

CONTRIBUTIONS
FROM THE
CUSHMAN LABORATORY
FOR
FORAMINIFERAL RESEARCH

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These contributions will be issued quarterly. They will contain short papers with plates, describing new forms and other interesting notes on the general research work on the foraminifera being done on the group by the workers in this laboratory. New literature as it comes to hand will be briefly reviewed.

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CONTRIBUTIONS FROM THE CUSHMAN LABORATORY FOR FORAMINIFERAL RESEARCH

30. FORAMINIFERA OF THE TYPICAL MONTEREY OF CALIFORNIA

By JOSEPH A. CUSHMAN

As there are so many different formation names applied to the Miocene of California without their exact correlation being known it seems wise to closely determine the faunas. The name Monterey was given to the Miocene shales in 1855 by William P. Blake (Proc. Acad. Nat. Sci. Philadelphia, vol. 7, 1855, pp. 328-331). The type locality is in the vicinity of Monterey. I have collections that may be considered typical: "Type locality, on road from Monterey to Pebble Beach, $\frac{3}{4}$ mile below Toll House on P. I. Co. road, collected by Hannibal and Waring, Stanford University locality 333." Also a similar lot of material from "Two miles south of Monterey, type locality." With these and abundant material in complete sections in San Luis Obispo County and elsewhere it seems very clearly that the typical Monterey is the upper portion of the section known as Monterey below the Santa Margarita sandstone. The Foraminiferal fauna is very abundant in individuals and contains about sixty species and varieties. These species have now been worked out in such stratigraphic detail that it is possible to state that the two samples from south of Monterey are about 200 feet apart in the ideal section as now worked out. This upper typical Monterey is in many respects distinct from the lower portion of the shales such as those exposed at Henry Ranch and elsewhere.

This upper typical Monterey fauna has in great abundance *Nonionina medio-costata*, *costifera*, and *incisa* each of which has its particular place in the section. These do not occur in the lower Monterey so far as seen. Nodosarias are very few in the typical Monterey and but two species are represented while in the lower part they are very abundant and of many species. The large *Cristellaria beali* is very abundant and characteristic of the typical Monterey.

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A very similar fauna is now living off the west coast of the United States and adjacent areas with many very closely related species. This relationship of the Miocene and Pliocene faunas with the fauna now living off the west coast will be discussed in a paper on the recent fauna soon to be published.

The close discrimination of these species of the typical Monterey will make possible a comparison with type material of the Maricopa, Modelo, Puente, Salinas, and Temblor most of which have foraminifera, and in this way make more evident the relationships of the various portions of the section included under the name Monterey. Work is nearly completed on other parts of the section which will throw more light on the relationships. My thanks are due to the Geological Department of Stanford University for much material including the typical Monterey and to the Geological Department of the Marland Oil Company of California for the use of very excellent material from San Luis Obispo County. In order to avoid repetition yet make the faunal records complete references are given to those species already described in these Contributions. The fauna is a very peculiar one as it is studied in complete detail as is also the recent west coast fauna. All the figured specimens are from Section 24, T. 28, S., R. 14 E., San Luis Obispo Co., California.

BOLIVINA ADVENA Cushman

Contrib. Cushman Lab. Foram. Res., vol. 1, part 2, July 1925, p. 29, pl. 5, figs. 1 *a, b*.

BOLIVINA ADVENA Cushman, Var. **ORNATA** Cushman

L. c., p. 29, pl. 5, figs. 2 *a, b*.

BOLIVINA ADVENA Cushman, Var. **STRIATELLA** Cushman

L. c., p. 30, pl. 5, figs. 3 *a, b*.

BOLIVINA BREVIOR Cushman

L. c., p. 31, pl. 5, figs. 8 *a, b*.

BOLIVINA CALIFORNICA Cushman

L. c., p. 32, pl. 5, figs. 10 *a, b*.

BOLIVINA CONICA Cushman

L. c., p. 30, pl. 5, figs. 4 *a, b*.

BOLIVINA DECUSSATA H. B. Brady

L. c., p. 31, pl. 5, figs. 6 *a, b*.

BOLIVINA IMBRICATA Cushman

L. c., p. 31, pl. 5, figs. 7 *a, b*.

BOLIVINA MARGINATA Cushman

L. c., p. 30, pl. 5, figs. 5 *a, b*.

BOLIVINA TUMIDA Cushman

L. c., p. 32, pl. 5, figs. 9 *a, b*.

VIRGULINA CALIFORNIENSIS Cushman

L. c., p. 32, pl. 5, figs. 11 *a-c*.

BULIMINA OVATA d'Orbigny

Plate 7, fig. 1

Bulimina ovata D'ORBIGNY, *Foram. Fossiles Vienne*, 1846, p. 185, pl. 11, figs. 13, 14.

Test tapering, fusiform, greatest width above the middle, both ends rounded, longer than broad, chambers distinct, high, not greatly overlapping.

Length 0.60 mm., breadth 0.30 mm.

This is close to the species described by d'Orbigny from the Miocene of the Vienna Basin.

BULIMINA OVULA d'Orbigny

Plate 7, fig. 2

Bulimina ovula D'ORBIGNY, *Voy. Amér. Mérid.*, 1839, vol. 5, pt. 5, "Foraminifères," p. 51, pl. 1, figs. 10, 11.

Test nearly as broad as long, initial end pointed, greatest width at about the middle, chambers high, much overlapping.

Length 0.60 mm., breadth 0.50 mm.

This is identical with the species described by d'Orbigny from the west coast of America.

BULIMINA PSEUDOTORTA Cushman, n. sp.

Plate 7, fig. 3

Test tapering, greatest breadth near the apertural end, outline slightly lobulate, initial end narrow, rounded, rapidly increasing in diameter to just below the broadly rounded or even truncate apertural end; chambers few, inflated; sutures distinct, very slightly depressed; wall thin, very finely perforate, smooth, matte; aperture either elongate or almost cruciform.

Maximum length 0.85 mm., breadth 0.50 mm. Holotype Cushman Coll. 5703.

This resembles *B. torta* Cushman described from the North Pacific between the California coast and Hawaii.

BULIMINELLA BREVIOR Cushman

Contrib. Cushman Lab. Foram. Res., vol. 1, part 2, July 1925, p. 33, pl. 5, fig. 14.

BULIMINELLA CALIFORNICA Cushman

L. c., p. 33, pl. 5, fig. 15.

BULIMINELLA CURTA Cushman

L. c., p. 33, pl. 5, fig. 13.

BULIMINELLA SUBFUSIFORMIS Cushman

L. c., p. 33, pl. 5, fig. 12.

CASSIDULINA CRASSA d'Orbigny

Plate 7, figs. 4 a, b

Cassidulina crassa D'ORBIGNY, Voy. Amér. Mérid. 1839, vol. 5, pt. 5, "Foraminifères," p. 56, pl. 7, figs. 18-20.

A few specimens with broadly rounded periphery and nearly parallel sides seem referable to this species described by d'Orbigny in his South American Monograph.

CASSIDULINA LIMBATA Cushman and Hughes

Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, March 1925, p. 12, pl. 2, figs. 2 a, c

A few of the Monterey specimens may be referred to this species described from the Pliocene of California and now living off the western coast of America.

CASSIDULINA PULCHELLA d'Orbigny

L. c., vol. 1, part 2, July 1925, p. 34, pl. 5, fig. 16.

NODOSARIA OBLIQUA (Linne)

Plate 7, fig. 5.

Nautilus obliquus LINNE, Syst. Nat., ed. 10, 1758, p. 711; ed. 13 (Gmelin's), 1788, p. 3372.

Nodosaria obliqua (LINNE), H. B. BRADY, Rep. Voy. *Challenger*, Zoology, Vol. 9, 1884, p. 513, pl. 64, figs. 20-22.

Test fairly large, tapering, slightly curved, chambers of the later portion more distinctly inflated, wall smooth, aperture radiate, eccentric.

This is the only species of the genus at all common in the upper portion of the Monterey and it continues into the Pliocene. It is usually broken in the preparation of material due to the stresses to which the shale has been subjected. The figured specimens are fragments from three portions of different specimens and the complete specimen would be much more elongate than the position of the fragments on the plate would seem to indicate.

NODOSARIA KOINA Schwager

Plate 7, fig. 6.

Nodosaria koina SCHWAGER *Novara-Exped.*, Geol. Theil., pt. 2, 1866, p. 220, pl. 5, fig. 47.

Test slender, slightly curved, very gently tapering, initial end rounded; chambers numerous, ten or more, inflated, gradually increasing in size as added; sutures distinct, but only slightly depressed; wall smooth, matte; aperture radiate, nearly central.

Length up to 1.30 mm., greatest breadth 0.28 mm.

Schwager described this species from the Pliocene of Kar Nicobar and his figured specimens appear to be identical with the Monterey species. This is probably the species referred by Chapman (Proc. Cal. Acad. Sci., ser. 3 (Geol.), vol. 1, No. 8, 1900, pl. 29, fig. 11) to *Nodosaria radicola* Linné.

NODOSARIA KOINA Schwager, Var. **HUGHESI** Cushman, n. var.
Plate 7, fig. 7.

Variety differing from the typical in the peculiar form of the chambers which at the base are slightly expanded and then cut under sharply Holotype Cushman Coll. 5688.

This variety occurs in a very narrow band of the section. It is named for Mr. Donald D. Hughes who first called my attention to the differences between this and the foregoing.

CRISTELLARIA BEALI Cushman

Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, April 1925, p. 25, pl. 4, figs. 6-13.

CRISTELLARIA MIOCENICA Chapman

Plate 7, fig. 8

Cristellaria miocenica CHAPMAN, Proc. Cal. Acad. Sci., ser. 3 (Geol.), vol. 1, 1900, p. 250, pl. 30, figs. 1, 1a.

This is apparently the species described by Chapman from the Monterey in the above reference.

There are several other species of *Cristellaria* from the upper Monterey but they are smooth and not well characterized. They are left for the present without specific determination.

FRONDICULARIA FOLIACEA Schwager

Plate 7, fig. 9

Frondicularia foliacea SCHWAGER, *Novara-Exped.*, Geol. Theil, pt. 2, 1866, p. 236, pl. 6, fig. 76.

Test elongate, tapering, very much compressed, periphery subacute; chambers few, distinct, elongate; sutures distinct, slightly depressed, nearly straight; wall very thin, finely perforate, matte; proloculum thicker than the remainder of the test.

This species is rare but the specimens are very similar to those figured and described by Schwager from the Pliocene of Kar Nicobar.

PLECTOFRONDICULARIA MIOCENICA Cushman, n. sp.

Plate 7, figs. 10, 11. Plate 8, figs. 11, 12

Test elongate, narrow, gradually tapering, very much compressed, periphery acute, keeled; chambers numerous, distinct, elongate, early ones biserial, alternating; sutures distinct, slightly depressed, curved; wall very thin except in the earlier chambers which are thickened, ornamented by a few longitudinal costae, strongest over the proloculum thence gradually spreading and decreasing in size.

Length 1.75 mm., breadth 0.65 mm. Holotype Cushman Coll. 5701.

This is apparently the ancestral form of the Pliocene *P. californica* Cushman and Stewart. It is much broader and only the earlier portion is keeled.

SUBGENUS UVIGERINELLA Cushman new subgenus

The species here referred to *Uvigerina* are characterized by a peculiar set of apertural characters. Instead of a definite tubular neck there is an elevated "collar" about the aperture the inner sides of which often do not meet but run down the sides of the test about the aperture. The aperture itself instead of being circular as in typical *Uvigerina* is elliptical and has usually a valvular tooth. This seems to be a unique development in this particular region in the Miocene. This type species is *Uvigerina (Uvigerinella) californica* Cushman, n. sp.

UVIGERINA (UVIGERINELLA) CALIFORNICA Cushman, n. sp.

Plate 8, figs. 2 a, b; 5

Test much longer than broad, greatest breadth near the apertural end, composed of 6 or 7 whorls; chambers distinct, inflated, 3 in each whorl, arranged in longitudinal series but slightly twisted so that each vertical series makes about $\frac{1}{4}$ turn of the test, last-formed chamber often slightly irregular; sutures distinct, depressed; wall smooth, finely perforate; aperture with a very short neck, not cylindrical, but somewhat compressed, from the inner portion of the chamber a very slight phialine lip and in some specimens apparently an apertural tooth, thin, plate-like, projecting in from the inner side of the aperture.

Length up to 1 mm., breadth 0.30 mm. Holotype Cushman Coll. 5739.

UVIGERINA (UVIGERINELLA) CALIFORNICA Cushman, n. sp.,
 var. **ORNATA** Cushman, n. var.
 Plate 8, figs. 1 a-c; 6

Variety differing from the typical in the shorter test usually not having more than 6 whorls, the surface ornamented with numerous distinct, longitudinal costae. Holotype Cushman Coll. 5751.

UVIGERINA (UVIGERINELLA) NUDO-COSTATA Cushman, n. sp.
 Plate 8, figs. 4 a-c, 8

Test small, elongate, tapering, broadest toward the apertural end; chambers numerous, inflated; sutures depressed, distinct; wall in the early chambers very finely costate, in the later ones smooth; aperture terminal, rather large, with a low lip or collar, open on the inner border and with a slight apertural tooth.

Length 0.50 mm., breadth 0.22 mm. Holotype Cushman Coll. 5758.

This is somewhat smaller than the other species and is more regular in the placing of the chambers.

UVIGERINA (UVIGERINELLA) OBESA Cushman, n. sp.
 Plate 8, figs. 3 a-c, 7

Test elongate, fusiform, greatest width above the middle; chambers numerous, inflated; sutures deeply depressed, the posterior portion of the later chambers overhanging; wall with numerous fine costae, those of each chamber independent of adjacent ones; aperture terminal, with a short neck and somewhat phialine lip usually open at the inner end.

Length 0.50-0.60 mm., breadth 0.25-0.28 mm. Holotype Cushman Coll. 5757.

SIPHOGENERINA COLLOMI Cushman

Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, April 1925, p. 2, pl. 4, fig. 3.

SIPHOGENERINA KLEINPELLI Cushman

L. c., p. 3, pl. 4, fig. 5.

SIPHOGENERINA REEDI Cushman

L. c., p. 3, pl. 4, fig. 4.

GENUS VALVULINERIA Cushman, new genus.

Test usually trochoid, close coiled, all chambers of the several coils visible from the dorsal side, only those of the last-formed coil from the ventral side, umbilicate; chambers numerous, wall

finely perforate; the aperture ventral, large, extending from the umbilical end of the chamber nearly to the periphery and covered by a thin, membrane-like plate which largely fills the umbilical area, in the adult the aperture often extends into the ventral or peripheral face of the chamber, sometimes becoming tripartite.

There is a very great development of this genus in the Miocene of the California region and the species take on various forms. In some of them the spire becomes depressed and the later chambers overlap those of the earlier coils on the dorsal side, in others the reverse appears and the last-formed coil becomes much more ventral. The apertural characters are very peculiar and will distinguish the genus. Recent species from off the west coast of America also belong here. There was evidently rapid evolution taking place at this time as in the very complete sections studied it is possible to trace the rapid changes in the species of this genus that takes place at succeeding levels. Genotype, *Valvulineria californica* Cushman, n. sp.

VALVULINERIA CALIFORNICA Cushman, n. sp.

Plate 9, figs. 1 a-c

Test large, rounded, rotaaliform, periphery broadly rounded, in the adult the last coil narrow on the dorsal side, the chambers overlapping the preceding coil very slightly, 6-8 chambers in the last-formed coil; sutures distinctly limbate; aperture ventral, from the umbilicus slightly out onto the ventral margin.

Length 0.65-0.80 mm., breadth 0.60 mm., thickness 0.50-0.55 mm. Holotype Cushman Coll. 5798.

VALVULINERIA CALIFORNICA Cushman, n. sp., Var. **APPRESSA**
Cushman, n. var.

Plate 9, figs. 5 a-c

Variety differing from the typical in the more rotaaliform test, broader in end view, in the adult the chambers on the dorsal side somewhat covering the preceding coil, ventral side more extended, peripheral margin broader, plate-like extension very distinct, later chambers on the dorsal side more inflated; sutures more distinct and depressed; chambers 6-8; aperture almost umbilical.

Length 1 mm., breadth 0.90 mm., thickness 0.50 mm. Holotype Cushman Coll. 5814.

VALVULINERIA CALIFORNICA Cushman, n. sp., Var. **OBESA** Cushman,
n. var.

Plate 9, figs. 2 a-c

Test with a very rounded periphery, the chambers comparatively few, earlier chambers exposed on the dorsal side, inflated, in peripheral view the test nearly equilateral.

Length 0.60-0.95 mm., breadth 0.50-0.80 mm., thickness 0.42-0.60 mm. Holotype Cushman Coll. 5804.

VALVULINERIA MIOCENICA Cushman, n. sp.

Plate 8, figs. 9, 10; plate 9, figs. 3 a-c

Test longer than broad, plano-convex, dorsal side flattened, ventral side convex, periphery broadly rounded in final chambers, in earlier ones often bluntly angled; chambers increasing much in height, especially in the last-formed portion, 8-10 in the last-formed coil, the last few inflated; sutures limbate; wall coarsely perforate; aperture slightly on the ventral side of the periphery in some specimens with the aperture developing long projections across the apertural face even becoming tripartite as in pl. 8, figs. 9, 10.

Length 0.70 mm., breadth 0.55 mm., thickness 0.35 mm. Holotype Cushman Coll. 5789.

VALVULINERIA MIOCENICA Cushman, n. sp., Var. **DEPRESSA**
Cushman, n. var.

Plate 9, figs. 7 a-c

Test small, nearly bilaterally symmetrical, periphery evenly rounded, dorsal side almost completely involute, only a very little of the previous coil showing, ventral side deeply umbilicate, 8 or 9 chambers in the last-formed coil; chambers somewhat inflated; sutures distinct, depressed; aperture extending nearly to the median line from the ventral side.

Length 0.50 mm., breadth 0.40 mm., thickness 0.28 mm. Holotype, Cushman Coll. 5783.

VALVULINERIA ORNATA Cushman, n. sp.

Plate 9, figs. 4 a-c

Test nearly bilaterally symmetrical, longer than broad, periphery rounded, about 10 chambers in the last-formed coil; chambers not greatly inflated; sutures limbate, distinct, very broad toward the umbilicus; wall coarsely and distinctly perforate, the perforations showing a tendency to be arranged in somewhat radial lines.

Length 0.60 mm., breadth 0.45 mm., thickness 0.32 mm. Holotype, Cushman Coll. 5810.

VALVULINERIA VILARDEBOANA (d'Orbigny)

Plate 9, figs. 6 *a-c*

Rosalina vilardeboana D'ORBIGNY, Voy. Amér. Mérid., 1839, vol. 5, pt. 5, "Foraminifères," p. 44, pl. 6, figs. 13-15.

Test biconvex, periphery slightly rounded or bluntly angled, 4 or 5 chambers in the last-formed coil, flattened; sutures fairly distinct, very slightly depressed, more so on the ventral side; wall roughened slightly with coarse perforations; aperture a low, elongate, arched slit on the ventral side extending from the umbilicus to the periphery.

Length 0.40 mm., breadth 0.35 mm., thickness 0.18 mm.

This is apparently the same as the species described by d'Orbigny from the coast of South America. It belongs in the genus with the other species described here.

TRUNCATULINA CF. BASILOBA Cushman

Test plano-convex, dorsal side nearly flat, ventral side somewhat convex, periphery sub-acute; chambers fairly distinct, 8-10 in the last-formed coil, the inner angle of each chamber on the dorsal side ending in a small, overlapping, rounded lobe, leaving a flat ring about the umbilicus outside of which is a series of depressions, one for each chamber; sutures slightly depressed, fairly distinct; wall rather coarsely perforated; aperture near the edge on the ventral side.

Length 0.45-0.60 mm., breadth 0.35-0.50 mm.

This very strikingly resembles a species I have described from the Miocene of South Carolina (Bull. 676, U. S. Geol. Survey, 1918, p. 64, pl. 21, fig. 2).

GENUS PULVINULINELLA Cushman, new genus

Test trochoid, close-coiled, all the chambers visible from the dorsal side, only those of the last-formed coil from the ventral side, very slightly umbilicate; chambers numerous and distinct; sutures on the dorsal side oblique, on the ventral side nearly radial; wall thin, finely perforate; aperture on the ventral side of the peripheral face, elongate, somewhat loop-shaped, nearly parallel to the axis of coiling, sometimes with a slight tooth-like projection of the margin on one side.

There is but a single species present in the upper Monterey

but in the lower portion and especially off the west coast of America in the present ocean there is a very considerable development of this genus. The type species *Pulvinulinella subperuviana* Cushman, n. sp., does not show the apertural characters so definitely as do the recent species. In these there is a tendency for the last-formed chambers to become slightly *Cassidulina* and the aperture is very similar to that of *Cassidulina*. It may be that this is the form from which *Cassidulina* originated and that *Cassidulina* is a biserially arranged offshoot from the Rotaliidae. A further discussion of this genus will be deferred until the recent species are described.

PULVINULINELLA SUBPERUVIANA Cushman, n. sp.

Plate 9, figs. 9 a-c

Test small, rotaaliform, biconvex, umbonate, periphery subacute; chambers numerous, 10 or 11 in the last-formed coil; sutures on the dorsal side strongly oblique, on the ventral side nearly straight, radial, distinct but only slightly depressed; last-formed coil thin and compressed forming a fringe about the more umbonate center; wall smooth; aperture a narrow slit on the ventral side of the last-formed chamber just below and parallel with the periphery, with a tooth-like projection from the edge.

Diameter 0.40 mm. Holotype, Cushman Coll. 5825.

This in some respects resembles the *Rosalina peruviana* of d'Orbigny from the coast of South America. It has fewer chambers and much less definite coils. D'Orbigny's description and figure of the aperture leave much to be desired but it probably belongs to this genus.

GENUS BAGGINA Cushman, new genus.

Test subglobular, trochoid, chambers relatively few, arranged in three or more coils, the dorsal side with the chambers more or less involute, the ventral side completely so; chambers large and inflated, sutures distinct but very slightly depressed, wall calcareous; finely perforate with a clear lunate space on the ventral side of the chamber near the aperture; aperture broadly oval on the ventral side of the last formed chamber without a definite lip. Genotype *Baggina californica* Cushman n. sp.

This genus is named in honor of Dr. Rufus M. Bagg, Jr., an American worker on the Foraminifera for many years. Some of the recent Pacific species should probably be referred to this genus.

BAGGINA CALIFORNICA Cushman, n. sp.

Plate 9, figs. 8 a-c

Test subglobular, the last-formed coil only visible from the ventral side, not completely covering the earlier ones on the dorsal side, periphery broadly rounded; chambers comparatively few, 5 in the last-formed coil, inflated, rather indistinct; sutures fairly distinct, hardly depressed except slightly so on the ventral side; wall smooth; aperture large and elliptical on the ventral side of the last-formed chamber near the umbilicus; each chamber with the wall finely and closely perforate except in a semi-elliptical area above the umbilicus which is apparently thinner, of clear material with few or no perforations.

Length 0.75 mm., breadth 0.60 mm., thickness 0.60 mm. Holotype, Cushman Coll. 5777.

This species is especially characteristic of the upper part of the Monterey.

GENUS NONIONELLA Cushman, new genus.

Test subtrochoid, the dorsal side only partially involute, ventral side completely so, close coiled, chambers especially in the adult inaequilateral, the ventral side developing a distinct elongate lobe at the umbilical end which covers the umbilicus; wall calcareous, finely perforate; aperture at the base of the chamber, low and elongate, extending from the peripheral border toward the ventral side.

Genotype *Nonionella miocenica* Cushman, n. sp.

The species of this genus have usually been placed under *Nonionina* but this distinct subtrochoid character with the lobed ventral side and inaequilateral aperture persists through many species at least from the early Eocene to the present. It seems worthy of generic distinction.

NONIONELLA MIOCENICA Cushman, n. sp.

Nonionina auris CUSHMAN (not D'ORBIGNY), Contrib. Cushman Lab. Foram. Res., vol. 1, part 4, 1926, p. 91, pl. 13, figs. 4 a-c

Test subtrochoid, small, periphery broadly rounded, 8-10 chambers in the last-formed coil, distinct, dorsal side not completely involute, the sutures obliquely curved, the last chambers with the umbilical end forming a distinct rounded lobe; wall smooth; aperture low, elongate.

Length 0.45 mm., breadth 0.35 mm., thickness 0.25 mm. Holotype, Cushman Coll. 4370.

This species has fewer chambers than *Nonionella auris* (d'Orbigny) and holds its characters in the upper Monterey very closely.

NONIONINA COSTIFERA Cushman

L. c., p. 90, pl. 13, figs. 2 *a-c*.

NONIONINA INCISA Cushman

L. c., p. 90, pl. 13, figs. 3 *a-c*.

NONIONINA MEDIO-COSTATA Cushman

L. c., p. 89, pl. 13, figs. 1 *a-c*.

The number of species and genera described as new from this upper Monterey material may seem large but as the collections have been more and more thoroughly studied the differences between this Miocene and other known faunas has become more and more apparent. It is most closely related to a very interesting fauna now living off this same coast. There are a very few species related to the Miocene of other regions and to the Pliocene of the general Pacific region but the number is very small. Paratypes of most of these species are to be found in the collections of Stanford University.

EXPLANATION OF PLATE 7

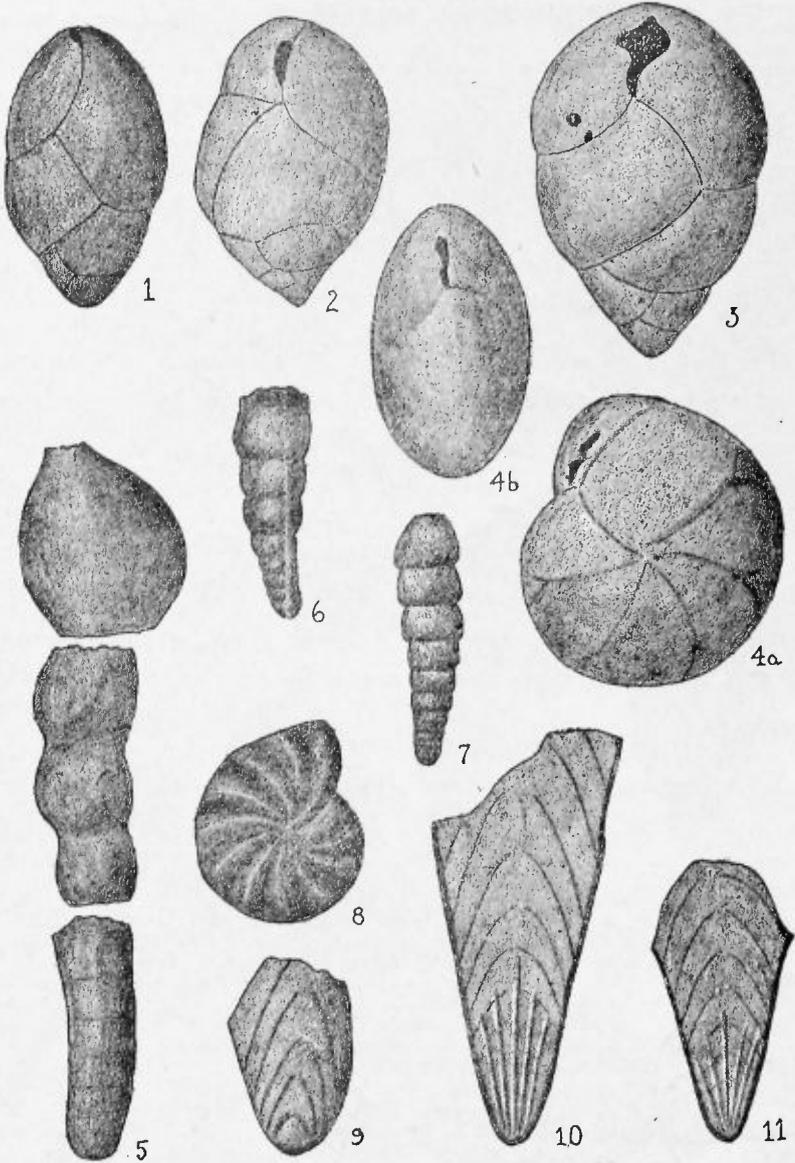
- FIG. 1. *Bulimina ovata* d'Orbigny. X 65.
 FIG. 2. *Bulimina ovata* d'Orbigny. X 65.
 FIG. 3. *Bulimina pseudotorta* Cushman, n. sp. X 65.
 FIGS. 4 a, b. *Cassidulina crassa* d'Orbigny. X 65.
 FIG. 5. *Nodosaria obliqua* (Linné). X 65. Three fragments of different parts of test.
 FIG. 6. *Nodosaria koina* Schwager. X 65.
 FIG. 7. *Nodosaria koina* Schwager, var. *hughesi* Cushman, n. var. X 65.
 FIG. 8. *Cristellaria miocenica* Chapman. X 65.
 FIG. 9. *Frondicularia foliacea* Schwager. X 65.
 FIGS. 10, 11. *Plectofrondicularia miocenica* Cushman, n. sp. X 65 .

EXPLANATION OF PLATE 8

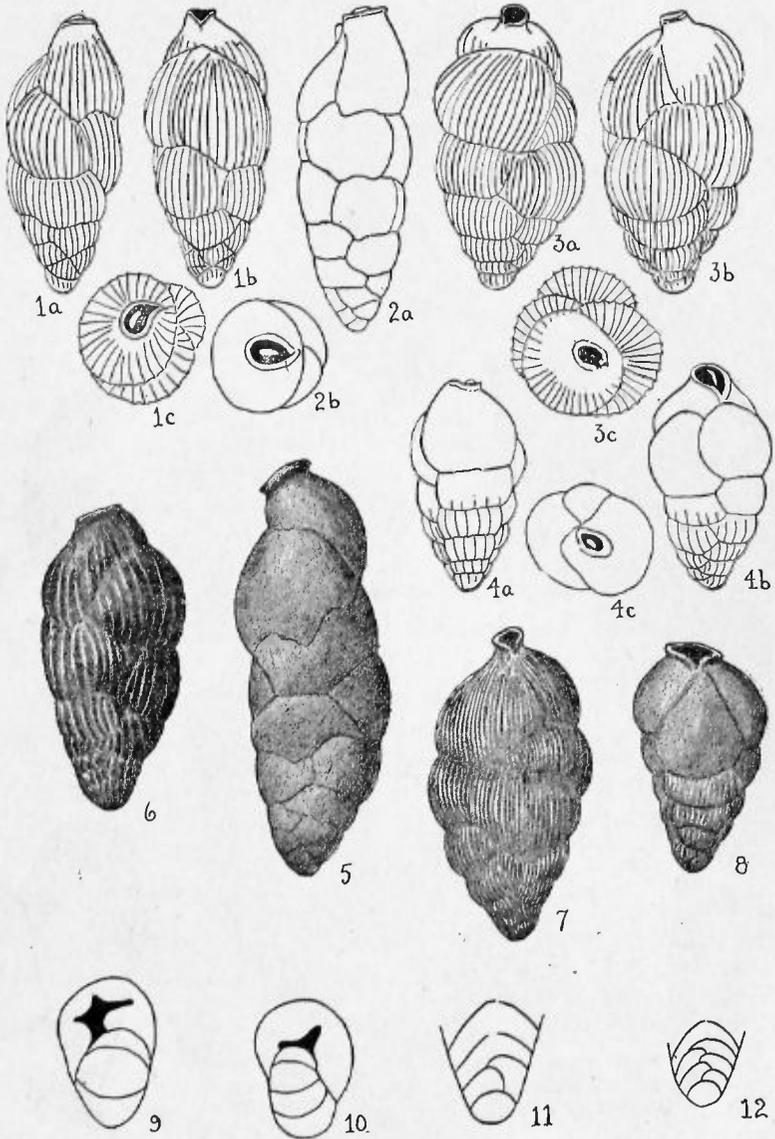
- FIGS. 1 a-c. *Uvigerina (Uvigerinella) californica* Cushman, n. sp., var. *ornata* Cushman, n. var. X 65. a, side view; b, front view; c, apertural view.
 FIGS. 2 a, b. *Uvigerina (Uvigerinella) californica* Cushman, n. sp. X 65. a, side view; b, apertural view.
 FIGS. 3 a-c. *Uvigerina (Uvigerinella) obesa* Cushman, n. sp. X 65. a, front view; b, side view; c, apertural view.
 FIGS. 4 a-c. *Uvigerina (Uvigerinella) nudo-costata* Cushman, n. sp. X 65. a, side view; b, front view; c, apertural view.
 FIG. 5. *Uvigerina (Uvigerinella) californica* Cushman, n. sp. X 75.
 FIG. 6. *Uvigerina (Uvigerinella) californica* Cushman, n. sp., var. *ornata* Cushman, n. var. X 75.
 FIG. 7. *Uvigerina (Uvigerinella) obesa* Cushman, n. sp. X 75.
 FIG. 8. *Uvigerina (Uvigerinella) nudo-costata* Cushman, n. sp. X 75.
 FIGS. 9, 10. *Valvulineria miocenica* Cushman, n. sp. Two forms of aperture. X 50.
 FIGS. 11, 12. *Plectofrondicularia miocenica* Cushman, n. sp. Early chambers.

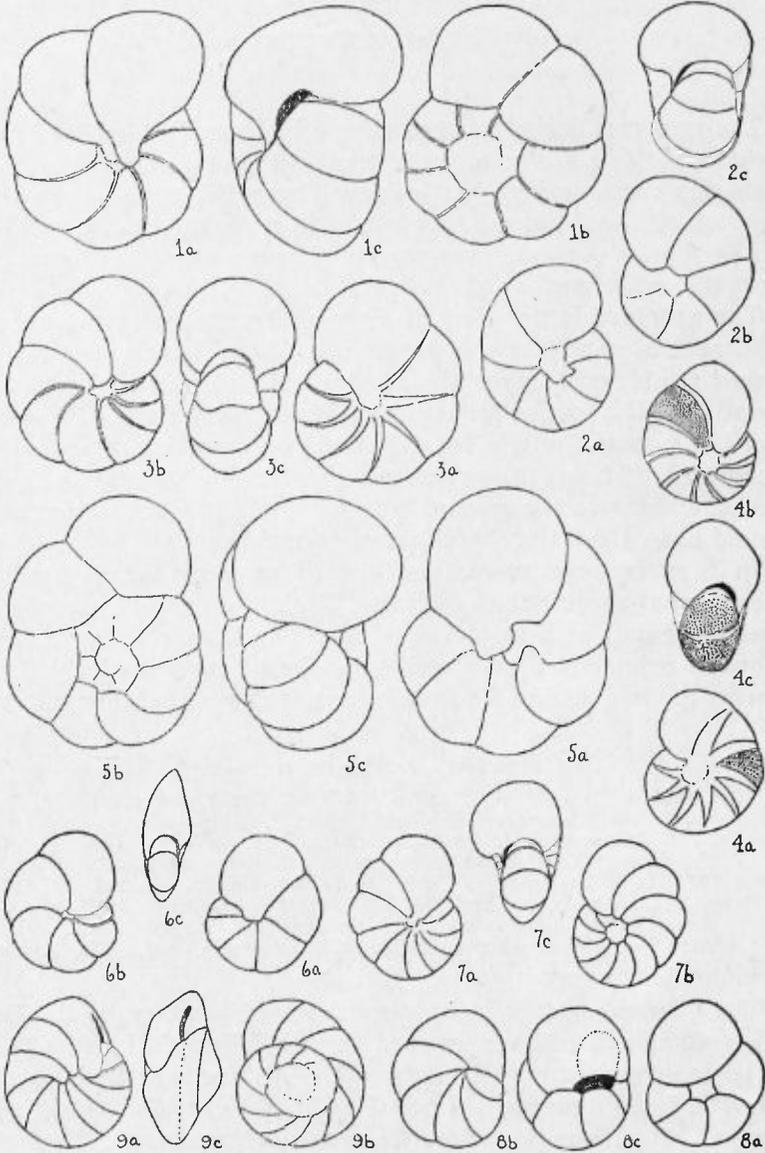
EXPLANATION OF PLATE 9

- FIGS. 1 a-c. *Valvulineria californica* Cushman, n. sp. X 65. a, ventral view; b, dorsal view; c, peripheral view.
 FIGS. 2 a-c. *Valvulineria californica* Cushman, n. sp., var. *obesa* Cushman, n. var. X 65. a, ventral view; b, dorsal view; c, peripheral view.
 FIGS. 3 a-c. *Valvulineria miocenica* Cushman, n. sp. X 65. a, ventral view; b, dorsal view; c, peripheral view.
 FIGS. 4 a-c. *Valvulineria ornata* Cushman, n. sp. X 65. a, ventral view; b, dorsal view; c, peripheral view.
 FIGS. 5 a-c. *Valvulineria californica* Cushman, n. sp., var. *appressa* Cushman, n. var. X 65.
 FIGS. 6 a-c. *Valvulineria vilardeboana* (d'Orbigny). X 65. a, ventral view; b, dorsal view; c, peripheral view.
 FIGS. 7 a-c. *Valvulineria miocenica* Cushman, n. sp., var. *depressa* Cushman, n. var. X 65. a, ventral view; b, dorsal view; c, peripheral view.
 FIGS. 8 a-c. *Baggina californica* Cushman, n. sp. X 65. a, ventral view; b, dorsal view; c, peripheral view.
 FIGS. 9 a-c. *Pulvinulinella subperuviana* Cushman, n. sp. X 100. a, ventral view; b, dorsal view; c, peripheral view.



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31. THE GENERIC POSITION OF "*PULVINULINA FAVUS*
H. B. BRADY"

By JOSEPH A. CUSHMAN

The very peculiarly ornamented species described by Brady as *Pulvinulina favus* is common in some parts of the Pacific. It is a species characterized particularly "by a thick exogenous deposit of shell-substance, forming a 'honeycomb' ornament not unlike that of *Lagena squamata* or *Lagena hexagona*, over almost the entire surface of the test."

The aperture is not that of *Pulvinulina* and with numerous specimens at hand sections were made. These show a very thick, almost friable covering of the harder test and when the sections are studied the species turns out as was suspected not a *Pulvinulina* but a true *Cassidulina*. Brady's own section, *Challenger* Report, pl. 104, fig. 14, also shows on close study that the alternate chambers do not reach the center in the median section and should have given the clue to its relationship.

In its surface ornamentation *Cassidulina favus* (H. B. Brady) is somewhat similar to *C. decorata* Sidebottom and *C. elegantissima* Cushman both known only from the Pacific. *Cassidulina favus* is primarily a cold water species of comparatively deep waters of the Pacific. The references to it are as follows:

CASSIDULINA FAVUS (H. B. BRADY)

Pulvinulina favus H. B. BRADY, Geol. Mag., Dec. 2, vol. 4, 1877, p. 294; Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 701, pl. 104, figs. 12-16.—Chapman, Journ. Linn. Soc., Zool., vol. 30, 1910, p. 423, pl. 55, fig. 15.—Schubert, Abhandl. geol. Reichsanst., vol. 20, pt. 4, 1911, p. 113.—Pearcey, Trans. Roy. Soc. Edinburgh, vol. 49, 1914, p. 1029.—Cushman, Bull. 71, U. S. Nat. Mus., pt. 5, 1915, p. 65.—Heron-Allen and Earland, British Antarctic Exped., Zool., vol. 6, 1922, p. 219.—Cushman, Publ. 342, Carnegie Inst., Washington, 1924, p. 42, pl. 13, figs. 7, 8.

The *Challenger* specimens were from deep water of the Pacific. Chapman's specimens are from off Funafuti, 1050-2728 fathoms. Pearcey records it from the Antarctic 1998 fathoms. I had it from numerous North Pacific stations, 847-2250 fathoms. A single specimen from Samoa is referred to it.

As a fossil it was described by Brady from the Pacific and is recorded from the Bismark Archipelago by Schubert. Heron-Allen and Earland record it fossil from the Antarctic, "not typical."

Egger (Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 18, 1893, p. 417, pl. 18, figs. 13-15) records this species in comparatively shallow water from Cape of Good Hope and from Mauritius but his figures do not give a very good representation of this species. The ventral side shows a deeply uniliculate specimen and the dorsal side is very distinctly trochoid. Halkyard (Mem. Proc. Manchester Lit. Philos. Soc., vol. 62, pt. 2, 1918 (1919), p. 123) records this species from the Eocene Blue Marl of Biarritz. He notes as do also Heron-Allen and Earland who edited his paper that the specimens are not the same as that of the Pacific in their characters and they undoubtedly are another thing.

32. SOME PHASES OF CORRELATION BY MEANS OF THE FORAMINIFERA

By JOSEPH A. CUSHMAN

While the foraminifera furnish excellent means for correlation often over wide distances there are certain limitations that a beginner in the work may not take into consideration and which should be understood. As to the general age of a deposit the foraminifera are very excellent if one is sufficiently familiar with faunas. In the Palaeozoic the forms were widely spread and the presence of certain genera will in any part of the world give the general age of the Mississippian or the Uralian.

With the Cretaceous also there are many genera that will at once in any part of the world give the clue to the certain Cretaceous age of the deposits containing them. Also the faunas of various parts of the world were fairly uniform and there are many species common to Europe and America for instance. A study of the Cretaceous of Mexico or of the coastal plain region of the United States must be made in connection with the literature and if possible the comparison with European material. Many of the species will be found to be identical. Rather widely separated areas will be found to have had the same species at the same age and distributions of known species are wide at the

same time and a definite horizon may be correlated over wide distances.

With the Tertiary this possibility of correlation is no longer so definite. To be sure some of the Orbitoid forms, as well as Nummulites and other genera are limited to the Eocene but they are no longer distributed so widely or at least not over such definite areas. They have become specialized as to habitat to a greater extent than was apparent in the Cretaceous and earlier periods. The genus *Hantkenina* is an excellent Eocene index fossil but it is limited in its habitat to a much deeper and probably colder water than is the case with the others mentioned. In America for example *Hantkenina* is known from the region of Alabama around the Gulf through the Gulf States into Mexico and South America but is always associated with deeper and colder water forms. On the other hand the species of *Discocyclina* are equally widely distributed but much more local as they were characteristic of shallow warmer waters which were not so widely distributed a habitat as was the deeper colder water.

The fauna so abundantly developed on the coastal plain region of Florida and closely adjacent regions which make up the Ocala limestone was very different from that developed in the deeper colder waters even of the same time along its borders. The contrast in the faunas is very great and very few of the species of the one fauna occur at all in the other. It may even be said that the fauna of the colder and deeper habitats is more closely related to the living fauna of the Gulf and the Atlantic coast than it is to the contemporaneous Ocala limestone fauna. The species of the shallower water were probably as is the case today more specialized in their ecologic relations and therefore could not exist over as great areas as could those of deeper colder waters. If the conditions continued however these species persisted and gave rise to others which were specially adapted to similar habitats. For example, *Valvulina ocalana* Cushman which was often abundant on the shallow water, warm portions of the Ocala Sea is very closely related to *V. oviedoiana* d'Orbigny which is found in great abundance on the coral reef regions of the general West Indian region today and to a similar species found in similar habitats in the Indo-Pacific. Habitat then in the Tertiary has played a very prominent part in the distribution of faunas and their constituent species.

The Oligocene continues even more strikingly this same character. Species and genera of various groups of animals which lived in the West Indian region in Oligocene times were not able

to persist through the Miocene changed conditions but still exist in the Indo-Pacific under similar conditions which they earlier found in the West Indian Oligocene Sea. Many of the smaller foraminifera species of the shallower portions of the American Oligocene must be compared with their living relatives now found only in the Indo-Pacific. This relationship is very much closer than any found in the Miocene or Pliocene of the general Gulf or West Indian regions.

The Miocene of the eastern and Gulf Coastal Plain has very little in common with the Miocene of the California region. Specialization to habitat has become very great. The foraminiferal fauna of the Miocene of the Bowden marl of Jamaica for example has little or nothing in common with the Miocene of the general coastal plain area or with that of the Monterey of California. It is strikingly like a peculiar fauna found off the Barbadoes at a depth of a hundred fathoms and at certain other favored spots in the same region. Here the same or very closely related species are now living in very considerable numbers as they did in the Bowden area during the Miocene. Not one of the large and striking species occurs in the Miocene of California or even of the general coastal plain region of our southeastern states.

The Pliocene of the Caloosahatchie marl of Florida has practically nothing in common with the Pliocene of the California region. The Caloosahatchie was very definitely a warm rather shallow habitat such as exists today off the southern coast of Florida and in the West Indies where most of the same species are now living. No species of *Bolivina*, *Cassidulina*, *Nodosaria* or *Uvigerina* occurs in the Caloosahatchie marl yet these are the common and dominant genera in the Pliocene of California and represent genera of cooler deeper waters and are abundant and dominant in the bottom deposits of such conditions existing off the western coast. In fact many if not most of the species of the California Pliocene exist today in the cooler waters off the coast from Panama to Oregon and Washington. *Cassidulina* for example is so abundant at some localities off the western coast of America that I have seen Albatross bottom samples which had probably ninety-five percent of the foraminifera belonging to different species of *Cassidulina* and the bottom might almost be characterized as a "*Cassidulina*-mud."

Enough examples have perhaps been given to show that in the Tertiary at least the foraminifera have come to be very specialized as to habitat and while they give most excellent correla-

tion over shorter distances and over long ones when ecologic conditions were similar they may be very misleading unless a considerable amount is known of the recent faunas of the same general areas and the genera and species that occur under certain habital conditions. As more is known of these faunal associations with habitat the foraminifera will become even more valuable as a means of interpretation of the conditions of deposition of many of our tertiary deposits.

RECENT LITERATURE ON THE FORAMINIFERA

Below are given some of the more recent works on the foraminifera that have come to hand.

Hofker, J.

Die Foraminiferen aus dem senon Limburgens. IV. *Sporodotrema errantium* nov. spec.

(Nat. Maan., Nat. Gen. Limburg, Jaarg. 15, No. 6, June 30, 1926, pp. 62-65, 1 plate.)

Limburg.

A paper devoted to exhaustive descriptive details with numerous figures of this new species.

Franke, A.

Die Foraminiferen des norddeutschen Unter-Oligocäns mit besonderer Berücksichtigung der Funde an der Fritz-Ebert-Brücke in Magdeburg.

(Abhandl. und Berichte Mus. Natur- und Heimatkunde und Nat. Ver., Bd. 4, Heft 2, 1925, pp. 146-190, pls. 5, 6.)

Magdeburg.

This paper contains 73 species from the Lower Oligocene 3 of which are described as new.

Darton, N. H.

Geology of the Guantanamo Basin, Cuba.

(Journ. Washington Acad. Sci., vol. 16, No. 12, June 1926, pp. 324-332, 5 text figs.)

Washington.

Three lists of foraminifera are given from this region of Cuba.

Galloway, J. J.

Methods of Correlation by Means of Foraminifera.

(Bull. Amer. Assoc. Petr. Geol., vol. 10, No. 6, June 1926, pp. 562-567.)

Chicago.

"The determined principles of paleontologic correlation are applied to the use of Foraminifera for age determination and horizon identification and the relative values of the different criteria are briefly considered in this paper."—
Author's abstract.

Cushman, Joseph A.

The Foraminifera of the Velasco Shale of the Tampico Embayment.

(Bull. Amer. Assoc. Petr. Geol., vol. 10, No. 6, June 1926, pp. 581-612, pls. 15-21.) *Chicago.*

"This paper describes and illustrates the foraminiferal fauna of the Velasco shale which occurs above the Papagallos in the Tampico Embayment region. The species are very numerous and show very interesting relationships with a fauna of similar age in Europe."—Author's abstract.

Carsey, Dorothy Ogden.

Foraminifera of the Cretaceous of Central Texas.

(Univ. of Texas Bulletin, No. 2612, July, 1926, pp. 1-56, pls. 1-8.) *Austin.*

According to the author this paper "was prepared to serve as a practical working basis for the study of the subsurface geology of the Cretaceous sediments of Central Texas." The different formations are taken up and a short description of the appearance given with a list of the foraminifera found in each. The latter part is taken up by description of species, many given as new, illustrated by plates from photographs. The figures unfortunately lack detail in many cases. A short bibliography is given.

Cushman, Joseph A.

Foraminifera of Tropical Central Pacific.

(Bernice P. Bishop Museum Bulletin No. 27, Tanager Exped. Publ. No. 1, 1925, pp. 121-144.) *Honolulu.*

The foraminifera noted are those from the Tanager Expedition between Hawaii and Midway Island, a region little known. There are new species of *Uvigerina* and *Discorbis*.

Stipp, Thomas F.

The Relation of Foraminifera to the Origin of California Petroleum.

(Bull. Amer. Assoc. Petr. Geol., vol. 10, No. 7, July 1926, pp. 697-702.) *Chicago.*

A discussion of the question of diatoms or foraminifera as the source of the petroleum of California with the author tending toward the diatoms as the more likely source.