

FORAMINIFERA FROM THE CRETACEOUS OF SOUTHERN LIMBURG, NETHERLANDS, XXIV.

THE DEVELOPMENT OF PARAROTALIA TUBERCULIFERA (Reuss).

by J. HOFKER

- Rotalia tuberculifera* Reuss, 1862, Die Foraminiferen des Kreides von Maastricht; Sitz. ber. K. Akad. Wiss. Wien, 44, p. 313, pl. 2, fig. 2.
- Nonion tuberculifera* (Reuss), Hofker, 1949, On Foraminifera from the Upper Senonian of South Limburg (Maestrichtian); Verh. Kon. Belg. Inst. Natuurw., 112, p. 26, fig. 14.
- Parella tuberculifera* (Reuss), Hofker, 1951, On Foraminifera from the Dutch Cretaceous; Publ. Natuurh. Gen., 4, p. 16, figs. 15—18.
- Rotalia tuberculifera* Reuss, Visser, 1951, Leidse geol. Med., 16, p. 274, pl. 5, fig. 14, pl. 10, figs. 9, 10.
- Rotalia choctawensis* van Bellen (non Cushman and McGlamery), 1946, Foraminifera from the Middle Eocene etc., Med. geol. Stichting, Ser. C, V, 4, p. 62, pl. 8, fig. 5—7.
- Rotalia armata* van Bellen, (non d'Orbigny), 1946, loc. cit., p. 60, pl. 7, fig. 16—18.

1949 Y. Le Calvez erected the new genus *Pararotalia* with the genotype *Rotalina inermis* Terquem (Révision des Foraminifères lutétiens du Bassin de Paris; Mém. Carte géol. France, Paris, p. 32—33.); 1952 Bermudez erected a new genus *Neorotalia*, with the genotype *Rotalia mexicana* Nuttall, 1928 (Bol. Geol. Venezuela, 2, pt. 4, 1952, p. 75). A study of both genotypes showed the author, that they belong to a single genus; thus *Neorotalia* Bermudez is a synonym of *Pararotalia* Le Calvez.

A large number of species belong to this genus; they all show the characters:

Test free, biconvex, calcareous; dorsal side often more flattened than the ventral one; in many forms each chamber of the last formed whorl shows a more or less developed spine at the periphery. Periphery sharpened, with distinct hyaline poreless margin. At dorsal side all chambers visible, often arranged as in *Globo-*

truncana or *Globorotalia*, with fine but distinct pores all over the wall, but for the margin; often the centre indistinct by chalk knobs. At the ventral side only the chambers of the last formed whorl visible, with radiate sutures, depressed, covered with distinct but fine pores, but for the margin and the centre. In most cases centre filled up by distinct chalk knob, well-separated from chamberwalls. Aperture at the ventral wall of the last formed chamber, more or less loop-shaped, often somewhat areal, with reduced toothplate, always present. To this genus belong, as verified by the author: *Pararotalia tuberculifera* (Reuss), Uppermost Cretaceous of Holland and France (Dordonian) to Montian (middle Paleocene); *Pararotalia inermis* (Terquem), Eocene of France and elsewhere; *Pararotalia spinigera* (Terquem), Eocene and Oligocene of Europe; *Pararotalia kalomphalia* (Gümbel), Stockletten, Batavia; *Pararotalia umbilicatulula* (Hantken), Oligocene of Europe; *Pararotalia byramensis* (Cushman), Oligocene of Alabama and elsewhere; *Pararotalia choctawensis* (Cushman and McGlamery), Oligocene of Middle and South America; *Pararotalia mexicana* (Nuttall), Oligocene of America; *Pararotalia tholus* (Galloway and Hemingway), Oligocene of Ecuador; *Pararotalia aculeata* (d'Orbigny), Miocene of Europe; *Pararotalia calcar* (d'Orbigny), recent Indo-Pacific; several other recent species along the coast of Africa.

The oldest species known seems to be *Pararotalia tuberculifera* from the Maestrichtian Chalk Tuff and the Dordonian of France. It begins in Holland with very small specimens in the uppermost Mb, rapidly increases in size during the transitional zone Mb-Mc, develops in the Mc and finds its largest development in the Lower Md; during the Md the number of specimens rapidly decreases and in the Upper Md it becomes more and more rare. In the overlying Paleocene only a very small species occurs which may be an aberrant form of *Pararotalia tuberculifera*, much alike the small specimens of the Mb; but in the tropical Montian it suddenly reappears in a slightly more advanced form, compared with the forms of the Lower Md, and at the end of the Montian it disappears totally.

It is not at all easy to describe the species

Pararotalia tuberculifera, for the forms at the beginning of the evolution are very different from those at the end of the series and the species is highly variable. At the beginning of the development the central knob at the ventral side is not yet fully developed, and so these small forms from the Upper Mb very much resemble a true *Globorotalia*, since *Pararotalia* only differs from *Globorotalia* by the ventral central knob and the more or less areal or loop-shaped aperture. But in those primitive forms even the aperture resembles that of *Globorotalia*, since it is not yet areal (Figs. 2, 3). Young specimens of the more advanced stages of the species also have not yet developed the central plug at the umbilicus and do not show the areal aperture either (Fig. 13).

These characters of the oldest and of young specimens obviously are primitive characters, pointing to the forefathers of *Pararotalia*, *Globorotalia* or even single-keeled *Globotruncana*.

A very typical feature of the species moreover is the ornamentation of the walls; even primitive forms may already develop irregular ridges on the surface of the last-formed chambers, very much resembling the ornamentation of *Rugoglobigerina* (Fig. 10). These ridges in older chambers fuse and form the tubercular pattern of the dorsal and ventral sides. At the ventral side the last formed chambers often show distinct „tena” ventrally from the aperture, and may even develop a small indentation at the proximal ventral suture which, in more-developed forms, remains open and gives rise to a distinct canal-system between the chambers; the tena form an area of knobs around the ventral central one (Figs. 11, 14, 15).

When many specimens are found in a sample, two different forms may be common; the one is a large form, often very bulky on both sides and showing many chambers in the last formed whorl, while the other form is smaller, more flattened at the dorsal side, and with a more distinct central knob at the ventral side. These two forms always show a different size of the proloculus, the large form being the B-form, the smaller and commoner one the A-form. Within this A-form, also two different characters may be found; there are specimens which are more bulky with, at the dorsal side, a well developed ornamentation, and others in which the dorsal side is very flat and nearly

without any ornamentation (Figs. 14, 15). Since, however, as in all species of *Pararotalia*, the size of the proloculus remains small, in the A₂-forms also, it is very difficult to obtain certainty which of the two forms is the form with smaller, and which that with larger proloculus. It seems, that the flat unornamented form is the A₂-generation.

These three generations are much more differentiated in the last appearance of the species, in the tropical Montian. Till now no localities with tropical Lowest Paleocene with *P. tuberculifera* could be studied; they are unknown to the author. Yet the reappearance of this species in the Montian shows that there must have been a continue development of the species elsewhere. In the Montian the very large B-form is very conspicuous; here this form attains not only its utmost size, but also its utmost ornamentation; only 3 or 4 chambers of the last formed whorl are visible and at the end the test becomes nearly biconvex; this form has been described by Van Bellen as *Rotalia choctawensis* Cushman and McGlamery; but it is quite different from that species (Fig. 17); the two smaller A-forms have been gathered by Van Bellen as *Rotalia armata* d'Orbigny; but that species, also a *Pararotalia*, is not only different from the form found in the Montian, but also appears much later, in the Oligo-Miocene. From these two generations the more bulky one is the form with smaller A-proloculus, and is much alike similar forms from the Lower Md; the other form, with the largest proloculus, is a very flat form, with most chambers visible at the dorsal side, and only in the central part with a slight ornamentation (Figs. 14, 15).

So *Pararotalia tuberculifera* (Reuss) begins its development in the Upper Mb; here it shows the type of a small *Globorotalia* rather than a *Pararotalia*; young specimens of later stages of the series also show this structure. During the development of the species the size increases, especially in the B-form; more and more three types become visible, the three generations of the species; in the latest known stage, in the Montian, these three forms show their utmost specialisation. In the Lowest Paleocene a small *Pararotalia* was detected which may be a nanified *P. tuberculifera*, but it differs considerably from the primitive type of the Mb in having always a developed central ventral

knob; it may be the first stage of a newly developing species, possibly *P. inermis* from the Eocene; but no series of development is known to the author.

In the Lower Md as well as in the Montian specimens are found in which the ornamentation at the dorsal side is intermediate between that of the A_1 and the A_2 -forms. Here the chambers at the dorsal side remain visible, but the slightly limbate sutures are indicated by pearl-like knobs, giving this side a very beautiful texture.

Diameter of specimens from the Upper Mb about 0.4 mm; from the boundary Mb-Mc about 0.5 mm; from the Mc about 0.9 mm; from the Lower Md up to 1.2 mm; in the Montian the A-forms reach 1.3 mm, the B-forms 1.6 mm.

We deal here with a phenomenon, not at all rare in Foraminifera, that the size of a species increases with time; this is also seen in *Rotalia trochidiformis* Lamarck from the Mc up to the Lutetian; in *Coleites reticulosus* (Plummer) from the Upper Cretaceous (Upper Maestrichtian) into the Paleocene; in *Sigmomorphina soluta* Brotzen and *S. brotzeni* Hofker from the Upper Maestrichtian into the Middle Paleocene (Montian); in the group of single-keeled *Globotruncanae* in the Upper Maestrichtian; in many groups of Globigerines in the Tertiary; in *Globorotalia menardii* in the late-Tertiary till recent; etc. This increase of size may be, in all these cases, the indication of the development of a species up to extinction.

Pararotalia tuberculifera occurs in the Upper Mb, the Mc, the Md and the Montian in Holland and Belgium; in the Kunrade Chalk in Holland, but here mostly in much eroded specimens, all from the type occurring in the Upper Mc or Lower Md; in the Tuff of Ilten in Germany; in the Dordonian of France, here in types which occur in the Lower Md. It is not found in the Tuffeau de St. Symphorien in Belgium, pointing thus to an age of that Tuff older than Upper Mb, which agrees with the other fossils in that formation. *Pararotalia tuberculifera* thus is a fine index-fossil.

FIGURES.

Fig. 1. *Pararotalia inermis* (Terquem), genotype of *Pararotalia*; Lutetian of Paris, Eocene. The figures are given here to illustrate the type to which *P. tuberculifera* belongs. a: dorsal side; b: apertural face; c: ventral side; d: transverse section; all

$\times 130$; e, f: apertures with the loop-shaped structure and the reduced toothplates; $\times 370$.

Fig. 2. *Pararotalia tuberculifera* (Reuss), from the Upper Mb, Savelbos, sample Jonker and De Vries, quarry 11, 14; $\times 60$.

Fig. 3. *Pararotalia tuberculifera* (Reuss), ENCI-quarry, outcrop 4; 9, 75 m; transitional zone Mb-Mc; $\times 60$.

Fig. 4. *Pararotalia tuberculifera* (Reuss), ENCI-quarry, outcrop 4; 13, 25 m; Lower Mc; $\times 60$.

Fig. 5. *Pararotalia tuberculifera* (Reuss), ENCI-quarry, outcrop 4; 15, 15 m; Mc; $\times 60$.

Fig. 6. *Pararotalia tuberculifera* (Reuss); Mc from Neercanne; pores, $\times 370$.

Fig. 7. *Pararotalia tuberculifera* (Reuss); Lowest Md in hard ground Mc-Md of quarry Curfs near Houthem; $\times 60$.

Fig. 8. *Pararotalia tuberculifera* (Reuss); Similar specimen from same locality, transverse section; $\times 115$.

Fig. 9. Part of transverse section, showing the poreless rim at the margin, $\times 370$.

Fig. 10. *Pararotalia tuberculifera* (Reuss); lowest Md in hard ground Mc-Md of quarry Curfs, near Houthem; specimen with the typical striate ornamentation; at the ventral side also the openings at the sutures are seen, which are similar to protoforamina but in reality are deepened sutures; $\times 60$.

Fig. 11. *Pararotalia tuberculifera* (Reuss); small specimen from same locality; $\times 60$.

Fig. 12. *Pararotalia tuberculifera* (Reuss); same locality; specimen with pearl-like ornamentation, dorsal side; $\times 60$.

Fig. 13. *Pararotalia tuberculifera* (Reuss); young specimen from the quarry Neercanne, Middle Mc; $\times 115$.

Fig. 14. *Pararotalia tuberculifera* (Reuss) described by Van Bellen as *Rotalia armata* d'Orbigny; shaft Maurits III; 177, 50 m; tropical marine Montian, Paleocene; A_1 -generation; $\times 60$.

Fig. 15. *Pararotalia tuberculifera* (Reuss) described by Van Bellen as *Rotalia armata* d'Orbigny; shaft Maurits III; 177, 50 m; tropical marine Montian, Paleocene; A_2 -generation; $\times 60$.

Fig. 16. *Pararotalia tuberculifera* (Reuss), same locality; transverse section through A_1 -generation; $\times 115$.

Fig. 17. *Pararotalia tuberculifera* (Reuss), described by Van Bellen as *Rotalia choctawensis* Cushman and McGlamery; shaft Maurits III; 177, 50 m; tropical marine Montian, Paleocene; B-generation, $\times 50$. The test at the end becomes nearly planospiral.

Fig. 18. *Pararotalia tuberculifera* (Reuss); same locality, B-generation; transverse section, $\times 100$. The initial part shows all characters of normal *Pararotalia tuberculifera*; in the end of the development of the test the chambers are overlapping at the dorsal side and become nearly symmetrical; even two foramina may be found in the septa.









