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An Early Miocene (Aquitanian) planktonic foraminiferal fauna from the Tsuro Formation, the youngest part of the Shimanto Supergroup, Shikoku, Japan

Tsunemasa SAITO*

Introduction

As much of our present-day knowledge on the stratigraphy of the Shimanto Supergroup has been formulated through Professor Jiro KATTO's extensive field works which were initiated in the early 1950's, it is particularly fitting to dedicate this short taxonomic note on the discovery of Early Miocene plankonic foraminiferal assemblage from the Shimanto to Professor KATTO at the occasion of his sixtieth birthday. The Aquitanian (Early Miocene) planktonic foraminiferal assemblage was recovered from the youngest, land-exposed strata of the Shimanto Supergroup and constitutes the first well-documented report of early Aquitanian planktonic foraminifera from Japan. Although extensive studies exist dealing with Miocene planktonic foraminifera from the Japanese Islands, most of them described post-Aquitanian faunas because the last, most extensive marine transgression over much of the Japanese Islands did not take place until near the end of the Early Miocene (Burdigalian). No attempt was made to quantitatively analyze this newly discovered Aquitanian fossil assemblage, as the species treated here are representatives of only those specimens which were fortuitously freed from a greatly indurated, calcareous siltstone after successively subjecting the rock to the sodium tetraphenylborate and hydrofluoric acid maceration methods.

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Geologic setting

A twin tectonic belt known as the Shimanto Belt extends in the southern part of Japan along the Pacific Ocean from the southern Boso Peninsula southward to southern Kyushu (Fig. 1). The Shimanto Belt consists of the Northern Subbelt and Southern Subbelt which are disjoined by a distinct tectonic line. Further to the north, it is separated by another tectonic line called Butsuzo Tectonic line from the Sambosan Belt of largely Triassic and Jurassic age.

Geologic formations of the Shimanto Belt, collectively called the Shimanto Supergroup because of their over-all lithological similarities, consist largely of greatly indurated siltstone and sandstone which alternate in various thickness and proportions and which occasionally intercalate with sedimentary melange comprising, conglomerate, limestone, radiolarian chert, red shale, basaltic lava with a pillow structure and greenstone (IMAI, 1977; SUGISAKI *et al.*, 1979; SUZUKI and HADA, 1979; TAIRA *et al.*, this volume). Megafossils, except for trace fossils, have been found only rarely and this paucity of fossil data has long been a contributing factor to the difficulties encountered in establishing stratigraphic successions and interpreting geologic structures of the Supergroup. In general, however, the Northern Subbelt is considered to comprise largely rocks of Cretaceous age and the Southern Subbelt mainly strata of Paleogene. Again, although only spotty evidence existed until the present discovery of Early Miocene planktonic

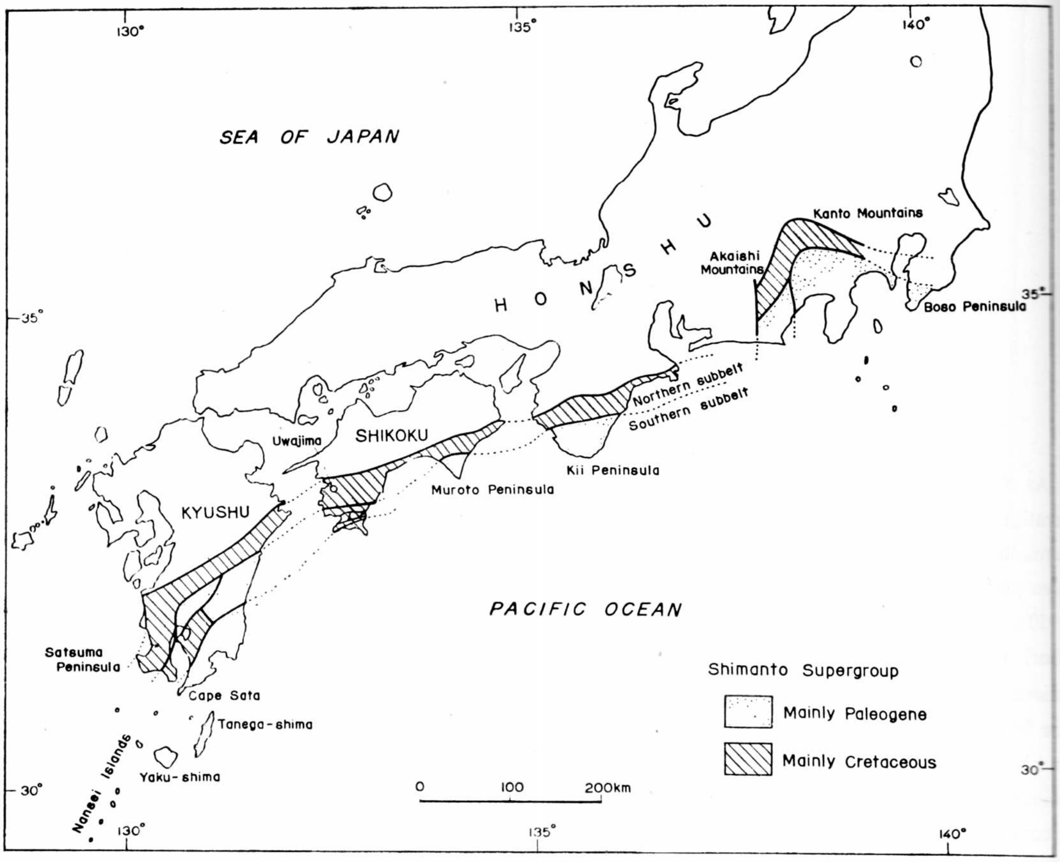

Fig. 1 Tectonic division and geographic distribution of the Shimanto Belt after uncovering all the post-orogenic Neogene and Quaternary rocks (after IMAI, 1977, reproduced with permission).

foraminifera, strata of the Southern Subbelt have been considered to become progressively younger oceanward and their geologic ages range from late Early Eocene to Early Miocene.

The Shimanto Supergroup has received much attention in the last few years because some geologists now consider these sediments to have been deposited in the trench or continental slope region and to be characterized by tectonic deformation associated with Mesozoic–Tertiary subduction along the eastern margin of the Japanese Island arc (see TAIRA, KATTO, TASHIRO and OKAMURA, this volume, for discussions and pertinent literature). If one subscribes to this tectonic interpretation for the formation of the Shimanto Supergroup, the present discovery of an Early Miocene planktonic foraminifera from the seemingly youngest part of the Supergroup suggests that the trench or near-trench type tectonic deformation associated with sudbuction along a deep-ocean trench system was acting in the southwestern part of Japan along the Pacific margin until as late as some 20 million years ago in the Early Miocene. As is well known, such an ocean trench is no longer located off the present coast of Shikoku, that is near the northern margin of the Shikoku Basin of the Philippine Sea.

Materials and methods

A rich and moderately well-preserved fauna of planktonic foraminifera that forms the basis for this study comes from an exposure of indurated

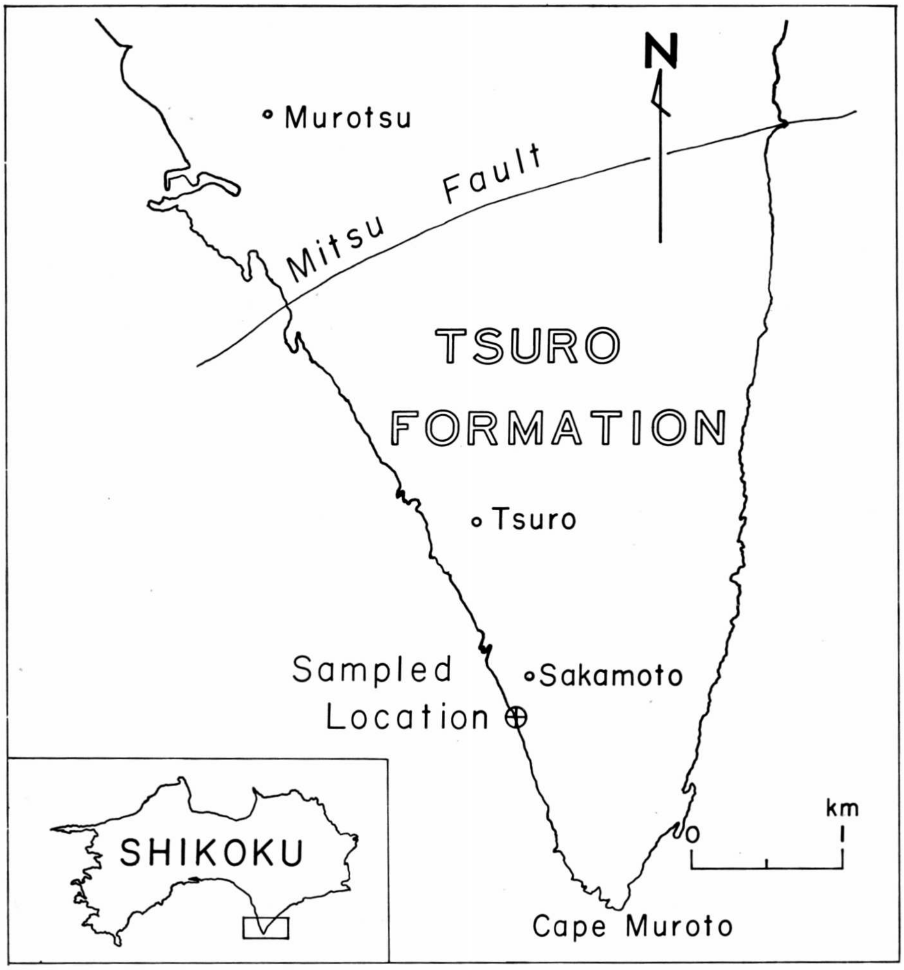

Fig. 2 Sketch map of the Muroto Peninsula showing the sample locality. The Tsuro Formation is in fault contact (Mitsu fault) with the remainder of the Southern Subbelt of the Shimanto Belt to the north.

calcareous siltstone on the coast in front of the village of Sakamoto, Murotomisaki Town, Kochi Prefecture. The locality lies about 1.4 km. north-northwest of Muroto Zaki (Cape Muroto) (Fig. 2). The sample was collected by Mr. Teruhisa ISHIKAWA, a senior student of Institute of Geology, Kochi University, during his field work for graduation thesis.

The foraminiferal fauna was discovered by Mr. ISHIKAWA when he treated the sample with a few percent solution of hydrofluoric acid for about 24 hours. The process was initially applied for intent of recovering radiolarian fossils. A much better extraction of foraminifera was made in T. SAITO's laboratory when the sample was first oven-heated to drive off interstitial water, covered with a mixture solution of 0.2 N NaTPB (Tetraphenylborate) and 1 N NaCl, let the solution completely soak into interstitial pore areas by placing the solution-immersed sample in a vacuum chamber and allowed the sample to disintegrate for several days (see HANKEN, 1979, for detailed description of NaTPB maceration method).

Geologic age

The conspicuous presence of such an age diagnostic species as *Globorotalia kugleri* BOLLI enables the placement of the present assemblage within the *Globigerinoides quadrilobatus primordius/Globorotalia (Turborotalia) kugleri* Concurrent-range zone or Zone N. 4 of BLOW (1969). The joint occurrence of several species belonging to the genus *Globigerinoides* also supports this age assignment, because the initial development of various species of *Globigerinoides* within the upper range of *G. kugleri* has been recognized as being one of the most reliable paleontological criteria for worldwide correlation (see LAMB and STAINFORTH, 1968 and HARDENBOL and BERGGREN, 1978, for pertinent literature and further discussion).

One apparent deviation in the ranges of planktonic foraminifera of the Shimanto is the joint occurrence of *Globigerinoides subquadratus* with the Zone N. 4 assemblage. CORDEY (1967) discussed in greater details the phylogenetic development of *Globigerinoides ruber* (D'ORBIGNY) in the Miocene-Recent interval and suggested that *G. ruber*'s homeomorphic *G. subquadratus* first appeared in the *Globigerinita stainforthi* Zone, equivalent of Zone N. 6. However, BLOW (1969) lowered the level of its first appearance into the middle of Zone N. 5. BRÖNNIMANN and RESIG (1971, p. 1311) further extended its range downward into Zone N. 4. Pending further elucidation of the level of the first appearance of *G. subquadratus* and at the same time placing a stronger emphasis on *G. kugleri*, the present assemblage is correlated with the topmost part of Zone N. 4. The trailing occurrence of such a characteristic Oligocene species as *Globigerina ouachitaensis* HOWE and WALLACE appears to support this older age assignment.

Systematic paleontology

At least 11 species and subspecies of planktonic foraminifera are recognized in the Shimanto assemblage, none of which are new. Besides the nine which are illustrated, two others, *Globigerinita incrusta* AKERS and *Globoquadrina altispira globosa* BOLLI, have been identified in the assemblage. The synonymic list is not intended to be complete ; only pertinent entries are included. All the illustrated specimens are deposited in the micropaleontology collection of Department of Earth Sciences, Faculty of Science, Yamagata University.

Family Globigerinidae CARPENTER, PARKER and JONES, 1862

Genus *Globigerina* D'ORBIGNY, 1826

Globigerina ouachitaensis HOWE and WALLACE

Plate 29, figures 2a-c, 3, 4

Globigerina ouachitaensis HOWE and WALLACE, 1932, p. 74, pl. 10, figs. 7a, b ; SAITO and BÉ, 1964, p. 703, text-fig. 2 (top right).

Globigerina ouachitaensis ouachitaensis HOWE and WALLACE. BLOW and BANNER, in EAMES *et al.*, 1962, p. 90, pl. 9, figs. D, H-K.

Remarks : -Although this is one of the characteristic species of the Gulf Coast Oligocene fauna (SAITO and BÉ, 1964), the present report appears to be the first one to describe this species from the western Pacific region. The species is distinguished by its small, high-spired trochoid test with four, subglobular, inflated chambers to each whorl. The aperture of the last chamber forms a distinct arch bordered by a narrow, thickened rim. BLOW (1969) described the stratigraphic range of this species to be from Zone P. 15 to N. 2. The present occurrence of this species in association with a typical *Globigerinoides*-assemblage indicates that it in fact ranges upward into Zone N. 4. Maximum diameters of figured specimens range from 194 μ to 223 μ.

Globigerina praebulloides BLOW, 1959

Plate 29, figure 5a-c

Globigerina praebulloides BLOW, 1959, pp. 180-181, pl. 8, figs. 47a-c ; pl. 9, fig. 48. —JENKINS, 1960, p. 352, pl. 2, figs. la-c. —SAITO, 1963, p. 187.

Globigerina praebulloides praebulloides BLOW. BLOW and BANNER, *in* EAMES *et al.*, 1962, p. 92, pl. 9, figs. O-Q. —SAITO and MAIYA, 1973, pp. 117-118, pl. 17, figs. la-c.

Remarks: —This species is distinguished by its elongate equatorial profile, the final chamber which increases rapidly in size and its low trochospiral coiling. The test surface is much finely pitted than those species of the genus *Globigerinoides*. Maximum diameter of figured specimen 228 μ.

Genus *Globigerinoides* CUSHMAN, 1927

Globigerinoides quadrilobatus (D'ORBIGNY) *primordius* BLOW and BANNER

Plate 28, figures 2a-c, 3a-c

Globigerinoides quadrilobatus primordius BLOW and BANNER, *in* EAMES *et al.*, 1962, p. 115, pl. 9, figs. Dd-Fr. -BANNER and BLOW, 1965, p. 110, fig. 10. —Blow, 1979, p. 325, pl. 20, figs. 1, 5, 6. —STAINFORTH *et al.*, 1975, pp. 305, 307, fig. 136.

Globigerinoides quadrilobatus (D'ORBIGNY) *primordius* BLOW and BANNER. BRÖNNIMANN and RESIG, 1971, p. 1310, pl. 13, figs. 6, 9.

Globigerinoides altiaperturus BOLLI. JENKINS, 1971, p. 174.

Remarks: -Two specimens, one having a missing last chamber and another with an umbilical bulla, are present in the present assemblage. In the bullate form, a single supplementary aperture can be seen on the spiral surface where the suture of the last chamber intersects with that of earlier chambers. In addition, these specimens have the coarse, well-reticulate test surface which is so characteristic of those species belonging to the genus *Globigerinoides*. Maximum diameters of figured specimens range from 236 μ to 280 μ.

Globigerinoides subquadratus BRÖNNIMANN, 1954

Plate 28, figure 5a-d

Globigerinoides subquadrata BRÖNNIMANN, 1954, pp. 680-681, pl. 1, figs. 5, 8a-c.

Globigerinoides rubra D'ORBIGNY. BOLLI, 1957, p. 113, pl. 25, figs. 12a-13b, text-fig. 21, no. 1.

Globigerinoides ruber subquadratus BRÖNNIMANN. SAITO, 1963, pp. 197-198, pl. 54, figs. 12a, b.

Globigerinoides subquadratus BRÖNNIMANN. CORDEY, 1967, p. 650, pl. 103, figs. 2-4. —BLOW, 1969, p. 326.

Globigerinoides subquadratus subquadratus BRÖNNIMANN. BRÖNNIMANN and RESIG, 1971, p. 1311, pl. 9, figs. 5, 6.

Remarks:- This homeomorphic species of *Globigerinoides ruber* (D'ORBIGNY) has long been confused with *G. ruber sense stricto* of Late Miocene to Recent age and this confusion is reflected on its taxonomy. CORDEY (1967) looked into the development of *G. ruber* within the post-Oligocene interval and suggested a phylogenetic as well as ontogenetic distinction between *G. ruber* and *G. subquadratus*. The single specimen identified here is crushed from the umbilical side and thus shows a somewhat broken umbilical side. Its fairly well-preserved spiral side, however, displays two distinct, round supplementary apertures and the specimen is identified with *G. subquadratus* in considering the three large chambers forming the last whorl and the position of primary as well as supplementary apertures relative to the last three chambers. Maximum diameter of figured specimen 260 μ.

Globigerinoides trilobus immaturus LEROY, 1939

Plate 28, figure la-c

Globigerinoides triloba immatura LEROY. BOLLI, 1957, p. 113, pl. 25, figs. 3a-4c.

Globigerinoides immaturus LEROY. SAITO, 1963, p. 196.

Remarks:- *Globigerinoides trilobus immaturus* differs from *G. trilobus trilobus* in having a final chamber that is smaller than all the earlier chambers combined. It is also distinguished from *Globigerinoides altiapertura* BOLLI (=*G. quadrilobatus altiapertura* of some authors) by its low-arched, crescent-shaped primary aperture. Maximum diameter of figured specimen 435 μ.

Globigerinoides trilobus trilobus (REUSS), 1850

Plate 28, figure 4a-c

Globigerinoides triloba triloba (REUSS). BOLLI, 1957, pp. 112–113, pl. 25, fig. 2a–c, text-fig. 21, no. 1.

Globigerinoides triloba (REUSS). BLOW, 1956, p. 62, text-fig. 1, nos. 1–3.

Globigerinoides trilobus (REUSS). SAITO, 1963, p. 199, pl. 54, fig. 15.

Remarks:– A well-preserved specimen with two distinct supplementary apertures on the dorsal face is present. The specimen shows characters somewhat transitional to *Globigerinoides sicanus* DE STEFANI in that its last chamber, as seen from the ventral side, appears to have the chamber size more or less similar to that of the penultimate and antepenultimate chambers combined. The coarse, well-reticulate test surface is typical of those species belonging to the genus *Globigerinoides*. Maximum diameter of figured specimen 369 μ.

Family Globorotaliidae CUSHMAN, 1927

Genus *Globorotaloides* BOLLI, 1957

Globorotaloides suteri BOLLI

Plate 29, figure 7a, b

Globorotaloides suteri BOLLI, 1957, p. 117, pl. 27, figs. 9–13. —BLOW and BANNER, *in* EAMES *et al.*, 1962, p. 122, pl. 13, figs. N–P. —JENKINS, 1971, pp. 189–190, pl. 22, figs. 646–648. —STAINFORTH *et al.*, 1975, pp. 322–323, fig. 146.

Remarks:– A small, rather poorly preserved specimen is identified with *G. suteri* because of its earlier, *Globorotalia*-like plano-convex coil followed by a low trochospire consisting of *Globigerina*-type inflated chambers. The umbilical bulla which characterizes the adult specimen of this species is not developed in the figured specimen probably owing to its immature growth stage. Maximum diameter of figured specimen 200 μ.

Genus *Globoquadrina* FINLAY, 1947

Globoquadrina dehiscens (CHAPMAN, PARR and COLLINS), 1934

Plate 29, figure 6

Globoquadrina dehiscens (CHAPMAN, PARR and COLLINS). BOLLI, 1957, p. 111, pl. 24, figs. 3–4. —SAITO, 1963, p. 191, pl. 55, fig. 9a–c. —JENKINS, 1971, pp. 165–166, pl. 20, figs. 595–597.

Globoquadrina dehiscens dehiscens (CHAPMAN, PARR and COLLINS). BLOW, 1969, p. 341, pl. 29, fig. 1.

Globoquadrina dehiscens Group. STAINFORTH *et al.*, 1975, pp. 266–267, fig. 113.

Remarks:– A relatively large specimen with a complete spiral side but broken umbilical side is present in the present fauna. Its flattened spiral side having a subquadrate peripheral outline gives a positive identification with *G. dehiscens*. Maximum diameter of figured specimen 490 μ.

Genus *Globorotalia* CUSHMAN, 1927

Globorotalia kugleri BOLLI, 1957

Plate 29, figure 1a–c

Globorotalia kugleri BOLLI, 1957, p. 118, pl. 28, figs. 5, 6. —STAINFORTH *et al.*, 1975, p. 289, fig. 126.

Globorotalia (*Turborotalia*) *kugleri* BOLLI. BLOW, 1969, pp. 350–351, 390–391, pl. 10, figs. 1–3; pl. 38, figs. 1–4. —BRÖNNIMANN and RESIG, 1971, pp. 1313–1314, pl. 39, figs. 1, 3–5.

Remarks:– A heavily calcite-encrusted specimen of this species is found in the present assemblage. The specimen is more closely comparable with the type specimens of *Globorotalia mendacis* BLOW than the typical *G. kugleri* in that the present specimen has less numerous chambers visible on the ventral face, its almost radial dorsal suture and a more nearly closed umbilical opening. The present specimen has about six chambers in the last whorl as seen from the spiral side and a distinctly plano-convex axial profile with a somewhat subacute peripheral margin. It can be distinguished from *Globorotalia peripheroronda* BLOW and BANNER on account of more gradual growth rates of chambers within the last two whorls of *G. kugleri*. Maximum diameter of figured specimen 170 μ.

Acknowledgment

The author wishes to thank Dr. Asahiko TAIRA, Associate Professor of Institute of Geology, Kochi University, who kindly arranged the use of the foraminiferous sample for the present study and who also has kindly led a field trip through the Southern Subbelt of the Shimanto Belt for the sake of the present author. Sincere thanks are extended to Mr. Teruhisa ISHIKAWA, a senior student of Koch University, who collected the sample. The laboratory work was supported by Ministry of Education (the Goverment of Japan) Grant-in-Aid for Scientific Research, no. 442013.

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An Early Miocene (Aquitanian) planktonic foraminiferal fauna from the Tsuro Formation, the youngest part of the Shimanto Supergroup, Shikoku, Japan

Tsunemasa SAITO*

Abstract A greatly indurated calcareous siltstone collected from the Tsuro Formation, the youngest, land-exposed part of the Shimanto Supergroup has yielded a fairly well-preserved planktonic foraminifera of Early Miocene (Aquitanian) age. At least 11 species and subspecies are identified, none of which are new. The joint occurrence of *Globorotalia kugleri* BOLLI and such species of the genus *Globigerinoides* as *G. trilobus* (REUSS) and *G. quadrilobatus primordius* BLOW and BANNER enables the zonal assignment of the fauna to the Zone N. 4 of BLOW (1969).

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Explanation of plate 28

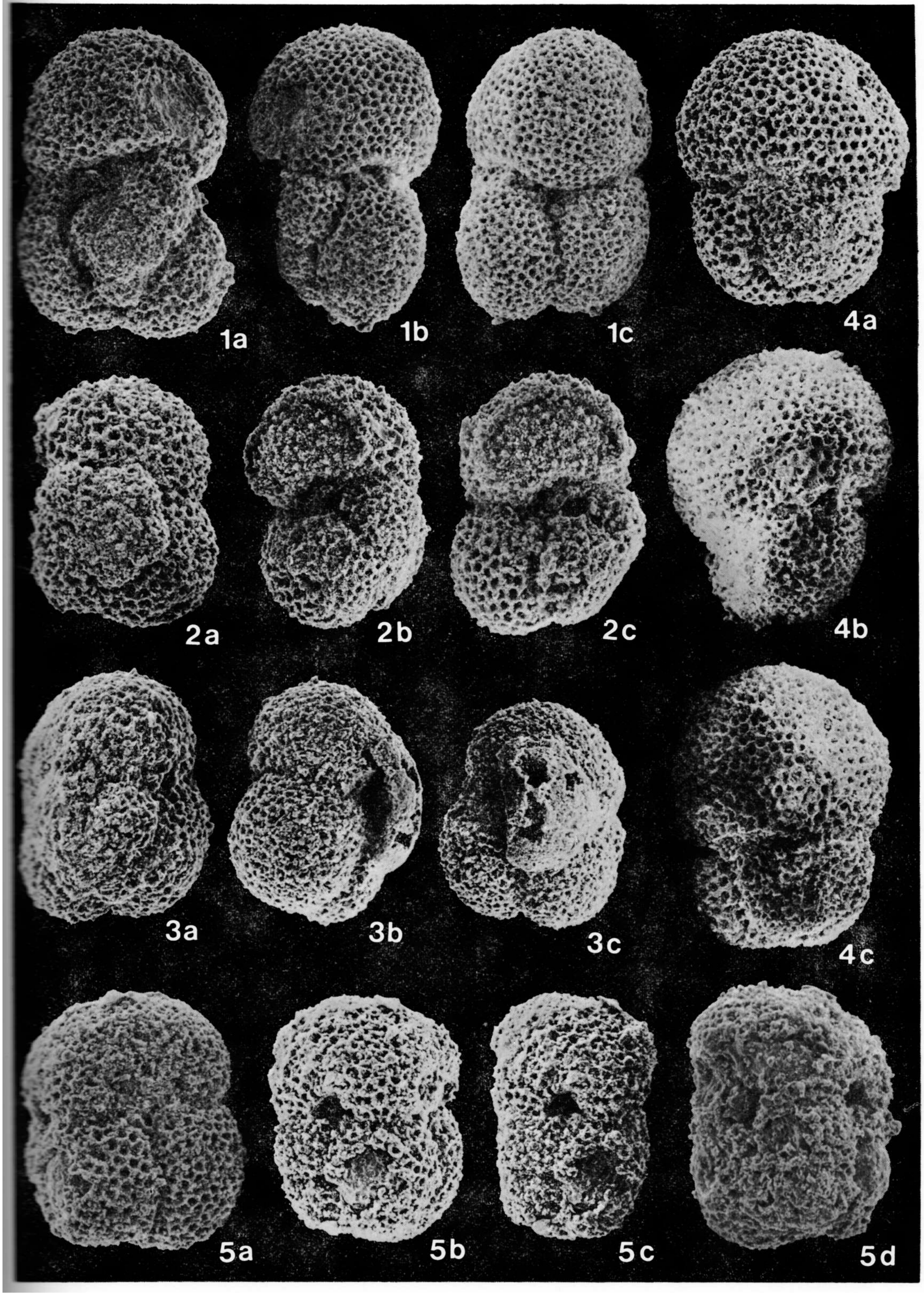
Figure 1. *Globigerinoides trilobus immaturus* LEROY.
a, spiral side. b, side view. c, umbilical side. ×115.

2. *Globigerinoides quadrilobatus primordius* BLOW and BANNER.
Specimen with a missing last chamber. a, spiral side. b, side view. c, umbilical side. ×152.

3. *Globigerinoides quadrilobatus primordius* BLOW and BANNER.
Specimen with an umbilical bulla. a, spiral side. b, side view. c, umbilical view showing a bulla. ×170.

4. *Globigerinoides trilobus trilobus* (REUSS).
a, spiral side. b, side view. c, oblique umbilical view. ×118.

5. *Globigerinoides subquadratus* BRÖNNIMANN.
Specimen with a somewhat broken umbilical side. a, oblique spiral side view. b, side view. c, another side view. d, oblique umbilical side view. ×152.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1c
4a
2a
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2c
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3a
3b
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4c
5a
5b
5c
5d

Explanation of plate 29

Figure 1. *Globorotalia kugleri* BOLLI.
a, spiral side. b, side view. c, umbilical side. ×258.

2. *Globigerina ouachitaensis* HOWE and WALLACE.
a, oblique spiral view. b, side view. c, umbilical side. ×195.

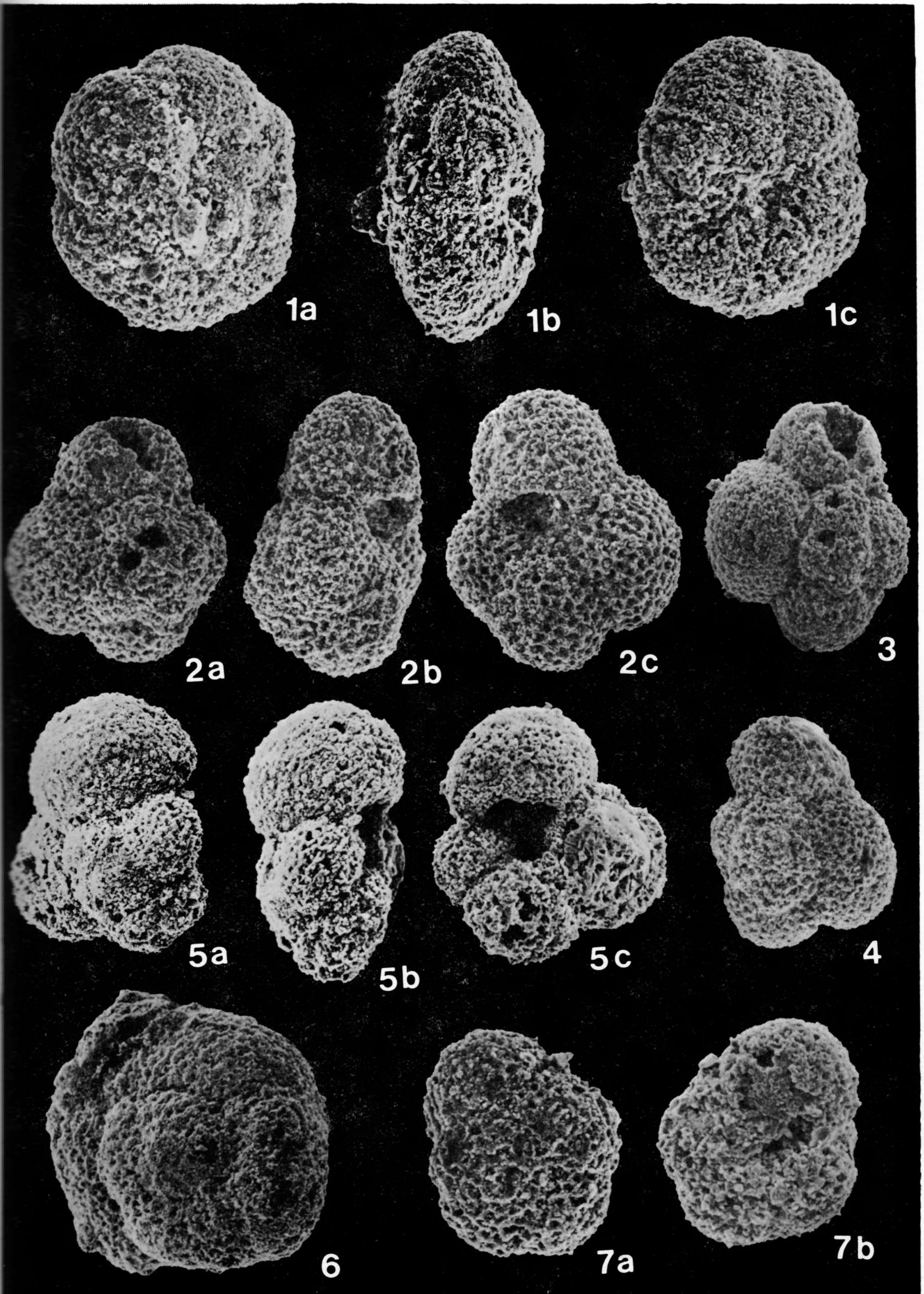
3. *Globigerina ouachitaensis* HOWE and WALLACE.
Spiral side view. ×198.

4. *Globigerina ouachitaensis* HOWE and WALLACE.
Oblique spiral side view. ×172.

5. *Globigerina praebulloides* BLOW.
a, spiral side. b, side view. c, umbilical side. ×175.

6. *Globoquadrina dehiscens* (CHAPMAN, PARR and COLLINS).
Specimen with a broken umbilical side. Spiral side view. ×98.

7. *Globorotaloides suteri* BOLLI.
a, spiral side. b, umbilical side. ×185.


1a
1b
1c
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2b
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7a
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