

[Zone AP6a, early Eocene, ODP Hole 738C/8R: 264.35 mbsf, Kerguelen Plateau, southern Indian Ocean].

ORIGINAL DESCRIPTION.—“Test biserial, periphery broadly rounded; chambers distinct, much inflated, increasing very rapidly in the adult so that the last four chambers make up a very considerable amount of the entire test; sutures distinct, depressed; wall distinctly papillate throughout; aperture a low opening at the base of the last-formed chamber in the median line. Length 0.45 mm; breadth 0.35 mm; thickness 0.25 mm.” (Cushman and Ponton, 1932:66.)

DIAGNOSTIC CHARACTERS.—Distinguished by large test size, broadly rounded periphery, rapid chamber-size increase in initial portion of test, and symmetrically centered, low-arched to semicircular aperture surrounded by an equidimensional lip.

DISCUSSION.—The final chamber in adult *Chiloguembelina wilcoxensis* may be normalform to strongly kummerform. The aperture on the final chamber may be a symmetrical low to moderately high semicircular arch, centered on the chamber face, and bordered by an equidimensional lip (Plate 70: Figures 11, 12), or they may be slightly asymmetrical, off-centered on the final chamber face, and bordered by an inequidimensional lip that is slightly infolded on one side (Plate 70: Figure 16).

The symmetrical shape and positioning of the aperture and equidimensional bordering lip on adult specimens of *C. wilcoxensis* are reminiscent of the Cretaceous Heterohelicidae. Dissection of adult tests with symmetrical apertures in the center of the final chamber, however, reveal that the apertures on pre-adult chambers are asymmetrical in position and shape and the bordering lip is infolded on one side (Plate 70: Figure 12). Apertural asymmetry in early ontogeny is taken to represent a primitive feature shared with the chiloguembelinid stock, whereas apertural symmetry in adult specimens is considered a derived character that first appeared in *C. trinitatensis*. *Chiloguembelina wilcoxensis* differs from this species by its larger, less tapering test.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Zone P4 to Zone P6a. The FAD of *C. wilcoxensis* is not well-constrained in published deep-sea records because many authors have not differentiated the chiloguembelinid species. In Trinidad, Beckmann (1957) recorded the FAD of *C. wilcoxensis* in the *Globorotalia pseudomenardii* Zone (= Zone P4), with an uncertain occurrence within the lower part of this zone, and the LAD at the top of the *Globorotalia velascoensis* Zone (= Zone P5). Observations by BTH of high-latitude samples from ODP Sites 698, 700, and 738 indicate that the FAD of this species is in the middle of Zone AP4 (~Zone P4) and its LAD in Zone AP6a (~Zone P6a).

GLOBAL DISTRIBUTION.—Reported from low to high latitudes worldwide.

ORIGIN OF SPECIES.—Although Beckmann (1957) suggested that *C. wilcoxensis* descended from *C. crinita* during the late Paleocene, it is more likely that *C. wilcoxensis* was derived

from *C. trinitatensis* during the late Paleocene because *C. wilcoxensis* and *C. trinitatensis* are more similar morphologically, and the study of Caribbean DSDP Site 152 indicates that the first occurrence of *C. trinitatensis* is older than that of *C. wilcoxensis* (B. Huber, pers. observ., 1995). Both species have a similar pustulose wall texture suggesting that they are phylogenetically related (Plate 70, compare Figures 14 and 18).

REPOSITORY.—Holotype (USNM 16218) deposited in the Cushman Collection, National Museum of Natural History. Examined by BTH.

Family HETEROHELICIDAE Cushman, 1927

(by B.T. Huber)

ORIGINAL DESCRIPTION.—“Test in the more primitive forms planospiral in the young, later becoming biserial, in the more specialized genera the spiral stage and even the biserial stage may be wanting and the relationships shown by other characters; wall calcareous, perforate, ornamentation in higher genera bilaterally symmetrical; aperture when simple, usually large for the size of the test, without teeth, in some forms with apertural neck and phialine lip.” (Cushman, 1927:59.)

DIAGNOSTIC CHARACTERS.—Test with biserial arrangement of alternating chambers, final arrangement either multiple or uniserial; chambers, globular to ovoid in shape; wall smooth or striated with fine to coarse parallel ridges; aperture, a low, symmetrical arch, usually at base of ultimate chamber, may be terminal, may have accessory sutural apertures.

DISCUSSION.—Only simple, biserial forms survived into the Cenozoic. The latter portion of the test often becomes uniserial.

Genus *Rectoguembelina* Cushman, 1932

TYPE SPECIES.—*Rectoguembelina cretacea* Cushman, 1932.

ORIGINAL DESCRIPTION.—“Test with the early chambers arranged in a biserial manner similar to *Guembelina*, later chambers uniserial and rounded in transverse section; chambers all inflated, distinct; sutures distinct, depressed; wall calcareous, thin, very finely perforate; aperture in the early stages similar to *Guembelina* in the adult terminal, rounded, with a distinct neck.” (Cushman, 1932:6.)

DIAGNOSTIC CHARACTERS.—Transition from biserial to uniserial portion of test very abrupt, occurring after first four or more pairs of biserial chambers, without an intervening interval of gradually increasing chamber overlap. Apertures on biserial portion interiomarginal with a small, narrow arch; apertures on uniserial chambers terminal, circular, and aligned in rectilinear fashion, without lip or toothplate. Wall calcareous, microperforate; surface smooth to finely pustulose.

DISCUSSION.—Glaessner (1936) and Montanaro Gallitelli (1957) considered *Rectoguembelina* to be a junior synonym of *Tubitextularia* Sulc (type species = *Pseudotextularia bohémica* Sulc, 1929), whereas Loeblich and Tappan (1964, 1988)

synonymized both of these genera under *Bifarina* Parker and Jones (type species = *Dimorphina saxipara* Ehrenberg, 1854). Comparison of the type species of *Rectoguembelina* with the type species of *Bifarina* and *Tubitextularia*, however, reveals significant differences. The holotype illustration of *Dimorphina saxipara*, which is a cross-sectional view, shows a tubular extension between the apertures of successive uniserial chambers (Loeblich and Tappan, 1988, pl. 491: fig. 4), and the apertures on the uniserial chambers of *Pseudotextularia bohémica* are described and illustrated as alternating from one side of the chamber to the other (Sulc, 1929, pl. 1: figs. 6–16); however, the uniserial apertures of *R. cretacea* lack any tubular extensions and are terminal in position. *Rectoguembelina cretacea* also differs from *P. bohémica* and *D. saxipara* by having a greater number of chambers, which are less globular and more distinctly biserial prior to the onset of the uniserial growth stage. Based on comparison of the type species, *Tubitextularia* is retained as a junior synonym of *Bifarina*, whereas *Rectoguembelina* is resurrected to accommodate the distinctly different *R. cretacea*.

The holotype and paratypes of *Rectoguembelina texana* Cushman and *R. trinitatis* Cushman and Renz are more appropriately assigned to *Bifarina* because the biserial stage is only represented by two to four very globular chambers, the wall texture is hispid rather than smooth, and the apertures on the uniserial chambers alternate from one side to the other prior to the final chamber. Presently, *R. cretacea* is the only species placed in *Rectoguembelina*.

Rectoguembelina differs from *Zeauvigerina* by having several, rather than one, fully uniserial chambers following the biserial stage. The early ontogeny of both taxa are similar though, as the biserial chambers have an asymmetrically positioned aperture surrounded by a narrow, equidimensional lip.

STRATIGRAPHIC RANGE.—Maastrichtian through Zone P2.

GLOBAL DISTRIBUTION.—Low to middle latitudes.

ORIGIN OF GENUS.—Probably derived from the same *Laeviheterohelix* stock that gave rise to the *Zeauvigerina* plexus.

Rectoguembelina cretacea Cushman, 1932

PLATE 13: FIGURES 1, 2; PLATE 71: FIGURES 24–26

Rectogümbelina cretacea Cushman 1932:6, pl. 1: figs. 11, 12 [upper Maastrichtian, Arkadelphia Clay, Hope, Arkansas].

Tubitextularia laevigata Loeblich and Tappan, 1957a:180, pl. 41: fig. 6 [lower Paleocene, McBryde Limestone Mbr., Clayton Fm., Wilcox Co., Alabama].

ORIGINAL DESCRIPTION.—“Test consisting of two unequal portions, the early portion consisting of several pairs of globular chambers arranged as in *Guembelina*, the adult stage uniserial, formed usually by three subglobular or slightly pyriform chambers, slightly overlapping, the apertural end extended out into a tapering neck; sutures distinct, depressed; wall smooth, translucent, very finely perforate; aperture

circular, at the end of the tubular neck. Length 0.25–0.35 mm; breadth 0.08–0.10 mm; thickness 0.05–0.07 mm.” (Cushman, 1932:6.)

DIAGNOSTIC CHARACTERS.—Distinguished by small, elongate biserial to uniserial test, usually with 2–4 uniserial chambers arranged in rectilinear fashion and bearing simple, terminal, round to oval-shaped aperture on short neck.

DISCUSSION.—The Paleocene holotype of *T. laevigata* Loeblich and Tappan is very similar to the *R. cretacea* holotype (Plate 13: Figures 1, 2) except for the presence of more globular chambers in the uniserial growth stage. Paleocene specimens of *Rectoguembelina* from DSDP Site 357, however, bear uniserial chambers that range in shape from the globular forms of the *T. laevigata* holotype to forms identical to the *R. cretacea* holotype (Plate 71: Figures 24–26). It is on this basis that *T. laevigata* is considered a junior synonym of *R. cretacea*.

STABLE ISOTOPES.—Stable isotopic evidence that *R. cretacea* inhabited upper surface waters is presented in Huber and Boersma (1994, table 1; = *T. laevigata*). The oxygen isotopic data reveal that *R. cretacea* was more than 1.5‰ more negative than the co-occurring benthic species *Nuttalites truempyi*, and it was more than 0.5‰ more negative than three other planktonic species (*Globoconusa daubjergensis*, *Globanomalina compressa*, and *Globanomalina* sp.).

STRATIGRAPHIC RANGE.—Maastrichtian through Zone P2.

GLOBAL DISTRIBUTION.—This species has a very irregular distribution, occurring only in near-shore sediments during the Maastrichtian and in offshore sediments at several deep sea sites during the Paleocene, ranging from the low to middle latitudes.

ORIGIN OF SPECIES.—The origin of *R. cretacea* is uncertain, but test dissections have revealed that apertures in the biserial growth stage are asymmetrically positioned and partially surrounded by a narrow lip of equidimensional thickness, which is identical to the apertures on biserial chambers of *Zeauvigerina waiparaensis*. This suggests that *Rectoguembelina* and *Zeauvigerina* shared a common phylogenetic stock, and *Laeviheterohelix* is suggested as the most closely related ancestral taxon based on similarities discussed in Huber and Boersma (1994).

REPOSITORY.—Holotype (USNM CC16308) deposited in the Cushman Collection, National Museum of Natural History. Examined by BTH.

Genus *Zeauvigerina* Finlay, 1939

TYPE SPECIES.—*Zeauvigerina zelandica* Finlay, 1939.

ORIGINAL DESCRIPTION.—“Genus similar to *Eouvigerina* in size, biserial arrangement of most chambers and spout-like uvigerine aperture, but differing in first and last stages. The early chambers show not the slightest trace, even in the microspheric form, of spiroplectine coiling; the final chambers have no tendency to become irregularly triserial, the whole test being regularly bolivine throughout.

"The general similarities to *Eouvigerina* (especially of the *aspera* and *gracilis* type, which have somewhat the same ornament) are so marked that close relationship must surely exist. If so, the elision of the theoretical coiled early chambers and the more settled and compact development throughout is probably due to the later appearance in time of this genus, *Eouvigerina* proper being an Upper Cretaceous form, while the New Zealand development is Upper Middle Eocene." (Finley, 1939:541.)

DIAGNOSTIC CHARACTERS.—Distinguished by biserial chamber arrangement with tendency in adult specimens toward development of uniserial final chamber with near terminal or terminal, oval-shaped aperture, partially or entirely surrounded by thickened, equidimensional lip. In pre-adult chambers, aperture a low, interiomarginal arch partially bordered by narrow, equidimensional lip. Wall calcareous, microperforate; surface smooth to finely pustulose.

DISCUSSION.—There has been some disagreement about the suprageneric classification of *Zeauvigerina* and whether or not this is a planktonic or benthic taxon. In his original description of this genus, Finley (1939) noted similarities in chamber arrangement and morphology of the necked aperture between *Zeauvigerina* and the benthic taxon *Eouvigerina* and suggested a strong likelihood that these were closely related. Following Finley's (1939) comments, Loeblich (1951) emended the definition of *Eouvigerina* to accommodate *Zeauvigerina* as a junior synonym. This classification was later adopted in Loeblich and Tappan (1964). In their more recent classification of foraminifera, Loeblich and Tappan (1988) resurrected the genus *Zeauvigerina* but placed it in the benthic superfamily Loxostomatacea without an explanation for this reallocation. In contrast, Finley (1947) noted that broken specimens of *Z. teuria* resemble *Gümbelina* (= *Chiloguembelina*) and suggested that *Zeauvigerina* was probably planktonic. Beckmann (1957) further noted that the necked, terminal aperture occurs only in the final chamber, and the earlier apertures are interiomarginal, semicircular, and eccentric in position, similar to *Chiloguembelina*, whereas the earlier chambers in *Eouvigerina* have tubular projections usually connected by a thin, band-like structure. Consequently, Beckmann (1957) and Reiss (1963) considered *Zeauvigerina* to be closely related to *Chiloguembelina*. This classification was followed by Jenkins (1965, 1971) and other subsequent workers until Huber and Boersma (1994) placed *Zeauvigerina* in the Heterohelcidae based on biometric and stratophenetic evidence. The generic description of *Zeauvigerina* was modified by the latter authors to accommodate wholly biserial forms of *Z. waiparaensis* (Jenkins, 1965) and "*Z. virgata* (Khalilov, 1967).

Zeauvigerina has been variously interpreted as having inhabited a planktonic or benthic habitat by various authors. The only stable isotopic data published for species of this genus were presented by Huber and Boersma (1994), who favored an interpretation of a planktic mode of life for *Z. aegyptiaca*, but suggested a benthic habitat or a deep-dwelling planktic habitat

for *Z. waiparaensis*. These authors preferred the latter interpretation based on relative abundance counts of *Z. waiparaensis* that were greater than the relative abundance of all benthic species combined in pelagic carbonate samples they studied.

STRATIGRAPHIC RANGE.—*Zeauvigerina waiparaensis*, the oldest species assigned to *Zeauvigerina*, first occurs just below the base of the *Abathomphalus mayaroensis* Zone at ODP Site 750 in the Antarctic Indian Ocean and DSDP Site 208 in the southwestern Pacific Ocean. This genus has not been recorded elsewhere until the lower Danian at ODP Site 690 (Maud Rise) and DSDP Site 528 (Walvis Ridge) in the South Atlantic Ocean and in New Zealand. *Zeauvigerina zelandica*, which has the highest range of the zeauvigerinids, last occurs in the Kaiatan Stage (upper Eocene) in New Zealand.

GLOBAL DISTRIBUTION.—Worldwide in high to low latitudes.

ORIGIN OF GENUS.—Probably derived from *Laeviheterohelix* (Heterohelcidae) during the late Campanian or early Maastrichtian.

Zeauvigerina aegyptiaca Said and Kenawy, 1956

FIGURE 36a; PLATE 71: FIGURES 19, 20

Zeauvigerina aegyptiaca Said and Kenawy, 1956:141, pl. 4: fig. 1 [Paleocene, Esna Shale, measured section at Nekhl, 29°50'N, 33°34'E, northern Sinai, Egypt].—Beckmann, 1957:92, text-fig. 15 (59–62), pl. 21: figs. 9a,b, 11 [upper Paleocene, Lizard Springs Fm., Trinidad].—Huber and Boersma, 1994:271, pl. 2: figs. 6–8 [upper Paleocene, DSDP Site 98/12/1: 119–120 cm; Blake Plateau, western North Atlantic Ocean].

ORIGINAL DESCRIPTION.—"Test small, about twice as long as broad, gradually broadening from the subacute initial end to the point of greatest breadth, which is slightly above the middle, after which the sides become parallel; periphery slightly rounded, in transverse section somewhat rectangular; biserial throughout; chambers broader than high, indistinct; sutures indistinct, slightly depressed; wall smooth; aperture rounded, at the end of a short but distinct neck, with a weakly-developed lip. Length 0.3 mm; breadth 0.2 mm." (Said and Kenawy, 1956:141.)

DIAGNOSTIC CHARACTERS.—Test variable in shape and size, length 150–370 μ m, with elliptical to moderately tapering outline and rounded periphery. Most specimens biserial with uniserial final chamber and a terminal aperture produced on short neck with a poorly to well-developed surrounding lip. Less common forms biserial throughout with off-centered interiomarginal aperture.

DISCUSSION.—Unlike the late Paleocene higher latitude zeauvigerinids, *Z. aegyptiaca* usually produces a final uniserial chamber with a distinct neck and bordering rim or lip, but, within the population of *Z. aegyptiaca*, there are a few uniserial specimens lacking a neck. These are very similar to *Z. teuria* Finley from New Zealand and may have been derived from that species during the late Paleocene.

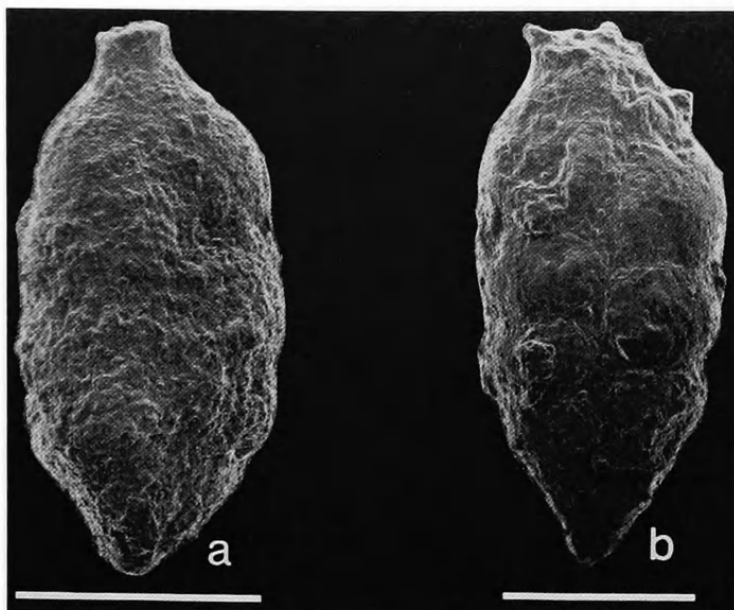


FIGURE 36.—Primary types of *Zeauvigerina*: a, *Zeauvigerina aegyptiaca* Said and Kenawy, holotype, USNM P4091, side view; b, *Zeauvigerina teuria* Finlay, paratype, USNM 689029, side view. (Scale bars = 100 μm .)

Ontogenetic growth patterns of *Z. aegyptiaca* were characterized for populations from DSDP Site 98 and for two of Beckmann's (1957) USNM hypotypes (Huber and Boersma, 1994: fig. 8). The growth trajectories show two patterns: one group includes specimens from DSDP Site 98 that are smaller than 200 μm and the other group, which includes the Trinidad hypotypes and several DSDP Site 98 specimens, reaches nearly 300 μm in length, has a more rapid chamber growth rate, and attains cross-sectional chamber areas that are more than twice the maximum values of the smaller forms. The former group shows growth patterns that are nearly identical to those of *Z. waiparaensis* (Jenkins, 1965). Because some intermediate forms also occur in the DSDP Site 98 populations, all of these forms are considered the same species.

Whereas the apertural necks and bordering rims are rather weakly developed in most *Z. aegyptiaca* specimens, these features are very pronounced on some forms (e.g., Plate 71: Figure 20). Some of the latter specimens closely resemble *Z. zelandica* Finlay, which was described from the Eocene in New Zealand. Biometric comparison of *Z. aegyptiaca* and *Z. zelandica* may reveal that these species are synonymous.

STABLE ISOTOPES.—Stable isotopic data for *Zeauvigerina aegyptiaca* were reported in Huber and Boersma (1994, table 1). The $\delta^{18}\text{O}$ values for this species are very close to co-existing *Chiloguembelina strombiformis* (= *C. midwayensis*), intermediate between the benthic *Nuttalites truempyi* and the planktic *S. triloculinoides*, but considerably more negative ($> 1\text{‰}$) than *A. mckannai*. The $\delta^{13}\text{C}$ values are much closer to co-occurring planktonic species than to *N. truempyi*.

STRATIGRAPHIC RANGE.—Said and Kenawy (1956) identified *Z. aegyptiaca* from the Paleocene Esna Shale of Sinai and

noted two occurrences of this species within the underlying Maastrichtian chalk. The Cretaceous occurrence of *Zeauvigerina*, however, was not confirmed in subsequent studies of Maastrichtian sediments underlying the Esna Shale at other sites in Egypt (Said and Kerdany, 1961; Said and Sabry, 1964). In fact, Said and Sabry (1964) stated that *Z. aegyptiaca* is a Landenian (upper Paleocene) index species, but they did not mention a previous occurrence in Maastrichtian sediments elsewhere. *Zeauvigerina aegyptiaca* was also reported by Beckmann (1957) from the lower Lizard Springs Formation in Trinidad, ranging from the *Globorotalia pseudomenardii* Zone through the *G. velascoensis* Zone (upper Paleocene), and by McGowran (1964) from the Kings Park Shale (Paleocene) in Western Australia. This species also occurs in upper Paleocene sediments from DSDP Sites 95 and 98 on Blake Plateau.

GLOBAL DISTRIBUTION.—Worldwide in the middle to low latitudes.

ORIGIN OF SPECIES.—This species is probably derived from *Z. teuria* Finlay during the late Paleocene (Huber and Boersma, 1994).

REPOSITORY.—Holotype (USNM P4091) deposited in the Cushman Collection, National Museum of Natural History (Figure 36a). Examined by BTH.

Zeauvigerina teuria Finlay, 1947

FIGURE 36b

Zeauvigerina teuria Finlay, 1947:276, pl. 4: figs. 49–54 [Paleocene, type Teurian Te Uri Stream section, Porangahau Survey District, New Zealand].—Jenkins, 1971:70, pl. 1: figs. 22, 23 [holotype reillustrated], figs. 24–26 [topotypes].—Webb, 1973:543, pl. 2: figs. 3, 4 [Paleocene, DSDP Site 208/30/1: 112–114 cm; Lord Howe Rise, Tasman Sea]. [Not Huber, 1991b:461, pl. 2: fig. 2.]

ORIGINAL DESCRIPTION.—“Large for the genus, $1\frac{1}{2}$ times length of *zelandica*, but more than twice its full size, stouter and thicker. Final chamber with flattish top instead of tapering to spout aperture, otherwise similar in chamber arrangement, proportions, and sutures. Very finely and densely roughened all over by minute papillae instead of actual fine, sharp spines. Aperture normal, at end of a short thick central tubular neck with distinct rim. Size, 0.45 mm.

“Broken specimens are easily confused with *Gümbelina*, which has more spherical chambers, deeper sutures, and when unbroken the characteristic quarter-moon-shaped aperture. It is quite probable, however, that *Zeauvigerina* was derived from *Gümbelina* and was pelagic. In the overlying Waipawan [Paleocene] superficially similar specimens are all true *Gümbelina*, the accompanying *Zeauvigerina* being the much smaller *zelandica* and the smooth *parri*.” (Finlay, 1947:276.)

DIAGNOSTIC CHARACTERS.—Distinguished from *Z. parri* and *Z. waiparaensis* by larger size and presence of necked aperture, and from *Z. zelandica* Finlay by absence of rim surrounding terminal aperture.

DISCUSSION.—Although Jenkins (1971) considered *Z. aegyptiaca* to be a junior synonym of *Z. teuria*, comparison of USNM paratypes indicates that these are distinct species. *Zeauvigerina aegyptiaca* has a more spherical final chamber and a terminal aperture that is produced on a longer neck and is surrounded by a narrow rim. It is not clear from the scattered reports of these latter two species whether their stratigraphic and biogeographic ranges overlap or are separated by significant gaps.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—This species occurs in the middle Teurian Stage (Danian) in New Zealand (Jenkins, 1971) and was reported in Danian sediments at DSDP Site 208 (Webb, 1973).

GLOBAL DISTRIBUTION.—Reported only from the middle latitudes in the Southern Hemisphere (New Zealand, DSDP Sites 208, and 277).

ORIGIN OF SPECIES.—This species probably derived from *Z. waiparaensis* (Jenkins) during the Danian (Huber and Boersma, 1994).

REPOSITORY.—Holotype and three paratypes (Register No. TF 1245) in the collections of the New Zealand Geological Survey. Paratype (USNM 689029) deposited in the Cushman Collection, National Museum of Natural History (Figure 36b). Examined by BTH.

Zeauvigerina waiparaensis (Jenkins, 1965)

FIGURE 37; PLATE 71: FIGURES 1–18

Chiloguembelina waiparaensis Jenkins, 1965:1095, pl. 1: figs. 1–6 [Danian, Teurian Stage, *Globigerina* (*Globigerina*) *pauciloculata* Zone, Middle Waipara River section, New Zealand]; 1971:68, pl. 1: figs. 10–15 [holotype and paratypes reillustrated].—Huber, 1991c:461, pl. 2: figs. 5, 6 [lower Paleocene, ODP Hole 738C/20R: 376.00 mbsf; Kerguelen Plateau, southern Indian Ocean].

Heterohelix glabrans (Cushman).—Webb, 1973:543, pl. 1: fig. 4 [upper Maastrichtian, DSDP Site 208/33/4: 128–130 cm; Lord Howe Rise, Tasman Sea]. [Not Cushman, 1938.]

Zeauvigerina waiparaensis (Jenkins).—Huber and Boersma, 1994:276, pl. 1: figs. 1–10 [fig. 1a,b, topotype; figs. 2–8, 10, *Abathomphalus mayaroensis* Zone, ODP Hole 750A/16R/1: 130–131 cm; fig. 9, *Globotruncanella havanensis* Zone, ODP Hole 750A/19R/1: 118–120 cm; Kerguelen Plateau, southern Indian Ocean], pl. 2: figs. 1–5, 10a,b [fig. 1a,b, late Paleocene, ODP Hole 738C/13C/CC; figs. 2–5c, ODP Hole 738C/21R/CC; fig. 10a,b, ODP Hole 750A/17R/1: 52–54 cm; both *Abathomphalus mayaroensis* Zone, Kerguelen Plateau, southern Indian Ocean].

ORIGINAL DESCRIPTION.—“Test free, small, elongate, biserial, tapering towards the prolocular end, compressed. Chambers subglobular, 17, the first 7 increasing slowly in size and the last 10 increasing more rapidly in size. Wall calcareous, finely perforate. Sutures subparallel in side view, slightly depressed, distinct. Aperture terminal, oval-shaped, symmetrical, with its open end towards the penultimate chamber. Length of holotype 0.26 mm.” (Jenkins, 1965:1095.)

DIAGNOSTIC CHARACTERS.—Distinguished by small, irregular outline of test, uneven biserial chamber addition, and

terminal, oval-shaped aperture on mature specimens. Equidimensional, narrow lip partially surrounds and folds into aperture.

DISCUSSION.—Biometric study of this taxon revealed considerable variability in chamber arrangement and apertural positioning (Huber and Boersma, 1994). This resulted in the recognition of a sensu stricto form and four forma, including forma *improcera*, forma *palmula*, forma *prolata*, and forma *velata*, which are considered ecophenotypes or ontogenetic variants. The sensu stricto phenotype conforms to the original holotype description. Tracings of x-radiograph images reveal a relatively uniform growth rate up to the ninth or tenth chamber (or test length of about ~90 μ m). This growth stage is followed by a series of chambers that have a diminished rate of size increase and are somewhat erratic in their growth pattern. *Zeauvigerina waiparaensis* sensu stricto begins to increase chamber overlap only in the last one or two chambers, and some chambers become nearly uniserial in position and have a nearly terminal aperture (e.g., Plate 71: Figures 1–4). The ultimate chambers of forms included in *Z. waiparaensis* sensu stricto are invariably smaller than the penultimate chambers, unlike specimens included in *Z. waiparaensis* forma *improcera* and *Z. waiparaensis* forma *prolata*. Dissection of the ultimate and earlier chambers of *Z. waiparaensis* sensu stricto reveals apertures that are quite different from the nearly terminal final chamber aperture; the aperture on the juvenile chambers is a small, semicircular arch oriented to the front of the test, off-centered, and interiomarginally positioned (Plate 71: Figures 11, 12). As with the ultimate chamber, an equidimensional, narrow lip partially borders the apertures of juvenile chambers. These features clearly distinguish taxa included in the *Zeauvigerina* plexus from species included in *Chiloguembelina*, which has a flange-like lip that is inequally broadened on one side of a narrow and highly arched aperture and that is oriented to the side of the test.

The forma *improcera* (Plate 71: Figures 13–15) and forma *prolata* (Plate 71: Figures 7, 8) are biserial throughout and have interiomarginal, low-arched apertures. These are both considered immature growth forms of *Z. waiparaensis* (Huber and Boersma, 1994). Forma *velata* (Plate 71: Figures 17, 18) differs from the other *Z. waiparaensis* by having a uniserial final chamber with a terminally positioned aperture. Dissection of forma *velata* (Plate 71: Figure 18) reveals an interiomarginal aperture identical to the *improcera* and *prolata* forma.

STABLE ISOTOPES.—*Zeauvigerina waiparaensis* sensu lato yields stable isotopic values that are close to benthic foraminifer values and consistently more positive in $\delta^{18}\text{O}$ and more negative in $\delta^{13}\text{C}$ than co-occurring planktonic taxa (Huber and Boersma, 1994). A planktic habitat was inferred by Huber and Boersma (1994) based on relative abundance counts of *Z. waiparaensis*, which were greater than the relative abundance of all benthic species combined in the pelagic carbonate samples that they studied.

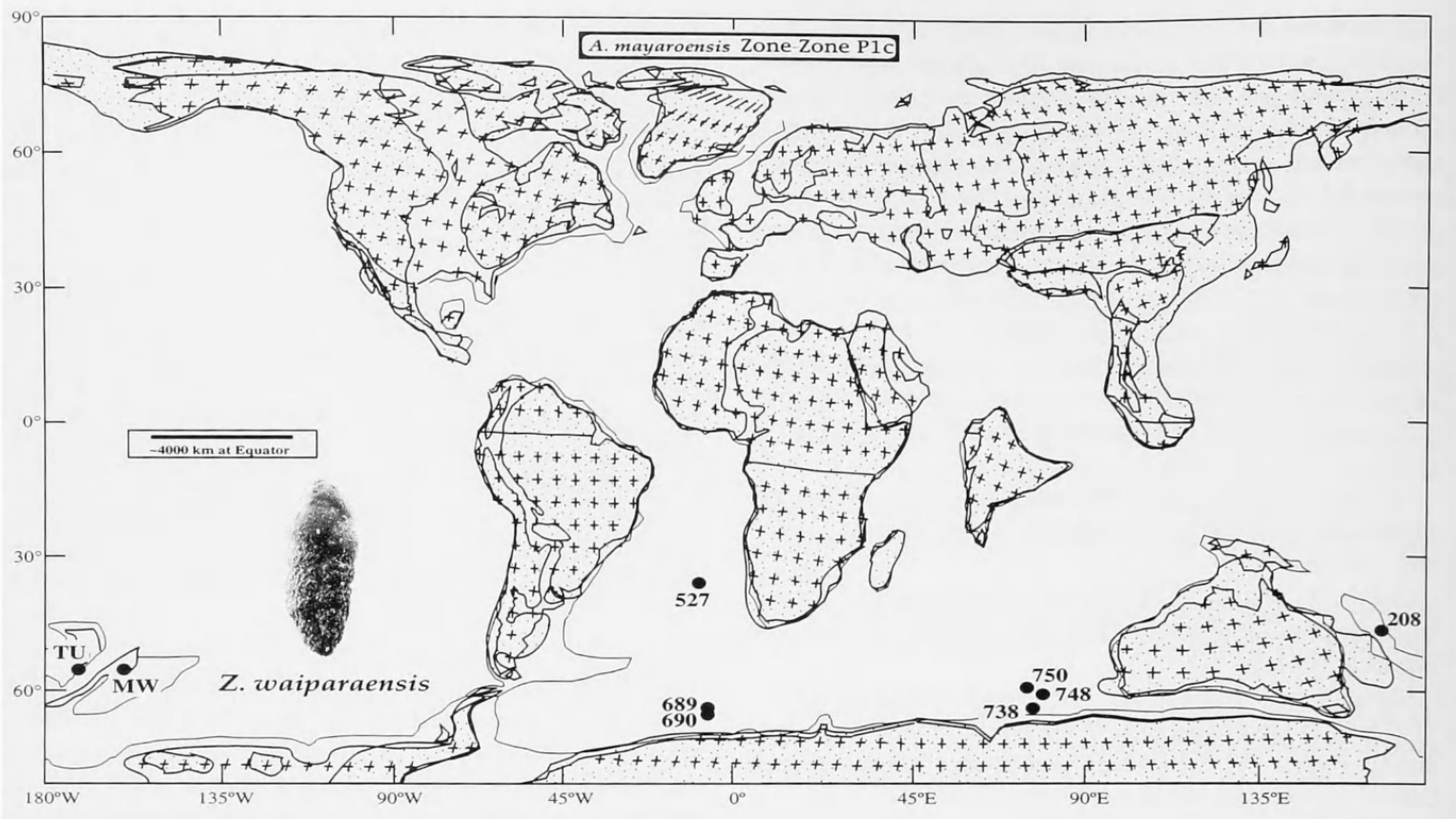


FIGURE 37.—Paleobiogeographic map showing distribution of *Zeauvigerina waiparaensis* (Jenkins) in the Danian.

STRATIGRAPHIC RANGE.—*Zeauvigerina waiparaensis* sensu stricto was described by Jenkins (1965) from Teurian (Danian) sediments in New Zealand. On the Kerguelen Plateau (ODP Sites 738 and 750) and Lord Howe Rise (DSDP Site 208), the *improcera*, *prolata*, *velata*, and sensu stricto forma first appear in the middle Maastrichtian, just below the base of the *Abathomphalus mayaroensis* Zone. These range into, but not above, the Danian in New Zealand and at the deep sea sites. Forma *palmula* has a separate range, first occurring in the upper Paleocene and last occurring in the lower Eocene.

GLOBAL DISTRIBUTION.—Restricted to the Pacific and Indian Ocean sectors of the Southern Ocean during the late Maastrichtian, but the sensu stricto forma is present at DSDP Site 528 in the Angola Basin in only two samples: at the top of the Maastrichtian as contaminants (having the color of the Paleocene forams), and in the lowest Danian (528/31/CC) at the K/T boundary. *Zeauvigerina waiparaensis* does not range farther into the Paleocene at this location and has not been found in Cretaceous or Paleocene levels at the adjacent DSDP Site 527 (Figure 37).

ORIGIN OF SPECIES.—The origin of this species is uncertain, but Huber and Boersma (1994) surmised that *Laeviheterohelix* was the most likely ancestor because of the similarities in wall texture, chamber morphology, and apertural features.

REPOSITORY.—Holotype and two paratypes (Register No. TF 1495) in the collections of the New Zealand Geological Survey.

"*Zeauvigerina*" *virgata* (Khalilov, 1967)

PLATE 71: FIGURES 21–23

Heterohelix virgata Khalilov, 1967:174, fig. 9a,b [Village of Zeid, northeastern Azerbaidzhan].

"*Zeauvigerina*" *virgata* (Khalilov).—Huber and Boersma, 1994:279, pl. 2: figs. 9a–c, 11a–c [lower Paleocene, ODP Hole 750A/11R/2: 40–42 cm; Kerguelen Plateau, southern Indian Ocean].

ORIGINAL DESCRIPTION.—"Test long, compressed bilaterally, slowly becoming broader toward the apertural end; initial end bluntly compressed, while the apertural end is obliquely cut off. At the apertural end the rows of chambers are much shifted with respect to one another. Chambers spherical, alternating in two rows, forming moderate zigzags along the depressed spiral suture. Often the initial end of the test is planispiral. Chambers gradually increase in size toward the apertural end. Septal sutures depressed, slightly curved. Aperture semilunate, placed somewhat further on relative to the frontal plane of the second row of chambers. Wall calcareous, rows of pores are observed on the surface. Along the length of the test the number of pores in each row on the chambers exceeds 3 to 5." (Khalilov, 1967:174; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Test elongate with very uniform chamber addition, biserial throughout; aperture interior-marginal, bordered by an equidimensional, thickened rim or lip.

DISCUSSION.—Examination of the holotypes of *Heterohelix oculis* Khalilov (labeled *H. ocutus* on the holotype slide) and *H. virgata* Khalilov (first called *Heterohelix parallelus*, then revised on the slide) revealed two species that are similar in most features. The holotype of *H. oculis* is smaller in size, is generally thinner side to side, and has a twisted initial portion, rounder chambers, finer and fewer chambers, and a less scalloped outline. The holotype of *H. oculis* resembles the type figure, but the aperture is not visible; however, the holotype of *H. virgata* shows less similarity to the type figure, as the strongly slanted sutures and distinctive aperture shown in the illustration are obscured in the holotype. Nonetheless, the Southern Ocean forms illustrated herein are most similar to the holotype of *H. virgata*.

This species resembles *Chiloguembelina* by having biserial chambers with an off-centered, asymmetrical aperture, but it differs from it in that the aperture is forward facing and the apertural lip is of uniform thickness throughout. It is tentatively placed in "*Zeauvigerina*" because it resembles the immature growth forms of *Z. waiparaensis* (forma *prolata*) in test coiling, test elongation, chamber number, absence of overlap of sequential chambers, and in the rounded aperture oriented to the front of the test (e.g., compare Plate 71: Figures 6–8 with Plate 71: Figures 21, 22). Biometric analysis by Huber and Boersma (1994) revealed that "*Z.*" *virgata* can be distinguished from *Z. waiparaensis* by its greater rate of chamber

inflation that begins half way up the test. SEM illustrations show that the lip of "*Z.*" *virgata* extends fully around the aperture (Plate 71: Figure 23) in contrast to the partial lip of *Z. waiparaensis* (Plate 71: Figures 5, 16). Although intermediate forms were not found, Huber and Boersma (1994) suggested that "*Z.*" *virgata* may have been derived from *Z. waiparaensis* sensu lato during the Danian. If this can be proven, then the species "*Z.*" *virgata* and its relatives belong in the genus *Zeauvigerina*.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—"*Zeauvigerina*" *virgata* was first identified from the upper Danian of the lower Caucasus where it is a rare component of faunas in the Zeid section (Khalilov, 1967). These faunas probably belong to upper Danian Zone P1d, but the full range of "*Z.*" *virgata* in the Caucasus is not currently known. Southern Ocean populations of "*Z.*" *virgata* range from about Zone P1b into Zone P3a, and rare specimens are found to the top of the Paleocene.

GLOBAL DISTRIBUTION.—Reported from the Caucasus and the Southern Ocean.

ORIGIN OF SPECIES.—Similarity between mature specimens of "*Z.*" *virgata* and immature forms of *Z. waiparaensis* suggests the former was derived from the latter during the early Paleocene (Huber and Boersma, 1994).

REPOSITORY.—Holotype no. 638 at the Institute of Geology of the Academy of Sciences of Azerbaidzhan, Baku.

PLATE 13

USNM Primary Type Specimens

(bars = 50 μ m)

- FIGURE 1.—*Rectogümbelina cretacea* Cushman, 1932, holotype, USNM CC16308; upper Maastrichtian, Arkadelphia Clay, Hope, Arkansas.
- FIGURE 2.—*Tübitextularia laevigata* Loeblich and Tappan, 1957 (= *Rectoguembelina cretacea* Cushman), holotype, USNM P5820; lower Paleocene, McBryde Limestone Mbr., Clayton Fm., Wilcox Co., Alabama.
- FIGURE 3.—*Guembelitra cretacea* Cushman, 1933, holotype, USNM CC19022; upper Maastrichtian, Navarro Fm., Texas.
- FIGURES 4, 5.—*Woodringina hornerstownensis* Olsson, 1960, holotype, USNM 626457; Zone P3b, Homerstown Fm., New Jersey.
- FIGURES 6, 7.—*Woodringina claytonensis* Loeblich and Tappan, 1957, holotype, USNM P5685; lower Danian, Pine Barren Mbr., Clayton Fm., Alabama.
- FIGURE 8.—*Woodringina kelleri* MacLeod, 1993 (= *Woodringina claytonensis* Loeblich and Tappan); Zone P α , DSDP Site 577A/12/2: 44–46 cm; Shatsky Rise, northwestern Pacific Ocean.
- FIGURES 9, 10.—*Gümbelina midwayensis* Cushman, 1940, holotype, USNM CC35715; basal Midway Fm., Sumter Co., Alabama.
- FIGURES 11, 16.—*Gümbelina trinitatensis* Cushman and Renz, 1942, holotype, USNM CC38198; Paleocene, Soldado Fm., Trinidad.
- FIGURES 12, 13.—*Chiloguembelina midwayensis strombiformis* Beckmann, 1957 (= *Chiloguembelina midwayensis* (Cushman)), holotype, USNM P5771; *Globorotalia pseudomenardii* Zone, Lizard Springs Fm., Trinidad.
- FIGURES 14, 15.—*Gümbelina morsei* Kline, 1943, holotype, USNM 487301; Danian, Porters Creek Clay, Clay Co., Mississippi.
- FIGURES 17, 18.—*Chiloguembelina subtriangularis* Beckmann, 1957, holotype, USNM P5783; *Globorotalia pusilla pusilla* Zone, lower Lizard Springs Fm., Trinidad.
- FIGURES 19, 20.—*Gümbelina wilcoxensis* Cushman and Ponton, 1932, holotype, USNM 16218; Wilcox Fm., Ozark, Alabama.

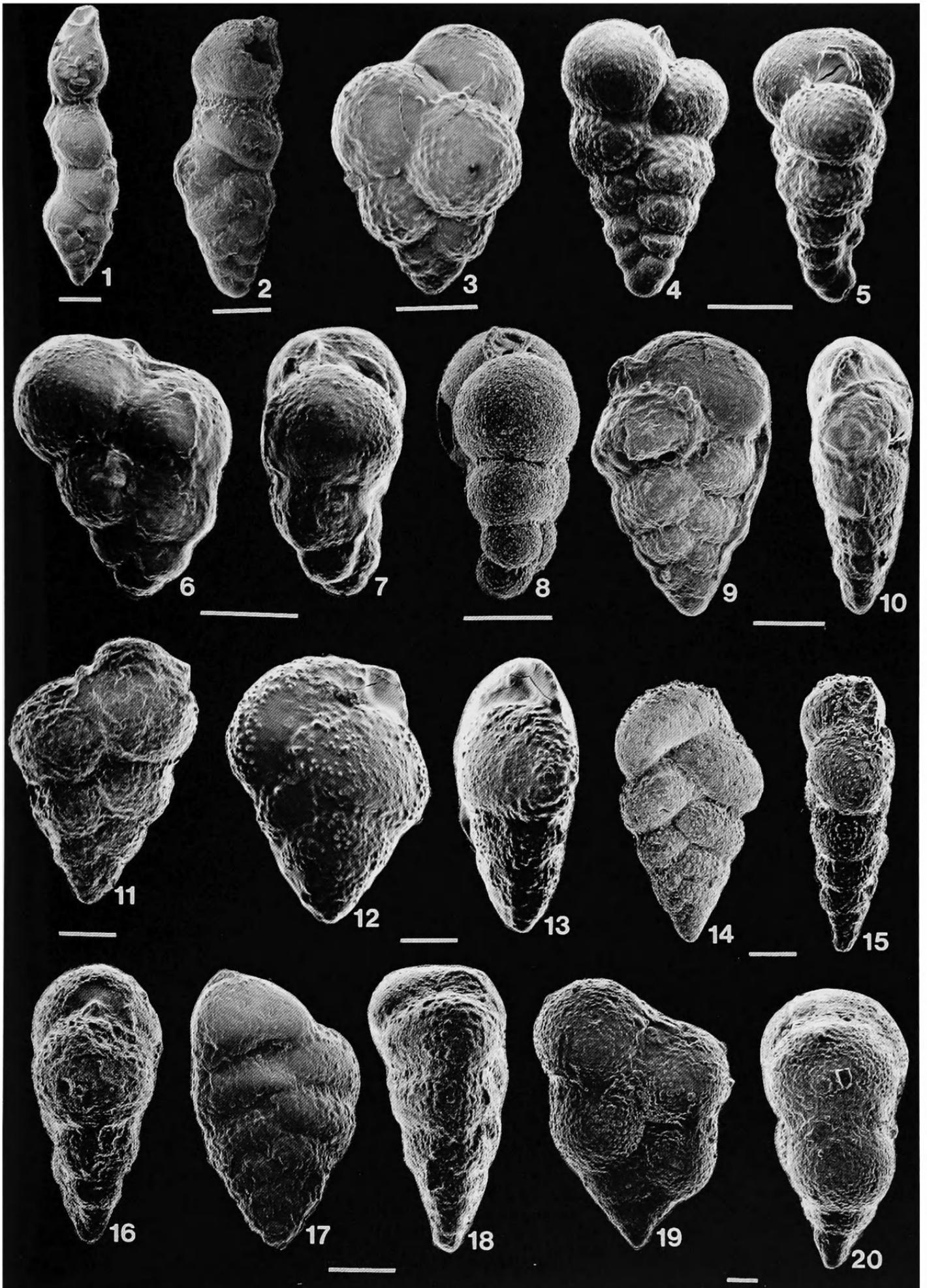


PLATE 71

Zeauvigerina waiparaensis (Jenkins, 1965)

(Figures 1–4, 6–15, 17, 18: bars = 50 μm ; Figures 5, 16: bars = 10 μm)

FIGURES 1–5.—*Z. waiparaensis* sensu stricto: Maastrichtian, ODP Hole 750A/46R/1: 130–131 cm; Figure 5, apertural view of Figure 4 showing equidimensional lip partially surrounding aperture.

FIGURE 11.—*Z. waiparaensis* sensu stricto: Maastrichtian, ODP Hole 750A/18X/CC.

FIGURE 12.—*Z. waiparaensis* sensu stricto: Maastrichtian, ODP Hole 750A/18R/CC.

FIGURES 6–8.—*Z. waiparaensis* forma *prolata*: Maastrichtian, ODP Hole 750A/17R/1: 52–54 cm.

FIGURES 9, 10.—*Z. waiparaensis* forma *palmula*: Late Paleocene, ODP Hole 738C/13R/CC.

FIGURES 13–16.—*Z. waiparaensis* forma *improcera*: Maastrichtian, ODP Hole 750A/16R/1: 130–131 cm; Kerguelen Plateau, southern Indian Ocean; Figure 16, apertural view of Figure 15 showing equidimensional lip partially surrounding aperture.

FIGURES 17, 18.—*Z. waiparaensis* forma *velata*: Maastrichtian, ODP Hole 738C/21R/CC; Kerguelen Plateau, southern Indian Ocean.

Zeauvigerina aegyptiaca Said and Kenawy, 1956

(bars = 50 μm)

FIGURES 19, 20.—Upper Paleocene, DSDP Site 98/12/1: 119–120 cm; Bahama Platform, western Atlantic Ocean.

“Zeauvigerina” virgata (Khalilov, 1967)

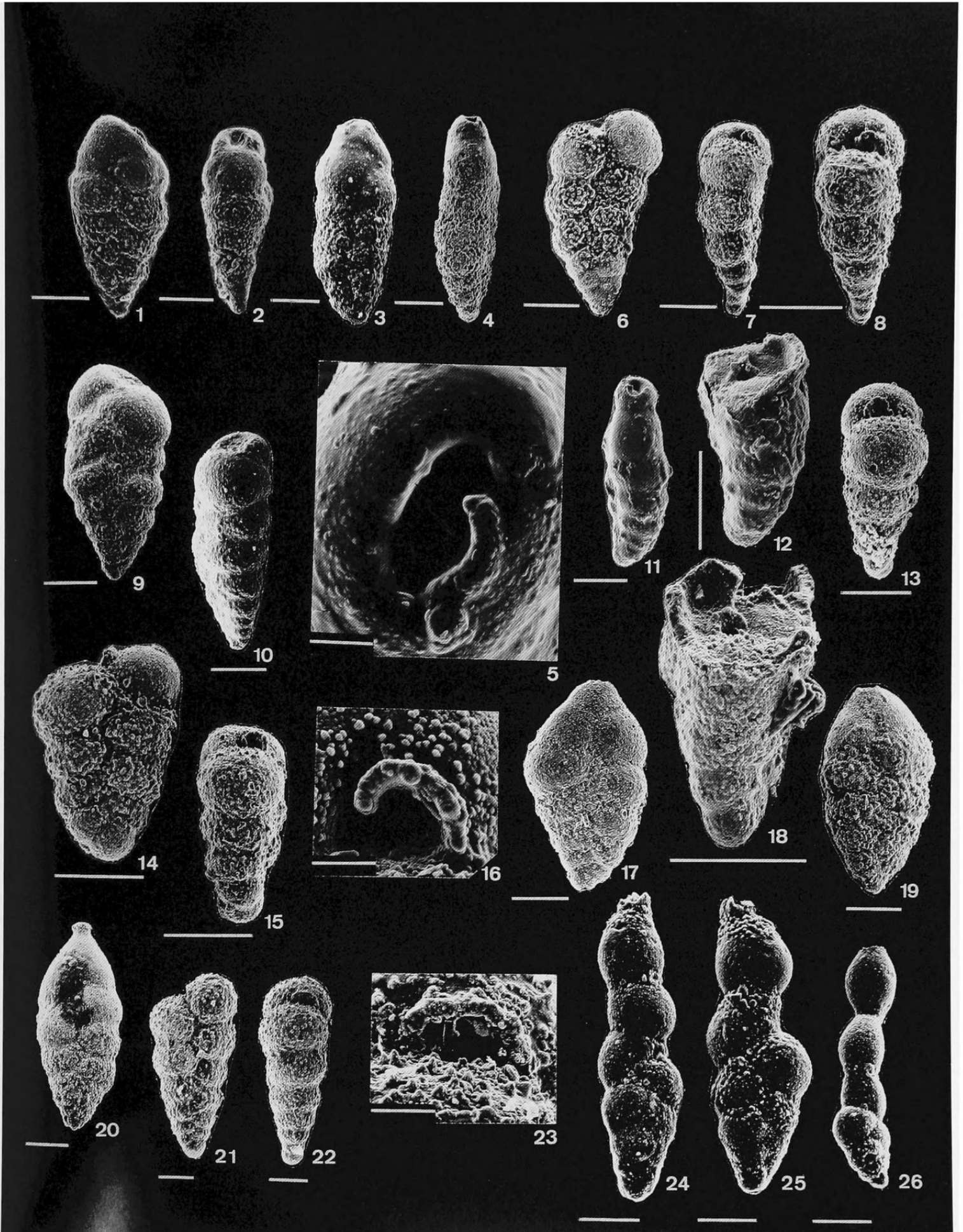
(Figures 21, 22: bars = 50 μm ; Figure 23: bar = 20 μm)

FIGURES 21–23.—Upper Paleocene, ODP Hole 750A/11R/2: 40–41; Kerguelen Plateau, southern Indian Ocean; Figure 23, apertural view of Figure 22.

Rectoguembelina cretacea Cushman, 1932

(bars = 50 μm)

FIGURES 24–26.—Upper Paleocene, DSDP Site 357/30/CC; Rio Grande Rise, South Atlantic Ocean.





Huber, Brian T. 1999. "Family Heterohelicidae Cushman, 1927." *Atlas of Paleocene planktonic foraminifera* 85, 93–99.

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