

ON THE TAXONOMIC IDENTITY OF THE PLANKTONIC FORAMINIFERAL SPECIES *GLOBOROTALIA BARISANENSIS* LE ROY, 1939

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ABSTRACT

Examination of the holotype of *Globorotalia barisanensis* Le Roy, 1939, has revealed that this species from the Middle Miocene of central Sumatra is non-keeled, contradicting the synonymizing of *G. barisanensis* with *Globorotalia fohsi*. Because the type sample is untraceable, we examined the available type specimens (holotype and eight paratypes), notes and data presented by previous researchers, and material from the near-topotype locality of *Paragloborotalia siakensis*, to clarify Le Roy's concept of *G. barisanensis*. Our investigation has revealed that the Middle Miocene of central Sumatra contains two different groups of globorotaliids: the *Globorotalia menardii* group and the *G. fohsi* group, and that *G. barisanensis* belongs to the latter.

The paratypes examined belong to *Globorotalia peripheroacuta* and to forms transitional between *G. peripheroacuta* and *Globorotalia praefohsi*. The holotype, as described by Le Roy, is included in *G. peripheroacuta* as well, despite the observation that it differs from the paratypes in the abnormally inflated final chamber. In retrospect, the specimen selected as the holotype was an unfortunate choice as it has long been misinterpreted and used to denominate the earliest representatives of the *G. fohsi* group (viz. *G. fohsi barisanensis*) until *G. barisanensis* was reinterpreted as a junior synonym of *G. fohsi* based on a flawed redrawing of a fully keeled holotype of *G. barisanensis*. We conclude that Le Roy's concept of *G. barisanensis* was broad and may have included *G. fohsi* and *Globorotalia peripheroronda* as well. Remarkably, after 67 years of misinterpretation since Bolli (1950), *G. barisanensis* appears to be a valid name and a senior synonym of *G. peripheroacuta*. However, we recommend that it will be more practical to conserve the latter name, which is well established in the literature.

INTRODUCTION

Globorotalia barisanensis Le Roy, 1939 was described from the Middle Miocene of the Tapung Kiri River area in central Sumatra and became a label for the earliest representatives of the *Globorotalia fohsi* lineage in the formative years of Neogene planktonic foraminiferal biostratigraphy (Bolli, 1950, 1957; Akers, 1955; Blow, 1959).

In a review of *G. barisanensis* and its taxonomic relation to *Globorotalia fohsi* Cushman & Ellisor, 1939, Blow & Banner (1966) reported that paratypes of *G. barisanensis* (deposited in the U.S. National Museum, Washington, D. C.) and ideo-

types (deposited at the Colorado School of Mines, Golden, Colorado, and specimens provided by Le Roy) are partly, and in the case of one paratype, even fully keeled (depicted by them on pl. 1, fig. 6). Upon request, a new drawing of the holotype was provided by H.M.S. Hartono of the Geological Survey of Indonesia (now Geological Research and Development Centre [GRDC] in Bandung) showing a fully keeled specimen as well (see pl. 1, fig. 7 in Blow & Banner, 1966). These new findings, in conjunction with their observation of (partly) keeled representatives of the *G. fohsi* group in the upper Kassikan section of central Sumatra from which Le Roy (1952) reported *G. barisanensis*, persuaded Blow & Banner (1966) to synonymize the holotypes of *G. barisanensis* and *G. fohsi*. Because of a slightly earlier publication date, *G. fohsi* (published in March 1939) would have priority over *G. barisanensis* (published in November 1939). Blow & Banner (1966) further concluded that Le Roy's (1939) concept of *G. barisanensis* must have been broad because seven of eight paratypes were partly keeled, consistent with the characteristics of their new species *Globorotalia praefohsi* (one of these paratypes is illustrated in Blow & Banner, 1966, pl. 1, fig. 3). In retrospect, the synonymizing of the *G. barisanensis* holotype with *G. fohsi* is amazing because Le Roy (1939) clearly described and illustrated a non-keeled holotype.

In accepting Blow and Banner's (1966) interpretation of *G. barisanensis*, Bolli (1967) implicitly recognized that the name of his subspecies *G. fohsi barisanensis*, as used for non-keeled representatives of the *G. fohsi* lineage, was invalid and appropriately renamed by Blow & Banner (1966) after their new species *Globorotalia peripheroronda*. Bolli (1967), however, criticized the synonymizing of the holotypes of *G. barisanensis* and *G. fohsi* on the basis of a difference in spiral-view chamber outline between Hartono's drawing of the holotype of *G. barisanensis* and the Blow & Banner (1966) redrawing of the holotype of *G. fohsi*, and concluded that *G. barisanensis* was related to the *Globorotalia menardii* group.

Since then no one has examined the taxonomic identity of *G. barisanensis* and its current status is that of a junior synonym of *G. fohsi* since Banner & Blow (1966), while Bolli's (1967) assertion that *G. barisanensis* belongs to the *G. menardii* group has never been challenged.

HOLOTYPE AND SPECIES NAME

In 1939, Leslie Walter Le Roy worked for Caltex in Medan and deposited the holotype of *Globorotalia barisanensis* in the paleontological collection of the Geological Museum of the Geological Survey of Indonesia (now GRDC) in Bandung. The holotype slide (Appendix 1) was discovered in 1960 on the GRDC premises (Hartono, 1960).

Le Roy (1939) selected the holotype from auger-hole sample Ho-862A in the drainage basin of the Tapung Kiri River on central Sumatra. The type stratum belongs to

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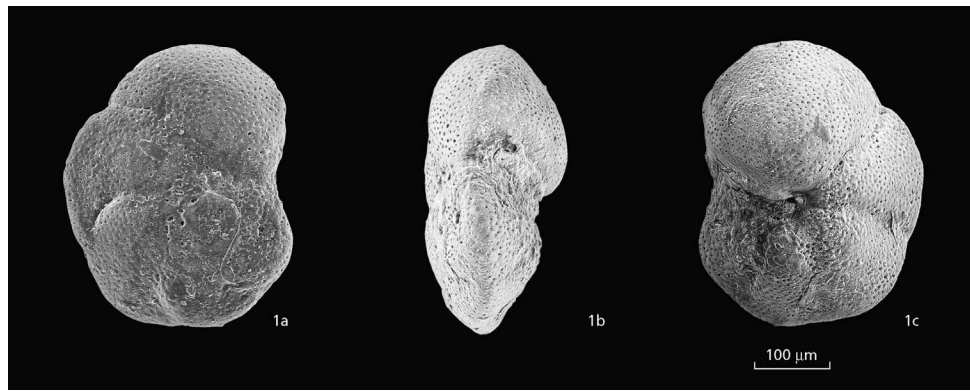


FIGURE 1. SEM images of the holotype of *Globorotalia barisanensis* LeRoy, 1939. The specimen is shown in spiral (a), axial (b) and umbilical (c) view.

the Transitional Zone (=Lower Palembang Formation in Le Roy, 1944). The species name is derived from the Barisan Mountains to the West and Southwest of the Tapung Kiri area, but in 1944 and again in 1952, Le Roy described the species under the name *G. barissanensis* (with double s) and in 1948 as *G. barrisanensis* (with double r). Also the original label on the holotype slide was with the double “s” but was corrected later (see Appendix 1).

OTHER TYPES SELECTED BY LE ROY

In the opening phase of World War II, Le Roy moved to Golden, Colorado (USA), assuming a position as instructor in Geology at the Colorado School of Mines. Amongst the material Le Roy took with him would have been the type sample of *G. barisanensis* because in ~1941 he sent eight specimens of *G. barisanensis* from sample Ho-862A to J. A Cushman, who deposited them in the Cushman Collection at the U.S. National Museum (USNM number 38164), see Blow & Banner (1966, p. 292). Because the specimens had been selected by Le Roy from the type sample, these eight specimens should be considered as paratypes. Until now, only one of these paratypes has been figured (pl. 1, fig. 3 in Blow & Banner, 1966, under the name *Globorotalia praefohsi*).

In 1944, Le Roy described and figured two ideotypes derived from two different sample localities in Sumatra. The provenance of samples could not be given due to loss of data during the Japanese invasion of the then Netherlands East Indies, but they were probably from the Lower Palembang Fm. Blow & Banner (1966) assigned one of these illustrated ideotypes (pl. 2, figs. 43–45) to *G. praefohsi* and the other (pl. 6, figs. 34–36) to *Globorotalia praemenardii* Cushman & Stainforth, 1945. The naming of the latter seems unfortunate because Le Roy’s (1944) illustration suggests that *Globorotalia peripheroacuta* Blow & Banner, 1966 would have been a more appropriate assignment.

IMAGES OF THE HOLOTYPE AND PARATYPES

The holotypes of *G. barisanensis* and *Globigerina siakensis* Le Roy, 1939 were brought to Utrecht in 2004 by Dr. Fauzie Hasibuan from the GRDC in Bandung. Both were photographed in a non-destructive way using the Fei Quanta

Feg Low Vacuum Scanning Electron Microscope (LVSEM) in Eindhoven (August 2004). The SEM images of *Globigerina siakensis* were published by Zachariasse & Sudijono (2012) as *Paragloborotalia siakensis*. However, those of *G. barisanensis* have not previously been published.

The holotype of *G. barisanensis* (Fig. 1) shows five chambers with depressed spiral-view sutures on the final whorl and a sub-rounded axial periphery. The aperture is covered by a distinct lip. The spiral side in axial view is flatter than the umbilical side.

Images of the eight paratypes (Fig. 2) were obtained using a High Vacuum SEM HVSEM) with backscatter electron (BSE) detector. Of these paratypes, seven have six chambers in the final whorl and one (Fig. 2.1) has five. The axial periphery of early chambers varies from sub-rounded (Fig. 2.1, 7) to sharply acute (Fig. 2.3), and in later chambers from acute (Fig. 2.1, 2, 7) to faintly keeled (Fig. 2.3, 4, 6). Final chambers are broken (off) in paratypes 5 and 8 (Fig. 2). Spiral side sutures are partly limbate (Fig. 2.4, 5 and perhaps 8) and apertures are covered by lips.

The note in Blow & Banner (1966) that seven of eight paratypes are partially and one even fully keeled is clearly exaggerated. The fully keeled paratype (Blow & Banner, 1966: pl. 1, fig. 6) is probably paratype 2 in Figure 2, but this specimen is not even partly keeled. Another paratype (Blow & Banner, 1966: pl. 1, fig. 3) is said to have keeled final chamber(s) but our SEM image of this specimen (Fig. 2.1) shows an acute axial periphery.

GLOBOROTALIA BARISANENSIS AND OTHER GLOBOROTALIIDS FROM THE MIDDLE MIOCENE OF THE CENTRAL SUMATRA BASIN

The geological stratum of the *Globorotalia barisanensis* type specimens belongs to the Transitional Zone (Le Roy, 1939), renamed Lower Palembang Formation (Le Roy, 1944), and in modern terminology belongs to the deep-marine, lower part of the Middle Miocene Petani Formation (Clarke et al., 1982). An overview of the subdivision of the Cenozoic succession in the central Sumatra Basin since Le Roy (1939) is given in Appendix 2.

In 1948 and 1952, Le Roy reported on the first occurrence of *Orbulina* in the central Sumatra Basin using 120

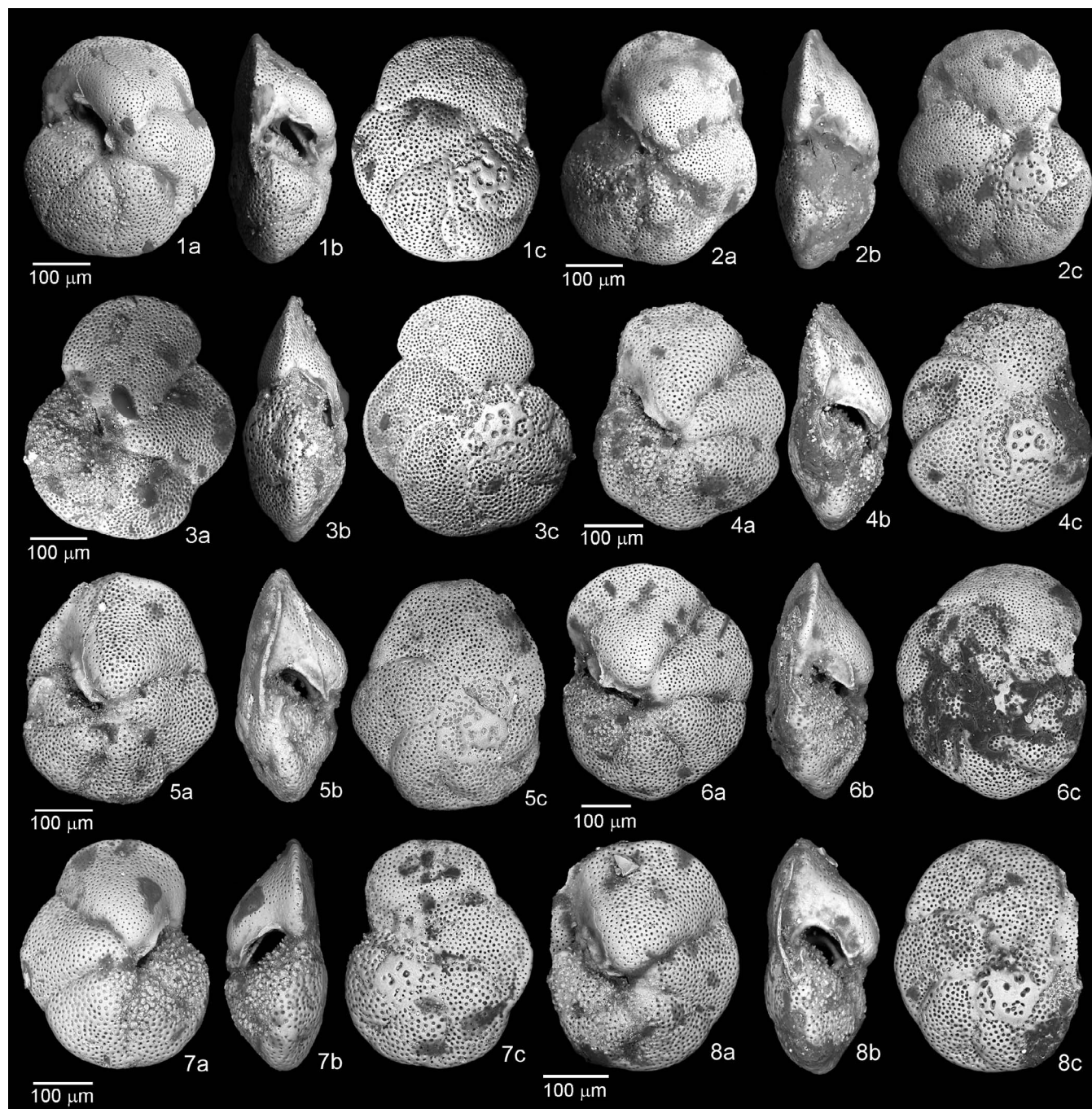


FIGURE 2. SEM images of the eight paratypes of *Globorotalia barisanensis*. Each specimen is shown in umbilical (a), axial (b) and spiral (c) view.

samples from the Kassikan traverse: a composite section assembled from outcrops, auger borings, and drill holes through ~760 m marine sediments of the Telisa and Lower Palembang Fms (see Appendix 2). Both units are clay dominated with the greenish grey and more turbiditic Lower Palembang Fm conformably overlying the dark (brownish) grey Telisa Fm (Le Roy, 1952). The foraminiferal distribution chart for the Kassikan section (Le Roy, 1952, fig. 3) shows that *G. barisanensis* first occurs at the Telisa/Lower Palembang boundary, well above the first occurrence of *Orbulina* in the uppermost part of the Telisa Fm. No other globorotaliid

species are recorded in his distribution chart. In the text Le Roy (1952) noted that *Globorotalia canariensis* (d'Orbigny, 1839) characterized the fauna in the uppermost Telisa Fm but he gave no description or figure of this species. His concept of *G. canariensis* is illustrated by only a single specimen (labelled *G. aff. canariensis* in Le Roy, 1939: figs. 14-16, pl. 4) and a reference to a species under the same name in Cushman (1929: pl. 14, fig. 14). Neither Le Roy nor Cushman described this species, but Le Roy's illustration clearly shows a biconvex, keeled specimen having ~4.5 chambers in the final whorl.

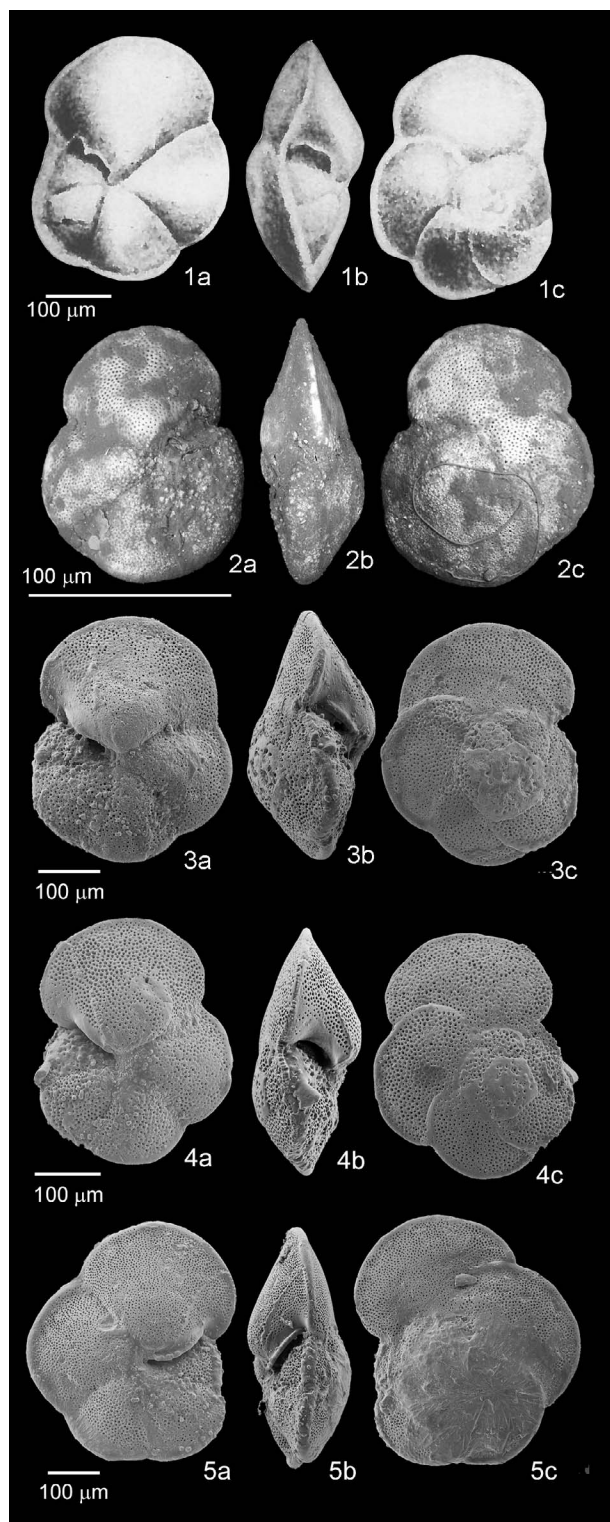


FIGURE 3. SEM images of *Globorotalia praemenardii*. 1 reproduction of the re-drawing of Le Roy's specimen of *Globorotalia* aff. *canariensis* (Le Roy, 1939: pl. 4, figs 14–16) by the staff of the GRDC in Bandung. This reproduction was attached to an unpublished manuscript entitled "On the holotype of *Globigerina siakensis* Le Roy, 1939" by Herman Soediono (1974) and made available to WJZ. 2 Holotype of *Globorotalia praemenardii* Cushman & Stainforth, 1945. 3–5 *Globorotalia praemenardii* from the near-type locality of *Paragloborotalia siakensis* [auger core TPKR III, depth 315–325 cm]. Each specimen is shown in umbilical (a), axial (b) and spiral (c) view.

Le Roy's figured specimen of *G. aff. canariensis* is from the type sample of *Paragloborotalia siakensis* (Le Roy, 1939) and was deposited in the paleontological collection of the Geological Museum of the Geological Survey of Indonesia (now GRDC) in Bandung as slide PS 1080. A redrawing of the specimen by the staff of the GRDC in the early seventies (reproduced here in Fig. 3.1) shows a keeled menardine globorotaliid very similar to the original drawing and SEM photograph of the holotype of *Globorotalia praemenardii* (Fig. 3.2).

The Kassikan section was also examined by Blow & Banner (1966) using samples from British Petroleum (BP), as well as some of the same samples studied by Le Roy (it is unclear whether Le Roy provided aliquots of some of his samples or that some of the BP samples are from Le Roy's sample levels). Blow & Banner (1966) report common occurrences of *G. praemenardii archeomenardii* Bolli, 1957 from the uppermost Telisa Fm (also mentioning *G. praemenardii praemenardii* in their text-figure 3), and conclude that such specimens were recorded by Le Roy under the name *G. canariensis*. They further mention that these menardine globorotaliids in the uppermost Telisa Fm occur together with *Globorotalia peripheroronda* and *Orbulina*. Samples from the Lower Palembang Fm were found to contain acute to fully keeled globorotaliids, which Blow & Banner interpreted as belonging to evolutionarily more advanced forms of *G. peripheroronda*. No mention of menardine globorotaliids was made, despite the fact that Le Roy (1939) reported *G. aff. canariensis* (= *G. praemenardii*, see above).

Figure 4 shows the names and distribution of globorotaliids in the uppermost Telisa and Lower Palembang Fms of the Kassikan section from Le Roy (1952) and Blow & Banner (1966).

DISCUSSION

From the summary provided, we conclude that there are representatives of two different groups of globorotaliids in the Middle Miocene of central Sumatra: the *Globorotalia menardii* group and the *Globorotalia fohsi* group. To which of these groups and species *Globorotalia barisanensis* belongs is central in this study.

The easiest way to solve this conundrum would be to examine the type sample of *G. barisanensis*. This sample was expected to be present in the collections of the Geological Museum of the Colorado School of Mines (the paratypes were sent by Le Roy to J.A. Cushman while being employed by the CSM) but could not be found (Dennis Gertenbach, written communication, September 2016).

We therefore re-examined samples from auger core TPKR III, which serves as the primary near-type locality of *Paragloborotalia siakensis* (Zachariasse & Sudijono, 2012). This locality is in the same formation (Lower Palembang Fm) and in the same area (Tapung Kiri River Basin) as the type locality of *G. barisanensis* and therefore TPKR III may offer a clue as to which of the two groups of globorotaliids the species in question belongs.

The 5 m long auger core TPKR III is decalcified in the upper 2 m due to intense tropical weathering, but the lower 3 m preserves deep-marine clayey sediments belonging to

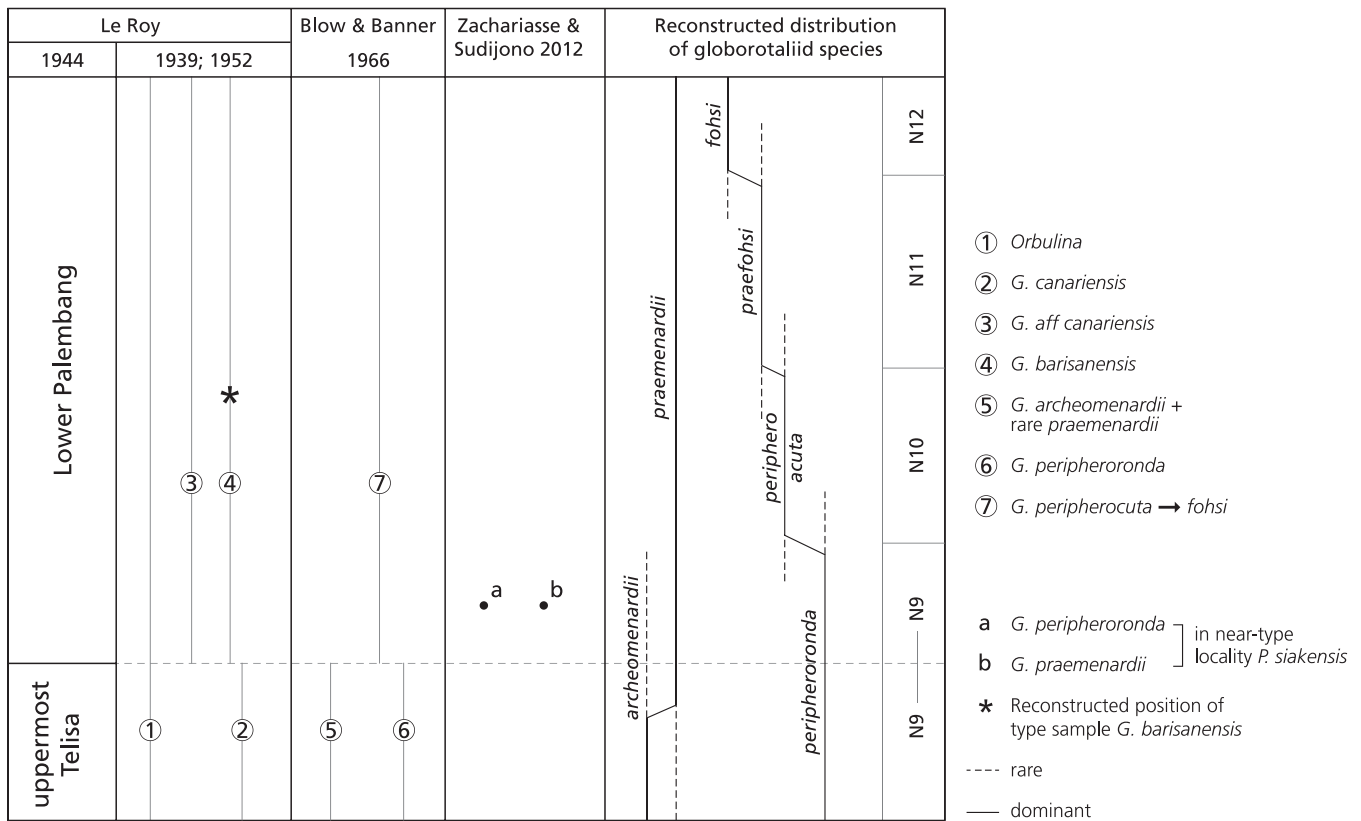


FIGURE 4. Globorotaliids in the uppermost Telisa and Lower Palembang Formations of the Kassikan section on central Sumatra and in the near-type locality of *Paragloborotalia siakensis* after Le Roy (1939; 1952), Blow & Banner (1966), Zachariasse & Sudijono (2012), and this study.

the Lower Palembang Fm (presumably the basal part as is inferred from plotting the locality on the geological map of Clarke et al., 2008). The planktonic foraminiferal fauna is characteristic of biozone N9 (Banner & Blow, 1965) or M6 (Berggren et al., 1995), with an age range of 15.10–14.24 Ma (Lourens et al., 2004; Wade et al., 2011) and includes *G. praemenardii* and *G. peripheroronda* (Zachariasse & Sudijono, 2012).

Globorotalia praemenardii is randomly coiled, clearly keeled and biconvex with 4.5–5 elongate chambers in the final whorl (Figs. 3.3–5). The near-type locality of *Paragloborotalia siakensis* thus contains the same menardine globorotaliid species as the one reported by Le Roy (1939) under the name *G. aff. canariensis* from the type sample of *P. siakensis* (Fig. 3.1). Particularly, Figure 3.3 is almost a copy of Le Roy's re-drawing of *G. aff. canariensis* (Fig. 3.1). As we have confirmed that Le Roy's *G. aff. canariensis* is synonymous with *G. praemenardii*, it is obvious that Le Roy's *G. barisanensis* belongs to the *G. fohsi* group.

There remains the question as to which of the species of the *G. fohsi* group *G. barisanensis* should be allocated. The clear and unambiguous answer to this comes from the paratypes. Their acute to weakly keeled last chamber (Fig. 2) sets them apart from the bluntly rounded axial periphery described by Blow & Banner (1966) for *G. peripheroronda*. The SEM images of the holotype of *G. peripheroronda* indeed show a fairly compact and nearly planoconvex specimen with a (sub) rounded axial periphery throughout (Fig. 5.1). Three of the paratypes match the defining characteristics of *Globorotalia*

peripheroacuta Blow & Banner, 1966, based upon acute final chambers (compare Fig. 2.1, 2 and 7 to Fig. 5.2). The faintly keeled last chamber in three other paratypes (Fig. 2.3, 4, and 6) suggest that they are transitional between *G. peripheroacuta* and *G. praefohsi*. The best example of a keeled final chamber is shown by Figure 2.6, but even this specimen is clearly less advanced than the holotype of *G. praefohsi*, which exhibits seven more arcuate chambers in spiral view and clearly limbate sutures between the last three chambers (compare Fig. 2.6 to Fig. 5.3). Although the final normal chamber in two paratypes (Fig. 2.5, 8) is missing, these types clearly fall in one of the two above mentioned taxonomic categories.

The holotype of *G. barisanensis* differs from all the paratypes in possessing a final chamber with an umbilical shoulder and a sub-rounded axial periphery (Fig. 1). This is also exemplified in the morphometric comparison between the type specimens of *G. barisanensis* and the species of the *G. fohsi* group (Fig. 6 and Appendix 3). The plot shows that the *G. barisanensis* holotype is indistinguishable from the paratypes in spiral view (Fig. 6A), but is distinct in edge view (Fig. 6B). The holotype of *G. barisanensis* appears to represent an evolutionarily less advanced form than the paratypes and the question arises to what degree the holotype differs from *G. peripheroronda*. The holotype of the latter species (Fig. 5.1) has a more convex umbilical side and more rounded axial periphery, but could there be morphological overlap between the *G. barisanensis* holotype and *G. peripheroronda* from the near-type locality of *Paragloborotalia siakensis*?

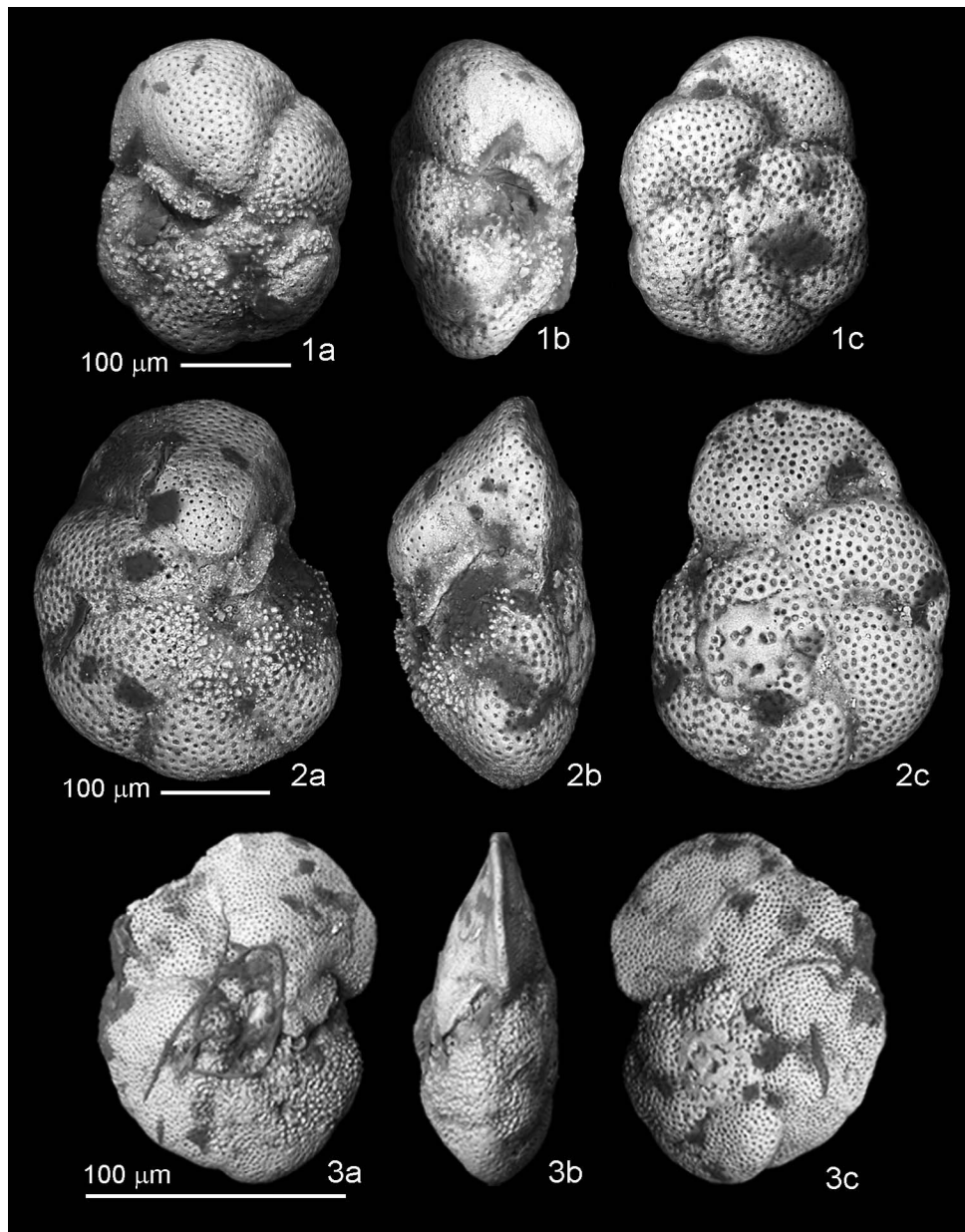


FIGURE 5. SEM images of USNM holotypes. **1** *Globorotalia peripheroronda* Blow & Banner, 1966, **2** *Globorotalia peripheroacuta* Blow & Banner, 1966, **3** *Globorotalia praefohsi* Blow & Banner, 1966. Each specimen is shown in umbilical (a), axial (b) and spiral (c) view.

Figure 7 depicts a spectrum of *G. peripheroronda* from TPKR III (the near-type locality of *P. siakensis*). The species is randomly coiled with 5–6 chambers in the final whorl and an axial periphery that is rounded in the early and (sub) rounded in the last chamber. None of the specimens approach the acute axial periphery of the *G. barisanensis* paratypes indicating that the type sample of *G. barisanensis* is from a younger stratigraphic level in the Lower Palembang Fm than the near-type samples of *P. siakensis* (see Fig. 4). Some specimens, however, show some resemblance to the holotype of *G. barisanensis*: for example the axial periphery in Figure 7.2, 3, 8, and 12 is somewhat sub-rounded in the last chamber, but early chambers are clearly more rounded than

in the *G. barisanensis* holotype. Overall, the *G. barisanensis* holotype does not truly fit in the variation displayed by *G. peripheroronda* from TPKR III.

CONCLUSIONS

1. *Globorotalia barisanensis*, as typified by the paratypes, was the name erected by Le Roy (1939) for globorotaliid forms that since 1966 have been known under the name *G. peripheroacuta*, as well as forms transitional between *G. peripheroacuta* and *G. praefohsi*.
2. The holotype of *G. barisanensis* exhibits a less advanced morphology than the paratypes because the final

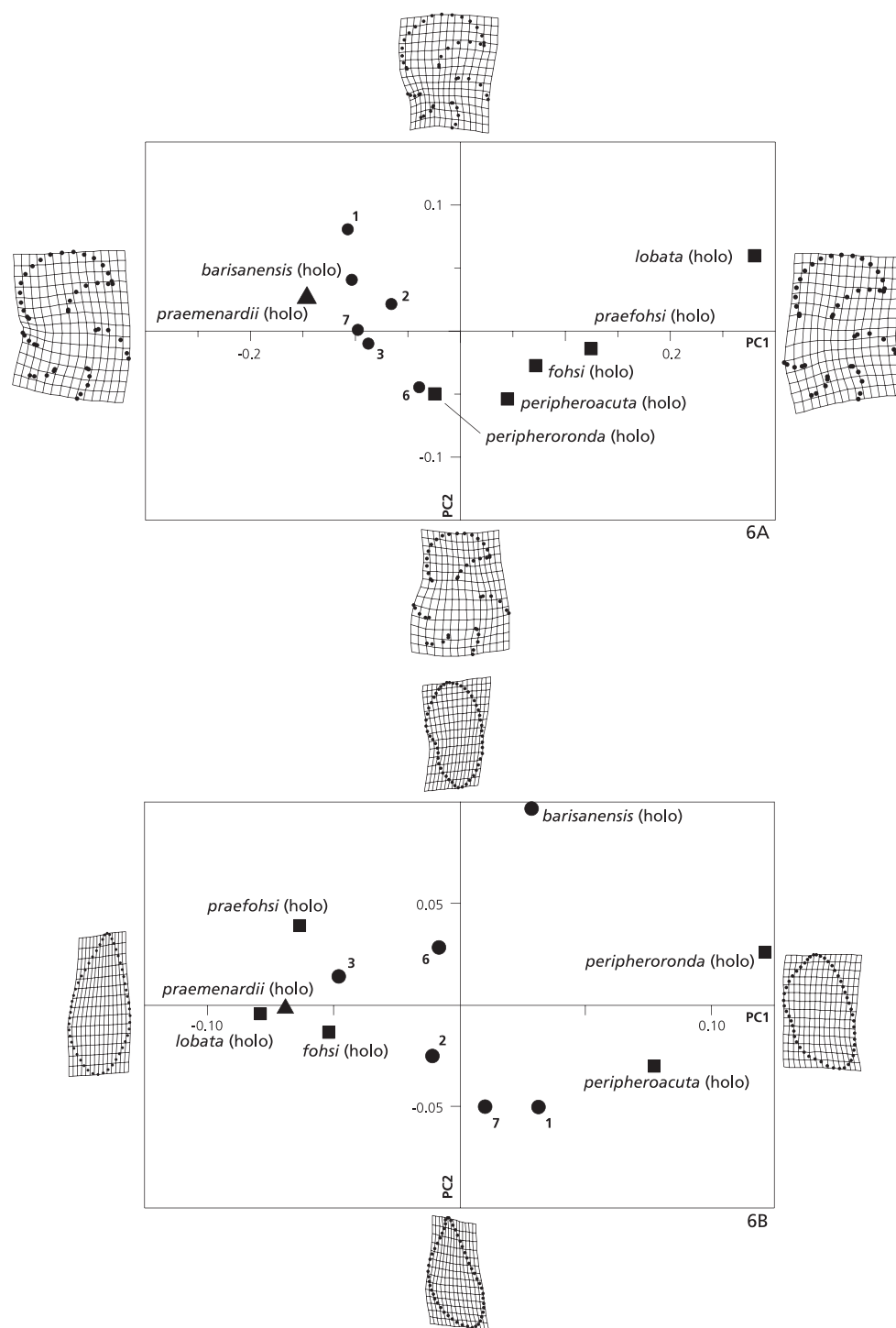


FIGURE 6. Plot of first two principal components of a landmark-based morphometric analysis on types of *Globorotalia barisanensis* and *Globorotalia fohsi* group. **6A** spiral view, **6B** axial view (see Appendix 3 for summary of method).

chamber has an umbilical shoulder and sub-rounded axial periphery. In these aspects the holotype is morphologically close to *G. peripheroronda*, but not in the acute periphery of the early chambers (compare Figs. 1 and 2). Le Roy (1939) made an unfortunate choice in selecting as his holotype a specimen with an abnormally inflated final chamber in an assemblage dom-

inated by *G. peripheroacuta* and mixed with forms that are transitional between *G. peripheroacuta* and *G. praefohsi*.

3. Le Roy's (1939) concept of *G. barisanensis* was broad, as illustrated by his type specimens that include forms that since 1966 have been known as *G. peripheroacuta* and forms transitional between *G. peripheroacuta* and

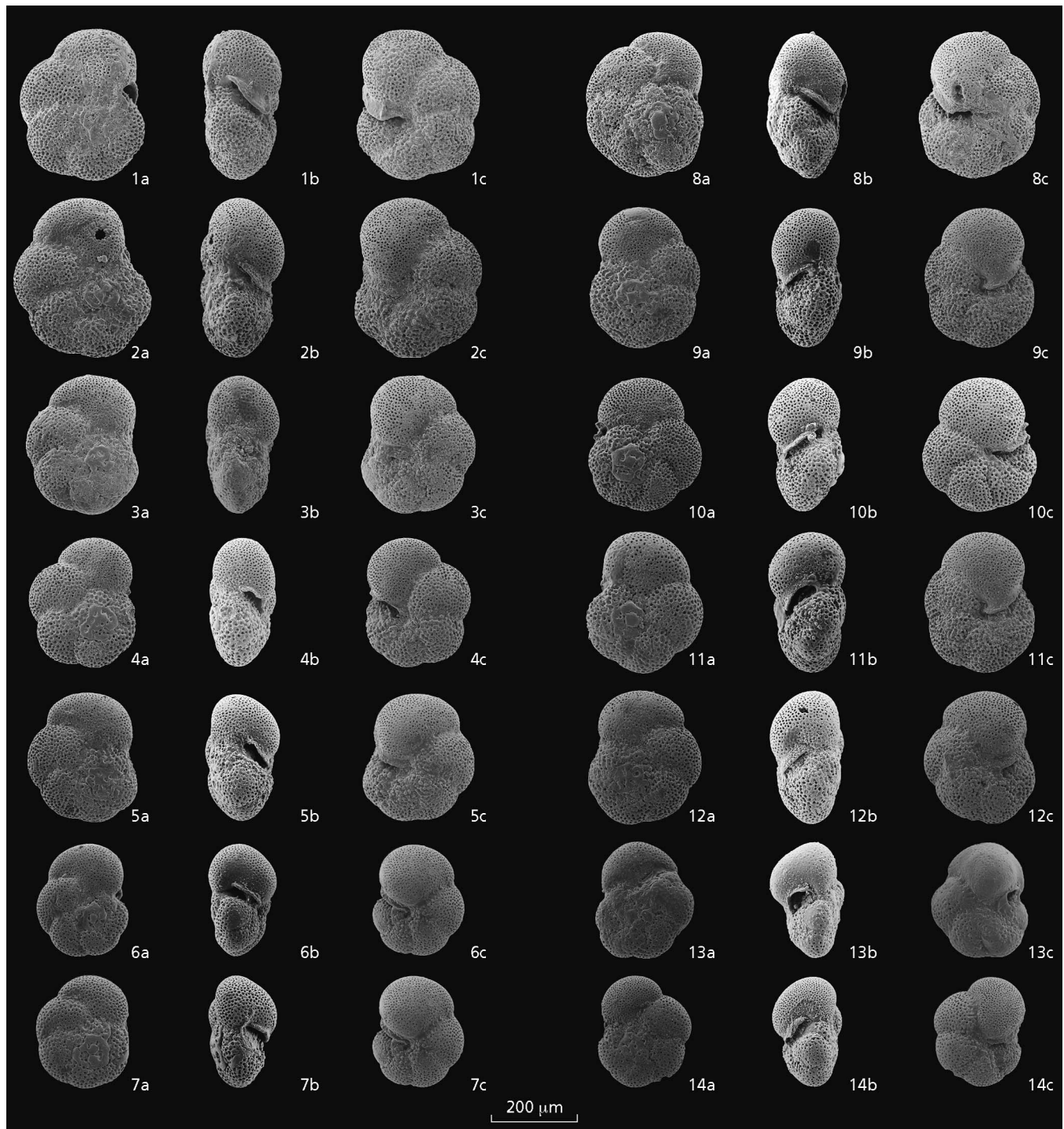


FIGURE 7. Fourteen specimens of *Globorotalia peripheroronda* from the near-type locality of *Paragloborotalia siakensis* (auger core TPKR III, depth 315-325 cm). Each specimen is shown in spiral (a), axial (b) and umbilical (c) view. Main variation is shown in the roundness of the axial periphery and convexity of the umbilical side whereby specimen 13 resembles *Globorotalia partimlabiata* Ruggieri & Sprovieri, 1970.

G. praefohsi. Moreover, Le Roy repeatedly stated that *G. barisanensis* is common throughout the Lower Palembang Fm (Le Roy, 1939, 1944 with a note in 1944 of rare occurrences in the Telisa Fm) and his distribution chart in 1952 shows this species to be exclusively present in the Lower Palembang Fm.

Since the near-type locality of *Paragloborotalia siakensis* is in the Lower Palembang Fm and contains *G. peripheroronda*, it cannot be excluded that *G. peripheroronda* fits in Le Roy's (1939) concept as well. On the other hand, if this is true, why then does his 1952 distribution chart for the uppermost Telisa Fm lack *G.*

barisanensis? Blow & Banner (1966) suggested that the globorotaliids from the uppermost Telisa Fm, which they allocated to *G. peripheroronda*, were included by Le Roy (1939) within his species *P. siakensis*. Indeed the difference between the two is sometimes small, as we observed in samples from the near-type locality of *P. siakensis*.

In addition to *G. peripheroacuta* and *G. praefohsi*, Blow & Banner (1966) observed *G. foysi* in the Lower Palembang Fm of the Kassikan section. We suspect that Le Roy (1939) included the latter species in his concept of *G. barisanensis* as well because, in a note added in 1952 (p. 583), he stated that “*Globorotalia barissanensis* (sic) shows considerable affinity to *Globorotalia foysi* Cushman & Ellisor of the West Indian region”. It is perhaps not surprising that Le Roy’s concept of *G. barisanensis* included acute to partly keeled and possibly also non-keeled and fully keeled forms because the existence of an evolutionary series from non- to fully keeled representatives in the *G. foysi* group became apparent some 10 years later (Bolli, 1950). Figure 4 shows our interpretation of the distribution of globorotaliids in the Middle Miocene of the central Sumatra Basin.

4. Our observations are not without taxonomic consequences. Since a species is typified by its holotype and paratypes, *G. barisanensis* and *G. peripheroacuta* are different names for the same species, whereby the former should have priority. But because the name *G. peripheroacuta* has been widely used since its introduction in 1966, we recommend that it is more pragmatic to retain the latter name, that is, *Globorotalia peripheroacuta*.
5. The Middle Miocene of central Sumatra contains two different groups of globorotaliids: the *G. menardii* group and the *G. foysi* group, and *G. barisanensis* belongs to the latter. In spiral-view analysis, the *G. barisanensis* types are distinct both from all *G. foysi* holotypes and from the *G. praemenardii* holotype (Fig. 6A). That is, *G. barisanensis* has somewhat less arcuate chambers than other species of the *G. foysi* group. Figure 6B shows that the *G. barisanensis* types are somewhat less planoconvex than the *G. peripheroronda* and *G. peripheroacuta* holotypes (Figs. 1, 2, 5). These morphological differences between the *G. barisanensis* types and all *G. foysi* holotypes may not come as a surprise given the fact that these type specimens are from widely different regions: the types of the *G. foysi* group are from the low latitude east Atlantic and the *G. barisanensis* types from the southwest Pacific.

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buan (GRDC in Bandung) is acknowledged for bringing the holotype of *G. barisanensis* to Utrecht. We further acknowledge Margot Stoete for composing some of the figures and drafting text figures. We thank two anonymous reviewers for their comments on this manuscript. The careful edits by Pamela Hallock Muller greatly improved the manuscript.

REFERENCES

- Akers, W. H., 1955, Some planktonic foraminifera of the American Gulf Coast and suggested correlations with the Caribbean Tertiary: *Journal of Paleontology*, v. 29, p. 647–664.
- Berggren, W. A., Kent, D. V., Swisher, C. C., III, and Aubry, M. P., 1995, A revised Cenozoic geochronology and chronostratigraphy: *SEPM Special Publication*, v. 54, p. 129–212.
- Blow, W. H., 1959, Age, correlation, and biostratigraphy of the upper Tocuyo (San Lorenzo) and Pozon Formations, Eastern Falcon, Venezuela: *Bulletins of American Paleontology*, v. 39, no 178, 251 p.
- Blow, W. H. and Banner, F. T., 1966, The morphology, taxonomy, and biostratigraphy of *Globorotalia barisanensis* Le Roy, *Globorotalia foysi* Cushman and Ellisor, and related taxa: *Micropaleontology*, v. 12, p. 286–302.
- Bolli, H. M., 1950, The direction of coiling in the evolution of some Globorotaliidae: *Contributions from the Cushman Foundation for Foraminiferal Research*, v. 1, p. 82–89.
- Bolli, H. M., 1957, Planktonic foraminifera from Oligocene-Miocene Cipero and Lengua Formations of Trinidad, B.W.I: *United States National Museum Bulletin* v. 215, p. 97–123.
- Bolli, H. M., 1967, The subspecies of *Globorotalia foysi* Cushman and Ellisor and the zones based on them: *Micropaleontology*, v. 13, no 4, p. 502–512.
- Clarke, M. C. G., Kartawa, W., Djunnuddin, A., Suganda, E., and Bagdja, M. 1982, The geology of the Pakanbaru Quadrangle (0816), Sumatra, Scale 1:250,000: Geological Survey of Indonesia, Directorate of Mineral Resources, Geological Research and Development Centre, Bandung.
- Cushman, J. A., 1929, A late Tertiary fauna of Venezuela and other related regions: *Contributions of the Cushman Laboratory for Foraminiferal Research*, v. 5, p. 77–105.
- Cushman, J. A., and Ellisor, A. C., 1939, New species of foraminifera from the Oligocene and Miocene: *Contributions from the Cushman Laboratory for Foraminiferal Research*, v. 15, p. 1–14.
- Cushman, J. A., and Stainforth, R. M., 1945, The foraminifera of the Cipero marl formation of Trinidad, British West Indies: *Cushman Laboratory for Foraminiferal Research, Special Publication* 14, p. 1–5.
- De Smet, M. E. M. and Barber, A. J., 2005, Tertiary stratigraphy, in Barber, A. J., et al., (eds.), *Sumatra: Geology, Resources and Tectonic Evolution*: Geological Society, London, *Memoirs*, v. 31, p. 86–97.
- Hartono, H. M. S., 1960, Collection of smaller foraminifera at the Paleontology Section of the Geological Survey of Indonesia: *Publikasi Teknik Djawatan Geologi, Seri Paleontologi*, v. 1, p. 13–19.
- Le Roy, L. W., 1939, Some small foraminifera, ostracoda and otoliths from the Neogene (“Miocene”) of the Rokan-Tapanoei area, central Sumatra: *Natuurkundig Tijdschrift Nederlandsch Indië*, v. 99, p. 214–296.
- Le Roy, L.W., 1944, Miocene foraminifera from Sumatra and Java, Part I: Miocene foraminifera of central Sumatra, Netherlands East Indies: *Quarterly of the Colorado School of Mines*, v. 39, p. 9–69.
- Le Roy, L.W., 1948, The foraminifer *Orbulina universa* d’Orbigny, a suggested middle Tertiary time indicator: *Journal of Paleontology*, v. 22, p. 500–508.
- Le Roy, L.W., 1952, *Orbulina universa* d’Orbigny in central Sumatra: *Journal of Paleontology*, v. 26, p. 576–584.
- Lourens, L. J., Hilgen, F. J., Laskar, J., Shackleton, N. J., and Wilson, D., 2004, The Neogene Period, in Gradstein, F.M., et al. (eds.), *A Geological Time Scale 2004*: Cambridge University Press, Cambridge, p. 409–440.

- d'Orbigny, A., 1839, Foraminifères des îles Canaries, in Barker-Webb, P. and Berthelot, S. (eds.), *Histoire Naturelle des îles Canaries*: Béthune, Paris, v. 2, pt. 2, p. 119–146
- Ruggieri, G., and Sprovieri, R., 1970, I microforaminiferi delle Marne di S. Cipirello: *Lavori dell'Istituto di Geologia della Università di Palermo*, v. 10, p. 1–26.
- Wade, B. S., Pearson, P. N., Berggren, W. A., and Pälike, H., 2011, Review and revision of Cenozoic tropical planktonic foraminiferal biostratigraphy and calibration to the geomagnetic polarity and astronomical time scale: *Earth Science Reviews*, v. 104, p. 11–142.
- Zachariasse, W. J. and Sudijono, 2012 - New data on the morphology and classification of the Oligocene-Miocene planktonic foraminifer *Paragloborotalia siakensis* (LeRoy, 1939): *Journal of Foraminiferal Research*, v. 42, p. 156–168.

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APPENDIX

These appendices can be found on the Cushman Foundation website in the JFR Article Data Repository (<http://www.cushmanfoundation.org/jfr/index.html>) as item number JFR_DR_2017010.

APPENDIX 1: Photograph of slide PS 1081a containing the holotype of *Globorotalia barisanensis* Le Roy, 1939.

APPENDIX 2: Lithostratigraphic units employed by Le Roy (1939, 1944) and modern equivalents (Clarke et al., 1982) along with lithology and depositional environment. Ages for lithostratigraphic units are from Clarke et al. (1982) and De Smet & Barber (2005). From Zachariasse & Sudijono (2012).

APPENDIX 3: Synopsis of the landmark-based morphometric method applied in this study.