2, 0–2 cm, (24) Sample 199-1215A-8H-3, 60–61 cm, (25) Sample 199-1221C-11X-2, 28–30 cm. 26, 27. *Bulimina impendens* Parker and Bermudez (Sample 199-1221C-11X-1, 43–45 cm). 28. *Bulimina velascoensis* Cushman (Sample 199-1221C-11X-3, 118–120 cm). 29, 30. *Bulimina* cf. *denticulata* Cushman and Parker (Sample 199-1220B-20X-2, 79–80 cm).

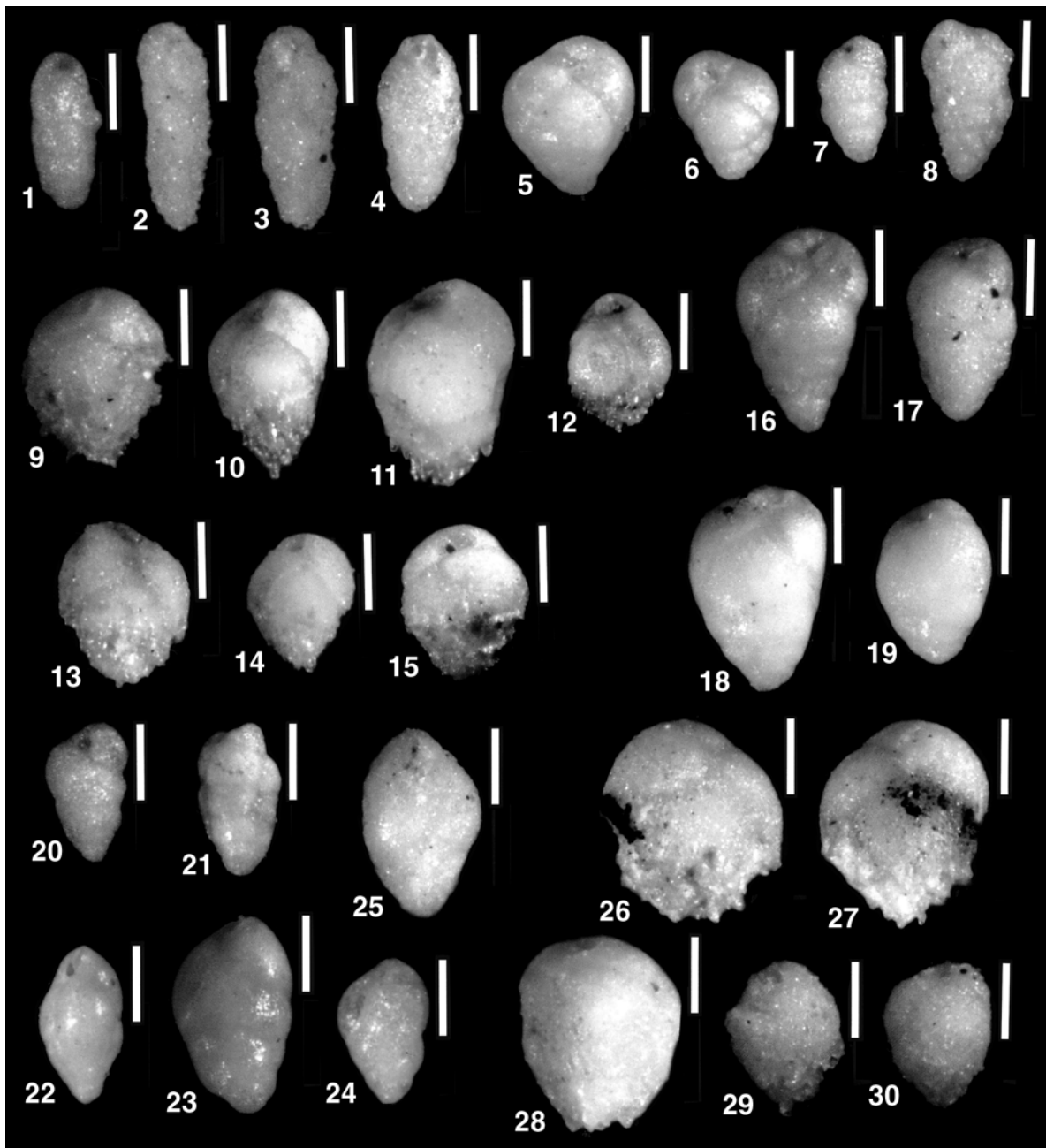


Plate P9. Scale bar = 100 μ m. 1–4. *Praebulimina reussi* (Morrow); (1) Sample 199-1215A-8H-4, 14–15 cm, (2) Sample 199-1221C-11X-3, 104–106 cm, (3) Sample 199-1215A-8H-4, 11–12 cm, (4) Sample 199-1221C-11X-3, 118–120 cm). 5–7. *Bulimina* sp. 1; (5, 6) Sample 199-1215A-8H-4, 10–11 cm, (7) Sample 199-1221C-11X-3, 118–120 cm. 8, 9. *Globimorphina trochoidea* (Reuss) (Sample 199-1220B-20X-2, 18–20 cm). 10–12. *Buliminella beaumonti* Cushman and Renz; (10) Sample 199-1215A-8H-4, 8–9 cm, (11) Sample 199-1221C-11X-3, 118–120 cm, (12) Sample 199-1215A-8H-4, 11–12 cm). 13. *Buliminella* cf. *grata* Parker and Bermudez (Sample 199-1220B-20X-2, 4–6 cm). 14–16. *Buliminella* sp. 1; (14) Sample 199-1221C-11X-3, 92–94 cm, (15) Sample 199-1215A-8H-3, 136–137 cm, (16) Sample 199-1215A-8H-4, 2–3 cm. 17, 18. *Globocassidulina globosa* Hantken; (17) Sample 199-1215A-8H-3, 24–25 cm, (18) Sample 199-1221C-11X-3, 60–62 cm. 19. *Globocassidulina* sp. 1 (Sample 199-1220B-20X-2, 62–63 cm). 20. *Fursenkoina* sp. (Sample 199-1215A-8H-3, 39–40 cm). 21. *Quadratobuliminella pyramidalis* de Klasz (Sample 199-1221C-11X-3, 106–108 cm).

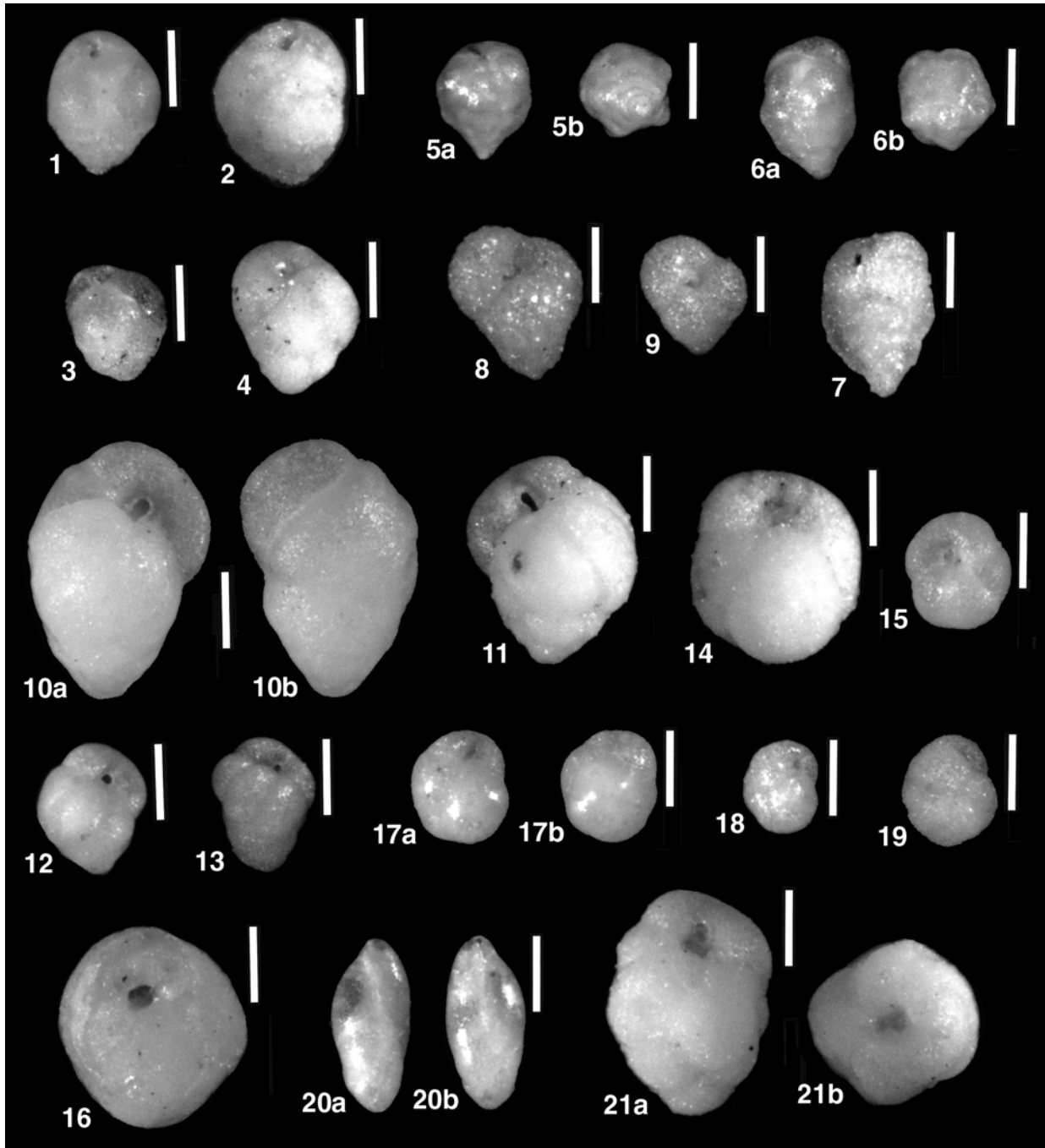


Plate P10. Scale bar = 100 μ m. 1. *Alabamina* sp. 1 (Sample 199-1215A-8H-4, 22–23 cm). 2. *Alabamina* dissonata (Cushman and Renz) (Sample 199-1220B-20X-2, 24–26 cm). 3, 4. *Alabamina* sp. 3 (Sample 199-1221C-11X-3, 92–94 cm). 5. *Alabamina* sp. 4 (Sample 199-1215A-8H-4, 12–13 cm). 6. *Alabamina* sp. 5 (Sample 199-1221C-11X-3, 90–92 cm). 7. *Nonion* sp. 1 (Sample 199-1215A-8H-4, 12–13 cm). 8, 9. *Nonion havanense* Cushman and Bermudez; (8) Sample 199-1221C-11X-1, 43–45 cm, (9) Sample 199-1215A-8H-4, 16–17 cm.

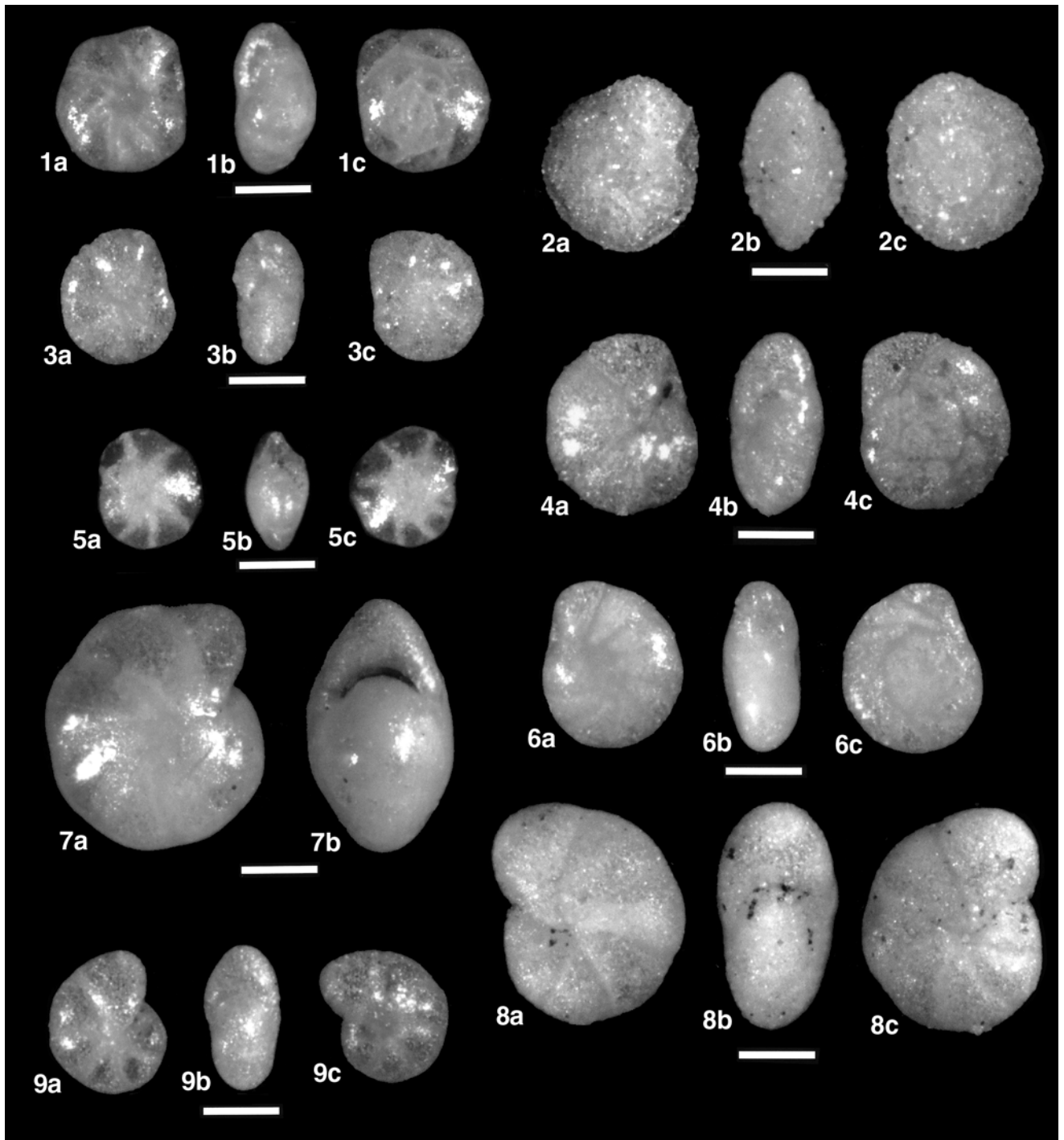


Plate P11. Scale bar = 100 μ m. 1–3. *Valvalabamina praeacuta* (Vasilenko); (1, 3) Sample 199-1215A-8H-4, 14–15 cm, (2) Sample 199-1221C-11X-3, 52–54 cm. 4. *Valvalabamina* sp. 1 (Sample 199-1221C-11X-3, 52–54 cm). 5. *Valvalabamina* sp. (Sample 199-1215A-8H-3, 126–127 cm). 6. *Linaresia semicibrata* (Beckmann) (Sample 199-1221C-11X-3, 113–115 cm).

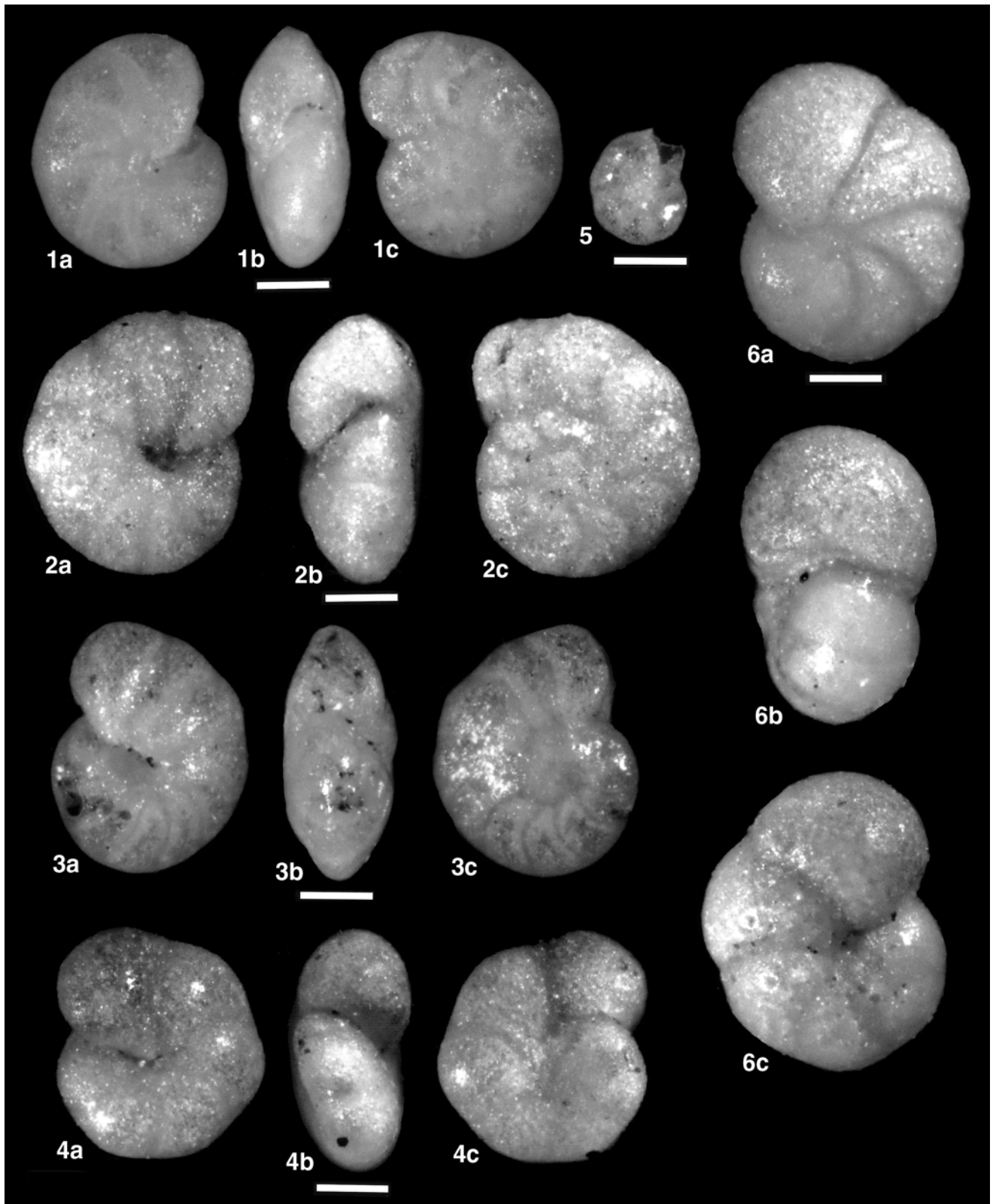


Plate P12. Scale bar = 100 μ m. 1, 2. *Globorotalites conicus* (Carsey); (1) Sample 199-1215A-8H-4, 2–3 cm, (2) Sample 199-1221C-11X-3, 94–96 cm. 3. *Gyroidinoides goudkoffi* (Trujillo) (Sample 199-1215A-8H-4, 36–37 cm). 4, 5. *Globorotalites micheliniana* (d'Orbigny) (Sample 199-1215A-8H-4, 11–12 cm). 6, 7. *Paralabamina lunata* (Brotzen); (6) Sample 199-1220B-20X-2, 16–18 cm, (7) Sample 199-1221C-11X-3, 123–125 cm.

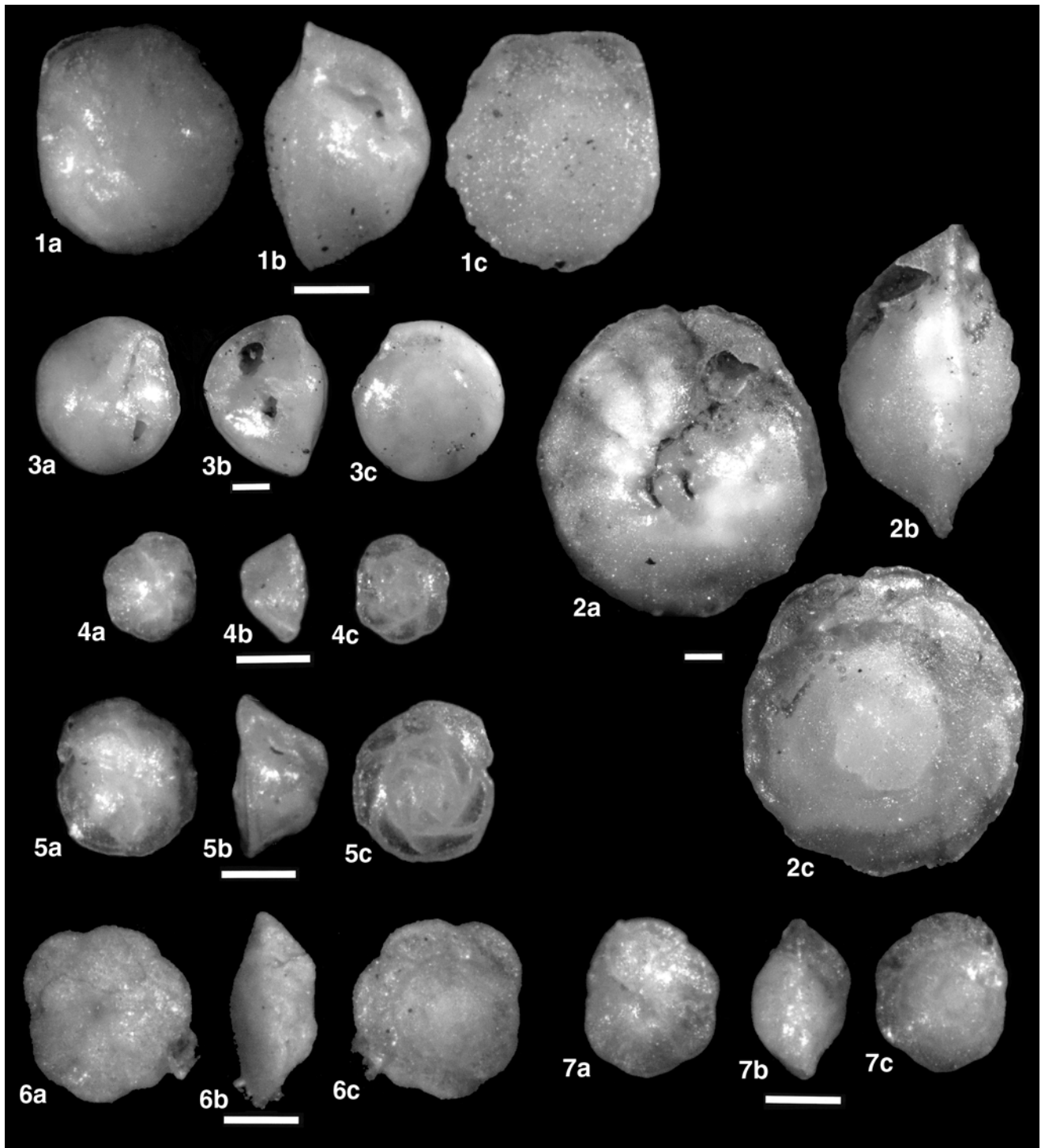


Plate P13. Scale bar = 100 μ m. 1, 2. *Quadrिमorphina profunda* Schnitker and Tjalsma (Sample 199-1215A-8H-3, 24–25 cm). 3, 4. *Abyssamina quadrata* Schnitker and Tjalsma (Sample 199-1215A-8H-3, 0–1 cm). 5. *Allomorphina minuta* Cushman (Sample 199-1220B-20X-2, 16–18 cm). 6, 7. *Pullenia subcarinata* (d'Orbigny); (6) Sample 199-1215A-8H-3, 24–25 cm, (7) Sample 199-1215A-8H-3, 24–25 cm. 8, 9. *Pullenia coryelli* White; (8) Sample 199-1215A-8H-4, 11–12 cm, (9) Sample 199-1221C-12X-1, 33–35 cm. 10. *Pullenia jarvisi* Cushman (Sample 199-1221C-11X-3, 94–96 cm). 11. *Pullenia cretacea* Cushman (Sample 199-1215A-8H-4, 11–12 cm).

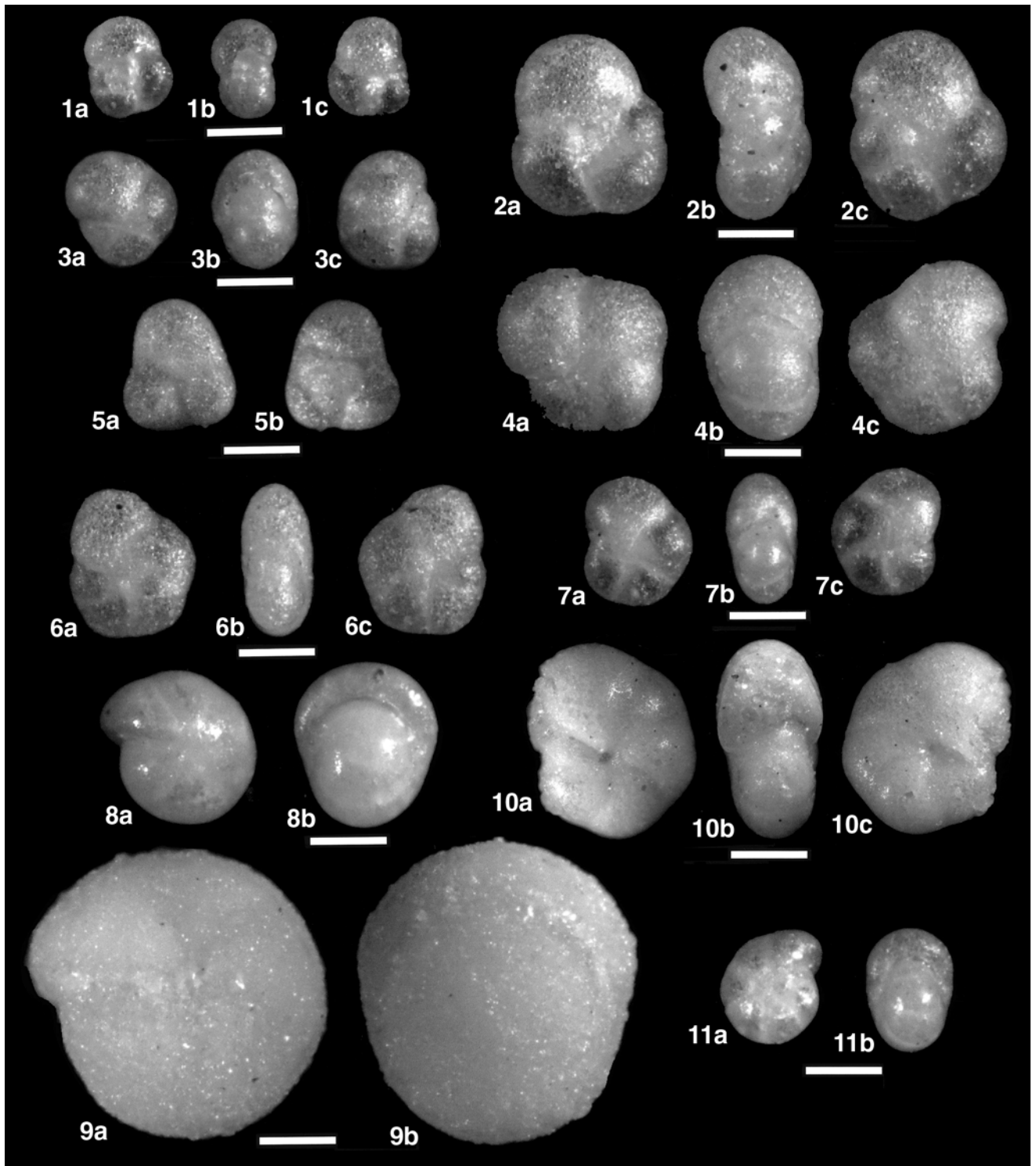


Plate P14. Scale bar = 100 μ m. 1, 2. *Cibicidoides eocaenus* (Gümbel) (1) Sample 199-1215A-8H-4, 30–31 cm, (2) Sample 199-1215A-8H-4, 30–31 cm. 3, 5. *Cibicidoides* cf. *dayi* (White) (3) Sample 199-1221C-12X-1, 8–10 cm, (5) Sample 199-1220B-20X-2, 81–82 cm). 4. *Cibicidoides subcarinatus* (Cushman and Deaderick) (Sample 199-1221C-11X-1, 63–65 cm).

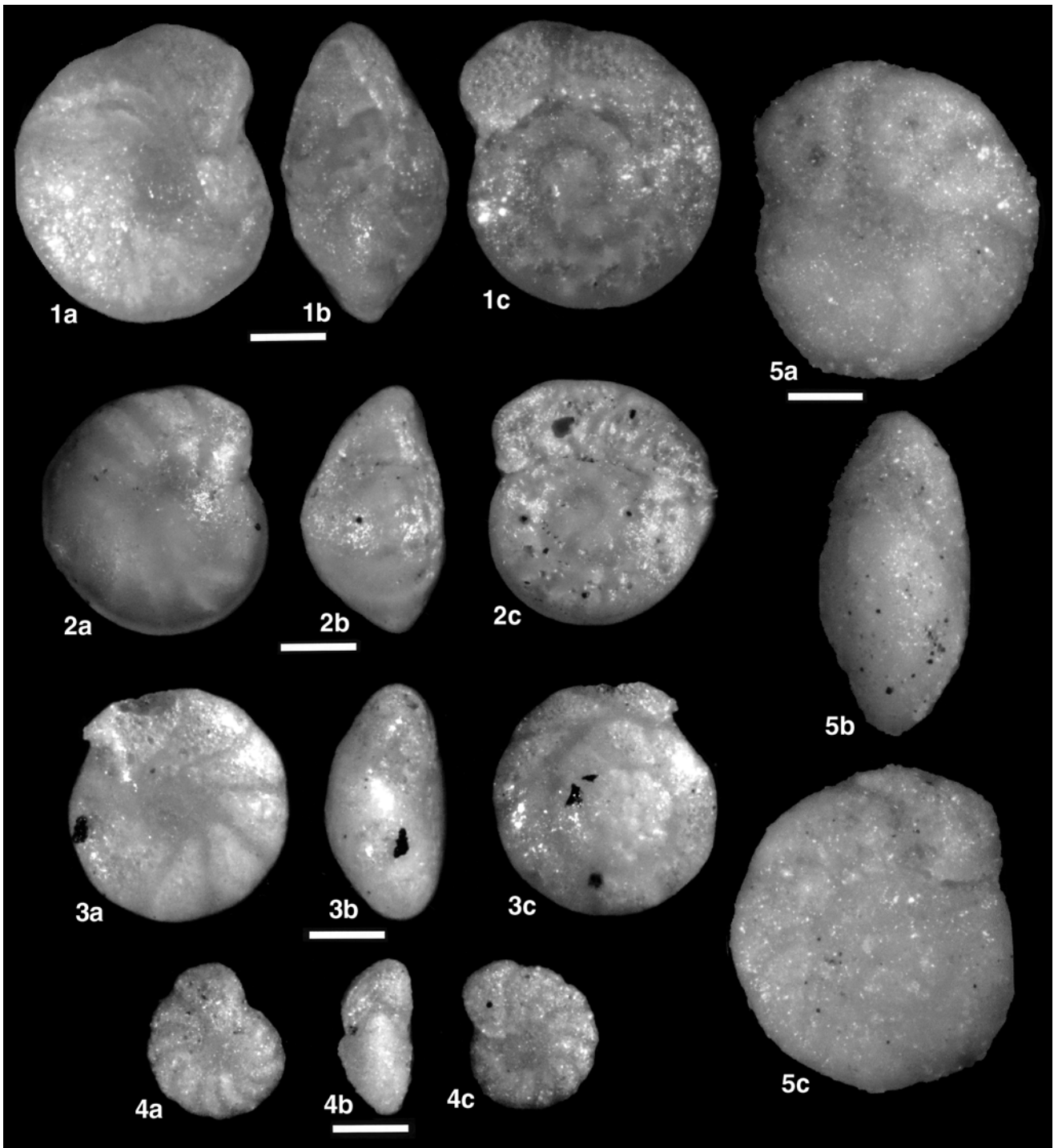


Plate P15. Scale bar = 100 μ m. 1. *Cibicidoides* sp. 2 (Sample 199-1221C-11X-2, 88–90 cm). 2. *Cibicidoides grimsdalei* (Nuttall) (Sample 199-1221C-12X-1, 8–10 cm). 3, 4. *Oridorsalis umbonatus* (Reuss); (3) Sample 199-1215A-8H-4, 11–12 cm, (4) Sample 199-1221C-11X-3, 123–125 cm. 5. *Oridorsalis plummerae* (Cushman) (Sample 199-1220B-20X-2, 2–4 cm).

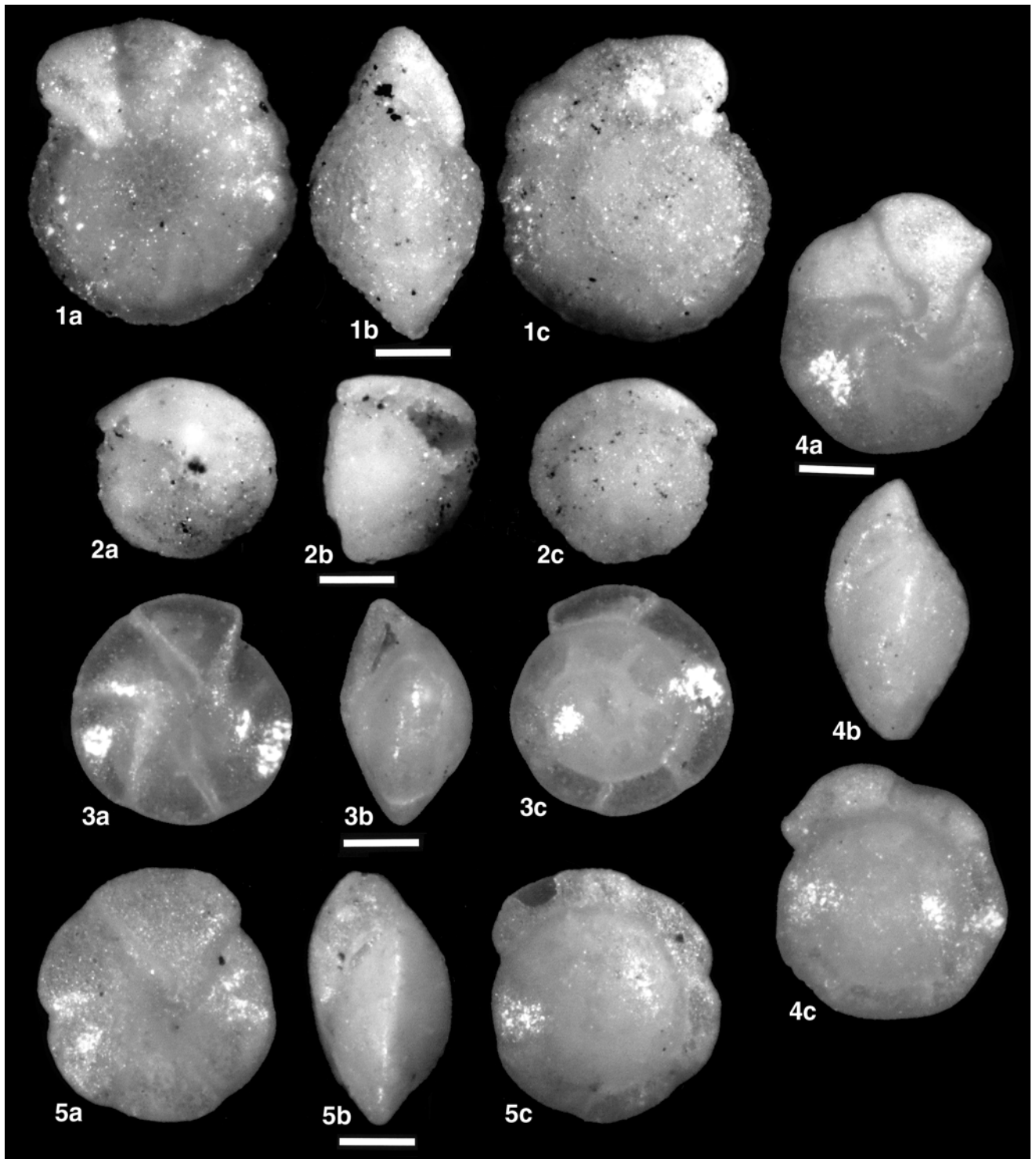


Plate P16. Scale bar = 100 μ m. 1. *Oridorsalis umbonatus* (Reuss) (Sample 199-1215A-8H-3, 15–16 cm). 2, 3. *Oridorsalis plummerae* (Cushman); (2) Sample 199-1215A-8H-4, 10–11 cm, (3) Sample 199-1221C-11X-3, 113–115 cm. 4. *Osangularia plummerae* Brotzen (Sample 199-1221C-11X-3, 113–115 cm). 5. *Gavelinella beccariiiformis* (White) (Sample 199-1215A-8H-4, 11–12 cm). 6. *Heronallenia* sp. (Sample 199-1220B-20X-2, 2–4 cm).

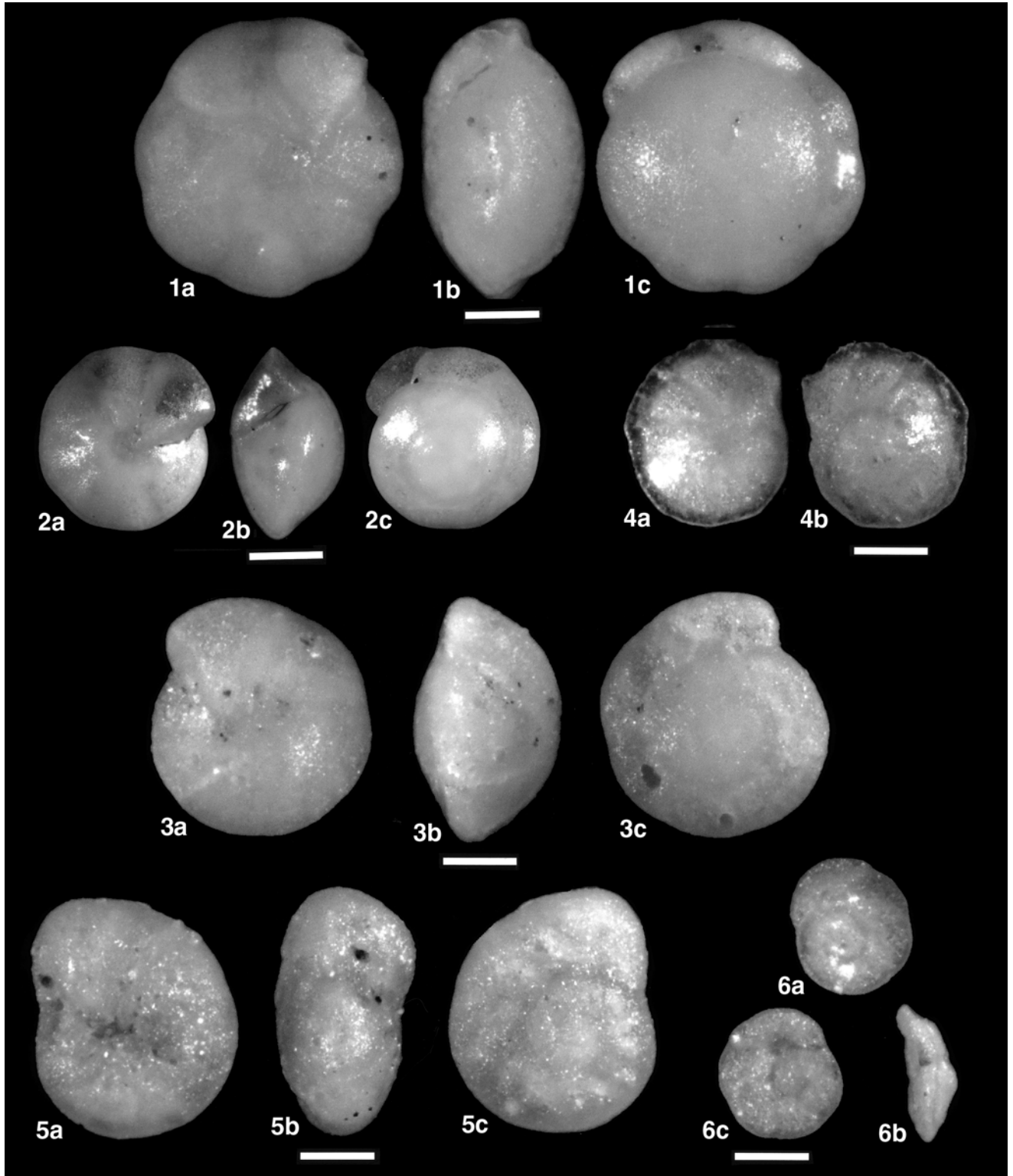


Plate P17. Scale bar = 100 μ m. 1, 2. *Nuttallides truempyi* (Nuttall); (1) Sample 199-1215A-8H-4, 14–15 cm, (2) Sample 199-1221C-11X-1, 23–25 cm. 3. *Nuttallides* sp. 1 (Sample 199-1215A-8H-3, 138–139 cm). 4. *Nuttallides truempyi* (Nuttall) (Sample 199-1221C-11X-3, 123–125 cm). 5–7. *Nuttallides* sp. 2; (5) Sample 199-1221C-11X-1, 23–25 cm, (6) Sample 199-1220B-20X-2, 4–6 cm, (7) Sample 199-1215A-8H-4, 16–17 cm.

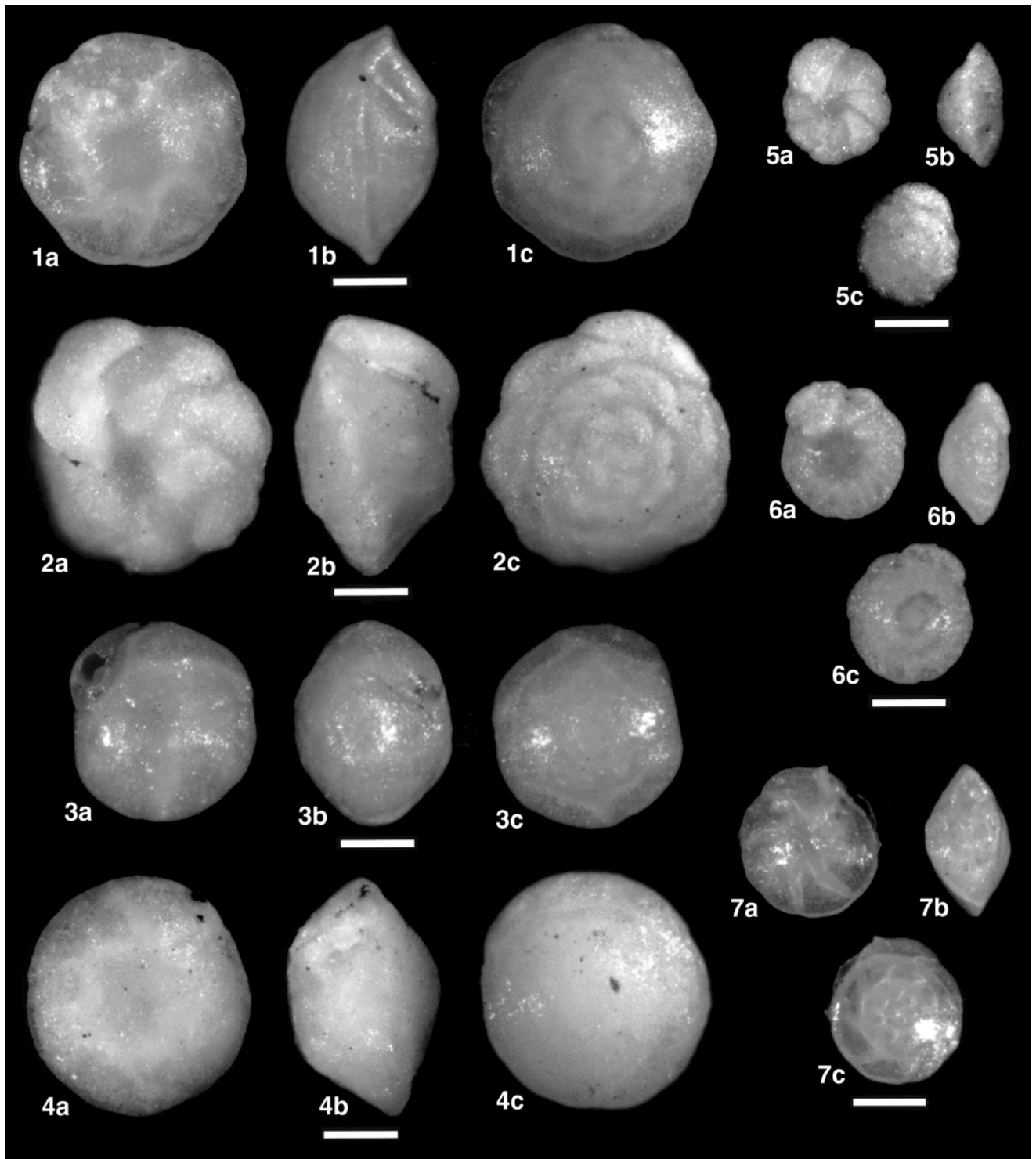


Plate P18. Scale bar = 100 μ m. 1, 2. *Neoeponides hillebrandti* (Fisher); (1) Sample 199-1215A-8H-3, 143–144 cm, (2) Sample 199-1221C-11X-3, 94–96 cm. 3. *Paralabamina* sp. 1 (Sample 199-1221C-11X-3, 123–125 cm). 4, 8, 9. *Paralabamina elevata* (Plummer); (4, 9) Sample 199-1215A-8H-4, 11–12 cm, (8) Sample 199-1221C-11X-3, 94–96 cm. 5, 7. *Paralabamina lunata* (Brotzen); (5) Sample 199-1221C-11X-1, 23–25 cm, (7) Sample 199-1221C-11X-1, 63–65 cm. 6. *Paralabamina* sp. (Sample 199-1221C-11X-1, 23–25 cm).

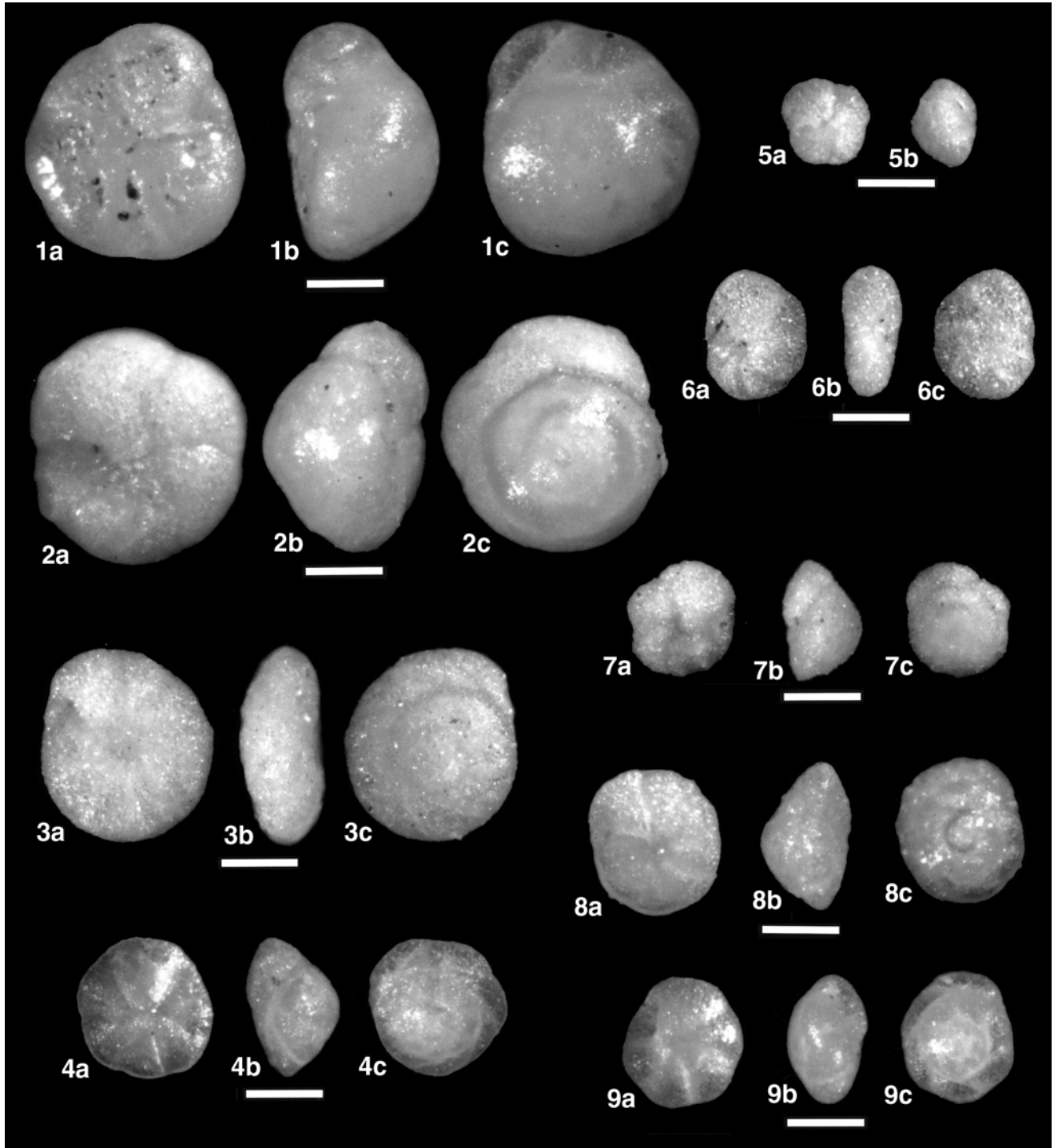


Plate P19. Scale bar = 100 μ m. 1. *Paralabamina* sp. 1 (Sample 199-1220B-20X-2, 80–81 cm). 2. *Paralabamina* sp. 4 (Sample 199-1221C-11X-2, 83–85 cm). 3. *Neoeponides infrequens* (Plummer) (Sample 199-1215A-8H-4, 8–9 cm). 4, 5. *Nonion havanense* Cushman and Bermudez; (4) Sample 199-1215A-8H-4, 14–15 cm, (5) Sample 199-1221C-11X-2, 88–90 cm. 6–8. *Valvalabamina* sp. 2; (6, 8) Sample 199-1220B-20X-2, 12–14 cm, (7) Sample 199-1221C-11X-3, 123–125 cm.

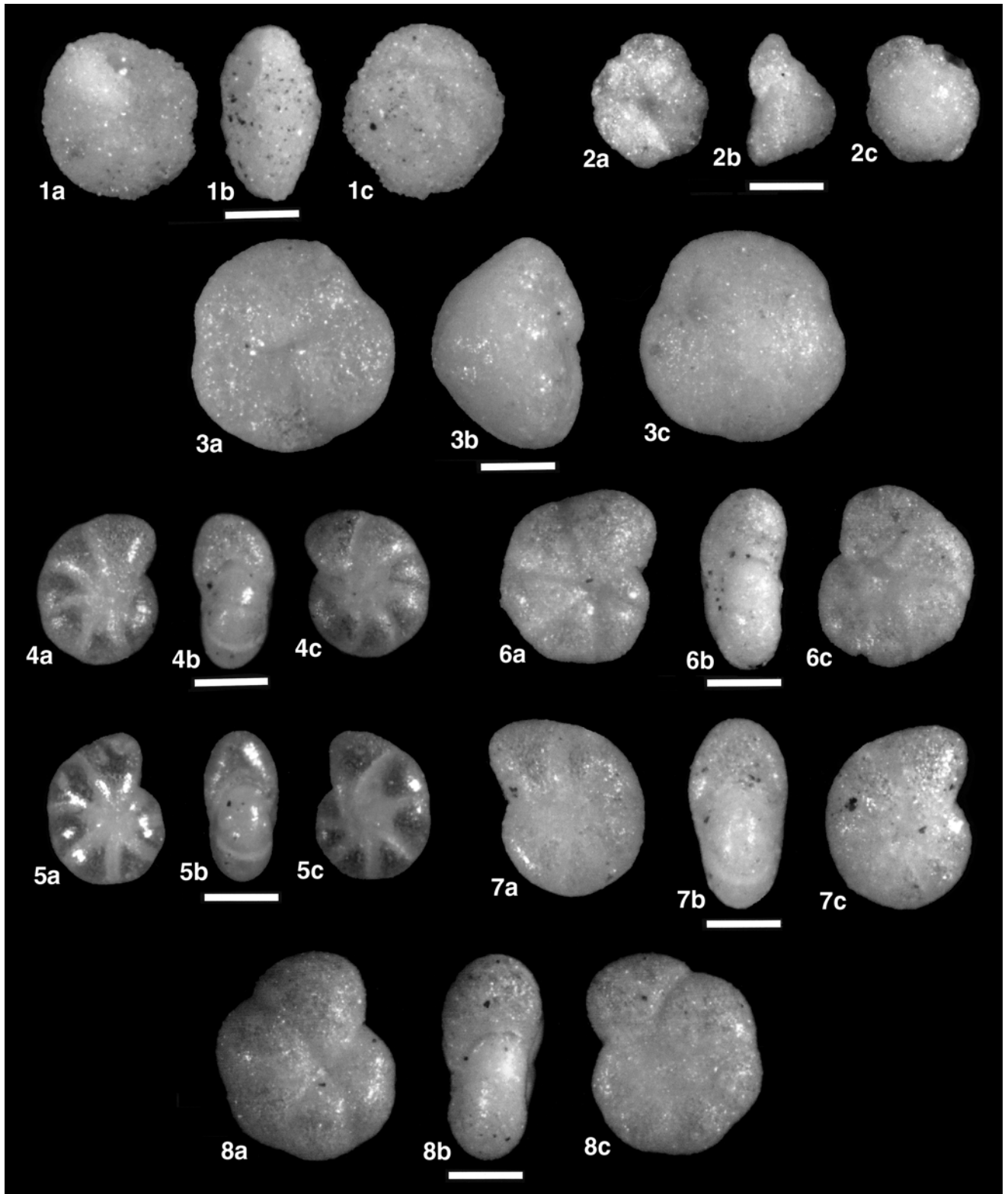


Plate P20. Scale bar = 100 μ m. 1. *Gyroidinoides beisseli* (White) (Sample 199-1215A-8H-4, 10–11 cm). 2. *Gyroidinoides subangulatus* (Plummer) (Sample 199-1215A-8H-4, 10–11 cm). 3. *Gyroidinoides globosus* (Hagenow) (Sample 199-1215A-8H-4, 10–11 cm). 4, 5. *Valvalabamina depressa* (Alth); (4) Sample 199-1215A-8H-4, 32–33 cm, (5) Sample 199-1221C-11X-3, 123–125 cm. 6. *Gyroidinoides octocameratus* (Cushman and Hanna) (Sample 199-1221C-11X-3, 128–130 cm).

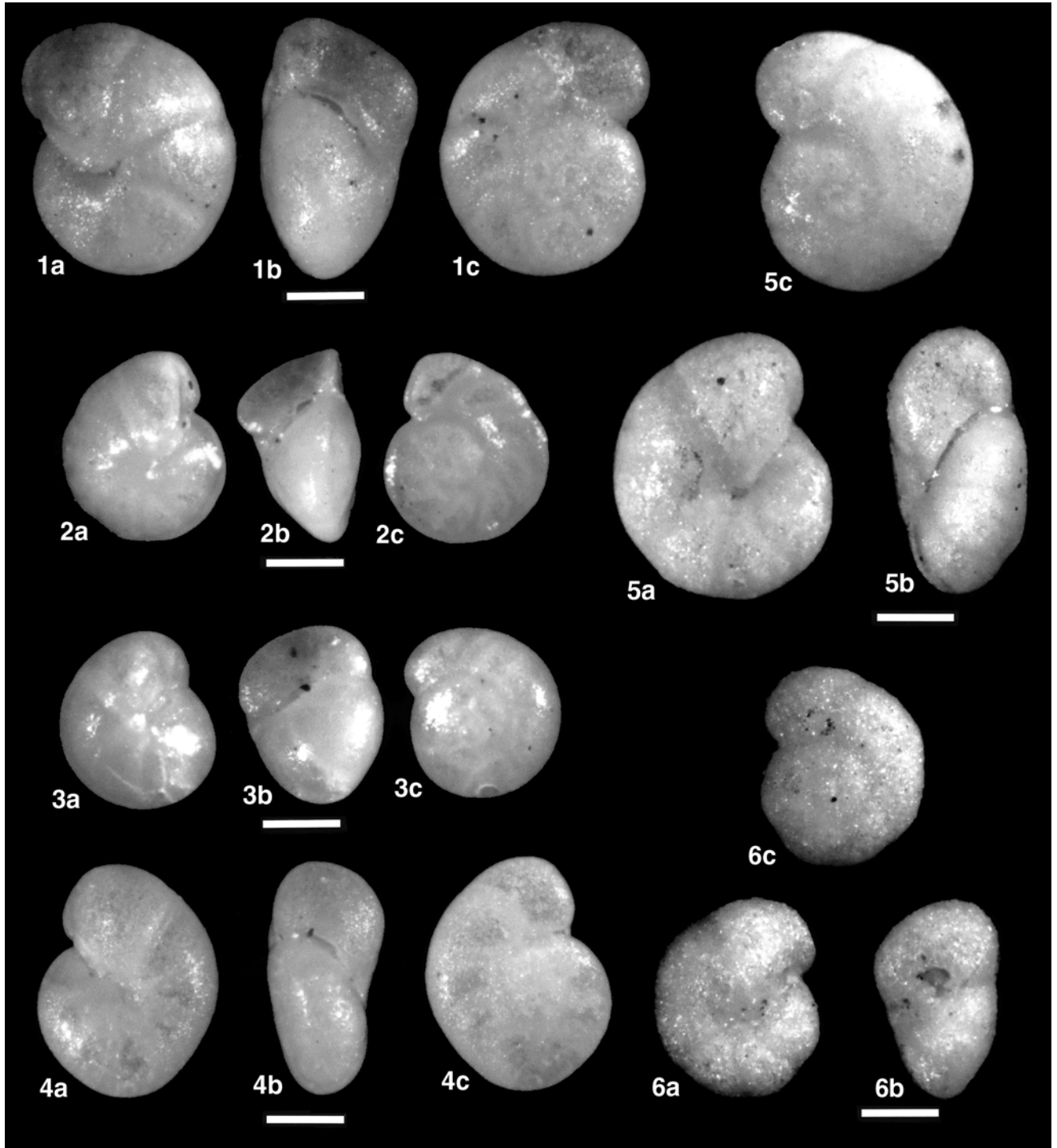


Plate P21. Scale bar = 100 μ m. 1, 2. *Gyroidinoides girardanus* (Reuss); (1) Sample 199-1220B-20X-2, 84–85 cm, (2) Sample 199-1221C-11X-3, 123–125 cm. 3. *Gyroidinoides nitidus* (Reuss) (Sample 199-1221C-11X-1, 63–65 cm). 4, 5. *Neoeponides haidingeri* (d'Orbigny) (Sample 199-1215A-8H-4, 1–2 cm). 6. *Cibicidoides* sp. 3 (Sample 199-1215A-8H-3, 9–10 cm). 7. *Gubkinella asiatica* Suleymanov (Sample 199-1220B-20X-2, 20–22 cm). 8. *Lenticulina* sp. (Sample 199-1215A-8H-4, 32–33 cm). 9. *Saracenaria midwayensis* Klein (Sample 199-1215A-8H-4, 10–11 cm). 10. *Eouvigerina* sp. (Sample 199-1215A-8H-3, 119–120 cm).

