

Length 0.35-0.50 mm.; breadth 0.27-0.37 mm.; thickness 0.08-0.12 mm.

Holotype (Cushman Coll. No. 22345) from the intertidal area (Leland Stanford Jr. University Locality No. 1164) of Monterey Bay, California, to a depth of 41 fathoms, (in samples from L. S. J. U. Loc. No. 1492).

163. NEW SPECIES OF FORAMINIFERA FROM THE KREYENHAGEN SHALE OF FRESNO COUNTY, CALIFORNIA

By JOSEPH A. CUSHMAN and STANLEY S. SIEGFUS

The Kreyenhagen shale formation was originally described in 1905 by F. M. Anderson* for the Eocene shales exposed near the Kreyenhagen wells at Canoas Creek. In the confusion that has resulted from the correlation of this formation, it has been apparent that more information was needed regarding the type locality at Canoas Creek. After considerable study in this area starting in 1932, it was found that because of the poor outcrops and heavy overburden, there was still much to be desired for a better understanding of this formation. Accordingly, the Garza Creek area, a little less than three miles to the southeast, was sampled and described in detail. The Garza Creek section was found to be far more complete and very much better exposed. Because of certain rather definite zones which will be described later in a separate paper by the junior author, correlations between the two localities can be made with considerable assurance. For a better understanding of the type locality of the Kreyenhagen shale formation, the Garza Creek section can well be used instead of the original Canoas Creek section.

The general features of the Kreyenhagen shale are described in the U. S. G. S. Bulletin No. 398 in connection with the Upper or shaley part of the Eocene (Tejon) formation. Studies by the junior author have shown that the formation has been affected by faulting throughout its extent south of Coalinga. Of all the

* Anderson, F. M., Cal. Acad. Sci., ser. 2, vol. II, No. 2, 1905, p. 183.

areas, the Garza Creek section appears to have been the least affected. In the region of the Canoas Creek, it is slightly less than one thousand feet in thickness, and underlies a zone of fine gray sand 35—153 feet in thickness, which is likely Vaqueros in age. The lower limit is the base of a zone of greenish-gray, silty shale which conformably overlies the Avenal sandstone in this area.

The age of the Kreyenhagen has been somewhat in doubt, but attention is here called to the occurrence of *Hantkenina*, as well as to the following: *Rhabdammina eocenica* Cushman and Hanna, *Bathysiphon eocenica* Cushman and Hanna, *Bolivinospis* sp(?) cf. Nuttall from Upper Eocene of Venezuela, *Cibicides venezuelana* Nuttall, *Cassidulina globosa* Hantken, *Uvigerina* cf. *jacksonensis* Cushman, *Gyroidina soldanii* (d'Orbigny) var. *octocamerata* Cushman and Hanna, together with many others. The following species appear to be new:

VULVULINA CURTA Cushman and Siegfus, n. sp. (Pl. 14, figs. 1, 2)

Test nearly as broad as long, compressed, periphery acute, spinose in the biserial portion; chambers rather indistinct, earliest ones planispiral, later biserial ones low and broad, of rather uniform height, the peripheral portion ending in a short, pointed spine, uniserial chambers only one or two, much narrower than the preceding portions of the test; sutures mostly indistinct except in the uniserial portion where they are distinctly depressed; wall finely arenaceous, mostly smooth; aperture in the uniserial portion elongate, elliptical, terminal. Length 0.60 mm.; breadth 0.50 mm.

Holotype (Cushman Coll. No. 22347) from Kreyenhagen shale, Garza Creek, San Joaquin Valley, California.

This species resembles most closely *Vulvulina advena* Cushman from the Eocene of the Gulf Coastal Plain region of the United States. The California species does not have as many uniserial chambers, and is more contracted laterally. It also resembles the form described by Nuttall as *Vulvulina pectinata* Hantken, var. *mexicana*, but the biserial chambers in our species are relatively broader, and the angles of the sutures much greater. The uniserial portion is also more prominent.

PLECTINA GARZAENSIS Cushman and Siegfus, n. sp. (Pl. 14, figs. 3, 4)

Test elongate, subcylindrical or slightly tapering from the greatest breadth near the apertural end, somewhat nodose, nearly circular in transverse section, earliest whorl with more than three chambers, then triserial, biserial in the adult or tending to become uniserial; chambers of the early portion indistinct, later ones somewhat inflated, increasing in height as added; sutures indistinct in the early stages, later more distinct and depressed; wall coarsely arenaceous, somewhat roughly finished; aperture in the adult nearly terminal, rounded, without a neck. Length up to 0.90 mm.; diameter 0.30-0.40 mm.

Holotype (Cushman Coll. No. 22350) from Kreyenhagen shale of Garza Creek, San Joaquin Valley, California.

This most closely resembles an Upper Eocene species from southern Europe, but is more slender and smaller than the European one.

TRITAXILINA COLEI Cushman and Siegfus, n. sp. (Pl. 14, figs. 5, 6)

Test $1\frac{1}{2}$ -2 times as long as broad, somewhat tapering at the base, and having its greatest breadth near the middle, the adult again tapering somewhat toward the apertural end, rounded in transverse section; chambers in the early portion with more than three to a whorl, having a distinct four-chambered stage, after which triserial, and then biserial chambers are developed; sutures distinct, slightly depressed; wall rather coarsely arenaceous, the basal portion of each chamber somewhat raised; aperture nearly terminal in the adult, and the whole test tending to become somewhat uniserial at that stage. Length 0.60-0.75 mm.; diameter 0.30 mm.

Holotype (Cushman Coll. No. 9500) from the Eocene, Chapapote formation, Chapapote, Mexico. Collected by W. S. Cole.

The species occurs in typical form in our material from the Kreyenhagen shales of Garza Creek. This is the same species as that occurring in the Upper Eocene of Mexico.

BULIMINA CORRUGATA Cushman and Siegfus, n. sp. (Pl. 14, figs. 7 a, b)

Test elongate, tapering, fusiform, greatest breadth above the middle, somewhat triangular in transverse section, angles bluntly rounded; chambers indistinct except the last three which are somewhat inflated, rather low and only slightly overlapping; sutures indistinct except in the later portion where they are dis-

tinctly depressed; wall covered by the longitudinal costae which are high and sharp, running from the initial end to the base of the last-formed chamber, continuous over the sutures, last-formed chamber smooth, distinctly perforate; aperture a rather broad, elongate opening, slightly if at all curved with a slight lip. Length 0.35-0.45 mm.; diameter 0.25 mm.

Holotype (Cushman Coll. No. 22354) from Kreyenhagen shale, Lower Garza Creek, California, 573 feet below top of Kreyenhagen.

This species somewhat resembles *B. rostrata* H. B. Brady. Our specimens have no basal spine. This is a very common species in this material, and should make a good marker.

BULIMINA GARZAENSIS Cushman and Siegfus, n. sp. (Pl. 14, figs. 8 a, b)

Test fusiform, greatest breadth above the middle, nearly circular in transverse section, initial end subacute or acute with a short spine, apertural end usually somewhat truncately rounded; chambers fairly distinct, especially toward the apertural end where they are inflated; sutures of the earlier portion indistinct, later somewhat depressed; wall except for the last whorl of chambers ornamented by longitudinal costae which are largely confined to the individual chamber to form an irregular reticulate pattern of variously shaped, depressed areas; aperture somewhat longer than broad, slightly curved, with a raised lip. Length 0.50-1.00 mm.; diameter 0.30-0.65 mm.

Holotype (Cushman Coll. No. 22356) from Kreyenhagen shale, Garza Creek, California.

This species is a very variable one belonging to the general group of *B. inflata*. The basal ends of the costae are not produced into spines, and the surface varies from one with a main ornamentation of continuous longitudinal costae to an irregularly reticulate surface.

BULIMINA CURTISSIMA Cushman and Siegfus, n. sp. (Pl. 14, figs. 9 a, b)

Test short and broad, only slightly longer than broad, fusiform in front view, greatest breadth somewhat below the middle, thence tapering to either end, initial end acute and spinose; chambers comparatively few, strongly inflated, increasing rapidly in size as added, the last whorl making a very large part of the surface of the test, much overlapping, the base with a few very short spines; sutures distinct, slightly depressed; wall smooth,

finely perforate; aperture elongate, slightly curved, with a slight lip. Length 0.30-0.35 mm.; diameter 0.22-0.25 mm.

Holotype (Cushman Coll. No. 22352) from Kreyenhagen shale, Upper Garza Creek, California, 83 feet below top of Kreyenhagen.

This is a very short species with strongly inflated chambers.

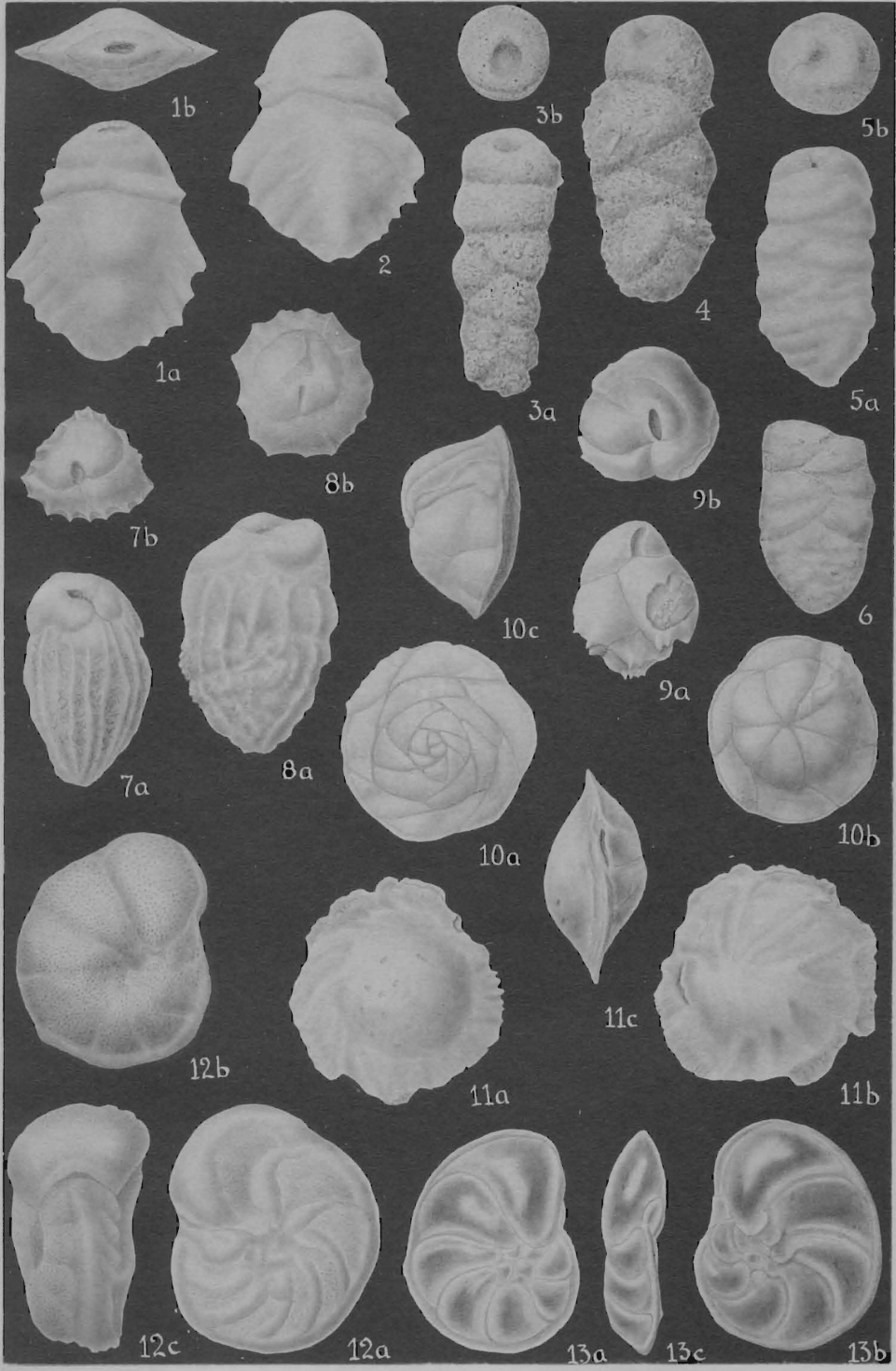
ASTERIGERINA CRASSAFORMIS Cushman and Siegfus, n. sp. (Pl. 14, figs. 10-12)

Test trochoid, plano-convex, dorsal side flattened, ventral side very strongly convex, especially in the central portion, completely involute, periphery acute, slightly keeled; chambers distinct, 6 or 7 in the adult whorl, dorsally narrow; much overlapping, of rather uniform size and shape, ventrally with rhomboid supplementary chambers forming an inner ring about an umbonate central area of clear shell material; sutures very distinct, very slightly limbate, dorsally very oblique, ventrally nearly radial and slightly depressed; wall smooth, finely perforate; aperture a

EXPLANATION OF PLATE 14

- FIGS. 1, 2. *Vulvulina curta* Cushman and Siegfus, n. sp. $\times 60$. Fig. 1, Holotype. a, front view; b, apertural view. Fig. 2, Paratype.
- FIGS. 3, 4. *Plectina garzaensis* Cushman and Siegfus, n. sp. $\times 45$. Fig. 3, Holotype. a, front view; b, apertural view. Fig. 4, Paratype.
- FIGS. 5, 6. *Tritaxilina colei* Cushman and Siegfus, n. sp. $\times 40$. Fig. 5, Holotype, from Chapapote, Mexico. Fig. 6, From Garza Creek, California. a, front view; b, apertural view.
- FIG. 7. *Bulimina corrugata* Cushman and Siegfus, n. sp. $\times 80$. a, front view; b, apertural view.
- FIG. 8. *Bulimina garzaensis* Cushman and Siegfus, n. sp. $\times 80$. a, front view; b, apertural view.
- FIG. 9. *Bulimina curtissima* Cushman and Siegfus, n. sp. $\times 85$. a, front view; b, apertural view.
- FIG. 10. *Asterigerina crassaformis* Cushman and Siegfus, n. sp. $\times 80$. a, dorsal view; b, ventral view; c, peripheral view.
- FIG. 11. *Pulvinulinella tenuicarinata* Cushman and Siegfus, n. sp. $\times 80$. a, dorsal view; b, ventral view; c, peripheral view.
- FIG. 12. *Anomalina crassisepta* Cushman and Siegfus, n. sp. $\times 60$. a, dorsal view; b, ventral view; c, peripheral view.
- FIG. 13. *Discorbinella montereyensis* Cushman and Martin, n. gen. and n. sp. $\times 100$. Recent, Monterey Bay, California. a, dorsal view; b, ventral view; c, peripheral view.

Figures drawn by Patricia G. Edwards.



narrow opening in the middle of the base of the final chamber on the ventral side. Diameter 0.40-0.50 mm.; thickness 0.25-0.40 mm.

Holotype (Cushman Coll. No. 22358) from Kreyenhagen shale, Garza Creek, California, 510 feet below top of Kreyenhagen.

This is a very striking species of value as a stratigraphic marker.

PULVINULINELLA TENUICARINATA Cushman and Siegfus, n. sp. (Pl. 14, figs. 11 a-c)

Test trochoid, biconvex, periphery acute, strongly carinate, the carina irregularly toothed; chambers somewhat obscure due to the secondary thickening over the sutures which nearly covers the chambers, about ten in the adult whorl; sutures on the ventral side slightly curved, nearly radiate, strongly limbate and fused over the umbilical area, on the dorsal side much thickened and fused, covering nearly the whole surface; wall finely perforate; aperture a small opening in the axis of coiling just ventral to the peripheral keel. Diameter 0.45-0.65 mm.; thickness 0.30-0.40 mm.

Holotype (Cushman Coll. No. 22363) from Kreyenhagen shale, Canoas Creek, California.

This species has the chambers on the dorsal side almost completely hidden by the secondary growth of the sutural thickenings, and has a very thin toothed carina. It is fairly common also in the material from Garza Creek.

ANOMALINA CRASSISEPTA Cushman and Siegfus, n. sp. (Pl. 14, figs. 12 a-c)

Test trochoid in the early stages, becoming nearly planispiral in the adult, almost completely involute, periphery in early stages subacute, in adult broadly truncate; chambers distinct, about nine in the last-formed whorl, increasing rather uniformly in size as added, ventrally slightly inflated; sutures distinct, on the ventral side slightly curved and depressed, dorsally very much thickened, especially toward the inner end, strongly curved and merging into a peripheral, raised border; wall coarsely perforate; aperture a low opening at the peripheral margin at the base of the last-formed chamber, and continuing somewhat to the ventral side. Length 0.65-0.80 mm.; breadth 0.55-0.65 mm.; thickness 0.25-0.30 mm.

Holotype (Cushman Coll. No. 22360) from Kreyenhagen shale, Garza Creek, California.

This is a very common species in the Kreyenhagen, and should make a good index fossil.