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Studies in some Globorotalia from the Paleocene and Lower Eocene of the Central Apennines

By **Hanspeter Luterbacher** [1])

With 134 figures

CONTENTS

RIASSUNTO

Il lavoro si compone di due parti. Nella prima, che ha carattere tassonomico, vengono prese in esame le forme «coniche» del gen. *Globorotalia* del Paleogene ed i loro probabili antenati. Si discute il significato del gen. *Globorotalia* e dei generi affini. Si descrive 22 specie provenienti dal Paleocene ed Eocene inferiore della Scaglia umbro-marchigiana.

Nella II parte, a carattere stratigrafico, l'autore sostiene che la zonazione, basata sulle microfaune planctoniche, elaborata da Bolli a Trinidad può essere applicata con poche e piccole modifiche anche nell'ambito del bacino appenninico. L'autore è convinto che la stratigrafia del Paleogene si deve basare sulla successione

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delle zone a Foraminiferi planctonici nella Tetide. Per ragioni storiche tutte le località-tipo dei piani del Paleogene si trovano in serie epicontinentali con faune di tipo boreale. Di conseguenza il loro valore e significato per quanto riguarda la stratigrafia del Terziario antico non dovrebbe essere sopravvalutato.

Vengono descritte tre serie, di cui due nei dintorni di Gubbio (Perugia) ed una presso Fossombrone (Pesaro).

РЕЗЮМЕ

В данной работе изучены эволюция и стратиграфическое распространение некоторых Глоборогалий в палеоцене и нижнем эоцене в формации Сгаля центральной части Апеннин (Италия).

Выбор ограничевается "коническими" Глобороталиями и видами, которые могут-быть рассматриваемы как их предки. 22 вида описаны и изображены.

Зональное расчленение, разработанное Болли (1957) в Тринидаде, может-быть с некоторыми незначительными изменениями применено также к формациям Сгаля.

Автор убежден, что стратиграфия палеогена будет основываться на зональной шкале по фауне планктонных фораминифер Средиземноморской области. По историческим причинам все стратотипические разрезы яруса палеогена лежат в эпиконтинентальных отложениях бореальной фаунистической области: Их значение для стратиграфии палеогена не должно быть поэтому преувеличено.

ABSTRACT

The taxonomy and stratigraphic distribution of some *Globorotalia* from the Paleocene and Lower Eocene of the Central Apennines are studied. The systematic descriptions are restricted to the «conical» *Globorotalia* and to species which are thought to be their predecessors. 22 species are described and figured.

In the Scaglia of the Central Apennines, the same zonal succession as established by Bolli (1957) in Trinidad is observed. A few minor modifications are due mainly to taxonomic reasons.

An attempt to correlate the planktonic foraminiferal zonation with the respective European stages is discussed.

PREFACE

The present paper is a doctoral thesis submitted to the Faculty of Science of the University of Basel. It has been prepared at the Geological Institute of this University.

Investigations on Lower Tertiary *Globorotalia* were started in late summer 1960 and finished in spring 1964. For different reasons, they had to be interrupted several times.

Three sections within the Central Apennines have been measured and sampled during two excursions in autumn 1961 and spring 1962. For comparison, classical localities of uppermost Cretaceous and Paleogene in the Netherlands, Belgium, Southern France, Northern Spain and Northern Italy have been visited. A visit at the Geological Institute of the Academy of Science of the Soviet Union in Moscow during August 1963 has been very instructive.

ACKNOWLEDGMENTS

I wish to express my sincere thanks to Professor Dr. M. REICHEL for suggesting the present thesis, and mainly for his invaluable help and advice during the investigations and the preparation of the manuscript and the illustrations. I am greatly indebted to him for introducing me to the methods and problems of micropaleontology.

Professor Dr. L. VONDERSCHMITT, Director of the Geological Institute of the University of Basel, is acknowledged for granting all kinds of facilities during the study at the Institute, for the interest he has taken in my work and the financial aid he granted me.

I want to thank Professor Dr. H. SCHAUB, Director of the Museum of Natural History, Basel, for introducing me to the stratigraphy of the Paleogene, for helpful suggestions and criticism, for giving me numerous samples and for his guidance during several excursions.

Dr. O. RENZ, at the Museum of Natural History, Basel, has kindly read and corrected the manuscript. It was a great honour for me to discuss many problems with him, who is the author of the fundamental work on the micropaleontology and stratigraphy of the Central Apennines.

I am greatly indebted to Dr. H. G. KUGLER, at the Museum of Natural History, Basel, for his stimulating interest and help in my studies, for much advice based on his vast experience and for having placed at my disposal his type-collection of Foraminifera from Trinidad.

I am pleased to thank Dr. M. B. CITA, Professor at the University of Milan, for discussing with me several problems concerning my investigations, for her aid in procuring literature not available in Basel and for having shared with me her vast experience in micropaleontological problems of the Scaglia.

Much is owed to Dr. I. PREMOLI SILVA, University of Milan, for her collaboration, for her guidance to numerous localities in Northern and Central Italy and for her help in obtaining literature and samples for comparison.

Professor Dr. W. W. HAY, University of Illinois, has contributed important samples from the Paleogene of the United States and Mexico and much information on stratigraphic problems related to them.

I want to express my gratitude to the Presidium of the Academy of Science of the Soviet Union for an invitation to the Geological Institute of the Academy, to Professor Dr. D. M. RAUZER-CHERNOUSSOVA and to Professor Dr. V. V. MENNER for their generous help, and especially to Dr. V. A. KRASHENNINIKOV for his introduction to the Paleogene of Southern Soviet Union, for numerous samples and literature and for all the trouble he took to help me during my stay in Moscow.

Professor Dr. N. N. SUBBOTINA, VNIGRI Leningrad, and Dr. E. K. SHUTZKAYA, VNIGNI Moscow, have kindly discussed many taxonomic and stratigraphic problems and have given me an invaluable set of topotypes and samples from Southern Soviet Union. Professor Dr. N. I. MASLAKOVA, Professor Dr. D. P. NAIDIN and Professor Dr. G. I. NIEMKOV of the Moscow University have furnished me with valuable information and samples.

I am greatly indebted to Dr. P. NATURAL, chargé d'affaires, and Dr. K. FRITSCHI, Secretary of the Swiss Embassy in Moscow, for their help and hospitality.

Dr. E. GASCHE, head of the Geological Department of the Museum of Natural History, Basel, facilitated the study of type-material deposited in the Museum.

The excursions in the Central Apennines have been made possible by the generous help of my colleagues H. G. LORENZ and Dr. F. STUMM.

Sincere thanks for helpful advice and/or gifts or the loan of material or literature are also due to: Dr. V. P. ALIMARINA, Moscow, Dr. P. J. BERMUDEZ, Caracas, Prof. Dr. H. M. BOLLI, Zürich, Prof. Dr. P. BRÖNNIMANN, Geneva, Dr. R. LEHMANN, Bègles, Dr. L. HOTTINGER, Basel, Prof. Dr. R. MARLIERE, Mons, Prof. Dr. J. SIGAL, Paris, Dr. H. FARKHAN, Teheran, Dr. F. ALLEMANN, Bern, Dr. C. G. ADAMS, London, Dr. A. CASTELLARIN, Bologna, Dr. R. HERB, Zürich, Prof. Dr. O. L. BANDY, Los Angeles, Prof. Dr. V. G. MOROZOVA, Moscow, Dr. W. GIGON, The Hague, Prof. Dr. M. F. GLAESSNER, Adelaide, Mr. and Mrs. C. SCHILLER-FISCHER, Mexico, H. MOHLER, Basel, and Dr. H. FISCHER, Basel.

Dr. D. GROENHAGEN, Basel, helped me in the translation of some Soviet literature.

I am also indebted to Mrs. T. MANGER and Mr. E. WAGNER, Geological Institute, Basel, and Miss D. GROENHAGEN, Museum of Natural History, Basel, for their assistance in several technical problems.

Part of the costs connected with the field work in the Central Apennines has been granted by the «August Tobler-Fund» of the Museum of Natural History, Basel. My studies have been made possible by a scholarship from my native town.

Above all, I want to thank my parents, who made possible the present work by many sacrifices.

INTRODUCTION

The last two decades have been marked by a rapid increase in the research on planktonic foraminifera and their application to the stratigraphical subdivision of the Paleogene. Two main centres of research have greatly contributed to this progress:

For the Western Hemisphere, it is the Caribbean region and mainly Trinidad, where a detailed zonation of world-wide applicability has been worked out (BOLLI, BRÖNNIMANN, BERMUDEZ, H. H. RENZ, CUSHMAN).

In the European part of the Southern Soviet Union, equivalent work has been done by Soviet specialists (SUBBOTINA, MOROZOVA, SHUTZKAYA, ALIMARINA and others).

By this almost independent and parallel development concerning the knowledge of planktonic foraminiferal faunas during the Paleogene, numerous differences, concerning the interpretation of different species and their stratigraphic range, have been inevitable.

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*.

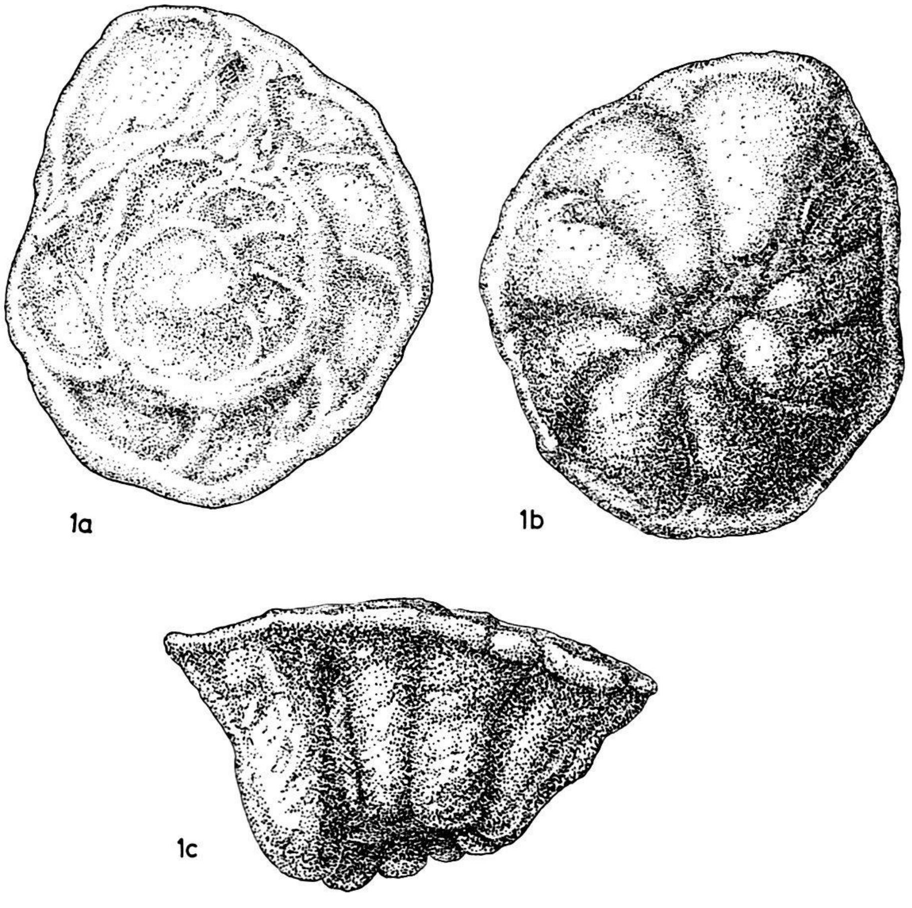

Fig. 1a–c. *Pseudogloborotalia ranikotensis* HAQUE (type-species of *Pseudogloborotalia* HAQUE), Ranikot, Mammal Gorge, Salt Range, Pakistan (paratype, dep. Brit. Mus. (Nat. Hist.), Ex P. 42420).

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.

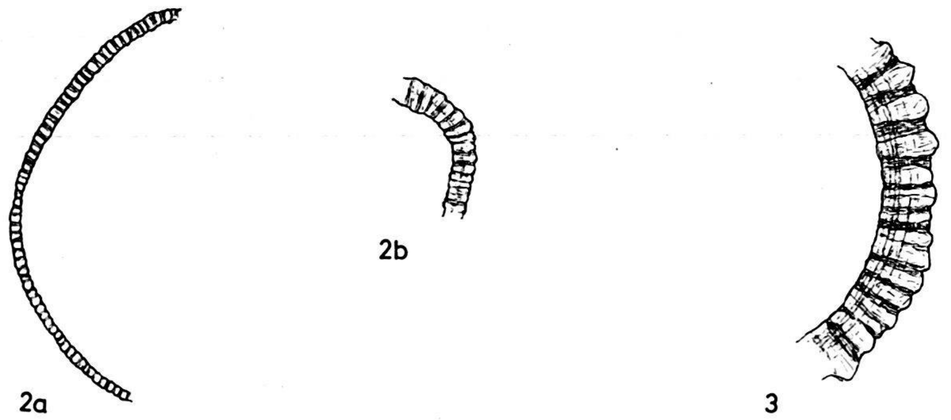

Fig. 2. *Globorotalia centralis* CUSHMAN & BERMUDEZ, 1937, type-species of *Turborotalia* CUSHMAN & BERMUDEZ, 1949, topotype from the upper Eocene of Cuba (C 20548) (leg. BERMUDEZ). (a) Section through the wall of the last chamber, × 130. (b) Section through the chamber wall in the first half of the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

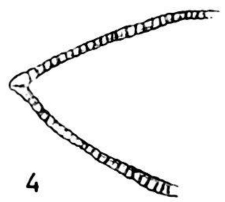

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Fig. 4. *Globorotalia pseudomenardii* BOLLI, 1957, proposed by MCGOWRAN (1964) as type-species of *Planorotalia* MOROZOVA, 1957. Specimen from the Velasco formation, Globorotalia pseudomenardii zone, San José de Soto las Rusias, Eastern Mexico (C 20550). 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.

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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.

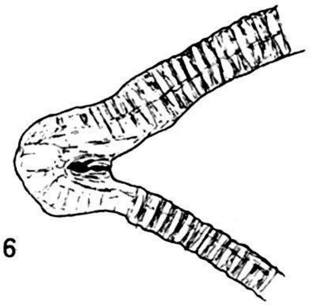

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Fig. 6. *Globorotalia tumida* (BRADY), 1877, type-species of Globorotalia CUSHMAN, 1927. Specimen from the Recent, off Southern California (C 20552). Section through the keel in the first half of the last whorl, × 130.

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).

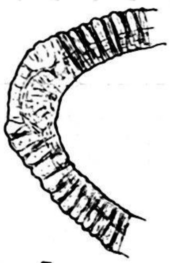

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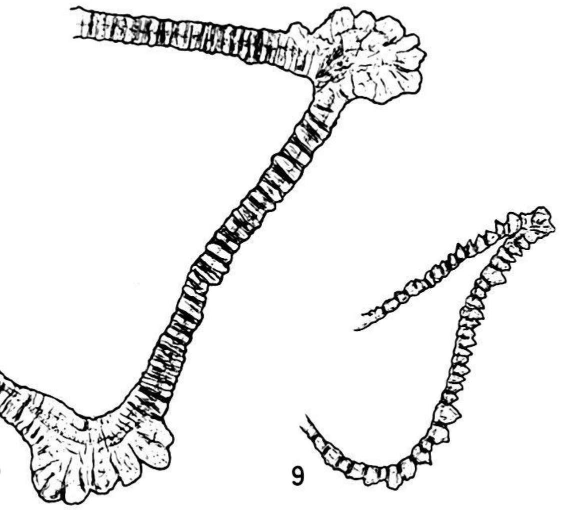
Fig. 7. *Globorotalia truncatulinoides* (D'ORBIGNY), 1839, type-species of *Truncorotalia* CUSHMAN & BERMUDEZ, 1949. Specimen from the Recent, off Southern California (C 20553). Section through the keel of the last chamber, × 130.

As shown above, *Pseudogloborotalia* HAQUE, 1956, is no planktonic genus and therefore cannot be used to include the Paleogene angular-conical *Globorotalia*.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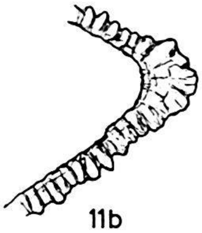
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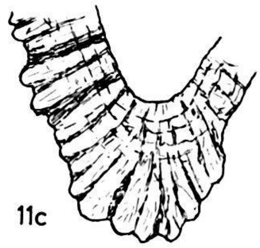
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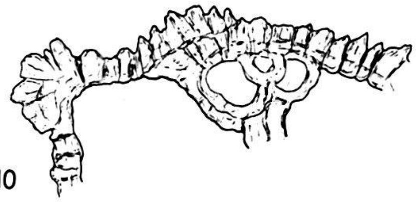
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Fig. 8. *Globorotalia velascoensis* (CUSHMAN), 1925, type-species of *Morozovella* McGOWRAN, 1964. Specimen from the Velasco formation, Globorotalia pseudomenardii zone, San José de Soto las Rusias, Eastern Mexico (C 20554). Section through the last 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.

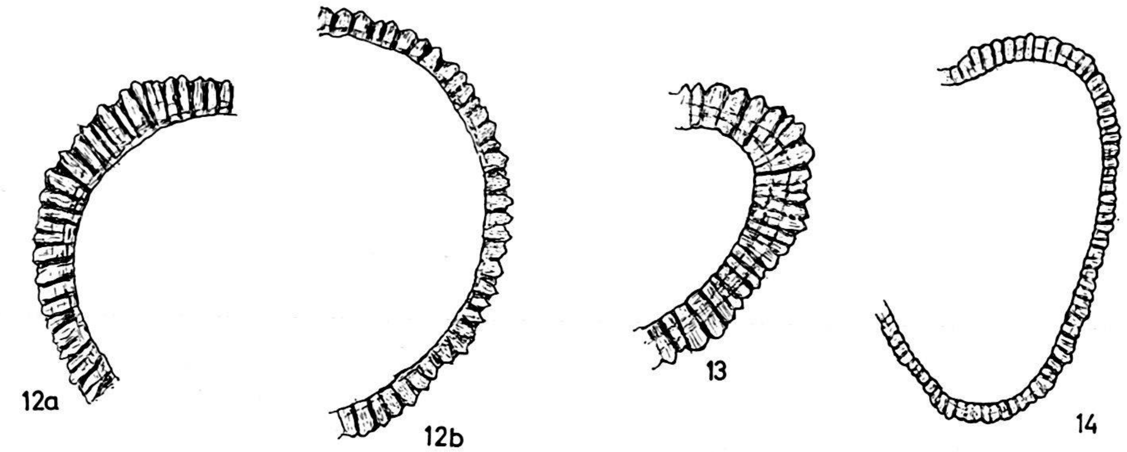


Fig. 12. *Globorotalia trinidadensis* Bolli, 1957. Topotype from the Globorotalia trinidadensis zone, Lower Lizard Springs formation, Trinidad (C 20558). (a) Section through the chamber wall in the first half of the last whorl, × 130. (b) Section through the last chamber, × 130.

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.

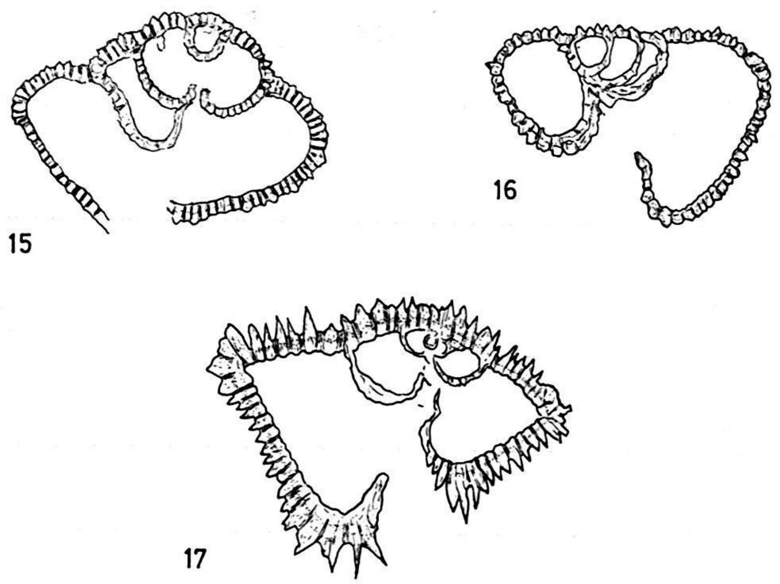


Fig. 15. *Globorotalia tadjikistanensis djanensis* Shutzkaya (ms). Specimen from the Globorotalia tadjikistanensis djanensis zone, Northern Caucasus (leg. Shutzkaya, C. 20561). Axial section, ×130.

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.

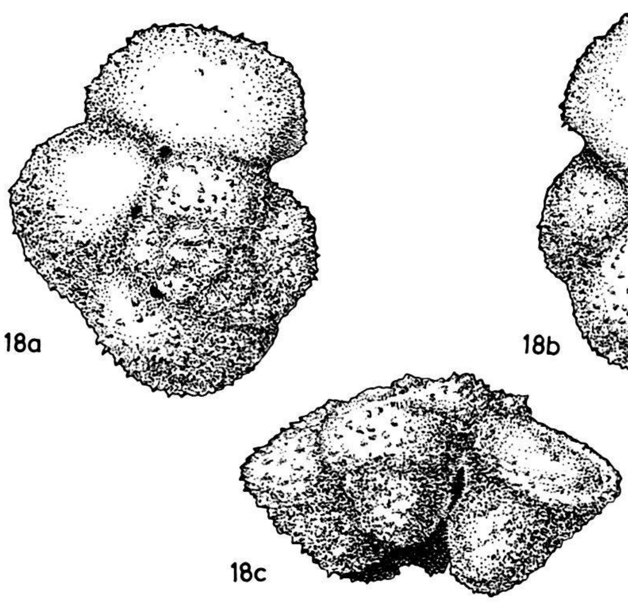


Fig. 18a–c. *Globorotalia* sp., with sutural apertures on the spiral side (C 20562). El Quss Abu Said (WD 116), Farafrah Oasis, Egypt, Globorotalia pseudomenardii zone.

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):

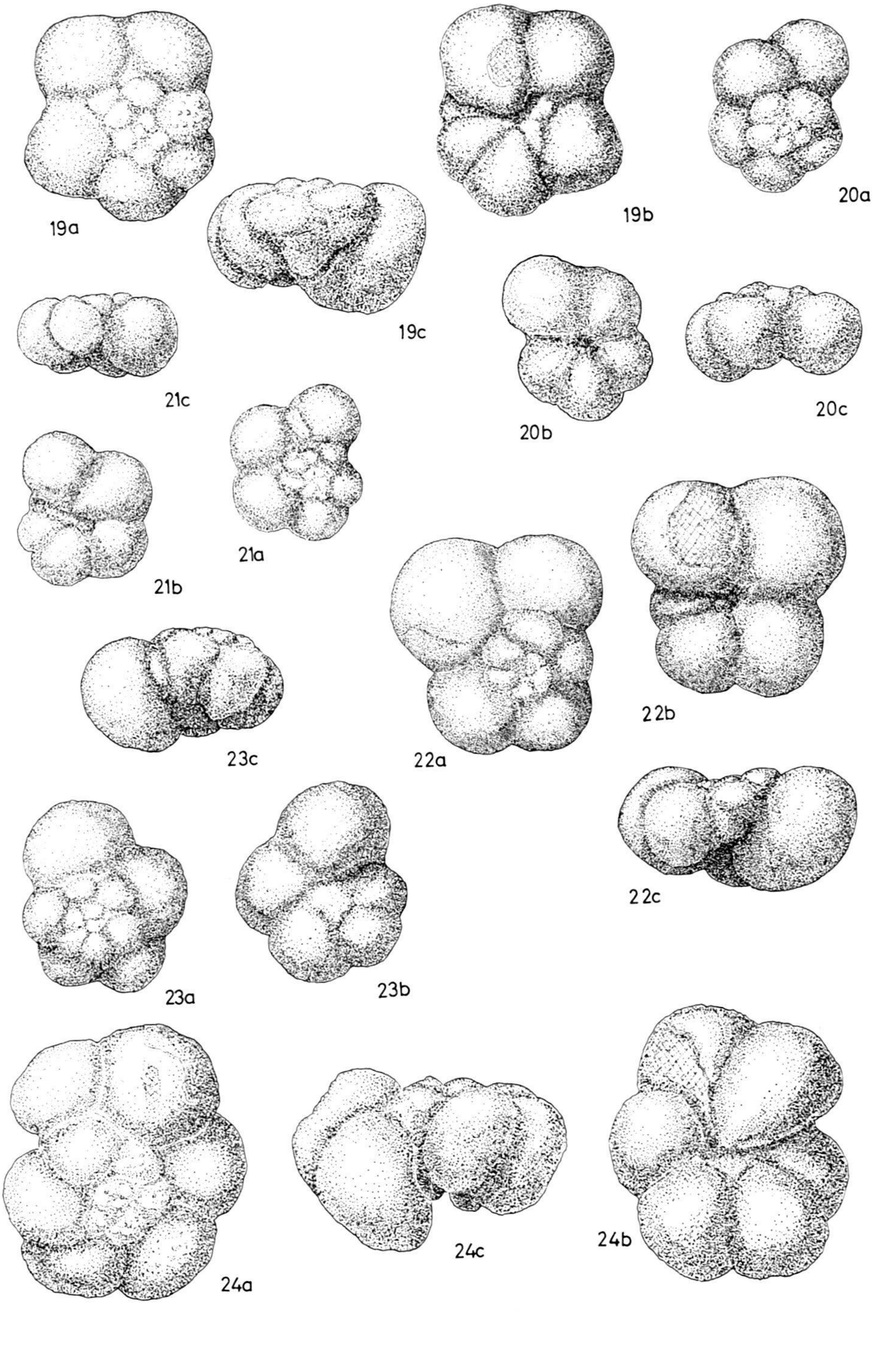
Globigerina inconstans SUBBOTINA, 1953
Globigerina schachdagica CHALILOV, 1956
Globorotalia trinidadensis BOLLI, 1957
Globorotalia uncinata BOLLI, 1957

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
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21a
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22b
23c
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22c
23a
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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

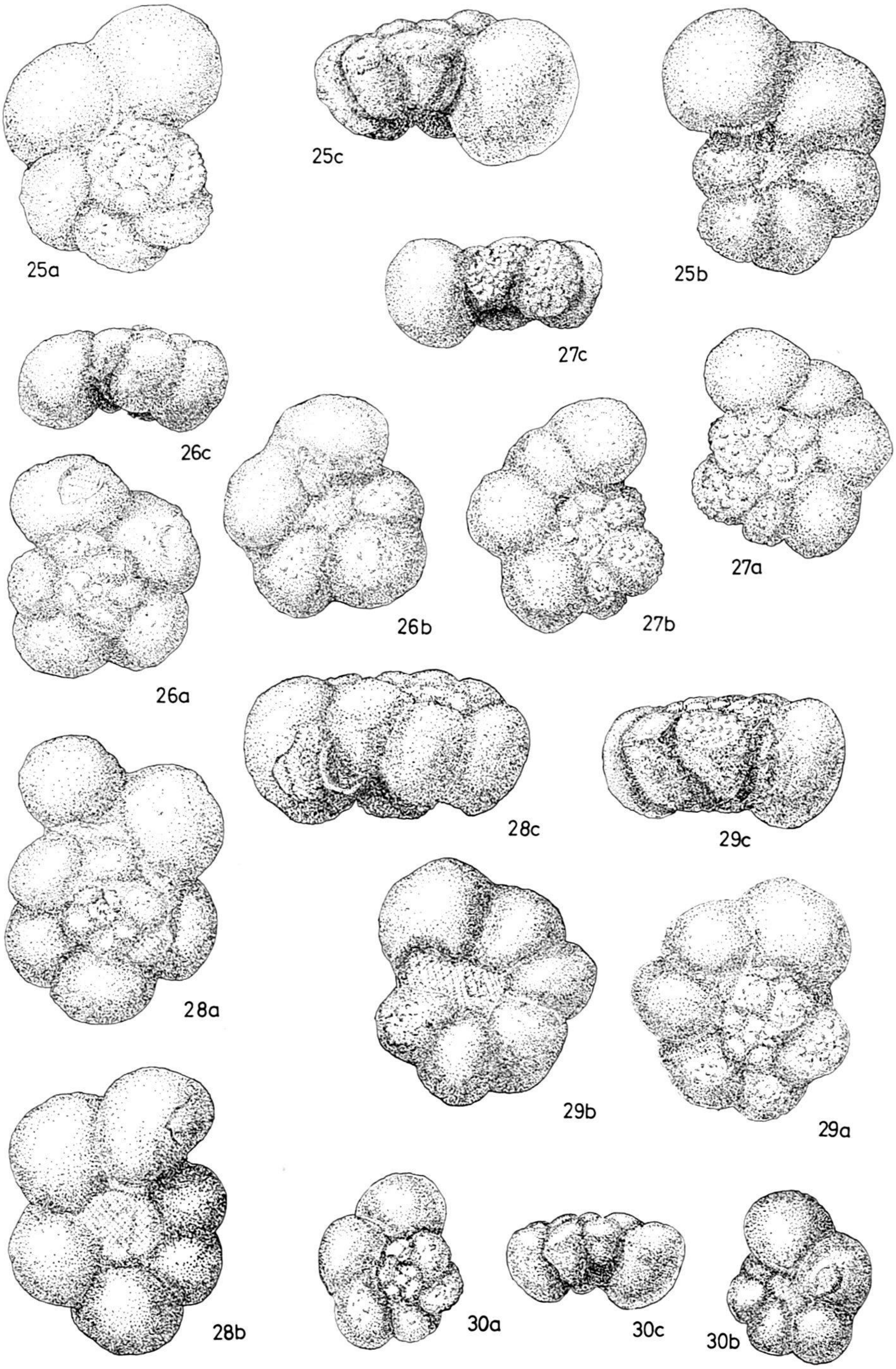
Fig. 25

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.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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.

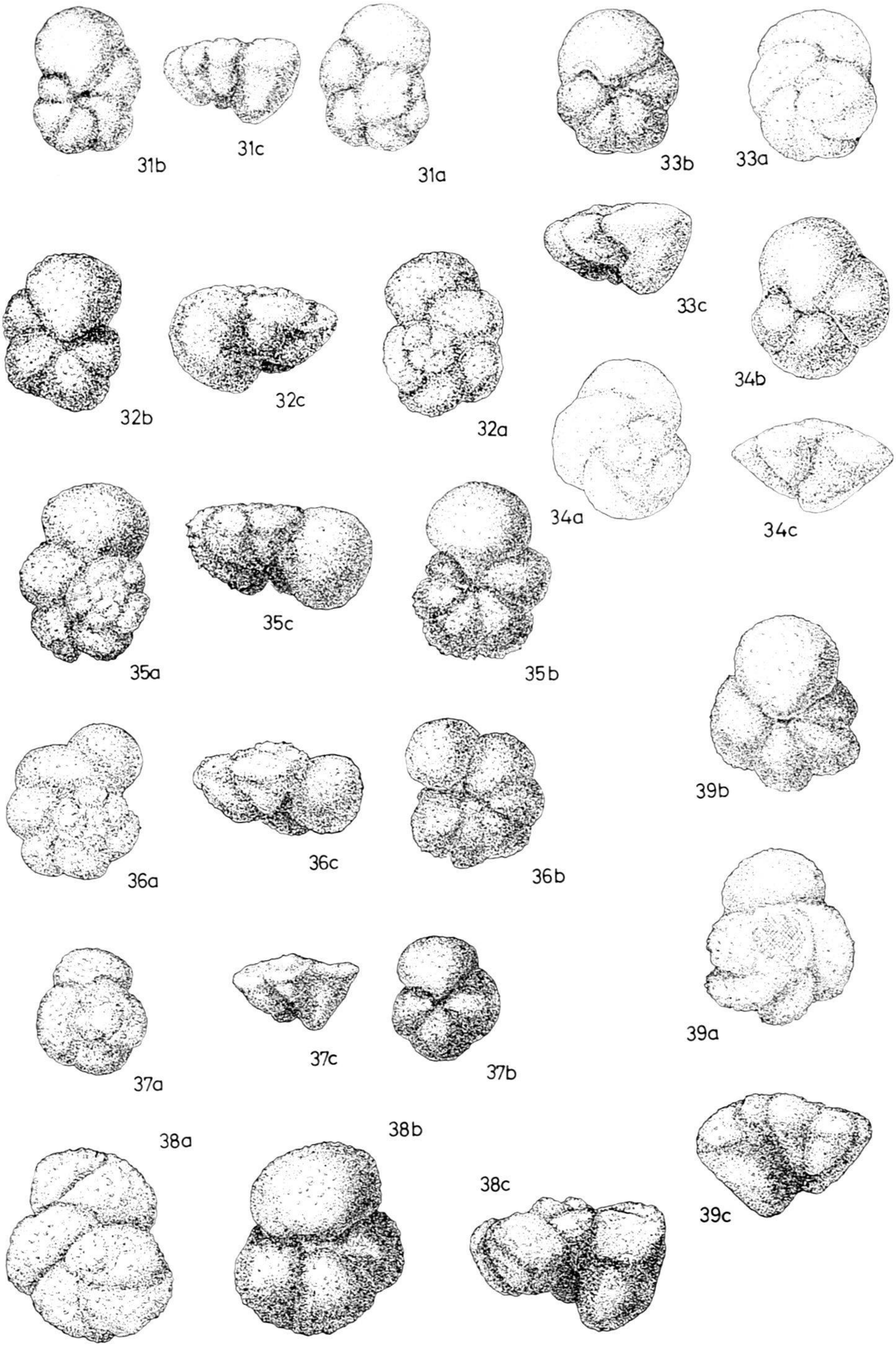
Figs. 33 and 34. *Globorotalia indolensis* (MOROZOVA), 1959. Acarinina indolensis subzone (Dn_2III_1), Tarkhankut, northwestern Crimea (leg. KRASHENINNIKOV, C 20578, C 20579), × 75.

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.

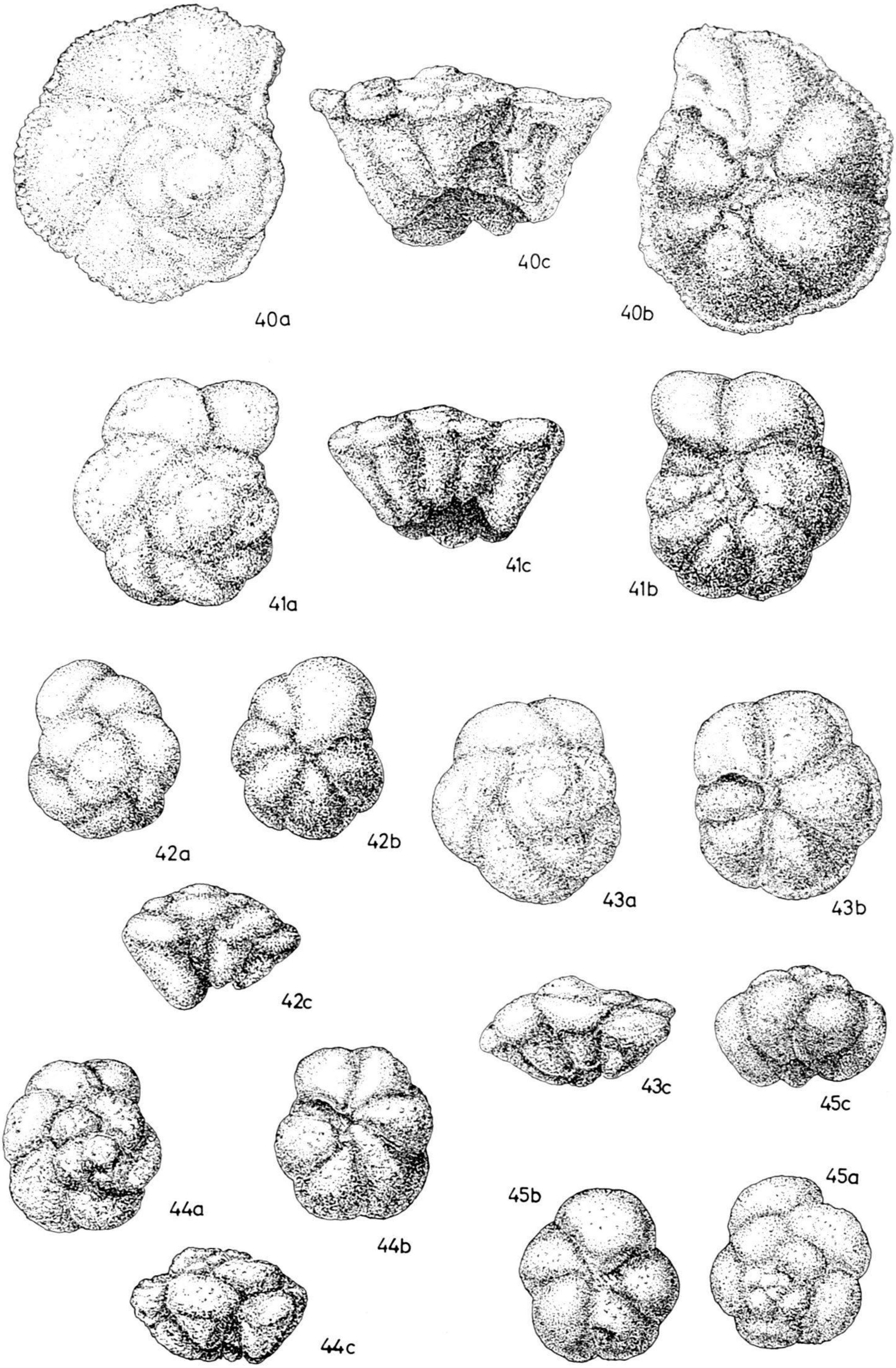
Fig. 40. *Globorotalia conicotruncata* Subbotina, 1947. «Zone of rotaloid Globorotaliids» Kheu river, Northern Caucasus (leg. et det. Subbotina, C 20584), × 75.

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

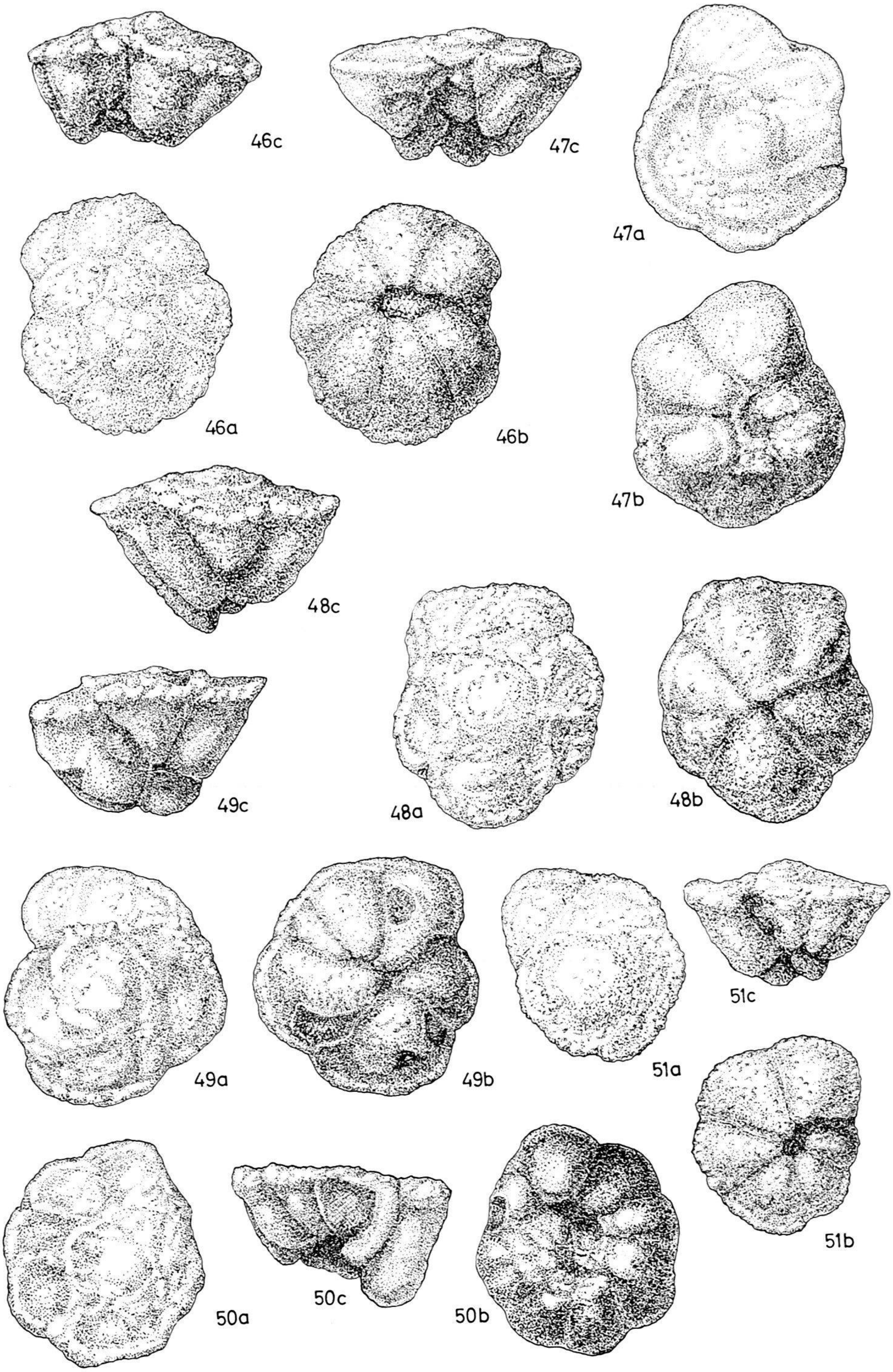
Fig. 52

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.

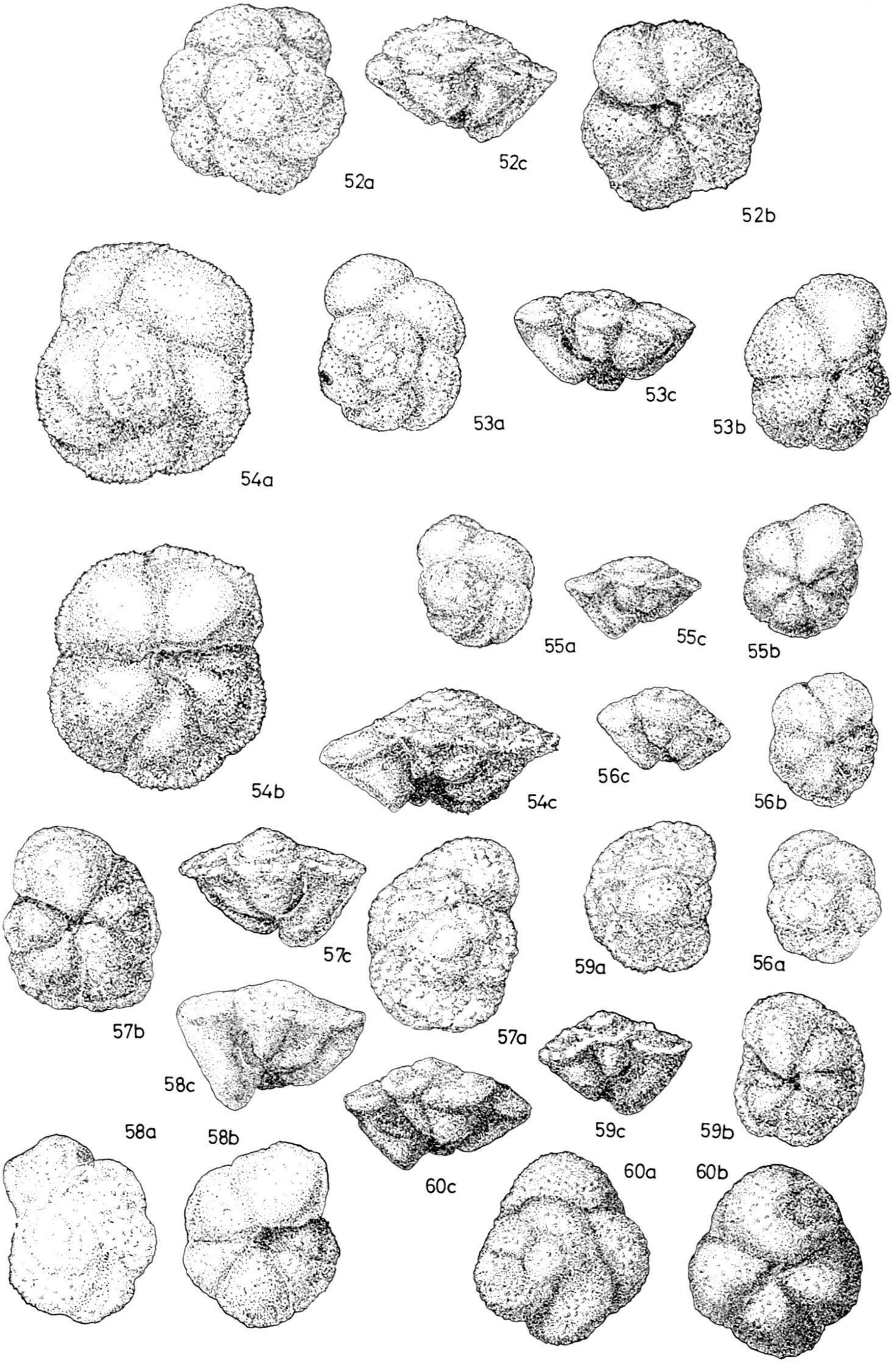
Figs. 53–55. *Globorotalia simulatilis* (SCHWAGER), 1883. Globorotalia pseudomenardii zone, El Quss Abu Said, Farafrah Oasis, Egypt (C 20597, C 20598, C 20599), × 75.

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.

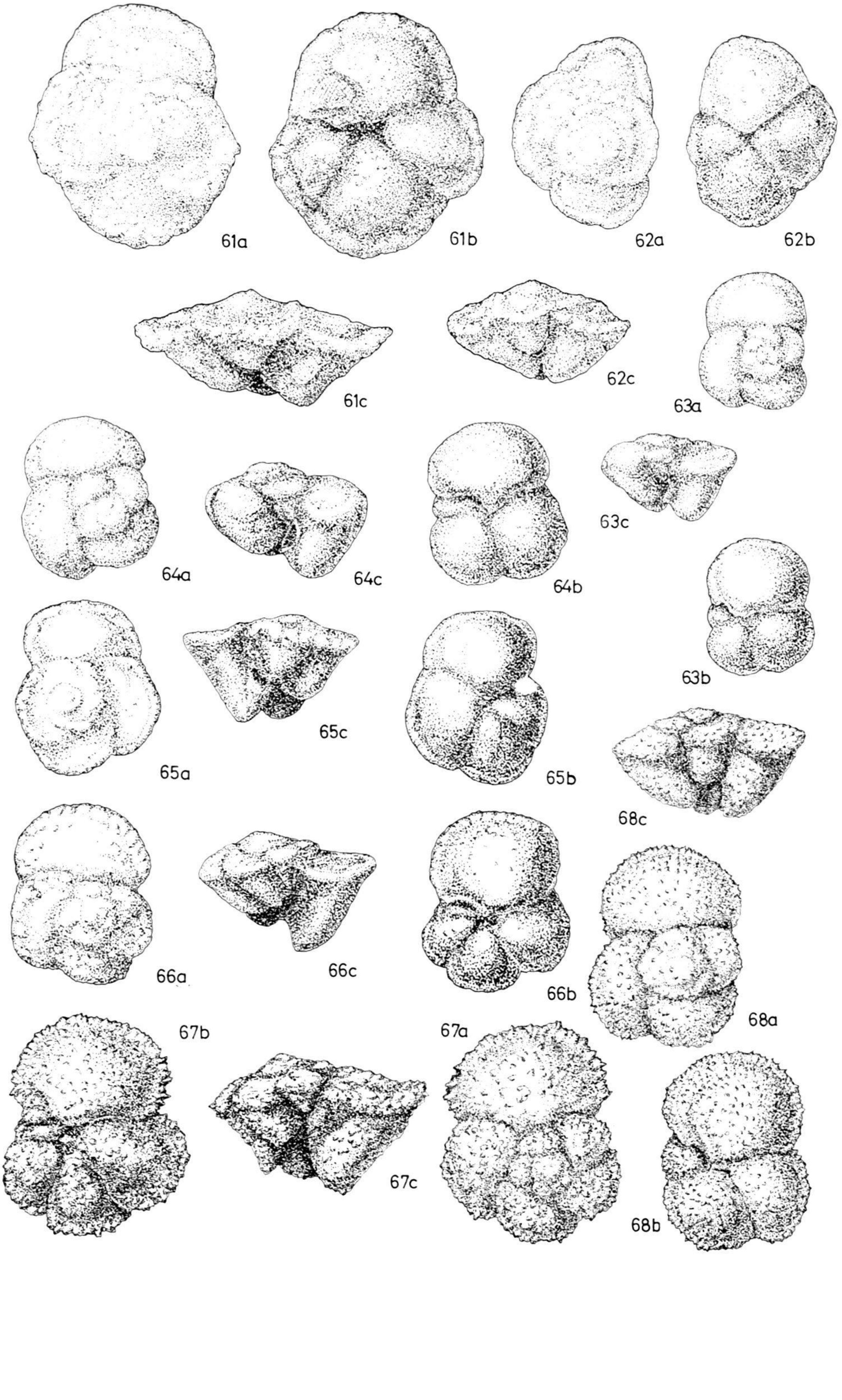
Remarks

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.

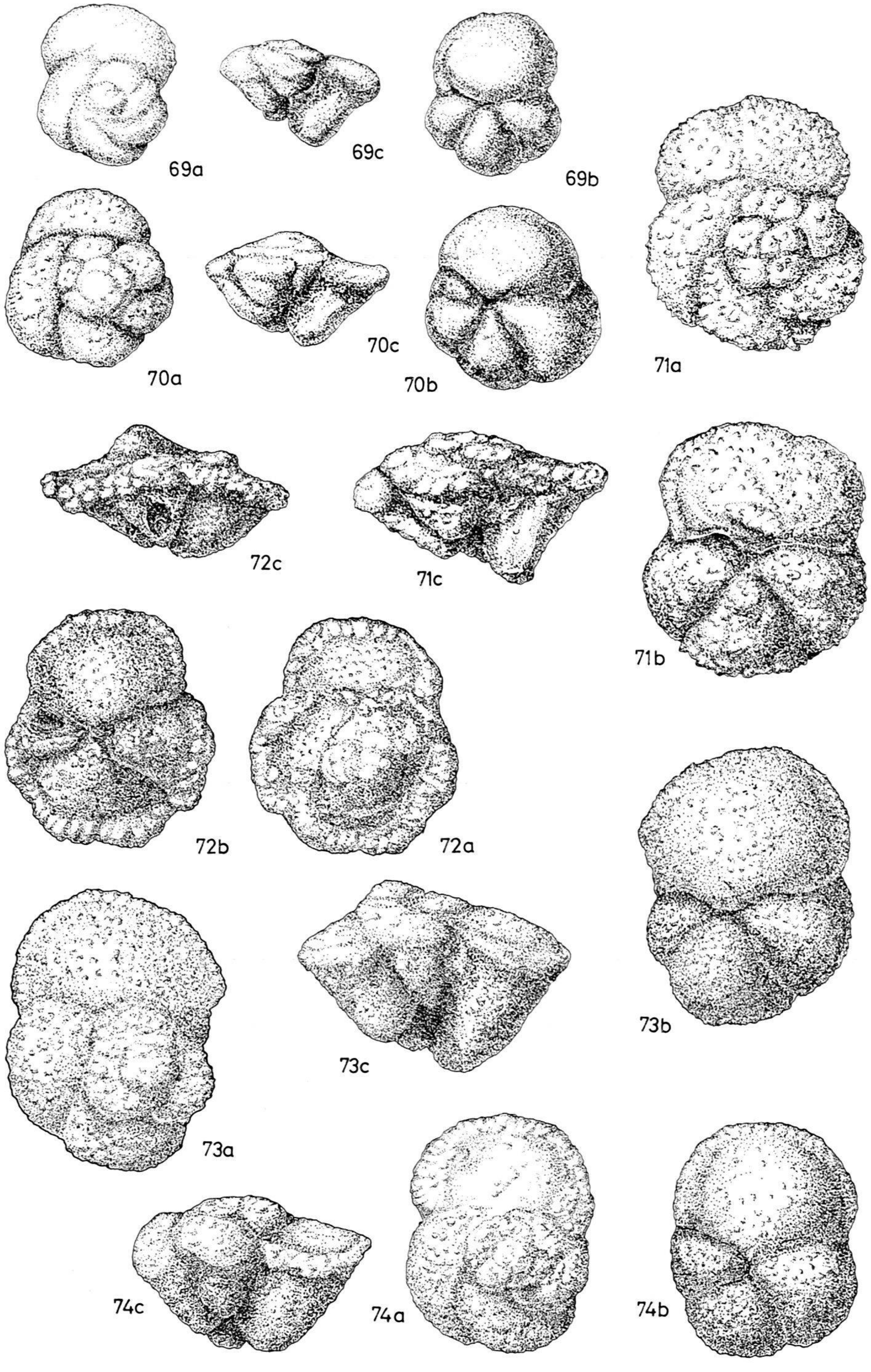
In the section of Gubbio, the species occurs first at the level G-74, where it is found rarely. The main distribution of the species lays between G-73 and G-66. The species shows strongly preferential dextral coiling throughout its range, as in the Lizard Springs formation of Trinidad. This late appearance 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).

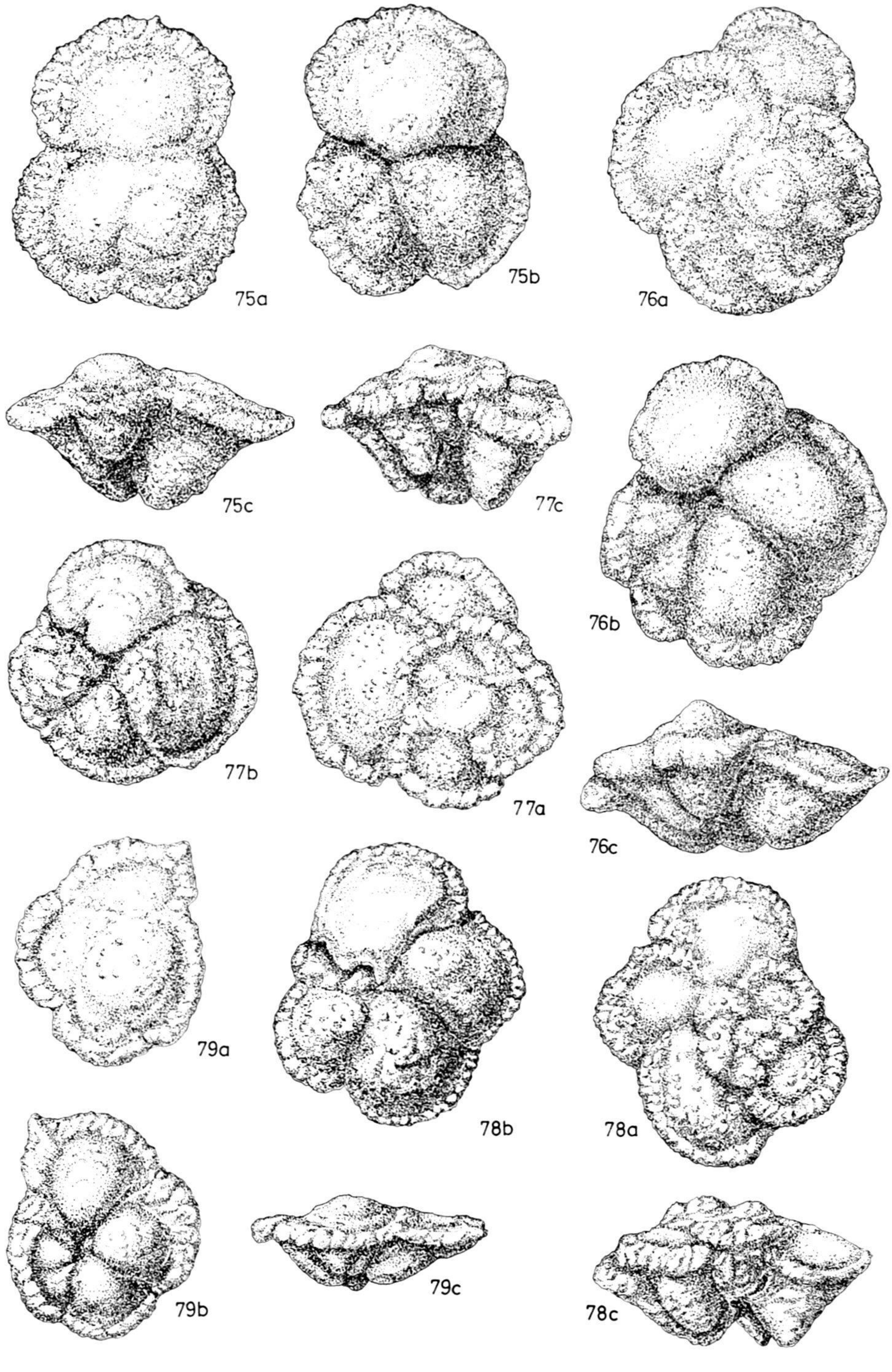
Globorotalia marginodentata is represented by typical specimens within the levels G-73 to G-58 of the Gubbio section (figs. 81, 82, 84). Coiling is predominantly dextral throughout its stratigraphical range. In the younger levels, however, the number of sinistral specimens increases.

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.

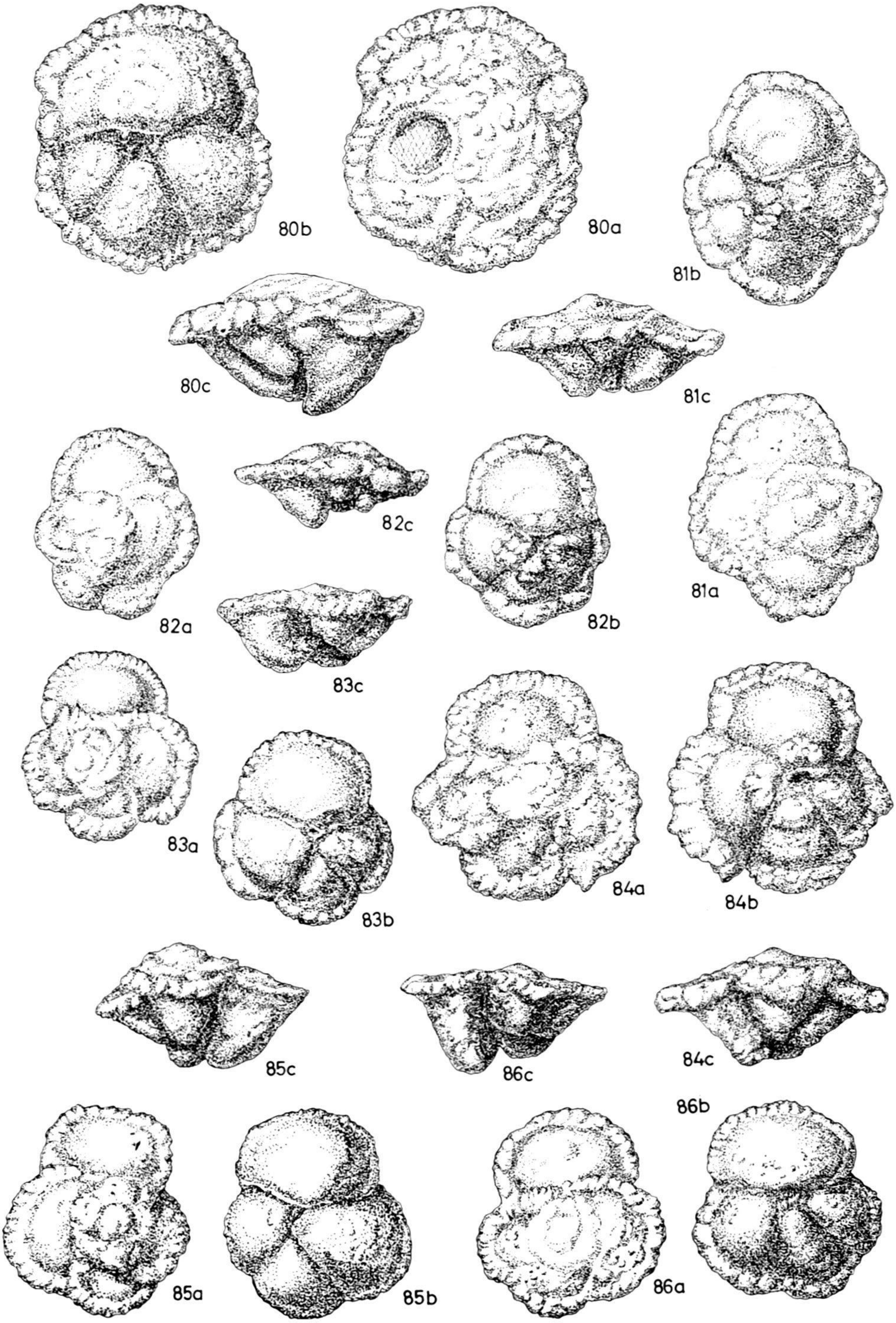
Figs. 81 and 82. *Globorotalia marginodentata* SUBBOTINA, 1953. Gubbio section, level G-71 (C 20624, C 20625), × 75.

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.

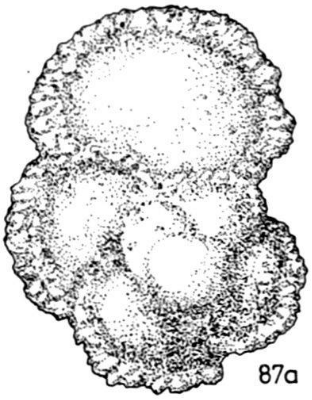
4. *Globorotalia velascoensis* group

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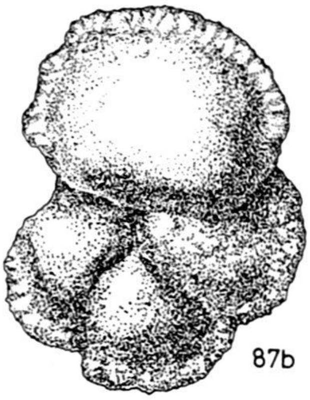
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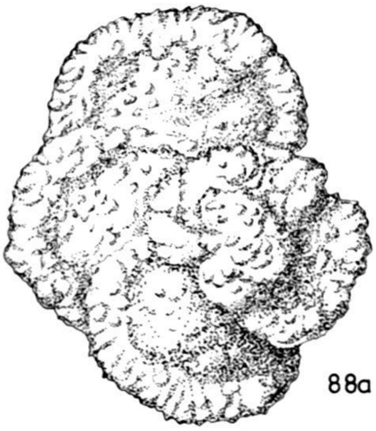
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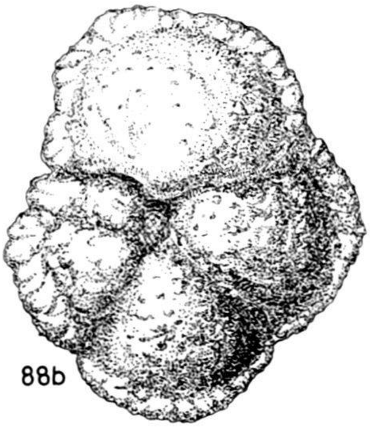
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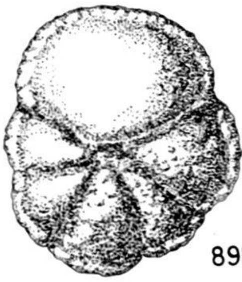
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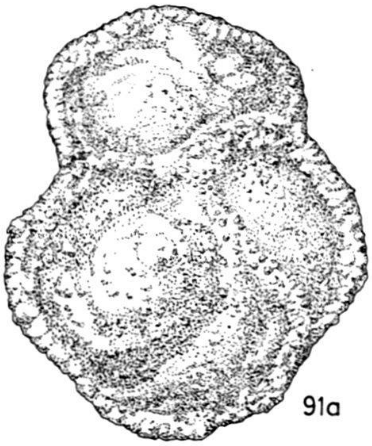
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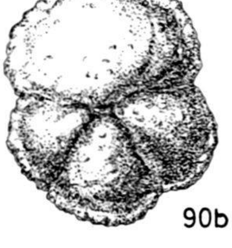
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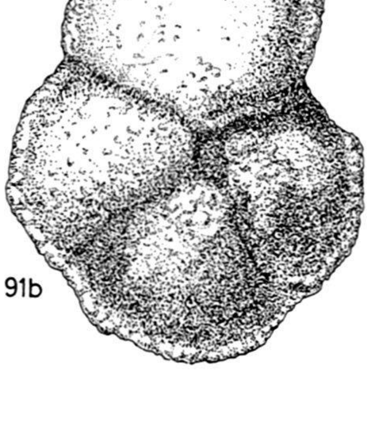
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The following species, belonging to this group, are known so far:

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.

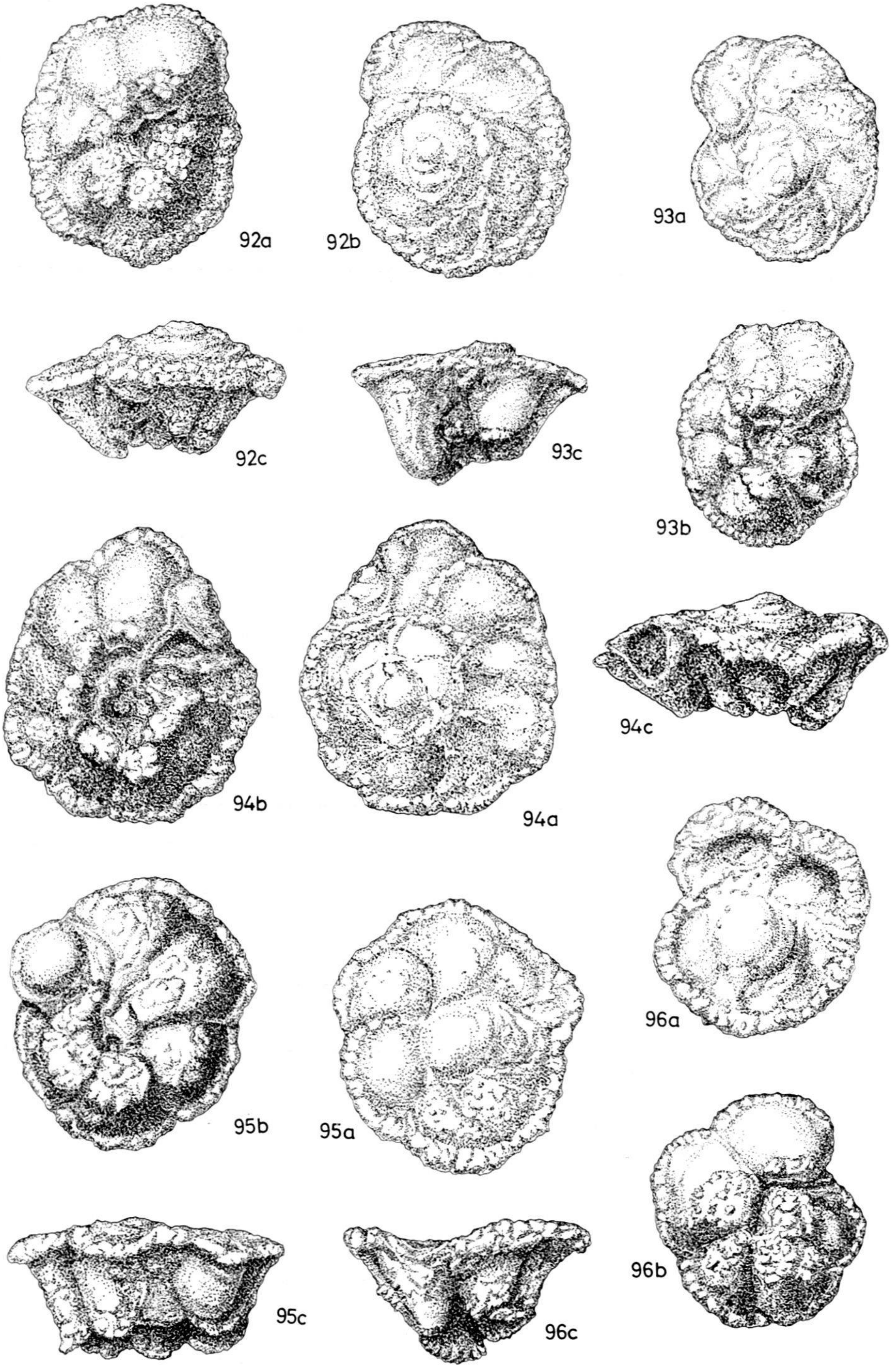
Description

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

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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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-

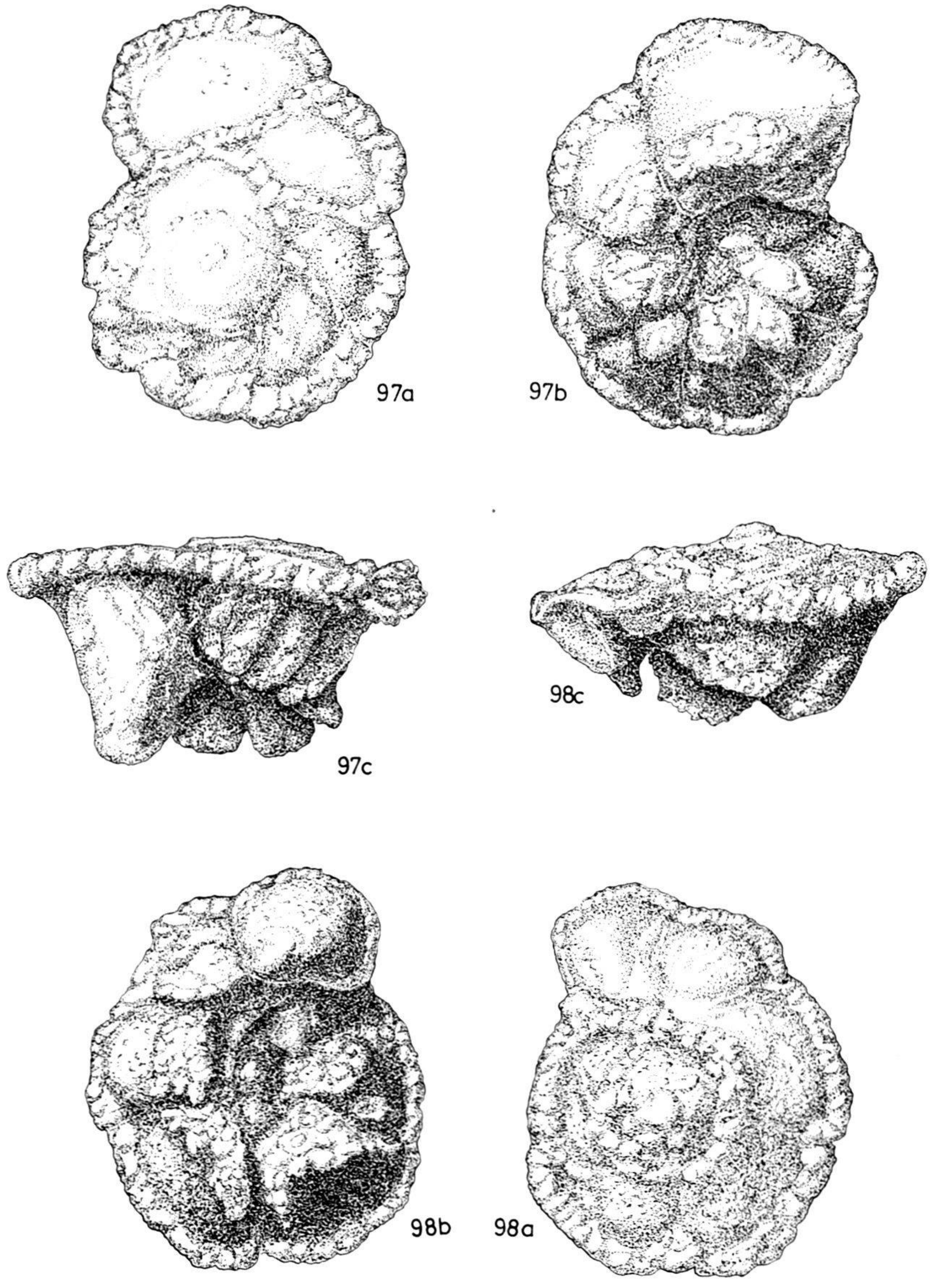

Fig. 97. *Globorotalia caucasica* GLAESSNER, 1937. «Zone of conical Globorotaliids», Keu river, Northern Caucasus (det. et leg. SUBBOTINA, C 20639), × 75.

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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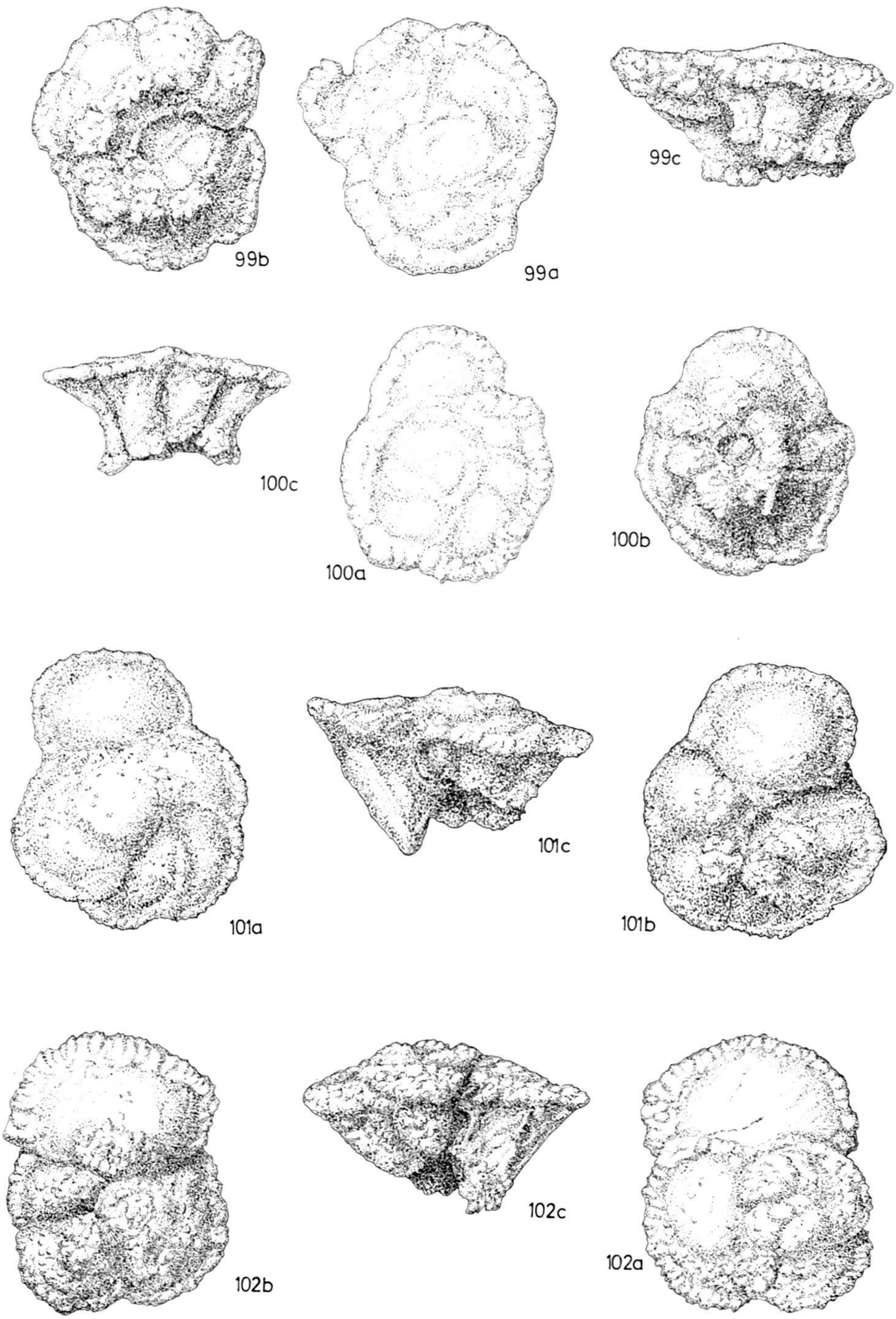
Fig. 99. *Globorotalia velascoensis* (CUSHMAN), 1925. Gubbio section, level G-74 (C 20641), × 75.
Fig. 100. *Globorotalia* sp. aff. *velascoensis* (CUSHMAN), 1925. Gubbio section, level G-71 (C 20642), × 75.
Fig. 101. *Globorotalia acuta* TOULMIN, 1941. Globorotalia pseudomenardii zone, El Quss Abu Said, 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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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

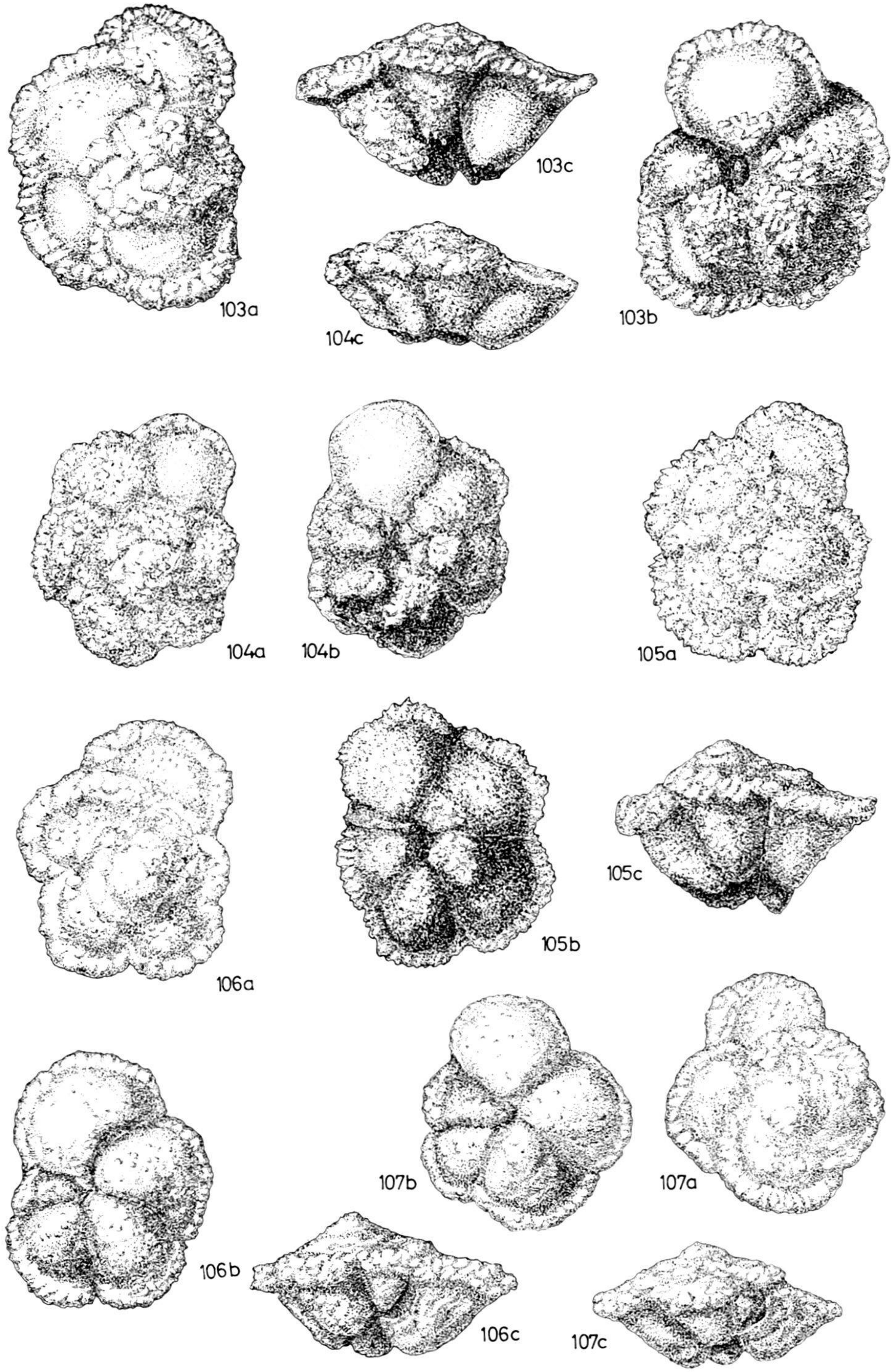
Globorotalia acuta is closely related to *Globorotalia velascoensis*, to which it was thought to be synonymous by some authors (BOLLI, 1957, HILLEBRANDT, 1962). The characteristics suitable for distinguishing the two species from one another are listed by LOEBLICH & TAPPAN (1957, pp. 185/6). Although 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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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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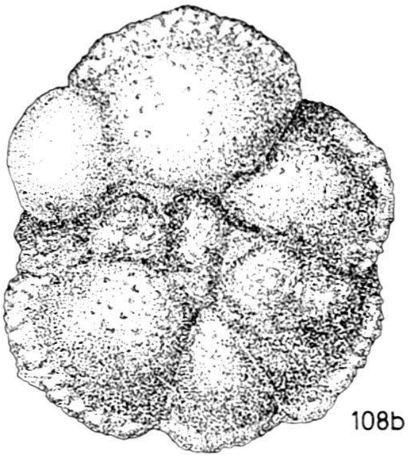
Fig. 108. *Globorotalia pasionensis* (BERMUDEZ), 1961. Topotype, Lower Eocene, Rio de la Pasion, El Petén, Guatemala (det. et leg. BERMUDEZ, C 20650), × 75.
Fig. 109. *Globorotalia pasionensis* (BERMUDEZ), 1961. Gubbio section, level G-71 (C 20651), × 75.
Fig. 110. *Globorotalia pasionensis* (BERMUDEZ), 1961. Gubbio section, level G-70a (C 20652), × 75.



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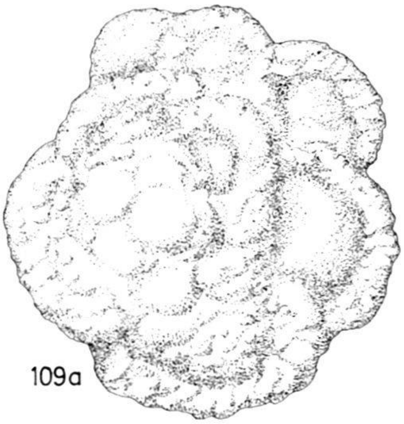

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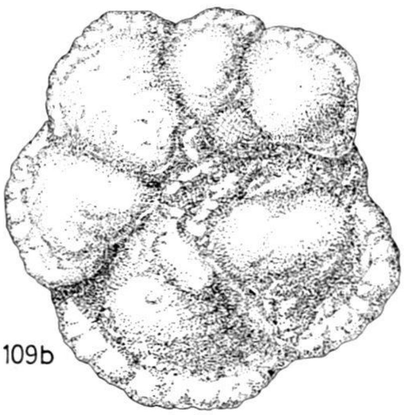

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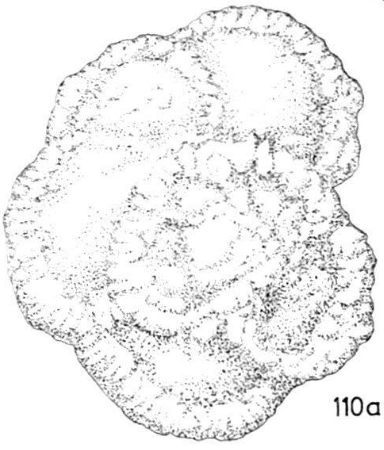

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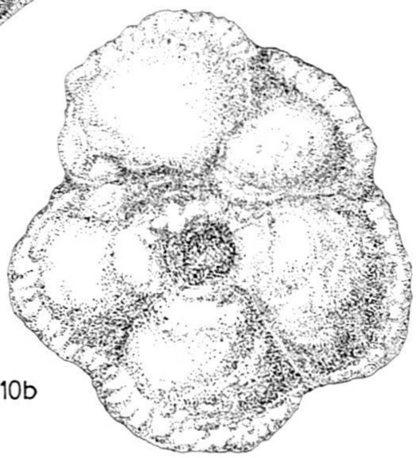


110b

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.

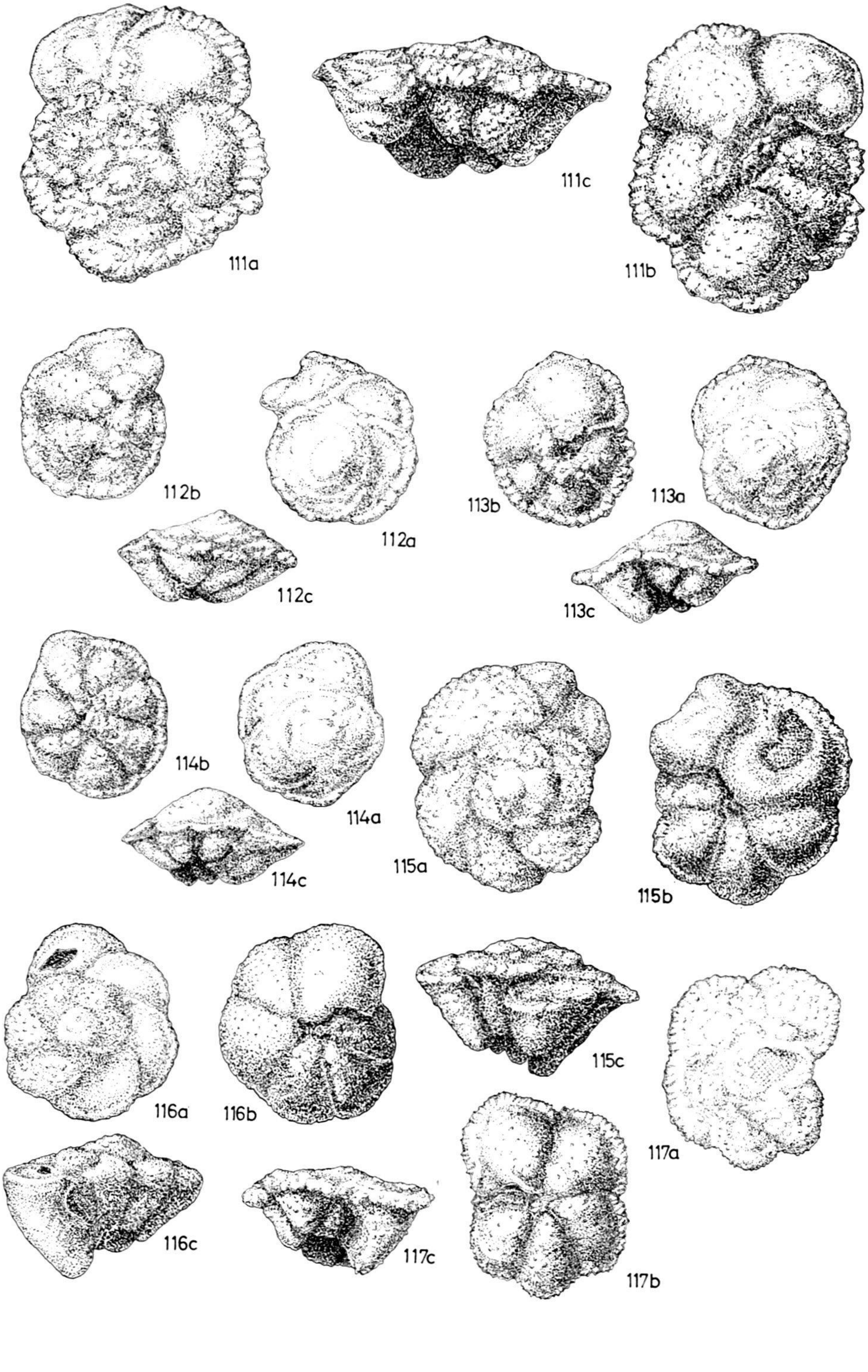
Figs. 112 and 113. *Globorotalia occlusa* LOEBLICH & TAPPAN, 1957. Globorotalia velascoensis zone, Velasco formation, Ebano, eastern Mexico (C 20654, C 20655), × 75.

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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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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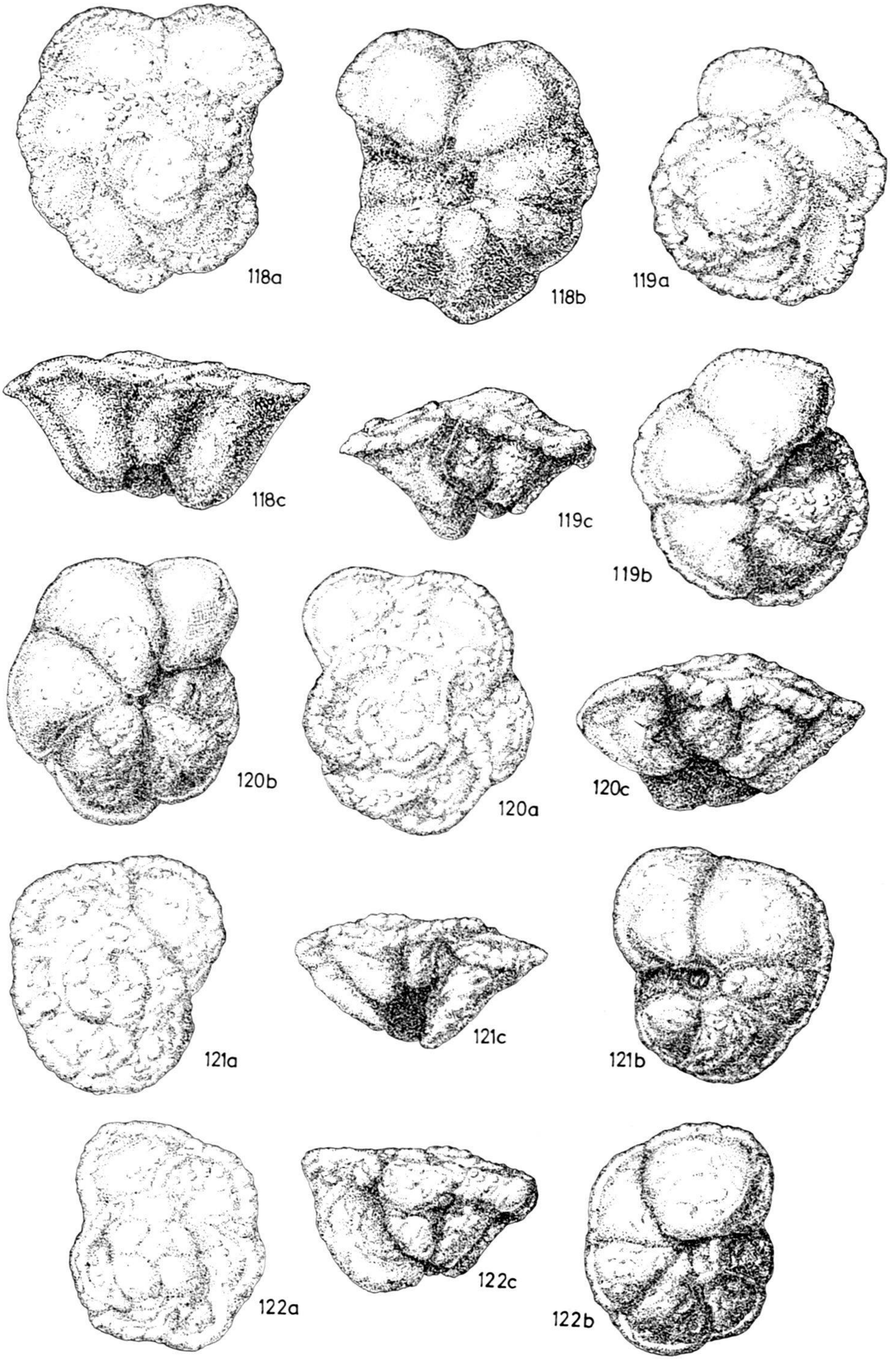
Fig. 118. *Globorotalia formosa formosa* BOLLI, 1957. Topotype, Globorotalia formosa formosa zone, Upper Lizard Springs formation, Trinidad (C 20660), × 75.
Fig. 119. *Globorotalia formosa formosa* BOLLI, 1957. Gubbio section, level G-70 (C 20661), × 75.
Fig. 120. *Globorotalia formosa formosa* BOLLI, 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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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

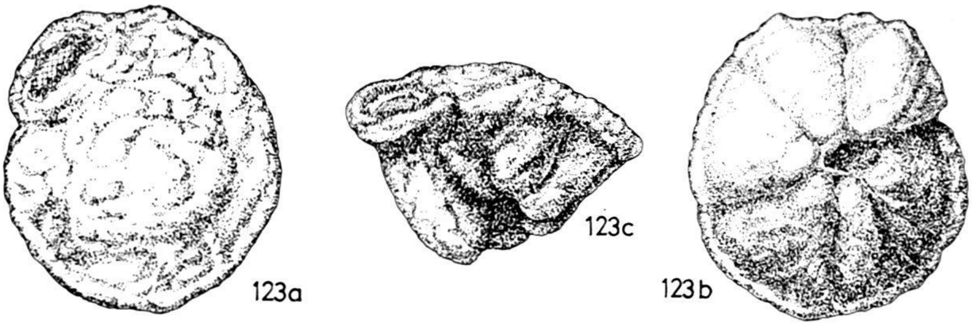
Figs. 121–126

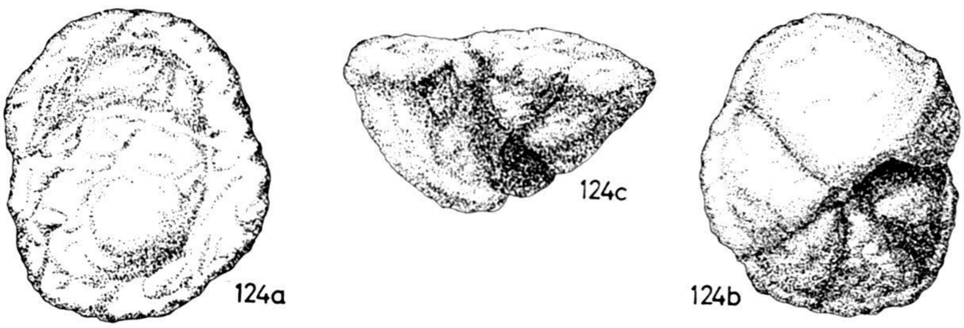
Globorotalia aragonensis n. sp. – NUTTALL, 1930, p. 288, pl. 24, figs. 6–8.
Globorotalia aragonensis NUTTALL – SUBBOTINA, 1953, pp. 215–16, pl. XVIII, figs. 6a–c.
Globorotalia aragonensis NUTTALL – BOLLI, 1957, p. 75, pl. 18, figs. 7–9, p. 167, pl. 38, figs. 1a–c.

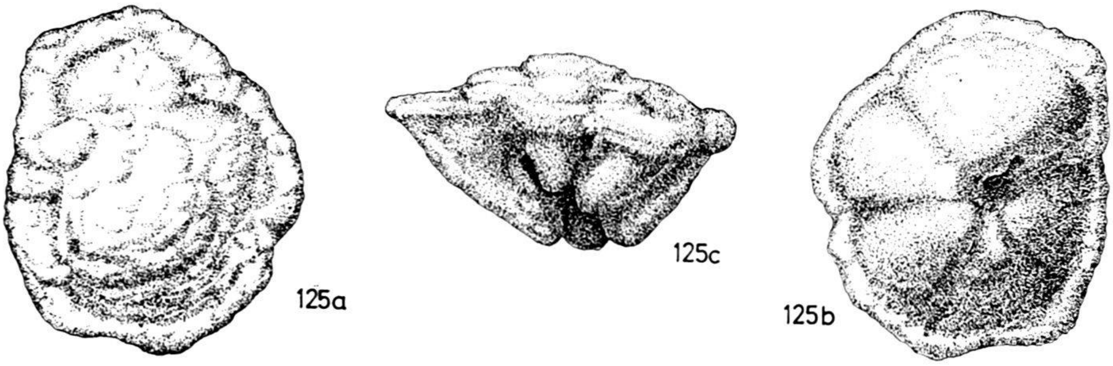
Description (see NUTTALL, 1930, SUBBOTINA, 1953, BOLLI, 1957)

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.







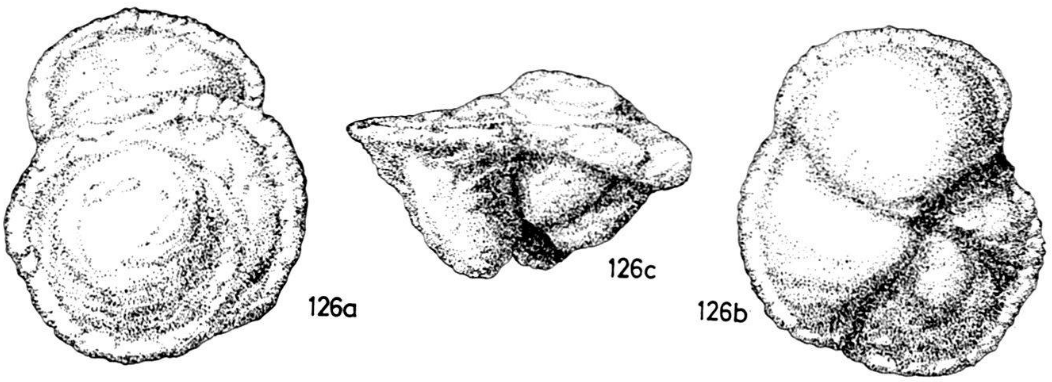


Fig. 123. *Globorotalia aragonensis* NUTTALL, 1930. Gubbio section, level G-38 (C 20665), × 75
Fig. 124. *Globorotalia aragonensis* NUTTALL, 1930. Gubbio section, level G-28 (C 20666), × 75
Figs. 125 and 126. *Globorotalia aragonensis* NUTTALL, 1930. Gubbio section, level G-22 (C 20667 C 20668), × 75.

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.

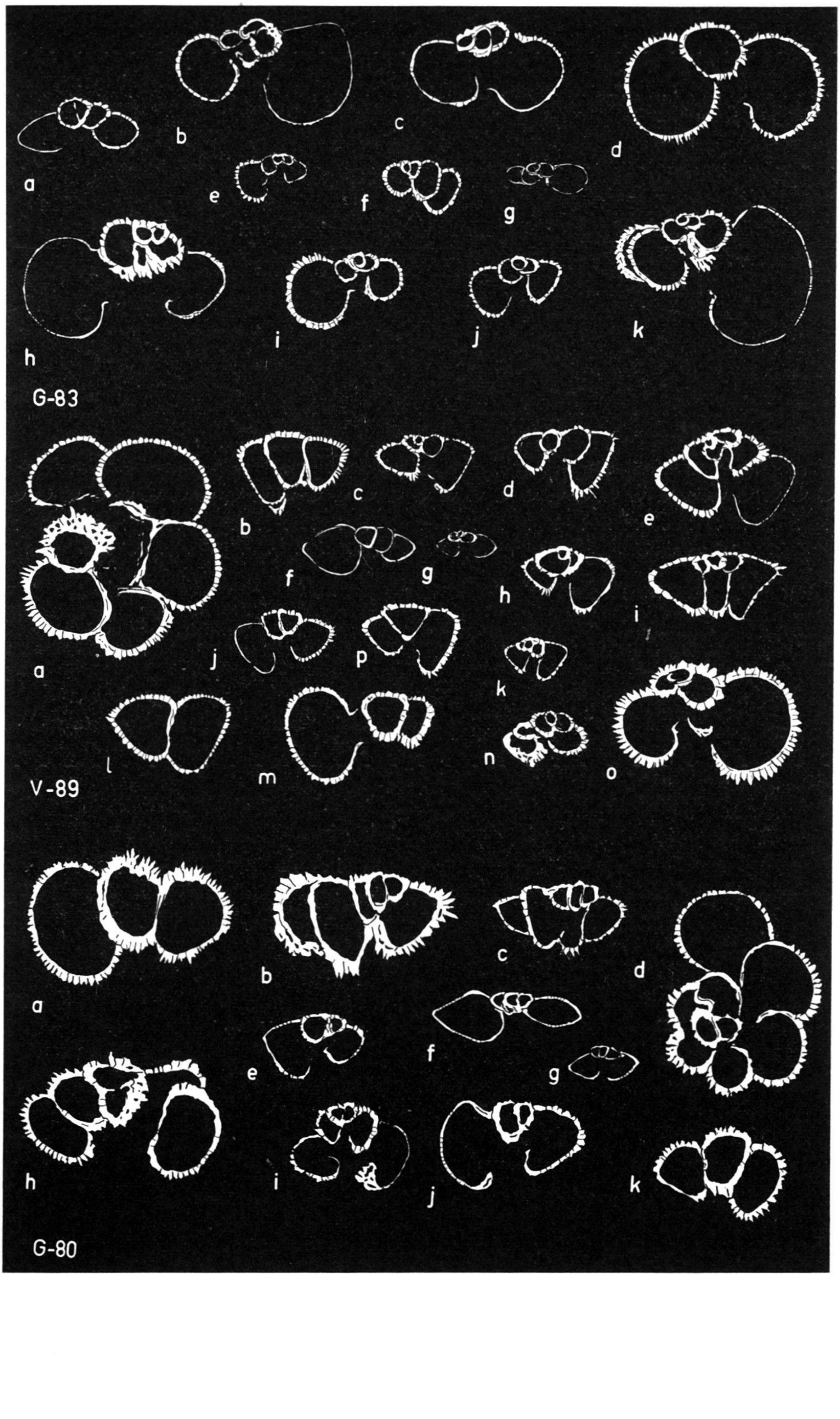
An exact specific determination of *Globorotalia* in thin section is possible only exceptionally. An approximate age determination is often possible by observing the necessary restrictions.

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).


G-83
V-89
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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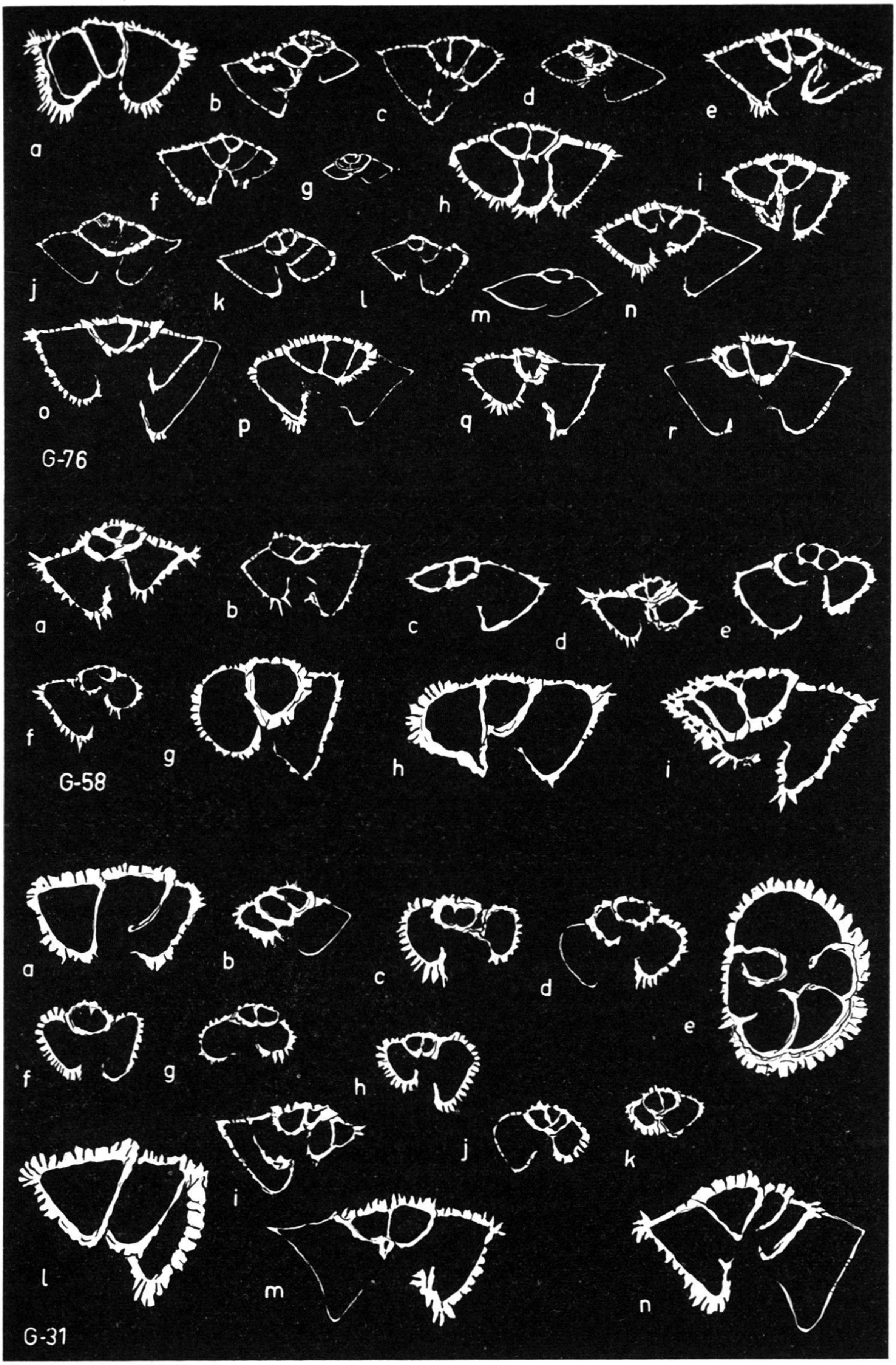
Fig. 128. Non-oriented thin sections of *Globorotalia* from levels G-76, G-58 and G-31 (Gubbio section).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are concentrated at the periphery and the umbilical shoulders. These characters are typical for the *Globorotalia velascoensis* group.

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).

The faunal break within planktonic foraminifera marking the Cretaceous/Tertiary boundary is sudden and very impressive. It occurs between the levels G-97B and G-97C. A detailed description of this interval is given in PREMOLI SILVA & LUTERBACHER (1964).

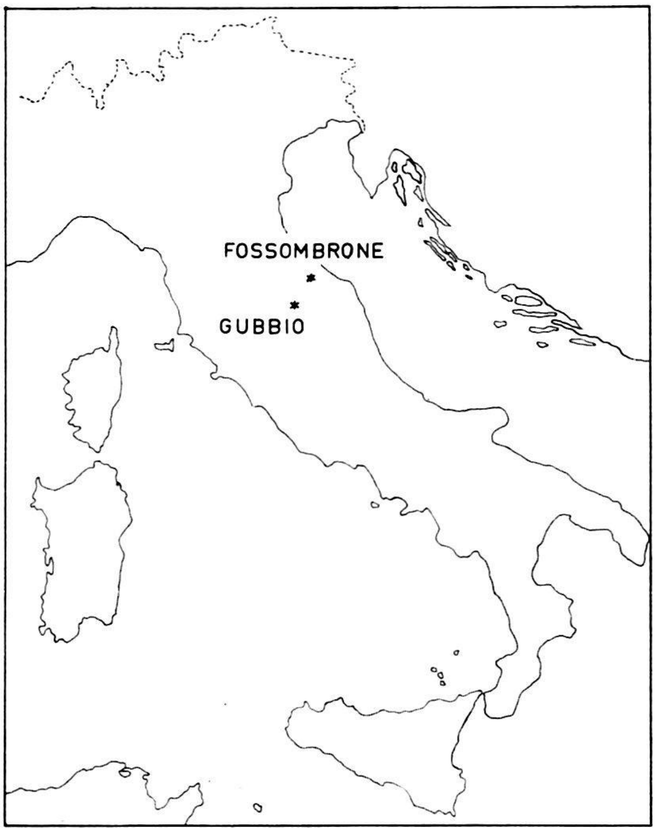


Fig. 129. Sketch-map of Italy with location of the studied sections.

G-97C–G-95. Irregularly thin-bedded reddish limestone with rare and thin (1–3 cm) marly seams. The faunas of G-97C–G-97L (lowermost 50 cm) belong to the Globigerina eugubina zone (type-locality). G-96 and G-95 contain badly preserved and poor faunas indicating the lower part of the Globorotalia pseudobulloides/Globigerina daubjergensis zone. Reworked Upper Cretaceous forms are present at level G-96 (*Rugoglobigerina*, *Globotruncana*, rare *Neoflabellina* and *Siderolites*).

G-94–G-89. Thin-bedded, reddish limestone, irregularly interbedded with argillaceous limestone and red marls. The samples G-94, G-93 and G-92 contain rich, but generally poorly preserved faunas of the Globorotalia pseudobulloides/Globigerina daubjergensis zone. G-91 to G-89 represent the lower part of the Globorotalia trinidadensis zone.

G-88–G-86. Irregularly thin-bedded, reddish, argillaceous limestone and marls, with only a few layers of compact limestone.
The rich and well preserved faunas are attributed to the Globorotalia trinidadensis zone (*Globorotalia trinidadensis*, *Globorotalia inconstans*, *Globigerina pseudobulloides*, *Globorotalia compressa*, *Globorotalia praecursoria* (beginning at level G-86), *Globigerina daubjergensis* (with secondary sutural apertures on its spiral side), *Globigerina trivialis*, *Globigerina varianta*, *Globigerina triloculinoides*). Sample G-87 contains rare reworked Upper Cretaceous forms (e.g. *Neoflabellina* ex gr. *sphenoidalis*).

G-85–G-79. Predominantly well-bedded, compact, reddish limestone, with a few layers of argillaceous limestone and red calcareous marls.

The levels G-85–G-82 are attributed to the Globorotalia uncinata zone. Faunas are rich in G-85, poor in G-84 (*Globorotalia trinidadensis*, *Globorotalia* sp. aff. *inconstans*, *Globorotalia praecursoria*, *Globorotalia schachdagica* (only in G-85, very rare), *Globorotalia perclara* (starting at G-82), *Globorotalia uncinata*, *Globorotalia ehrenbergi* (starting at G-84), *Globorotalia angulata* (starting at G-83).

The beds between G-82 and G-79 belong to the Globorotalia pusilla pusilla zone (*Globorotalia praecursoria* (only until G-81), *Globorotalia perclara*, *Globorotalia angulata*, *Globorotalia conicotruncata* (starting at G-80), *Globorotalia tadjikistanensis* (starting at G-79), *Globorotalia simulatilis*, *Globorotalia pusilla pusilla*, *Globorotalia ehrenbergi*, *Globorotalia chapmani* (only in G-79).

In G-82 and G-81, rare reworked *Globotruncana* are observed.

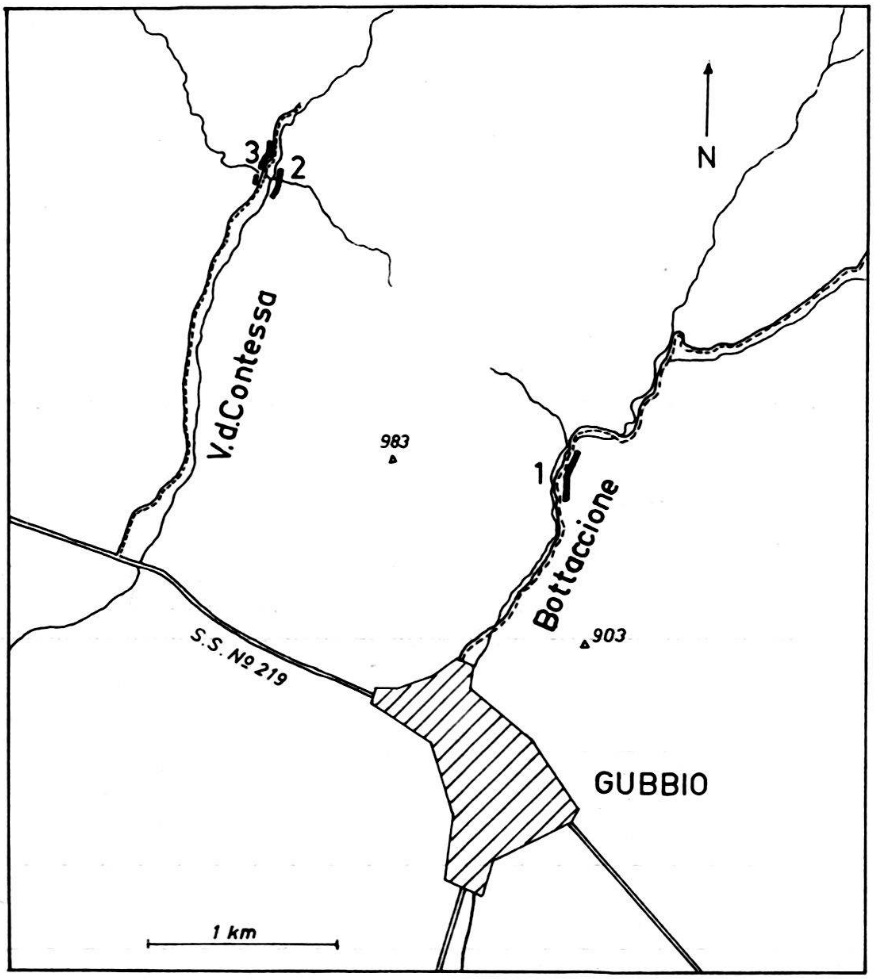


Fig. 130. Sketch-map of the region of Gubbio with location of the studied sections.

G-78–G-75a. Generally well-bedded reddish limestone with fewer argillaceous layers.

Rich, generally incrusted faunas could be isolated from the marly seams at G-78 and G-77. They belong to the Globorotalia pseudomenardii zone (*Globorotalia angulata* (not in G-77), *Globorotalia conicotruncata*, *Globorotalia simulatilis*, *Globorotalia* sp. aff. *kolchidica* (rare), *Globorotalia acutispira* (G-78–G-76), *Globorotalia acuta*, *Globorotalia chapmani*, *Globorotalia pseudomenardii*, *Globorotalia pusilla pusilla*, *Globorotalia pusilla laevigata*).

The samples G-76a, G-76 and G-75a could be investigated in thin sections only. The presence of flattened, keeled «*Planorotalia*» indicates the Globorotalia pseudomenardii zone. At level G-76a, the first forms appear which might be compared to *Globorotalia velascoensis*.

G-75–G-70a. Irregularly bedded, reddish, argillaceous limestone and marls with sporadic layers of compact limestone. The faunas of G-75–G-73a belong to the Globorotalia velascoensis zone. The absence of large multichambered *Globorotalia velascoensis*, abundant in G-74, causes a pronounced change between the faunas of G-74 and G-73. Samples G-73–G-70a contain: *Globorotalia marginodentata, Globorotalia subbotinae*, rare *Globorotalia acuta* and *Globorotalia pasionensis* (only in G-71a and G-71).
The sample G-72 consists almost entirely of reworked Upper Cretaceous forms.
The samples G-73–G-70a are attributed to the Globorotalia aequa zone.

G-70–G-64. Generally well-bedded, compact reddish limestone with a few marly seams.
The poor faunas contained in the samples G-70–G-64 indicate the Globorotalia formosa formosa/Globorotalia subbotinae zone (*Globorotalia aequa, Globorotalia marginodentata, Globorotalia subbotinae, Globorotalia formosa formosa, Globorotalia formosa gracilis*).

G-63–G-60. Irregular alternation of reddish, compact limestone, argillaceous limestone and thin layers of red marls. At G-60, 20–30 cm of marls are intercalated. (Between G-60 and G-59, the ancient aqueduct, which has now – summer 1964 – been barbarically destroyed, passes over the road.)
The fauna is still characteristic for the Globorotalia formosa formosa/Globorotalia subbotinae zone.

G-59–G-53. Reddish, compact limestone, interbedded with argillaceous limestone and few thin layers of marls. In this part of the section, the stratification is slightly disturbed, probably caused by surface sliding.
The faunas are characterized by the presence of *Globorotalia formosa formosa, Globorotalia formosa gracilis, Globorotalia quetra, Globorotalia bullbrooki, Globorotalia marginodentata* (only G-59, G-58) and *Globorotalia aragonensis* (starting at G-55). They are intermediate between the Globorotalia formosa formosa/Globorotalia subbotinae zone and the Globorotalia aragonensis zone.

G-53–G-52. Alternation of compact limestone, argillaceous limestone and marls. First occurrence of red and greenish chert nodules («selci»).

G-51–G-31. Well-bedded compact limestone with irregularly scattered layers of chert nodules and lenses (largest up to 50 cm long and 5 cm thick). The limestone is predominantly reddish at the base and predominantly greenish at the top. Only a few thin layers of marls (G-49, 15–20 cm thick) and marly seams are present, but become more frequent between G-39 and G-36.
The faunas between G-51 and G-39 belong to the Globorotalia aragonensis zone (*Globorotalia formosa formosa* (only until G-49), *Globorotalia bullbrooki, Globorotalia broedermanni* (starting at G-46), *Globorotalia aragonensis, Globorotalia pentacamerata* (flooding in G-49)).
The faunas between G-39 and G-31 are difficult to correlate with the zonation established by BOLLI in Trinidad. The zonal marker *Globorotalia palmerae* of the uppermost zone of the Lower Eocene has not yet been found. The faunas in this part of the section correlate best with the Globorotalia «crassaformis» zone of Soviet authors.
G-37 has yielded a reworked fauna from the Globorotalia aequa zone.

G-31–G-29. Compact, greenish, partly reddish limestone without chert nodules.
The thin marly layer at G-30 contains a reworked fauna, probably corresponding to the faunas in samples G-56–G-50.

G-29–G-20. Regular alternation of compact to argillaceous, greenish and reddish limestone and marls. The samples from the reddish marls at G-28, G-25 and G-21 display intensive reworking.
By the presence of «*Globigerinoides higginsi, Globigerina senni, Globorotalia bullbrooki* and predominantly sinistrally coiled *Globorotalia aragonensis* (coiling random at G-28), this interval may correspond to the upper part of the Globorotalia palmerae zone or to the Hantkenina aragonensis zone (BOLLI, 1957).

In this part of the section, only keeled *Globorotalia* have been studied. Knowledge of the whole fauna would probably allow a better correlation with the current zonations. The appearance of *Hantkenina liebusi* and *Hantkenina dumblei* in sample G-20 marks definitively the beginning of the Middle Eocene.

2. Valle della Contessa

2–3 km northeast of Gubbio, in the Valle della Contessa, a recently constructed road along the western slope of the valley has uncovered a section parallel to that of the Gola del Bottaccione (see BARNABA, 1959, sketch-map fig. 130).

Because of a gap within the main section, caused by the bridge at Pt. 585 (no. 3 on the sketch-map, samples V-1–V-119), a complementary section has been measured on the eastern slope of the valley, along the small path leading to Osteria Valderchia (no. 2 on sketch-map fig. 130, samples K-1–K-42).

The Cretaceous/Tertiary boundary (K-1) is situated about 70 m south of the small bridge at Pt. 558, north of Casa Bruciata. It is similar to that in the section of the Gola del Bottaccione (see PREMOLI SILVA & LUTERBACHER, 1964).

K-1–K-2. Thin-bedded red limestone and argillaceous limestone. At K-2, a thin layer (3 cm) of dark red marls.
The faunas contained in the basal 0.75 cm of the Tertiary correspond to the Globigerina eugubina zone.
The sample K-2 contains a fauna of the lowermost part of the Globigerina pseudobulloides/Globigerina daubjergensis zone. *Rugoglobigerina* are reworked.

K-3–K-5. Irregular alternation of compact limestone, argillaceous limestone and marls.
The rich and well preserved faunas indicate the Globigerina pseudobulloides/Globigerina daubjergensis zone.

K-5–K-6. Compact reddish limestone and argillaceous limestone.
The well preserved fauna contained in a marly layer at K-6 indicates the Globorotalia trinidadensis zone.

K-6–K-8. Well bedded, compact limestone.
A thin section from K-7 contains conicotruncate *Globorotalia*, lenticular *Globorotalia* of the *pusilla* group and flattened «*Planorotalia*». They may be attributed to the Globorotalia pusilla pusilla zone.

K-8–K-13. Thin-bedded, reddish limestone and argillaceous limestone with intercalations of red marls.
Samples K-8 and K-9 represent the Globorotalia pseudomenardii zone.
In the sample K-10, no representatives of the *Globorotalia pusilla* group or of *Globorotalia pseudomenardii* can be observed. The fauna is mainly composed of *Globorotalia acuta*.
K-10 and K-12 are comparable to the samples G-75 and G-74 of the Gubbio section (= Globorotalia velascoensis zone). In K-12, a few reworked *Globotruncana* occur.
K-13 has yielded a poor and badly preserved fauna dominated by *Globorotalia acuta*. Typical *Globorotalia velascoensis* are missing.

K-13–K-15. Well-bedded compact limestone.
The faunas within the thin marly intercalations at K-15 and K-14 are incrusted and could not be determined.

K-15–K-22a. Alternation of reddish limestone, argillaceous limestone and red marls.
K-16 and K-17 contain poorly preserved faunas with *Globorotalia aequa*, *Globorotalia subbotinae* and *Globorotalia formosa gracilis*.
Level K-18 has furnished a poor and crushed fauna, which is indeterminable.
K-20 contains exclusively specimens of small size.
A well preserved fauna, mainly of *Globorotalia subbotinae*, is present in sample K-21.
The rich and well preserved faunas of K-22 and K-22a are composed of *Globorotalia subbotinae*, *Globorotalia formosa formosa* and *Globorotalia formosa gracilis*.

K-22a–K-23. Irregularly thin-bedded, compact limestone.
The thin section K-23 contains mainly forms which are comparable to *Globorotalia subbotinae*.

K-24–K-32. Irregular alternation of compact reddish limestone, argillaceous limestone and rare thin beds of red marls. Reddish-brown chert nodules occur first about 0.80 m below K-31.

The sample K-24 contains *Globorotalia subbotinae* as the only representative of the keeled *Globorotalia*.

The poorly preserved faunas in samples K-25 and K-26 are indeterminable.

The well preserved fauna at K-27 is mainly composed of *Globorotalia aragonensis*. A few reworked *Hedbergella* of Albian character are present. *Globorotalia bullbrooki* (which is retained as synonymous to *Globorotalia spinuloinflata* (BANDY), 1949 by BANDY (1964)) and frequent *Globorotalia pentacamerata* are also present.

In samples K-30, K-31 and K-32, no determinable forms occur.

K-34–K-40. (Between K-32 and K-34, the section along the road is covered for a distance of 10–12 m.)

Well-bedded reddish to greenish dense limestone with layers of predominantly reddish brown chert nodules and a few irregularly distributed thin beds of red marls.

K-34 has furnished a poor fauna (*Globorotalia aragonensis, Globorotalia broedermanni*). The rich assemblage at K-35 is composed almost exclusively of *Globorotalia aragonensis* and *Globorotalia pentacamerata*, whereas *Globorotalia bullbrooki* is rare.

K-36 contains a similar and better preserved assemblage.

Samples K-38 and K-37 contain a few *Globorotalia aragonensis*.

In samples K-39 and K-40, *Globorotalia bullbrooki* dominates, whereas *Globorotalia aragonensis* is rare. K-39 contains numerous small fish teeth.

K-40–K-42. Thin-bedded greenish and reddish limestone with a few layers of reddish marls. The last chert nodules have been observed about 1 m above K-40.

Samples K-41 and K-42 are to be placed in the Globorotalia bullbrooki zone.

Along the road section on the western slope of the Valle della Contessa, the Cretaceous/Tertiary boundary is outcropping 14 m from the southern end of the bridge at Pt. 585.

The uppermost Cretaceous is represented by a well-bedded, light pink limestone which contains a rich fauna. The fauna present in a marly seam at V-80 corresponds to G-99 in the Gola del Bottaccione section. The Cretaceous/Tertiary boundary has been described by PREMOLI SILVA & LUTERBACHER (1962, 1964).

V-80–V-88. Irregularly thin-bedded red limestone and argillaceous limestone with thin layers of red marls.

The lowermost 0.5 m of the Tertiary belongs to the Globigerina eugubina zone.

V-82–V-86 contain rich and well preserved faunas of the Globigerina pseudobulloides/Globigerina daubjergensis zone.

V-87 and V-88 are attributed to the Globorotalia trinidadensis zone.

V-88–V-99. Generally well-bedded, compact, reddish limestone.

A thin section of sample V-89 shows a fauna, comparable to the basal part of the Globorotalia pusilla pusilla zone.

Between V-89 and V-90 (85 m), the measured section is interrupted by the bridge over the small river originating near S. Angelo Crepegge. The total thickness of the missing strata may be 60 m.

V-90–V-95. Alternation of reddish and greenish limestone with layers of chert nodules and thin beds of reddish marls. The uppermost layer of chert nodules occurs 1.50 m above V-93.

V-90 and V-91 contain poor and indeterminable faunas.

V-92 yielded a well preserved and rich assemblage, dominated by *Globorotalia bullbrooki*; *Globorotalia aragonensis*, however, is rare.

In samples V-93 and V-94, the faunas consist of reworked specimens from the Globorotalia aequa zone (*Globorotalia aequa, Globorotalia formosa formosa, Globorotalia subbotinae, Globorotalia marginodentata*). The reworked specimens are better preserved than the autochthonous *Globorotalia bullbrooki*.

V-95 is to be attributed to the Globorotalia bullbrooki zone.

3. Fossombrone

The section of Fossombrone is situated on the eastern flank of the Cesena anticline (see SELLI, 1954, CATI, 1962). The section described here does not correspond to the one described by O. RENZ (1936) from near S. Lazzaro on the western flank of the same anticline. This section is at present only partly exposed, because of a recently constructed dam.

The section described hereafter has been measured in the easternmost limestone quarries, near Madonna del Sasso, south of Fossombrone, along the road Fossombrone–S. Ippolito (see sketch-map, fig. 131). The upper part of the sequence (Fo-27–Fo-40) is exposed along the trail leading to the houses at Pt. 191 and Pt. 227 on the eastern slope of the Valle del Sasso.

The Cretaceous/Tertiary boundary has been described and illustrated already by PREMOLI SILVA & LUTERBACHER (1964).

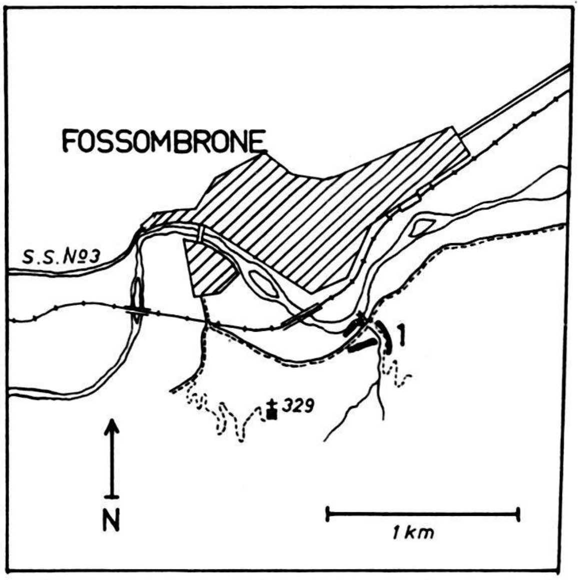


Fig. 131. Sketch-map of the region of Fossombrone with location of the studied section.

In contrast to the sections in the Gubbio anticline, where the lowermost Tertiary is complete, Paleogene starts here only with the Globorotalia trinidadensis zone. The gap in sedimentation is indicated by 1–2 cm of sandy marls with agglutinating foraminifera and numerous small teeth of fishes. A few meters below the lowermost Tertiary, a few layers show laminated bedding, indicating resedimentation.

The lowermost Tertiary is represented by about 0.80 m thin-bedded red limestone containing a fauna of the Globorotalia trinidadensis zone.

Fo-5–Fo-6. Light-coloured well-bedded reddish to yellowish limestone with a few marly seams in its upper part.
A thin section taken at Fo-5 shows a very rich fauna of conicotruncate *Globorotalia*, flattened «*Planorotalia*» and forms of the *Globorotalia pusilla* group.
Fo-6 contains a rich and well preserved fauna with *Globorotalia pusilla pusilla*, *Globorotalia chapmani*, *Globorotalia angulata*, *Globorotalia conicotruncata*, *Globorotalia tadjikistanensis* and *Globorotalia simulatilis*, which is typical for the Globorotalia pusilla pusilla zone.

Fo-6–Fo-7. Thin-bedded reddish limestone with only a few marly layers. About 0.50 m above Fo-7, a distinct layer of light limestone occurs.
The fauna of Fo-7 is attributed to the Globorotalia pseudomenardii zone.

Fo-8–Fo-9. Reddish limestone with layers of red marls. Approximately 1.5 m below Fo-8 and 4.0 m above Fo-9, two distinct beds of light-coloured limestone are present.
The assemblage of Fo-8 still belongs to the Globorotalia pseudomenardii zone, whereas the Globorotalia velascoensis zone begins at level Fo-9.

To fill the gap between the two lower quarries (Fo-9/Fo-10), a few samples have been taken along the Metauro river (Me-1–Me-11), below the road Fossombrone–S. Ippolito. The lowermost of these samples (Me-11) has been taken about 1.0 m above a distinct layer of light-coloured limestone, which correlates lithologically with a similar bed approximately 0.5 m above Fo-7.

Me-11–Me-10. Thin-bedded reddish limestone and argillaceous limestone with thin beds of red marls.
Me-11 contains a poor and badly preserved fauna of the Globorotalia pseudomenardii zone.
The poor preservation of the assemblages at Me-10 does not permit a specific determination.

Me-9–Me-7. Irregularly bedded, reddish, compact limestone with a few marly seams and rare thin beds of red marls.
The shaly marls at Me-8 and Me-9 have a reduced carbonate content and therefore furnished few and poorly preserved agglutinating foraminifera.
A thin section from Me-7 shows a few keeled *Globorotalia* of the *Globorotalia aequa* group.

Me-1–Me-5. Thin-bedded, reddish limestone and red marls. The relatively rich, but poorly preserved faunas from samples Me-1 and Me-2 are attributed to the Globorotalia aequa zone.
The assemblages from Me-3 and Me-4 are too poorly preserved to be determined.
In the sample Me-5, *Globorotalia* are represented almost exclusively by *Globorotalia subbotinae.*

Me-5–Me-6. Reddish to greenish well-bedded limestone. The first layer of chert nodules is observed 0.80 m below the pale red marls at Me-6.
The fauna of Me-6 contains numerous *Globorotalia aragonensis* and scarcely *Globorotalia subbotinae, Globorotalia pentacamerata* and *Globorotalia bullbrooki.* Me-6 corresponds lithologically and faunistically to Fo-16.

The measurement of the section has been continued at the base of the second quarry. Its lowermost 10 m correspond to the top of the strata measured along the Metauro river.

Fo-10–Fo-15. Generally well-bedded reddish to greenish limestone with a few thin layers of red to pale red marls.
The faunas at levels Fo-10, Fo-11 and Fo-12 are poor and badly preserved and could not be determined.
Sample Fo-13 has yielded a rich, but generally crushed assemblage with *Globorotalia aragonensis* and *Globorotalia subbotinae,* whereas the faunas of Fo-14 and Fo-15 are again indeterminable.

Fo-16–Fo-26. Well-bedded reddish and greenish limestone with irregularly scattered layers of reddish, brown and green chert nodules. Layers of predominantly pale reddish marls are rare and irregularly scattered. The last layer of pale-greenish chert nodules is situated 2.0 m above level Fo-25. The top of the quarry is formed by well-bedded reddish to greenish limestone, which becomes predominantly reddish and intercalated with a few layers of red marls in its uppermost 3.0 m.
Fo-16 contains the same fauna as Me-6 and is placed in the basal part of the Globorotalia aragonensis zone.
Sample Fo-17 has yielded a fauna which is almost exclusively composed of «*Acarinina*», whereas keeled *Globorotalia* are rare.
The faunas from the levels Fo-18, Fo-19 and Fo-20 belong to the Globorotalia aragonensis zone.
The samples Fo-12, Fo-23 and Fo-25 have not furnished determinable forms; only in Fo-22 and Fo-24 may a few *Globorotalia bullbrooki* and rare *Globorotalia aragonensis* be recognized.
The last sample at the top of the quarry, Fo-26, contains a relatively rich fauna, indicating the Globorotalia bullbrooki zone. Some of the *Globorotalia pentacamerata* and *Globorotalia aragonensis* may be reworked, because they are differently coloured.
The section is continued along the trail on the left slope of the Valle del Sasso.

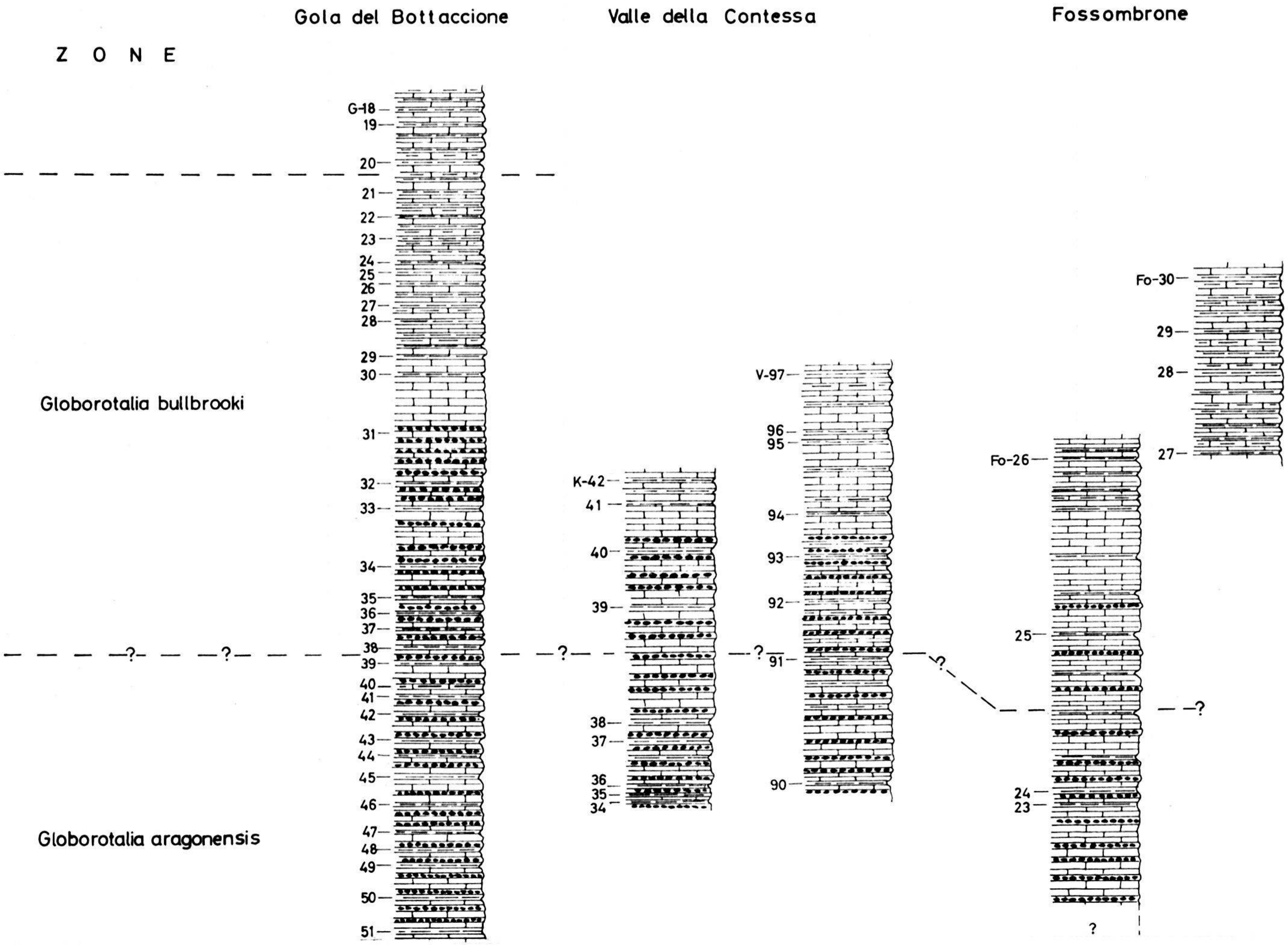
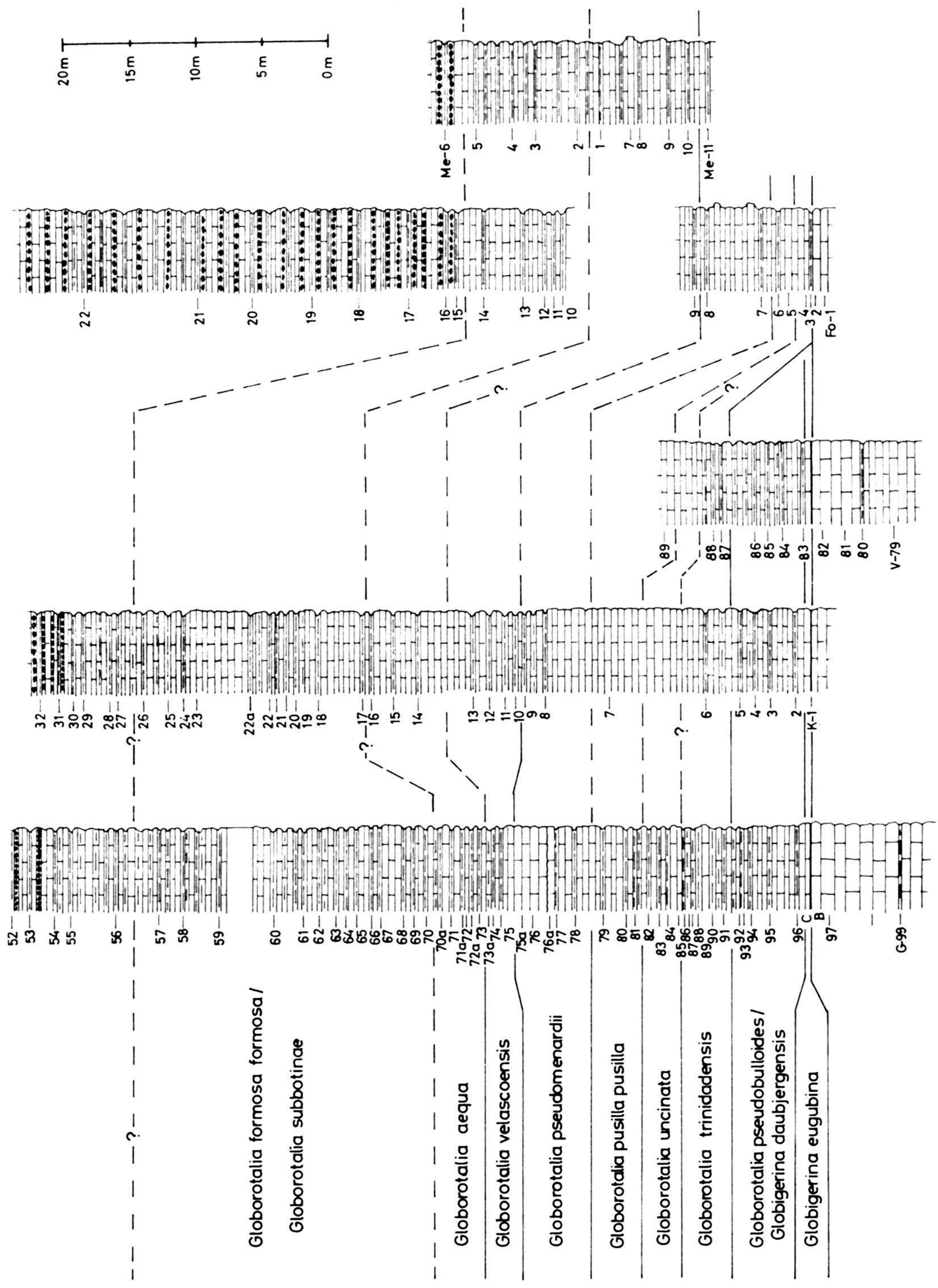


Fig. 132. Columnar sections of the Paleocene and Lower Eocene of the Scaglia, Central Apennines.


20m
15m
10m
5m
0m
Me-6
Me-11
Fo-1
V-79
K-1
G-99
Globorotalia formosa formosa / Globorotalia subbotinae
Globorotalia aequa
Globorotalia velascoensis
Globorotalia pseudomenardii
Globorotalia pusilla pusilla
Globorotalia uncinata
Globorotalia trinidadensis
Globorotalia pseudobulloides / Globigerina daubjergensis
Globigerina eugubina

Fo-27–Fo-30. Regular alternation of reddish limestone, argillaceous limestone and red marls. The fauna of sample Fo-27 corresponds to that of Fo-26. Within the levels Fo-28, Fo-29 and Fo-30, *Globorotalia bullbrooki* prevails, whereas *Globorotalia aragonensis* is less frequent. In the well preserved fauna from Fo-30, *Globorotalia pseudotopilensis* and *Aragonia anauna* may be mentioned.

A comparison of the three measured sections shows little differences in lithology and thickness. The Scaglia is very uniform in its general aspect.

A detailed knowledge of the biostratigraphy of the Scaglia, however, indicates a more vivid history of the basin and details may differ considerably over short distances.

The important differences at the Cretaceous/Tertiary boundary and the existence of gaps in sedimentation along this boundary are already described by PREMOLI SILVA & LUTERBACHER (1964).

A comparison of the thicknesses of the different zones is given in the following tabulation:

Zone	Gola del Bottaccione	Valle della Contessa	Fossombrone
Globorotalia bullbrooki	35 m	> 25 m	> 35 m
Globorotalia aragonensis	28–30 m	28–30 m	45–55 m
Globorotalia formosa formosa/Globorotalia subbotinae	22–24 m	16–18 m	10–12 m
Globorotalia aequa	4–5 m	6–7 m	8 m
Globorotalia velascoensis	2.5 m	4–6 m	
Globorotalia pseudomenardii	5–6 m	5 m	5 m
Globorotalia pusilla pusilla	4–5 m	4–5 m	2 m
Globorotalia uncinata	3 m	3 m	1.5 m
Globorotalia trinidadensis	4 m	3–4 m	
Globorotalia pseudobulloides/Globigerina daubjergensis	5–7 m	5–7 m	–
Globigerina eugubina	0.5 m	0.5–0.75 m	–

In the upper part of the three sections, a strong increase in thickness of the individual zones is observed.

In the section of the Gola del Bottaccione, the thickness of strata attributed to the Globorotalia bullbrooki zone exceeds by about 5 m the interval between the Globigerina eugubina zone and the Globorotalia aragonensis zone. In the Lower Eocene and Paleocene near Fossombrone, the discrepancy between the thicknesses of the zones is even more obvious: Globorotalia aragonensis zone 45–55 m, Globorotalia trinidadensis zone to Globorotalia aequa zone ca. 25 m.

This close succession of planktonic foraminiferal zones in the Paleocene compared with the looser succession within the Lower Eocene may have three reasons:

(a) The rate of sedimentation was considerably lower during the Paleocene than during the Lower Eocene.

(b) The evolutionary speed of planktonic foraminifera slowed down in Lower Eocene time. In the course of evolution of planktonic foraminifera, several epochs of increased «evolutionary speed» are noted. During the Upper Albian/lowermost

Cenomanian, a rapid change of short living planktonic species is observed. After the extinction of almost all planktonic foraminifera at the end of the Upper Cretaceous, a rapid evolution starts again during Paleocene time.

(c) The present knowledge of the genus *Globorotalia* during the Lower Eocene is not yet sufficient enough to allow a further splitting of zones. The author thinks that a detailed study of more sections with better preserved faunas will lead to a more perfect zonation.

The abundant reworking of older faunas in the Scaglia is another interesting fact. Reddish layers within the greenish limestones and marls of the upper part of the sections are almost always connected with reworking. The reworking of forms from the Globorotalia aequa zone within the upper part of the Globorotalia bullbrooki zone might indicate the exposition of sediments of the Globorotalia aequa zone to – probably submarine – erosion during the deposition of the Globorotalia bullbrooki zone. A better knowledge of reworking is fundamental to understand the history of the Scaglia basin.

The zonation of the Paleocene and Lower Eocene of the Central Apennines by means of planktonic foraminifera

Planktonic foraminiferal zones are in the majority assemblage- or concurrent-range zones. Only a few of these zones (e.g. Globorotalia uncinata zone, Globorotalia pseudomenardii zone) represent real range zones. Therefore, some authors (HILLEBRANDT, 1962, GOHRBANDT, 1963) have preferred to use for their zonation letters (A, B, C...) to designate the individual zones rather than species names. This author prefers to use species names for the different zones, mainly for practical, especially mnemonic reasons. Concurrent-range and assemblage zones have the advantage of not being defined by the range of only one species. They may, therefore, be recognized also if part of the characterizing assemblage is missing.

The present paper follows the zonation established by BOLLI (1957) for the Paleocene and Lower Eocene of the Lizard Springs formation in Trinidad. It has proved to be the most adequate zonation for subdividing the sections of the Scaglia basin. The correlation with BOLLI's zonation is based on the type-samples of each of his zones.

For taxonomic reasons, two minor modifications are necessary.

Towards the base of the Paleocene, two additional zones must be added: Globigerina eugubina zone and Globigerina pseudobulloides/Globigerina daubjergensis zone (see PREMOLI SILVA & LUTERBACHER, 1964). Because of its reduced thickness, the Globigerina eugubina zone might also be considered as a lowermost subzone of the Globigerina pseudobulloides/Globigerina daubjergensis zone.

Within the interval between the Globorotalia trinidadensis zone and the Globorotalia velascoensis zone, the same distribution of species may be observed in the Scaglia as in Trinidad. Minor differences are only due to a somewhat divergent interpretation of some species.

Above the Globorotalia velascoensis zone, a certain discrepancy with the zonation as introduced by BOLLI exists. As stated in the systematic part, *Globo-*

rotalia «rex» in Bolli (1957) differs markedly from *Globorotalia rex* as described by Martin.

The abrupt change in the composition of both planktonic and benthonic foraminiferal faunas at the boundary between the Upper and the Lower Lizard Springs formation (southwestern Trinidad), suggests the presence of a gap in sedimentation between the Globorotalia velascoensis zone and the Globorotalia «rex» zone in this region. According to oral communication by Dr. Kugler, this assumption may be supported by the lithology.

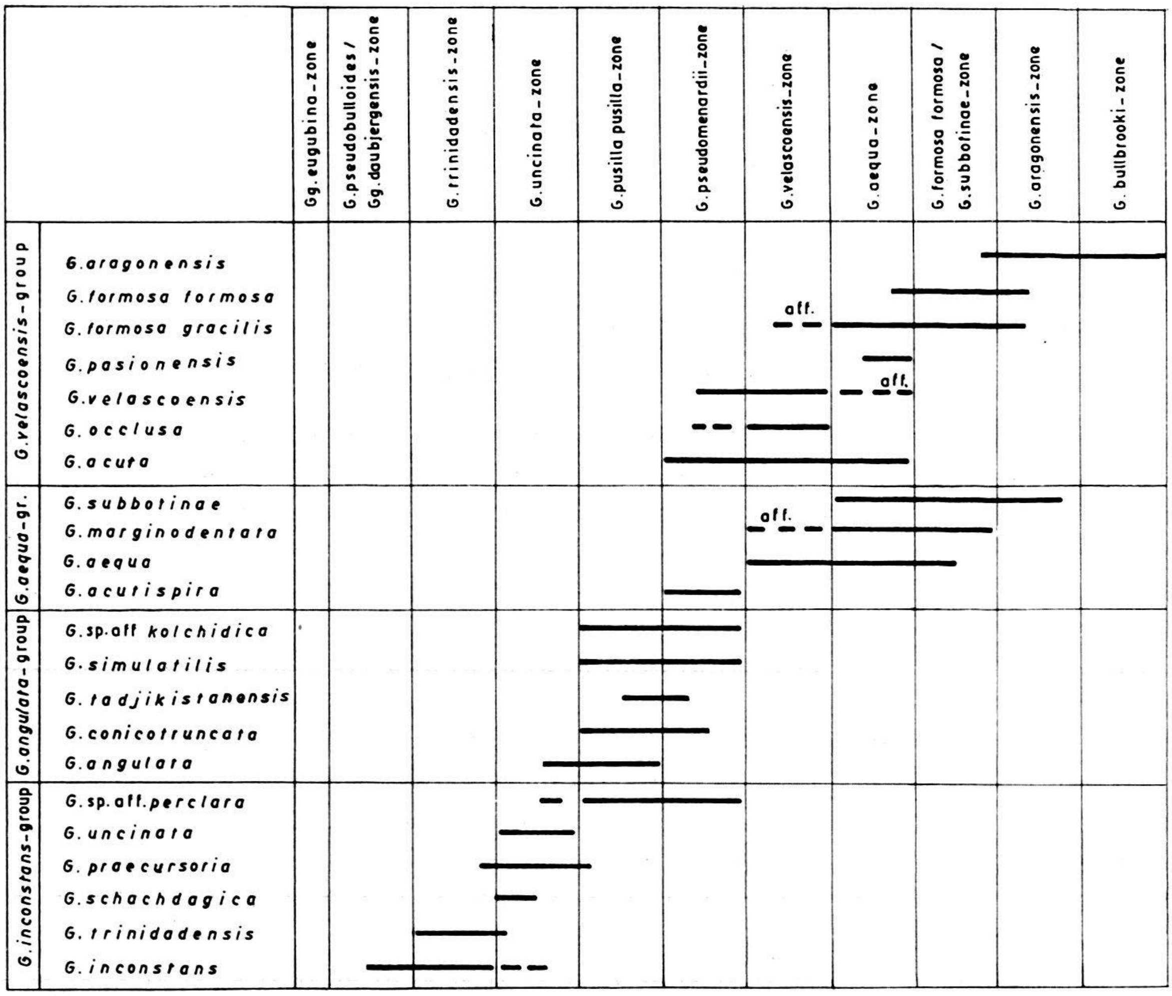


Fig. 133. Species distribution of the studied *Globorotalia* in the Paleocene-Lower Eocene of the Gubbio section, Central Italy.

The Globorotalia aequa zone is characterized by the presence of *Globorotalia aequa, Globorotalia acuta, Globorotalia* sp. aff. *velascoensis, Globorotalia marginodentata, Globorotalia formosa gracilis,* and *Globorotalia subbotinae.* In its upper part, *Globorotalia formosa formosa* appears.

The type-sample of the Globorotalia «rex» zone of Bolli belongs to the Globorotalia aequa zone. The type-sample of *Globorotalia aequa* from the Soldado Rock (Kugler, 1938, Cushman & Renz, 1942) represents the basal part of this zone.

The Globorotalia formosa formosa zone of BOLLI is correlated with the Globorotalia formosa formosa/Globorotalia subbotinae zone as used in the present paper. Because of the scarcity of *Globorotalia formosa formosa* in the sections of the Central Apennines, especially in that of Fossombrone, the more frequent *Globorotalia subbotinae* has been added to *Globorotalia formosa formosa* to designate this zone. The limits towards the neighbouring zones are indistinct. BOLLI & CITA (1960) and PREMOLI SILVA & PALMIERI (1962) found similar difficulties when establishing the zonation of corresponding parts of sections in Northern Italy.

The Globorotalia aragonensis zone is characterized by the presence of abundant *Globorotalia aragonensis* and *Globorotalia bullbrooki.* Some samples from this zone are flooded with *Globorotalia pentacamerata.* In the Scaglia, *Globorotalia bullbrooki* appears already in the upper part of the Lower Eocene, whereas BOLLI mentions this species only from the lower Middle Eocene of Trinidad. A similar extension of the stratigraphical range of *Globorotalia bullbrooki* (= *Globorotalia spinuloinflata,* following BANDY, 1964) has also been observed by PREMOLI SILVA & PALMIERI (1962) in the sections of the Val di Non (Alto Adige).

The Globorotalia bullbrooki zone is correlated with the Globorotalia «crassaformis» zone of the Soviet authors. *Globorotalia crassaformis*, as interpreted by SUBBOTINA (1953), is synonymous to *Globorotalia bullbrooki* BOLLI, which is a somewhat homomorphous form of the Pleistocene *Globorotalia crassaformis* GALLOWAY & WISSLER. The name Globorotalia bullbrooki/Globorotalia aragonensis zone was used by BRÖNNIMANN & RIGASSI (1963) for the uppermost zone of the Lower Eocene from Cuba. Since *Globorotalia palmerae* has not yet been found in the sections of the Central Apennines, it is not possible to use the term Globorotalia palmerae zone, although the Globorotalia bullbrooki zone might correspond to it at least partly.

On the stratigraphic subdivision of the Paleocene and Lower Eocene

The still doubtful correlations established between the planktonic foraminiferal zonation and the stages of the Paleocene have already been discussed in a previous paper (PREMOLI SILVA & LUTERBACHER, 1964), which should be referred to for more detailed discussions.

The planktonic foraminifera of the stratotype of the Danian are well known through the papers of BRÖNNIMANN (1952), TROELSEN (1957), HOFKER (1960, 1962, etc.) and BERGGREN (1960, 1962). The faunas correspond to the Globigerina pseudobulloides/Globigerina daubjergensis zone and to the lower part of the Globorotalia trinidadensis zone. *Globorotalia trinidadensis* itself is not yet recorded from the type-Danian, from which it is likely to be missing for ecological reasons. The occurrence of *Globorotalia compressa* and *Globorotalia* sp. aff. *reissi* (see BANG, 1962) allows, nevertheless, a tentative correlation of the uppermost type-Danian with the Globorotalia trinidadensis zone.

In the central part of the Northern Caucasus, the Danian corresponds to the Kuban horizon, which is attributed to the Globigerina pseudobulloides/Globigerina daubjergensis zone (LEONOV & ALIMARINA, 1961, ALIMARINA, 1963, SHUTZKAYA, 1962). This correlation by planktonic foraminifera is proved by the occurrence of macrofossils (e.g. MOSKVIN & NAIDIN, 1960). The lower part of the overlying Elburgan svita is placed in the Upper Danian by MOSKVIN & NAIDIN (1960). Following SHUTZKAYA (1962), it corresponds to the upper part of her Globorotalia compressa/Globigerina daubjergensis/Globigerina trivialis zone and to the «Acarinina» inconstans zone. The latter zone compares approximately with the lower part of the Globorotalia trinidadensis zone[5]). ALIMARINA (1963) subdivided the «Acarinina» inconstans zone into two subzones: «Acarinina» indolensis zone and «Acarinina» praecursoria zone. The second zone is likely to correpond to the Globorotalia uncinata zone.

LOEBLICH & TAPPAN (1957) erroneously considered the type-Montian to be contemporaneous to the type-Danian. In southwestern Crimea, in the region of Bakhtchissaray, the superposition of layers corresponding to these two stages is well exposed. Here, faunas of undoubtedly Danian age are overlain by limestones containing macro- and microfaunas identical to those of the «Calcaire de Mons» (MURATOV & NIEMKOV, 1960, MOSKVIN & NAIDIN, 1960, SHUTZKAYA, 1960).

Two possibilities for drawing the limit between Danian and Montian have been proposed by MOSKVIN & NAIDIN:

(a) above the top of the layers with *Protobrissus tercensis* and *Coraster ansaltensis*;

(b) below these layers and above those with *Cyclaster gindrei* and *Protobrissus depressus*.

According to the second proposition, adopted in this paper, the Danian corresponds to the interval of *Hercoglossa danica* or to the type-section of the Danian in Denmark. Following SHUTZKAYA (1962), the layers with *Protobrissus tercensis* correlate with planktonic faunas containing *«Acarinina» inconstans*, *«Acarinina inconstans uncinata»*, rare *Globorotalia angulata* and other species. According to the opinion of the present writer, these faunas compare with the upper part of the Globorotalia trinidadensis zone and with the Globorotalia uncinata zone.

The upper part of the Elburgan svita corresponds to the Inkerman stage, correlating to the type-Montian. (LEONOV (1963) prefers to correlate the «Inkerman stage» of southwestern Crimea with the lower part of the Elburgan svita. In the section of Bakhtchissaray, a gap in sedimentation between the «Inkerman stage» and the «Katchinsk stage» would probably correspond to the upper part of the Elburgan svita.) SUBBOTINA (1953) placed the upper part of the Elburgan svita in her «zone of rotaloid Globorotaliids», which she assumed to be of Danian age. SHUTZKAYA (1962) subdivided this part of the Elburgan svita into two zones: Globorotalia angulata zone and Globorotalia conicotruncata zone; whereas ALIMARINA (1963) shows it to belong mainly to her «Acarinina» angulata subzone and to the lowermost part of the subzone with *«Acarinina» conicotruncata*, rounded *«Acarinina» tadjikistanensis* (= *Globorotalia tadjikistanensis djanensis*) and *Globorotalia kolchidica*. KOROBKOV (in SHUTZKAYA, 1956) correlated the upper part of the Elburgan svita with the Montian.

The faunas of the «Acarinina» angulata zone correspond to the uppermost part of the Globorotalia uncinata zone and the lower part of the Globorotalia pusilla

[5]) Correlations with faunasfrom the southern Soviet Union are mainly based on samples obtained from V. A. KRASHENNINIKOV, N. N. SUBBOTINA, E. K. SHUTZKAYA, N. I. MASLAKOVA, D. P. NAIDIN and G. I. NIEMKOV.

TRINIDAD Bolli 1957	CENTRAL APENNINES Luterbacher 1964	CENTRAL PART OF NORTHERN CAUCASUS Subbotina 1953		Strat. Commission USSR 1963	Alimarina 1963	
H. aragonensis		A. crassaformis		A. crassaformis	A. crassaformis	
G. palmerae	G. bullbrooki	zone of conical Globorotaliids		G. aragonensis	group of T. aragonensis	T. caucasica
G. aragonensis	G. aragonensis					
G. formosa formosa	G. formosa formosa / G. subbotinae	zone of flattened Globorotaliids	G. marginodentata	G. subbotinae	group of A. subsphaerica & group of G. aequa	G. marginodentata
G. rex gap ?	G. aequa			G. aequa		G. aequa & G. wilcoxensis
G. velascoensis	G. velascoensis		G. crassata & A. intermedia	A. acarinata		
G. pseudomenardii	G. pseudomenardii			A. subsphaerica		A. aff. subsphaerica
G. pusilla pusilla	G. pusilla pusilla			A. tadjikistanensis djanensis A. conicotruncata	group of A. angulata	G. (?) kolchidica rounded A. tadjikistanensis A. conicotruncata
G. uncinata	G. uncinata	zone of rotaloid Globorotaliids	Gg. inconstans Gg. triviatis	A. angulata		A. angulata A. praecursoria
G. trinidadensis	G. trinidadensis				group of A. inconstans	A. indolensis
(Rzehakina epigona)	G. pseudobulloides / Gg. daubjergensis Gg. eugubina				group of G. pseudobulloides	reticulate Globigerina "Eoglobigerina"

Fig. 134. Correlation of some biostratigraphic zonations of the Paleocene-Lower Eocene by means of planktonic foraminifera (partly after KRASHENINNIKOV, personal communication). (*G.* = *Globorotalia*, *Gg.* = *Globigerina*, *H.* = *Truncorotalia*, *A.* = *Acarinina*.)

pusilla zone. The Globorotalia conicotruncata zone is entirely placed in the Globorotalia pusilla pusilla zone.

In the «Decision of the Stratigraphic Commission on the Paleogene of the USSR», the overlying «Acarinina» tadjikistanensis djanensis zone and the «Acarinina» subsphaerica zone of the Goriatchy Kliutch svita are attributed to the Katchinsk stage, which is said to correspond to the Thanetian of Western Europe. (Following LEONOV (1963), in the stratotypical section of Bakhtchissaray, only layers corresponding to the «Acarinina» tadjikistanensis djanensis zone would be represented. He considers the possibility of a gap in sedimentation within this section, which may represent the interval between the «Acarinina» subsphaerica zone and the Globorotalia aequa zone of the Kuban section in the Northern Caucasus.) A comparison of the faunas from the «Acarinina» tadjikistanensis djanensis zone (= approximately «Acarinina» conicotruncata, rounded «Acarinina» tadjikistanensis, Globorotalia (?) kolchidica zone in ALIMARINA, 1963) with faunas from Trinidad and the Central Apennines is somewhat difficult. Although the fauna is still very rich in individuals, it is already impoverished in its specific content. This may be caused by the predominance of an uncalcareous facies in the Goriachi Kliutch svita. The «Acarinina» tadjikistanensis djanensis zone is tentatively correlated with the upper part of the Globorotalia pusilla pusilla zone and the lower part of the Globorotalia pseudomenardii zone. Species with well developed keel (e.g. *Globorotalia acuta, Globorotalia acutispira*), which are to be expected within this stratigraphical level, are missing. *Globorotalia pseudomenardii* is very rare, and forms of the *Globorotalia pusilla* group – always abundant in the corresponding faunas of the Thetys faunal province – have not been found in the samples from southern Soviet Union.

The «Acarinina» subsphaerica zone contains a very specialized fauna of rounded «Acarinids». This fauna is difficult to correlate with the zonation used in the present paper. Among species characteristic for this zone are *Globorotalia velascoensis, Globorotalia apanthesma* and *Globorotalia pseudomenardii* («Stratigraphic Commission,» 1963). They have not been observed within the examined samples. The occurrence of these species allows to correlate the «Acarinina» subsphaerica zone with the upper part of the Globorotalia pseudomenardii zone.

The presence of Discoasterids of the Heliolithns riedeli zone (BRAMLETTE & SULLIVAN, 1961) in the type-Thanetian and in the type-sample of the Globorotalia pseudomenardii zone in Trinidad, indicates the Thanetian age of the lower part of this zone. This correlation corresponds satisfactorily to the conclusions reached by LEONOV & ALIMARINA (1961).

In 1960, HOTTINGER & SCHAUB introduced the term Ilerdian as a stage name for the Upper Paleocene. Its validity is still wide open to discussion. Several stipulations for the establishment of a new «time-stratigraphic unit» – as specified by the «Code of Stratigraphical Nomenclature» – are not yet satisfied. In its type-region, the Ilerdian is limited at its base and at its top by continental sediments, and therefore its relations to the Thanetian and the Cuisian cannot be observed. Planktonic foraminifera (GARTNER & HAY, 1962) cannot be used for correlation. Reworking is frequently observed in this extremely epicontinental section.

In the classic section of El Quss Abu Said (Farafrah Oasis, Western Egypt), the first *Nummulites*, marking the beginning of the Ilerdian, appear within the Globorotalia pseudomenardii zone. This zone contains an assemblage of Discoasterids of the Discoaster multiradiatus zone, as in its upper part in the Velasco formation (Eastern Mexico). In the section of the Schlierenflysch (Central Switzerland), the earliest *Nummulites* appear within the same Discoaster zone. The Globorotalia pseudomenardii zone therefore corresponds to the uppermost Thanetian and to the lowermost Ilerdian.

In the «parastratotype» section of the Kuban-river, lowermost Eocene (Bakhtchissaray stage) begins with the «Acarinina» acarinata zone (lower part of the Abazinsk svita). The fauna of this zone differs considerably from faunas of the Thetys. It is not attempted to correlate this zone with the zonation used in the present paper. The upper part of the Abazinsk svita (= Globorotalia aequa zone) corresponds in its faunal composition to the homonymous zone of the Central Apennines. In samples from the Northern Caucasus, heavily keeled *Globorotalia acuta* and similar forms have not been observed. LEONOV & ALIMARINA (1961) correlated the Labinsk group (upper part = Abazinsk svita) with the Globorotalia velascoensis zone and the Globorotalia «rex» zone of Trinidad. SUBBOTINA (1953) placed the Abazinsk svita in the Globorotalia marginodentata subzone, whereas SHUTZKAYA (1956, 1960) mentioned the following characteristic species for these layers (= upper part of the Naltchik horizon): *«Acarinina» subsphaerica*, *«Truncorotalia» praenartanensis*, *Globorotalia densa* and *Globorotalia membranacea*. KOROBKOV (in SHUTZKAYA, 1956) correlated the upper part of the Naltchik horizon with the Ypresian.

In the stratotype section of Bakhtchissaray (southwestern Crimea), the Globorotalia aequa zone is placed in the Operculina semiinvoluta subzone, which is characterized also by *Nummulites mouratovi* and *Nummulites globulus* (MURATOV & NIEMKOV, 1960). In the Schlierenflysch section (Central Switzerland), *Nummulites globulus* ranges from Middle Ilerdian to Lower Cuisian (SCHAUB, 1951).

The type sample of the Globorotalia velascoensis zone in Trinidad is placed by HAY in the Discoaster multiradiatus zone and has therefore to be attributed to the Lower Ilerdian. In the section of Paderno d'Adda (Northern Italy, BOLLI & CITA, 1960), a breccia within the Globorotalia velascoensis zone contains *Nummulites exilis*, which is characteristic for the Middle Ilerdian.

The Lower and Middle Ilerdian can be correlated by quite good arguments with planktonic foraminiferal zones. Approaching the Upper Ilerdian and the Lower Cuisian, the relations are more confused. (These stratigraphical terms are used as defined by HOTTINGER & SCHAUB, 1960.)

Nummulites, indicating a Lower Cuisian age, are interbedded in the Paderno d'Adda section (level 9 in VIALLI, 1951) in a planktonic fauna, attributed – with some restrictions due to poor preservation – to the Globorotalia aequa zone (see BOLLI & CITA, 1960). In the condensed and incomplete sequence of Valdeforte (Northern Italy, CITA, BOLLI & SCHAUB, 1962), Lower Cuisian *Nummulites* and *Alveolina* are associated with planktonic foraminifera of the Globorotalia «rex» zone. In both localities, thin sections demonstrate that larger and planktonic foraminifera are embedded in a different matrix.

On the other hand, the type-sample of the Globorotalia «rex» zone in Trinidad is to be placed, according to HAY, in the Discoaster contortus zone. In the Schlieren section, this zone contains *Nummulites* of the Middle Ilerdian.

In the section of El Quss Abu Said, faunas of the Globorotalia aequa zone occur in the upper Farafrah shales, below the Maqfi beds, the latter containing *Nummulites* and *Alveolina* of Middle to Upper Ilerdian.

The Globorotalia aequa zone apparently reaches from Middle Ilerdian to lowermost Cuisian. It straddles over the Paleocene/Eocene boundary as interpreted by HOTTINGER & SCHAUB.

SHUTZKAYA (1956, 1960) and ALIMARINA (1963) place this boundary above the Abazinsk svita and consequently above the Globorotalia aequa zone. In the «Decision of the Stratigraphical Commission», the Globorotalia aequa and the «Acarinina» acarinata zones are already placed in the Lower Eocene.

In the clay pit of the «Tuilerie de Gan» (southwestern France), a well preserved planktonic fauna, which is placed in the Globorotalia formosa formosa/Globorotalia subbotinae zone, is present in the middle part of the section. The same layers are dated as uppermost part of Lower Cuisian by larger foraminifera.

In the region of Haimana (Anatolia, Turkey, see HOTTINGER, 1962), a rich and well preserved fauna, which strikingly resembles faunas of the Globorotalia subbotinae zone from the Northern Caucasus, is overlain by *Alveolina*, indicating a Lower Cuisian age. Although differences in the specific composition of the fauna cannot be denied, the Globorotalia subbotinae zone of SHUTZKAYA (1956, 1960) might be correlated with the Globorotalia formosa formosa/Globorotalia subbotinae zone, as done in this paper. Contemporaneous deposits are placed by ALIMARINA (1963) in her Globorotalia marginodentata subzone.

In southwestern Crimea, the Globorotalia subbotinae zone is placed in the upper part of the Bakhtchissaray stage, which contains *Nummulites* of Lower Cuisian age (Nummulites planulatus zone).

The Globorotalia aragonensis zone of Soviet authors corresponds satisfactorily to the homonymous zone of BOLLI. By decision of the Stratigraphical Commission (1963), this zone forms the lower part of the Simferopol stage, which is characterized by *Nummulites* of Upper Cuisian age in the section of Bakhtchissaray. It does not correspond to the Lutetian of the Paris Basin, as supposed by Soviet authors (NIEMKOV & BARKHATOVA, 1959, «Decision of the Stratigraphical Commission», 1963).

The rich and well preserved faunas of the «Marnes de Donzacq» (southwestern France) with *Globorotalia aragonensis* and *Globorotalia caucasica* are retained as Upper Cuisian by HOTTINGER & SCHAUB (1960). LEHMANN (personal communication) has found a fauna with *Globorotalia aragonensis* and *Globorotalia caucasica* overlain by deposits with *Nummulites* indicating Upper Cuisian. In the Erevan basin (Armenian SSR) GABRELYAN, SAHAKYAN & MARTIROSYAN (in MENNER, 1960) reported a similar occurrence of *Globorotalia aragonensis* and *Globorotalia caucasica* below layers with *Nummulites murchisoni*.

The Globorotalia bullbrooki zone, as used in the present paper, at least in part corresponds to the Globorotalia palmerae zone and to the «Acarinina crassaformis» zone of Soviet authors (SUBBOTINA, 1953, SHUTZKAYA, 1956, 1960, ALIMARINA, 1963, KRASHENINNIKOV & PONIKAROV, 1964).

CITA, BOLLI & SCHAUB (1962) described from Cerbiolo (Monte Baldo, Northern Italy) a planktonic fauna of the Globorotalia palmerae zone, which is dated by *Nummulites* as topmost Cuisian. In the «Decision of the Stratigraphical Commission» (1963), the «Acarinina crassaformis» zone is placed in the upper part of the Simferopol stage, which – in southwestern Crimea – corresponds to the Nummulites polygyratus zone. Following SCHAUB, *Nummulites polygyratus* indicates topmost Cuisian. It is therefore assumed that the Globorotalia bullbrooki zone begins in the uppermost Cuisian.

Contrary to this assumption, the correlation chart given in the introduction to the symposium on the Paleogene deposits of the Southern part of the European Soviet Union (MENNER, 1960) shows a «Truncorotalia» aragonensis zone, linked with *Nummulites laevigatus* (= Lower Lutetian) and, moreover, an «Acarinina crassaformis» zone correlated with a Nummulites perforatus zone (upper Middle Eocene).

An attempt to correlate the planktonic foraminiferal zones with the stages of the Paleocene and the Lower Eocene is given in the following chart:

		Planktonic foraminiferal zone	Stage (after HOTTINGER & SCHAUB)
EOCENE	MIDDLE	Globorotalia bullbrooki	«Lowermost Lutetian»
	LOWER	Globorotalia aragonensis	
		Globorotalia formosa formosa/Globorotalia subbotinae	«Cuisian»
PALEOCENE	UPPER	Globorotalia aequa	
		Globorotalia velascoensis	«Ilerdian»
	MIDDLE	Globorotalia pseudomenardii	
		Globorotalia pusilla pusilla	«Thanetian»
		Globorotalia uncinata	«Montian»
	LOWER	Globorotalia trinidadensis	
		Globorotalia pseudobulloides/Globigerina daubjergensis	«Danian»
		Globigerina eugubina	

On account of the historic development of stratigraphical geology, all type-localities of Paleogene stages have been defined in epicontinental series of the boreal faunal province. Incomplete outcrops, differences in facies and fossil content of the numerous Western European stages prevent their satisfactory definition.

One way out of this dilemma has been chosen by the «Decision of the Permanent Interdepartmental Stratigraphical Commission on the Paleogene of the USSR» (1963). Because of the non-existence of a uniform and generally accepted scale for the stratigraphical subdivision of the Paleogene, it was decided to establish an independent stratigraphical standard scale for the Paleogene of the Soviet Union. The classical section of Bakhtchissaray in southwestern Crimea was chosen as «stratotype» for this scale. The section along the Kuban river (central part of Northern Caucasus) serves as «para-stratotype» for the pelagic facies.

This new standard scale has been recommended for general use in Europe.

Since the present paper deals only with planktonic foraminifera, it is mainly concerned with the Kuban section.

The planktonic foraminiferal faunas of the Central Northern Caucasus differ markedly from corresponding faunas of the Thetys province, although many species common to both provinces allow a limited correlation. The well known difference in planktonic foraminifera from Thetydal and Boreal faunal provinces, existing during the Upper Cretaceous, is also observed during the Paleogene (see also BANDY, 1964).

Faunas from Anatolia, Aquitania, Vicentino, the northern part of the Atlantic coast of North America and the Lodo formation in California show great affinities to the corresponding faunas of Crimea, Northern Caucasus and Western Turkmenia; whereas the faunas of the Scaglia of Central and Northern Italy, Southern Iran, Egypt, Morocco and eastern Mexico compare well with the zonation established by BOLLI in Trinidad. For different faunal provinces, different zonations have to be established.

The Goriachy Kliutch svita and the Abazinsk svita of the central Northern Caucasus are characterized by impoverished and specialized planktonic faunas, inappropriate for a stratigraphical standard of more than regional value. The same is valid for the Upper Eocene Kumsk horizon.

The stratigraphical scale of the Paleogene has to be based on the sections developed in continuous pelagic facies from the Thetys faunal province with rich planktonic faunas. It is dangerous to base a standard zonation on only one section, which is never free from local and regional peculiarities. The attempted standard zonation will be purified from local trends and abnormalities by detailed studies of more and more sections in different regions of the Thetys. In this way, a useful tool for stratigraphic work of increasing refinement will be obtained. If the present paper might be a little step towards this goal, it has attained its purpose.

A stratigraphy based on the above principles should not be encumbered by stage names connected to strato-types more or less luckily chosen. The fundamental unit of a stratigraphy, based on fossil records, is the biozone. The assignment of biozones to stratigraphical units of higher rank is in great part a convention. The author of the present paper prefers the use of neutral terms, such as Lower, Middle and Upper Paleocene, rather than the misuse of poorly defined stage names.

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Abbreviations

BMOIP: Biulleten Moskovskovo obshchestva ispytatelei prirody.
CCLFR: Contributions from the Cushman Laboratory for foraminiferal research.
CCFFR: Contributions from the Cushman Foundation for foraminiferal research.
VNIGRI: Vsiesoyusnovo neftyanovo nauchno-isslyedovatelskovo geologo-rasvyedochnovo instituta.