

CONTRIBUTIONS
FROM THE
CUSHMAN FOUNDATION
FOR
FORAMINIFERAL RESEARCH

Volume VIII, Part 4
October, 1957

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VOLUME VIII, PART 4, OCTOBER, 1957

174. THE BILAMELLIDEA, NOV. SUPERFAM.,
AND REMARKS ON CRETACEOUS GLOBOROTALIIDS

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ABSTRACT

The new superfamily Bilamellidea is described. It includes several families of Foraminifera having a test built of lamellae of radial-hyaline calcite, such as the Globorotaliidae, as herein amended, the Anomalinidae, the Discorbidae (*pars*), most, if not all, Globigerinidae, *et al.*, thus corresponding to part of the superfamily Discorbidea Smout, 1954. The remainder of the Discorbidea Smout is renamed in Monolamellidea, *nom. nov.* The Globotruncaninae, *emend.* and the Globorotaliinae, *nov. subfam.*, are defined as subfamilies of the Globorotaliidae, *emend.* The wall-structure, the keels and the apertural characters of the Globotruncaninae are discussed. The new genera *Helvetoglobotruncana*, *Globotruncanella* and *Globotruncanita* are described. The genus *Planomalina* is regarded to belong to the Globotruncaninae. The phylogenetic relationships of the genera belonging to the Globotruncaninae are briefly discussed.

INTRODUCTION

During an investigation of various "rotaliform" Foraminifera, now in progress and carried out by this writer, it has been shown that the Discorbidea Smout, 1954, include two distinct groups of Foraminifera building their test of lamellae of radial calcite: one, comprising canalliculate, double-walled forms, described herein as the Bilamellidea, *nov. superfam.*, and a second group, comprising non-canalliculate, single-walled forms, corresponding to the original definition of the Discorbidea Smout (1954, 1955), to which — for reasons to be discussed below — the new name Monolamellidea is given.

To the Bilamellidea, *nov. superfam.*, belong certain important "rotaliform" families, like the Globorotaliidae, as herein amended, the Anomalinidae, part of the Discorbidae, most, if not all, Globigerinidae, etc. An investigation in progress will show how far certain families must be redefined and which families must be included in the Bilamellidea.

The family Globorotaliidae, *emend.*, is believed to comprise two subfamilies: the Globotruncaninae, *emend.*, and the Globorotaliinae, *nov. subfam.* Certain observations on the genera of the Globotruncaninae with regard to wall-structure, keels and apertural characters are herein presented and the new genera *Helvetoglobotruncana*, *Globotruncanella* and *Globotruncanita* are described. The genus *Planomalina* shows characters of the Globotruncaninae and is placed in this subfamily. The phylogenetic relationships of the genera of the Globotruncaninae are briefly discussed.

ACKNOWLEDGEMENTS

The writer feels greatly obliged to M. Avnimelech, Jerusalem, for constructive criticism of the present paper; to Mrs. P. Merling for preparing about 120 oriented thin-sections of globorotaliids; to Mrs. R. Strassburger-Frankel for preparing the accompanying drawings; and to the following persons who during the last years have put at this writer's disposal precious type-material, without which the present work would not have been possible: Mrs. E. R. Applin, Jackson, U.S.A.; H. Bolli, Trinidad; D. Boulanger, Paris; F. Brotzen, Stockholm; J. Cuvillier, Paris; F. Dalbiez, Bordeaux; A. G. Davis, London; A. Debourle, Pau; Brooks F. Ellis, New York; R. Grill, Vienna; H. Hagn, Munich; H. Hiltermann, Hannover; Mme. Y. LeCalvez, Paris; M. Lys, Rueil-Malmaison; P. Marie, Paris; M. Reichel, Basel; J. Sigal, Rueil-Malmaison; C. A. Wicher, Hannover.

METHODS AND TECHNIQS

Isolated specimens were cleaned with the aid of brush, needle and cactus-spines and many of them calcinated or stained with a solution of methylene-blue. They were examined under a stereoscopic microscope with a magnification of 80-200 \times . Oriented thin-sections were prepared by the usual Canada-balsam method and examined under a high-power binocular microscope with a magnification from 200-600 \times . It is only with high magnification that the wall-structure of certain bilamellids can be studied.

Superfamily BILAMELLIDEA *nov.*

(see pl. 18, figs. 1-4; pl. 19, figs. 1-8; pl. 20, figs. 1-9)

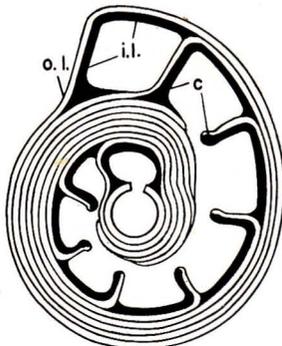
Description.—Pluriloculinid, spirally arranged Foraminifera, the test of which is built of lamellae of radial calcite; chamber-walls double, formed by an outer lamella, one per instar and covering the whole test, and by an inner one, lining each chamber and confined to it, partly coalescing with the outer lamella and adhering to a small extent only to the margins of the previous septum, which is primarily double; both parts of the chamber-wall partly perforate and partly imperforate; canal-system present; aperture well-defined and primarily formed, single or accompanied by accessory apertures.

Remarks.—The Bilamellidea, nov. superfam., differ from the Lagenidea Glaessner, 1945, emend. Smout, 1955, by their double chamber-walls and by the presence of a canal-system, as well as by the position of the aperture which is never terminal in the Bilamellidea; from the Discorbidea Smout, 1954, 1955 (*pars*), by their double walls and septa and by the presence of a canal-system; from the Rotaliidea Glaessner, 1945, emend. Smout 1954 (1955), by their primarily formed double walls and septa in all chambers, including the last one, by the lack of a septal flap and by the presence of a well-defined and primarily formed aperture.

The Discorbidea Smout, 1954 (1955), must be restricted to non-canalliculate Foraminifera with single walls and septa and renamed for the following reasons: the central group from which the Discorbidea derive their name is that of *Discorbis*, s. l., with *Discopulvinulina* Hofker as central genus (Hofker, 1951). Typical *Discopulvinulina* have been shown, however, to have the structure of the Bilamellidea (see pl. 19, fig. 1). The name Monolamellidea, nom. nov., is herewith proposed for the non-canalliculate, single-walled Discorbidea Smout, 1954, as redefined by Smout, 1955 (see pl. 18, figs. 5, 6).

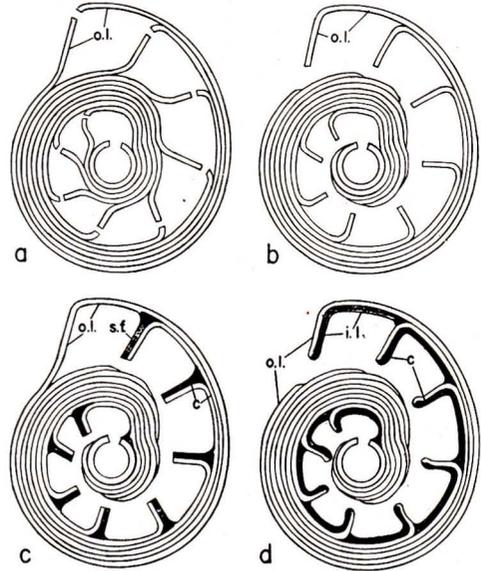
In section, bilamellid Foraminifera are easily distinguished from other "rotaliform" groups of lamellar Foraminifera by the double walls in all chambers, including the last one, in both horizontal and vertical sections (see text figs. 1 and 2).

It seems that the outer lamella is deposited by the ectoplasm, the inner lining by the endoplasm. By maintaining the presence of protoplasmic matter between them during and after deposition a canal-system is formed. Perforate and imperforate parts of the inner lining correspond to the perforate and imperforate parts of the outer lamella. Part of the distal chamber-face (and, therefore, part of each septum) is



TEXT FIGURE 1

Schematic drawing showing a slightly oblique, horizontal section near the surface of the evolute (dorsal) side of a flatly trochospiral bilamellid. Details omitted. (o.l. - outer lamella; i.l. - inner lining; c. - canal-system).



TEXT FIGURE 2

Schematic drawings showing equatorial sections of planispiral lamellar Foraminifera. a. Lagenidea. b. Monolamellidea. c. Rotaliidea. d. Bilamellidea. Details omitted. (o.l. - outer lamella; i.l. - inner lining; s.f. - septal flap; c. - canal-system). (Fig. c after Smout, 1954).

imperforate and so are the apertural face (the peristomal area), the apertural lips (if present) and very often the peripheral margin. The imperforate parts of the test are the main regions of canal-system development. Keels, often canalliculate, are frequent. Canalliculate keels are formed by the outward bending of the outer lamella. Outer lamella and inner lining coalesce in the apertural region either at the border of a thickened "rim" (formed by an inflection of the lamellae) or at the border of apertural lips, if such are present. Communications of the canal-system with the main protoplasmic mass is maintained by "pores," situated in the imperforate parts of the test and different from the normal pores of the perforate parts of the chamber-walls as far as size and regularity of arrangement are concerned.

It is noteworthy that this writer observed at least in one case (see pl. 18, fig. 3) what seems to be a shrivelled and partly destroyed chitinous chamber-lining, yellowish-brown in colour, as described by Brotzen (1942) in *Gavelinella* and by Hagn (1955) in *Eorupertia*. Although further study is needed to ascertain the exact systematic position of *Eorupertia*, it seems that the latter genus, as described by Hagn (*op. cit.*) belongs rather to the Bilamellidea, than to the Rotaliidea. The "Zentrallamelle" of Hagn (*op. cit.*) seems to correspond to our "outer lamella," the "Primärlamelle"

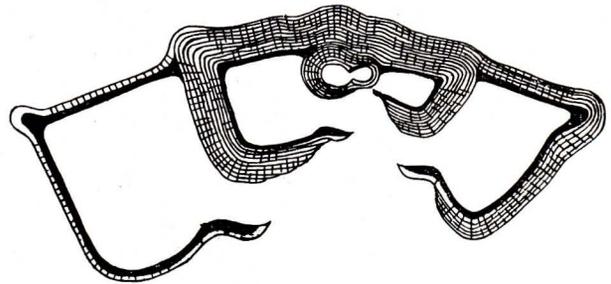
of Hagn to our "inner lining." The "Sekundärlamelle" as described by Hagn seems to be actually the inner lining sectioned in the area of its adherence to the margin of the previous septum. This "overlap" is visible in sections passing near to the lateral chamber-wall (and to the margin of the septum), but is absent from sections passing through a plane more removed from this margin. Our figured specimen (pl. 18, fig. 1) shows "three-layered" septa; the backward bending of the inner lining and its overlap on the previous septum can, however, be clearly seen in the chambers of the last coil.

Family GLOBOROTALIIDAE Cushman,
1927, emend.

Amended description.—Bilamellid Foraminifera, mostly trochospirally and rarely planispirally arranged, provided with canaliculate keels at least in the earlier chambers or with incipient canaliculate keels at least in earlier chambers (in the most primitive forms of the group); proloculus and the earliest few chambers globular; lamellae usually fairly thin; pores medium- to large-sized; test surface smooth, granular, pustulose, spinose or covered by ridge-shaped protuberances, often arranged in a regular pattern; parts of the wall forming these ornamentations imperforate; part of the distal face of each chamber, hence at least part of each septum, apertural face, peristomal thickening ("rim") and apertural lips (if present) imperforate; keels imperforate; scattered "pores" at the junction between apertural face and peristomal "rim" and in the keels; aperture primarily formed, rounded and usually large, fringed by a "rim" and provided in many genera with an apertural lip; usually single with the exception of a few genera having accessory cameral apertures; position of main aperture interiomarginal, interiomarginal-umbilical or umbilical; accessory cameral apertures in sutural position; apertural lips fused in many Cretaceous genera, forming "labial apertures" and covering partly or entirely the umbilical cavity; canal-system carinal and peristomal (septal). Lower Cretaceous to Recent. Largely pelagic.

Remarks.—The Globorotaliidae, emend., include the subfamilies Globotruncaninae, emend., and Globorotaliinae, nov. subfam. The connection between these two subfamilies poses various problems and they may still have to be regarded as independent families. The relationship between the Globorotaliidae and the Globigerinidae also requires further study. Generally the Globorotaliidae differ from the Globigerinidae only by the presence of keels in the former. The wall-structure of all hitherto examined globigerinids (including Cretaceous, Tertiary and Recent specimens) is in principle the same as that of the Globorotaliidae (see pl. 20, figs. 1-4, 6-9) (compare, however, Reichel, 1949,

and Smout, 1954). Although generally the chamber-form of globigerinids is spherical or nearly so and that of globorotaliids mostly asymmetrically flattened, there are globorotaliids with globular or nearly spherical



TEXT FIGURE 3

Schematic drawing of a globorotaliid in axial section.

chambers and various genera regarded as belonging to the Globigerinidae have asymmetrically flattened chambers. Certain globorotaliids are provided with primitive, incipient keels only and some forms having the general characters of the Globigerinidae and nearly spherical chambers are provided with keels. Certain globorotaliids doubtless originate from globigerinids; certain globigerinids have been regarded lately as having originated from globorotaliids, etc. All these problems will have to be investigated in detail, especially in connection with the revision of the Globigerinidae. It might still be necessary to revise the validity of the Globigerinidae as a family.

There is little doubt that the earliest globorotaliids have evolved from such bilamellids as *Pseudovalvulineria lorneiana* (Gandolfi) (*non* d'Orbigny), a conclusion arrived at by many authors, but unaccepted by others who believe the Cretaceous globorotaliids to have evolved from globigerinids. It might be that the Cretaceous globorotaliids originate from the same stock from which the Cretaceous globigerinids evolved, the latter being possibly derived from the same group of globular-chambered, early Cretaceous *Pseudovalvulineria* to which *P. lorneiana* (Gandolfi) and *P. lorneiana trochoidea* (Gandolfi) belong. At least one Cretaceous globorotaliid has doubtless evolved from a middle Cretaceous *Globigerina* (s. l.). Brotzen (1942) regards the Globigerinidae as a planktonic specialization of the Valvulineriidae (Brotzen, *op. cit.*) and the Globotruncaninae (Brotzen, *op. cit.*), which include among others all Globorotaliidae as herein amended, as having evolved from the Globigerinidae. The family Valvulineriidae Brotzen is, however, heterogeneous and includes monolamellids, bilamellids and granular-calcareous (perforate) forms. Topotypes of *Valvulineria californica* Cushman show monolamellid structure, while all hitherto examined globigerinids show bilamellid structure. Hofker (1951) regards the Globigerinidae as directly derived from the Valvulineriidae Hofker (*non* Brotzen). The latter family is, how-

ever, heterogeneous, too, and includes monolamellids, bilamellids and perforate, granular-calcareous forms. *Globigerina* is believed by Hofker (*op. cit.*) to be derived from *Valvulineria* (see, however, above). The family Marginolamellidae Hofker (1951, 1954), which includes the Globorotaliidae, as herein redefined, in addition to *Cancriis* as central genus, is regarded by Hofker to have evolved from the Discopulvinulinidae Hofker, independently from the Globigerinidae. The genus *Cancriis*, however, has the typical structure of the Monolamellidea, while *Discopulvinulina* has all attributes of the Bilamellidea (see pl. 18, fig. 6).

All these problems need careful study and other points will have to be cleared up (e. g. the possible connection between Cretaceous *Globigerina* (s. l.) and certain Trochamminidae on one hand and certain monolamellids (e. g. *Valvulineria*) on the other, the relationship between Cretaceous and Tertiary globigerinids, as well as that between Cretaceous and Tertiary globorotaliids, the relationship between such forms as *Pseudovalvulineria lorneiana* (Gandolfi) (*non* d'Orbigny) and Cretaceous globigerinids, etc.) before it will be possible to answer the many questions involved.

From the Globorotaliidae, emend., we exclude for the time being such genera as *Sherbornina*, *Cycloloculina*, all Cymbaloporidae, as well as the genus *Globorotalites* Brotzen (having two apertures, see also Gandolfi, 1955b). The position of *Globoquadrina* Finlay, having a toothed aperture, is doubtful.

Subfamily GLOBOROTALIINAE nov. subfam.

Description.—Trochospiral, partly or entirely, but always single-keeled, globorotaliids; keels peripheral ("spiral") with septal (sutural) branches present on the dorsal (spiral) side only; aperture single in most genera, fringed by a thickened "rim", in interiomarginal or interiomarginal-umbilical position; secondary apertures in sutural position on the dorsal side of the test present in one genus; apertural lips greatly reduced, mostly absent, never forming umbilical cover-plates; canal-system carinal and septal-peristomal. Paleocene to Recent. Pelagic.

Remarks.—To the Globorotaliinae, nov. subfam., belong the genera *Globorotalia* Cushman, *Truncorotalia* Cushman and Bermudez, *Truncorotaloides* Bronnemann, *Turborotalia* Cushman and Bermudez and some new genera to be described elsewhere. The origin of the Globorotaliinae needs further study. For various groupings of the Globorotaliinae, as well as of the Globorotaliidae, emend., the reader is referred to the publications by Bermudez, Brotzen, Cushman, Gallo-way, Glaessner, Sigal (in Piveteau), etc.

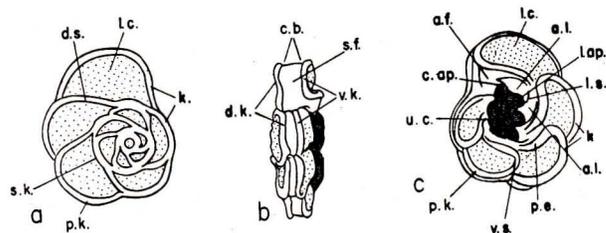
Subfamily GLOBOTRUNCANINAE Brotzen, 1942, emend.

Amended description.—Mostly trochospiral, rarely

planispiral, partly- or entirely-keeled globorotaliids; keels undifferentiated (broad) (see below), double, single or single and dichotomic; peripheral ("spiral") with septal (sutural) branches on both dorsal (spiral) and ventral (umbilical) sides, mostly with periumbilical extensions on the ventral side at least on earlier chambers; peripheral margin of keeled chambers imperforate, provided with an undifferentiated (broad) keel or with a single keel, or bordered by the branches of a dichotomous keel or by two keels ("carinal band"); adult chambers often devoid of keels; primary aperture large, rounded, single, in interiomarginal-umbilical or in umbilical position, in one genus accompanied by an accessory cameral aperture in sutural position on the ventral side of adult chambers; apertural lips strongly developed, forming "labial apertures" (see below); lips U-shaped in section and arched towards the umbilical cavity, slightly to strongly arched lengthwise; lips covering partly or entirely the umbilical cavity (umbilical plates); canal-system carinal and septal-peristomal. (Late Aptian?), Albian to Maestrichtian. Probably pelagic.

Remarks.—To the Globotruncaninae, emend., belong the genera: *Ticinella* Reichel, *Thalmanninella* Sigal, *Rotalipora* Brotzen, *Planomalina* Loeblich and Tappan, *Praeglobotruncana* Bermudez, *Globotruncana* Cushman, as well as the new genera *Globotruncanita*, *Globotruncanella* and probably *Helvetoglobotruncana*. They form in part the subfamily Globotruncaninae Bermudez, 1952.

The origin of the Globotruncaninae is subject to discussion (see also above). Some authors believe them to have evolved from *Globigerina* (s. l.), either ortho- or proterogenetically, others believe them to have evolved from *Pseudovalvulineria*. Still others believe that the Globotruncaninae have evolved repeatedly towards *Globigerina* (s. l.) and *Rugoglobigerina* and have produced different species of the lat-



TEXT FIGURE 4

Explanation of terms used in the present paper in the description of Globotruncaninae on a drawing of *Globotruncana*. a. dorsal view. b. profile view. c. ventral view. l.c. - lateral chamber-wall; k. - keel; p.k. - peripheral keel; s.k. - "spiral" keel; d.s. - dorso-septal (-sutural) branch of keel; d.k. - dorsal keel; c.b. - carinal band; v.k. - ventral keel; s.f. - septal face; a.f. - apertural face; a.l. - apertural lip; l.ap. - labial aperture; c.ap. - cameral aperture; l.s. - labial suture; p.e. - periumbilical extension of keel; v.s. - ventro-septal (-sutural) branch of keel; u.c. - umbilical cavity.

ter genera by mutation, conditioned by ecological factors (adaptation, preadaptation). A polyphyletic origin of the Globotruncaninae has been advocated by some authors (reference is made to the publications listed at the end of the present paper, especially to those by Bolli, Brotzen, Cita, Gandolfi, Hagn and Zeil, Reichel, Sigal, and Thalmann). As pointed out above, further study is needed to approach a solution of the many problems involved. Little attention has been paid up to the present to the concept of "plexus" in the sense of Sigal (1952c). The existence of such "plexus"-groups, as well as phenomena of convergence might greatly hamper the drawing of final conclusions.

In this writer's opinion the Globotruncaninae have evolved from such forms as *Pseudovalvulineria lornei-ana* (Gandolfi) (*non* d'Orbigny) in two main branches: one leading by way of *Ticinella* towards *Thalmaninella*, *Rotalipora* and *Planomalina*; the other evolving, either directly or by way of a *Globigerina*-like form (compare Reichel, 1949), towards *Praeglobotruncana* and leading to *Globotruncanella* on one hand and to *Globotruncana* and *Globotruncanita* on the other. *Helvetoglobotruncana* has evolved from a *Globigerina* (s. l.), which in turn might have evolved from a *Pseudovalvulineria* (s. l.)-stock. The position and origin of certain forms, morphologically intermediate between *Globotruncana* and *Globigerina* (s. l.) or *Rugoglobigerina*, will be discussed below.

In the following paragraphs certain structural and morphological details of the Globotruncaninae, emend., are discussed.

Wall-structure

With regard to the wall-structure of the Globotruncaninae there is little which may be added to the general description of that of the Bilamellidea in general and of the Globorotaliidae in particular. The most important structural features of some genera of the Globotruncaninae have been described already by Reichel (1949). He pointed out the presence of two calcareous layers in the septa and in the apertural lips, as well as in the chamber walls, and stated that earlier chambers show more than two layers in the wall, forming a parallelly striated, thickened zone ("zone d'épaississement"); the perforate and imperforate parts of the test; the presence of canals in the keels, in the septa and in the peristome. These observations agree fully with the bilamellid structure of the Globotruncaninae. Published photographs and careful drawings of sections of certain Globotruncaninae illustrate the structural features of this subfamily (see publications listed at the end of this paper and especially those by Bolli, Hagn and Zeil, Ksiazkiewicz, deLapparent, Renz, Reichel).

Keels and Carinal Band

(See text figs. 5 a-k).

The keels of all Globotruncaninae (and of the Globorotaliidae in general) are formed by the outward bending of the outer lamella which leaves an enlarged space between the latter and the inner lining, forming a canal. Very slight bending will result in not more than a hardly distinguishable sharpening of the peripheral chamber-margin. Strong bending will result in a hemicylindrically shaped (in section), elongated marginal protuberance. The portion of the outer lamella forming the keel is imperforate (except for scattered canal-communications) and so is the corresponding part of the inner lining. The chamber-wall near and along the keel is imperforate and so is the area comprised between two keels or between the branches of a single, but dichotomic keel. This imperforate area is the "carinal band." Hofker (1954) calls the carinal band the "poreless margin of the test" and regards the double keels as being actually a single keel with two rims bordering the poreless margin. We believe, however, that the form and number of keels are of taxonomical and systematical importance and that the canaliculate keels of the Globotruncaninae (and of the Globorotaliidae in general) must be sharply distinguished from the poreless, thickened margin of various bilamellids, in which these thickened "keels" are non-caliculate. Communication between the carinal canals and the main protoplasmic mass is maintained by the scattered "pores" which open either through the outer lamella or through the inner lining or through both. The beaded, spinose or fimbriated form of globorotaliid keels might be connected with these communications. Although keels of Globotruncaninae are present mostly in those areas of the chamber-wall which bend more or less sharply or show a tendency to, they are present on segments of nearly spherical parts of the test. In some Tertiary globorotaliids (e. g. *Globorotalia*, *Truncorotalia*) sharply bending wall-regions do not form keels at all, those being replaced by some kind of pillars. It seems, therefore, that keel-formation in the Globorotaliidae is connected both with strengthening weak (bending) chamber-wall regions and with the canal-system.

Whereas, as pointed out above, the Globorotaliinae have only peripheral keels with septal branches on the dorsal side, the Globotruncaninae have various kinds of keels and exhibit a variable development of the carinal band.

The only genus of the Globotruncaninae devoid of a definite keel or carinal band, *Ticinella*, shows a weakening of the pores in the peripheral region of the chambers and enlarged spaces between outer lamella and inner lining in this region. These features repre-

sent the most primitive type of Globotruncaninae-keel and *Ticinella* is regarded as the most primitive member of the Globotruncaninae. The incipient keel of *Ticinella* evolves towards that of *Thalmaninella*.

In *Thalmaninella* the keel is already well-developed, at least in earlier chambers in geologically older forms and in all chambers in geologically younger ones. The chamber-wall bends more or less sharply at the periphery, recurving slightly and forming a hemicylindrically shaped, single keel. The peripheral keel merges into a septal extension (the "sutural" keel in earlier chambers) on the dorsal side. On earlier chambers in geologically older forms and in all chambers in geologically younger ones of *Thalmaninella*, branches of the peripheral keel are formed which bend away from the latter at its junction with the dorso-septal branch, fringing the septal face of the chambers on the ventral side. These form a ventro-septal branch and continue backwards above the umbilical part of the apertural area, along the bending of the chamber-wall towards the umbilicus, forming a "periumbilical extension." The branching of the peripheral keel — or dichotomy — takes place always in the region where lateral chamber-walls meet the septal face.

In the genus *Rotalipora* the keels are like those in geologically younger *Thalmaninella*. In both genera the keels and their branches are stronger in earlier chambers than in later ones. This is also more apparent because of "secondary thickening," i. e. superposition and adjustment to form of lamellae in earlier chambers. This is true of all other genera of the Globotruncaninae as well.

Thalmaninella and *Rotalipora* have, therefore, a single keel, which splits into branches and is thus "dichotomic." The dichotomization takes place at the junction of the septal face with the lateral chamber-walls.

The genus *Planomalina* shows the same kind of a single, dichotomic keel. For this and other reasons to be discussed below, *Planomalina* is placed in the Globotruncaninae, in the same group as *Thalmaninella* and *Rotalipora*. All these genera are distally-dichotomic, single-keeled.

The genus *Praeglobotruncana* presents a different type of keel, incorrectly called a "single" keel (compare, however, Mornod, 1949, and Reichel, 1949). It is formed by a rather broad arching of the outer lamella at the periphery of the chamber and has a distinct tendency to split into two parallel ones, without reaching, however, such a definite differentiation. The peculiarly broad, apparently "single" keel is covered by two rows of beads or spines (see Küpper, 1955, Mornod, 1949, Reichel, 1949). This broad peripheral keel splits into septal branches on the dorsal side and ventro-septal branches and periumbilical extensions

are present at least in earlier chambers, especially in geologically younger forms, although bad state of preservation or strong inflation and bulging of the chambers on the ventral side may hamper their being easily visible. Adult chambers of *Praeglobotruncana*-species are mostly devoid of keels and have a more or less rounded periphery.

The type of keel found in *Praeglobotruncana* can be called "broad" or "undifferentiated." From this type of keel evolved apparently the double keel of *Globotruncana*, as well as that of *Globotruncanella*, gen. nov. (compare also Hagn and Zeil, 1954, and Reichel, 1949). The keel of *Globotruncanella*, gen. nov., is not much different from that of *Praeglobotruncana*, being rather broad, but it does not show a tendency to form two keels, while no ventro-septal branches are formed. The dichotomic keel of *Globotruncana* (?) *imbricata* Mornod (dichotomization proximal, not distal) originates apparently from a *Praeglobotruncana*-type of keel and represents an attempt to produce two keels by "accelerated," proximal dichotomization (see also Mornod, 1949). The absence of ventro-septal branches, the small umbilicus, the type of apertural lips, etc., point also to a derivation of *G. (?) imbricata* from *Praeglobotruncana*, an assumption supported by the latter's stratigraphical position (compare also Hagn and Zeil, 1954, Mornod, 1949, and Reichel, 1949).

The complete splitting into two parallel keels of an undifferentiated *Praeglobotruncana*-type of keel is achieved in *Globotruncana* (the imperforate marginal area bordered by the two keels is the carinal band or "bandeau carenal" of French authors). To distinguish between the two keels of *Globotruncana*, we shall call them "dorsal" and "ventral" in accordance with dorsal and ventral sides respectively (to avoid confusion, the terms "dorsal" and "ventral" instead of "spiral" and "umbilical" are used here). In earlier forms of *Globotruncana* the ventral keel is usually weaker than the dorsal one and might be discernible only in earlier chambers, being still united with the dorsal keel in adult chambers. Septal (sutural) branches on the dorsal side are formed by the dorsal keel, ventro-septal (-sutural) ones by the ventral keel. This is also true of those chambers in which both keels are still united and not differentiated into two (keel differentiation seems to start mostly on earlier chambers progressing towards later chambers during phylogeny); ventro-septal branches are always present and the single keel of later chambers of such "partly double-keeled" early (Cenomanian-Coniacian (Santonian?)) forms of *Globotruncana* is usually fairly thick and distally dichotomous (e. g. *G. renzi* Thalman, *G. sigali* Reichel, *G. schneegansi* Sigal).

A second type of *Globotruncana*-keel is the fully

and equally developed "double" one, found in many Turonian-Maestrichtian species of *Globotruncana* (e.g. *G. lapparenti* group, etc.). Both dorsal and ventral keels are equally strong or nearly so and present on all chambers; septal branches are present on both sides in all chambers, as well as periumbilical extensions. Ventro-septal and periumbilical extensions might be difficult to see because of inflation or bulging of the chambers ("depressed sutures," but nevertheless "raised" because of ventro-septal (-sutural) branches).

A third type of *Globotruncana*-keel apparently must be distinguished. It is in principle very similar to that mentioned above as the first type: double in earlier chambers, single and branching in adult ones. The derivation of the third type of keel seems, however, not to be from an undifferentiated keel with a tendency to split into two equally strong keels, but from a well-differentiated double keel, dorsal and ventral, with a tendency to approach and finally to coalesce in the late adult chambers into a single keel (e.g. *G. wiedenmayeri* Gandolfi group, *G. gagnebini* Tilev). From this last type of keel the one found in *Globotruncanita*, gen. nov., is derived.

The keel of *Globotruncanita* is single both in early and adult chambers, distally dichotomic and forming septal branches on both dorsal and ventral sides, as well as periumbilical extensions in all chambers. Its derivation is different from that of the keel of *Thalmaninella* or *Rotalipora*, which originates from a broadly rounded, incipient one (*Ticinella*).

A different type of single keel is present in *Helvetoglobotruncana*, gen. nov. It is dorsal, not necessarily peripheral, with septal branches on the dorsal side only, never dichotomic. Canal weak.

The last type of keel to be mentioned here is that found in certain "globigerinid" species of *Globotruncana* (see below). Although double and bordering an imperforate carinal band, as in *Globotruncana* with two keels equally developed, it is often extremely weak and hardly distinguishable and moreover formed by rows of pustules more or less regularly arranged along two parallel lines, forming "interrupted" keels. The genesis of this type of keel needs further study.

Apertural Lips and Labial Apertures

(See text figs. 6-7)

The apertural (or "umbilical") lips are strongly developed in all members of the Globotruncaninae. They may be free on three sides or they may be fused partly or entirely, in the latter case forming "umbilical cover-plates." This fusion may be such as to leave openings between consecutive lips, often referred to as "accessory apertures" or "intraumbilical apertures." Any opening formed by the free parts of the apertural lips will be called herein "labial aperture" and repre-

sents a passage way for the protoplasmic mass to pass from the main aperture of the respective chamber to the outside. Labial apertures are present in all Globotruncaninae and must be distinguished from main or accessory apertures formed by the chamber-wall and not by the lips. Only one genus of the Globotruncaninae has true, cameral, accessory apertures: *Rotalipora*. The so-called accessory apertures of other genera of the Globotruncaninae are actually labial apertures. The term "cameral aperture" is used herein instead of "septal aperture" (Brotzen *et al.*) for the main chamber-opening; a cameral aperture might be quite removed from the actual septum. Additional openings of the chambers not formed by lips will be called "accessory cameral apertures."

The apertural lips are U-shaped in section, arched towards the umbilical cavity to a smaller or greater degree. They may be nearly flat or arched lengthwise, sometimes strongly so and becoming hemicylindrical in form. The forms of lips are manifold and so are the forms of the labial apertures; both are important in classification. Apertural lips have been described under various names (see Reichel, 1949, pp. 598-599); we prefer to call them "apertural lips" since they are covering part of the main cameral aperture and since they form, themselves, various kinds of apertures.

The first type of apertural lips found in the Globotruncaninae (and the most primitive one, being found also in the ancestors of the Globotruncaninae) is that where the lips are not fused one with the other, being, therefore, free on three sides. The lips are fairly flat, although U-shaped in section, not arched lengthwise or only slightly so. Proximal and distal sides (in direction of coiling) are nearly equal in length. They leave passage-ways for the protoplasm directed forwards, backwards and towards the umbilicus-centre. These might be termed "interiomarginal-umbilical-sutural" labial apertures. This type is found in the earlier chambers of *Ticinella*, in *Planomalina* and in the early Cretaceous *Pseudovalvulineria*.

By partly fusing one with the other in "sutural" (with regard to two consecutive lips) position, as well as by several or all lips fusing together in the central area of the umbilical cavity, the lips form a second type of labial aperture: "interiomarginal and sutural." A "pierced" umbilical cover-plate is thus formed. The lips are relatively long, both sides being of nearly equal length. Such lips and labial apertures are found in *Ticinella*, *Thalmaninella*, as well as in primitive species of *Rotalipora*. More evolved *Rotalipora* have only "interiomarginal" labial apertures.

A further type of labial aperture is found in the genera *Praeglobotruncana* and *Globotruncanella*, gen. nov. The lips are relatively longer in the latter, both sides being nearly equal in length, the distal side tend-

ing to be somewhat longer. They are slightly arched lengthwise and fused in sutural position. Their umbilical tips are broadly rounded or truncated, not fused. The labial apertures thus formed may be termed "interiomarginal-umbilical."

From such lips and labial apertures have apparently developed those found in early "partly double-keeled" *Globotruncana*. The lengthwise arching of the lips increases, the distal side is conspicuously longer than the proximal one, the lips remaining fairly long. Fused in sutural position, the lips form "interiomarginal-umbilical" labial apertures. The interiomarginal part of the latter is greatly reduced (main cameral aperture moving into an almost umbilical position) and the umbilical part points backwards (through differences in length between distal and proximal sides of the lip). This type of lips and labial aperture has been well-figured and described by Reichel (1949) in *Globotruncana sigali*.

The lips of double-keeled (throughout) *Globotruncana* are very similar to the last described type, but much more arched lengthwise and more enlarged towards the umbilical cavity. The interiomarginal part of the labial aperture is almost entirely absent (main aperture being in completely umbilical position) and there remains only an "umbilical" labial aperture, directed backwards with regard to the direction of growth.

From this latter type apparently evolves one found in later "partly double-keeled" *Globotruncana* and in *Globotruncanita*, gen. nov. The lips are shortened on the proximal side and long on the distal one. They are extremely highly arched lengthwise, narrow at the junction with the chamber-wall and greatly enlarged at their umbilical extremities, forming arches or "arcades" (Reichel, 1949), becoming trumpet-shaped and overriding each other ("cornets" of Reichel, 1949). The labial apertures are pointing strongly backwards and "umbilical" in position. Reichel (*op. cit.*) has pointed out already the resemblance of this type of opening formed by lips with that of *Thalmaninella*, the genesis being, however, different in both cases. A further development of the trumpet-shaped lips mentioned above is that described by Reichel (*op. cit.*) in *Globotruncana* aff. *G. conica* (White). Strongly backward and finally recurving and outward bending of the lips (towards the periphery) results in labial apertures pointing towards the peripheral margin and in "suprasutural" position. Fusion of the lips is strongly developed, resulting in the formation of an umbilical cover-plate, covering the umbilicus entirely. This last type is found in certain later species of *Globotruncana*

(partly-keeled) and *Globotruncanita* (e. g. *G. conica*).

The type of development of lips and labial apertures found in *Helvetoglobotruncana*, gen. nov., as well as in certain Cretaceous species of *Globigerina* (s.l.) is that in which the lips are slightly arched lengthwise, fairly large and partly covering each other in consecutive chambers, free on three sides. Certain Cretaceous species of *Globigerina* (s.l.), as well as *Rugoglobigerina*, show a variant of this type of lips, viz. fusion in an irregular manner, connected with the formation of umbilical cover-plates with irregularly arranged labial apertures. The same type is found in certain "globigerinid" species of *Globotruncana* (see below).

The Genera of the Globotruncaninae

There follow brief redefinitions of the already described genera of the Globotruncaninae and descriptions of three new genera. The question whether a group of species should be regarded as forming a genus or a subgenus is difficult to answer, especially when fossil forms are involved. In any case it seems inadequate to regard all Globotruncaninae (the "Roselines" of French authors) as subgenera of *Globotruncana* (s.l.). On the other hand *Ticinella*, *Thalmaninella*, *Rotalipora* and *Planomalina* might be regarded as subgenera of one and the same genus; *Globotruncanella*, gen. nov., and *Praeglobotruncana* as subgenera of *Praeglobotruncana* (both have been included apparently in the invalid genus *Rotundina* Subbotina, see Küpper, 1955, 1956); *Globotruncanita*, gen. nov., as a subgenus of *Globotruncana* s. s.; or all last mentioned four genera might be regarded as subgenera of one genus. *Helvetoglobotruncana*, gen. nov., must be separated. From a practical point of view this question is, however, immaterial and the application of subgeneric names for the various forms herein regarded as genera will not lessen the number of names on the supraspecific and infrafamilial level.

For reasons to be discussed below the genus *Rugoglobigerina* Bronnimann and its allies have not been included for the time being in the Globotruncaninae, as proposed by Gandolfi (1955a), who regards the latter genus and its allies as a subgenus of *Globotruncana*. The same is true of *Tritinella* Bronnimann, although it is morphologically somewhat similar to *Globotruncanita*. No specimens of *Tritinella* have been available to this writer and it seems that the latter belongs rather to the family (?) Globigerinidae, having flattened chambers (and, therefore, an acute or subacute periphery) in the very last ontogenetic stages only and not in the earlier stages as in all other genera included here in the Globotruncaninae.

Superfamily BILAMELLIDEA, nov.

Family GLOBOROTALIIDAE Cushman,
1927, emend.Subfamily GLOBOTRUNCANINAE Brotzen,
1942, emend.Genus *Ticinella* Reichel, 1949Type-species: *Anomalina roberti* Gandolfi, 1942

Amended description.—Test trochospiral; chambers globular; keels and carinal band incipient on earlier chambers; cameral aperture single, interiomarginal-umbilical; labial apertures interiomarginal and sutural; lips partly fused forming an umbilical cover-plate. (Late Aptian?), Albian to lower Cenomanian.

Genus *Thalmaninella* Sigal, 1948Type-species: *Thalmaninella brotzeni* Sigal, 1948

Amended description.—Test flatly trochospiral; chambers flattened to subglobular; partly or entirely keeled; keel single, peripheral, with dorso-septal branches and distally dichotomic, forming ventro-septal branches and periumbilical extensions at least in earlier chambers; cameral aperture single, interiomarginal-umbilical; labial apertures interiomarginal and sutural; lips long, slightly arched lengthwise, if at all, fused and covering the umbilical cavity with an umbilical cover-plate. Upper Albian to upper Cenomanian.

Genus *Planomalina* Loeblich and Tappan, 1946Type-species: *Planomalina apsidostroba* Loeblich
and Tappan, 1946

Amended description.—Test flat, planispiral throughout; biumbilicate; partly or entirely keeled; keel peripheral, distally dichotomic, forming septal branches on both sides of the test at least in earlier chambers; cameral aperture symmetrical, interiomarginal-umbilical; labial apertures interiomarginal-umbilical-sutural; apertural lips slightly, if at all, arched lengthwise; umbilici partly covered by the lips on both sides. (Late Aptian?), Albian to lower Cenomanian.

Remarks.—This genus is usually placed in the Anomalinidae together with *Planulina*. The well-differentiated lips, the canaliculate, dichotomic keel and the relatively deep umbilici point clearly to its relationship to the Globotruncaninae, as herein redefined (compare also Reichel, 1949, p. 616). It is probably related to *Thalmaninella*, possibly in the same way as *Globigerinella* is related to *Globigerina*. Its occurrence in large numbers with other genera, usually regarded as pelagic, points to a pelagic habitat. Geologically older species of *Planomalina* have the later chambers devoid of keels, geologically younger ones are keeled throughout.

Genus *Rotalipora* Brotzen, 1942Type-species: *Rotalipora turonica* Brotzen, 1942

Amended description.—Test flatly to highly trochospiral; chambers flat or inflated; often elongated towards the umbilicus; peripheral margin always acute; single-keeled throughout; keel peripheral, distally dichotomic, forming dorso-septal and ventro-septal branches, as well as periumbilical extensions; cameral aperture interiomarginal-umbilical, accompanied by an accessory cameral aperture in sutural position at least in adult chambers; labial apertures interiomarginal and sutural in all chambers or in early chambers only, later chambers being provided with an interiomarginal labial aperture only, the proximal side of the lip being fused with the previous lip entirely; lips slightly, if at all, arched lengthwise; fused and forming an umbilical cover-plate. Cenomanian to Turonian.

Remarks.—In well-preserved specimens of *Rotalipora* a ventro-septal keel-branch can always be observed, at least in earlier chambers (compare Reichel, 1949, p. 604). Transition-forms between *Thalmaninella*- and *Rotalipora*- types of labial apertures are frequent (see text figs. 6 d-e).

Genus *Praeglobotruncana* Bermudez, 1952Type-species: *Globorotalia delrioensis* Plummer, 1931

Amended description.—Test flatly to highly trochospiral; chambers flat, slightly or strongly inflated to subglobular, always more rounded in adult stages; broadly, undifferentiatedly keeled; keel showing tendencies to split into a double one, weak or absent in adult chambers, pustulose or spinose, peripheral and dorso-septal with ventro-septal and partly periumbilical extensions at least in earlier chambers of geologically younger forms; cameral aperture single, interiomarginal-umbilical; labial apertures interiomarginal-umbilical; lips, relatively short, slightly, if at all, arched lengthwise, covering partly the umbilical cavity. Lower Cretaceous to Turonian.

Remarks.—There is general agreement among authors that the genus *Globotruncana* s. s. evolved from *Globotruncana stephani* Gandolfi, which is actually a *Praeglobotruncana* (see also Küpper, 1956). The ancestor of *Praeglobotruncana* might be a *Pseudovalvulineria* (s. l.), a *Ticinella* or — as suggested by Reichel (1949) — a *Globigerina*-like form related to the group of *Pseudovalvulineria lorneiana*.

Genus *Globotruncanella*, gen. nov.Type-species: *Globotruncana citae* Bolli, 1951

Description.—Test flatly trochospiral; chambers flat, slightly inflated; peripheral margin subacute to acute, imperforate, provided with an undifferentiated keel; keel pustulose to spinose, never showing tendencies to

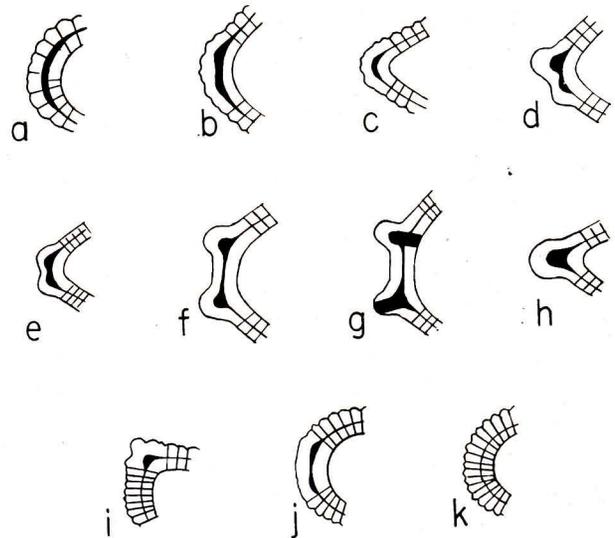
split into two keels, forming dorso-septal branches only, which are usually weak; ventro-septal branches and periumbilical extensions absent; cameral aperture interiomarginal-umbilical; lips fairly long, slightly arched lengthwise, covering partly the small umbilicus. Cenomanian to Maestrichtian.

Remarks.—*Globotruncanella*, gen. nov. differs from *Praeglobotruncana* to which it is closely related, by its less broad, but “undifferentiated” keel, which shows no tendencies to split into a double keel, by the absence of ventro-septal keel-branches and by the peripheral margin in adult chambers which is hardly more rounded than in earlier chambers (as is typical for *Praeglobotruncana*) as well as by its larger and longer lips, which are more arched lengthwise than those of the latter genus. Various, hitherto undescribed species of *Globotruncanella* have been observed by this writer in material from Africa and Europe, of Cenomanian to Senonian age. *Rugoglobigerina petaloidea petaloidea* and *R. petaloidea subpetaloidea* as described by Gandolfi (1955a) are apparently species of the genus *Globotruncanella*. This seems to be true also of certain species described as *Globigerina* (e. g. by Sigal, 1952b, compare Küpper, 1956; *Globigerina aumalensis* Sigal is, however, rather a *Globotruncanella* than a *Praeglobotruncana*). The section of a supposed globigerinid published by Renz (1936, pl. 6, fig. 14) might be that of either a *Praeglobotruncana* or a *Globotruncanella*. The transition from *Globotruncana intermedia* Bolli to *Globotruncanella citae*, assumed by Bolli, needs further study. A possible relationship between *Globotruncanella* and such Tertiary forms as *Globigerina* (?) *compressa* Plummer needs careful study.

Genus *Globotruncana* Cushman, 1927

Type-species: *Pulvinulina arca* Cushman, 1927

Amended description.—Test flatly to highly trochospiral; chambers flat to subspherical, elongated, sub-elliptical to polygonal in outline; partly or entirely double-keeled; keels peripheral with dorsal-septal and ventro-septal branches from the dorsal and from the ventral keels respectively, with periumbilical extensions; dorsal and ventral keels separated and well-differentiated at least in earlier chambers, approaching and coalescing in some forms in later chambers, forming one distally dichotomic keel with dorso-septal and ventro-septal branches; cameral aperture single, in umbilical position; labial apertures umbilical, pointing backwards, often strongly so; lips fairly large, distinctly to very strongly arched lengthwise, shorter on the proximal side than the distal one, narrower at the junction with the chamber-wall of the corresponding chamber, irregularly half-cylindrically shaped to trumpet-shaped in form; umbilicus large, partly or entirely covered



TEXT FIGURE 5

Schematic drawings of sections through various types of peripheral margins and keels. a. *Ticinella*, *Thalmaninella*. b. *Praeglobotruncana*. c. *Globotruncanella*. d. *Globotruncana* (gr. 1 and 3). e. *Globotruncana* (gr. 1 and 3). f. g. *Globotruncana* (gr. 2) (g. showing communications of canal-system). h. *Thalmaninella*, *Rotalipora*, *Globotruncana* (gr. 1 and 3), *Globotruncanita*. i. *Helvetoglobotruncana*. j. “Globigerinid” *Globotruncana*. k. *Globigerina*, s.l., *Ticinella*, “globigerinid” *Globotruncana*. Depending upon the point of section *Planomalina* shows keel-sections of type e, f, or h.

by the lips, which form in some species an umbilical cover-plate. Upper Cenomanian to Maestrichtian.

Remarks.—Three groups of *Globotruncana* could be distinguished:

1. Partly double-keeled forms which evolve from undifferentiatedly-keeled ones, with rather long lips, which are slightly arched lengthwise (e. g. *G. sigali* Reichel).

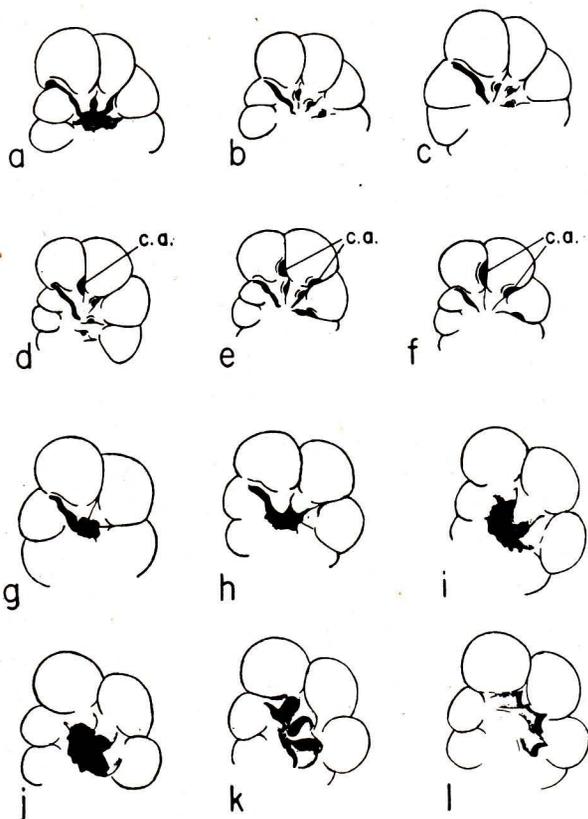
2. Double-keeled (throughout) forms, which evolved from the partly double-keeled ones mentioned above; lips more strongly arched, labial apertures pointing more strongly backwards (e. g. *G. arca* (Cushman), *G. lapparenti* Brotzen group).

3. Partly double-keeled forms which evolved from entirely double-keeled ones by approach and coalescence of the two keels in later chambers. Lips highly arched to trumpet-shaped, often very large, labial apertures pointing strongly backwards (e. g. *G. wiedenmayeri* Gandolfi group, *G. cretacea* Cushman). (*G. cretacea* apparently has been often confused with such forms as *G. sigali*). It is from this third group that *Globotruncanita*, gen. nov., evolved.

Genus *Globotruncanita*, gen. nov.

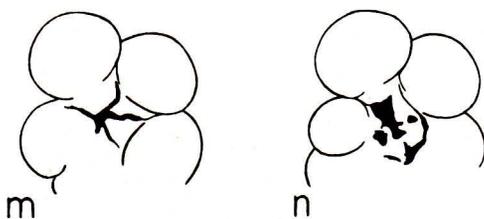
Type-species: *Rosalina stuarti* de Lapparent, 1918

Description.—Test highly trochospiral; chamber form variable, mostly polygonal in outline; single-



TEXT FIGURE 6

Various types of labial apertures. (Chamber-form simplified and not corresponding to the actual one of the respective genera). c.a. - cameral aperture. a. *Pseudovalvulinaria*, *Planomalina*. b. *Ticinella*. c. *Thalmaninella*. d. *Rotalipora* (transition from *Thalmaninella*- to *Rotalipora*-type). e. *Rotalipora* (combined *Thalmaninella*-*Rotalipora*-type). f. *Rotalipora*. g. *Praeglobotruncana*. h. *Globotruncanella*. i. *Globotruncana* gr. 1. j. *Globotruncana* gr. 2. k. *Globotruncana* gr. 3, *Globotruncanita*. l. *Globotruncanita*.



TEXT FIGURE 7

Types of labial apertures (continued). m. *Globigerina*, s.l. (Cretaceous forms), *Helvetoglobotruncana*. n. *Globigerina*, s.l. (Cretaceous forms), *Rugoglobigerina*, "globigerinid" *Globotruncana*.

keeled throughout; keel present on all chambers (except the earliest ones), distally dichotomic with dorso-septal and ventro-septal as well as periumbilical extensions; spine-shaped extensions of the chambers present in some forms; cameral aperture umbilical, single; labial aperture pointing strongly backwards, in reflexed position opening into the umbilical cavity or suprasuturally towards the periphery; lips much longer on the distal side than on the proximal one, extremely

highly arched, much narrower at the junction with the corresponding chamber and trumpet-shaped, overriding each other or fusing the strongly recurring distal ends and forming an umbilical cover-plate covering entirely the umbilical cavity with labial apertures opening towards the periphery; umbilicus large, partly or entirely covered by the apertural lips. Late Santonian to Maestrichtian.

Remarks.—*Globotruncanita*, gen. nov., resembles somewhat *Truncorotalia* Cushman and Bermudez, but differs from the latter in many respects. There is apparently no connection between these genera (*Truncorotalia* appears in the Paleocene) and they have been often confused. It has been emphasized by various authors that the *stuarti*-group is very distinct from other "Globotruncanas," as far as chamber-form, keels and apertural characters are concerned (see among others Reichel, 1949, Gandolfi, 1955a). To *Globotruncanita* belong many species, e. g. *G. elevata* (Brotzen), *G. stuartiformis* (Dalbiez), *G. calcarata* (Cushman), *G. conica* (White), etc. The single-keeled *Globotruncana helvetica* Bolli, which resembles *Globotruncanita*, shows, however, distinctive features and is included in a new genus, *Helvetoglobotruncana*.

Genus *Helvetoglobotruncana*, gen. nov.

Type-species: *Globotruncana helvetica* Bolli, 1945

Description.—Test flatly trochospiral; chambers globular, slightly to strongly flattened on the dorsal side; keel dorsal, not necessarily peripheral (subperipheral keel) at the margin of the flattened part of the chamber-wall with dorso-septal branches and never dichotomic; keels granular to subspinose; cameral aperture umbilical, extending slightly into a partly interiomarginal position; labial apertures interiomarginal-umbilical-sutural (latter part often reduced through partial fusion of the lips); lips very slightly, if at all arched lengthwise, covering partly the umbilical cavity. Upper Cenomanian to lower Coniacian.

Remarks.—The systematic position of *Helvetoglobotruncana helvetica* has been regarded by various authors as uncertain (see also Bolli, 1945) and it has been repeatedly emphasized by many of them (Bolli, 1945, Schijfsma, 1955, Sigal, 1955b, etc.) that transitions between a *Globigerina* and this form can be observed. Schijfsma and Sigal (*op. cit.*) stated that *Globotruncana helvetica* is derived from a *Globigerina*. This writer's observations fully support the above-mentioned authors' conclusions. *Helvetoglobotruncana helvetica* evolves gradually from a certain, apparently as yet undescribed *Globigerina* (s.l.) ("grandes Globigerines" of Sigal, 1955b, figured by Schijfsma, 1955), which appears in the Cenomanian and is most abundant in later Cenomanian and Turonian strata (prae-

cursors already occur in the Vraconian). It exists together with *H. helvetica* up to the early Coniacian. The presence of a keel in the latter form is the only difference between it and the mentioned *Globigerina* (s.l.). The resemblance of *H. helvetica* to *Globotruncana gansseri* Bolli (= *G. lugeoni* Tilev) is only slight: the latter has a dichotomic peripheral keel, as well as lips and labial apertures characteristic of *Globotruncanita*. The chamber-form is also quite different.

As already pointed out above, the relationship between the Globigerinidae and the Globotruncaninae needs further study, the results of which will show whether or not *Helvetoglobotruncana* should be placed in the Globotruncaninae.

The "Globigerinid" *Globotruncana*

Under this name is included a group of Cretaceous forms which shows the attributes of the Cretaceous species of *Globigerina* (s.l.) and *Rugoglobigerina* (wall-structure, ornamentation, apertures, apertural lips, chamber-form, etc.), but differs from the latter by the presence of weak, incomplete, often interrupted or discontinuous keels or rows of papillae or pustules, arranged in two parallel lines [e.g. *Globotruncana* cf. *G. globigerinoides* Brotzen, as figured by Bolli (1951), various keeled forms described as *Rugoglobigerina* by Gandolfi (1955a), many of the forms recorded as *Globotruncana globigerinoides* Brotzen (including the holotype), etc.]. These Cretaceous forms have been treated in detail by Gandolfi (1955a). He regards some of these forms as transitions to *Rugoglobigerina* and others as belonging actually to the latter genus. It seems, however, that various questions in connection with this group are not yet satisfactorily answered and some of the problems involved will be briefly reviewed below. For this reason the genus *Rugoglobigerina*, as amended by Gandolfi (*op. cit.*) has not been included for the time being in the genus *Globotruncana*, as he proposed, or in the Globotruncaninae, as herein amended.

Gandolfi regards *Rugoglobigerina*, as amended by him, as forms which "are genetically related to *Globotruncana* but morphologically reminiscent of *Globigerina*" (*op. cit.* p. 15) or "as forms with a *Globigerina*-form and a *Globotruncana*-like umbilicus" (p. 87). *Rugoglobigerina* should be regarded, therefore, as a subgenus of *Globotruncana* (s.l.), (in the sense of Gandolfi, *op. cit.*, as well as in that of Reichel, 1949). According to Gandolfi the *Globigerina*-form is nothing but a form of adaptation to pelagic life, which develops in species and genera of quite different genetical relationship (convergence). The process of "globigerinization" is regarded by Gandolfi as conditioned by ecological factors and as having taken place repeatedly

during Cretaceous times in *Globotruncana*, s.s., as well as in *Rotalipora* and possibly also in *Ticinella* and *Thalmanninella*. According to the results of Gandolfi's study both double- and single-keeled species of *Globotruncana* have produced *Rugoglobigerina* (in the sense of Gandolfi). A derivation of *Globotruncana* from *Globigerina* (s.l.), assumed by various authors, is, therefore, regarded by him as highly improbable.

Reichel (1949) pointed out that certain species of *Globotruncana* show a great resemblance to *Globigerina*, possibly a phenomenon of convergence. The tendency to globular chambers is present in various groups of *Globotruncana*, especially in that of *G. marginata*, of which *G. globigerinoides* Brotzen would be the end-form, viz. a "globigerinized" *Globotruncana* with keels which tend to disappear. A *Globigerina*-*Globotruncana* lineage seems doubtful also to Reichel (compare also Hagn and Zeil, 1954), since the true *Globigerina* is an evolved form, adapted to full pelagic life and tending towards a perfectly spherical form, *Orbulina*. Reichel admits, however, the possibility of the *stephani-linnei* lineage having originated from a *Globigerina*-like form, belonging to the *Pseudovalvulineria*-group from which *Ticinella* evolved.

Due consideration must be paid, however, to several points before final conclusions are drawn both with regard to the origin of *Globigerina* (s.l.) and *Rugoglobigerina* on one hand and of *Globotruncana* and its allies on the other.

In the first place it is highly questionable, as pointed out by various authors (see also Reiss, 1955), whether the Cretaceous forms traditionally placed in *Globigerina* actually belong to this latter genus: ornamentation, apertural lips, pore-size, etc. of Cretaceous forms distinguish them clearly from Tertiary species of *Globigerina*. The Cretaceous species of "*Globigerina*" apparently must be separated from the Tertiary ones and possibly split in several genera. They apparently belong to the same group to which *Rugoglobigerina* belongs. It seems, however, difficult to accept fully Gandolfi's emendation of this latter genus, for the following reasons:

In the paper in which Bronnimann described *Rugoglobigerina* (Bronnimann, 1952a) the author clearly stated that this genus differs from all other Upper Cretaceous and Tertiary species of *Globigerina* by its regular pattern of ornamentation — the "meridional pattern" of rugosities —, present at least in adult chambers. Furthermore, *Rugoglobigerina* has been defined as having rounded to subglobular (although truncated towards the umbilicus) chambers, without hantkeninoid spines (subgen. *Rugoglobigerina*) or provided with such spines (subgen. *Plummerita*). The genus *Trinitella*, showing ornamentational affinities with *Rugoglobigerina*, but flattened adult chambers,

has been distinguished by Bronnimann as a separate genus.

By including in *Rugoglobigerina* forms with or without the characteristic meridional ornamental pattern, forms with subglobular or flattened chambers with a rounded to acute periphery, forms without keels, as well as forms with one or two keels, the genus is rendered almost meaningless, its definition and separation from other genera, as *Globigerina* s. l. or *Globotruncana*, being extremely difficult if not impossible. *Plummerita*-forms would have to be relegated to specific level (*Rugoglobigerina* becoming a subgenus) and *Trinitella* would fall evidently in the scope of *Rugoglobigerina*. It is still not clear what actually is meant by a "*Globigerina*"-form (in the sense of Gandolfi). Furthermore the status of the subgenus *Rugoglobigerina* Bronnimann, emend. Gandolfi (*non* subgen. *Rugoglobigerina* Bronnimann) is not clear. If *Rugoglobigerina* is actually a phylogenetic subgenus of a morphogenic genus (in the sense of Tintant, 1952) there is no reason why keeled species of *Rugoglobigerina* (which according to Gandolfi evolve from *Globotruncana*, s. s.) should not be transferred to *Globotruncana*, while the unkeeled ones should be regarded as belonging to a morphogenic genus (which is polyphyletic), like *Globigerina*, s. l. or any other genus which would include, from a morphological point of view, all Cretaceous species of *Globigerina*, s. l. or *Rugoglobigerina*. On the other hand most of the species of *Rugoglobigerina* described by Gandolfi have a keeled subspecies and an unkeeled one, the latter being, according to Gandolfi, only an end-member of a certain *Globotruncana*-group. The separation of such a keeled subspecies of *Rugoglobigerina* from *Globotruncana* remains almost arbitrary.

If *Rugoglobigerina* is only an ecologically conditioned form of (various) *Globotruncana*, its separation as a subgenus (even morphogenic) might be questionable. Such a form would have at best subspecific value, receiving the species-name of the *Globotruncana* which produced it. On the other hand such ecologically conditioned forms (if thus conditioned) as species of *Rugoglobigerina* would be quite different from ecological "phases" (e. g. as in *Tretomphalus*). As pointed out by Gandolfi (1955a) the process of "globigerinization" must have taken place repeatedly throughout Cretaceous times in various species, species-groups and genera. That means that a certain species of *Globotruncana*, for example, has lived for a certain geological time-span as a benthonic organism and has developed afterwards an offshoot adapted to full pelagic life. The latter would have lived for a certain time-span together with the benthonic form, which, however, ultimately disappeared. This process has been repeated time and again, producing stratigraphical se-

quences of benthonic and pelagic forms (compare Gandolfi's plate 8) in all groups of *Globotruncana*. It seems, however, that this kind of repeated and phylogenetic evolution, explained by Gandolfi by ecological adaptation, needs further study, especially since certain groups of *Globotruncana* (e. g. the forms described herein as *Globotruncanita*) do not produce "globigerinids," as shown by Gandolfi himself.

Furthermore, several forms described by Gandolfi as *Rugoglobigerina* (in his sense) seem to belong actually to other genera and are, therefore, no proof for the process of "globigerinization" (*Rugoglobigerina petaloides* Gandolfi, for example, which according to him is closely related to *Globotruncana citae*, which in turn, however, is a *Globotruncanella*). *Praeglobotruncana* or *Globotruncana* are not derived from *Thalmaninella* as stated by Gandolfi (compare also Reichel, Sigal, *et al.*) and the inflated chambers of *Praeglobotruncana* are, therefore, no indication of a "globigerinization." On the contrary, *Praeglobotruncana* produces the flat and strongly keeled *Globotruncana* s. s. In the same way *Ticinella* produces the flat *Thalmaninella*. *Helvetoglobotruncana helvetica* is not connected with *Globotruncana* aff. *G. renzi*, as shown by Gandolfi, but has doubtless evolved from a *Globigerina* s. l. It has also not produced any "*Globigerina*" or *Rugoglobigerina* as assumed by him. *H. helvetica* is a convincing example of the existence of a process leading from a "*Globigerina*"- to a "*Globotruncana*"-form.

It has been pointed out by Brotzen (1936) that although *Globotruncana globigerinoides* resembles extremely globular-chambered forms of *G. ventricosa* (Brotzen, *non* White), no transition between them could be observed. On the other hand, according to Brotzen it is difficult to separate *G. globigerinoides* from *Globigerina cretacea*, as described and figured by the latter author. The only difference between them is, according to Brotzen, the presence of extremely faint keels in *G. globigerinoides*. Gandolfi, however, states that *G. globigerinoides* produced *Rugoglobigerina hexacamerata* Bronnimann. The present writer has examined various faunules containing "*Globigerina*" *cretacea* and found associated with it forms which differed only in the presence of extremely faint keels (often visible only after calcination and under high magnification) and which corresponded to Brotzen's original description and figures of *Globotruncana globigerinoides*. Size, form, wall-structure and ornamentation (irregular pustules or granules) are the same in both forms. No specimens which could be identified as *Rugoglobigerina hexacamerata* have been found associated with them. Both forms have thinner walls than the accompanying species of true *Globotruncana*. This is true of all Cretaceous keeled "globigerinids."

There is apparently no correlation between weak-

ness of keel and increase of ornamentation (compare also Gandolfi). Extremely faintly keeled, "globigerinid" species of *Globotruncana* have been shown to have a very strongly developed ornamentation of tubercles or pustules, while others, just as faintly keeled, have smooth walls.

There is much less difference between a keeled "*Globigerina*" or *Rugoglobigerina* (i. e. a "globigerinid" *Globotruncana*) and the accompanying species of *Globigerina* s. l. or *Rugoglobigerina*, than between such keeled forms and the accompanying species of *Globotruncana*, no matter how globular the latter's chambers are. It is noteworthy in this connection that Gandolfi sharply separated most keeled species of *Rugoglobigerina* from those of *Globotruncana* from which they are supposed to evolve and placed them as subspecies of *Rugoglobigerina* species.

Various Cretaceous *Globigerina*, s. l., species as well as all those of *Rugoglobigerina* show a strong development of apertural lips; this is in fact one of the main differences between the Cretaceous and Tertiary globigerinids. On the other hand the lips of Cretaceous globigerinids and of the "globigerinid" species of *Globotruncana* are much less regular in shape than those of true *Globotruncana*, resulting in the formation of labial apertures which are irregular in size and position.

While agreeing with Reichel (1949) that the spherical form of the proloculus in the Globotruncaninae is no indication of their derivation from a globigerinid stock (the spherical shape of the proloculus being determined by the laws of liquid drops in suspension) and that many *Globotruncana* species show a tendency towards globular chambers and weakening of the keels, we can not overlook the fact that apparently all Globotruncaninae, as herein redefined, evolved from ancestors with strongly globular chambers and apparently always have the earliest few chambers in globular form. Reichel himself pointed out that *G. stephani* (i. e. *Praeglobotruncana*) might have evolved from a *Globigerina*-like form of the *Pseudovalvulineria*-group, from which *Ticinella* evolved. *Pseudovalvulineria lorneiana* (Gandolfi, non d'Orbigny) and *P. lorneiana trochoidea* (Gandolfi) have strongly globular chambers. Both groups, *Ticinella* and *Praeglobotruncana*, have evolved towards flat forms which are strongly keeled and peripherally truncated in many

species. The case of *Helvetoglobotruncana helvetica* has been mentioned above. Also it must not be overlooked that e. g. *Ticinella-Thalmaninella* assemblages occur always associated with "*Globigerina*"; usually all are numerically abundant and occur in sediments deposited apparently under open-sea (not necessarily deep-water) conditions. There is nothing in chamber-form, in numerical association of their members, or in type of sediment in which they occur which would contradict a pelagic habitat for such *Ticinella-Thalmaninella*-"*Globigerina*" assemblages. They very much resemble Recent *Globigerinoides-Globorotalia-Globigerina* assemblages, which are evidently pelagic. Chamber-form in relation to habitat is still a problem of foraminiferal research.

The various points mentioned above still need clarification. A revision of the Globigerinidae as a whole will probably be helpful in this respect.

Until such a revision is carried out it seems adequate to separate from *Globotruncana* all Cretaceous species of "*Globigerina*" and *Rugoglobigerina*, as well as forms which show all attributes of the latter two groups, but are provided with carinal bands and with incomplete, discontinuous keels. These "globigerinid" species of *Globotruncana* might have originated from *Globotruncana*, as suggested by Gandolfi; or — as believed by this writer — they have originated from Cretaceous "globigerinids." Evidence at hand is not yet fully convincing.

Rugoglobigerina should be separated from other species of Cretaceous *Globigerina* s. l., as originally defined by Bronnimann. The Cretaceous "*Globigerina*" species must be separated from the Tertiary ones and described as distinct genera and subgenera. The position of the "globigerinid" species of *Globotruncana* seems doubtful for the moment. In daily routine-work at this writer's laboratory the Cretaceous species of *Globigerina* (s. l.) (except *Rugoglobigerina*) are referred to under various provisional genera-names and the "globigerinid" species of *Globotruncana* as "*Globiglobotruncana*" and "*Rugoglobotruncana*" respectively; the difference between the latter forms is the same as that between the Cretaceous species of "*Globigerina*" and *Rugoglobigerina*, viz. the presence or absence of a meridional pattern of ornamentation. "*Globiglobotruncana*" is frequent in the early Senonian of Israel;

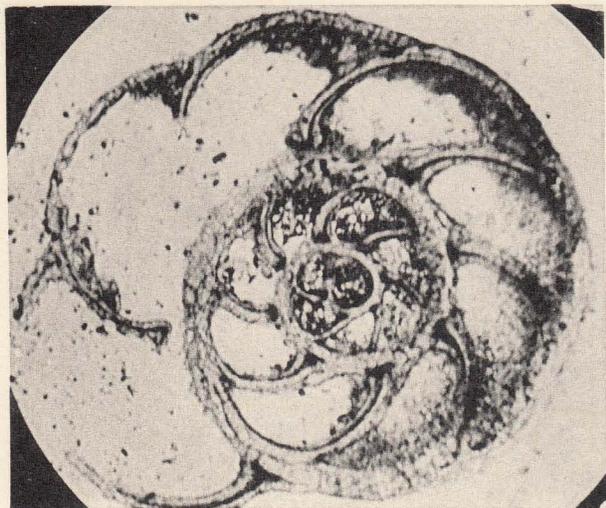
EXPLANATION OF PLATE 18

(BILAMELLIDEA, figs. 1-4 and MONOLAMELLIDEA, figs. 5-6)

FIGS.	PAGE
1-4. <i>Pseudovalvulineria lorneiana</i> (d'Orbigny). Campanian. Paris-basin.	128
5. <i>Valvulineria californica</i> Cushman. Miocene. California.	128
6. <i>Cancris</i> sp. Miocene. Israel.	128, 130

Figs. 1, 2, 3, 5 and 6, horizontal sections. Fig. 4, vertical section. All figures $\times 100$.

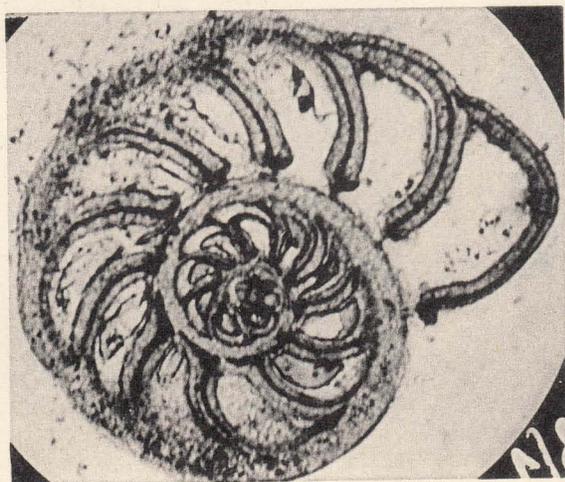
Note double septa and walls, as well as relationship between outer lamella and inner lining in figs. 1-4 and the simple (single) septa and walls in figs. 5 and 6.



1



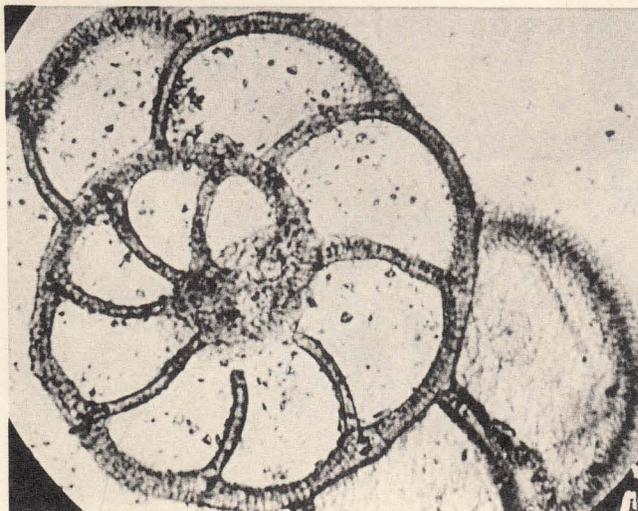
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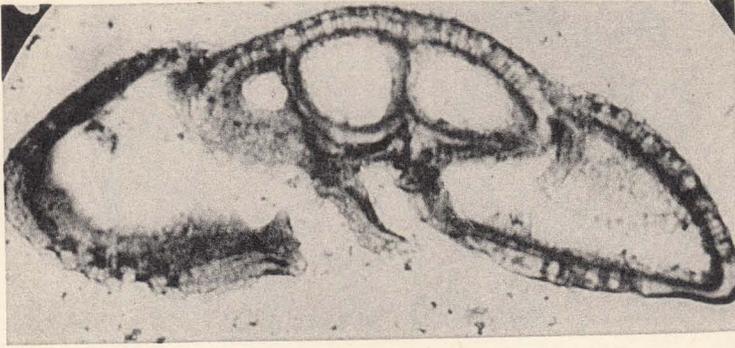


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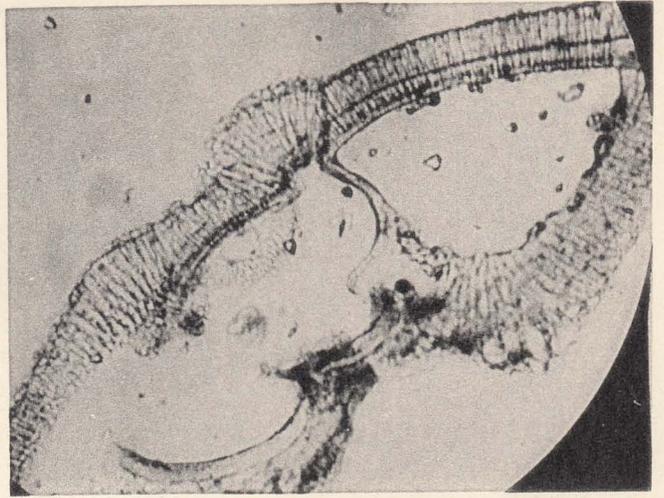


6

Reiss: Bilamellidea nov. superfam.; Cretaceous globorotaliids



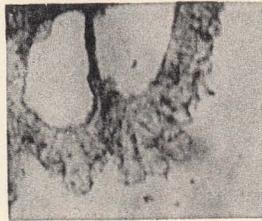
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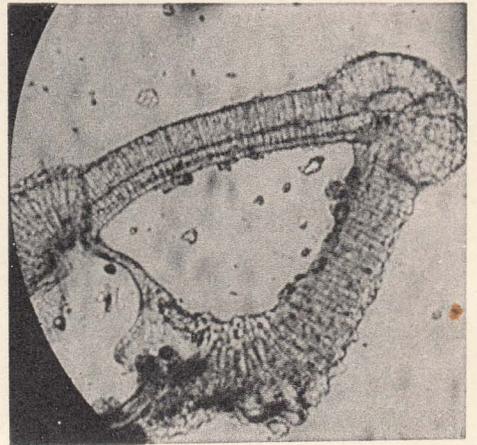
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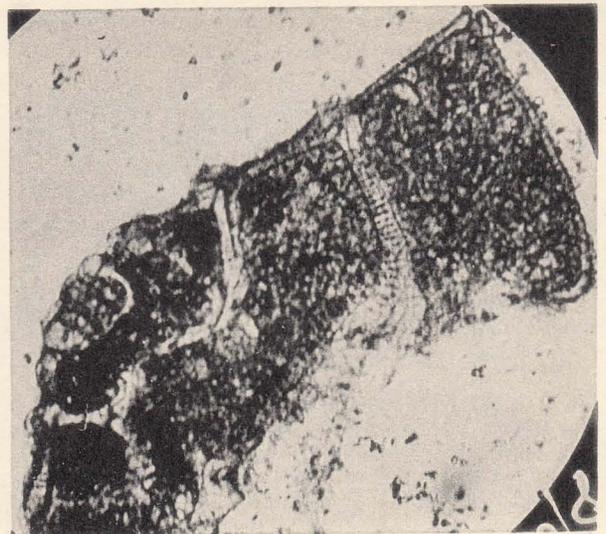
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6



7



8

Reiss: Bilamellidea nov. superfam.; Cretaceous globorotaliids

"Rugoglobotruncana" is very frequent in the late Campanian and in the early Maestrichtian of that country.

It is possible that the Globigerinidae are more closely related to the Globorotaliidae than chamber-form and certain morphological details (e. g. keels) would suggest and that present concepts of genera and higher systematic groups of Foraminifera are inadequate. The concept of "plexus" in the sense of Sigal might prove a more satisfactory approach to foraminiferal systematics and would help to curtail the — at present necessary — proliferation of genera.

Stratigraphical Distribution of the Globotruncaninae

The accompanying table shows the stratigraphical distribution of the various genera of the Globotruncaninae, as well as their assumed phylogenetic relationships.

The very low stratigraphical occurrence of *Planomalina* is based on the record of a typical species of this genus (*P. cheniourensis*) from the Aptian-Albian boundary in Algeria (Sigal, 1952b), that of *Ticinella* at the Aptian-Albian boundary on the record of a new *Ticinella* from North Africa by Sigal (1955a).

ADDENDUM

After the completion of the typescript of the present paper the publication "Taxonomy of the Globotruncanidae" by P. Bronnimann and N. K. Brown, Jr. (Ecl. Geol. Helv. vol. 48, No. 2, 1955) came to hand. The subfamily Globotruncaninae Brotzen, 1942, is elevated to the rank of family. It includes 12 genera, three of them new, as follows: without "costellae" (rugosities arranged in a meridional pattern), without accessory apertures — *Hedbergina* and *Praeglobotruncana*, or with accessory apertures — *Ticinella*, *Rotalipora*, *Thalmaninella* and *Globotruncana*; with costellae, without accessory apertures — *Kuglerina* and *Bucherina*, with accessory apertures — *Rugoglobigerina*, *Plummerita*, *Rugotruncana* and *Trinitella*. All these genera are regarded as having a granular-calcareous structure (see, however, Reichel, 1955, "Sur une Trocholine du Valanginien d'Arzier": Ecl. Geol. Helv. vol. 48, No. 2). The two layers of the double walls

are believed to be two parts of a "primary" lamella, deposited on both sides of a capsular membrane or diaphragma, which enclosed the protoplasmic mass. Later lamellae have been added on the outside only. The dark "dots" visible in section at the border of the aperture and at the periphery of the test are not regarded as canals (in section). The genera of the Globotruncanidae are believed to have evolved either by proterogenesis or by palingenesis from Cretaceous species of "*Globigerina*" (which are regarded to be different generically from the Tertiary ones) in 4 main groups, comprising 14 lineages. All genera of the Globotruncanidae have early globular chambers. *Pseudovalvulineria lorneiana* (Gandolfi, non d'Orbigny) and *P. lorneiana trochoidea* (Gandolfi) are placed in the new genus *Hedbergina*, which has evolved from "*Globigerina*" towards *Ticinella* and *Thalmaninella*. *Rotalipora* is regarded to be devoid of an umbilical cover-plate and to have evolved from *Praeglobotruncana*. The latter is regarded to be double-keeled. The double keel of the Globotruncanidae is regarded as being actually one keel with two rims. *Rugotruncana* comprises single- and double-keeled forms, having costellae or traces of them. It includes among others *Globotruncana citae*, *G. gansseri*, *G. calcarata*, *G. mayaroensis*, *G. intermedia*; (our "*Rugoglobotruncana*" is congeneric with the type-species of *Rugotruncana*). *Globotruncana fornicata* Plummer is believed to be derived from *G. imbricata*; *G. linneiana* to be distinct from *G. lapparenti* and to have evolved from a "*Globigerina*"-*Globotruncana saratogaensis* (Applin) (= *G. globigerinoides* Brotzen)-*G. marginata* lineage; *G. arca* to be derived from *G. lapparenti tricarinata*; *G. rosetta* (Carsey) to be derived from a *G. lapparenti-cretacea* lineage. *G. stuarti* and *G. conica* are believed to have evolved from a *G. marginata-renzi-sigali* lineage. *Rugotruncana calcarata*, *R. gansseri* and the *R. havanensis* (= *Globotruncana citae*)-*intermedia-mayaroensis* lineages are believed to have evolved independently from *Rugoglobigerina*. The main trends of evolution are: increase in size of individuals, intensification of ornamentation, progressive modification of shape, increase in size of the umbilicus, increase in size of the

EXPLANATION OF PLATE 19

(BILAMELLIDEA)

FIGS.	PAGE
1. <i>Discopulvinulina</i> sp. Recent. Atlantic Ocean.	128
2, 3, 5. <i>Globorotalia menardii</i> (d'Orbigny). Recent. Atlantic Ocean. (Details).	130
4. <i>Truncorotalia</i> cf. <i>aragonensis</i> (Nuttall). Lower Eocene. Israel.	130
6, 8. <i>Globotruncanita stuarti</i> (de Lapparent). Maestrichtian. Aquitaine, France. (Details).	136
7. <i>Planomalina buxtorfi</i> (Gandolfi). Vraconian. Ticino.	136

All figures $\times 100$ and representing vertical sections.

Note double walls in last chamber, peristomal canals and non-canalicate keel in fig. 1; the lamellar structure and keel-canals in figs. 2, 3 and 5-8; the pillar-like structures in the wall at point of sharp inward-bending of chamber-wall in fig. 4; the canalicate keels in fig. 7 (in lower part of picture section passes through the keel far from the point of dichotomization, in upper part of picture near to this point).

apertural flaps, increase in height of coiling and progressive refinement of shell-wall material.

As can be seen from the present paper, this writer does not agree with Bronnimann and Brown (*op. cit.*) with regard to various points (wall-structure, keels, interpretation of various genera, etc.). The conclusions reached by those authors with regard to the phylogeny of the Globotruncanidae are opposed to those of other authors, especially Gandolfi, and are nearer in certain points to those reached by Sigal, being in disagreement in various points with the present writer's views. It seems that all conclusions with regard to the phylogeny of the "Globotruncanas," reached lately by various authors (including the present one) warrant further study and discussion.

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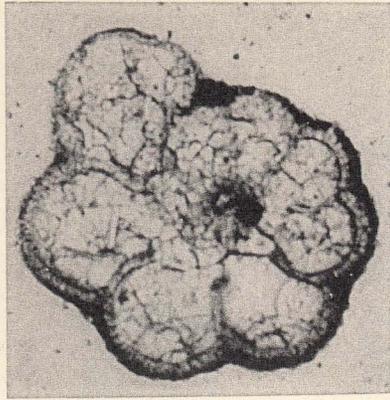
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EXPLANATION OF PLATE 20
(BILAMELLIDEA)

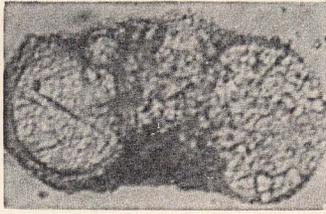
FIGS.	PAGE
1. <i>Globigerina</i> (s.l.) sp. Vraconian. Algeria.	129
2. <i>Globigerina</i> (s.l.) sp. transition to <i>Helvetoglobotruncana helvetica</i> (Bolli). Upper Cenomanian. Israel.	129, 137
3. <i>Globigerina</i> (s.l.) sp. Upper Cenomanian. Israel.	129
4. <i>Globigerina</i> (s.l.) <i>cretacea</i> d'Orbigny. Campanian. Paris-basin.	129
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7. <i>Globigerina</i> sp. Recent. Atlantic Ocean.	129
8. <i>Globigerina</i> sp. Recent. Atlantic Ocean. (Detail).	129
9. <i>Globigerina</i> sp. Pliocene. Israel.	129

All figures, except fig. 8, $\times 100$; fig. 8, $\times 200$. Figs. 1 and 4, horizontal sections; figs. 2, 3, 5-9, vertical sections.

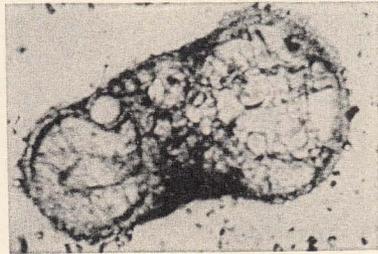
Note the lamellar structure, the double walls and the peristomal-septal canals in the various figured specimens.



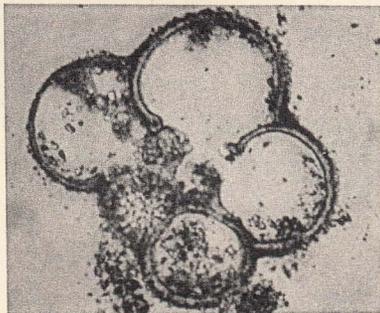
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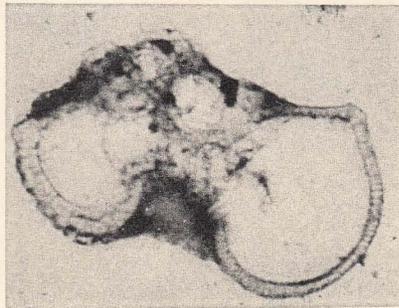
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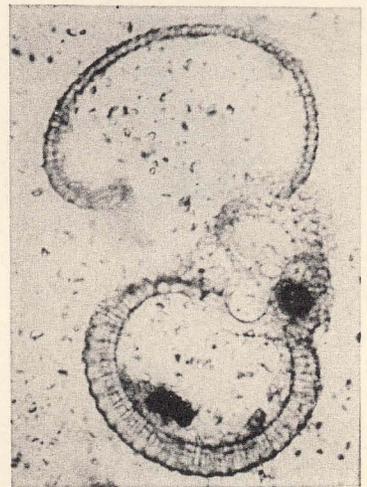
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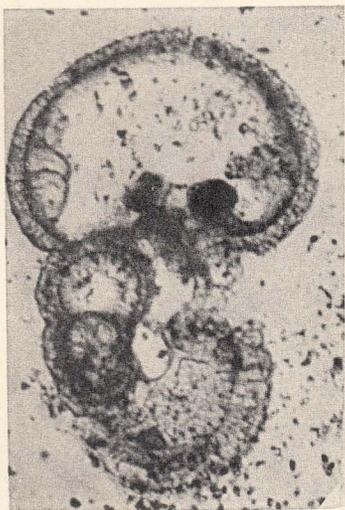
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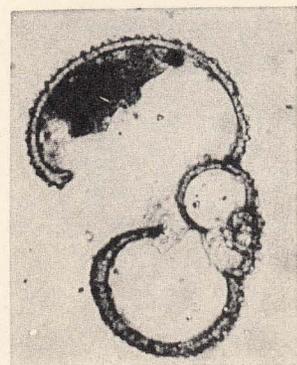
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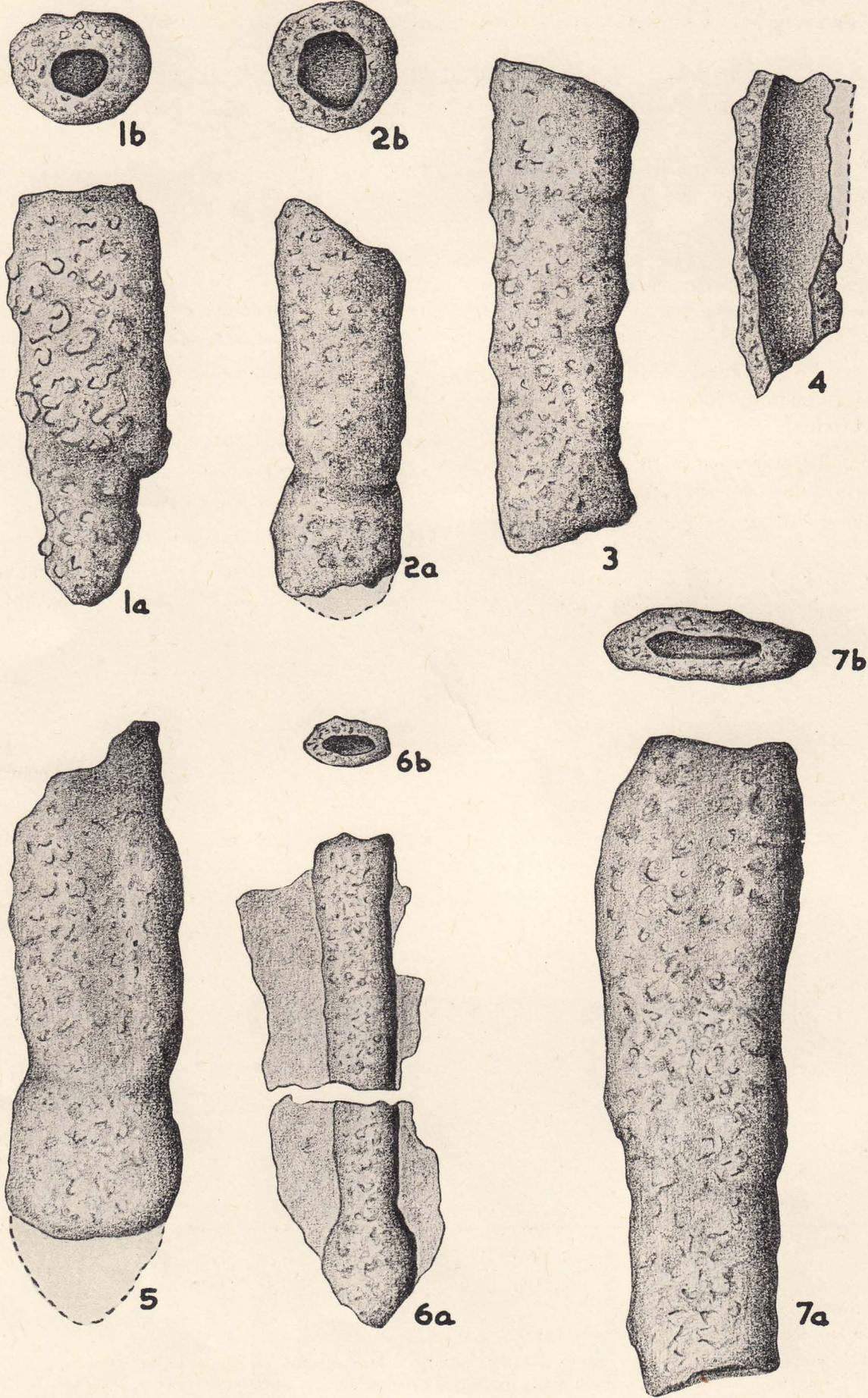


8



9

Reiss: Bilamellidea nov. superfam.; Cretaceous globorotaliids



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EXPLANATION OF PLATE 21

All figures $\times 42$

FIGS.	PAGE
1-4. <i>Hyperammina</i> aff. <i>H. elongata</i> Brady var. <i>clavatula</i> Howchin	147
1a, complete specimen with unequal cementation of sand grains on the tubular chamber; 1b, apertural view; 2a, specimen with damaged proloculus; 2b, apertural view; 3, fragment of another specimen, showing feeble external constrictions; 4, section of a fragment of the tubular chamber.	
5-7. <i>Hyperammina gracilis</i> Waters	146
5, specimen with damaged proloculus; 6a, attached specimen showing the fusiform proloculus; 6b, apertural view; 7a, fragment of another specimen; 7b, apertural view of the highly compressed tubular chamber.	

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH

VOLUME VIII, PART 4, OCTOBER, 1957

175. OCCURRENCE OF THE GENUS *HYPERAMMINA* IN THE MARINE
PERMO-CARBONIFEROUS BED AT UMARIA, CENTRAL INDIA

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ABSTRACT

The foraminiferal genus, *Hyperammina*, is recorded for the first time from the marine Permo-Carboniferous bed at Umaria, Central India. The genus is represented by two species — *H. gracilis* Waters and *H. aff. H. elongata* Brady var. *clavatulula* Howchin.

INTRODUCTION

The marine Permo-Carboniferous bed at Umaria in Central India has attracted great attention since its occurrence was first recorded by K. P. Sinor in the General Report of the Geological Survey of India for the year 1921 (*vide* Fermor, 1923, pp. 14-16). The thin marine bed, 10 feet thick, occurs intercalated with fresh-water beds of the Lower Gondwana System. It unconformably overlies the Talchir Boulder bed and is overlain by the fresh-water Barakar sandstones and grits. The stratigraphy of these beds, together with that of the coal-bearing formations of the Umaria Coalfield, has already been described in detail (Gee, 1928).

According to Wadia (1953, p. 232) "This bed must be regarded as a solitary record of an evanescent transgression of the sea-waters into the heart of the Peninsula, either from the North through Rajputana, or from the West Coast, induced by some diastrophic modification of the surface of the land, which, however, must have been of a transient nature and must have soon ceased to operate."

Krishnan (1954, p. 5) postulated that there was a marine connection between Umaria and the Salt Range through the Narbada valley, Gujarat, Kutch and western Rajasthan.

The marine bed contains four distinct fossiliferous bands (Gee, *op. cit.*). These bands are of variable thickness and lithology and are crowded with agglomerated shells of brachiopods, gastropods, etc. Reed (1928) recorded a rich fauna from them, the predominant species being *Productus umariensis* Reed, *P. umariensis* var. *spinifera* Reed, *P. rewahensis* Reed, *Spirifer narsarhensis* Reed, *Reticularia barakarensis* Reed, *Pleurotomaria umariensis* Reed, *Rhombopora* sp., crinoid stems, etc.

Although these bands are rich in megafossils, particularly brachiopods, microfossils have been considered to be comparatively rare. Only a few ostracods (*Jonesina* ? sp., *Cytherella* ? sp., *Palaeocypris* sp.) and

some dermal tubercles of fish have been reported (Reed, *op. cit.*). This paper reports the first known occurrence of the arenaceous foraminiferal genus *Hyperammina*. The following species have been recognized: *H. gracilis* Waters and *H. aff. H. elongata* Brady var. *clavatulula* Howchin. The former species is present in great abundance.

PROVENANCE OF MATERIAL

The marine bed at Umaria is exposed on both sides of the railway cutting, near Narsarha Nala, two miles west of Umaria railway station (Topographic sheet No. 64 A/14: 23° 31' 30" N.; 80° 49' 30" E.). The material from which the species of *Hyperammina* were obtained comes from the yellowish-brown calcareous siltstone band, 5 inches thick, exposed on the western side of the railway cutting (*vide etiam* Gee, 1928). The material was collected several years ago by the junior author.

DESCRIPTION OF SPECIES

Family HYPERAMMINIDAE

Subfamily HYPERAMMININAE

Genus *Hyperammina* Brady, 1878, emend Conkin,
1954

Hyperammina gracilis Waters

Plate 21, figures 5-7

1927, *Hyperammina gracilis* WATERS, Journ. Paleont.,
vol. 1, p. 130, pl. 22, figs. 4-5.

Description.—Test free or attached; proloculus somewhat fusiform in shape; second chamber consisting of a straight, undivided, strongly compressed tube, very slightly increasing in width towards the aperture; test often feebly constricted externally at irregular intervals; aperture elliptical, terminal; wall arenaceous, thick, fine to medium grained, pale brown to cream coloured.

Dimensions.—Length, up to 2.1 mm.; longer diameter, up to 0.77 mm.; shorter diameter, up to 0.30 mm.

Discussion.—The species resembles *H. glabra* Cushman and Waters, from the Pennsylvanian of Texas, but differs from it in the greater size of the proloculus and the nearly uniform width of the second chamber. *H. compressa* Paalzow, from the Permian of Germany,

appears to be closely related to the present species and may come within its range of variation. Although topotype specimens of the two species were not available for study, the differences between the two appear to be trivial (as is evident from their description).

Remarks.—Specimens of this species are very fragile and the proloculus is seldom found intact. Out of over 25 specimens examined, only one was complete. The interior of the tubular chamber is invariably 'filled' with clay material.

**Hyperammina aff. *H. elongata* Brady
var. *clavatula* Howchin**

Plate 21, figures 1-4

1888, *Hyperammina elongata* BRADY var. *clavatula*
HOWCHIN, Roy. Micr. Soc. Lond., Journ., p. 535,
pl. 8, figs. 1-2.

Description.—Test free, consisting of a rounded proloculus and an elongate, straight tubular second chamber of uniform diameter throughout; tube circular in cross section, occasionally irregular in shape, often constricted externally at irregular intervals; wall arenaceous, texture variable, pale brown to cream coloured.

Dimensions.—Length up to 2.14 mm.; diameter, up to 0.71 mm.

Discussion.—This species differs from *H. gracilis* in the circular cross section of the tubular second chamber. A few specimens, which may be questionably referred to it, occur in our material. It was originally described from the Carboniferous limestone of northern England.

Remarks.—It is possible that the two species described here represent dimorphic generations. Owing to the fragile nature of the tests, only three complete specimens have been found, the rest being represented only by the tubular chamber. Other better preserved specimens are required before any definite relationship between the two can be established. For the present, however, they are considered to be separate species.

**GENERAL REMARKS
ON THE AGE OF THE BED**

Although the genus *Hyperammina* has a long stratigraphical range — Silurian to Recent — some of the species have a limited vertical range.

H. gracilis was originally described from the lower Pennsylvanian rocks of the Dornick Hills formation, Ardmore Basin, while *H. elongata* var. *clavatula* was described from the Carboniferous limestones of northern England. Cooper (1947, pp. 88-89) recorded the following species of *Hyperammina* from the upper Kinkaid (Mississippian) of Illinois: *H. cf. H. elongata clavatula*, *H. cf. H. glabra* and *H. sp.* Conkin (1954) recorded a monospecific assemblage comprised of *H.*

kentuckyensis Conkin from the Mississippian of Kentucky.

Conflicting views have been expressed concerning the age of the Umaria Marine bed. Reed (1928, pp. 393-394) on the basis of the contained megafossils concluded that the bed is of Permo-Carboniferous age, with a noticeable admixture of types possessing affinities with both Carboniferous and Permian species, but as Krishnan (1944, p. 250) pointed out ". . . . the species are all new, with highly individual characters." Wadia (1953, p. 232) also assigns a Permo-Carboniferous age to the bed. Krishnan (1953, p. 20; 1954) groups the Umaria Marine bed along with the Barakar and Karharbari stages in the lower Permian. Fox (1931) while placing the marine bed at the base of the Barakar series, assigned an upper Carboniferous age to it, and Permian to the over-lying beds.

It would be manifestly suspect to draw conclusions regarding the age of the marine bed, based entirely on the evidence of *Hyperammina* spp. Of the two species recorded, only one has been definitely identified. *H. gracilis*, originally described from the Carboniferous, might range upwards to the Permian, should *H. compressa* be synonymous with it. The topotype specimens of these two species have to be studied to clarify this point. It is hoped that future work, planned by the authors, will clarify the disputed problem of the age of the bed.

ACKNOWLEDGEMENTS

The authors are indebted to Prof. S. R. N. Rao for his painstaking work in reading the manuscript and giving valuable suggestions.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME VIII, PART 4, OCTOBER, 1957
RECENT LITERATURE ON THE FORAMINIFERA

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

- AKERS, W. H., and DROOGER, C. W. Miogypsinids, planktonic Foraminifera, and Gulf Coast Oligocene-Miocene Correlations.—Am. Assoc. Petr. Geol. Bull., v. 41, No. 4, April 1957, p. 656-678, text figs. 1, 2 (correlation table, map).—By means of miogypsinid species in common between Mediterranean and Gulf Coast regions, the European time scale is applied to the planktonic zones established in Trinidad with the result that the *Globigerinatella insueta* zone is tentatively placed in late Helvetian. Eleven species of *Miogypsina* are discussed.
- ALMGREN, A. A., and SCHLAX, W. N. Post-Eocene age of "Markley Gorge" fill, Sacramento Valley, California.—Am. Assoc. Petr. Geol. Bull., v. 41, no. 2, Febr. 1957, p. 326-330, figs. 1-4.—Oligocene age of the lower part of the fill is based on Foraminifera.
- ASCOLI, P. Diagnosi di forme nuove. *Cibicides floridanus* (Cushman) var. *suturatus* n. var.—Riv. Ital. Pal. Stratig., v. 62, No. 4, 1956, p. 265, 266, text fig. 1.—From Tortonian of Mombisaggio.
- Microfaune del Tortoniano di Mombisaggio e della serie pliocenica di Volpeglino.—Riv. Ital. Pal. Stratig., v. 63, No. 1, 1957, p. 3-30, pls. 1, 2, text fig. 1, table 1.—Table shows range and abundance of about 60 Pliocene species. The Miocene species are listed. Two photographs illustrate assemblages typical of the two ages.
- BARNARD, TOM. *Frondicularia* from the Lower Lias of England.—Micropaleontology, v. 3, No. 2, April 1957, p. 171-181, pls. 1, 2, text figs. 1, 2, table 1.—Evolutionary study of a group of smooth forms (*F. brizaeformis*) and a group of ornamented forms (*F. sulcata*), including discussion of significance and range of the chief variants.
- BERRY, E. WILLARD. Fossil *Cyclammina*, with a description of two new species from Peru.—Bol. Soc. Geol. Peru, v. 30, 1956, p. 81-97, text figs. 1, 2, table 1.—Fifty-two fossil species of *Cyclammina* are listed with their recorded occurrences.
- BIEDA, F. Die Fauna Grosser Foraminiferen im Obereozän der Slowakei (German summary).—Geol. Sbornik, Slovenska Akad. Vied, Bratislava, Rocnik 8, cislo 1, 1957, p. 28-71, pls. 2-6.—Descriptions and illustrations of nummulites and related forms.
- BYKOVA, E. V. Foraminifery Ordovika I Silura Sovetskoy Pribaltiki, in Mikrofauna SSSR, Sbornik 8.—Russia, Vses. neft. nauch.-issl. geol. instit., Trudy, n. ser., no. 98, 1956, p. 6-37, pls. 1-5.—Twenty-one species, 11 new and 7 indeterminate, in 9 genera, 2 new.
- COLE, W. STORRS. Variation in American Oligocene species of *Lepidocyclina*.—Bull. Amer. Pal., v. 38, No. 166, May 10, 1957, p. 27-51, pls. 1-6, table.—Three species of the subgenus *Lepidocyclina* are illustrated and discussed and a species is transferred to *Amphistegina* from *Operculinoides*. A key includes the 7 known American Oligocene and Miocene species of the subgenus *Lepidocyclina*.
- COLOM, G. Notas sobre Foraminiferos fosiles.—Instit. "Lucas Mallada" Invest. Geol., Madrid, No. 33, 1957, p. 27-34, text figs. 1, 2 (pls.).—Two new species, one Miocene and one Lower Cretaceous, and a new subspecies from the Miocene.
- DABAGJAN, N. V., MJATLJUK, E. V., and PISHVAN-OVA, L. S. Novye Dannye Po Stratigrafii Tretichnykh Otlozhenij Zakarpat'ja Na Osnovanii Izuchenija Fauny Foraminifer.—Geol. Sbornik, 2-3, 1956, p. 220-236, pls. 1, 2.—Eight species, 4 new.
- DALBIEZ, F. The generic position of *Rotalia deecke* Franke, 1925.—Micropaleontology, v. 3, No. 2, April 1957, p. 187, 188, text figs. 1-5.—Belongs to *Thalmaninella* which is regarded as a subgenus of *Rotalipora*.
- EDGEELL, H. S. The genus *Globotruncana* in Northwest Australia.—Micropaleontology, v. 3, No. 2, April 1957, p. 101-126, pls. 1-4, text figs. 1-4, table 1.—Thirteen species (1 new) and 1 subspecies of *Globotruncana* and 1 of *Rugoglobigerina* are described and illustrated and their structural characteristics compared in tabular form. Correlation with European and American Upper Cretaceous is indicated. The species are combined into 6 morphological groups and their morphogenetic trends are discussed. Quantitative analysis of the faunas suggests that the genus is chiefly benthonic, at least in adult stages.
- FRANZENAU, A., and MAJZON, L. New and interesting Foraminifera species.—Ann. Hist.-Nat. Mus. Nat. Hungarici (n. ser.), v. 7, 1956, p. 211-220, pl. 1.—Publication, on the centenary of Franzenau's birth, of previously unpublished notes, descriptions, and illustrations. Twenty-three species, 11 new and 6 others first illustrated here, from Miocene and Rupelian beds. Lists of species also included.
- GANELINA, R. A. Foraminifery Vizejskikh Otlozhenij Severo-Zapadnykh Rajonov Podmoskovnoj Kotloviny, in Mikrofauna SSSR, Sbornik 8.—Russia, Vses. neft. nauch.-issl. geol. instit., Trudy, n. ser., no. 98, 1956, p. 61-183, pls. 1-12, tables.—Fifty-nine species, nearly all new, from the late Paleozoic. One new genus.
- GIANNINI, ENZO. Studio micropaleontologico di un livello argilloso di dubbia interpretazione nel complesso neo-autoctono mio-pliocenico, presso Pomaia (Pisa).—Atti. Soc. Toscana Sci. Nat., ser. A, v. 62, fasc. 2, 1955, p. 445-466, pls. 1, 2.—A rich lower Pliocene fauna, no new species, a few illustrated.
- GIUNTA ILACQUA, M. I Foraminiferi Calabrieri di Rometta Superiore (Messina).—Riv. Ital. Pal. Stratig., v. 62, No. 4, 1956, p. 225-238, pl. 20.—A largely planktonic fauna; no new species.
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