

Revised Systematics of the Schlumbergerinida (Phylum Foraminifera)

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ABSTRACT

The newly revised systematics of the foraminiferal order Schlumbergerinida is here presented, with diagnoses of all taxa, comprising 21 genera, seven families and eleven subfamilies, of which three families (Trilocularenidae, Ammomassilinidae, Ammoflentinidae) and five subfamilies (Psamminopeltinae, Birsteiniollinae, Silicomassilininae, Spirolocammininae, and Pseudoflentininae) are new. A key to the genera and subfamilies of the order is also given.

INTRODUCTION

According to new concepts of the foraminiferal macrosystem and evolution, the former Textulariina (sensu Loeblich & Tappan, 1987) represents a heterogeneous group belonging to five different subclasses: Astrorhizana Saidova, 1981, Ammodiscana Mikhalevich, 1980, Miliamminana, Mikhalevich, 1980, Hormosinana Mikhalevich, 1980 and Textulariana Mikhalevich, 1980 of the corresponding classes Astrorhizata Saidova, 1981, Spirillinata Maslakova, 1990, Miliolata Saidova, 1981, Nodosariata Mikhalevich, 1992, and Rotaliata Mikhalevich, 1980 (Mikhalevich, 1992, 1999, 2000, 2004). The five foraminiferal classes can be characterised morphologically, and include isomorphic subclasses with a more primitive shell wall (mostly agglutinated) and a more advanced one (usually different types of secreted calcareous wall, except among primitive unilocular forms of the class Astrorhizata where the representatives of their higher subclass Astrorhizana have an agglutinated wall and those of the lower subclass Lagynana - have a tectinous wall). Thus, it has been suggested that the transition from a more primitive agglutinated wall to the different types of the fully secreted calcareous wall took place independently and in parallel lines during geological history, within each class representing a separate phyletic line. The majority of agglutinated and calcareous isomorphs are therefore not the result of convergence as was previously thought, but are in close relationship. Consequently, isomorphic forms of the subclass Miliamminana are considered to be the ancestral forms of the subclass Miliolana; the order Schlumbergerinida of the subclass Miliamminana -

the ancestral order to the order Miliolida of the subclass Miliolana. The unity of both orders within a single phyletic line is supported by (1) the similarity of their morphological features; (2) the profound similarity of their ontogenetic and phylogenetic tendencies; (3) cases of gradual transition from an agglutinated to a porcellaneous secreted wall (Mikhalevich *et al.*, 1986, 2004, pl. 1, figs. a, b); (4) molecular data (Fahrni *et al.*, 1997, Pawlowski *et al.*, 2003).

All this makes it necessary to transfer the schlumbergerinids from the former Textulariina (or from the order Lituolida, where they were placed later by Loeblich & Tappan (1992)) to the subclass Miliamminana Mikhalevich, 1980 as the separate order Schlumbergerinida Mikhalevich, 1980 (Jurassic to Holocene).

Because the representatives of the order Schlumbergerinida are analogous in their shell and chamber form to those of the order Miliolida (as well as in features of their apertural structures) the principles and approaches used in their classification ought to be the same to follow classificatory principles at a uniform level. Thus the type of the shell structure (including the mode of coiling, form of the chambers and their disposition) is considered as serving as a feature at a family level. The type of apertural structure (the presence or absence of a tooth, its modification) is used as a feature at the subfamily level. The same approach was used earlier in the classification of the order Miliolida (Mikhalevich, 1988).

SYSTEMATICS

The new taxonomic position and the composition of

the order Schlumbergerinida Mikhalevich, 1980 designated here is based on the new concepts of foraminiferal evolution and higher systematics mentioned above, and on the uniform principles of their classification for each of the groups, firstly within the class Miliolata. The stratigraphic and palaeoenvironmental conclusions depend strongly upon the taxonomic base.

Subclass **MILIAMMINANA** Mikhalevich, 1980
(= Rzehakinicae Saidova, 1981 = Schlumbergerinana Mikhalevich, 1992)

Test free, pseudo-twochambered, pseudo-multi-chambered, multichambered, the predominant type of coiling-irregular- and regular glomerate, planispiral (often combined with glomerate); shells of the higher representatives can be cyclical and fusulinoid in form; a piece of the tubular chamber may be preserved around the proloculus; chambers predominantly tubular, usually two (more rarely three) per whorl, in some forms more wide as in *Peneroplis*-like forms or sometimes subsphaerical, may be strongly embracing. In higher representatives the chamber number greatly increases, chamber lumen can be subdivided by the inner skeletal elements, advanced forms may have integrative systems (stolons, tunnels); wall agglutinated on the organic base, microgranular or agglutinated and partly with secreted needles; aperture terminal, simple in the most primitive forms, in more complex ones - with the outer (flap) or inner tooth of a special structure, sometimes aperture secondarily multiple, additional apertures non developed; benthic forms, mostly free living. Nuclear apparatus and gametes unstudied. Carboniferous to Holocene.

Remarks. The representatives of this subclass often display similarities in form with some of the secreted Miliolata groups.

Order **SCHLUMBERGERINIDA** Mikhalevich, 1980

(= ord. Rzehakinida Saidova, 1981)

Test multichambered, usually elongated, of one of the miliolid types of construction - glomerate at least at the early stage - quinqueloculine, sigmoidal, triloculine, may also be planispiral (mostly spiroloculine) or combined, more often with long tubular chambers, two per whorl, more rarely with wider chambers three per whorl resulting in a broader test; wall agglutinated on an organic base or agglutinated and combined with calcareous needles at the base of the wall; aperture simple or with a tooth or trematophore. Jurassic to Holocene.

Remarks. The finding of *Miliammmina gerochi* Tyszka, 1997 in the Middle Jurassic of Poland (Tyszka, 1997) extends the known geologic range of this group from the Cretaceous to the Jurassic.

Family **RZEHAKINIDAE** Cushman, 1933

Test entirely planispiral; wall agglutinated on an organic base; aperture without a tooth. Cretaceous to Paleocene.

Remarks. Without *Rothina*, which is considered to represent a broken chamber of *Caudammmina*, and is therefore synonymous (Bubík, 1997, Kaminski, 2004b, Kaminski *et al.*, 1996), and without *Ammoflintina*, *Spirolocammmina*, *Spirosigmoilinella*, *Silicosigmoilina*, *Trilocularena*, *Silicomassilina* placed here into other families according to their mode of coiling and shell structure, and *Miliammmina*, *Birsteiniola* transferred into Miliammmininae.

Subfamily RZEHAKININAE Cushman, 1933

Test oval and slightly elongated in outline, planispiral, flattened, but with a thickening at the centre because of the partly overlapping chambers, chambers half a coil in length, broad, flattened to the periphery, inflated at their inner side; wall agglutinated on an organic base; aperture without a tooth. Cretaceous to Paleocene.

Rzehakina Cushman, 1927

Type species: *Silicina epigona* Rzehak, 1895

Test and chambers as described for the family; chambers broad, slightly tapering at the base and at the end, with four to five chambers visible from one side, only two or two and a half from the other side; wall finely agglutinated; aperture irregularly oval. Cretaceous to Paleocene.

Subfamily PSAMMINOPELTINAE, subfam. nov.

Test broadly ovoid in outline, flat, fully evolute; chambers half coil in length, narrow, strongly elongated, of nearly equal width along the whole length of the chamber; all chambers visible from both sides; wall agglutinated on an organic base; aperture a subcircular opening. Cretaceous-Miocene.

Remarks. The new subfamily differs from the subfamily Rzehakininae of the same family in being wholly evolute, with non-embracing narrow chambers all visible on both sides of the test.

Psamminopelta Tappan, 1957 (type genus)

Type species: *Psamminopelta bowsheri* Tappan, 1957. Test as described for the subfamily; wall finely agglutinated; aperture a small subcircular opening. Cretaceous.

Subfamily SPIROGLUTININAE Mikhalevich, 1983

Test broadly ovoid in outline, flat, fully evolute; chambers half a coil in length, narrow, strongly elongated, of nearly equal width along the whole length of the chamber; all chambers visible from both sides; wall agglutinated on a calcareous base; aperture a small circular opening with a short tooth. Miocene to Holocene.

Remarks. Placed by Loeblich & Tappan (1987) into the synonymy of the Hauerinidae, but differs from the representatives of this heterogeneous family in its planispiral coiling and agglutinated test, and in having two chambers per whorl in the final part.

Spiroglutina Mikhalevich, 1983

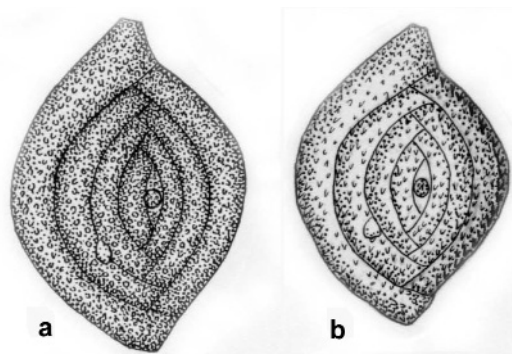


Figure 1. *Spiroglutina* Mikhalevich, 1983; 1a,b. *Spiroglutina asperula* (Karrer), 1868 (x80), Canary Islands, 440 m, vessels of ATLANTNIRO (from Mikhalevich, 1983).

Type species: *Spiroloculina asperula* Karrer, 1868

Test broadly oval, flat and thin, with the prominent base and apertural end, with very narrow peripheral margin, fully evolute; chambers narrow, very slightly inflated, of nearly equal width along the whole length of the chamber; wall with an outer layer of fine sand grains, rough; aperture small, with a short tooth. Miocene to Holocene.

Remarks. The genus very close to the genus *Psamminopelta* differs from it in having a tooth. Placed by Loeblich & Tappan (1987) into the synonymy of the genus *Sigmoilinita* Seiglie, 1965, but the genus is reinstated here as it differs from the latter in its agglutinated wall and in the absence of a definite sigmoidal part (the curve in the central part mentioned by Karrer (1868) is very slight, not more than the slightest curve in *Psamminopelta* or in the isomorphic spiroloculinids).

Family **MILIAMMINIDAE** Saidova, 1981, stat. nov. Test quinqueloculine, chambers half coil in length, usually four chambers visible on one side, less chambers on the opposite side; wall agglutinated on an organic base or agglutinated on a calcareous base; aperture simple without a tooth or having a tooth. Middle Jurassic to Holocene.

Remarks. The family differs from the family Rzehakinidae in its quinqueloculine coiling.

Subfamily **BIRSTEINIOLLINAE**, subfam. nov.

Test quinqueloculine; wall agglutinated on an organic base; aperture simple, without a tooth. Holocene.

Birsteiniolla Mayer, 1974 (type genus)

Type species: *Birsteiniolla macrostoma* Yankovskaya & Mikhalevich, 1972 (as *Birsteiniolla*)

Test broadly ovate in outline, with large globular proloculus and broadly tubular second chamber making nearly a coil, next chambers half coil in length, wide, of nearly equal wideness along the chamber, in quinqueloculine arrangement, later tending to become planispiral; wall finely agglutinated; aperture - widely circular open end of the tubular chamber, may be slightly bordered, without a tooth. Holocene.

Remarks. The genus is transferred from the Rzehakinidae.

Subfamily **MILIAMMININAE** Saidova, 1981

(=Siphonapertinae Saidova, 1975 (part), =Agglutinellinae El-Nakhal, 1985).

Test quinqueloculine; wall agglutinated on an organic base or agglutinated on a calcareous base; aperture with a tooth. Middle Jurassic to Holocene.

Remarks. The subfamily is here reinstated from the synonymy of the subfamily Rzehakininae where it was placed by Loeblich & Tappan, 1987, and its diagnosis and composition are emended. The genus *Miliammelus* Saidova & Burmistrova, 1978 is excluded as having a fully secreted shell wall with mineralised needles arranged in three layers like in the miliolids, though considered to be made of opaline silica, and the aperture has an external flap rather than an inner tooth; the genera *Silicosigmoilina* and *Trilocularena* are excluded as having sigmoid and triloculine chamber arrangements, respectively. Three other genera *Agglutinella*, *Dentostomina* and *Siphonaperta* are transferred into this subfamily from the former Siphonapertinae Saidova, 1981. These have quinqueloculine coiling and an inner tooth in their aperture; their wall has a thick agglutinated layer on a calcareous base.

Miliammina Heron-Allen & Earland, 1930

Type species: *Miliolina oblonga* (Montagu) var. *arenacea* Chapman, 1916, non *Miliolina arenacea* Rhumbler, 1906 = *Miliolina oblonga* Heron-Allen & Earland, in Earland, 1933, non *Vermiculium oblongum* Montagu = *Miliammina earlandi* Loeblich & Tappan, 1955.

Test elongate and ovate in outline, with more or less parallel sides, peripheral margin broadly rounded; with tubular chambers half a coil in length, somewhat widening at the base and near the apertural end; wall rather thick, finely agglutinated on an organic base; aperture may be produced on a short rather wide neck, with a tooth. Middle Jurassic to Holocene.

Remarks. The genus is transferred from the Rzehakinidae.

Agglutinella El-Nakhal, 1983

Type species: *Agglutinella soriformis* El-Nakhal, 1983
 Test broadly ovate, somewhat tapering to the base and to the apertural end, with early stage quinqueloculine, latest pseudotriloculine, with only three chambers visible externally, peripheral margin broadly rounded, chambers half coil in length; wall with a very rough agglutinated cover on a calcareous base; aperture at the slightly produced neck bordered by a porcellaneous lip, with simple or bifid tooth. Eocene to Holocene.

Remarks. The genus differs from other genera of the subfamily in the pseudotriloculine tendency at the later stage and very large and prominent sand particles in the wall. The genus transferred from the Miliolacea.

Dentostomina Carman, 1933

Type species: *Dentostomina bermudiana* Carman, 1933

Test ovate in outline, with a broad base and apertural end, wider at the middle part of the test, peripheral margin broadly rounded; chambers rather broad and only slightly widening near the base and the aperture, half coil in length; wall with a thick agglutinated layer of sand grains on the calcareous base; aperture circular, may be dentate in outline, with a bifid tooth and multiple short simple teeth along the inner side of the apertural periphery (=along the circumference) at the adult stages. Holocene.

Remarks. The simple teeth along the inner circumference of the aperture may be developed only in the adult stage and absent in the earlier stage. The complex apertural teeth distinguish this genus from all other genera in the subfamily. The genus is transferred from the Miliolacea.

Siphonaperta Vella, 1957

Type species: *Siphonaperta macbeati* Vella, 1957
 (= *Rudolocolina* Guilbault & Patterson, 1998)

Test ovate in outline, with a broad base and narrowed apertural end, may be triangular or polygonal in transverse section depending on the form of the peripheral margin - subacute or broad and flattened, forming nearly right angles with the lateral wall of the chambers; chambers rather broad, of nearly equal width along the chamber, half a coil in length; wall with an agglutinated outer coating on a calcareous base; aperture a circular opening bordered by a porcellaneous rim, with a short and simple or bifid inner tooth. Miocene to Holocene.

Remarks. The genus is transferred from the Miliolacea. The genus *Rudolocolina* described by Guilbault & Patterson (1998) is considered here to be a synonym of *Siphonaperta* differing from the latter only in the subquadrate form of the chambers, wide and flattened peripheral margin, the larger

diameter of the circular aperture and the bifid tooth in adult specimens - all these distinctions serve as features at the specific level. The chamber arrangement ("quinqueloculine throughout, with 5 chambers visible from exterior") and the presence of the agglutinated material on a calcareous base give reason to move it from the subfamily Hauerininae where it was originally placed, to this subfamily.

Family **TRILOCULARENIDAE** fam. nov.

Test with triloculine coiling; chambers half coil in length, broad, of nearly equal width along the chamber, only three of them visible on one side, two on the other side; wall agglutinated on an organic base or with a calcareous inner layer; aperture with a bifid tooth or an external flap formed by infolding of the wall margin. Holocene.

Remarks. The new family differs from all other families of the order in its triloculine chamber arrangement. The representatives of this family are isomorphic in chamber arrangement to the porcellaneous *Triloculina*.

Trilocularena Loeblich & Tappan, 1955 (type genus)

Type species: *Miliammmina circularis* Heron-Allen & Earland, 1930

Test triangular, close to subcircular in outline, with very broad rounded peripheral margins; chambers half coil in length, broad, of nearly equal width along the chamber, only three of them visible on one side, two on the other side; wall agglutinated on an organic base; aperture lunate, parallel to the suture between the last two chambers, with an external tooth (flap) formed by the infolding of the wall margin. Holocene.

Remarks. Wall finely agglutinated. The genus is transferred from the Rzehakinidae.

Falsagglutinella Loeblich & Tappan, 1994

Type species: *Falsagglutinella byrsa* Loeblich & Tappan, 1994

Test triloculine, elongated-oval in outline, periphery broadly rounded, chambers half a coil in length, broad and significantly widening at their base, three chambers visible on one side, two on the other side; wall agglutinated on a calcareous base; aperture elongated, perpendicular to the suture between the last two chambers, with an everted lip and a bifid tooth.

Remarks. The wall may be finely or coarsely agglutinated. Loeblich & Tappan (1994) described two species of *Falsagglutinella* from the Timor Sea. Differs from *Agglutinella* in its fully triloculine coiling, and from *Trilocularena* in the character of the aperture and the shell wall. The genus is transferred from the Siphonapertinae, where it was placed by Loeblich & Tappan.

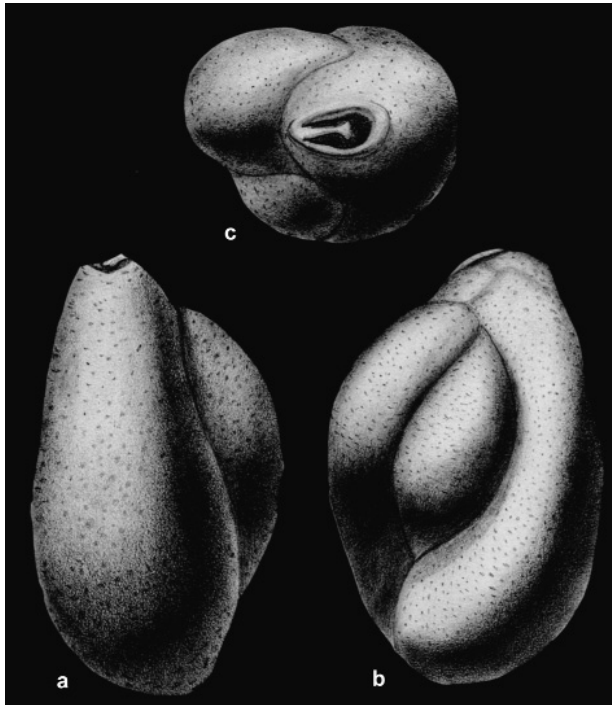


Figure 2. *Falsagglutinella* Loeblich & Tappan, 1994. Paratype of *Falsagglutinella byrsa* Loeblich & Tappan, 1994, Core V-192, Sahul Shelf, 25 m depth, x45 (modified from Loeblich & Tappan, 1994).

Family **AMMOMASSILINIDAE** fam. nov.

Test of the massiline type: early chambers in a quinqueloculine arrangement, later planispiral; chambers half a coil in length, many of them visible on both sides of the test; wall agglutinated on an organic wall or on a calcareous base; aperture with a tooth or with a trematophore. Paleocene to Holocene.

Remarks. The family differs from the other families of the order Schlumbergerinida in the massiline structure of the shell. The representatives of the family are isomorphic to the porcellaneous *Massilina*.

Subfamily **SILICOMASSILININAE** subfam. nov.

Test massiline, wall agglutinated on an organic base; aperture with an inner tooth. Paleocene.

Remarks. Subfamily differs from the other subfamily of Ammomassiliniidae in its apertural character (possessing a tooth).

Silicomassilina Serova, 1966 (type genus)

Type species: *Silicomassilina sinigorica* Serova, 1966
Test nearly circular in outline, flattened at the center of the shell, narrowing towards the periphery, with subacute peripheral margin; chambers half coil in length, rather wide; wall of fine chalcedony grains; aperture rounded to oval, with a simple tooth slightly developed, which may be obscured. Paleocene (Danian).

Remarks. The genus is transferred from the Rzehakinidae.

AMMOMASSILININAE subfam. nov.

Test massiline, wall agglutinated on a calcareous base; aperture with a trematophore. Holocene.

Remarks. Subfamily differs from the subfamily Silicomassiliniinae in its apertural apparatus (possessing a trematophore).

Ammomassilina Cushman, 1933 (type genus)

Type species: *Massilina alveoliniformis* Milleit, 1898

Test broadly oval to nearly circular in outline, flat, with an outstanding central quinqueloculine part, peripheral margin rounded, narrow; chambers narrow, subcylindrical, of equal width along the chamber; wall with sand grains externally; aperture small, circular, with a trematophore. Holocene.

Remarks. The genus is transferred from the Miliolacea.

Family **SIGMOILOPSIDAE** Vella, 1957, stat. nov.

Test sigmoiline, with chambers added slightly less than 180 apart, so that in transverse section the chambers form a sigmoid series, at least at the early stages, later may be planispiral; chambers half coil in length; wall agglutinated on an organic base or agglutinated on a calcareous base; aperture with or without a tooth. Upper Cretaceous to Holocene.

Remarks. The rank of the subfamily Sigmoidopsinae is here elevated and its composition changed. The representatives of the family are isomorphic to those of the Sigmoidilinidae with a fully porcellaneous wall.

Subfamily **SPIROLOCAMMININAE** subfam. nov.

Test sigmoiline in its most part or with the early part sigmoiline, later planispiral; wall agglutinated on an organic or a calcareous base; aperture without a tooth. Lower Miocene to Holocene.

Spirolocammina Earland, 1934 (type genus)

Type species: *Spirolocammina tenuis* Earland, 1934

Test minute, strongly elongated and strongly flattened, coiling nearly planispiral with a sigmoiline curve in the long axis; chambers narrow, tubular, of nearly equal width along the chamber; wall finely agglutinated on an organic base; aperture rounded on an elongated neck, without a tooth. Holocene.

Remarks. The genus is transferred from the Rzehakinidae.

Spirosigmoilinella Matsunaga, 1955

Type species: *Spirosigmoilinella compressa* Matsunaga, 1955.

Test small, broadly ovate, early chambers show a sigmoid curve, later planispiral; chambers very narrow, of equal width along their length; wall finely agglutinated on an organic base; aperture rounded, on a short neck, without a tooth. Lower Miocene to Middle Miocene.

Remarks. This genus differs from *Spirolocammina* in its broader test and shorter neck. These features are more of specific value and the genus needs further reinvestigation to support its validity. The genus is transferred from the Rzehakinidae.

Ammosigmoilinella Zheng, 1988

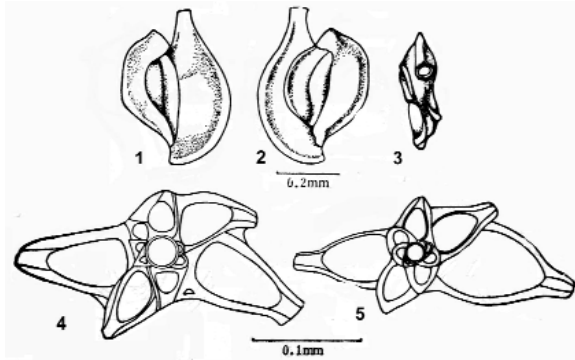


Figure 3. *Ammosigmoilinella* Zheng, 1988. 1-3. Lateral and apertural views of type species, *Ammosigmoilinella eximia* Zhang, 1988. 4-5. Transverse sections.

Type species: *Ammosigmoilinella eximia* Zheng, 1988
Test small, somewhat compressed, broad but tapering to the base and apertural end, which are both protruding, nearly fully evolute sigmoidal with 7 to 8 chambers visible externally, only last two chambers placed in one plane, peripheral margin looks as a wide opaque band; chambers broad, with the flattened sides in adults, tapering towards the base and the apertural neck, last chambers may be transversely wavy; wall very finely agglutinated on a calcareous base but not smooth; aperture semicircular on an elongated cylindrical neck, without a tooth. Holocene.

Remarks. The genus differs from the two other genera of the subfamily in its thicker nearly fully sigmoid test with only weakly developed planispiral part and in the form of the wider chambers having a peculiar peripheral margin. All these features only hardly could be considered as having taxonomic significance at the generic level. The siliceous granules in the shell wall mentioned by the author of the genus (Zheng, 1988) are likely sand grains. After Zheng dissolved the wall in weak HCl, only the soft envelope preserving the shell form was left. The small number of specimens studied (only four) and with most of them having a broken apertural end does not allow us to be certain about the absence of a tooth.

Initially placed into the subfamily Flintininae, this genus differs from the representatives of the above-mentioned subfamily in its shell structure, in the number and form of the chambers in the last whorls, in the absence of a well-developed special tooth, and in the agglutinated rather than porcellaneous wall.

Subfamily SIGMOILOPSINAE Vella, 1957

Test sigmoiline throughout or at the latest stage may turn planispiral; wall agglutinated on an organic or calcareous base; aperture with a tooth. Upper Cretaceous to Holocene.

Remarks. The sigmoidal part makes up the greater part of the test. Test is isomorphic to the porcellaneous *Sigmoilina*.

Sigmoilopsis Finlay, 1947

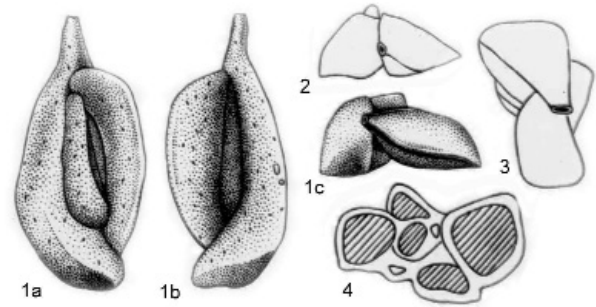


Figure 4. *Sigmoilopsis* Finlay, 1947; *Sigmoilopsis procericollis* Mikhalevich, 1977 (x78), coast of West Africa, near Monrovia, 58 m, vessels of ATLANTNIRO (from Mikhalevich, 1983). 1a-c. External view of the shell (side views and apertural view); 2-3. Outlines of the apertural views of two other specimens; 4. Transverse section of another specimen.

Type species: *Sigmoilina schlumbergeri* Silvestri, 1904
Test ovate in outline, thick, sigmoid throughout or slightly planispiral at the very adult stage, peripheral margin narrow to subacute; chambers narrow, four or more of them visible on one side, three or more at the opposite side; wall agglutinated on a calcareous base; aperture circular, with a tooth. Miocene to Holocene.

Remarks. In the type species the peripheral margin is narrowly oval, wall thick and rather rough, apertural end slightly tapering and short. In *S. procericollis* Mikhalevich, 1977 the peripheral margin is subacute and chambers are subangular, wall thin and finely agglutinated, apertural end extended into thin elongated neck. These features could be considered as variable within the genus as the main features of the two species (the character of coiling and the presence of the tooth) are those characteristic for the genus. The character of the peripheral margin and of the length of the apertural neck varies within the genus as can be seen in the species *S. arenata* and *S. flintii* (Mikhalevich, 1983, figs. 176 - 178). The thickness of the outer agglutinated layer and the roughness of the surface also varies. Thus it is very rough and thick in *S. flintii*, less so in *S. arenata*, finely and rather smoothly agglutinated in *S. procericollis*. In specimens of *S. schlumbergeri* from the coast of West Africa (Mikhalevich, 1983) it is somewhat less rough than in *S. arenata*, but consti-

tutes a layer of significant thickness similar to the *S. schlumbergeri* described by Schlumberger (1887) from the Gulf of Gascogne, France. The genus is here transferred from the Miliolacea.

Silicosigmoilina Cushman & Church, 1929

Type species: *Silicosigmoilina californica* Cushman & Church, 1929.

Test ovate in outline, thick, sigmoid throughout, at the last stage appearing to be pseudotriloculine; chambers broad, only three chambers visible on one side, two on the opposite side; wall agglutinated on an organic base; aperture rounded to ovate, with a small tooth. Upper Cretaceous to Paleocene.

Remarks. The genus is transferred from the Rzehakinidae.

Family **SCHLUMBERGERINIDAE** Mikhalevich, 1980

Test glomerate, with five or more planes of coiling; wall agglutinated on a calcareous base; aperture with a trematophore. Lower Cretaceous? to Holocene.

Schlumbergerina Munier-Chalmas, 1882

Type species: *Schlumbergerina arenifora* Munier-Chalmas, 1882.

Test elongated, with tapering ends; chambers tubular, slightly inflated, of nearly equal width along the chamber, many of them visible from the outside; wall agglutinated on a calcareous base; aperture directed laterally, with trematophore. Holocene.

Remarks. Test is isomorphic to the porcellaneous *Miliola*. The very latest chambers may be situated planispirally as can be seen from the section. The genus transferred from the Miliolacea.

? *Tekkeina* Farinacci & Yeniay, 1994

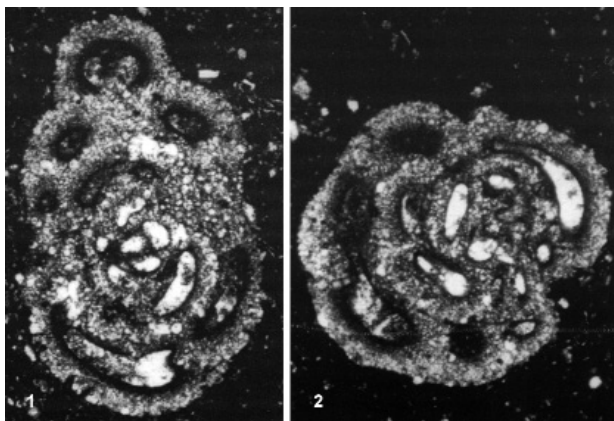


Figure 5. 1. Holotype of *Takkeina anatoliensis* Farinacci and Yeniay, 1994, Tekke section, western Taurus, Turkey, $\times 30$; 2. Paratype, $\times 30$.

Type species: *Tekkeina anatoliensis* Farinacci & Yeniay, 1994

Test with coiling initially streptospiral, later irregularly planispiral, evolute; whorls partially overlapping on the lateral sides; "wall of two layers, the outer layer is thick, made of coarse agglutinated sparry calcite grains, the inner one thin, of black material" (Farinacci & Yeniay, 1994); aperture presumed to be simple, at the base of the septa, shape unknown. Upper Cretaceous (Santonian).

Remarks. This is a doubtful genus as neither the exterior view, nor the aperture are known. It also seems to have nothing in common with the subfamily Ammobaculinidae where it was originally placed (Farinacci & Yeniay, 1994).

Family **AMMOFLINTINIDAE** fam. nov.

Test planispiral or irregularly planispiral, may be with small initial quinqueloculine part, with three chambers per whorl; chambers wide, wedge-shaped or tending to be pyriform; wall agglutinated on an organic or on a calcareous base; aperture with or without a tooth. Holocene.

Remarks. The shape of the chambers (rather wide rather than of long tubular form) and their number per whorl (three) influencing the whole outline of the test distinguishes this family from all other families of the order Schlumbergerinida.

Subfamily **AMMOFLINTININAE** subfam. nov.

Test irregularly planispiral; wall agglutinated on an organic base; aperture without a tooth. Holocene.

Ammoflintina Earland, 1934 (type genus)

Type species: *Ammoflintina trihedra* Earland, 1934.

Test roughly triangular or subquadrate in outline, flattened on one side, with one or two irregularly planispiral whorls; chambers broad, wedge-shaped; wall finely agglutinated; aperture at the somewhat narrowed edge of the final chamber, wide circular opening without a tooth. Holocene.

Remarks. The genus is transferred from the Rzehakinidae.

Subfamily **PSEUDOFLINTININAE** subfam. nov.

Test with an early very small and unclear quinqueloculine part, later planispiral; earlier chambers half coil in length, later chambers, forming the larger part of the test - three per whorl; aperture with a tooth. Holocene.

Remarks. This subfamily differs from the subfamily Ammoflintininae by the presence of quinqueloculine coiling in its initial part, in its wall agglutinated on a calcareous base, and in its aperture provided with a tooth.

Pseudoflintina Saidova, 1981 (type genus)

Type species: *Miliolina triquetra* Brady, 1879.

Test flattened, subtriangular in outline, early part visible only in sections with the chambers half a coil

in length in quinqueloculine arrangement, later chambers planispiral, three per whorl and more loosely coiled, subcylindrical or pyriform; wall externally rather coarse; aperture at the constricted end of the final chamber, rounded, with a short simple tooth. Holocene.

Remarks. The genus is transferred from the Miliolacea.

DISCUSSION

The schlumbergerinids represent a peculiarly well-defined foraminiferal group which is characterised by the predominance of several special shell types (miliolid types) not occurring in any other foraminiferal phyletic line except the class Miliolata. They differ from their isomorphic forms within the subclass Miliolana in the agglutinated character of their wall (mainly agglutinated on an organic base). Genera having a thick agglutinated layer of the wall though underlain by a thin calcareous layer characteristic for the porcellaneous miliolids are also included here in the order Schlumbergerinida. They are regarded as transitional forms between these two types of the wall, as was shown for some species of *Dentostomina* and *Siphonaperta* (Mikhalevich *et al.*, 1986). Following the insight of Arnold (1978a,b; 1979) the primitive miliolids arose firstly as forms with a tectinous shell wall (*Periptygma* Arnold, 1978a). The next step in their evolution was obviously represented by forms with an agglutinated wall on an organic base, and later on a secreted calcareous base.

From this point of view, the shell form is here regarded as being more conservative than the composition of the shell wall and is conserved and repeated during geologic time. The gradual changes of the composition of the shell wall from organic, then to agglutinated, and finally to calcareous took place in the presence of a shell morphostructure that was already composed. The agglutinated isomorphs of calcareous forms may represent ancestral forms or closely related sister groups to the latter ones.

The wall of all these forms as well as the wall of the porcellaneous miliolids was usually considered to be imperforate. Nevertheless, occasional pseudopore openings that penetrate the whole thickness of the wall have been observed in some species (Mikhalevich, 2004, Mikhalevich *et al.*, 1986).

The constructive opportunities of the agglutinated wall are fewer than those of the porcellaneous calcareous wall and the variability and complexity of the apertural apparatus of such forms is usually more poorly represented. In rare genera a complex trematophore is developed. The inner complication of the chamber lumen in these agglutinated forms is not developed, in contrast with their porcellaneous isomorphs.

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KEY TO THE GENERA OF THE ORDER SCHLUMBERGERINIDA

- 1(35) Shell more or less elongated, oval in outline, with two tubular chambers per whorl, each half coil in length.
- 2 (7) Coiling planispiral throughout - family Rzehakinidae.
- 3 (4) Shell flattened but thickening at the centre because of the partly overlapping chambers, chambers broad, inflated at their inner side, aperture without a tooth - subfamily Rzehakininae, *Rzehakina*.
- 4 (3) Shell fully evolute; all chambers visible from both sides.
- 5 (6) Aperture without a tooth - subfamily Psamminopeltinae, *Psamminopelta*.
- 6 (5) Aperture with a tooth - subfamily Spiroglutininae, *Spiroglutina*.
- 7 (2) Other types of coiling.
- 8 (17) Coiling quinqueloculine - Family Miliamminidae.
- 9 (10) Aperture without a tooth - subfamily Birsteiniollinae, *Birsteiniolla*.
- 10 (9) Aperture with a tooth - subfamily Miliammininae.
- 11 (12) Shell wall agglutinated on an organic base - *Miliammina*.
- 12 (11) Shell wall agglutinated on a calcareous base.
- 13 (14) Aperture in the adults with multiple teeth - *Dentostomina*.
- 14 (13) Aperture in the adults with a single tooth.
- 15 (16) Shell at the adult stage pseudotriloculine, with only three chambers visible externally - *Agglutinella*.
- 16 (15) Shell wholly quinqueloculine, subtriangular in section - *Siphonaperta*.
- 17 (18) Coiling triloculine - family Trilocularenidae,
- 18 (19) Aperture with a flap, shell wall agglutinated on an organic base - *Trilocularena*.
- 19 (18) Aperture with an inner tooth, shell wall agglutinated on a calcareous base - *Falsagglutinella*.
- 20 (23) Coiling massiline-type (early stage quinqueloculine, later planispiral) - family Ammomassilinidae.
- 21 (22) Aperture with a tooth - Silicomassilininae, *Silicomassilina*.
- 22 (21) Aperture with a trematophore - subfamily Ammomassilininae, *Ammomassilina*.
- 23 (32) Coiling sigmoidal - family Sigmoidopsidae.
- 24 (29) Aperture without a tooth - subfamily Spirolocammininae.

- 25 (26) Shell with nearly fully sigmoidal coiling, somewhat compressed but thick, with only the last two chambers planispiral - *Ammosigmoilinella*.
- 26 (25) Shell with a small sigmoidal part in the center of the shell, later part planispiral, strongly flattened.
- 27 (28) Shell strongly elongated, with a very long apertural neck - *Spirolocammina*.
- 28 (27) Shell broadly ovate, with short apertural neck - *Spirosigmoilinella*.
- 29 (24) Aperture with a tooth - subfamily Sigmoilopsinae.
- 30 (31) Shell with four or more chambers visible on one side, three or more on the opposite side - *Sigmoilopsis*.
- 31 (20) Shell in adult stage looking pseudotriloculine: with three chambers visible on one side, only two on the opposite side - *Silicosigmoilina*.
- 32 (23) Coiling in more than five planes like in Schlumbergerina - family Schlumbergerinidae.
- 33(34) Aperture as a trematophore - *Schlumbergerina*.
- 34 (33) Aperture unknown - ? *Tekkeina*.
- 35 (1) Shell wide, subquadrate or subtriangular in outline, with more than two (usually three - three and a half) broad chambers per whorl - family Ammoflinterinidae.
- 36 (37) Aperture without a tooth - *Ammoflinterina*.
- 37 (36) Aperture with a tooth - *Pseudoflinterina*.

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