Systematic part

It seemed, therefore, necessary to revise some Paleogene *Globorotalia* and to furnish additional data on their stratigraphic distribution and taxonomic relations. In the beginning, much time was spent with a rich and excellently preserved fauna from the Velasco shales of Eastern Mexico. Statistical analysis of the forms belonging to the *Globorotalia velascoensis* group, which has been undertaken in collaboration with W. W. HAY, has not yet been successful. The present writer shares the scepticism expressed by R. LEHMANN (1963) towards the application of statistical analysis to smaller foraminifera.

Since the relations of different species are not controllable in a stratigraphically isolated sample, it soon became necessary to study the development of the species in a continuous section. Based on the thesis of O. RENZ (1936), such sections have been found in the Scaglia exposed in the Central Apennines. The present study is based on isolated faunas, whereas RENZ based his information on thin sections. The stratigraphic section in the Gola del Bottacione («Gubbio section») immediately north of the town of Gubbio (Prov. di Perugia) has been chosen as a standard section. Two neighbouring parallel sections have been investigated as a control.

The present paper is restricted to the group of «keeled» *Globorotalia* within the Paleocene and Lower Eocene and moreover to forms which are thought to be their predecessors.

The quite puzzling problems of synonymy which sometimes arose, made it necessary to examine, as far as possible, topotypes and type-samples. For this purpose, KUGLER's type-collection of species established for the Caribbean region and topotypes donated by SUBBOTINA and SHUTZKAYA have been of great value.

The achievements of Soviet specialists are discussed to some extent. They have not yet obtained the evaluation they deserve by most of the authors in Western Europe and America.

The present paper is divided into two main parts. The first one is mainly dedicated to systematic problems and to the description of the different species. The second part is restricted to the description of the measured sections and to a brief discussion of some stratigraphic questions.

The present paper has not the aspiration to settle exhaustively the problems concerned. On the contrary, more problems have arisen with the study of additional material. It is hoped, however, that some of them may be discussed in future papers.

The figures represent camera lucida drawings executed by the author.

If not mentioned otherwise, the figured specimens are deposited in the collections of the Museum of Natural History, Basel (catalogue numbers C 20548–C 20668).

A. SYSTEMATIC PART

Remarks on the generic classification of *Globorotalia*

Before 1927, the species referred at present to the genus *Globorotalia* were placed in such different genera as *Pulvinulina*, *Discorbina*, *Rosalina*, *Rotalina*, *Planulina* and others.

In 1927, CUSHMAN established the genus *Globorotalia*, defining it as follows: «Test trochoid, early chambers often like *Globigerina*, dorsal side often flat, the ventral side broadly convex, aperture usually umbilicate, wall frequently roughened throughout, mostly pelagic.
Type species: *Pulvinulina menardii* (D'ORBIGNY) var. *tumida* BRADY, 1877.»

This rather broad definition of a stratigraphically important and widely distributed genus has been modified and restricted by many subsequent authors. Actually, the following taxons of generic or subgeneric rank will be discussed hereafter:

Rosalinella MARIE, 1941
Turborotalia CUSHMAN & BERMUDEZ, 1949
type-species: *Globorotalia centralis* CUSHMAN & BERMUDEZ, 1937
Truncorotalia CUSHMAN & BERMUDEZ, 1949
type-species: *Rotalina truncatulinoides* D'ORBIGNY, 1839
Truncorotaloides BRÖNNIMANN & BERMUDEZ, 1953
type-species: *Truncorotaloides rohri* BRÖNNIMANN & BERMUDEZ, 1953
Acarinina SUBBOTINA, 1953
type-species: *Acarinina acarinata* SUBBOTINA, 1953
Globanomalina HAQUE, 1956
type-species: *Globanomalina ovalis* HAQUE, 1956
Pseudogloborotalia HAQUE, 1956
type-species: *Pseudogloborotalia ranikotensis* HAQUE, 1956
Planorotalia MOROZOVA, 1957
type-species: *Planulina membranacea* EHRENBERG, 1854
Planorotalites MOROZOVA, 1957
type-species: *Globorotalia pseudoscitula* GLAESSNER, 1937
Globorotaloides BOLLI, 1957
type-species: *Globorotaloides variabilis* BOLLI, 1957
Neotruncorotalia REISS, 1957
no type-species designated
Pseudotruncorotalia REISS, 1957
no type-species designated
Astrorotalia TURNOVSKY, 1958
type-species: *Globorotalia* (*Astrorotalia*) *stellaria* TURNOVSKY, 1958
Morozovella MCGOWRAN, 1964 (ms)
type-species: *Pulvinulina velascoensis* CUSHMAN, 1925

Since the present paper deals only with Paleocene and Lower Eocene *Globorotalia*, the genera (or subgenera) *Globorotaloides* and *Astrorotalia* are not considered. *Rosalinella* MARIE, 1941, *Neotruncorotalia* REISS, 1957, and *Pseudotruncorotalia* REISS, 1957, are invalid for nomenclatorial reasons (THALMANN, 1946, BERMUDEZ, 1961).

The genus *Globanomalina* HAQUE, 1956, has been erected «to include all the species of *Anomalina* with globose chambers, evolute dorsally without any umboplug, and those species of *Globigerina* with a smooth wall» (HAQUE, 1956, p. 147). Such a generic definition is beyond discussion.

Pseudogloborotalia HAQUE, 1956, has been very superficially described by its author. The reproduced figures furnish practically no information. BERMUDEZ (1961), restricting – for morphological reasons – *Truncorotalia* to recent and Neogene forms, used *Pseudogloborotalia* as generic name for Paleogene *Globorotalia* with conical chambers.

By courtesy of C. G. ADAMS, it was possible to examine paratypes of *Pseudogloborotalia ranikotensis*, deposited in the collections of the British Museum. One of them is reproduced (fig. 1a–c). The structure of the test is smooth with very fine pores and therefore differs from planktonic foraminifera. *Pseudogloborotalia ranikotensis* seems to be related to the *Discorbidae*. LOEBLICH & TAPPAN (1964) included *Pseudogloborotalia* in the *Eponididae*. The genus is therefore not suitable for the purpose intended by BERMUDEZ (see also MCGOWRAN (1964), BRÖNNIMANN & RIGASSI (1963)).

Turborotalia CUSHMAN & BERMUDEZ, 1949, includes the species with globular chambers, rounded periphery and without distinct umbilicus. BOLLI, LOEBLICH & TAPPAN (1957) considered *Turborotalia* to be synonymous with *Globorotalia*, whereas BANNER & BLOW (1959), REISS (1963), LOEBLICH & TAPPAN (1964) and others maintained that it was a separate genus or subgenus of *Globorotalia*.

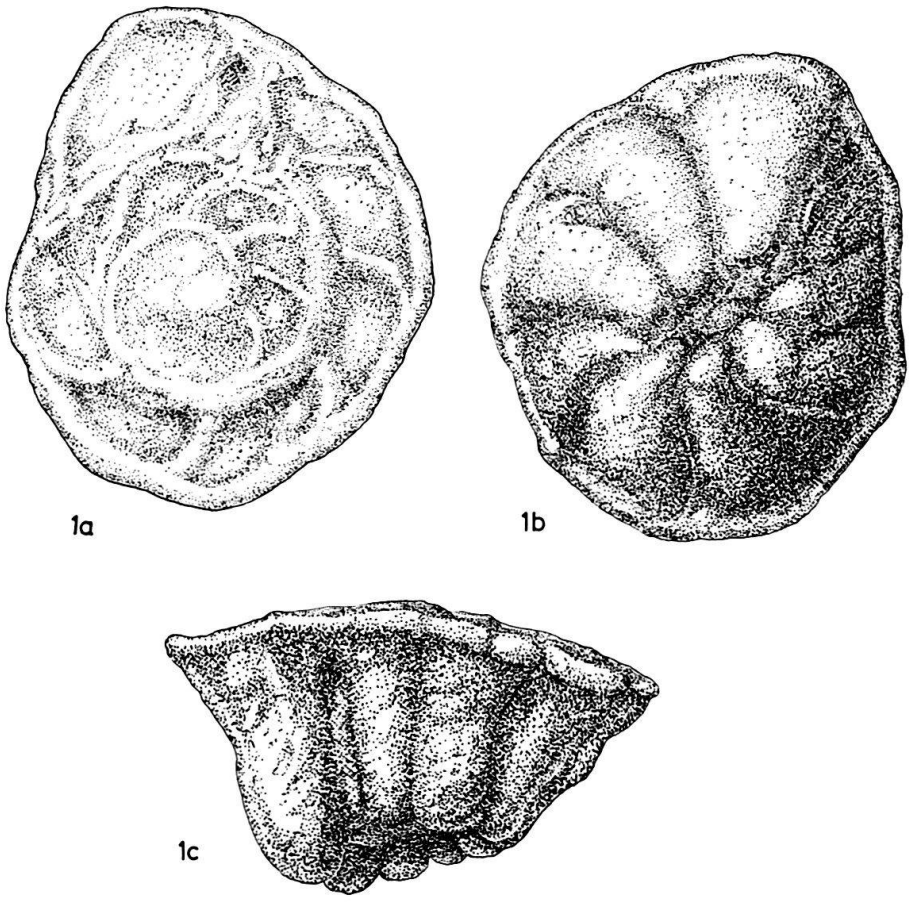


Fig. 1a–c. *Pseudogloborotalia ranikotensis* HAQUE (type-species of *Pseudogloborotalia* HAQUE), Ranikot, Mammal Gorge, Salt Range, Pakistan (paratype, dep. Brit. Mus. (Nat. Hist.), Ex P. 42420).

Acarinina SUBBOTINA, 1953, was erected out of similar reasons as the genus *Turborotalia*. SUBBOTINA originally even included in *Acarinina* the type-species of the latter genus. A comparison of the wall structures of topotypes of both type-species, *Acarinina acarinata* and *Turborotalia centralis* is given in figs. 2 and 3.

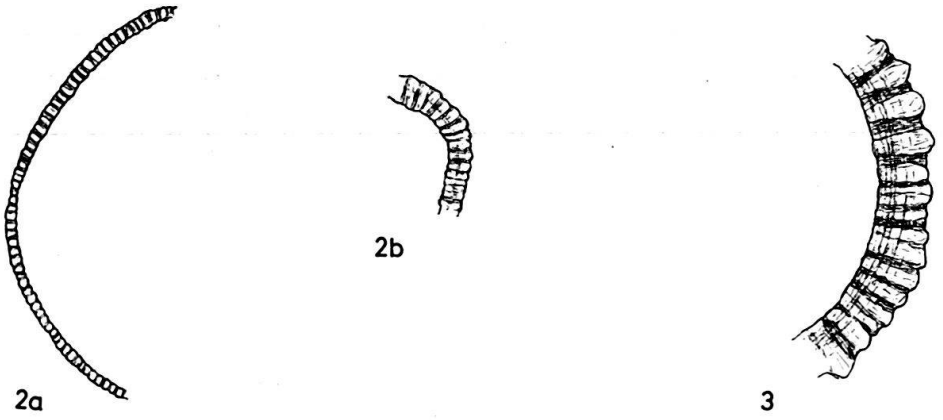


Fig. 2. *Globorotalia centralis* CUSHMAN & BERMUDEZ, 1937, type-species of *Turborotalia* CUSHMAN & BERMUDEZ, 1949, topotype from the upper Eocene of Cuba (C 20548) (leg. BERMUDEZ). (a) Section through the wall of the last chamber, × 130. (b) Section through the chamber wall in the first half of the last whorl, × 130.

Fig. 3. *Globorotalia acarinata* (SUBBOTINA), 1953, type-species of *Acarinina* SUBBOTINA, 1953. Topotype (C 20549) from the «zone of flattened Globorotaliids», r. Kheu, Northern Caucasus (leg. SUBBOTINA). Section through the wall of the last chamber, × 130.

In *Turborotalia centralis*, the chamber walls, especially those of the last chamber, are almost smooth, whereas in *Acarinina acarinata* they are very stout, with considerably large pores and blunt spines, which are more prominent around the umbilical depression. These «supplementary skeletal formations» (ALIMARINA, 1963), which are lacking in *Turborotalia centralis*, are emphasized as typical for the genus by Soviet authors. In *Acarinina* are also included species with conical chambers («intermediate *Acarinina*» of SUBBOTINA, 1953) of the Paleocene («*Acarinina*» *conicotruncata*, «*Acarinina*» *tadjikistanensis*), which are grading into forms with keels as *Globorotalia velascoensis* and others. The definition of *Acarinina* varies considerably among the Soviet specialists, especially its delimitation towards the «keeled Globorotalia» of Upper Paleocene and Lower Eocene (e.g. «*Acarinina*» *velascoensis* (CUSHMAN) in MOROZOVA, 1961)[2]).

Most workers outside the Soviet Union (BERGGREN, 1960, BANNER & BLOW, 1959, HILLEBRANDT, 1962, BERMUDEZ, 1961, REISS, 1963, LOEBLICH & TAPPAN, 1964) consider *Acarinina* as synonymous, or at least partly synonymous, to *Turborotalia*. If subgeneric classification is to be used, it is in many cases quite difficult to differentiate between these two subgenera, but their purpose is only partly overlapping. Later, SUBBOTINA (1959, 1960) excluded *Globorotalia centralis* from *Acarinina* and recognized *Turborotalia* as an independent genus. *Acarinina*

[2]) To design keeled *Globorotalia* as «*Acarinina*» is a «contradictio in adiectu».

was restricted to highly spinous forms such as *Acarinina conicotruncata* and *Acarinina acarinata.*

In 1957, MOROZOVA splitted the genera *Planorotalia* and *Planorotalites* from the stock of *Globorotalia* s.l. *Planorotalia* was said to be characterized by its flattened test and its thin, finely perforate and smooth chamber wall. *Planulina membranacea* EHRENBERG, 1854, was designated as type-species. This type-species, being a Pliocene form, is therefore not available for the intended purpose (misidentified type-species, see HAY, 1962). MCGOWRAN (1964) proposed *Globorotalia pseudomenardii* BOLLI, 1957 as new type-species of *Planorotalia.* The wall structure of *Globorotalia pseudomenardii* is illustrated in fig. 4. It is the only Paleogene form which has an imperforate keel. It differs, however, from modern *Globorotalia* (e.g. *Globorotalia tumida*) in its much more fragile test.

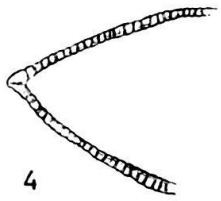


Fig. 4. *Globorotalia pseudomenardii* BOLLI, 1957, proposed by MCGOWRAN (1964) as type-species of *Planorotalia* MOROZOVA, 1957. Specimen from the Velasco formation, Globorotalia pseudomenardii zone, San José de Soto las Rusias, Eastern Mexico (C 20550). Section through the chamber wall in the first half of the last whorl, × 130.

Planorotalites MOROZOVA, 1957 with *Globorotalia pseudoscitula* GLAESSNER, 1937, as type-species was erected to include *Globorotalia* with small biconvex or planoconvex tests, with acute peripheral angle, small umbilicus and hispid chamber walls. The wall structure of *Globorotalia pseudoscitula* is illustrated in fig. 5.

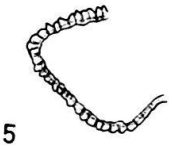


Fig. 5. *Globorotalia pseudoscitula* GLAESSNER, 1937, type-species of *Planorotalites* MOROZOVA, 1957. Specimen from the «zone of conical Globorotaliids», r. Kheu, Northern Caucasus (leg. SUBBOTINA, C. 20551). Section through the chamber wall in the first half of the last whorl, × 130.

CUSHMAN & BERMUDEZ (1949) intended to include in their subgenus *Truncorotalia* all *Globorotalia* with «planoconvex thick test, flattened dorsal side, sharply conical ventral side except for a large open umbilicus surrounded by the raised knobs of the inner ends of the chamber on the ventral side and throughout angular periphery». In addition to the recent type-species *Globorotalia truncatulinoides* (D'ORBIGNY), 1839, they grouped in this subgenus also the angular-conical *Globorotalia* of Paleogene age, such as *Globorotalia aragonensis, Globorotalia velascoensis* and their related forms.

REISS (1957) was one of the first to emphasize the structural difference between «modern» and Paleogene «*Truncorotalia*». He proposed the invalid genus *Pseudotruncorotalia* for the Paleogene group of angular-conical *Globorotalia* (see also HORNIBROOK, 1958).

In *Globorotalia truncatulinoides*, the test is almost smooth and finely porous, the peripheral keel is formed by an imperforate limbate rim as in *Globorotalia tumida* (see fig. 6, = «carina» in BANNER & BLOW, 1959). In Paleogene «*Truncorotalia*», the peripheral keel is merely formed by the accumulation of large spines on the periphery of the test, which may become partly fused to imitate a keel-like appearance (see figs. 8–11, = «pseudocarina» in BANNER & BLOW, 1959). In contrast to recent «*Truncorotalia*», the somewhat homeomorphic Paleogene species are relatively coarsely perforate with generally heavily spinose test.

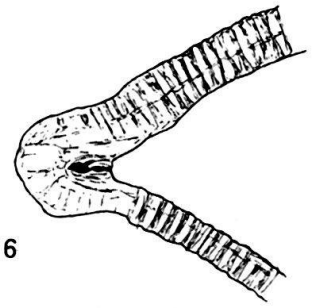


Fig. 6. *Globorotalia tumida* (BRADY), 1877, type-species of Globorotalia CUSHMAN, 1927. Specimen from the Recent, off Southern California (C 20552). Section through the keel in the first half of the last whorl, × 130.

Conscious of these differences, BERMUDEZ (1961) restricted *Truncorotalia* to forms related to *Globorotalia truncatulinoides* of late Neogene to recent age. The genus therefore resulted in being almost monotypic. The structural differences between recent forms of the *Globorotalia tumida* group and *Globorotalia truncatulinoides* are very insignificant, especially the aspect of the keel, the perforation and the surface of the test (see fig. 7). It is therefore proposed to abandon the genus, or subgenus, *Truncorotalia*. The wall structure of *Globorotalia* s.str. is thoroughly discussed by PESSAGNO (1964).

Fig. 7. *Globorotalia truncatulinoides* (D'ORBIGNY), 1839, type-species of *Truncorotalia* CUSHMAN & BERMUDEZ, 1949. Specimen from the Recent, off Southern California (C 20553). Section through the keel of the last chamber, × 130.

As shown above, *Pseudogloborotalia* HAQUE, 1956, is no planktonic genus and therefore cannot be used to include the Paleogene angular-conical *Globorotalia*.

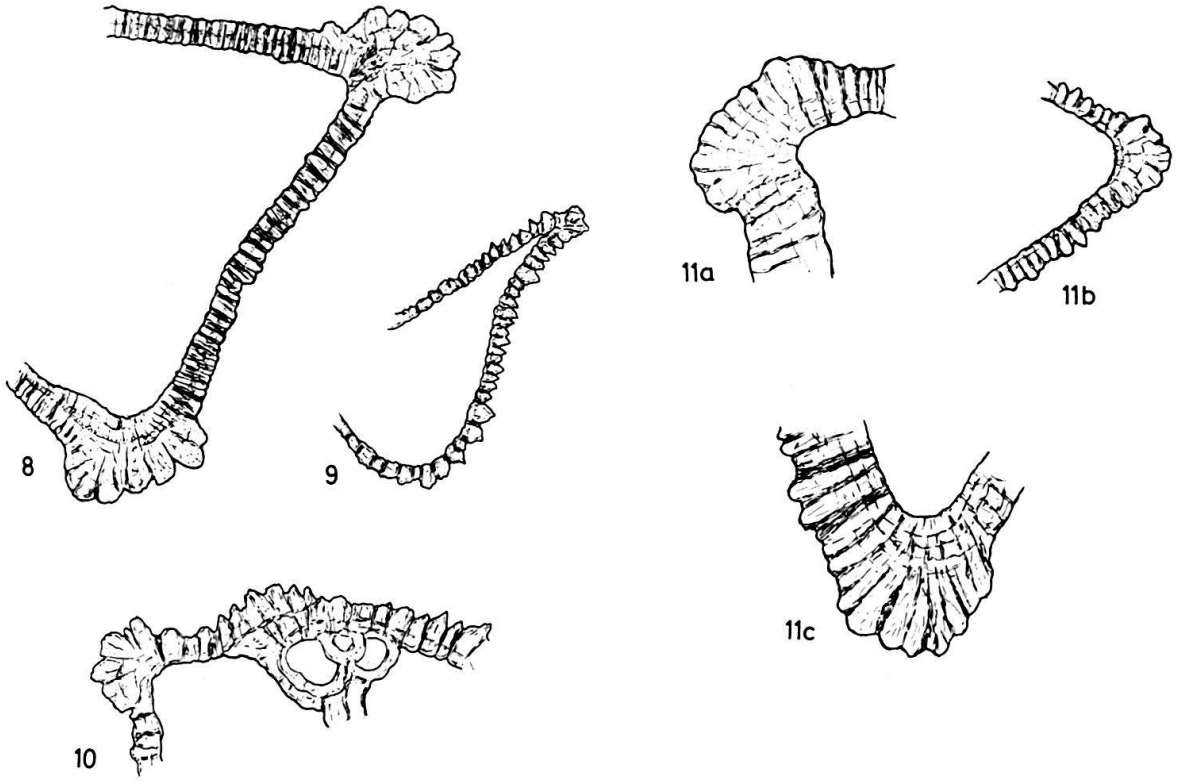


Fig. 8. *Globorotalia velascoensis* (CUSHMAN), 1925, type-species of *Morozovella* MCGOWRAN, 1964. Specimen from the Velasco formation, Globorotalia pseudomenardii zone, San José de Soto las Rusias, Eastern Mexico (C 20554). Section through the last chamber, × 130.

Fig. 9. *Globorotalia* sp. aff. *velascoensis* (CUSHMAN), «rachitic». Specimen from the Velasco formation, Globorotalia pseudomenardii zone, Tantoyuquita, Eastern Mexico (see p. 683) (C 20555). Section through the last chamber, × 130.

Fig. 10. *Globorotalia aragonensis* NUTTALL, 1930. Specimen from the type-sample of the Globorotalia aragonensis zone, Upper Lizard Springs formation, Trinidad (C 20556). Section through the first half of the last whorl, × 130.

Fig. 11. *Globorotalia caucasica* GLAESSNER, 1937. Specimen from the «zone of conical Globorotaliids», Northern Caucasus (leg. SUBBOTINA, C 20557). (a) Section through the keel in the first half of the last whorl, × 130. (b) Section through the keel of the last chamber, × 130. (c) Section through the umbilical chamber tip, × 130.

MCGOWRAN (1964 ms), giving a thorough discussion of the structure and the classification of *Globorotalia* has therefore erected the new genus *Morozovella* to designate the Paleogene angular-conical *Globorotalia*[3]). The diagnosis is as follows: «Test trochoid, coiling random to strongly preferential; chambers becoming laterally compressed, then more or less conical, during ontogeny, developing an angular margin and sometimes a strongly and irregularly thickened marginal keel, umbilical shoulders may become thickened; surface more or less roughened primarily, especially at margins; secondarily accentuated so that the test may become coarsely spinose or nodular at margins and on umbilical shoulders. Pores rather coarse and tending to funnel outwards, especially secondarily. Test umbilicate; aperture basal and umbilical, a low rimmed arch surrounded by a poreless area.»

[3]) The present writer is greatly indebted to Dr. MCGOWRAN for the permission to use the manuscript of his thesis.

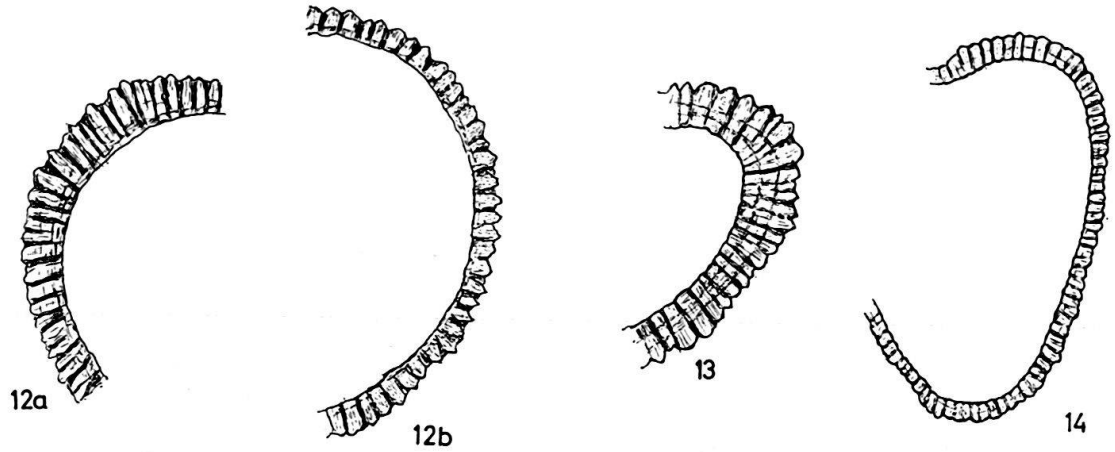


Fig. 12. *Globorotalia trinidadensis* BOLLI, 1957. Topotype from the Globorotalia trinidadensis zone, Lower Lizard Springs formation, Trinidad (C 20558). (a) Section through the chamber wall in the first half of the last whorl, × 130. (b) Section through the last chamber, × 130.

Fig. 13. *Globorotalia praecursoria* (MOROZOVA), 1957. Specimen from the «Acarinina schachdagica subzone», Lower Paleocene, northwestern Crimea (leg. KRASHENINNIKOV, C 20559). Section through the chamber wall in the first half of the last whorl, × 130.

Fig. 14. *Globorotalia uncinata* BOLLI, 1957. Topotype from the Globorotalia uncinata zone, Lower Lizard Springs formation, Trinidad (C 20560), ×130.

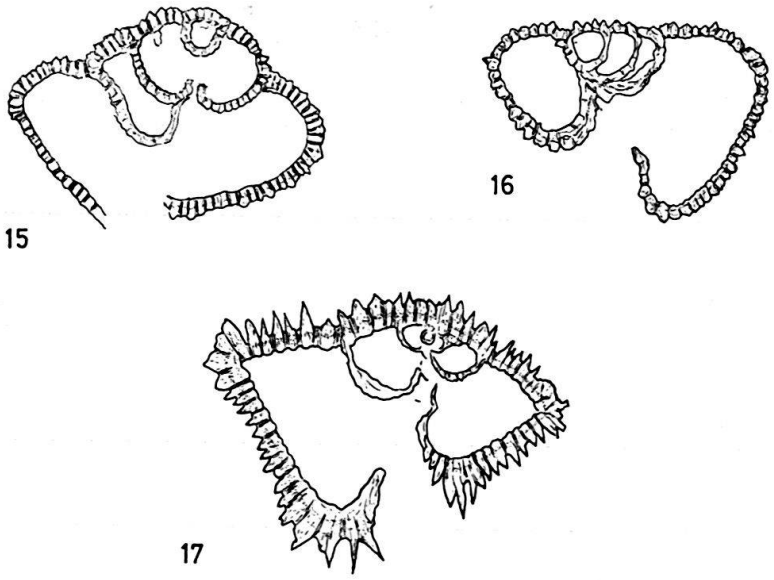


Fig. 15. *Globorotalia tadjikistanensis djanensis* SHUTZKAYA (ms). Specimen from the Globorotalia tadjikistanensis djanensis zone, Northern Caucasus (leg. SHUTZKAYA, C. 20561). Axial section, × 130.

Fig. 16. *Globorotalia aequa* CUSHMAN & RENZ, 1942. Juvenile (?) specimen from the Soldado Rock, Trinidad (C 20562). Axial section, × 130.

Fig. 17. *Globorotalia* sp. Specimen from «Tertiäre Leimern», Hohe Kugel, Vorarlberg, Western Austria (Coll. of the Geol.-Pal. Institute, Basel).

BRÖNNIMANN & BERMUDEZ (1953) included in *Truncorotaloides* all «*Globorotalia*» with secondary sutural apertures on the spiral side. Relict sutural apertures on the spiral side may be observed in well preserved *Globorotalia*, such as from the

Farafrah shales (Middle Paleocene) (see fig. 18). MOROZOVA (1958) mentions sutural apertures on the spiral side of *Globorotalia caucasica* and *Globorotalia pentacamerata* from the Middle Eocene. It is possible that relict apertures on the spiral side may remain open in species occurring at different stratigraphical levels. *Truncorotaloides* seems therefore to be a very heterogenetic genus. *Truncorotaloides topilensis* of the Middle Eocene is quite an aberrant form.

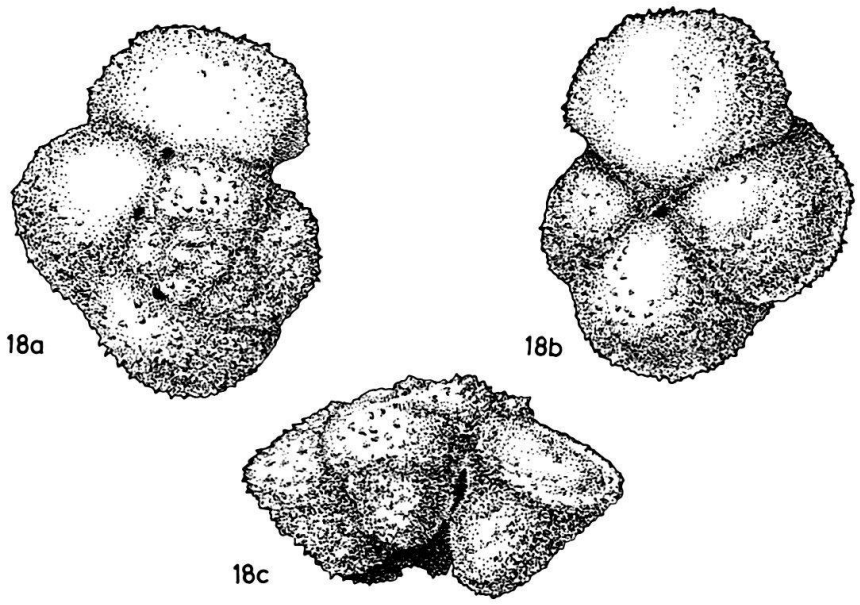


Fig. 18a–c. *Globorotalia* sp., with sutural apertures on the spiral side (C 20562). El Quss Abu Said (WD 116), Farafrah Oasis, Egypt, Globorotalia pseudomenardii zone.

HOFKER (1956, 1960, e.g.) emphasized the fundamental differences in the structure of the test between keeled *Globorotalia* and *Globigerina* s.l. In the latter, he included also such forms as *Globorotalia centralis*. Following this author, the capacity for floating is supported in «true» *Globorotalia* by a fan of protoplasma, attached to the poreless peripheral margin. In *Globigerina*, flotability is due to rigid fibres of protoplasma, coated to the more or less prominent spines of the test. HOFKER therefore considers *Globorotalia* not to derive from *Globigerina*-like ancestors, but from forms related to *Globorotalites*. In planktonic foraminifera, the wall structure may change during ontogenesis (see e.g. RHUMBLER, 1909). Also in Paleogene keeled *Globorotalia*, the whole test may be covered with large spines (see fig. 17, e.g.), which seem to have the same function as in *Globigerina*.

A direct deduction of *Globorotalia* from Upper Cretaceous species seems not very probable to students who have worked with continuous sections with fully developed planktonic foraminifera, in which the continuous change from *Globigerina* to heavily keeled *Globorotalia* may be observed almost step by step. In the lowermost Paleogene, no forms are known which could serve as intermediate link between *Globotruncana* of the *Globotruncana rosetta* group and such *Globorotalia* as *Globorotalia conicotruncata* (SUBBOTINA, 1953, 1960). «*Truncorotalia*» *mosae* HOFKER is no planktonic foraminifera. The lowermost Paleocene is characterized by the exclusive survival of primitive and unspecialized planktonic foraminifera (see e.g.

MOROZOVA, 1960, 1961, PREMOLI SILVA & LUTERBACHER, 1964), from which all Tertiary and recent planktonic foraminifera have evolved. For this reason, the association of *Acarinina* and *Turborotalia* together with *Rugoglobigerina* in the same subfamily *Rugoglobigerininae* (SUBBOTINA, 1959 in ORLOV, 1959) is to be rejected.

An ideal classification should satisfy two main purposes:

a) it should reflect the phylogenetic relationships,
b) it has to be suitable for practical work.

Classifications of planktonic foraminifera, prior to 1957, have been discussed by BOLLI, LOEBLICH & TAPPAN, 1957. The classification proposed by these authors fulfils the demands of practical work. It is logically founded on a clear hierarchy of morphologic features. In this classification, the main character of generic rank is the shape and position of the apertures, whereas such characters as relative proportions and shape of the test and the chambers are given only specific rank.

In the case of *Globorotalia*, this conception leads to a lumping, based on the umbilical-extraumbilical position of the aperture, of such different forms as *Globorotalia pseudobulloides*, *Globorotalia velascoensis*, *Globorotalia centralis* and *Globorotalia pseudomenardii* in one and the same genus.

The interpretation of the taxonomic importance of morphological features is very subjective and therefore widely open to controversy. SIGAL (1958) opposed the overwhelming importance given to the position of the aperture in comparison to other characters.

A classification of planktonic foraminifera based on quite different principles was introduced in 1959 by BANNER & BLOW. The species discussed in this paper are grouped in the subfamily *Globorotaliinae*, which is characterized by a trochoid test and an umbilical-extraumbilical aperture.

The following genera and subgenera are recognized within this subfamily:

genus *Globorotalia*
  subgenus *Globorotalia*
  subgenus *Turborotalia*
  subgenus *Hastigerinella*
genus *Truncorotaloides*
genus *Pulleniatina*

Although BANNER & BLOW claimed their classification to be more «biological» than the one proposed by BOLLI, LOEBLICH & TAPPAN, it seems somewhat astonishing to define *Hastigerinella* as a subgenus of *Globorotalia*.

In the classification published by LOEBLICH & TAPPAN (1964) in the «Treatise on Invertebrate Paleontology», *Turborotalia* (in which *Acarinina* is included as synonymous) is recognized as distinct genus, whereas the genus *Globorotalia* is restricted to keeled forms.

MCGOWRAN (1964 ms) classified «*Globorotalia*» as follows:

subfamily *Globorotaliinae*
  genus *Globorotalia*
    subgenus *Turborotalia*
    subgenus *Globorotalia* s.str.

genus *Planorotalia*
genus *Truncorotaloides*
subgenus *Acarinina*
subgenus *Morozovella*
subgenus *Truncorotaloides* s.str.

McGowran is separating the Paleogene group of *Morozovella*, *Acarinina*, *Truncorotaloides* and *Planorotalia* from the modern *Globorotalia* as «phyletically independent and morphologically distinguishable» group. As a result of this consequent splitting, the genus *Globorotalia* is completely banished from the Paleogene. The two groups are separated by the Upper Eocene and the Oligocene, in which similar species are likely to be missing.

From the point of view of the present writer, it is questionable whether the morphologic differences between Paleogene and Neogene *Globorotalia* are really significant enough to abolish the use of *Globorotalia* as the generic name for such species as *Globorotalia velascoensis* or *Globorotalia angulata* which should now be called *Truncorotaloides* (*Morozovella*) *velascoensis* and *Truncorotaloides* (*Morozovella*) *angulata*. For the sake of stability of names, the present author prefers to maintain *Globorotalia* also for the Paleogene species. (G. Thomas, 1956, p. 30: «Practical considerations demand that genera, wholly subjective and widely used in field paleontology, should be left undisturbed as much as possible.») The introduction of more and more new generic names is an unnecessary complication for all those workers who are not specialized enough to follow all the tortuous paths of generic classification in planktonic foraminifera.

One possible way to escape this taxonomic dilemma would be the application of subgeneric classification: to use *Globorotalia* s.l. as the generic name and adding subgeneric names to give more precision. It may, however, be questioned whether this complication of taxonomy is necessary and advisable. For practical work, it is of little importance whether the species *Globorotalia velascoensis* is additionally labelled as «*Truncorotalia*», «*Pseudogloborotalia*», «*Acarinina*» or «*Morozovella*». The problem of whether the classification reflects the effective phylogenetic relationship or not, is reduced if a subgeneric classification is applied, but it does not change its principle character. Also the generic and subgeneric classification as used by McGowran is based on morphological groups of polyphyletic origin. The step from *Globigerina* to «*Acarinina*», from «*Acarinina*» to «*Morozovella*» has occurred several times during the evolution of these forms during the Paleogene. They are, in almost all stratigraphical levels, interrelated by intermediate species, which have been iteratively developed.

The consequent application of a generic or subgeneric splitting of *Globorotalia* s.l. – based on the use of different generic names for each group of homeomorphic forms which have been repeatedly differentiated during the Tertiary – would lead to the introduction of more and more generic names, justified by the more or less individual and subjective interpretation of phylogenetic relations among planktonic foraminifera.

For practical reasons, this author prefers to maintain *Globorotalia* – as defined by Bolli, Loeblich & Tappan (1957) – as only taxon of generic rank, in spite of

this definition lumping together species of different phylogenetic origin. He is fully aware that the above interpretation is a subjective one, and that other solutions of this taxonomic problem are also justified.

On the species concept in Paleogene *Globorotalia*

In the planktonic foraminifera, the concept of species is subject to large variation. Forms considered by one specialist as distinct species of stratigraphical importance may be classified by others as intraspecific variations.

This multiplicity of opinions is no tragedy, as long as the species concept is clearly stated by the authors and may therefore serve as a basis for subsequent evaluation by others (see G. THOMAS, 1956). Too loose definitions of species are reducing their stratigraphical value, although such a wide interpretation may be justified from a theoretical point of view. K. YOUNG (1960) defined the term species for use in paleontology as follows: «...any group of fossils which differ morphologically from other fossils of the same genus and which occupy a certain level». The choice of the morphological features characterizing such a group is due to the personal interpretation of each specialist and therefore in great part subjective. This author fully adopts the statement of W. J. ARKELL (1956): «Thus the only logical criterion for the size and definition of the taxon in paleontology is its usefulness. To be useful, it should not unite too many forms that can be distinguished, and should not split up a group of forms so as to give an unnecessary crowd of names.»

Whereas conservatism is to be preferred in generic classification, the elaboration of a detailed stratigraphic subdivision demands precisely defined species. The more restricted the group of forms which are to be labelled by the same species name for mainly mnemonic reasons, the more such species will become a refined instrument for stratigraphical work. Nevertheless, the danger of creating «stratigraphic» species, which are not based on sufficiently justified morphological criteria, is imminent.

On the other hand, this will lead to an increasing crowd of specific names, the application of which will become more and more unwieldy for workers who are not specialized enough in the materia.

The taxonomic characters of planktonic foraminifera have been extensively discussed by SUBBOTINA (1953), BOLLI, LOEBLICH & TAPPAN (1957) and MOROZOVA (1958). A few specific characters of *Globorotalia* may nevertheless be discussed here. They may be divided into two main groups:

1. Shape of the test
2. Ornamentation

1. Shape of the test

Paleogene *Globorotalia* range from *Globigerina*-like to conicotruncate forms. The transition from spheroidal to angular-conical chambers is often observed in the same individual. Early chambers of the inner whorls are always *Globigerina*-like and the youngest chambers of the last whorl may recover again an undifferentiated

spheroidal shape. The contour of the peripheral margin is related to the number of chambers in the last whorl, the rate of increase in size of the chambers, and the tightness of coiling. The last chamber shows often abnormal growth; it may be smaller in size than the preceding one («senile») and change its position to the general level of coiling. This great variability of the youngest chamber makes it inappropriate for a character of specific rank. The typical shape of chambers is observed best in the early chambers of the last whorl.

The width of the umbilicus is related to the tightness of coiling and, to a minor extent, to the degree of convexity of the spiral side. In forms with wide umbilicus, all chambers are generally attached at the same level. The relation between the diameter of the last whorl and that of the inner whorls shows no major discrepancy in these forms. The number of chambers in the last whorl is given specific rank only as far as it influences the general shape of the test.

2. Ornamentation

The gradual development of a keel may occur in one individual. It is due to secondary thickening of the peripheral margin by concentration of spines and therefore can best be observed in the earlier chambers of the last whorl. The surface ornamentation is subject to the state of preservation. It should therefore be given specific rank only in combination with other characters. The youngest chambers remain very often smooth. The same is observed during the development of the thickenings on the umbilical chamber tips («umbilical collar»).

The ornamentation of the sutures depends to some extent on the arrangement of the chambers. In species with imbricated attachment of the chambers, sutures are depressed and strongly curved. In some species, the sutures form a characteristic angle with the periphery. The sutures separating the youngest chambers are less valuable as specific characters.

As a rule, a species should not be defined on one single character, but on a combination of several characters. The variation of one character might best be interpreted as an intraspecific variation. Nevertheless, it has to be noted that most of the characters are strongly interdependent and therefore difficult to express by statistical methods. The present writer has therefore preferred to document his views on intraspecific variation by illustrations rather than by statistics.

Description of the species

In the following systematic descriptions, the species are arranged in different groups. This arrangement is in great deal inspired by the paper of ALIMARINA (1963), in which she described the development of the planktonic foraminifera in the Lower Paleogene of the Northern Caucasus. In the present paper, the attribution of the species to such groups is based on morphological characteristics, although species intermediate between two groups have been placed in one of these groups on a rather arbitrary basis.

Phylogeny of Paleogene *Globorotalia* has been already discussed by several authors (among others BOLLI (1957), SUBBOTINA (1953, 1960), SHUTZKAYA (1956), ALIMARINA (1963), BERGGREN (1964)). In planktonic foraminifera, the recognition of phylogenetic lineages encounters more difficulties than in larger foraminifera

(e.g. *Nummulites*, Fusulinids). The size of the tests and the development of supplementary shell structures (ornamentation, etc.) are limited by the needs of flotability. Repeated realisation of homomorphic forms may mask phylogenetic relations. In addition, the dependence of morphology on environment has not yet been sufficiently studied. For instance, forms related to *Globorotalia velascoensis*, abundant in the sections of the Central Apennines, are almost absent in more boreal regions. On the other hand, the group of *Globorotalia subsphaerica* (see ALIMARINA, 1963), which is abundant in the Southern Soviet Union, is represented very poorly in Central Italy. The faunal composition may be different already between neighbouring sections. Among species not having a similar distribution and frequency within the studied sections, *Globorotalia formosa formosa* and *Globorotalia pentacamerata* may be mentioned.

At the present stage of knowledge, the writer is not attempting phylogenetic interpretation of the studied species. Too many problems need a more detailed research.

1. Globorotalia inconstans group

According to ALIMARINA (1963), the first stage in the development of planktonic foraminiferal fauna during the Paleocene and Lower Eocene is represented by the *Globigerina pseudobulloides* group, whereas the second stage is characterized by the group of *Globorotalia inconstans*. The latter group evolved from the primitive stock of lowermost Tertiary Globigerinids and represents the transition towards the more specialized *Globorotalia* of the Middle Paleocene.

The characters of the *Globorotalia inconstans* group are still very similar to *Globigerina*, but the distinct umbilical-extraumbilical position of the aperture places them in the genus *Globorotalia*. In the more primitive representatives, such as *Globorotalia inconstans*, all the chambers are still spherical. In the more advanced forms, however, the first chambers of the last whorl become first subrounded and later angular-conical. Simultaneously, the spinosity of the tests gets more differentiated and is more prominent on the periphery and the umbilical side. The spiral side is always more flattened than the umbilical one. Species such as *Globorotalia uncinata* mark the transition to the next higher *Globorotalia angulata* group.

The following species belong to the *Globorotalia inconstans* group (the species are listed with their original generic designation):

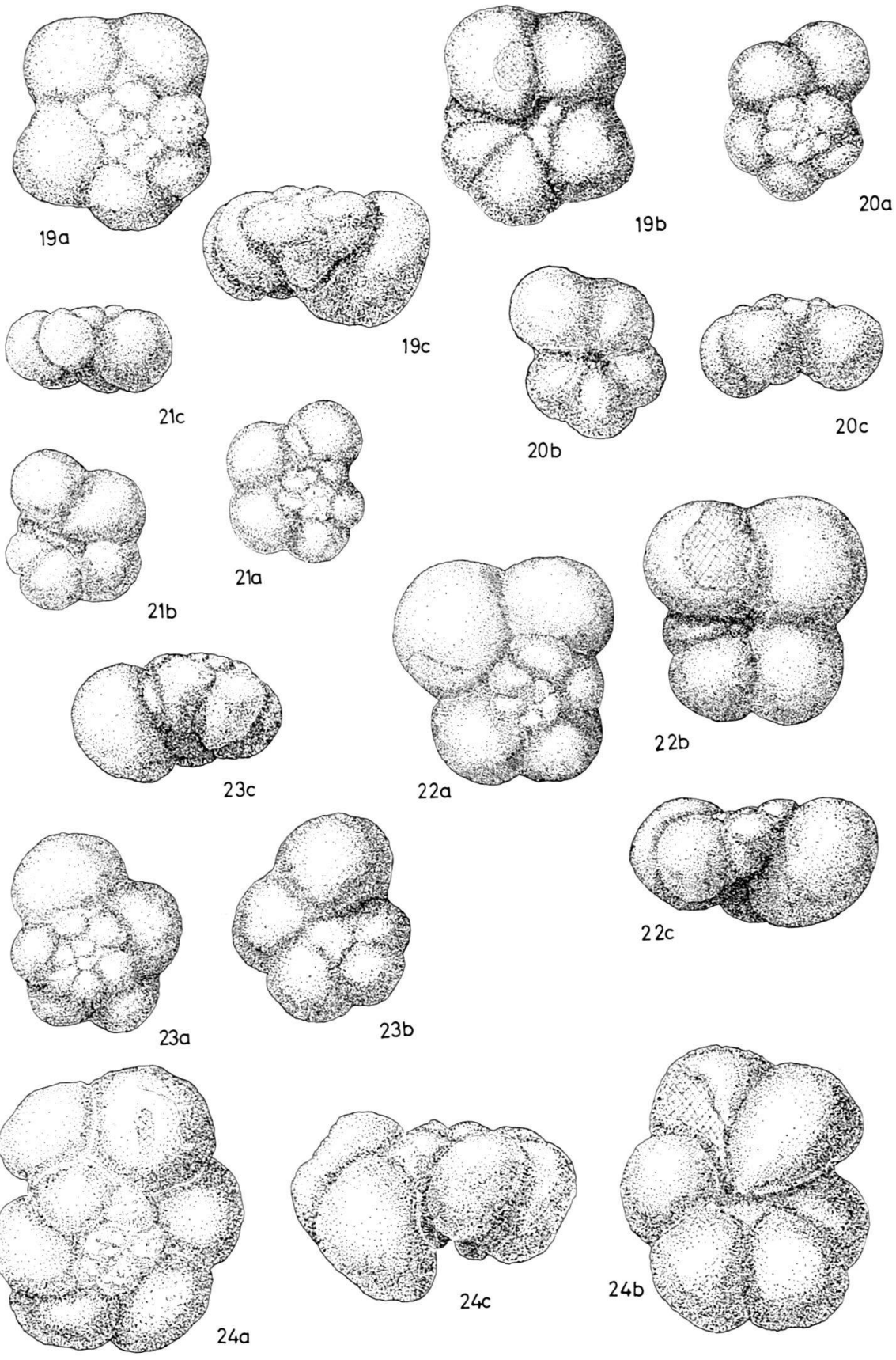
Globigerina inconstans SUBBOTINA, 1953
Globigerina schachdagica CHALILOV, 1956
Globorotalia trinidadensis BOLLI, 1957
Globorotalia uncinata BOLLI, 1957

Figs. 19 and 23. *Globorotalia inconstans* (SUBBOTINA), 1953. Topotypes from the «zone of rotaloid Globorotaliids», upper part of Elburgan svita, Kuban river, Northern Caucasus (leg. SUBBOTINA, C 20563, C 20564), × 75.

Figs. 20 and 22. *Globorotalia inconstans* (SUBBOTINA), 1953. Gubbio section, level G-86 (C 20565, C 20566), × 75.

Fig. 21. *Globorotalia inconstans* (SUBBOTINA), 1953. Gubbio section, level G-89 (C 20567), × 75.

Fig. 24. *Globorotalia schachdagica* (CHALILOV), 1956. Middle part of the «Acarinina inconstans» zone, western Turkmenia, USSR (det. et leg. SHUTZKAYA, C 20568), × 75.


19a
19b
20a
19c
21c
20b
20c
21a
21b
22b
23c
22a
22c
23a
23b
24a
24c
24b

Globorotalia perclara LOEBLICH & TAPPAN, 1957
Acarinina praecursoria MOROZOVA, 1957
Acarinina indolensis MOROZOVA, 1959
Globigerina scabrosa BERMUDEZ, 1961
Globigerina scobinata BERMUDEZ, 1961
Acarinina multiloculata MOROZOVA, 1961
Acarinina primitiva MOROZOVA, 1961
Globigerina (Globigerina) pseudobulloides subquadrata MOROZOVA, 1961

Globorotalia inconstans (SUBBOTINA), 1953

Figs. 19–23

Globigerina inconstans n. sp. – SUBBOTINA, 1953, pp. 58–59, pl. III, figs. 1a–c, 2a–c.
Globorotalia (Acarinina) inconstans (SUBBOTINA) – LEONOV & ALIMARINA, 1961, pl. III, figs. 2, 5–8.

Description (see SUBBOTINA, 1953)

Test composed of 12–14 globular to ovoid chambers, arranged in 2–2 1/2 whorls. Periphery broadly rounded, lobulate. 5–6 chambers in the last whorl, which increase fairly rapidly in size as added. Last chamber may be considerably larger than preceding one. Sutures on both sides depressed, straight, or slightly curved on spiral side. Umbilicus well developed, but shallow. Spiral side flattened, inner whorls small, depressed, often indistinct. Aperture a low umbilical-extraumbilical arch. Structure of the wall relatively coarsely perforate, almost smooth, undifferentiated.

Variability

In the original description, SUBBOTINA attributes to this species a large range of variability. Besides forms with 5–5 1/2 chambers in the last whorl, specimens with 6 or even 7 chambers occur. Characteristic for the species is the disproportion in size between the inner and the last whorl. Specimens with 6 or 7 chambers in the last whorl may possess – according to SUBBOTINA (1953) – 3 last chambers of the same size, with the youngest chamber displaying a «bubble-like» appearance. Its wall structure is not changing (see also LOEBLICH & TAPPAN, 1957, pl. 44, fig. 2). ALIMARINA (1963) and LEONOV & ALIMARINA (1961) attribute to *Globorotalia inconstans* an even larger interpretation, including in its synonymy also *Globorotalia trinidadensis* and, moreover, the specimen intermediate between *Globigerina pseudobulloides* and *Globorotalia uncinata* figured by BOLLI (1957, pl. 17, figs. 16–18). Following SUBBOTINA (1960), *Globigerina varianta* is the ancestor of *Globorotalia inconstans*.

Stratigraphical distribution

This species has been first described by SUBBOTINA from the upper Elburgan horizon of the Kuban river section in the central part of the Northern Caucasus. These beds, which SUBBOTINA considered to be of Danian age, are likely to correspond to the Globorotalia trinidadensis or the Globorotalia uncinata zone. ALIMARINA (1963) restricts the distribution of her *Acarinina inconstans* group to the lower part of the Elburgan svita. (The Russian term «svita» does not correspond to «formation», see KRASHENINNIKOV & PONTZARKOV, 1964.)

In the section of Gubbio, *Globorotalia inconstans* occurs first in level G-91 and ranges up to the level G-83, with its main development between G-90 and G-86. Coiling is random throughout its range.

The type-level of *Globorotalia inconstans* in the Northern Caucasus seems to be younger than the layers, in which the species shows its main distribution in the Central Apennines.

HILLEBRANDT (1962) mentions *Globorotalia inconstans* from his zone B, which he correlates with the Globorotalia uncinata zone. It is said to occur together with *Globorotalia ehrenbergi*. In the section of Gubbio, this latter species starts at the level G-84. The inclusion of *Globorotalia uncinata* in the synonymy of *Globorotalia inconstans* indicates the misinterpretation of this species by HILLEBRANDT.

The generic attribution of *Globorotalia inconstans* is based on the umbilical-extraumbilical position of the aperture, whereas the general shape of the test remains *Globigerina*-like. ALIMARINA (1963), who re-examined the holotype, places this species to *Acarinina*.

Globorotalia trinidadensis BOLLI, 1957

Figs. 26–29

Globorotalia trinidadensis n. sp. – BOLLI, 1957, p. 73, pl. 16, figs. 19–21.
Globorotalia trinidadensis BOLLI – BOLLI & CITA, 1960, pp. 389–90, pl. XXXV, fig. 1a–c.

Description (see BOLLI, 1957)

Test composed of 14–18 chambers, arranged in $2^1/_2$ whorls, with 5 to 8 (mostly 6) chambers in the last whorl. Coiling low trochospiral, inner whorl very often slightly depressed on the spiral side. Chambers of the last whorl increasing slowly in size. Last chamber often slightly detached from the previous one by deeper sutures, umbilicus so wide that sometimes parts of chambers of the inner whorl are still visible. Aperture umbilical-extraumbilical, with small lip. Chambers pear-shaped to globular, surface of inner whorl and 2–3 oldest chambers of the last whorl covered with well developed rugosities, which may become somewhat more concentrated at the periphery. Wall structure relatively coarsely perforate (figs. 12a, b).

Variability

Variable characters are the number of chambers in the last whorl (5–8), moreover the size and shape of the youngest chamber, which may become considerably smaller in size than the preceding one.

Globorotalia trinidadensis differs from *Globorotalia inconstans* by more chambers in the last whorl, by a more flattened, sometimes even depressed spiral side and by a less smooth surface of the test.

The species differs from the closely related *Globorotalia praecursoria* in having less rugose inner whorls. The periphery of the early chambers of the last whorl is less ornamented and the sutures are less strongly curved backwards between the early chambers of the last whorl on the spiral side than in *Globorotalia praecursoria*. In the latter species, the early chambers of the last whorl show already a distinct tendency towards an angular-conical shape.

HILLEBRANDT (1962) supposed *Globorotalia trinidadensis* to be synonymous to *Globigerina edita* SUBBOTINA. This species, however, is higher trochospiral, has only $4^1/_2$–5 chambers in the last whorl, is distinctly smaller in size and has different proportions between the size of chambers of inner and outer whorls. *Globigerina edita* occurs at a lower stratigraphical level than *Globorotalia trinidadensis*.

Stratigraphical distribution

In the Lower Lizard Springs formation of Trinidad (BOLLI, 1957), *Globorotalia trinidadensis* ranges from the Globorotalia trinidadensis zone to the Globorotalia uncinata zone. BOLLI & CITA (1960) observed an analogous distribution in the Scaglia of Paderno d'Adda (Northern Italy).

In the Northern Caucasus, forms which occur within the upper part of the Globorotalia inconstans subzone (ALIMARINA, 1963) may belong to this species. They have been figured by LEONOV & ALIMARINA (1961), pl. III, figs. 1a–c, 3a–c) and named as *Globorotalia* (*Acarinina*) *inconstans*. *Globorotalia trinidadensis* is present in the Dn_2III of Northwestern Crimea.

HAY (1960) recorded *Globorotalia trinidadensis* from the basal Velasco formation of Eastern Mexico.

In the section of Gubbio, *Globorotalia trinidadensis* ranges from G-89 to G-84, with a maximum development at G-86.

Globorotalia trinidadensis may have evolved from forms related to *Globorotalia inconstans* by increasing its number of chambers and by developing a more differentiated ornamentation.

Globorotalia praecursoria (MOROZOVA), 1957

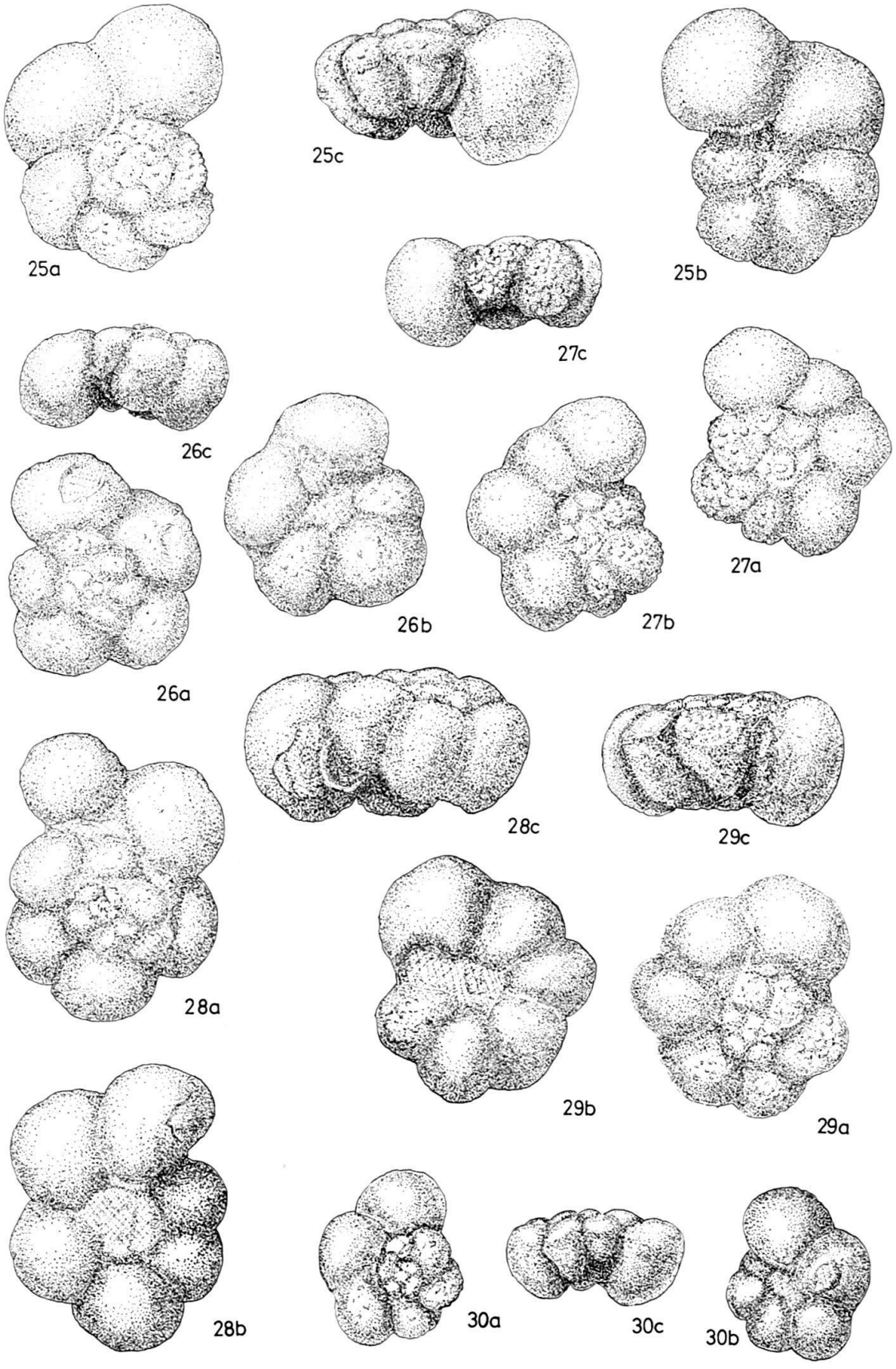
Fig. 25

Acarinina praecursoria n. sp. – MOROZOVA, 1957, p. 1111, fig. 1.

Description (see MOROZOVA, 1957)

Test low trochospiral, with flattened spiral side, composed of $2^1/_2$ whorls with 5–$7^1/_2$ chambers in the last whorl. Peripheral outline lobulate. The first 2–3 chambers of the last whorl are distinctly angular-conical, the younger ones globular. Chambers of the last whorl increasing relatively slowly. Sutures on umbilical side straight and depressed, on the spiral side depressed, in the beginning of the last whorl strongly curved backwards, later radial. The first 2 or 3 chambers of the last whorl are somewhat imbricated on the spiral side. Umbilicus fairly wide. Aperture slit-like, umbilical-extraumbilical, with small lip visible in well preserved specimens.

Fig. 25. *Globorotalia praecursoria* (MOROZOVA), 1957. Globoconusa daubjergensis/Acarinina indolensis zone (Dn_2III), Tarkhankut, northwestern Crimea (leg. KRASHENINNIKOV, C 20569), × 75.
Figs. 26 and 27. *Globorotalia trinidadensis* BOLLI, 1957. Topotypes, type-sample of Globorotalia trinidadensis zone (TLL 192632), Lower Lizard Springs formation, Trinidad (C 20570, C 20571), × 75.
Figs. 28 and 29. *Globorotalia trinidadensis* BOLLI, 1957. Gubbio section, level G-86 (C 20572, C 20573), × 75.
Fig. 30. *Globorotalia uncinata* BOLLI, 1957. Gubbio section, level G-85 (C 20574), × 75.


25a
25c
25b
27c
26c
26b
27b
27a
26a
28c
29c
28a
29b
29a
28b
30a
30c
30b

Test rugose, especially in the inner whorl and in the oldest chambers of the last whorl. Last chamber almost smooth. Ornamentation concentrated on the peripheral margin and on the umbilical shoulders of the chambers. Wall coarsely perforate, with heavy secondary layers in the older chambers (fig. 13).

Variability

Variable characters are the number of chambers in the last whorl (5–7 1/2, predominantly 6) and the shape and size of the last chamber. Diagnostic for the species are the angular-conical shape of the early portion of the last whorl, the imbricated appearance of the chambers and the differentiation in the distribution of the ornamentation.

Stratigraphical distribution

Globorotalia praecursoria was first described by MOROZOVA from beds with *Echinocorys sulcatus* of the Northern Caucasus. In Northwestern Crimea, the species ranges from zone Dn_2III^2 to zone Ms V (Morozova, 1961).

Following ALIMARINA (1963), *Globorotalia praecursoria* has its main distribution in the upper part of the Acarinina inconstans zone (= Acarinina praecursoria subzone).

In the Gubbio section, this species is very rare (G-86, G-84, G-83, G-81 = top of Globorotalia trinidadensis zone to base of Globorotalia pusilla pusilla zone).

Globorotalia schachdagica (CHALILOV), 1956

Fig. 24

Globigerina schachdagica n. sp. – CHALILOV, 1956, p. 246, pl. 1, fig. 3a–c.

Description (see CHALILOV, 1956, also ELLIS & MESSINA, Catalogue of Foraminifera, supplement 1963, No. 1)

The main features of this species are the pear-shaped chambers and the abnormal position of the last chamber, which tends to overlap the umbilicus. The youngest chamber may be considerably smaller than the previous one.

These characteristics distinguish the species easily from all the other species of the *Globorotalia inconstans* group.

Stratigraphical distribution

Globorotalia schachdagica is first described by CHALILOV from the Lower Paleocene of the Azerbaidzhan S.S.R. In Northwestern Crimea, it represents the marker for the subzone Dn_2III^2, where this species occurs together with *Globorotalia praecursoria* and primitive *Globorotalia angulata* (MOROZOVA, 1961).

The figured specimen derives from the middle part of the Globorotalia inconstans zone of Western Turkmenia, U.S.S.R.

In the section of Gubbio, *Globorotalia schachdagica* is rarely found in level G-85 (base of Globorotalia uncinata zone).

Globorotalia sp. aff. *perclara* LOEBLICH & TAPPAN, 1957

Figs. 32, 35, 36

aff. *Globorotalia perclara* n. sp. – LOEBLICH & TAPPAN, 1957, p. 191, pl. 42, fig. 4a–c.

Description

This species is characterized by a low trochospire, fairly wide umbilicus, slow increase in size of the older chambers and a distinct spinosity on the umbilical side. The last chamber may be considerably larger than the previous ones.

The numerous figures given of *Globorotalia perclara* in the original publication, show the great variability attributed to this species by its authors.

Stratigraphical distribution

The holotype of the species originates from the Lower Paleocene Brightseat formation (Maryland, U.S.A.). Moreover, it has been mentioned from several other Lower and Middle Paleocene formations of the Gulf and Atlantic coastal regions. Some occurrences, which LOEBLICH & TAPPAN thought to be of Upper Paleocene or Lower Eocene age, could be placed in the Middle Paleocene (GARDNER & HAY, 1962). OLSSON (1960) has figured the species from the Paleocene of New Jersey. The forms figured by BERGGREN (1962, pl. XI, figs. 2a–3c) from the Lower Eocene of Northwestern Germany belong to a different species.

In the Gubbio section, specimens which doubtfully may be attributed to this species start in G-82 and are well represented in the levels G-80–G-77 (Globorotalia pusilla pusilla zone to Globorotalia pseudomenardii zone).

Globorotalia uncinata BOLLI, 1957

Figs. 30, 31

Globorotalia uncinata n. sp. – BOLLI, 1957, p. 74, pl. 17, figs. 13–15.

Description (see BOLLI, 1957)

This species has strongly curved sutures on the spiral side, a relatively narrow umbilicus and subangular-conical chambers in the last whorl.

The number of chambers in the last whorl varies from 5–6. Additional variable characters are the shape and width of the umbilicus and the ornamentation.

Stratigraphical range

In the section of Gubbio, *Globorotalia uncinata* is represented by a few specimens (samples G-85–G-82). This restricted stratigraphic occurrence proves the great value of this species (see also BOLLI & CITA, 1960).

Remarks

A similar species is *Globorotalia indolensis* (MOROZOVA, 1959, p. 1114, fig. 1 d–f), first described as *Acarinina*, from the «Upper Danian» of Northwestern Crimea. This species has 4–5 chambers in the last whorl, which increase slowly in size with the exception of the last one, which is considerably larger. Coiling is tight. In specimens with only 4 chambers in the last whorl, the umbilicus is narrow and

almost closed by the protruding end of the last chamber. Shape of chambers angular conical, periphery of the test subangular. Sutures depressed, radial on umbilical side, curved on spiral side. Surface of the test finely spinose, without differentiation in ornamentation. Diameter of the holotype 0.275 mm. The figured specimens originate from the lower part of Dn_2III of Northwestern Crimea (figs. 33, 34).

Globorotalia indolensis differs from *Globorotalia uncinata* in having 4–5 instead of 5–6 chambers in the last whorl. The umbilicus is narrower and smaller in size. Following MOROZOVA (1961), *Globorotalia indolensis* is characteristic of the lower subzone (= Dn_2III^1) of the «Upper Danian» («Mitchurian») of Northwestern Crimea. ALIMARINA (1963) mentions *Globorotalia indolensis* from the lower and middle part of the Elburgan svita (= Globorotalia indolensis subzone).

The species has not been found in the Scaglia of the Central Apennines and Northern Italy. It is discussed here because it occurs in the Crimea earlier than *Globorotalia uncinata.* It represents the earliest form with angular-conical chambers.

Another species related to *Globorotalia uncinata* is *Globorotalia primitiva* (MOROZOVA) (*Acarinina primitiva* in MOROZOVA, 1961, p. 15, pl. II, fig. 1a–c). It is characterized by 4–$4^1/_2$ tightly coiled chambers in the last whorl, a slightly flattened spiral side and a narrow umbilicus. The shape of the chambers is oval and elongate in the axial direction. The distinct spinosity is concentrated on the umbilical tips and on the peripheral margin of the chambers. The species is somewhat comparable to *Globorotalia praecursoria,* but differs in having fewer chambers in the last whorl, tighter coiling and less differentiated spinosity.

Globorotalia primitiva ranges from Dn_1II to Dn_2III, and occurs in Northwestern Crimea and other regions of the Southern Soviet Union.

Some nomenclatorial confusion may be caused by shifting *Globoquadrina primitiva* FINLAY to the genus *Acarinina* (HILLEBRANDT, 1962).

Globorotalia indolensis and *Globorotalia primitiva* represent probably an independent lineage, and therefore are not related to the lineage which includes *Globorotalia pseudobulloides, Globorotalia uncinata* and *Globorotalia angulata* (BOLLI, 1957).

Species not discussed in this paper, but which probably belong to the *Globorotalia inconstans* group, are:

Globigerina scobinata BERMUDEZ, 1961, pp. 1197, pl. 5, figs. 6a, b, from the Paleocene Madruga formation of Cuba.

Fig. 31. *Globorotalia uncinata* BOLLI, 1957. Topotype, Globorotalia uncinata zone (KR 23575), Lower Lizard Springs formation, Trinidad (C 20575), × 75.

Figs. 32 and 35. *Globorotalia* sp. aff. *perclara* LOEBLICH & TAPPAN, 1957. Gubbio section, level G-81 C 20576, C 20577), × 75.

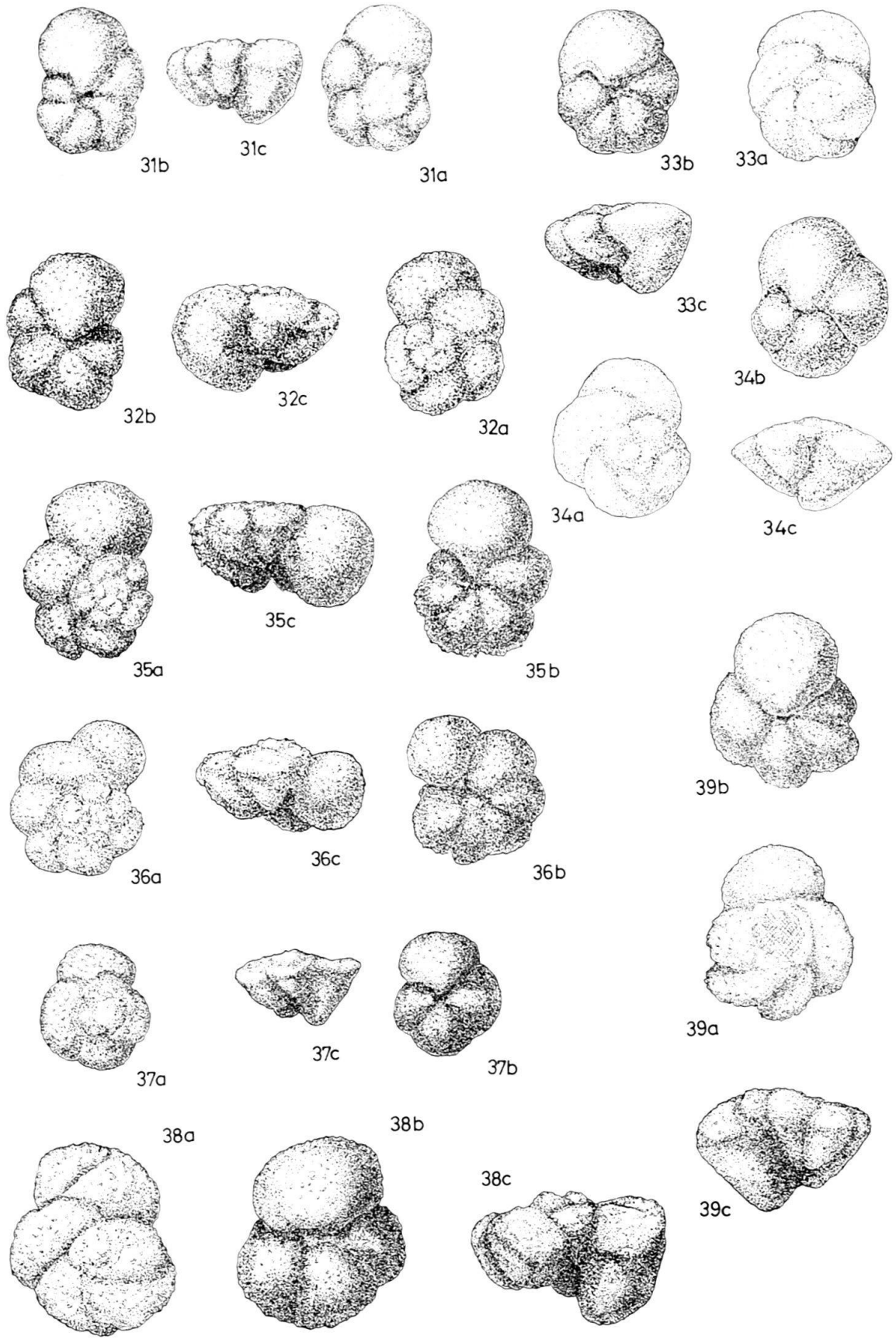
Figs. 33 and 34. *Globorotalia indolensis* (MOROZOVA), 1959. Acarinina indolensis subzone (Dn_2III_1), Tarkhankut, northwestern Crimea (leg. KRASHENINNIKOV, C 20578, C 20579), × 75.

Fig. 36. *Globorotalia* sp. aff. *perclara* LOEBLICH & TAPPAN, 1957. Gubbio section, level G-80 (C 20580), × 75.

Fig. 37. *Globorotalia angulata* (WHITE), 1928. Gubbio section, level G-78 (C 20581). × 75.

Fig. 38. *Globorotalia angulata* (WHITE), 1928. Gubbio section, level G-81 (C 20582), × 75.

Fig. 39. *Globorotalia angulata* (WHITE), 1928. Specimen with strongly imbricated chambers in the last whorl, Gubbio section, level G-82 (C 20583), × 75.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Globigerina scabrosa BERMUDEZ, 1961, p. 1196, pl. 5, figs. 5a, b, from the Paleocene of Veracruz, Mexico.
Globigerina (Globigerina) pseudobulloides subquadrata MOROZOVA, 1961, p. 14–15, pl. II, fig. 4, from the «Upper Danian» and «Montian» of the Southern Soviet Union.
Acarinina multiloculata MOROZOVA, 1961, pp. 15–16, pl. II, fig. 5, from the «Montian» of Crimea.
Globorotalia reissi LOEBLICH & TAPPAN, 1957, p. 194, pl. 58, fig. 3, from the Paleocene Aquia formation of Virginia (see also I. BANG, 1962).

2. *Globorotalia angulata* group

Globorotalia assigned to the group of *Globorotalia angulata* are intermediate between the globigerinid forms of the Lower Paleocene and the heavily keeled *Globorotalia* of the Middle and Upper Paleocene. Within the evolutionary stages, as distinguished by ALIMARINA (1963), this group corresponds more or less to the III stage, in which she includes *Acarinina angulata*, *Acarinina conicotruncata*, *Acarinina tadjikistanensis* and *Globorotalia kolchidica* as characteristic species. SUBBOTINA (1953) named this group «intermediate *Acarinina*». The common characters of all species placed in this group are the angular-conical to angular-rhomboidal chambers. In contrast to the *Globorotalia velascoensis* and the *Globorotalia aequa* groups, with which they share the angular-conical chambers, the development of the keel remains always modest. Species such as *Globorotalia kolchidica* are transitional towards the *Globorotalia aequa* group.

The following species and subspecies, belonging to the *Globorotalia angulata* group, will be discussed:

Globigerina angulata WHITE, 1928
Discorbina simulatilis SCHWAGER, 1883
Globorotalia conicotruncata SUBBOTINA, 1949
Globorotalia tadjikistanensis BYKOVA, 1953
Globorotalia angulata abundocamerata BOLLI, 1957
Globorotalia angulata kubanensis SHUTZKAYA, 1956
Globorotalia angulata praepentacamerata SHUTZKAYA, 1956
Globorotalia apanthesma LOEBLICH & TAPPAN, 1957
Globorotalia trichotrocha LOEBLICH & TAPPAN, 1957
Globorotalia strabocella LOEBLICH & TAPPAN, 1957
Globorotalia hispidocidaris LOEBLICH & TAPPAN, 1957
Globorotalia quadrata NAKKADY & TALAAT, 1959
Globorotalia crosswickensis OLSSON, 1960
Globorotalia kolchidica MOROZOVA, 1961.

Globorotalia angulata (WHITE), 1928

Figs. 37–39

Globigerina angulata n. sp. – WHITE, 1928, p. 191, pl. 27, fig. 13.
Globorotalia angulata (WHITE) – GLAESSNER, 1937, p. 383, pl. IV, fig. 35a–c.
Globorotalia angulata (WHITE) – BOLLI, 1957, p. 74, pl. 17, figs. 10–12.
Globorotalia angulata (WHITE) – LOEBLICH & TAPPAN, 1957, p. 187, pl. 45, figs. 7a–c, pl. 48, figs. 2a–c, pl. 55, figs. 6a–7c, pl. 64, figs. 5a–c.
Globorotalia quadrata n. sp. – NAKKADY & TALAAT, 1959, p. 491, pl. 4, fig. 1a–c.

Globorotalia angulata (WHITE) – BOLLI & CITA, 1960, p. 378, pl. XXXV, figs. 8a–c.
Truncorotalia angulata angulata (WHITE) – GOHRBANDT, 1963, p. 57, pl. 4, figs. 4–6.
Globorotalia (Truncorotalia) angulata (WHITE) – LEONOV & ALIMARINA, 1961, pl. V, figs. 2a–c, 7a–c.
Truncorotaloides (Morozovella) angulata (WHITE) – MCGOWRAN, 1964 (ms).

Description (see WHITE, 1928)

Test angular-conical with only slightly concave or flattened spiral side, peripheral angle 45°–70°. Periphery lobulate. Composed of 10–12 chambers arranged in $2^1/_2$ whorls. 4–5 chambers of the last whorl increasing rapidly in size. Last one comprising generally about $^1/_3$ of the whole whorl. The umbilical chamber tips are rounded and protruding over the relatively narrow and deep umbilicus. Last chamber distinctly higher than older ones, with its umbilical shoulder rising above the level of the others. Sutures depressed on both sides, radial on the umbilical, strongly curved on the spiral side. Spiral suture depressed, often indistinct in the inner whorl. Aperture typical for the genus, with usually only faintly developed lip. Surface of the test covered with fine spines, spinosity accentuated on the peripheral edge and the umbilical shoulders, where spines become quite blunt, but a distinct keel is not yet formed.

Size of the test relatively small, maximum diameter ranging from 0.25–0.40 mm, height 0.2–0.3 mm.

Variability

Variable characters are the number of chambers in the last whorl and the size of the last formed chamber. Specimens with a «senile» last chamber have been figured, e.g. by OLSSON (1960) and GLAESSNER (1937). A similar great variation shows the differentiation in ornamentation.

Relations and stratigraphical distribution

Globorotalia angulata was first described by WHITE in 1928 from the Paleocene Velasco formation of the Tampico Embayment. Topotypic material enabling an exact age determination of the type-level was not available to the writer.

In the original publication, WHITE includes in the synonymy of his new species the recent *Globorotalia* figured by BRADY (1884, pl. CIII, figs. 11a–c) as *Pulvinulina crassa* (= *Globorotalia punctulata* (D'ORBIGNY), following BARKER, 1960). Since the figure published from the holotype does not show all necessary details for an exact evaluation, WHITE's comparison with a recent species may serve to interpret his intentions concerning *Globorotalia angulata.*

Since 1928, *Globorotalia angulata* has been cited by many authors. GLAESSNER (1937) has given a broad range of variation to this species, based on material from the Northern Caucasus. He included in *Globorotalia angulata* also forms possibly belonging to *Globorotalia aequa* (pl. IV, figs. 36a–c) or *Globorotalia conicotruncata* (pl. IV, figs. 37a–c). SHUTZKAYA (1956) followed GLAESSNER's interpretation of this species and included in its synonymy also *Globorotalia conicotruncata* SUBBOTINA. She introduced, moreover, two new subspecies – *Globorotalia angulata praepentacamerata* (fig. 45) and *Globorotalia angulata kubanensis* (fig. 43) – to which later (1963) specific rank was given.

BOLLI (1957) included in *Globorotalia angulata* also specimens which in the present paper would be determined as *Globorotalia conicotruncata* and *Globorotalia simulatilis*. The stratigraphic range of *Globorotalia angulata*, in the Lower Lizard Springs formation of Trinidad, is given as upper Globorotalia uncinata zone and Globorotalia pusilla pusilla zone. A similar distribution has been observed by BOLLI & CITA (1960) in the Paleocene of Paderno d'Adda (Northern Italy).

LEONOV & ALIMARINA (1961) (see also ALIMARINA, 1963) included in *Globorotalia angulata* also forms which differ considerably from the conception of this species as adopted by the present writer (e.g. pl. V, figs. 3a–c, 5a–c, 9a–c). The main distribution is given as upper Globorotalia inconstans/Globorotalia angulata zone. A similar broad view of the species is advocated by GARDNER & HAY (1962), HILLEBRANDT (1962) and GOHRBANDT (1963).

MOROZOVA (1961) notes the first occurrence of this species in the Dn_2III^2 of Northwestern Crimea.

In the section of Gubbio, *Globorotalia angulata* is found first in level G-83, but here only in a restricted number of small specimens (maximum diameter 0.20–0.28 mm) with 5 chambers in the last whorl. Level G-83 is attributed to the Globorotalia uncinata zone. In sample G-82, the number of specimens and also their size has considerably increased (maximum diameter 0.22–0.37 mm). Coiling is about random, but becomes slightly preferential to sinistral in G-81. In G-79 and G-78, *Globorotalia angulata* occurs in relatively few specimens. In G-77, *Globorotalia angulata* has practically disappeared. Some specimens in the samples G-79 and G-78 show only 4 chambers in the last whorl, with a «senile» last chamber and already strong concentration of the spines at the peripheral margin, as in *Globorotalia quadrata* NAKKADY & TALLAT. Following the proposition by HILLEBRANDT (1962), the present writer includes the latter species in the synonymy of *Globorotalia angulata*.

Globorotalia conicotruncata SUBBOTINA, 1947

Figs. 40–42, 46–51

Globorotalia conicotruncata n. sp. – SUBBOTINA, 1947, pp. 115–117, pl. IV, figs. 11–19; pl. IX, figs. 9–11.

Acarinina conicotruncata (SUBBOTINA) – SUBBOTINA, 1953, pp. 220–222, pl. XX, figs. 6a–c, 7a–c, 8a–c, 10a–c.

Truncorotalia conicotruncata (SUBBOTINA) – SUBBOTINA, 1960, p. 33, fig. 2.

Globorotalia (*Acarinina*) *conicotruncata* SUBBOTINA – LEONOV & ALIMARINA, 1961, pl. VI, figs. 1a–c, 2a–c, 3a–c.

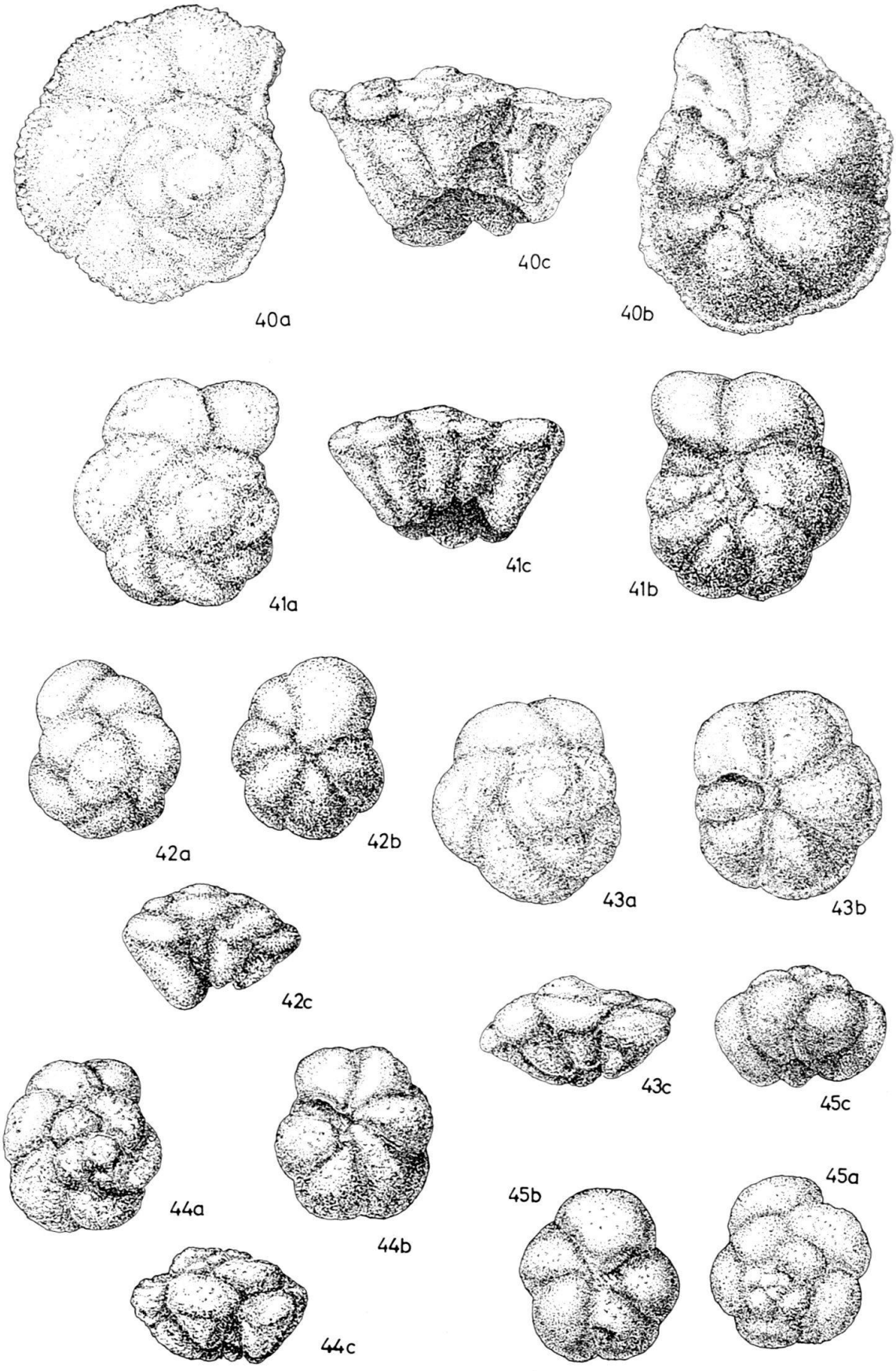
Fig. 40. *Globorotalia conicotruncata* SUBBOTINA, 1947. «Zone of rotaloid Globorotaliids» Kheu river, Northern Caucasus (leg. et det. SUBBOTINA, C 20584), × 75.

Figs. 41 & 42. *Globorotalia angulata abundocamerata* BOLLI, 1957. Topotypes, Globorotalia pusilla pusilla zone (TLL 232705), Lower Lizard Springs formation, Trinidad (C 20585, C 20586), × 75.

Fig. 43. *Globorotalia kubanensis* SHUTZKAYA, 1956. Topotype, Acarinina conicotruncata zone, Kuban river, Northern Caucasus (det. et leg. SHUTZKAYA, C 20587), × 75.

Fig. 44. *Globorotalia tadjikistanensis djanensis* (SHUTZKAYA) (ms). Acarinina tadjikistanensis djanensis zone, eastern Caucasus (det. et leg. SHUTZKAYA, C 20588), × 75.

Fig. 45. *Globorotalia praepentacamerata* SHUTZKAYA, 1956. Acarinina tadjikistanensis djanensis zone, Elburgan svita, Kheu river, Northern Caucasus (det. et leg. SHUTZKAYA, C 20589), × 75.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Description (see also SUBBOTINA, 1947, 1950, 1953)

Test conical, spiral side flattened or slightly convex, inner whorls slightly raised above the level of the last one. Umbilical side strongly convex. The test has the shape of a truncated cone. Periphery rounded to slightly lobulate, acute, sometimes with a faint keel. Peripheral angle 70°–90°. Umbilicus open, fairly wide. Last whorl composed of 5–8 chambers, tightly adherent to each other and increasing slowly in size. Last chamber quite often «senile» or of the same size as the preceding one. Umbilical shoulders rounded. On spiral side, sutures curved, depressed or flush, very often indistinct in the inner whorl; on umbilical side radial and depressed. Aperture as typical for the genus, usually low, with only a faint lip. Test covered with fine spines, becoming stronger on the umbilical side and more concentrated at the peripheral edge, which may adopt a keel-like appearance.

Dimensions of the holotype: maximum diameter 0.42 mm, height 0.23 mm.

Variability

In the original publication, SUBBOTINA (1949) attributed a quite large range of variability to *Globorotalia conicotruncata*, which she increased further in 1953. The holotype is said to represent an extreme variant by having a wide umbilicus and a large number of chambers in the last whorl. In the present paper, *Globorotalia conicotruncata* is interpreted according to the original description (see also MOROZOVA, 1961, footnote p. 9; LEONOV & ALIMARINA, 1961, p. 34). A very typical representative of *Globorotalia conicotruncata* is shown in fig. 40.

Variable features are the number of chambers in the last whorl (mainly 6), the shape of the peripheral edge, varying from subacute to faintly keeled, and the convexity of the spiral side.

Relations and stratigraphical distribution

Globorotalia conicotruncata has been treated as a synonym of *Globorotalia angulata* by SHUTZKAYA (1956), BERGGREN (1960), GARDNER & HAY (1962, HILLEBRANDT (1962, only partim) and GOHRBANDT (1963, only partim). It differs, however, from the latter species in having a greater number of and more slowly increasing chambers in the last whorl, in the conicotruncate lateral view of the test, the less lobulate periphery and the open umbilicus.

It differs from *Globorotalia simulatilis* in its axial view, the wide umbilicus and the generally larger dimensions. The two species are linked by intermediate forms. A very characteristic feature – as mentioned by SUBBOTINA – is the equal height of chambers throughout the whole last whorl.

Globorotalia apanthesma LOEBLICH & TAPPAN, 1957, is likely to be synonymous to *Globorotalia conicotruncata.* It shares with the latter species such characteristic features as the conicotruncate shape of the test, the very slow increase of chamber size in the last whorl and the wide umbilicus. The species has been described from the Middle Paleocene (see GARDNER & HAY, 1962) of the Atlantic coastal regions of the U.S.A. (see also OLSSON, 1960). *Globorotalia hispidocidaris* LOEBLICH & TAPPAN, 1957, has already been compared by its authors with *Globorotalia conicotruncata*, from which, however, it was said to differ by a smaller size and a more spinose surface. It is here considered as synonymous to *Globorotalia conicotruncata.*

BOLLI & CITA (1960, p. 379) suggested *Globorotalia angulata abundocamerata* BOLLI, 1957, to be synonymous to *Globorotalia conicotruncata* (see also GOHRBANDT, 1963). A comparison of topotypes from Trinidad (figs. 41, 42) with those from the Caucasus fully confirms this suggestion. In Trinidad, *Globorotalia angulata abundocamerata* ranges from the Globorotalia pusilla pusilla zone to the lower part of the Globorotalia pseudomenardii zone.

In 1956, SHUTZKAYA splitted from *Globorotalia angulata* (in which she also included *Globorotalia conicotruncata*) a new subspecies, namely *Globorotalia angulata kubanensis*, which she thought differed from the original species by possessing a smaller peripheral angle and a more convex spiral side (see fig. 43). The holotype was described from the Globorotalia conicotruncata zone within the uppermost Elburgan svita. A set of topotypes, donated by SHUTZKAYA, demonstrates that *Globorotalia kubanensis* (it was later – 1963 – given specific rank by its author) might be united with *Globorotalia conicotruncata*. Both species occur within the same stratigraphical interval. *Globorotalia kubanensis* has a smaller umbilicus, a more convex spiral side and a less truncate umbilical side than the typical *Globorotalia conicotruncata*. It might therefore represent a transition to *Globorotalia simulatilis* (SCHWAGER).

In the Gubbio section, *Globorotalia conicotruncata* reaches its greatest development in the levels G-79 to G-77, corresponding to the Globorotalia pusilla pusilla and the lower Globorotalia pseudomenardii zones.

The species possibly derived from *Globorotalia praecursoria*. *Globorotalia conicotruncata*, however, is more conicotruncate, due to an enlargement of the umbilicus and a subsequent shifting outwards towards the periphery of the umbilical chamber ends. Intermediate forms, which may already be classified as *Globorotalia conicotruncata*, occur at level G-80. In all samples, coiling is preferentially sinistral. The average maximum diameter is about 0.375 mm. In the younger samples, specimens with a faint keel are present. In G-78, a few specimens with 9 chambers in the last whorl, a wide umbilicus and a partly concave spiral side are observed (fig. 50). They possibly are extreme variations of *Globorotalia conicotruncata*.

Globorotalia tadjikistanensis BYKOVA, 1953

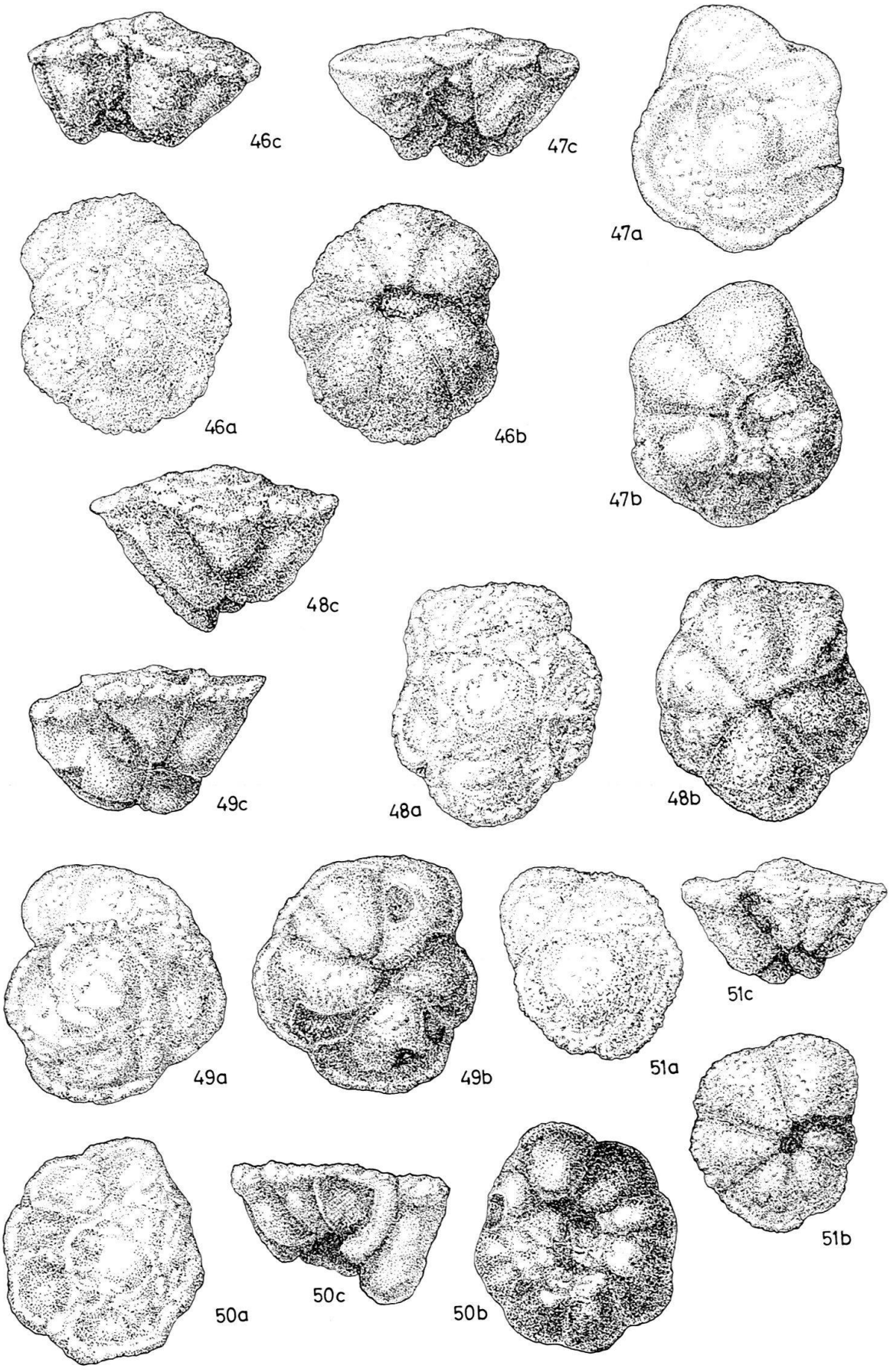
Fig. 52

Globorotalia tadjikistanensis n. sp. – BYKOVA, 1953, p. 86, pl. III, fig. 5a–c.

Description (see BYKOVA, 1953)

Test biconvex, inner whorl on the spiral side distinctly raised above the level of the last whorl, giving it a dome-shaped appearance. Peripheral angle acute, but without a distinct keel. On umbilical side, chambers sloping gently towards the umbilicus, which is of medium size. Within the last formed whorl 6–8 chambers, increasing slowly in size. Last chamber often «senile». Sutures depressed on both sides of the test, curved on the spiral side, radial on the umbilical side. Aperture characteristic for the genus. Surface of the test roughened, covered with spines.

Maximum diameter of the holotype 0.32 mm, height 0.20 mm.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Remarks

The most characteristic feature of this species is the biconvexity of its test, differentiating it from *Globorotalia conicotruncata*. It differs from *Globorotalia angulata* by more and slowly increasing chambers within the last whorl. *Globorotalia tadjikistanensis* was first described from the «Suzak stage» of the Tadshiksk depression in Central Asia. LEONOV & ALIMARINA (1961) figured a few specimens of this species from the Globorotalia conicotruncata/Globorotalia tadjikistanensis zone (Northern Central Caucasus). This zone is partly corresponding to the Acarinina tadjikistanensis djanensis zone (Stratigraphic Commission, 1963).

Globorotalia tadjikistanensis djanensis SHUTZKAYA (ms) (= «rounded form of *Acarinina tadjikistanensis*» in ALIMARINA, 1963) is here not separated as a subspecies, in spite of having less chambers in the last whorl and a more rounded axial periphery than the typical form. A topotype, donated by SHUTZKAYA, is illustrated in fig. 44. It may be noted that in the last whorl the periphery of the early chambers is broadly rounded, whereas in the younger chambers it is still subacute.

Another species related to *Globorotalia tadjikistanensis* is *Globorotalia angulata praepentacamerata* SHUTZKAYA (fig. 45). It differs from *Globorotalia tadjikistanensis* in having fewer (5–6) and more subglobular chambers in the last whorl. By its recurrence towards a Globigerina-like appearance, it is differentiated from all other *Globorotalia* of the *Globorotalia angulata* group, to which it is linked by intermediate forms.

Globorotalia strabocella LOEBLICH & TAPPAN (1957, pl. 61, figs. 6a–c), from the Middle Paleocene Nanafalia formation (Alabama, see also GARDNER & HAY, 1962), shares most of its characters with *Globorotalia praepentacamerata*, and might be a synonym of it. In the samples from the Scaglia of the Central Apennines, *Globorotalia praepentacamerata* has not yet been discovered.

In the Gubbio section, *Globorotalia tadjikistanensis* occurs rarely within the levels G-79–G-77 (Globorotalia pusilla pusilla and Globorotalia pseudomenardii zones).

Globorotalia simulatilis (SCHWAGER), 1883

Figs. 53–60

Discorbina simulatilis n. sp. – SCHWAGER, 1883, p. 120, pl. XXIX, figs. 15a–d.

Description (see also SCHWAGER, 1883)

Test biconvex, spiral side only slightly convex. Peripheral angle 55°–70°. Composed of 10–12 chambers, arranged in $2^1/_2$ whorls. The 5–6 chambers of the last whorl are increasing regularly in size as added, last chamber occupying $^1/_4$–$^1/_5$ of the whole whorl. Periphery rounded to slightly lobulate, acute, but not distinctly

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Figs. 46 and 50. *Globorotalia conicotruncata* SUBBOTINA, 1947. Gubbio section, level G-78 (C 20590, C 20591), × 75.

Figs. 47 and 49. *Globorotalia conicotruncata* SUBBOTINA, 1947. Gubbio section, level G-77 (C 20592, C 20593), × 75.

Fig. 48. *Globorotalia conicotruncata* SUBBOTINA, 1947. Atypical specimen with narrow umbilicus, Gubbio section, level G-78 (C 20594), × 75.

Fig. 51. *Globorotalia conicotruncata* SUBBOTINA, 1947. Gubbio section, level G-79 (C 20595), × 75.

keeled. Umbilical chamber-tips rounded, tightly arranged around the narrow but deep umbilicus. On the spiral side chambers somewhat overlapping (imbricated). Sutures on spiral side depressed, curved and passing without any break in the faintly lobulate or rounded periphery. On the umbilical side sutures depressed and radial. Aperture umbilical-extraumbilical, with faint lip. Surface of the test covered with small spines, which may become more concentrated at the peripheral margin and on the umbilical side.

Dimensions of topotypes: maximum diameter 0.25–0.40 mm, height 0.18–0.22 mm.

Variability

The number of chambers in the last whorl, the size of the last chamber and the distribution of the spinosity are inconstant features. Fig. 60 shows an atypical specimen with only 4 chambers in the last whorl and some resemblance to *Globorotalia quadrata* NAKKADY & TALAAT.

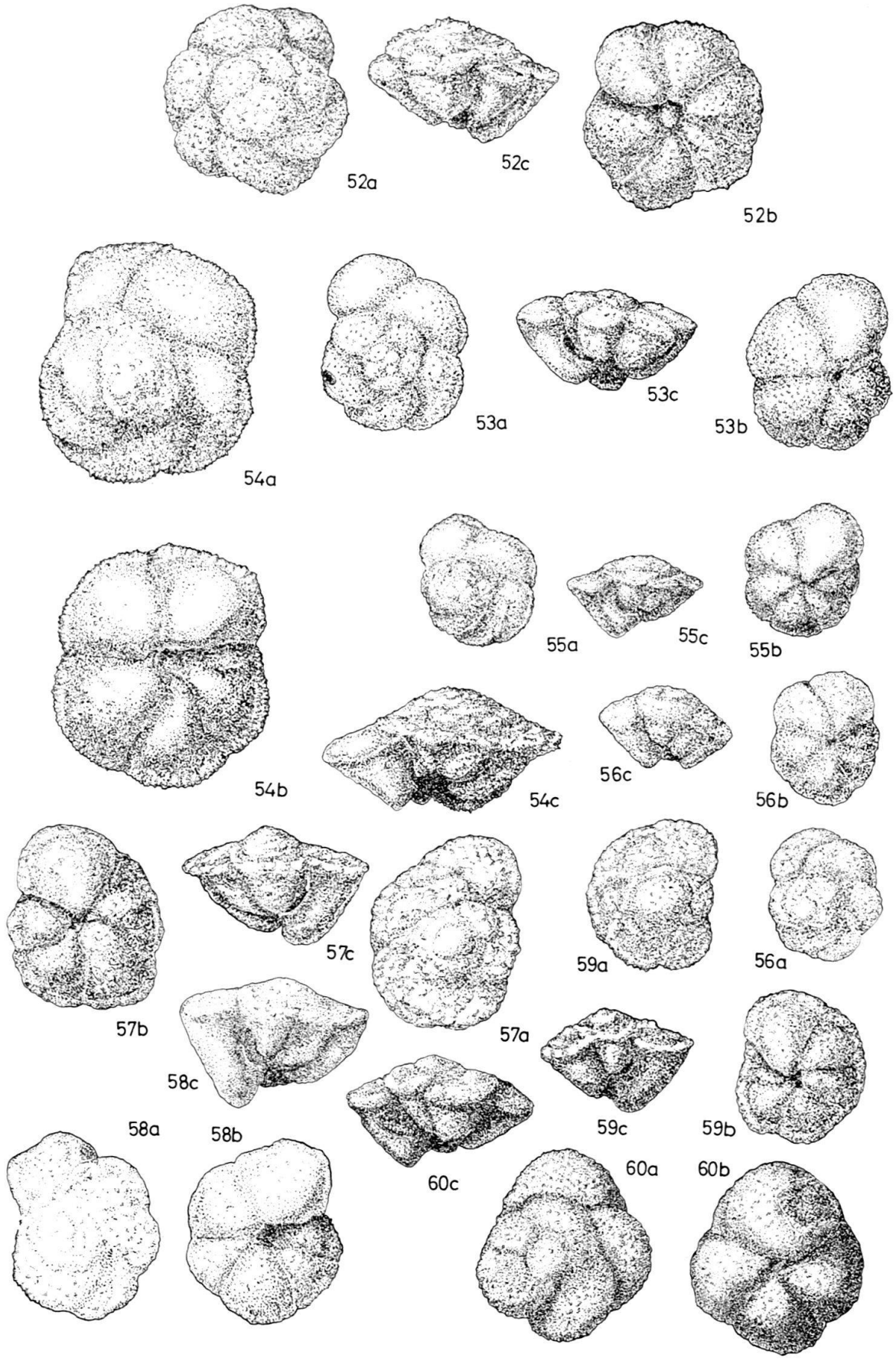
Relations and stratigraphical distribution

Globorotalia simulatilis is the earliest described species among the Paleogene *Globorotalia*. This species has been ignored by most authors – with a few exceptions (e.g. GLAESSNER, 1937, REICHEL, 1952) – although the type-figure given by SCHWAGER is quite clear and its description much more precise than some more modern ones. In recent papers dealing with planktonic foraminifera from the Near East (LEROY, 1953, SAID, 1960, NAKKADY, 1959, SAID & KERDANY, 1961) and Europe (HILLEBRANDT, 1962), *Globorotalia simulatilis* has been rediscovered.

The collections of SCHWAGER in Munich were destroyed during world war II. A large set of samples from the Farafrah Oasis and other localities of the Western Desert, donated by the BIPM to the Museum of Natural History, Basel, allowed an examination of possible topotypes of *Globorotalia simulatilis*. In the section of El Quss Abu Said, this species occurs in the lowermost Esna shales, which are to be placed in the Globorotalia pseudomenardii zone. This age-determination is strengthened by the occurrence of *Discoaster multiradiatus* in the samples (personal communication by H. MOHLER). SCHWAGER has given an average diameter of *Globorotalia simulatilis* of 0.40 mm. Diameters of topotypes are generally less.

Globorotalia simulatilis is related to *Globorotalia conicotruncata*, from which it differs by a narrower umbilicus, a usually less flattened spiral side and a more rapid increase of the chambers of the last whorl. *Globorotalia conicotruncata* has a typical conicotruncate lateral view, whereas *Globorotalia simulatilis* has a more acute peripheral angle.

Fig. 52. *Globorotalia tadjikistanensis* BYKOVA, 1953. Gubbio section, level G-79 (C 20596), × 75.
Figs. 53–55. *Globorotalia simulatilis* (SCHWAGER), 1883. Globorotalia pseudomenardii zone, El Quss Abu Said, Farafrah Oasis, Egypt (C 20597, C 20598, C 20599), × 75.
Fig. 56. *Globorotalia simulatilis* (SCHWAGER), 1883. Gubbio section, level G-81 (C 20600), × 75.
Figs. 57 and 59. *Globorotalia simulatilis* (SCHWAGER), 1883. Gubbio section, level G-78 (C 20601, C 20602), × 75.
Fig. 58. *Globorotalia simulatilis* (SCHWAGER), 1883. Gubbio section, level G-82 (C 20603), × 75.
Fig. 60. *Globorotalia* sp. aff. *simulatilis* (SCHWAGER), 1883. Similar to *Globorotalia quadrata* NAKKADY & TALAAT, 1958, Gubbio section, level G-78 (C 20604), × 75.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It is distinguished from *Globorotalia angulata* (which GRIMSDALE (1953) supposed to be synonymous to *Globorotalia simulatilis*) by more chambers in the last whorl, a less lobulate periphery and a more lenticular shape of the test.

LEROY (1953, pl. 9, figs. 1–3) and HILLEBRANDT (1962, p. 134) have misinterpreted *Globorotalia simulatilis*, by considering forms related to *Globorotalia subbotinae* or *Globorotalia marginodentata* to belong to this species. As a consequence of this erroneous interpretation, HILLEBRANDT placed *Globorotalia simulatilis* in his «Zone G», which he correlates with the Globorotalia rex zone of BOLLI, 1957.

In the Soviet Treatise on Paleontology (volume I, p. 268, fig. 473 A–C), «*Discorbina*» *simulatilis* SCHWAGER is interpreted as *Globorotalites*.

In the section of Gubbio, *Globorotalia simulatilis* occurs first at the level G-82. It is here linked to *Globorotalia angulata* by intermediate forms. It reaches its maximum development in the levels G-80–G-77 (Globorotalia pusilla pusilla zone to Globorotalia pseudomenardii zone). Coiling is here preferentially sinistral throughout its whole range.

Globorotalia sp. aff. *kolchidica* MOROZOVA, 1961

Figs. 61, 62

aff. *Globorotalia kolchidica* n. sp. – MOROZOVA, 1961, p. 17, pl. II, figs. 2a–c.

Description

Test flattened, umbilical side strongly convex, spiral side slightly convex. Chambers angular-rhomboidal in specimens with high spiral side. Periphery lobulate, acute, keeled. Umbilicus deep and narrow, umbilical shoulders of the chambers rounded and smooth. 4–5 chambers in the last whorl, which increase rapidly in size. Last chamber occupying $^1/_3$ of the whole whorl. Sutures radial and depressed on umbilical side, curved and slightly raised or flush on the spiral side, indistinct in the inner whorl. Arrangement of chambers somewhat imbricated. Aperture as typical for the genus, badly visible on account of poor preservation. Wall rugose, especially in early chambers.

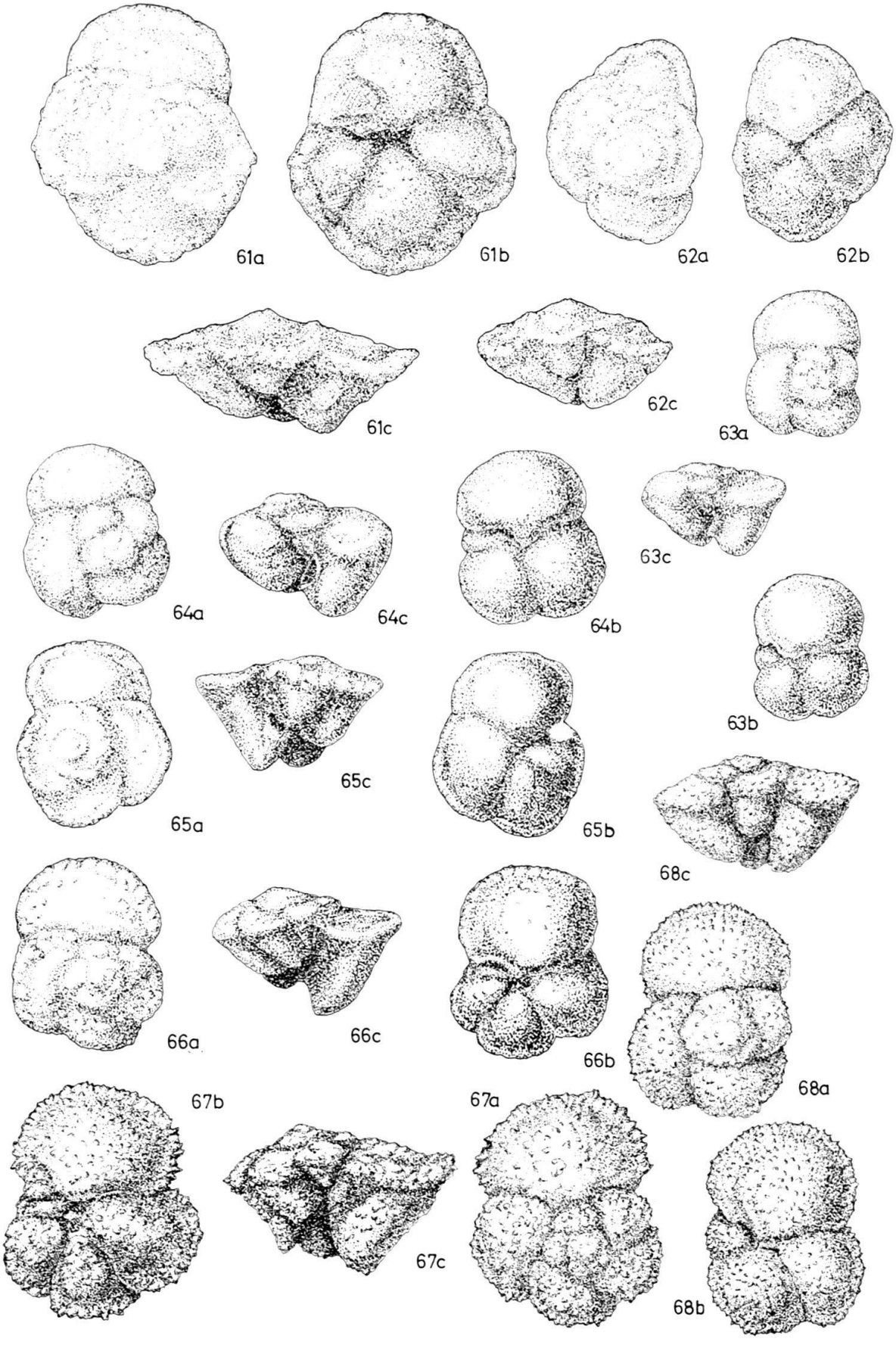
Remarks

The figured specimens have been determined as *Globorotalia* sp. aff. *kolchidica* as they display more affinities to this species than to any other. They differ from typical *Globorotalia kolchidica* by having only 4–5 instead of 5–6 chambers in the last whorl, and by lacking the «thickenings» on the umbilical shoulders – described by MOROZOVA as typical for this species. The sutures on the spiral side are slightly raised or flush, instead of flush or even slightly depressed.

Figs. 61 and 62. *Globorotalia* sp. aff. *kolchidica* MOROZOVA, 1961. Gubbio section, level G-81 (C 20605, C 20606), × 75.

Figs. 63–66. *Globorotalia aequa* CUSHMAN & RENZ, 1942. Topotypes, Soldado formation (K 2950), Soldado Rock, Trinidad (C 20607, C 20608, C 20609, C 20610), × 75.

Figs. 67 and 68. *Globorotalia aequa* CUSHMAN & RENZ, 1942. Globorotalia velascoensis zone, Velasco formation, Ebano, eastern Mexico (C 20610, C 20612), × 75.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Globorotalia kolchidica has been mentioned by its author from the «Montian» of Crimea, Northern Caucasus and Kopiet-Dag.

In the Gubbio section, *Globorotalia* sp. aff. *kolchidica* occurs rarely within the levels G-81–G-77. The small number of specimens available is insufficient to determine the definite trend of coiling.

3. *Globorotalia aequa* group

Species included in this group have 4–5 chambers in the last whorl, the keel may be faintly to strongly developed or may be missing. The delimitation of this group towards the *Globorotalia angulata* group is somewhat arbitrary.

ALIMARINA (1963) proposed to subdivide this group into three subgroups: *Globorotalia marginodentata* (which she thought to be a probable synonym of *Globorotalia rex*), *Globorotalia aequa* (= *Globorotalia crassata* of Soviet authors) and *Globorotalia wilcoxensis* (to which she attributed *Globorotalia praenartanensis*).

The following species are related to the *Globorotalia aequa* group:

Globorotalia crassata var. *aequa* CUSHMAN & RENZ, 1942
Globigerina decepta MARTIN, 1943
Globigerina nitida MARTIN, 1943
Globorotalia rex MARTIN, 1943
Globorotalia nicoli MARTIN, 1943
Globorotalia lacerti CUSHMAN & RENZ, 1946
Globorotalia velascoensis var. *parva* REY, 1955
Globorotalia acutispira BOLLI & CITA, 1960
Globorotalia wilcoxensis CUSHMAN & PONTON, 1932
Pulvinulina crassata CUSHMAN, 1925
Pulvinulina crassata var. *densa* CUSHMAN, 1925
Globorotalia nartanensis SHUTZKAYA, 1956
Globorotalia praenartanensis SHUTZKAYA, 1956
Globorotalia subbotinae MOROZOVA, 1939
Globorotalia lensiformis SUBBOTINA, 1953
Globorotalia marginodentata SUBBOTINA, 1953
Globorotalia marginodentata aperta GOHRBANDT, 1953.

Globorotalia aequa CUSHMAN & RENZ, 1942

Figs. 63–71

Globorotalia crassata (CUSHMAN) var. *aequa* n. var. – CUSHMAN & RENZ, 1942, p. 18, pl. 3, figs. 3a–c.
Globorotalia aequa CUSHMAN & RENZ – BOLLI, 1957, pp. 74–75, pl. 17, figs. 1–3, pl. 18, figs. 13–15.

Description (see CUSHMAN & RENZ, 1942, BOLLI, 1957)

Test umbilico-convex, spiral side almost flat, umbilical side strongly convex. Periphery lobulate, acute, often with a faint keel. Umbilicus narrow, but deep. $3^1/_2$ to $4^1/_2$ chambers in the last whorl, which increase rapidly in size. Last chamber occupying $^1/_3$ to $^1/_2$ of the whole whorl. On spiral side, chambers imbricated. Sutures on umbilical side radial and depressed; on spiral side curved, depressed or flush.

Aperture as typical for the genus, relatively large, with lip. Surface of the test covered with small spines, last chamber often smooth.

Variability

The variability of the species is demonstrated by the figured topotypes (figs. 63–66) from the type-sample (Soldado Rock, K 2950) kindly given by Dr. H. H. RENZ. The juvenile (?) specimens (figs. 63, 64) show a subacute periphery, whereas in the fully developed individuals (fig. 66) a faint keel is present. Parallel to this development, the umbilical shoulders become more acute and the shape of the chambers more angular-conical. In the type-sample, all specimens of planktonic foraminifera appear to be somewhat polished. In well preserved faunas, *Globorotalia aequa* has a spinose surface (see the figured specimens from the Velasco shales, figs. 67, 68).

Relations and stratigraphical distribution

BOLLI (1957, p. 65) has redetermined the age of the type-sample of *Globorotalia aequa* and attributed it to the Globorotalia velascoensis zone. The present writer prefers to place it in the Globorotalia aequa zone.

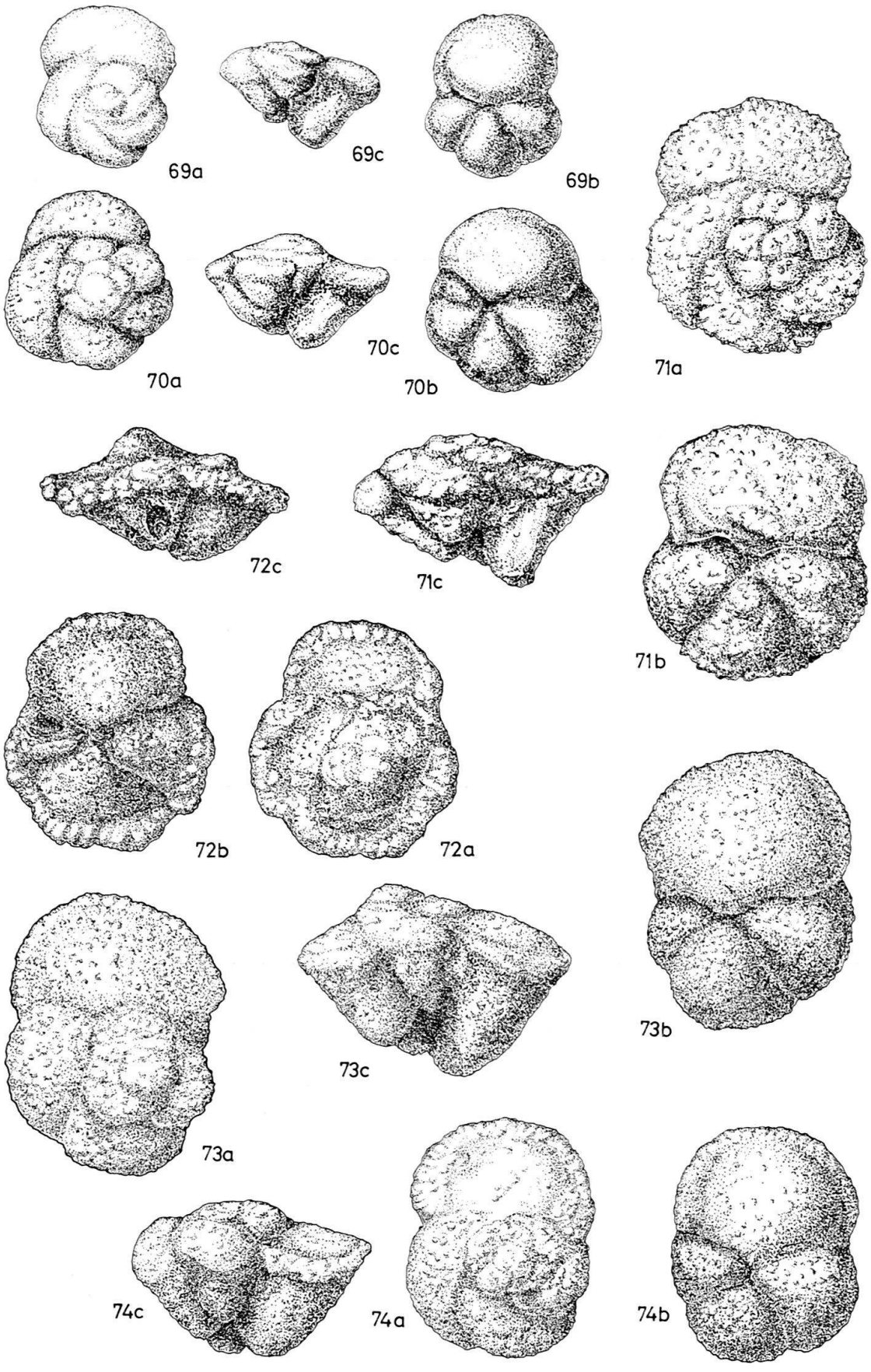
In the section of Gubbio, the species occurs first at the level G-74, where it is found rarely. The main distribution of the species lays between G-73 and G-66. The species shows strongly preferential dextral coiling throughout its range, as in the Lizard Springs formation of Trinidad. This late appearance of *Globorotalia aequa* seems to be a local feature. The species is observed already in the Globorotalia pseudomenardii zone in Trinidad, in the Velasco shales and in the sections of Paderno d'Adda and Val di Non (Northern Italy).

Species related to *Globorotalia aequa* are *Globorotalia praenartanensis* SHUTZKAYA, 1956 and *Globorotalia lensiformis* SUBBOTINA, 1953.

Globorotalia praenartanensis SHUTZKAYA was first described from the uppermost Paleocene of the Central Northern Caucasus (Acarinina acarinata zone, Abazinsk svita). It is characterized by an almost close umbilicus and a faintly indicated keel (see topotype, fig. 73). The dimensions of the topotypes from the Northern Caucasus are generally considerably larger than those of *Globorotalia aequa* from the Soldado Rock formation. Nevertheless, *Globorotalia praenartanensis* may be included in the synonymy of *Globorotalia aequa*, as proposed by HILLEBRANDT (1962). It corresponds to this species in its more important characteristics and, moreover, shows a similar stratigraphic distribution.

As already mentioned by BOLLI & CITA (1960, p. 378), *Globorotalia lensiformis* SUBBOTINA, 1923 is also closely related to *Globorotalia aequa*. It differs from it by having a less pronounced preference to dextral coiling, as stated by HILLEBRANDT (1962, p. 136), and by a higher stratigraphic position. In *Globorotalia lensiformis*, the spiral side is almost smooth and the sutures are flush (see fig. 74). ALIMARINA (1963) assumes *Globorotalia lensiformis* to be intermediate between the *Globorotalia aequa* and the *Globorotalia aragonensis* groups. The problem of whether the two species are really synonymous or not, cannot be decided on the available material. Additional investigations are needed.

Globorotalia angulata differs from *Globorotalia aequa* in being more lobulate and less tightly coiled.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Globorotalia acutispira BOLLI & CITA, 1960

Fig. 72

Globorotalia acutispira n. sp. – BOLLI & CITA, 1960, pp. 375–77, pl. XXXV, fig. 3a–c.
Globorotalia acutispira BOLLI & CITA – CITA & BOLLI, 1961, p. 386, fig. 2.

Description (see BOLLI & CITA, 1960)

Remarks

The holotype kindly lent by Mrs. CITA is here refigured (fig. 72). The most typical characteristic of this species is the strongly apiculate inner whorl on the spiral side, causing the typical lateral view of the test.

The differences between *Globorotalia acutispira* and its related species have been discussed in detail by BOLLI & CITA (1960).

Stratigraphical distribution

In the section of Gubbio, this species occurs very sporadically in the levels G-78 and G-77 (Globorotalia pseudomenardii zone). The axial section of a *Globorotalia* figured by REICHEL (1952, fig. 3d) from the level 34 (RENZ, 1936) might belong to this species (BOLLI & CITA, 1960, p. 377). Level 34 RENZ is situated between G-77 and G-75.

Globorotalia marginodentata SUBBOTINA, 1953

Figs. 75–76, 81–84

Globorotalia marginodentata n. sp. – SUBBOTINA, 1953, pp. 212–13, pl. XVII, figs. 15a–c, 16a–c, pl. XVIII, figs. 2a–c.
Globorotalia marginodentata aperta n. ssp. – GOHRBANDT, 1963, p. 63, pl. 5, figs. 13–15.

Description (see SUBBOTINA, 1953)

Test flattened, spiral side distinctly to slightly convex, umbilical side strongly convex. Form of chambers angular-rhomboidal to angular-conical. Peripheral angle low, 50°–70°. Periphery lobulate with broad and heavy keel, armoured with blunt spines. Last whorl composed of 4–6, mostly 4–5, rapidly increasing chambers. Last chamber occupying $^1/_3$ to $^1/_2$ of the whole whorl, but often «senile». Spiral sutures strongly curved, varying from distinctly beaded to flush, generally in-

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Fig. 69. *Globorotalia aequa* CUSHMAN & RENZ, 1942. Gubbio section, level G-71 (C 20613), × 75.
Fig. 70. *Globorotalia aequa* CUSHMAN & RENZ, 1942. Gubbio section, level G-65 (C 20614), × 75.
Fig. 71. *Globorotalia aequa* CUSHMAN & RENZ, 1942. Gubbio section, level G-60 (C 20615), × 75.
Fig. 72. *Globorotalia acutispira* BVLLI & CITA, 1960. Holotype, Globorotalia pseudomenardii zone, Paderno d'Adda, Northern Italy (dep. Collezione Lab. Micropal. Ist. Geol. Univ. Milano, no. 1278), × 75.
Fig. 73. *Globorotalia praenartanensis* SHUTZKAYA, 1956. Topotype, Acarinina acarinata zone, Kuban river, Northern Caucasus (det. et leg. SHUTZKAYA, C 20616), × 75.
Fig. 74. *Globorotalia lensiformis* SUBBOTINA, 1953. Topotype, «zone of conical Globorotaliids», Northern Caucasus, Kheu river (det. et leg. SUBBOTINA, C 20617), × 75.

distinct in the inner whorl. Umbilical shoulders rounded and smooth to acute and ornamented. Umbilicus closed to open. Aperture as typical for the genus, generally low and with a faintly developed lip. Coiling preferentially dextral.

Variability

The most characteristic features differentiating *Globorotalia marginodentata* from all other contemporaneous species of this genus, are the flattened, lenticular appearance in lateral view and the broad and thickened keel. The number of chambers within the last whorl is variable. Their arrangement quite often shows irregular growth. The ornamentations of the sutures on the spiral side and of the umbilical shoulders are variable too.

Relations and stratigraphical distribution

Globorotalia marginodentata was first described from the Kuban-river section (Central Northern Caucasus) in the lower part of the «Green svita» of Lower Eocene age.The type-level of *Globorotalia marginodentata* corresponds to the Georgiyevskaya svita, whose upper part is equivalent to the Globorotalia marginodentata subzone («Stratigraphic Commission,» 1963). This subzone corresponds to the upper part of the Globorotalia rex zone and to the Globorotalia formosa formosa zone of Trinidad.

In the type-sample of the Globorotalia rex zone from the Upper Lizard Springs formation (Trinidad), *Globorotalia marginodentata* is present in a few specimens only, whereas in contemporaneous samples from the Caucasus it is dominating.

In a sample of the Velasco formation from Ebano (Eastern Mexico), few specimens with abnormal chamber growth (figs. 77, 78) and heavy keel are determined as *Globorotalia* sp. aff. *marginodentata.* They differ from typical representatives of this species by a higher umbilical side and by a less lobulate periphery. Similar specimens occur within the levels G-75 and G-74 of the Gubbio section (figs. 79, 80).

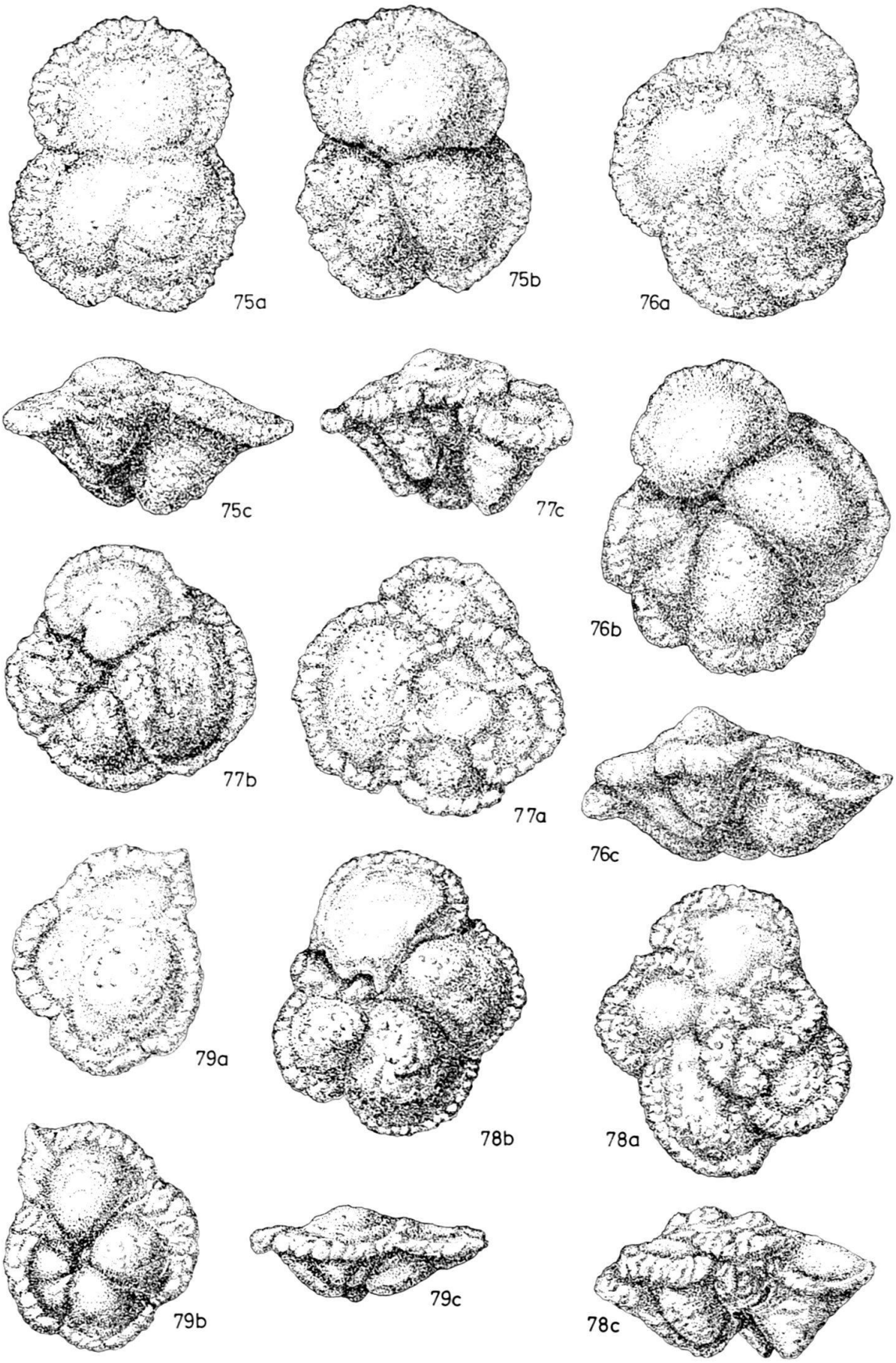
Globorotalia marginodentata is represented by typical specimens within the levels G-73 to G-58 of the Gubbio section (figs. 81, 82, 84). Coiling is predominantly dextral throughout its stratigraphical range. In the younger levels, however, the number of sinistral specimens increases.

The lectotype of *Globorotalia crassata* (CUSHMAN) designated by BANDY (1964, p. 34, fig. 1) shows strong affinities to *Globorotalia marginodentata.* For an exact evaluation, a more precise age-determination of the type-level would be needed (see also TODD, 1961: «On selection of lectotypes and neotypes»).

Figs. 75 and 76. *Globorotalia marginodentata* SUBBOTINA, 1953. «Zone of flattened Globorotaliids», Kheu river, Northern Caucasus (det. et leg. SUBBOTINA, C 20618, C 20619), × 75.

Figs. 77 and 78. *Globorotalia* sp. aff. *marginodentata* SUBBOTINA, 1953. Globorotalia velascoensis zone, Velasco formation, Ebano, eastern Mexico (C 20620, C 20621), × 75.

Fig. 79. *Globorotalia* sp. aff. *marginodentata* SUBBOTINA, 1953. Gubbio section, level G-75 (C 20622), × 75.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Globorotalia subbotinae MOROZOVA, 1939

Figs. 85–90

Globorotalia subbotinae n. sp. – MOROZOVA, 1939, p. 80, pl. 2, figs. 16, 17.
? Globorotalia rex n. sp. – MARTIN, 1943, p. 117, pl. 8, figs. 2a–c.
Globorotalia crassata (CUSHMAN) – SUBBOTINA, 1953 (partim), pl. XVII, figs. 7a–c, 13a–c.

Description

Test umbilico-convex; spiral side only slightly, umbilical side strongly convex. Periphery lobulate, acute, keeled. Peripheral angle generally 70°. Test composed of 12–14 chambers, arranged in $2^1/_2$ whorls. In the last whorl 4–6, mostly 4–5, chambers, increasing rapidly. Last chamber occupying $^1/_3$ to almost $^1/_2$ of the whole whorl. Umbilical shoulders almost rounded and smooth. Umbilicus well developed, deep, narrow to medium. Keel moderately developed, composed of 2–4 rows of spines, which may partly fuse. Sutures on spiral side curved, varying from slightly beaded to distinctly depressed, passing without a break in the peripheral keel.

On umbilical side, sutures radial and depressed. In the inner $1^1/_2$ whorls, no spiral suture is developed. The somewhat globular chambers are here separated by depressed sutures. Wall spinose. Aperture extraumbilical-umbilical, with a narrow lip.

Variability

Variable characters are: the number of chambers in the last whorl, the ornamentation of the sutures, and the development of the keel and of the umbilicus.

Relations and stratigraphical distribution

Globorotalia subbotinae was first described from the Lower Eocene of the Emba region (Kazakhstan). It has been reported from the type-section of Bakhtchissaray (southeastern Crimea), where it occurs in the Bakhtchissaray stage, together with *Nummulites planulatus* (MURATOV & NIEMKOV, 1960, «Stratigraphic Commission,» 1963). In the para-stratotype section of the Kuban-river (Northern Caucasus), the Globorotalia subbotinae zone corresponds to the Georgiyevskaya svita (= upper part of Bakhtchissaray stage).

Globorotalia rex has been described by MARTIN (1943) from the Lodo formation of California. According to BRAMLETTE & SULLIVAN (1961) and HAY (personal communication), the type-level of *Globorotalia rex* is placed within the Discoaster lodoensis zone. This latter zone correlates with the Nummulites planulatus zone (Lower Cuisian) within the Schlieren section (Central Switzerland, SCHAUB, 1951).

Fig. 80. *Globorotalia* sp. aff. *marginodentata* SUBBOTINA, 1953. Gubbio section, level G-74 (C 20623), × 75.

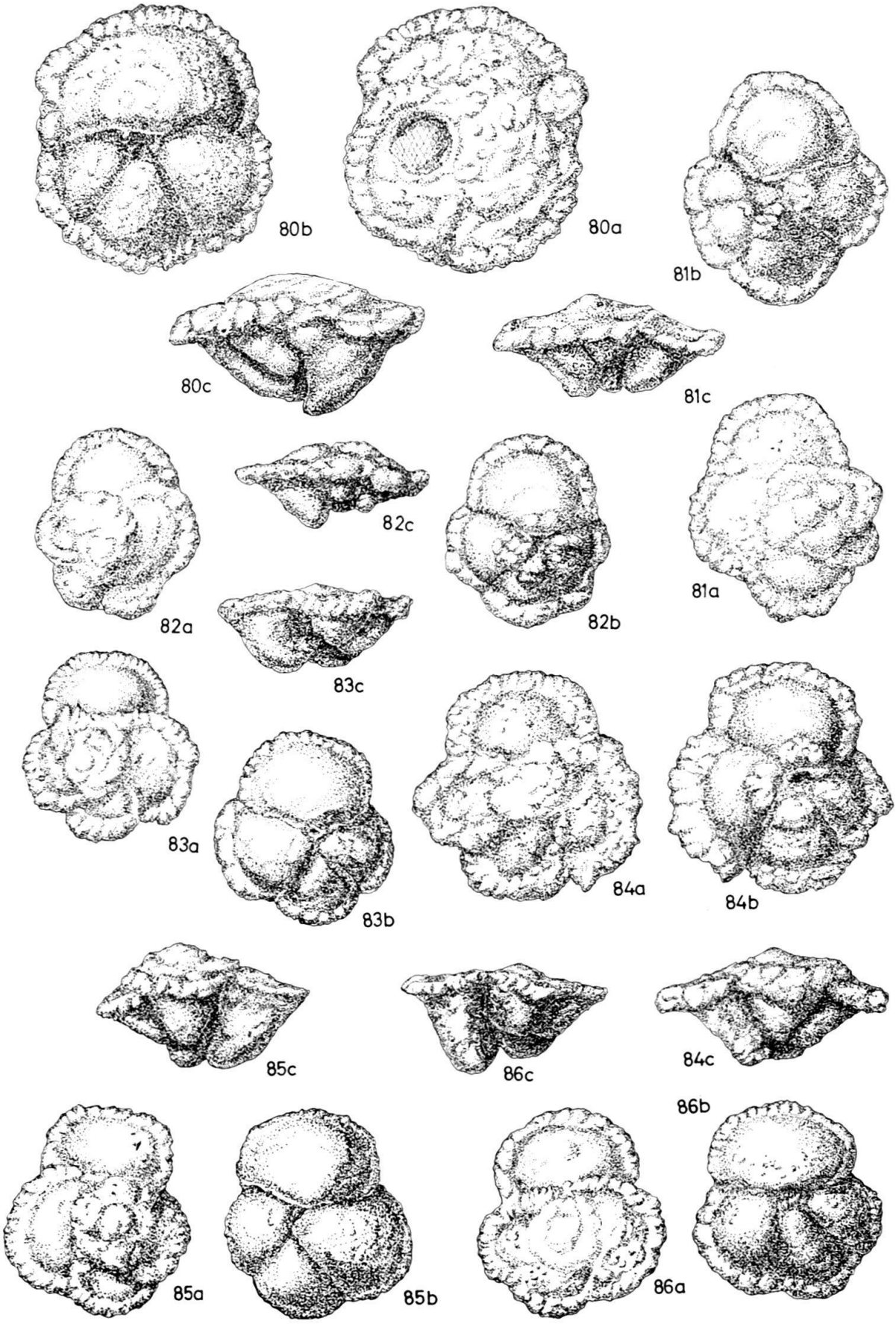
Figs. 81 and 82. *Globorotalia marginodentata* SUBBOTINA, 1953. Gubbio section, level G-71 (C 20624, C 20625), × 75.

Fig. 83. *Globorotalia marginodentata* SUBBOTINA, 1953. Specimen intermediate between *Globorotalia marginodentata* and *Globorotalia subbotinae*; Gubbio section, level G-71 (C 20626), × 75.

Fig. 84. *Globorotalia marginodentata* SUBBOTINA, 1953. Gubbio section, level G-58 (C 20627), × 75.

Fig. 85. *Globorotalia subbotinae* MOROZOVA, 1939. Gubbio section, level G-73 (C 20628), × 75.

Fig. 86. *Globorotalia subbotinae* MOROZOVA, 1939. Gubbio section, level G-71 (C 20629), × 75.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According to a personal communication by HAY, the type-sample of the Globorotalia rex zone (Upper Lizard Springs formation, Trinidad) contains an assemblage of the Marthasterites contortus zone, which correlates with the Nummulites exilis/Nummulites praecursor zone (Middle Ilerdian) in the Schlieren section. The specimen figured by BOLLI (1957, pl. 18, figs. 10–12) from the Globorotalia rex zone of Trinidad does not belong to *Globorotalia rex* (= (?) *Globorotalia subbotinae*). It differs from this species by a heavy keel, by well developed and beaded sutures in the inner whorl and by a flat, partly even concave, spiral side. BOLLI's specimen may be tentatively interpreted as a variety of *Globorotalia aequa*, which has an extremely heavy keel. For the morphological and stratigraphical reasons discussed above, a new name for the Globorotalia rex zone is unavoidable.

Globorotalia rex MARTIN is regarded as being synonymous to *Globorotalia subbotinae* (see also BERGGREN, 1964). The following characteristics are common to the holotypes of *Globorotalia rex* and *Globorotalia subbotinae*: number of chambers in the last whorl, moderately developed keel, identical appearance in lateral view and depressed sutures in the inner whorl. *Globorotalia rex* differs from typical *Globorotalia subbotinae* by a more compact arrangement of chambers and a slightly higher umbilical side. In the sample furnished by HAY from the Lodo formation, typical *Globorotalia rex* grade into typical *Globorotalia subbotinae.*

Globorotalia subbotinae differs from *Globorotalia aequa* by possessing a distinct keel and a less tight coiling. Intermediate forms between the two species are observed (fig. 65).

Globorotalia nartanensis SHUTZKAYA from the Tcherkessk svita of the Central Northern Caucasus is closely related to *Globorotalia subbotinae.* It is compactly coiled and covered with blunt spines. Since topotypes have not been available, the relation between the two species are not known to the present writer.

Another problematic species of the same group is *Globorotalia velascoensis parva* REY. Its name is somewhat misleading, because one of its main characteristics is its large size. This species seems not to be closely related to *Globorotalia velascoensis.*

With the help of R. LEHMANN, a specimen of *Globorotalia velascoensis parva* was obtained from the collections of the «Société Chérifienne des Pétroles, Petitjean, Maroc» (fig. 91). Whether this specimen is identical to the holotype or not, could not be decided. Its most important characteristics are the apiculate inner whorl on the spiral side, the relatively little difference in size between the 4 chambers of the last whorl and the slightly raised and beaded sutures on the spiral side. As mentioned above, its dimensions are remarkably large (maximum diameter 0.615 mm, height 0.335 mm).

An examination of the type-sample TB 450 of *Globorotalia velascoensis parva* shows that the topotypes are preferentially sinistral in coiling. The fauna of the type-sample contains also *Globorotalia aequa.* This fauna is younger than the Globorotalia velascoensis zone, but too poor in stratigraphically significant species to state its exact age. Moreover, the fauna contains Miocene planktonic foraminifera (*Globigerinoides transitoria* BLOW, *Globigerinoides bisphaerica* TODD, *Globigerinoides glomerosa* BLOW, kindly determined by I. PREMOLI SILVA).

BOLLI & CITA (1960) used the name *Globorotalia velascoensis parva* for an unnamed form derived from the Globorotalia pseudomenardii zone. GARDNER &

HAY (1962) and GOHRBANDT (1963) followed this interpretation. This form differs, however, from representatives of *Globorotalia velascoensis parva* from Morocco by a heavy keel and a flat spiral side.

AUBERT (1963) has again figured *Globorotalia velascoensis parva* from the Paleocene of Koudiat-bou-Khélif (Morocco), where it occurs together with *Globorotalia membranacea* (= ? *Globorotalia pseudomenardii*).

In the sections of the Central Apennines, no specimens comparable to this doubtful species could be observed.

Globorotalia subbotinae ranges between the levels G-73 and G-52 of the Gubbio section. The coiling is preferentially dextral throughout its whole range. In the younger levels, the number of specimens with sinistral coiling increases considerably.

The species attains its greatest development within the levels G-71 to G-65. A general increase in size is observed towards the younger levels.

Species not investigated, which may also belong to the *Globorotalia aequa* group, are:

Globigerina decepta MARTIN, 1943, p. 24, pl. VII, figs. 2a–c, from the Lower Eocene Lodo formation, California.

Globigerina nitida MARTIN, 1943, p. 25, pl. VII, figs. 1a–c, from the Lower Eocene Lodo formation, California.

Globorotalia nicoli, MARTIN, 1943, p. 27, pl. VII, figs. 3a–c, from the Lower Eocene Lodo formation, California.

Globorotalia wilcoxensis CUSHMAN & PONTON, 1932, p. 71, pl. 9, figs. 10a–c, from the Eocene Wilcox formation, Alabama.

Globorotalia crassata (CUSHMAN), 1925, p. 300, pl. 7, figs. 4, from the Middle (?) Eocene of Vera Cruz, Mexico.

Globorotalia crassata densa (CUSHMAN), 1925, p. 301, from the Middle(?) Eocene of Vera Cruz, Mexico.

Globorotalia lacerti CUSHMAN & RENZ, 1946, p. 47, figs. 11 and 12 (not figs. 14, 13, see RENZ, 1951), from the Upper Lizard Springs formation, Trinidad.

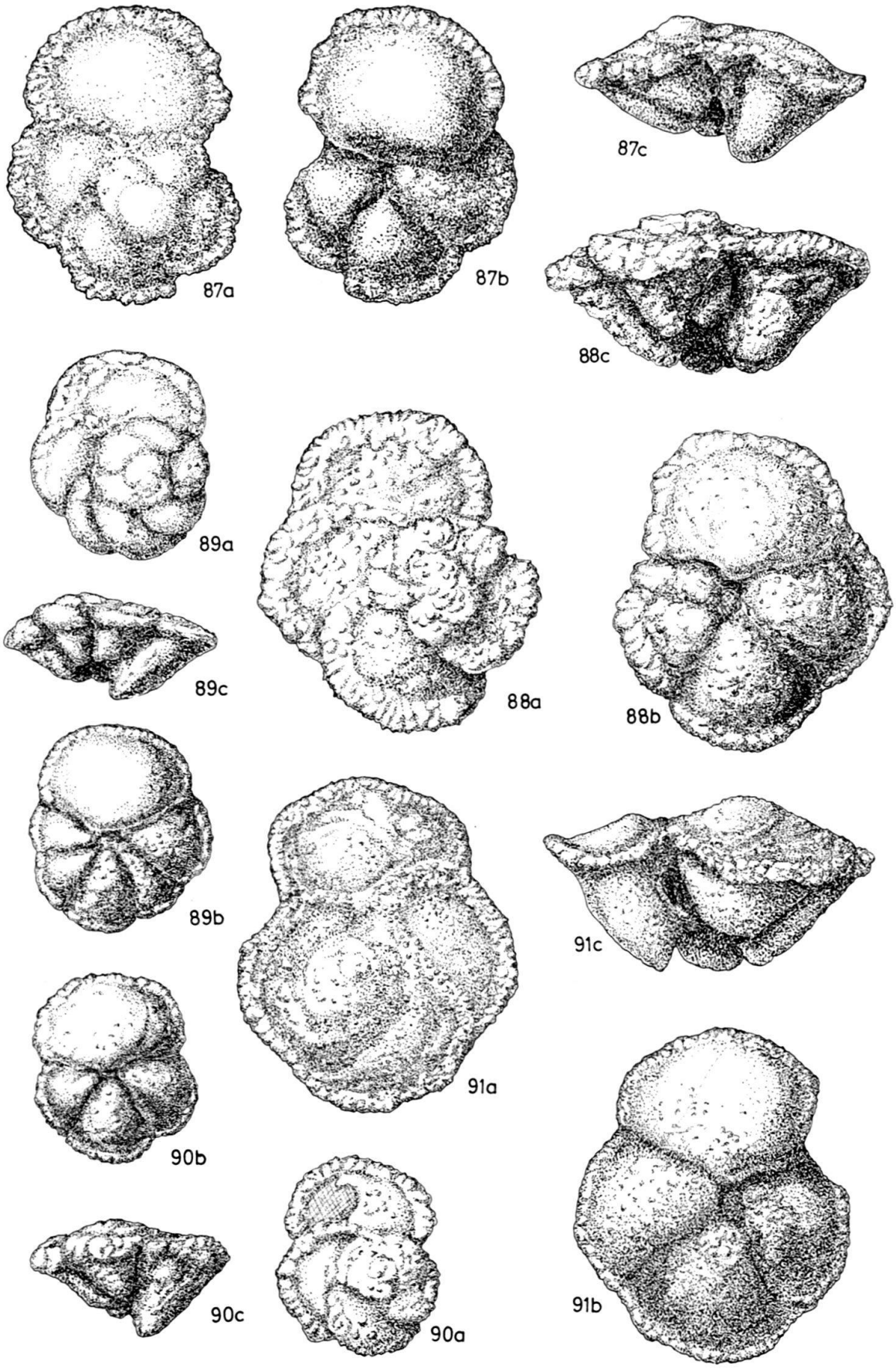
4. *Globorotalia velascoensis* group

This group includes species with multichambered and highly ornamented tests. They are widely spread within the Upper Paleocene and the Lower Eocene of the Mediterranean province.

Amongst the forms of the *Globorotalia aequa* group, some might have developed independently further to species which are here included in the *Globorotalia velascoensis* group. The heavily ornamented homomorphous *Globorotalia velascoensis* and *Globorotalia caucasica* are separated by a considerable time gap and have to be deducted from different origins.

ALIMARINA (1963) considered *Globorotalia lensiformis* to be the ancestor of her «*Truncorotalia*» *aragonensis* group. The Upper Paleocene representatives of the *Globorotalia velascoensis* group are almost absent in the Northern Caucasus.

Further investigations are needed to decide if this group has to be subdivided into an Upper Paleocene *Globorotalia velascoensis* group «s. str.» and a Lower to Middle Eocene *Globorotalia aragonensis* group.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91b

The following species, belonging to this group, are known so far:

Pulvinulina velascoensis CUSHMAN, 1925
Globorotalia aragonensis NUTTALL, 1930
Globorotalia wilcoxensis var. *acuta* TOULMIN, 1941
Globorotalia naussi MARTIN, 1943
Globorotalia marksi MARTIN, 1943
Globorotalia aragonensis var. *caucasica* GLAESSNER, 1937
Globorotalia crater FINLAY, 1939
Globorotalia occlusa LOEBLICH & TAPPAN, 1957
Globorotalia formosa gracilis BOLLI, 1957
Globorotalia formosa formosa BOLLI, 1957
Pseudogloborotalia pasionensis BERMUDEZ, 1961
Pseudogloborotalia guatemalensis BERMUDEZ, 1961

Globorotalia velascoensis (CUSHMAN), 1925

Figs. 92–94, 98–99

Pulvinulina velascoensis n. sp. – CUSHMAN, 1925, p. 19, pl. 3, figs. 5a–c.
Globorotalia velascoensis (CUSHMAN) – WHITE, 1928, p. 281, pl. 38, fig. 2.
Globorotalia velascoensis (CUSHMAN) – BOLLI, 1957, p. 76, pl. 20, figs. 1–3.
Globorotalia velascoensis (CUSHMAN) – LOEBLICH & TAPPAN, 1957, pl. 64, figs. 1a–c, 2a–c.

Description

Test umbilico-convex, spiral side flat or slightly convex, in «abnormal» specimens slightly concave. Umbilical side strongly convex, with prominent umbilical chamber tips. Test composed of 12–17 chambers. Last whorl with 5–8 chambers, which increase gradually in size as added. Last chamber may be often smaller than the previous one, especially in specimens with more than 6 chambers in the last whorl. Periphery rounded, acute, with well developed keel formed by 2–3 rows of blunt, fused spines (fig. 8). Spiral suture well developed, raised and beaded. Sutures between the chambers radial and depressed on the umbilical side, curved, raised and beaded on the spiral side, except between the youngest chambers, where they may be flush. In heavily ornamented specimens, the sutures of the inner whorls may become indistinct. Aperture a low arch, umbilical-extraumbilical, provided with a well developed lip, which remains also in the older chambers, bordering the well developed large umbilicus as a distinct rim. Umbilical shoulders sharp, with bunches of thick spines which may fuse in thick pillows in early chambers.

Variability

To examine the variability of this species, a sample from the Velasco formation, collected near Ebano (59 km of the road Tampico–Cd. Valles, Mexico), has been

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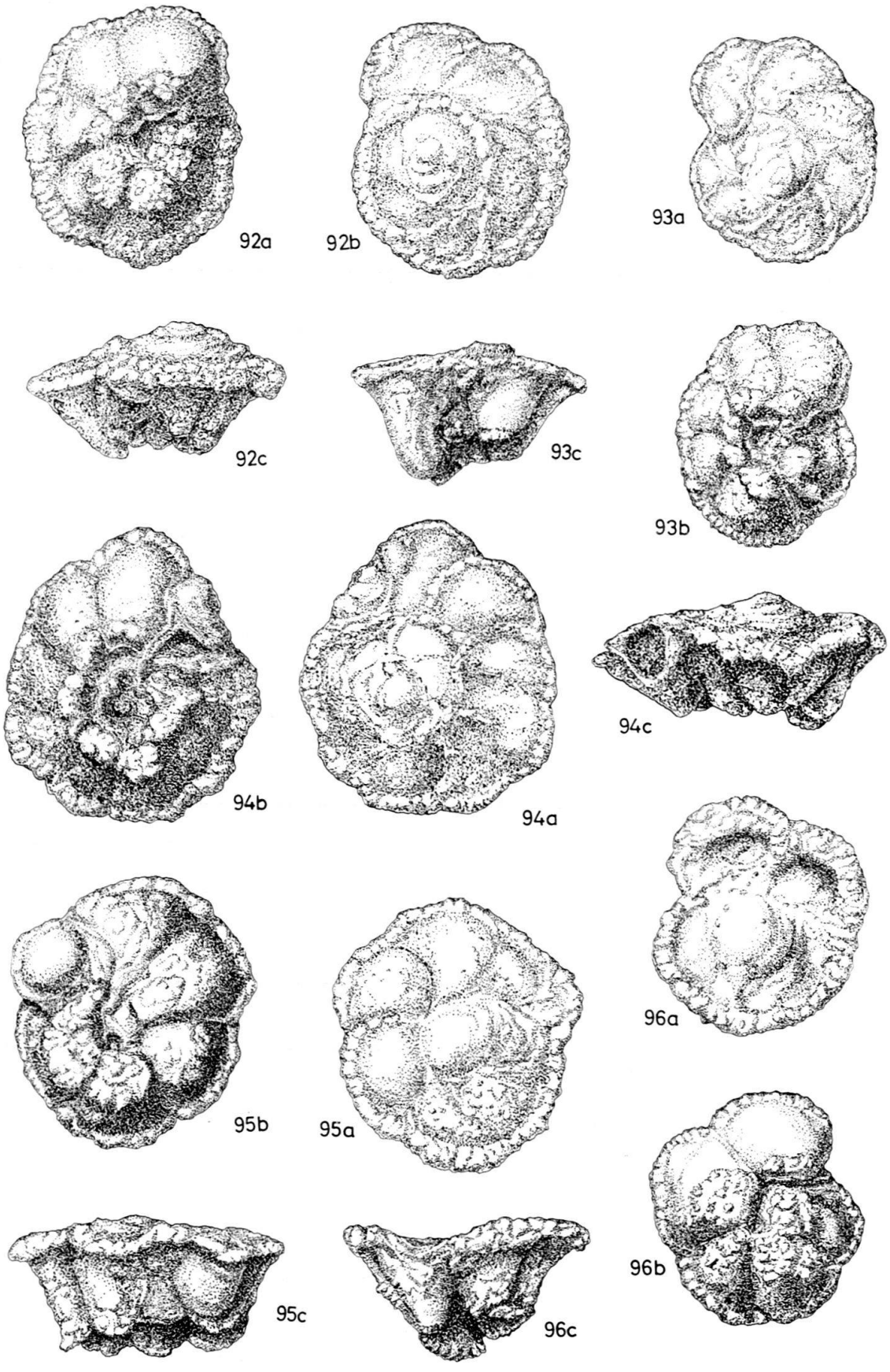
Fig. 87. *Globorotalia subbotinae* MOROZOVA, 1939. Globorotalia subbotinae zone, Eastern Caucasus (det. et leg. SHUTZKAYA, C 20630), × 75.
Fig. 88. *Globorotalia subbotinae* MOROZOVA, 1939. Gubbio section, level G-58 (C 20631), × 75.
Fig. 89. *Globorotalia subbotinae* MOROZOVA, 1939. Gubbio section, level G-71 (C 20632), × 75.
Fig. 90. *Globorotalia subbotinae* MOROZOVA, 1939. Gubbio section, level G-73 (C 20633), × 75.
Fig. 91. *Globorotalia velascoensis parva* REY, 1955. Koudiat bou Khelif, northern Morocco (coll. Soc. Chérif. Pétroles, Petitjean, TB 1,935, holotype ?), × 75.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96b

studied in detail. (The sample was collected by Mr. and Mrs. C. SCHILLER-FISCHER, Mexico City.) It is attributed to the base of the Globorotalia velascoensis zone. The soft friable rock is composed entirely of well preserved tests of planktonic foraminifera, partly filled with asphaltic material.

The distance between the type-locality of *Globorotalia velascoensis* (Hacienda El Limon) and the above sample is only 8 km. According to HAY, the type-sample of *Globorotalia velascoensis* originates from a well or a pit. A sample from a clay pit near Hacienda El Limon, furnished by HAY, has yielded only a poor and badly preserved fauna, which belongs to the Globorotalia pseudomenardii zone. Mud samples from a well at the Hacienda El Limon contain mixed and contaminated assemblages. The fauna from Ebano is likely to be somewhat younger than the type-level of *Globorotalia velascoensis*. It may be attributed to the basal part of the Globorotalia velascoensis zone. It contains a nannoplankton assemblage of the Discoaster multiradiatus zone. In the same outcrop near Ebano, the less carbonaceous basal layers belong to the Globorotalia pseudomenardii zone. The limit towards the overlying sediments, corresponding to the Globorotalia velascoensis zone, is sharp. (Data communicated by HAY.)

Apart from the dominating form described above (fig. 92), additional variations of *Globorotalia velascoensis* are observed. Specimens with only 5 chambers in the last whorl are rare. They differ from the related *Globorotalia acuta* by having a rounded periphery and by a last chamber which increases moderately in size compared to the preceding one. The angle between the spiral side and the umbilical side varies between 60° and 80°.

Coiling is about 99 % sinistral.

The results of the measurement of 300 specimens are condensed in the following tabulation:

	Minimum	Main distribution	Maximum
Maximum diameter	0.325 mm	0.375–0.500 mm	0.645 mm
Relation maximum diameter/minimum diameter	1.02	1.1–1.2	1.40
Height	0.135 mm	0.190–0.205 mm	0.300 mm
Relation height/maximum diameter	0.30	0.4–0.5	0.58
Height of convexity of spiral side	0.000 mm	0.01–0.02 mm	0.080 mm

Rarely does a depressed spiral side occur. In these specimens, the chamber walls are concave and the test has a somewhat emaciated and rachitic appearance (figs. 9, 96). The heavily ornamented umbilical shoulders are turned outwards, comparable to the specimen figured by WHITE (1928, pl. 38, fig. 2). These aberrant forms are rare in the samples from Ebano (= basal Globorotalia velascoensis zone)

Figs. 92–94. *Globorotalia velascoensis* (CUSHMAN), 1925. Globorotalia velascoensis zone, Velasco formation, Ebano, eastern Mexico (C 20634, C 20635, C 20636), × 75.

Fig. 95. *Globorotalia* sp. aff. *velascoensis* (CUSHMAN), 1925. Globorotalia velascoensis zone, Velasco formation, Ebano, eastern Mexico (C 20637), × 75.

Fig. 96. *Globorotalia* sp. aff. *velascoensis* (CUSHMAN), 1925. «Rachitic» specimen; Globorotalia velascoensis zone, Velasco formation, Ebano, eastern Mexico (C 20638), × 75.

and San José de Soto las Rusias (see LOEBLICH & TAPPAN, 1957) (= Globorotalia pseudomenardii zone). In contrast, they occur abundantly in a sample from Tantoyuquita (MUIR, 1936, p. 78) (= Globorotalia pseudomenardii zone). Such rachitic forms do not seem to be linked to definite stratigraphic levels, but depend rather on environment. Similar phenomena of «rachitis» in planktonic foraminifera are observed in Campanian and Maestrichtian Globotruncanids.

Size and shape of the last chamber are variable, too. It may often be atrophic (fig. 94), or smooth with rounded umbilical shoulders.

Large specimens, occurring sporadically, develop a tendency to become evolute in the younger part of the last whorl. The umbilicus widens to such an extent that the umbilical chamber tips of a few chambers of the early whorl are visible. This characteristic is shared with *Globorotalia pasionensis*. Topotypes of the latter species (kindly donated by BERMUDEZ) have, however, a lobulate periphery and rounded umbilical shoulders, instead of the sharp and heavily ornamented umbilical shoulders as developed in the aberrant forms from the Velasco formation (fig. 94). Another difference of these forms, separating them from typical *Globorotalia velascoensis*, is the relation between dextral and sinistral coiling (about 1:1).

Two specimens from the fauna of Ebano show a rounded, smooth, «bulla-like» last chamber, which is separated from the preceding one by a broad and deep suture (fig. 95). Other characteristics, differentiating these specimens from typical *Globorotalia velascoensis*, are the depressed sutures on the spiral side and the conico-truncate aspect of the test in lateral view. The two specimens show dextral coiling. They are here determined as *Globorotalia* sp. aff. *velascoensis*, because the few available specimens are not sufficient to establish a new species.

Relations and stratigraphical range

On account of misinterpretation, *Globorotalia caucasica* (fig. 97) has been often included in the synonymy of *Globorotalia velascoensis* (e.g. SUBBOTINA, 1953 (non 1960), GRIMSDALE, 1951, BERMUDEZ, 1961). The morphological differences between the two species have already been discussed by GLAESSNER (1937) and more extensively by REISS (1957). The intermediate forms between *Globorotalia caucasica* and *Globorotalia aragonensis*, which always are associated (e.g. SUBBOTINA, 1953, pl. IX, fig. 4a–c) with *Globorotalia caucasica* demonstrate the differences by which they are separated from *Globorotalia velascoensis*.

Globorotalia crater FINLAY, 1939, figured by HORNIBROOK (1958, pl. 1, figs. 3–5), is probably synonymous to *Globorotalia caucasica*.

Globorotalia caucasica occurs in the Globorotalia aragonensis zone and in the «Acarinina crassaformis» zone of the Northern Caucasus. Very well preserved specimens are present at the type-locality of the «Marnes de Donzacq» (Upper Cuisian, southwestern France). The stratigraphic range of *Globorotalia velascoensis* is restricted to the Upper Paleocene.

The typical, well ornamented *Globorotalia velascoensis* has a restricted geographical distribution. According to LOEBLICH & TAPPAN (1957), this species is not present in the Upper Paleocene of the Gulf and Atlantic coastal regions of North America. (APPLIN (1964) describes, however, typical *Globorotalia velascoensis* from Western Florida.) It occurs abundantly in faunas of corresponding age in the Carib-

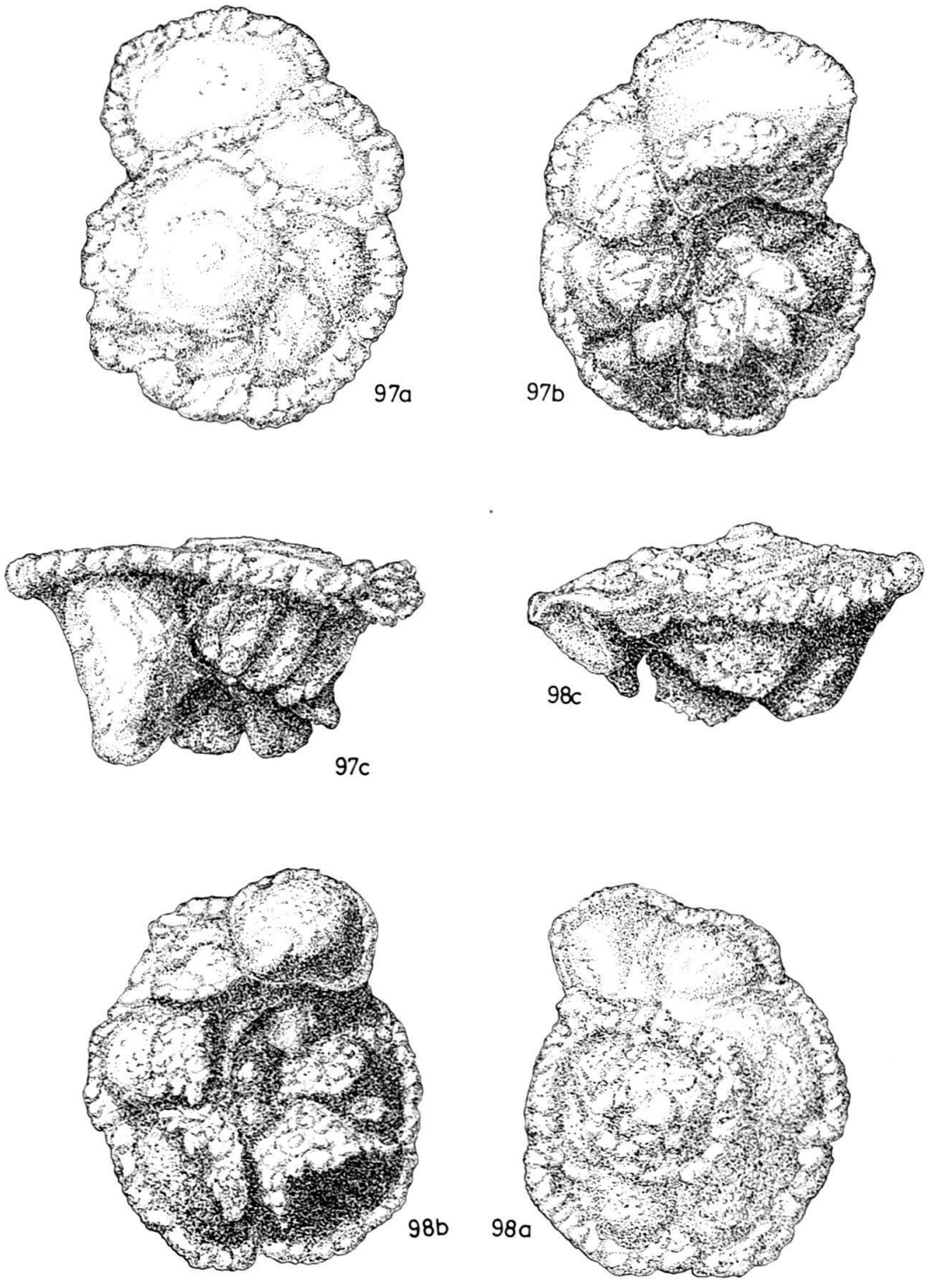

Fig. 97. *Globorotalia caucasica* GLAESSNER, 1937. «Zone of conical Globorotaliids», Keu river, Northern Caucasus (det. et leg. SUBBOTINA, C 20639), × 75.
Fig. 98. *Globorotalia velascoensis* (CUSHMAN), 1925. Globorotalia velascoensis zone, Velasco formation, Ebano, Eastern Mexico (C 20640), × 75.

bean region and Eastern Mexico. A similar decrease from south to north in the percentage of well ornamented *Globorotalia velascoensis* is also observed in the Scaglia basin, which includes the «Couches rouges» of the Western and Central Swiss Alps.

In the section of Gubbio, typical *Globorotalia velascoensis* are first observed in thin sections within the level G-76. The first isolated but poorly preserved specimens are obtained from sample G-75. Coiling is 75% sinistral. A rich assemblage is present at level G-74. The range of variability is identical with that described from the Velasco formation. The largest diameter, however, does not exceed 0.500 mm. A tendency to uncoil the last few chambers is shown by a few specimens. These few specimens have a greater affinity to dextral coiling than the remaining *Globorotalia velascoensis*. In G-74, coiling is about 85% sinistral.

In the poor and badly preserved fauna of G-73a, G-73 and G-72a, *Globorotalia velascoensis* has almost disappeared and is only represented by 1 or 2 specimens in each sample.

In G-72, a few specimens of typical *Globorotalia velascoensis* are observed. Here, the fauna consists mainly of reworked Cretaceous and Lower Paleocene species and is therefore not reliable.

In G-71a, G-71 and G-70a, several specimens similar to *Globorotalia velascoensis* are observed. They share with the typical *Globorotalia velascoensis* the strongly developed umbilical collar and the heavy keel, but they differ from this species by having a larger last chamber, which increases abruptly in size in comparison to the preceding chambers (fig. 100). The earlier chambers of the last whorl increase only very slowly. The spiral side is always flat, the roof of the chambers sometimes depressed and the aspect of the test in lateral view strongly conico-truncate. The specimens are here designated as *Globorotalia* sp. aff. *velascoensis*.

Globorotalia acuta Toulmin, 1941

Figs. 101–104

Globorotalia wilcoxensis Cushman & Ponton var. *acuta* n. var. – Toulmin, 1941, p. 608, pl. 82, figs. 6–8.

Globorotalia acuta Toulmin – Loeblich & Tappan, 1957, p. 185, pl. 47, figs. 5a–c, pl. 55, figs. 4a–c, 5a–c, pl. 58, figs. 5a–c.

Description (see Toulmin, 1941, Loeblich & Tappan, 1957)

Test umbilico-convex with only slightly elevated spiral side and strongly convex umbilical side. Peripheral angle 60°–80°. Periphery keeled, slightly to distinctly lobulate. Umbilicus deep and open. 4–6 chambers of the last whorl increasing fairly

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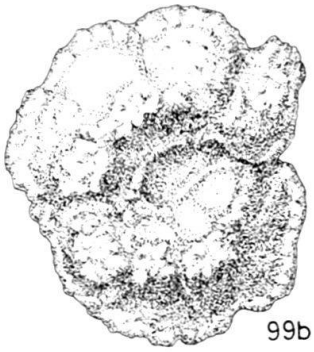
Fig. 99. *Globorotalia velascoensis* (Cushman), 1925. Gubbio section, level G-74 (C 20641), × 75.

Fig. 100. *Globorotalia* sp. aff. *velascoensis* (Cushman), 1925. Gubbio section, level G-71 (C 20642), × 75.

Fig. 101. *Globorotalia acuta* Toulmin, 1941. Globorotalia pseudomenardii zone, El Quss Abu Said, Farafrah Oasis, Egypt (C 20643), × 75.

Fig. 102. *Globorotalia acuta* Toulmin, 1941. Globorotalia velascoensis zone, Velasco formation, Ebano, eastern Mexico (C 20644), × 75.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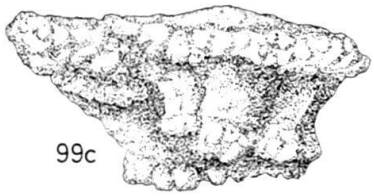
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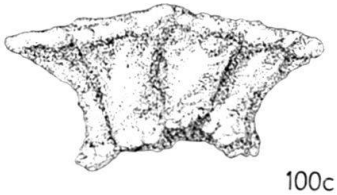
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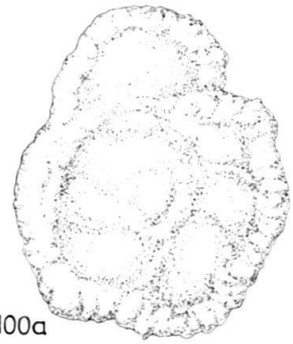
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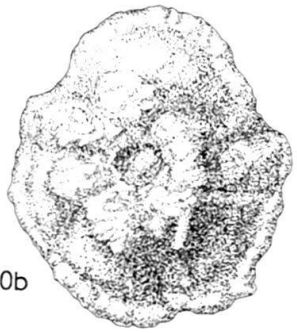
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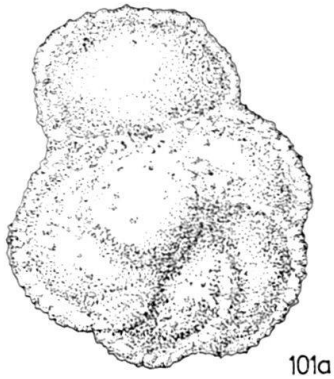
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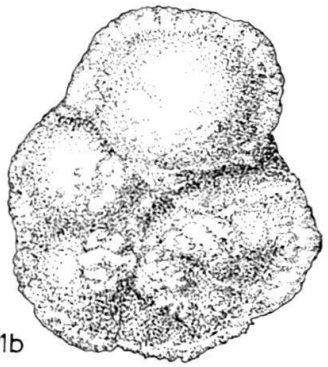
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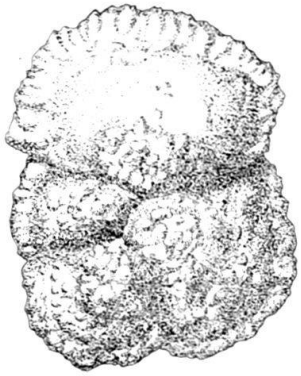
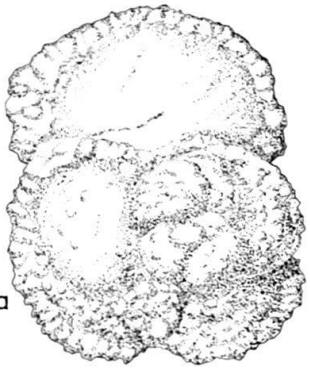

102b


102c


102a

rapidly in size. Last chamber occupying $^1/_5$ to $^1/_3$ of the whole whorl. Umbilical shoulders sharp, ornamented with thick spines, except in the last chamber, where it may be rounded and smooth. Sutures depressed and radial on the umbilical side, curved and beaded on the spiral side, where they may become flush between the youngest chambers. Surface of the test may be covered with short spines in the early portions of the test. Last chamber often smooth. Aperture as typical for the genus, with distinct lip.

Range of dimensions in the fauna from Ebano:

	Minimum	Main distribution	Maximum
Maximum diameter	0,300 mm	0,360–0,415 mm	0,515 mm
Relation maximum/minimum diameter	1.10	1.2–1.3	1.5
Height	0.110 mm	0.145–0.175 mm	0.260 mm
Relation height/maximum diameter	0.30	0.45–0.50	0.60

Variability

Variable characters are the number of chambers in the last whorl (mainly 4–5), the dimensions of the umbilicus, the intensity of lobulation of the equatorial periphery and the development of the last chamber.

Relations and stratigraphical distribution

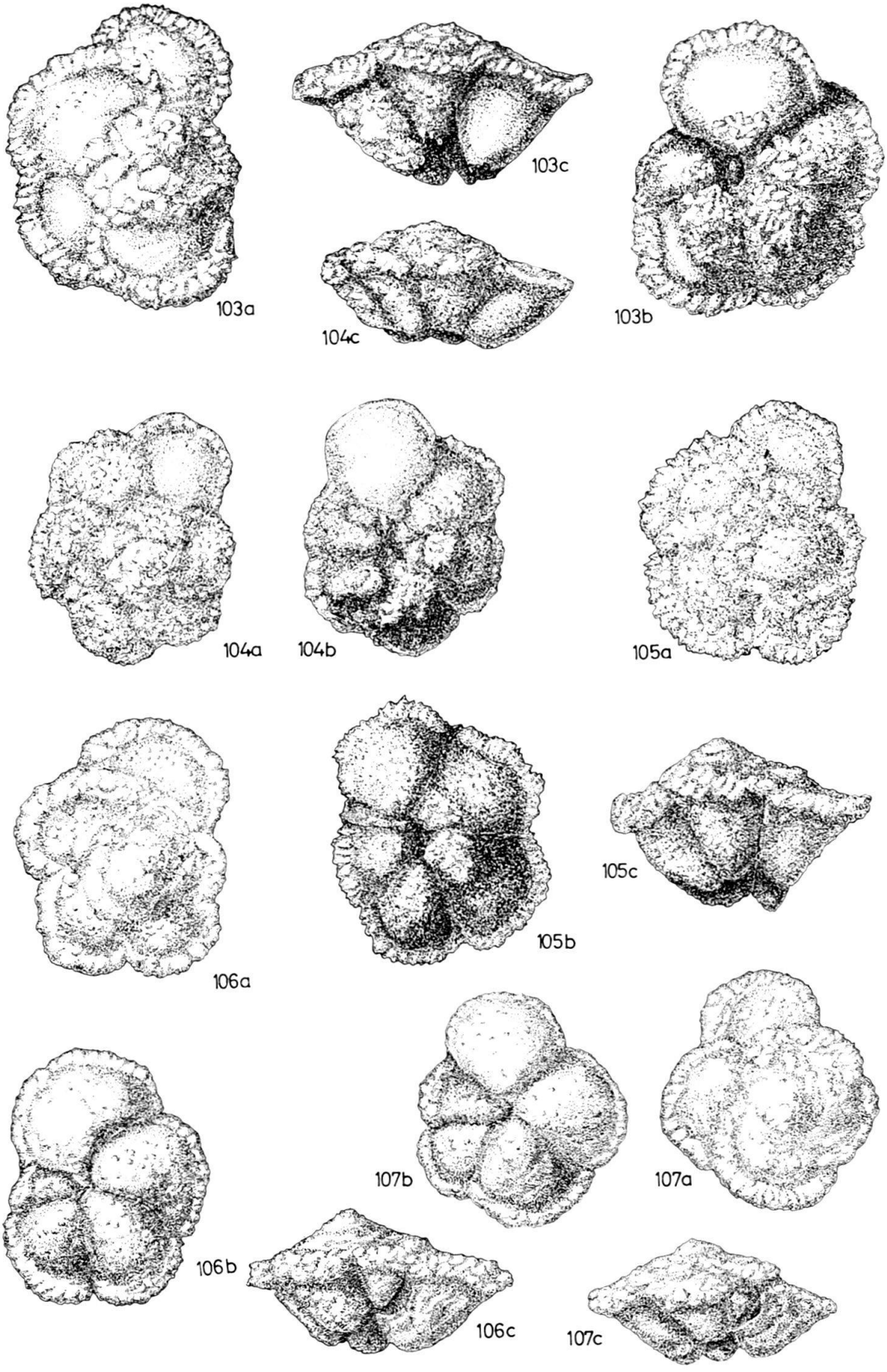
Globorotalia acuta is closely related to *Globorotalia velascoensis*, to which it was thought to be synonymous by some authors (Bolli, 1957, Hillebrandt, 1962). The characteristics suitable for distinguishing the two species from one another are listed by Loeblich & Tappan (1957, pp. 185/6). Although the two species are linked by intermediate forms, their separation is justified by the wider stratigraphical range and the more extensive geographical distribution of *Globorotalia acuta*.

In the section of Gubbio, *Globorotalia acuta* occurs first at level G-77 (Globorotalia pseudomenardii zone). In this sample, specimens with 5–6 chambers in the last whorl and poorly developed sutures on the spiral side prevail. They suggest a relation between *Globorotalia conicotruncata* and *Globorotalia acuta*. In the samples G-75 and G-74, the species is well represented. Coiling is here predominantly sinistral, the percentage of dextral coiling is higher in $4^1/_2$ and 5 chambered specimens. Beginning with level G-73a, *Globorotalia acuta* gets less and less abundant and disappears at level G-70.

Figs. 103–104. *Globorotalia acuta* Toulmin, 1941. Globorotalia velascoensis zone, Velasco formation, Ebano, eastern Mexico (C 20645, C 20646), × 75.

Fig. 105. *Globorotalia* sp. aff. *formosa gracilis* Bolli, 1957. Globorotalia velascoensis zone, Velasco formation, Ebano, eastern Mexico (C 20647), × 75.

Figs. 106–107. *Globorotalia* sp. aff. *formosa gracilis* Bolli, 1957. Gubbio section, level G-74 (C 20648, C 20649), × 75.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107c

Globorotalia pasionensis (BERMUDEZ), 1961

Figs. 108–110

Pseudogloborotalia pasionensis n. sp. – BERMUDEZ, 1961, p. 1.346, pl. 16, figs. 8a, b.

Description (see BERMUDEZ, 1961)

Test umbilico-convex, spiral side flat, umbilical side strongly convex. Periphery gently lobulate, acute, keeled; peripheral angle about 60°. Umbilicus wide, open. In extreme specimens chambers of earlier whorl visible. 5–7 chambers in the last whorl without distinct ornamentation. Keel well developed, with exception of the last chamber, which is attached below the level of the older ones and very often «senile». Sutures on spiral side raised and beaded in early portion of the test, flush or depressed between the younger chambers, passing without a break into the peripheral keel. On umbilical side, sutures depressed and radial. Aperture as typical for the genus, with faintly developed lip. The whole surface of the test, especially in its older parts, is covered with small spines. (The above description is based on a set of topotypes given by BERMUDEZ.)

Relations and stratigraphical distribution

This species differs from *Globorotalia velascoensis* by a more lobulate periphery, more rounded umbilical shoulders, a somewhat imbricated arrangement of the chambers on the spiral side and a very wide umbilicus. It is flatter and has a broader umbilicus than *Globorotalia formosa formosa*. The species has been described by BERMUDEZ from the Lower Eocene of Guatemala.

In the section of Gubbio, *Globorotalia pasionensis* occurs very rarely within the levels G-71 and G-70a. The few specimens available do not permit the determination of a trend in coiling. It occurs as an extremely rare form in the fauna from Ebano (Velasco formation) (fig. 111).

Globorotalia occlusa LOEBLICH & TAPPAN, 1957

Figs. 112–114

Globorotalia occlusa n. sp. – LOEBLICH & TAPPAN, 1957, p. 191, pl. 64, figs. 3a–c.

Description

Test almost biconvex, umbilical side only slightly more convex than spiral side. Chambers angular-rhomboid. Periphery rounded, acute, keeled; peripheral angle 50°–75°. Umbilicus deep, almost closed to fairly wide. 5–8 chambers in the last whorl, increasing slowly in size, last chamber often «senile». Umbilical shoulders covered with blunt spines, in youngest chambers often smooth. Sutures on umbilical side depressed and radial, on spiral side raised and beaded. Between the

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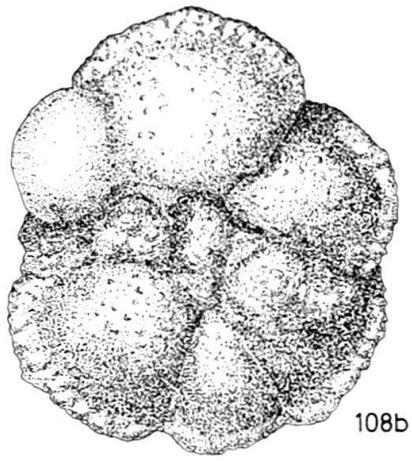
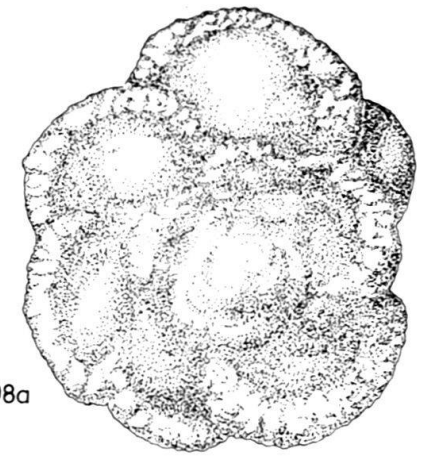
Fig. 108. *Globorotalia pasionensis* (BERMUDEZ), 1961. Topotype, Lower Eocene, Rio de la Pasion, El Petén, Guatemala (det. et leg. BERMUDEZ, C 20650), × 75.

Fig. 109. *Globorotalia pasionensis* (BERMUDEZ), 1961. Gubbio section, level G-71 (C 20651), × 75.

Fig. 110. *Globorotalia pasionensis* (BERMUDEZ), 1961. Gubbio section, level G-70a (C 20652), × 75.



108b



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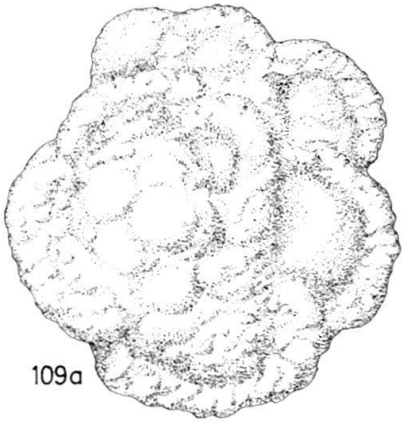

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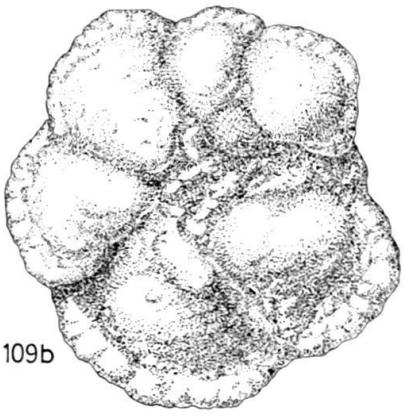

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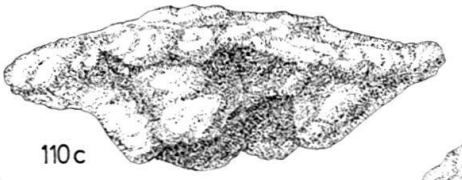

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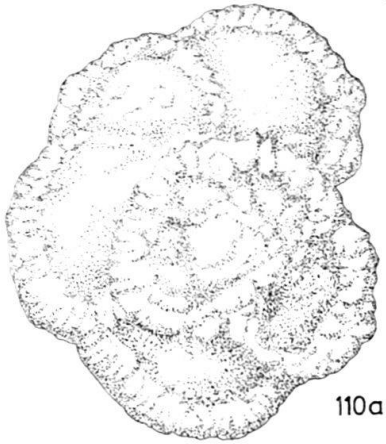

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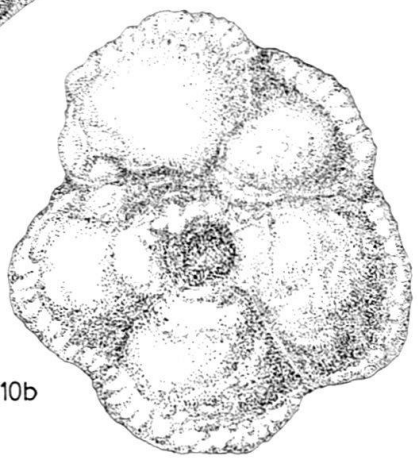


110b

younger chambers almost flush. Surface of the test in early whorl rugose, in the younger part of the test almost smooth, except for the ornamentation. Aperture as typical for the genus, usually with a lip.

Variability

Variable characters are the number of chambers in the last whorl, the dimension of the umbilicus and the intensity of ornamentation.

Relations and stratigraphical distribution

The description of *Globorotalia occlusa*, as given above, differs somewhat from the conception of the species as adopted by its authors and follows mainly the interpretation given by HILLEBRANDT (1962). The most important characteristic is the strong convexity of the spiral side, which gives the test a somewhat lenticular appearance. The species differs from *Globorotalia velascoensis* in its smaller dimensions, weaker ornamentation and more tightly arranged umbilical shoulders, which are not individualized by strongly incised sutures, as in typical *Globorotalia velascoensis*. The two species are linked by intermediate forms.

Globorotalia occlusa has in common with *Globorotalia simulatilis* the convexity of the spiral side. It differs by a well developed keel, the ornamentation and the raised sutures on the spiral side.

Globorotalia crosswickensis OLSSON, 1960, which was thought to be synonymous to *Globorotalia occlusa* by HILLEBRANDT (1962) and GOHRBANDT (1963), has a more pronounced ornamentation and depressed sutures on its spiral side.

Globorotalia occlusa occurs in the Globorotalia pseudomenardii zone and in the Globorotalia velascoensis zone of the Velasco formation (Eastern Mexico) and of the Lower Lizard Springs formation (Trinidad).

In the section of Gubbio, the species is found within the levels G-75 and G-74.

Globorotalia formosa gracilis[4]) BOLLI, 1957

Figs. 115, 117

Globorotalia formosa gracilis n. sp. – BOLLI, 1957, p. 75, pl. 18, figs. 4–6.

Description (see BOLLI, 1957)

Test umbilico-convex; spiral side slightly, umbilical side strongly convex. Periphery lobulate, acute, with spinose keel. 5–6 chambers in the last whorl, which

[4]) Although binominal nomenclature is preferred in the present paper, the two species *Globorotalia formosa gracilis* and *Globorotalia formosa formosa* are used in their original trinominal designation for the sake of stability of well-known names.

Fig. 111. *Globorotalia* sp. aff. *pasionensis* (BERMUDEZ), 1961. Globorotalia velascoensis zone, Velasco formation, Ebano, eastern Mexico (C 20653), × 75.

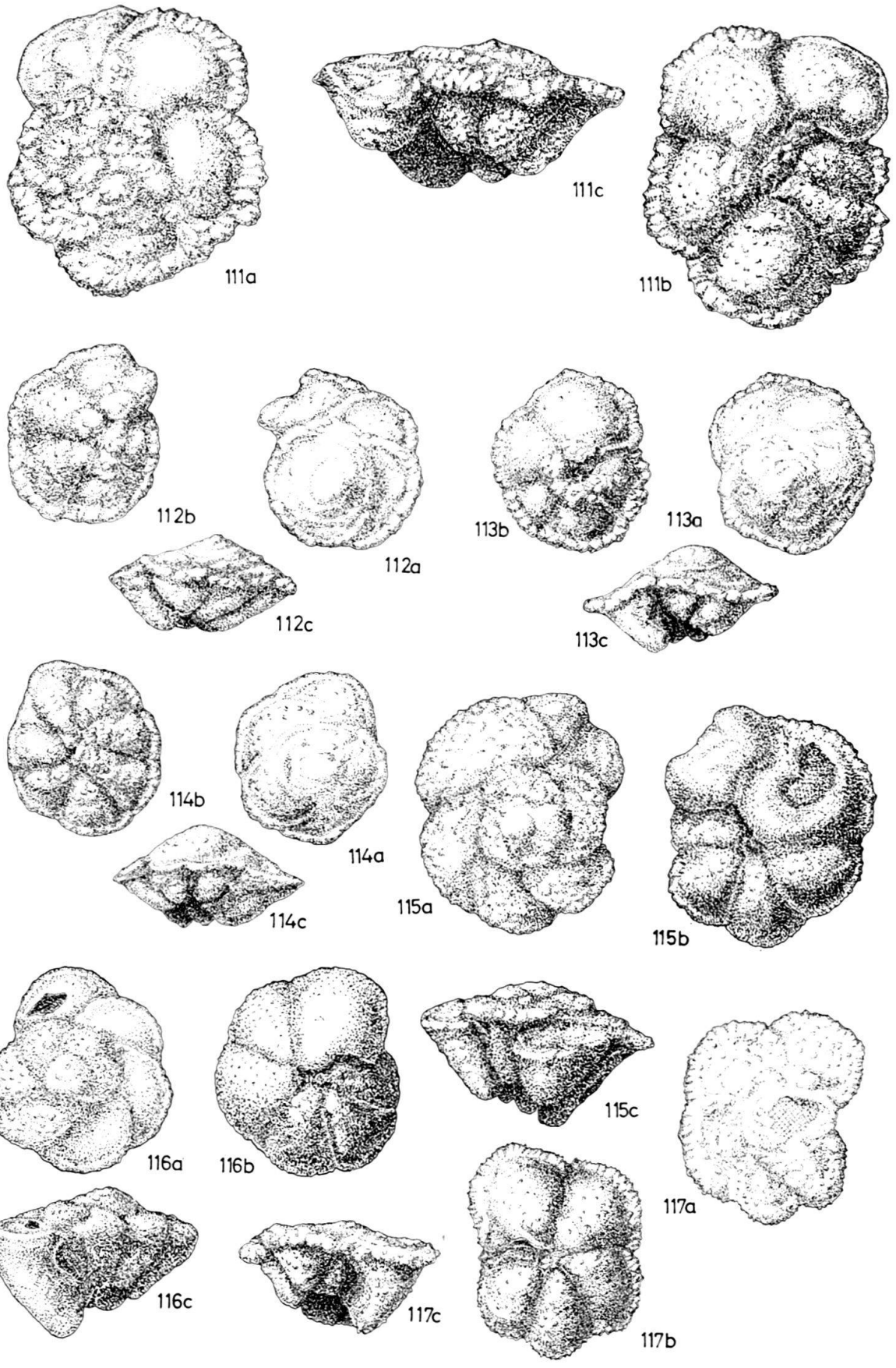
Figs. 112 and 113. *Globorotalia occlusa* LOEBLICH & TAPPAN, 1957. Globorotalia velascoensis zone, Velasco formation, Ebano, eastern Mexico (C 20654, C 20655), × 75.

Fig. 114. *Globorotalia occlusa* LOEBLICH & TAPPAN, 1957. Gubbio section, level G-74 (C 20656), × 75.

Fig. 115. *Globorotalia formosa gracilis* BOLLI, 1957. Topotype, Globorotalia rex zone (TLL 232994), Upper Lizard Springs formation, Trinidad (C 20657), × 75.

Fig. 116. *Globorotalia guatemalensis* (BERMUDEZ), 1961. Topotype, Upper Paleocene, Rio de la Pasion, El Petén, Guatemala (det. et leg. BERMUDEZ, C 20658), × 75.

Fig. 117. *Globorotalia formosa gracilis* BOLLI, 1957. Gubbio section, level G-58 (C 20659), × 75.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117b

increase rapidly in size. Last chamber occupying $^1/_3$ to $^1/_5$ of the whole whorl. On spiral side, chambers imbricated, sutures curved, passing without a break into the periphery, depressed, distal part of the chambers ornamented with spines. Between the younger chambers, the sutures may become indistinct. Umbilicus of medium size, deep; umbilical shoulders without special ornamentation. Aperture as typical for the genus, lip missing or only faintly developed. Surface of the test spinose. Coiling predominantly dextral in the younger levels, almost random in the oldest levels.

Relations and stratigraphical distribution

Globorotalia formosa gracilis was thought to be synonymous to *Globorotalia marginodentata* by HILLEBRANDT (1962). It differs, however, from the latter species by a less broad and heavy keel, by a higher test and a more regular chamber growth.

Globorotalia acuta has generally a wider umbilicus with acute and ornamented umbilical chamber tips.

Globorotalia aequa has only a faintly developed keel or no keel at all and generally less chambers in the last whorl.

A closely related species is *Globorotalia guatemalensis* (BERMUDEZ) from the Upper Paleocene of Guatemala, of which topotypes were kindly furnished by BERMUDEZ (fig. 116). It differs from typical *Globorotalia formosa gracilis* in being more compact and having a more convex spiral side.

Globorotalia formosa gracilis is assumed to be characteristic for the Globorotalia marginodentata subzone (= upper part of the Globorotalia subbotinae zone) of the Central Northern Caucasus.

In the section of Gubbio, *Globorotalia formosa gracilis* starts with typical representatives at level G-73 and ranges up to level G-49.

Related forms, which differ in having a more robust keel, coarser spines and a more convex spiral side, occur already at level G-75 and in the fauna from Ebano. They are determined as *Globorotalia* sp. aff. *formosa gracilis* (figs. 105–107).

Globorotalia formosa formosa BOLLI, 1957

Figs. 118–120

Globorotalia formosa formosa n. sp. – BOLLI, 1957, p. 76, pl. 18, figs. 1–3.

Description (see BOLLI, 1957)

Test umbilico-convex; spiral side only slightly, umbilical side strongly convex. Periphery almost rounded, acute, with well developed keel; peripheral angle 70°–80°. Last formed whorl with 6–7 (rarely 8) chambers, which increase regularly

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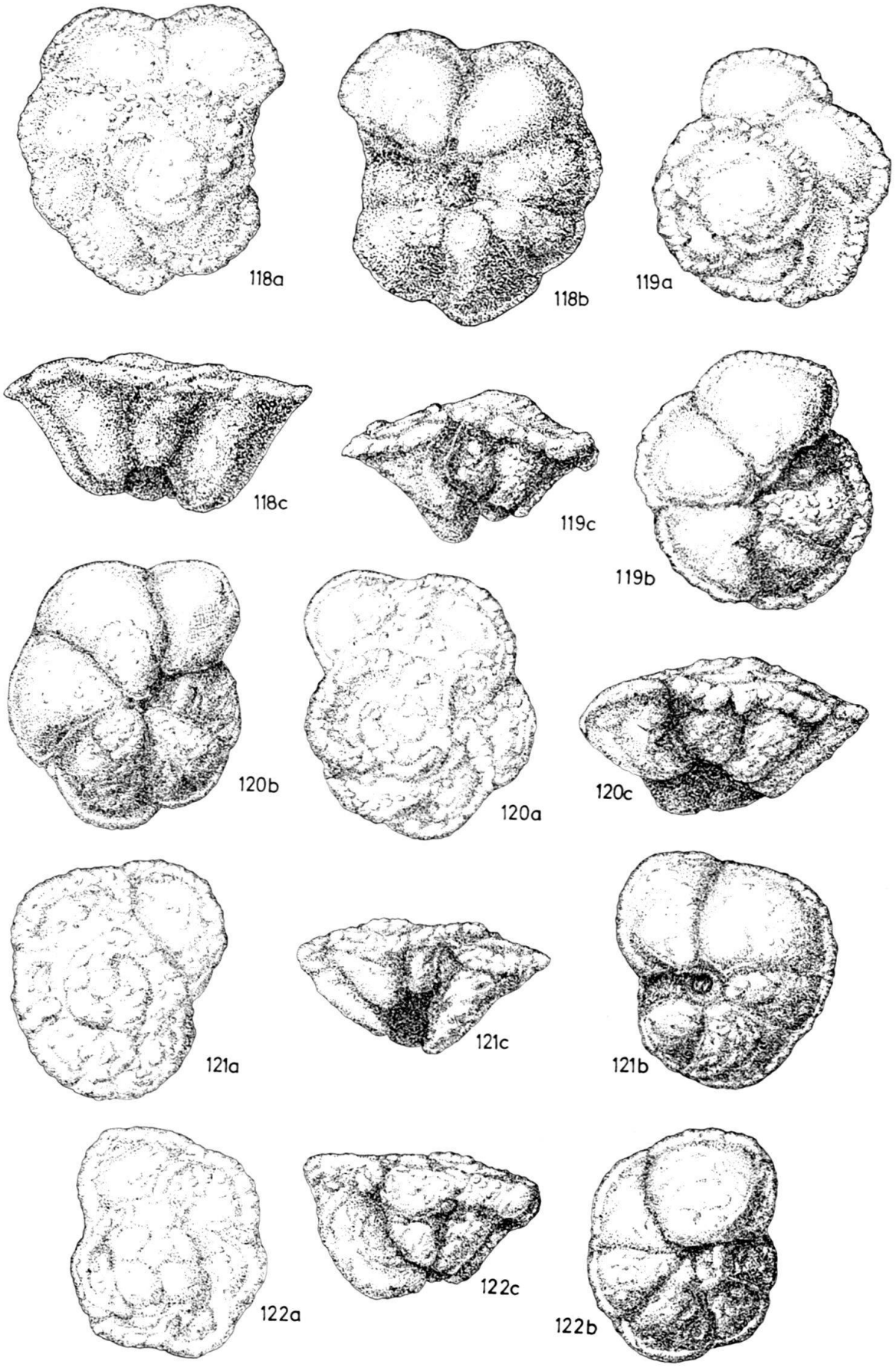
Fig. 118. *Globorotalia formosa formosa* BOLLI, 1957. Topotype, Globorotalia formosa formosa zone, Upper Lizard Springs formation, Trinidad (C 20660), × 75.
Fig. 119. *Globorotalia formosa formosa* BOLLI, 1957. Gubbio section, level G-70 (C 20661), × 75.
Fig. 120. *Globorotalia formosa formosa* BOLLI, 1957. Gubbio section, level G-52 (C 20662), × 75.
Fig. 121. *Globorotalia aragonensis* NUTTALL, 1930. Gubbio section, level G-52 (C 20663), × 75.
Fig. 122. *Globorotalia aragonensis* NUTTALL, 1930. Gubbio section, level G-49 (C 20664), × 75.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122b

in size. Last chamber occupying $^1/_5$–$^1/_6$ of the whole whorl, but often «senile». Umbilicus well developed, open and deep. Umbilical shoulders of the chambers rounded, without special ornamentation. Chambers on spiral side somewhat overlapping, sutures curved, beaded or spinose, passing without a break into the peripheral keel. On umbilical side, sutures depressed and radial. Aperture as typical for the genus, with a lip. Surface of the test spinose.

Relations and stratigraphical distribution

Globorotalia formosa formosa ranges from the Globorotalia rex zone to the Globorotalia formosa formosa zone in the Upper Lizard Springs formation (Trinidad). Its type-level corresponds to the type-locality of the Globorotalia formosa formosa zone.

Globorotalia formosa gracilis has a more lobulate periphery and fewer chambers in the last whorl.

It is not clear why HILLEBRANDT (1962) supposed *Globorotalia formosa formosa* to be synonymous to *Globorotalia caucasica*. He does not give any arguments for this opinion.

The specimen figured by SUBBOTINA (1960, fig. 2) as «*Truncorotalia*» *lensiformis* can probably be attributed to *Globorotalia formosa formosa*.

In the section of Gubbio, *Globorotalia formosa formosa* ranges from level G-71 to level G-49. In the older levels, coiling is preferentially sinistral, but becomes predominantly dextral in the younger samples (G-55–G-49). The youngest representatives of the species are intermediate to *Globorotalia aragonensis*.

Globorotalia aragonensis NUTTALL, 1930

Figs. 121–126

Globorotalia aragonensis n. sp. – NUTTALL, 1930, p. 288, pl. 24, figs. 6–8.
Globorotalia aragonensis NUTTALL – SUBBOTINA, 1953, pp. 215–16, pl. XVIII, figs. 6a–c.
Globorotalia aragonensis NUTTALL – BOLLI, 1957, p. 75, pl. 18, figs. 7–9, p. 167, pl. 38, figs. 1a–c.

Description (see NUTTALL, 1930, SUBBOTINA, 1953, BOLLI, 1957)

Test conico-truncate, spiral side flat or with only slightly convex inner whorl, umbilical side strongly convex. Periphery almost completely rounded, acute, keeled; peripheral angle 60°–80°. Last whorl with 5–7 chambers, increasing slowly in size in specimens with 6–7 chambers and fairly rapidly in those with 5 chambers in the last whorl. Sutures on spiral side almost flush or slightly raised and beaded, often hidden by the general rugosity of the test. The sutures on the spiral side form a distinct and characteristic angle with the periphery. On umbilical side, sutures radial and moderately depressed. Umbilical chamber tips rounded, tightly arranged around the deep and narrow umbilicus. Aperture as typical for the genus, lip missing or only faintly developed. Wall generally thick and rugose, especially on the umbilical side.

Dimensions: maximum diameter 0.35–0.60 mm, height 0.23–0.40 mm.

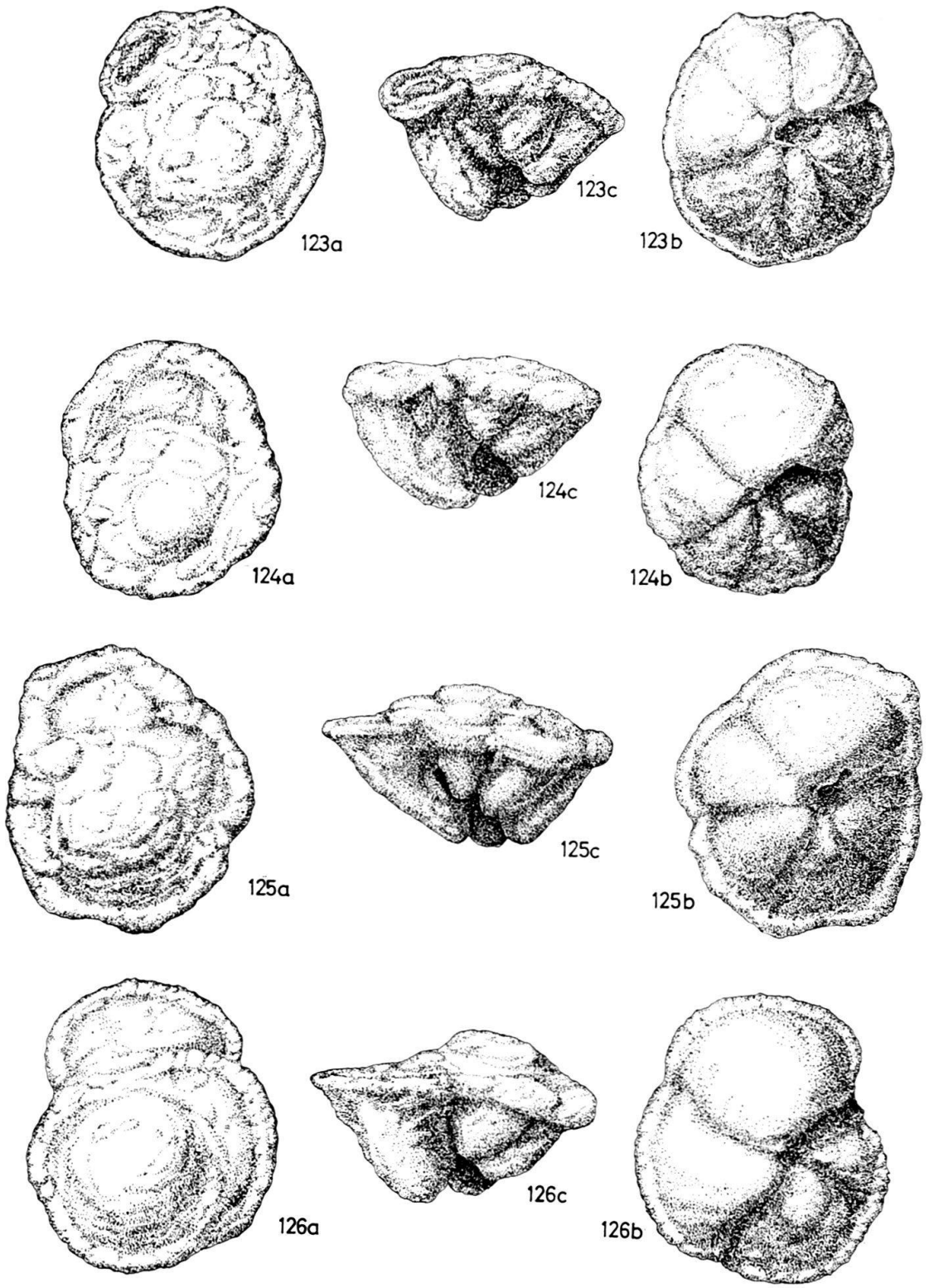


Fig. 123. *Globorotalia aragonensis* NUTTALL, 1930. Gubbio section, level G-38 (C 20665), × 75
Fig. 124. *Globorotalia aragonensis* NUTTALL, 1930. Gubbio section, level G-28 (C 20666), × 75
Figs. 125 and 126. *Globorotalia aragonensis* NUTTALL, 1930. Gubbio section, level G-22 (C 20667 C 20668), × 75.

Remarks

In the Gubbio section, *Globorotalia aragonensis* shows a similar change in the direction of coiling as described by BOLLI (1957) from the Upper Lizard Springs formation in Trinidad. In the early levels of its range (G-58–G-50), the species has almost exclusively dextral coiling. Beginning with the level G-49, the number of specimens with sinistral coiling increases, until it predominates within the younger levels (G-24–G-10). At level G-28, coiling is about random. From G-38 to G-10, *Globorotalia aragonensis* is less and less abundant. Its representatives in these younger levels have generally only 5 chambers in the last whorl, which increase quite rapidly in size. The last chamber shows a tendency to overlap the umbilicus with its protruding umbilical chamber end. In the younger levels, the wall is less stout and rugose.

Globorotalia aragonensis was first described from the Aragon formation of Eastern Mexico. The occurrence of *Hantkenina aragonensis* in its type-sample indicates a Middle Eocene age, it is therefore younger than the type-sample of the Globorotalia aragonensis zone in Trinidad. Together with *Globorotalia caucasica*, the species is abundant in the «Marnes de Donzacq» (southwestern France), which are regarded as being of Upper Cuisian age by HOTTINGER & SCHAUB (1960).

Species not investigated, which belong to the *Globorotalia velascoensis* group, are:
Globorotalia naussi MARTIN (1943, p. 26, pl. VIII, figs. 3a–c) and *Globorotalia marksi* MARTIN (1943, p. 25, pl. VIII, figs. 1a–c), both from the Lower Eocene Lodo formation of California.

Remarks on the determination of Paleogene *Globorotalia* in thin sections

In the Apennines and especially in the Alps, Paleogene deposits in pelagic facies are very often represented by hard compact limestone. Age determination is only possible by examining thin sections.

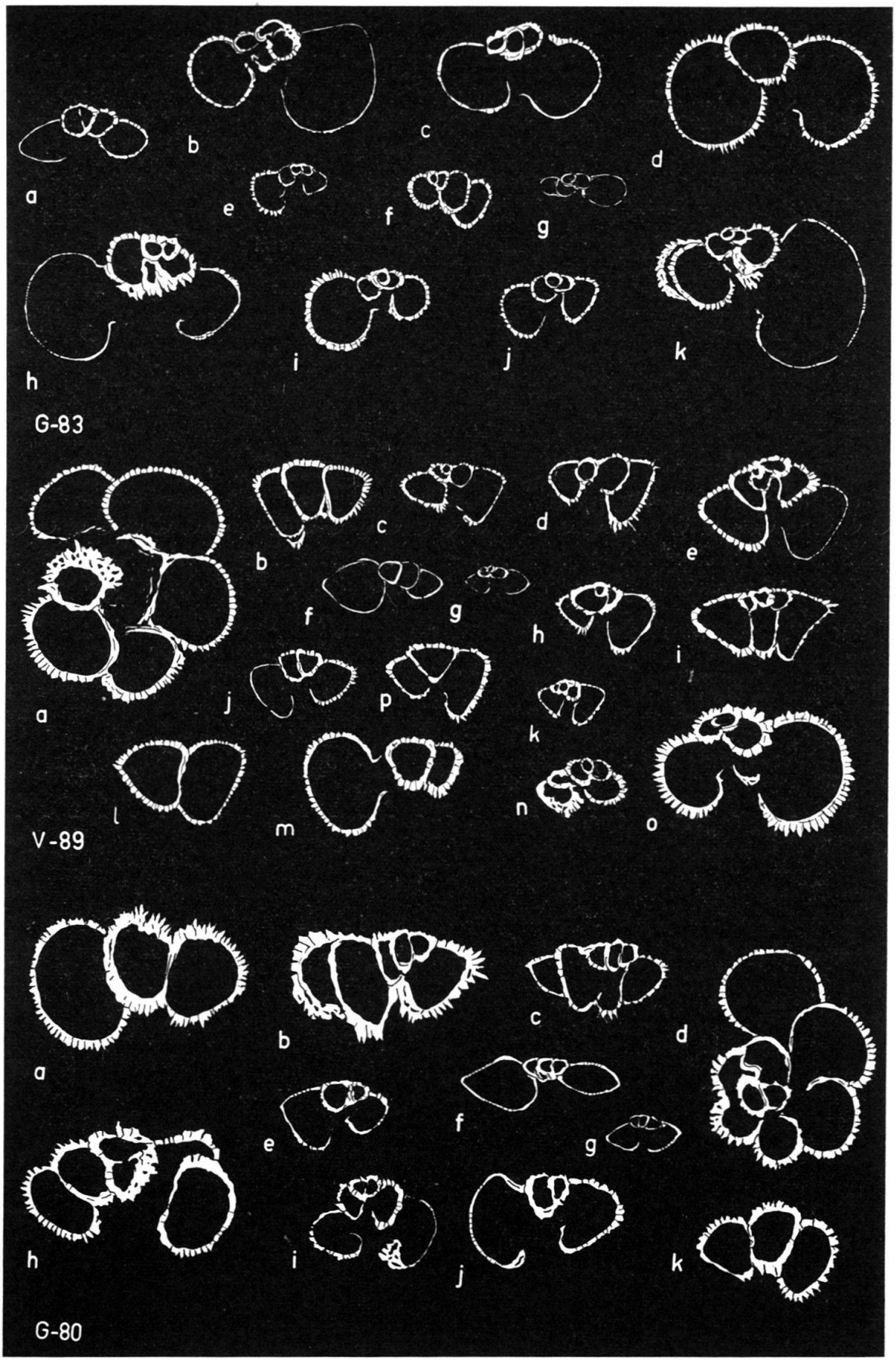
An exact specific determination of *Globorotalia* in thin section is possible only exceptionally. An approximate age determination is often possible by observing the necessary restrictions.

O. RENZ (1936), basing his study of the Scaglia exclusively on thin sections, distinguished the Lower and Upper Paleocene, and the Lower, Middle and Upper Eocene.

REICHEL (1952) illustrated and discussed thin sections from the collection of O. RENZ from the Gubbio section. (Fig. 2 (= RENZ level 33) is to be placed in the Globorotalia trinidadensis zone, fig. 3 (= RENZ level 34) in the Globorotalia pseudomenardii zone and fig. 4 (= RENZ level 35) in the Globorotalia formosa formosa/Globorotalia subbotinae zone.)

The aspect of thin sections from the Globigerina eugubina and the Globorotalia trinidadensis zones has already been illustrated by PREMOLI SILVA & LUTERBACHER (1964).

Fig. 127. Non-oriented thin sections of *Globorotalia* from levels G-83, G-80 (Gubbio section) and V-89 (Valle della Contessa).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G-83
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p
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V-89
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j
k
G-80

Based on the determination of isolated specimens, level G-83 (fig. 127) is attributed to the Globorotalia uncinata zone. The fauna is still dominated by large *Globigerina*-like forms with a flattened spiral side, which belong to the *Globorotalia inconstans/Globorotalia trinidadensis* group (b, c, d, h, i, k). Fig. g shows a flattened form with rotaloid chambers and almost smooth and fragile chamber walls as in *Globorotalia compressa.* A few, generally smaller forms, have chambers with a subacute periphery and belong to *Globorotalia uncinata* or *Globorotalia praecursoria* (a, j).

The fauna of level V-89, from the section in the Valle della Contessa, belongs to the basal part of the Globorotalia pusilla pusilla zone. Specimens of the *Globorotalia pusilla* group are easily recognizable in thin section (fig. g), because of their compact lenticular test and the almost smooth and thin chamber walls. Other specimens with strongly flattened chambers and thin tests (f) belong to the *Globorotalia pseudomenardii* group. The absence of an imperforate limbate periphery suggests *Globorotalia chapmani.* Large specimens with globular chambers are still present, but compared to older levels, their number has considerably decreased. Their tests have become thicker and more spinose (m, o). Sections of forms with a flattened spiral side, subacute periphery and spinose test resemble *Globorotalia angulata* (c, d, h, i, j, k). Larger forms with almost plane spiral side and larger peripheral angle may be referred to *Globorotalia conicotruncata* (b, p, l), whereas similar forms with raised inner whorls might be attributed to *Globorotalia tadjikistanensis* (e).

Level G-80 belongs also to the Globorotalia pusilla pusilla zone. Its fauna differs slightly from level V-89. Sections comparable to *Globorotalia conicotruncata* are more frequent (b, c, d, h). The walls of the tests are generally stouter, the thick spines may become already somewhat concentrated at the periphery and the umbilical chamber tips.

Level G-76 (fig. 128) contains a fauna corresponding to fig. 3 in REICHEL (1952). It is placed in the upper part of the Globorotalia pseudomenardii zone. The strongly flattened form with acute limbate periphery (m) and smooth and thin chamber walls is attributed to *Globorotalia pseudomenardii.* A more compact and lenticular specimen with a similar wall structure belongs to the *Globorotalia pusilla* group. Sections «o» and «r» are of large specimens with strongly convex umbilical side, almost flat spiral side and quite large umbilicus. The wall of the tests is relatively thin, especially in the younger chambers of the last whorl. Spinosity is only moderately developed. These forms are likely to be intermediate between *Globorotalia conicotruncata* and *Globorotalia acuta.*

D, k, l and n represent *Globorotalia* with angular-rhomboidal chambers and almost biconvex tests. The umbilicus is of medium size; the spinosity is fairly well developed, especially in the older chambers. They may be compared with *Globorotalia simulatilis.*

A third group of forms (a, e, h, i, p, q) is characterized by a highly spinose test, a well developed umbilicus and a strongly conical umbilical side. Bundles of spines

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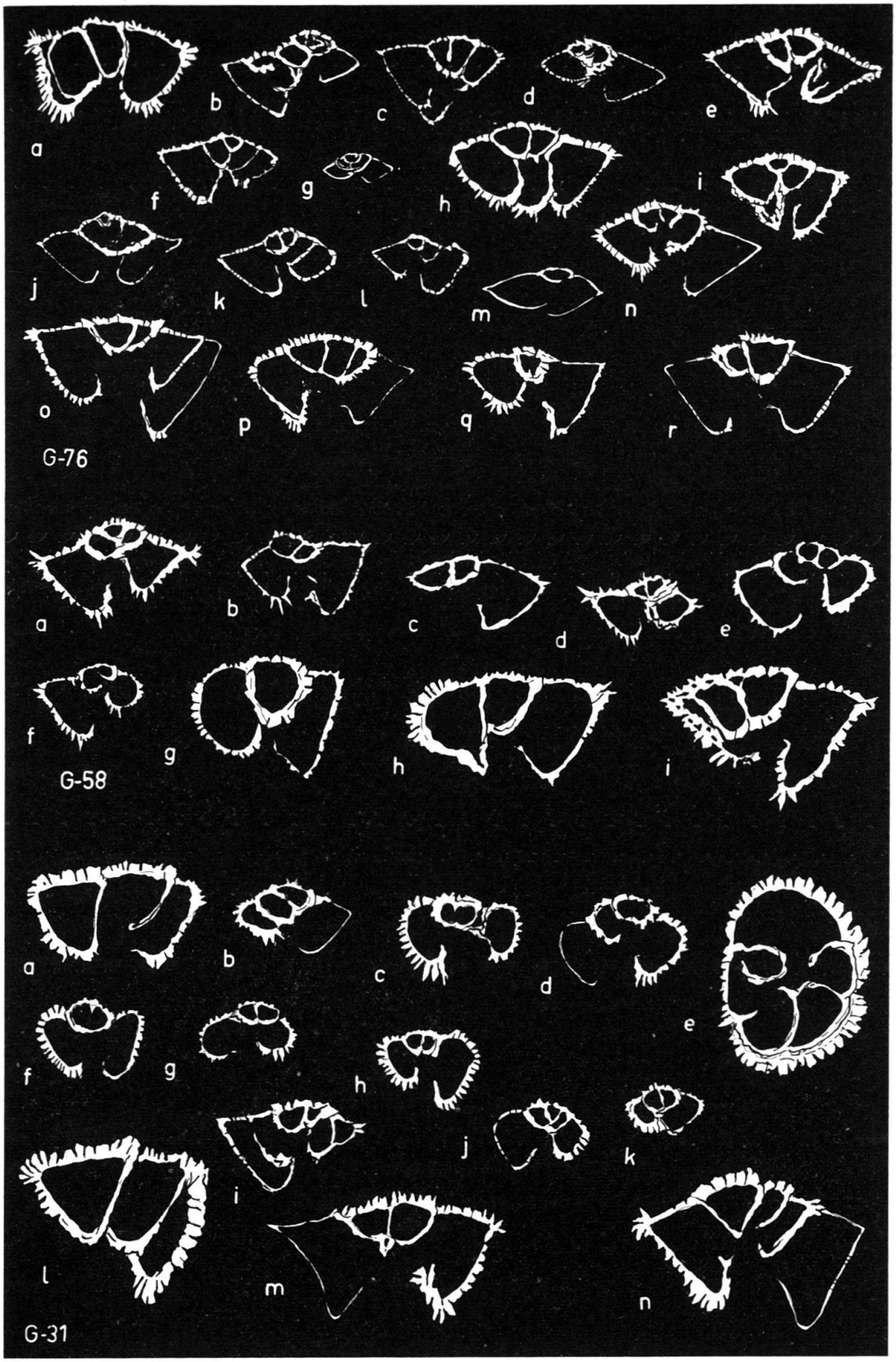
Fig. 128. Non-oriented thin sections of *Globorotalia* from levels G-76, G-58 and G-31 (Gubbio section).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G-76
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G-58
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b
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G-31

are concentrated at the periphery and the umbilical shoulders. These characters are typical for the *Globorotalia velascoensis* group.

The fauna within level G-58 is characteristic for the upper part of the Globorotalia formosa formosa/Globorotalia subbotinae zone. The sections «a» and «d» show highly spinose forms with biconvex tests and well developed keels with large spines. They may be compared with *Globorotalia marginodentata*. A spiny conical form (b) might belong to *Globorotalia subbotinae*. Large specimens with flat spiral side, rounded umbilical shoulders and well developed umbilicus are referable to *Globorotalia formosa formosa* (i). Sections of conical *Globorotalia* with rounded periphery, spinose test (f, g, e) and slightly detached last chamber show affinities to *Globorotalia bullbrooki* or *Globorotalia quetra*.

Level G-31 is to be placed in the Globorotalia bullbrooki zone. Sections of highly conical *Globorotalia* with stout chamber walls (a, l, m, n) probably belong to *Globorotalia aragonensis*. In an oblique equatorial section (e), the characteristic abrupt angle between the periphery and the septa is observable.

Sections of *Globorotalia* with detached last chamber and rounded periphery suggest affinities to *Globorotalia bullbrooki* (c, f, h). Other forms with higher spire and more globular chambers in the last whorl (g, h, d, j, k) are related to the group of *Globorotalia broedermanni/Globorotalia rotundimarginata*.

Index to the genera and species discussed in the systematic part

(main entry page numbers in italics)

B. STRATIGRAPHICAL PART

Description of the sections

(Fig. 132)

The three sections, measured in the Scaglia of the Central Apennines, belong to the North Umbrian facies belt (see O. RENZ, 1936). This belt is characterized by a continuous pelagic facies, ranging from Albian to Oligocene.

Turbidites of clastic material – as characteristic for the South Umbrian facies – are practically absent within these sequences, although a few layers with laminated bedding may occur locally (e.g. Fossombrone, Furlo, Genga). The present description is restricted to the Paleocene and Lower Eocene. Two of the sections are situated immediately north of Gubbio (Prov. di Perugia), the third section is located near Fossombrone (Prov. di Pesaro ed Urbino) (see sketch map, fig. 129).

1. Section of the Gola del Bottaccione («Gubbio section»)

A few hundred meters north of the medieval town of Gubbio, in the Gola del Bottaccione, there is an outcrop along the Gubbio–Scheggia road (fig. 130) of a continuous section ranging from Upper Jurassic to Lower Oligocene. Since the thesis of O. RENZ (1936), this section represents one of the classic European localities for the study of the Upper Cretaceous and the Lower Paleogene in pelagic facies. For further references, the papers of O. RENZ (1936), BARNABA (1959), and PREMOLI SILVA & LUTERBACHER (1962) may be consulted.

The Cretaceous/Tertiary boundary is exposed about 60 m below the bridge of the old aqueduct over the road. The highest layers of Maestrichtian age (G-99–G-97B) are represented by a well bedded reddish limestone rich in *Globotruncana*, *Rugoglobigerina* and costate *Heterohelicidae* (see faunal list in PREMOLI SILVA & LUTERBACHER, 1962).