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PROBLEMS ON BISERIAMMINOIDEA, MISSISSIPPIAN-PERMIAN BISERIALLY COILED FORAMINIFERA. A REAPPRAISAL WITH PROPOSALS

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Abstract

A reappraisal of the biserially coiled Palaeozoic Biseriamminoidea leads to revise the so-called primitive Biseriamminidae, the possibly transitional family Koktjubinidae and the typical Globivalvulinidae. The superfamily Biseriamminoidea belongs to the Foraminifera (class) Fusulinida (order) Endothyrina (suborder). The following Biseriamminidae are discussed: *Biseriammina* and *Lipinella* (Biseriamminininae); *Dariopsis,* and *Globochernella* (Dariopsinae); the Koktjubinidae: *Koktjubina, Dzhamansorina,* and *Admiranda. Globispiroplectammina*, assigned by some authors to the Biseriamminoidea, is excluded from this group and related to *Spireitlina*. The stratigraphical distribution of the Biseriamminidae is limited to the Mississippian (Tournaisian and Visean); the Koktjubinidae can survive up to the Moscovian. The Globivalvulinidae (?latest Tournaisian; late Visean-latest Permian) are subdivided here into four subfamilies: Globivalvulininae, Paraglobivalvulininae, Dagmaritinae, and Paradagmaritinae, especially developed in the late Middle and Late Permian. The following genera are listed: *Biseriella, Globivalvulina, Tenebrosella, Charliella, Siphoglobivalvulina, Retroseptellina, Septoglobivalvulina, Paraglobivalvulina, Paraglobivalvulinoides, Urushtenella, Sengoerina, Dagmarita, Bidagmarita, Louisettita, Paradagmarita, Siphodagmarita, Paradagmaritopsis, Paradagmaritella, Paradagmacrusta* and *Paremiratella*. The biozones based on the Permian genera are generally short and precise, while the stratigraphical importance of *Globivalvulina* sensu lato must be clarify, especially during the Pennsylvanian. Some palaeobiogeographical data are provided, which prove the close relations of Iran and China, at least during the Late Permian but probably also during the entire Carboniferous and the Early and Middle Permian.

Key words: Foraminifera, Permian, Carboniferous, Taxonomy, Biostratigraphy, Palaeogeography.

Resumen

La revisión de los foraminíferos paleozoicos que presentan un enrollamiento biserial ha dado como resultado la enmienda de las familias Biseriamminidae, Koktjubinidae y de las formas típicas que se consideran aquí como Globivalvulinidae emend. Todas estas familias plantean muchos problemas de definición, límites genéricos y de mono o polifiletismo, es decir, de taxonomía en general. Los Biseriamminidae son parte de estas formas del suborden Endothyrina que poseen una pared microgranular sencilla o gruesa, a veces con aglutinado calcáreo. Se describen los siguientes géneros: *Biseriammina, Lipinella, Dariopsis* y *Globochernella*. Se han detectado tendencias intermedias entre los Koktjubinidae: *Koktjubina, Dzhamansorina, Admiranda*, que fueron muchas veces confundidas con *Biseriella* o *Biseriammina sensu lato*. La distribución estratigráfica de los Biseriamminidae queda

limitada al Tournaisiense y al Viseense; los Koktjubinidae son siempre raros, aunque están presentes desde el Viseense-Serpukhoviense hasta al Bashkiriense-Moscoviense. El tercer grupo está constituido por la familia Globivalvulinidae, recientemente dividida en cuatro subfamilias: Globivalvulininae, Paraglobivalvulininae, Dagmaritininae y Paradagmaritininae. Los géneros siguientes son mencionados: *Biseriella, Globivalvulina, Tenebrosella, Siphoglobivalvulina, Charliella, Retroseptellina, Septoglobivalvulina, Paraglobivalvulina, Paraglobivalvulinoides, Urushtenella, Dagmarita, Bidagmarita, Louisettita, Crescentia, Siphodagmarita, Paradagmarita, Paradagmaritopsis, Paradagmaritella, Paradagmacrusta* and *Paremiratella*. Finalmente, se indica la importancia bioestratigrafica y palaeobiogeográfica de los tres grupos, y los problemas que tendrán que ser resueltos en próximos trabajos.

Palabras clave: Foraminíferos, Pérmico, Carbonífero, Taxonomía, Bioestratigrafía, Paleogeografía.

INTRODUCTION

The biserially coiled Foraminifera are rare from the Triassic to Holocene. Recently, Tyszka (2006, p. 8), in his review of the types of growth of Foraminifera, indicated: "even 'coiled biserial' forms, that seem to be nonexistent (...) are known from reality (sic) as *Plectorecurvoides* (...) or the whole superfamily Cassidulinacea". This author has only forgotten the existence of a group which was relatively widespread during the Carboniferous and Permian, namely the Biseriamminoidea. Their ontogenesis is probably the most complicated to reconstruct among Palaeozoic Foraminifera but they can be compared with the modern *Cassidulina* or *Cassigerinella* (see Fig. 1. 1-5), and considered as "similar to a *Textularia* coiled along one of its great sides" (Reichel, 1946, p. 549). Several genera of the group remain problematic because of their rare occurrences in the geological series, and the difficulty to combinate the complementary sections: axial, transverse, tangential to the apertures, and subaxial showing the elements of endoskeleton. The biostratigraphic value of this group was probably underestimated in the Carboniferous (e.g., Perret, 1993; Pinard & Mamet, 1998). In term of palaeobiogeography and biostratigraphy, the group seems to be fundamental during the Permian times (Gaillot, 2006; Gaillot & Vachard, submitted; Gaillot *et al.*, submitted a, b). The Carboniferous genera of Marfenkova (1991) were neglected for a long time, but they now appear as potentially useful. The aim of this preliminary paper is a reappraisal of the group and a discussion of very important problems in its history: (1) the origins; (2) the Viséan/Serpukhovian lineages; (3) the nomenclatural problem of the genus *Globivalvulina* and its limit with "*Biseriella*"; (4) some specific and generic problems of Pennsylvanian globivalvulinids; (5) the Pennsylvanian-early Cisuralian acme; (6) the decrease in diversity during the late Cisuralian-Early/Middle Guadalupian; (7) the possible causes of the flourishment during the Lopingian and the behaviour of the group at the Permian-Triassic Boundary.

PREVIOUS WORK

The history of the taxonomical description of group is well known (see Palmieri, 1988; Pinard & Mamet, 1998). The first species was created by Brady (1876) under the name *Valvulina bulloides*, and the genus *Globivalvulina* was erected by Schubert (1921). Chernysheva (1941) created the genus *Biseriammina* and the second species of *Globivalvulina*, *G. parva*, was later described by Chernysheva (1948). Then, five milestone studies were published by Reichel (1946), Plummer (1948), Morozova (1949) and Reitlinger (1949, 1950), mainly concerning the late Tournaisian, middle Pennsylvanian, and Early and Late Permian species. The last important group of Carboniferous species of *Globivalvulina* were published by Konovalova (1962), and a synthesis was finally provided by Pinard & Mamet (1998). The genus *Biseriella* warmly advocated by Mamet,

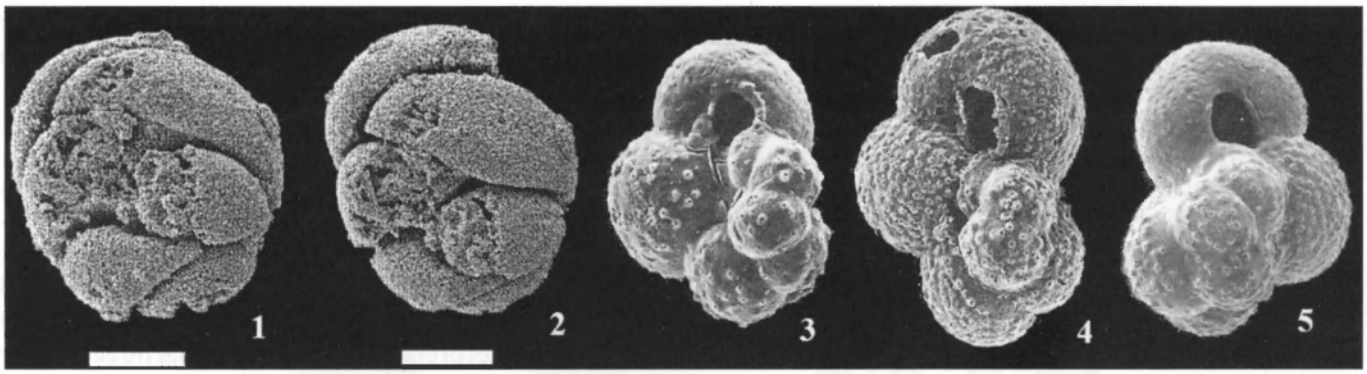


FIGURE 1–Comparison between the coilings of *Globivalvulina* (*1-2*) and *Cassigerinella* (*3-5*). *1-2*, *Globivalvulina* sp. Two specimens in dorsal view (collection Błazejowski, ZPAL F.56/I/SPI-6), Spitsbergen, Kapp Starostin Formation, Late Permian. Scale bars = 0.200 mm. *3-5*, *Cassigerinella boudecensis* Pokorny, 1955 sensu Li Quianyu, 1986. Three dorsal views showing three types of coiling (more or less twisted) and the apertures. Cipero Formation, Trinidad, Miocene, P21 zone. (*3* = Pl. 1, Fig. 1, x 250; *4* = Pl. 1, Fig. 2, x 170; *5* = Pl. 1, Fig. 4, x 170).

Brenckle or Groves was often quoted in the studies during the seventies. An interesting but controversed contribution was given by Marfenkova (1991). Diverse Permian genera were described between 1965 and 1981 by Reitlinger (1965), Lys & Marcoux (1980) and by workers of the "Geneva school" (e.g., Bronnimann, Zaninetti, Altiner, Jenny-Deshusses) with new genera such as *Dagmarita, Paraglobivalvulina, Paraglobivalvulinoides*, and *Paradagmarita*. The genera *Tenebrosella* Villa & Sanchez de Posada, 1986 and *Verispira* Palmieri, 1988, later described, remain poorly mentioned in the literature. Recent contributions were published by Altiner (1997, 1999), Altiner & Ozkan-Altiner (2001), Mohtat-Aghai & Vachard (2003, 2005), and Brenckle (2005). A revision of the Late Permian taxa has been prepared by Gaillot (2006) and Gaillot & Vachard (submitted).

The great micropalaeontological treatises and/or important revisions successively analyzed the biseriamminoids as follows:

1. Sigal (1951) in Piveteau's Treatise assigned (p. 174) *Biseriammina* to the (Textulariida) Lituolinae while *Globivalvulina* was attributed (p. 164) to the Tetrataxinae.

2. Orlov's Treatise (1959) listed only one family: Biseriamminidae with two genera: *Biseriammina* and *Globivalvulina*.

3. Loeblich & Tappan in Moore's Treatise (1964, p. C338) described the unique family Biseriamminidae synonimized with Globivalvulinidae, and composed of *Biseriammina, Globivalvulina*, and *Olympina* Reichel (1946). This latter is in fact a nodosarioid similar to *Robuloides*.

4. Conil *et al.* (1980) only took into account the Visean Biseriamminidae: *Biseriammina, Lipinella, Biseriella* and *Globispiroplectammina*.

5. Zaninetti & Altiner (1981) considered one family (Biseriamminidae) subdivided into two subfamilies: Biseriamminiae: *Biseriammina, Globivalvulina, Paraglobivalvulina, Biseriella*?, *Globispiroplectammina*; and Dagmaritinae, with *Dagmarita, Paradagmarita* and *Louisettita*.

6. Contrary to the Treatise of 1964, the second monumental work of Loeblich & Tappan (1987) was of fundamental importance because the authors did not consider the Palaeozoic literature (especially Russian) as a hotchpotch of synonyms. Loeblich & Tappan (1987) subdivided the family Biseriamminidae into three subfamilies: Biseriamminiae Chernysheva, 1941 (with *Biseriammina, Biseriella, Globispiroplectammina, Globivalvulina, Lipinella, Paraglobivalvulina, Paraglobivalvulinoides*); Dagmaritinae Bozorgnia, 1973 (with *Dagmarita* and *Paradagmarita*) and Louisettitinae Loeblich & Tappan, 1984 (with only *Louisettita*).

7. Rauzer-Chernoussova *et al.* (1996) described the superfamily Biseriamminacea belonging to the order Palaeotextulariina, with three families: Biseriamminidae, Dagmaritidae and Louisettitidae. The Biseriamminidae are composed of *Biseriammina, Biseriella, Globispiroplectammina, Globivalvulina, Lipinella, Paraglobivalvulina, Paraglobivalvulinoides*, and *Tenebrosella*. The Dagmaritidae are limited to *Dagmarita* and *Paradagmarita* and the Louisettitidae are monogeneric with *Louisettita*.

THE ORIGINS OF THE LINEAGES

The origins of the group are peculiarly obscure with unsolved questions about the mono- or polyphyletism and recurring features in wall microstructures (i.e., granular versus microgranular wall). Because of the particularity of the biserially coiled development combined with the spectrum of microstructural types of wall, we accept the monophyletism of the group, and therefore, the lineage Biseriamminidae, Koktjubinidae and Globivalvulinidae. Another question is: Are related forms like Biseriamminidae, Globivalvulinidae, Palaeotextulariidae and Tetrataxidae constituting a homogenous monophyletic suborder of Fusulinida: Palaeotextulariina Hohenegger & Piller, 1975, different from Endothyrina or Tournayellina? The Palaeozoic foraminiferal coilings differ sensibly from those of other periods, because biseriate coiled tests are numerous, whereas trochospiral forms are only known in the superfamily Tetrataxoidea. In fact, these particular types of coiling could justified the reality of the suborder Palaeotextulariina Hohengger & Piller, 1975 (more than of the poor arguments of its authors, moreover). Nevertheless, because the lineages with a terminal biseriate coiling have many unlinked initial coiled parts (e.g., endothyrid, chernyshinellid, haplophragmellid), this order is not admitted here. It is more likely that numerous Endothyrina and Tournayellina exhibit a terminal biseriate part and *Biseriammina* is related with a simple granuliferelloid Endothyrina (i.e., a representative of the superfamily Haplophragmelloidea sensu Rauzer-Chernousova *et al.*, 1996). Consequently, Biseriamminoidea should belong to the suborder Endothyrina, as well as Tetrataxoidea and Palaeotextularioidea.

After its first appearance datum (FAD) in the late Tournaisian with *Biseriammina uralica* Chernysheva, 1941 and *Globivalvulina*? *bristolensis* Reichel, 1946, the group seems to disappear almost completely during the early-middle Viséan (e.g., Conil *et al.*, 1980), although some forms are rarely present (Meissami *et al.*, 1978; Marfenkova, 1991).

The genus *Biseriammina* is especially poorly known and it was not re-found in the Tournaisian of Urals, where subsequent detailed studies were nevertheless performed (e.g., Malakhova, 1956; 1975a, b; Lipina, 1965; Brenckle, 1997a). Two explanations are possible: (1) *Biseriammina* is very rare (only one true microphotograph of *B. uralica* was provided in the literature; i.e, Grozdilova *et al.* (1975, Pl. 1, Fig. 7) re-illustrated here Fig. 2.1 and a *Biseriammina* sp. sensu Ganelina (1966, Pl. 12, Fig. 17), while many illustrations must be excluded of the genus: *Globivalvulina uralica* sensu Deleau & Marie, 1961 (= *Endothyra prisca*); *Biseriammina* sp. sensu Sánchez *et al.*, 1991 (= *Plectogyranopsis*, *Cribrospira* or "*Bibradya*"); *Biseriammina*? sp. sensu Igo & Adachi, 1981 (= *Globivalvulina eogranulosa*); (2) *Biseriammina* was misinterpreted, because of the great difficulty to combinate the transverse, axial and oblique sections. Possibly, the transverse sections have been confused with endothyroid or chernyshinelloid taxa, and the axial ones interpreted as Palaeotextulariidae and/or *Palaeospiroplectammina*. The absence of *Biseriammina*, among the isolated specimens of Michelsen (1971), is notable. Consequently, *Biseriammina* might be a teratogenic form of another genus (compare with the "double tests" of Recent *Ammonia* illustrated by Stouff *et al.*, 1999, Pl. 1, Figs. 3-5). For example, one of the idealized subtransverse section of Chernysheva (1941) looks like *Septatournayella pseudocamerata* Lebedeva, 1954, illustrated by Michelsen (1971, Pl. 7, Fig. 1), and might be a double test of this species. Furthermore, some taxa are diversely interpretable; e.g., *Endothyra (Birectoendothyra) schlykovae* Poyarkov in Lipina (1970) from the Tian-Shan (Fig. 2.2) could constitute another misinterpreted section of *Biseriammina* or a related genus; this explanation can be also proposed for *Chernyshinella (Birectochernyshinella) mirabilis* (Lipina, 1948), *C. (R.) spinosa* (Lipina, 1955), "*Palaeospiroplectammina*" *parva* (Chernysheva, 1940), and *P.* ? *sibirica* (Lebedeva, 1954) (reproduced here Fig. 2. 3). In this case, many forms considered as uncoiled biseriate are probably entirely biseriate, including the initial coiled part, not only endothyroid or chernyshinelloid as traditionally to a teratogenic form interpreted. In general, this interpretation could explain the several Palaeozoic "*Spiroplectammina* " that were never re-found after their creation.

As *Biseriammina*, *Globivalvulina*? *bristolensis* seems to be poorly known and/or endemic. It is indeed only described from England (e.g., Reichel, 1946; Austin *et al.*, 1974), eastern Ireland (Devuyst, 2006, Fig. 4. 26. 15-18, 21-22), Belgium (Hance *et al.*, 1981; Devuyst, 2006, Figs. 2.29. 1-2; 2.32. 2-4, 8-10) and northern France (Avesnois; Mansy *et al.*, 1989).

Concerning the last ap pearance datum (LAD) of "*Globivalvulina*?" (= *Biseriella* auctorum), considered here as the first typical globivalvulinid, three hypotheses are proposed (Fig. 3 A-C):

1) Traditionally, the authors admit the lineage *Biseriammina-Globivalvulina*? *bristolensis- Globi-*

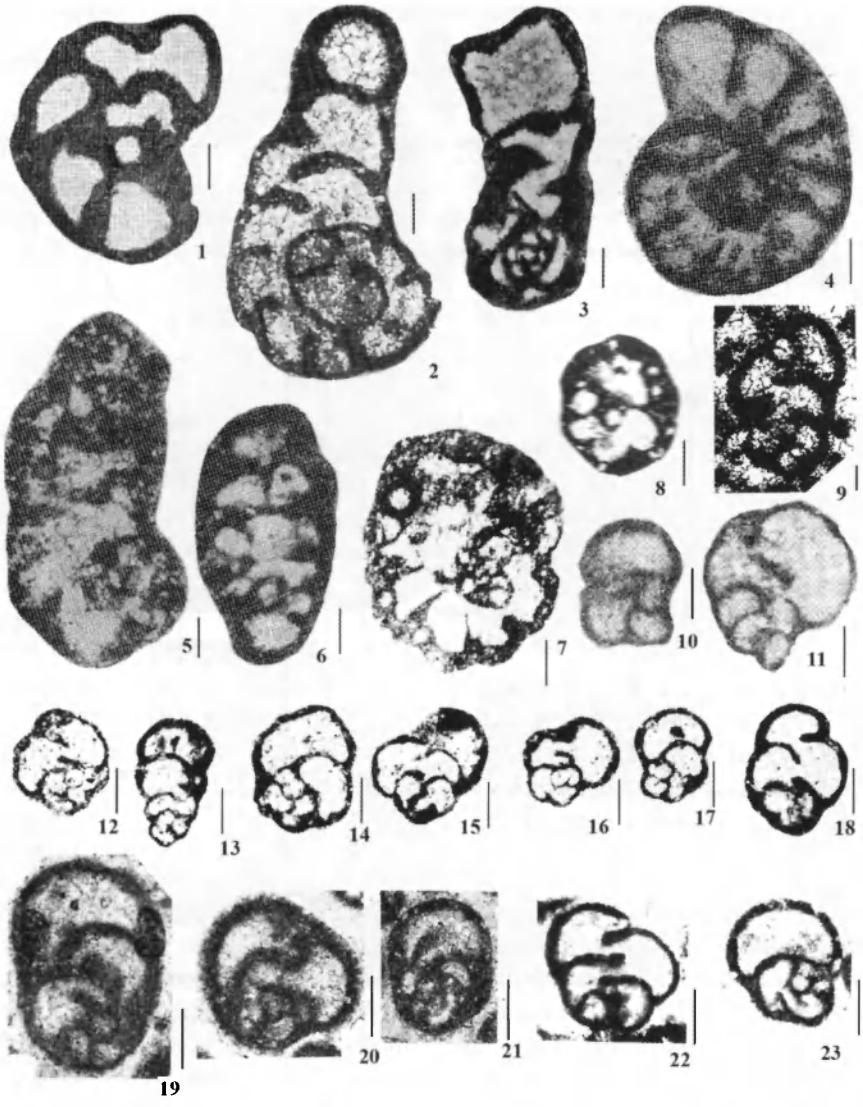


FIGURE 2–Biseramminidae and Koktjubinidae. *1, Biseriammina uralica* Chernysheva, 1941 according to Grozdilova *et al.*, 1975 (Pl. 14, Fig. 7), transverse section. *2, Endothyra (Birectoendothyra) schlykovae* Poyarkov in Lipina, 1970, holotype, subtransverse section (from Lipina, 1970, Pl. 1, Fig. 13) considered here as a possible equivalent of *Biseriammina*, Badamski Horizon, late Tournaisian, Tian-Shan. *3, Palaeospiroplectammina (?) sibirica* (Lebedeva, 1954) sensu Lipina 1965 (Pl. 24, Fig. 19), as another possible equivalent of *Biseriammina*, holotype, subtransverse section, lower part of Denisov limestones, Kuznetsk Basin. *4, Lipinella notata* Malakhova, 1975b (from Pl. 3, Fig. 14, holotype, Ust-Grekhovsky horizon (early Visean), southern Urals (Khudolaz river), Russia. *5-6, Dariopsis curviseptum* Malakhova, 1975b, 5, transverse section (= Pl. 2, Fig. 7), *6,* axial section (= Pl. 2, Fig. 12), Gusikhinsky horizon, southern Urals, Russia. *7, Globochernella braibanti* Hance, 1983 (= Pl. 2, Fig. 10), holotype, transverse section, Braibant, Condroz (Belgium), early Visean (Cf4). *8, Globochernella overlaui* Hance, 1983 (= Pl. 2, Fig. 5), holotype, transverse section, Braibant, Condroz (Belgium), early Visean (Cf4). *9, Koktjubina*? sp. 1 = *Globospiroplectammina* (sic) *windsorensis* (Mamet, 1970) sensu Brenckle, 1997b (= Pl. 4, Fig. 13), late Visean, Battleship, Nevada (USA). *10, Dzhamansorina grata* Marfenkova, 1991, paratype, transverse section, middle-late Visean, Kazakhstan. *11, Admiranda convexa* Marfenkova, 1991, holotype, axial section, Serpukhovian, Kazakhstan. *12-18, Dzhamansorina* sp. 1 (= *Globispiroplectammina* sp. nov. of Laloux, 1988), *12,* transverse section (= Pl. 1, Fig. 14), *13,* frontal subaxial section. (= Pl. 1, Fig. 15), *14,* transverse section (= Pl. 1, Fig. 16), *15,* sagittal subaxial section (= Pl. 1, Fig. 19), *16,* transverse section (= Pl. 1, Fig. 21), *17,* transverse section (= Pl. 1, Fig. 22), *18,* Sagittal axial section (= Pl. 1, Fig. 20). *19-21, Koktjubina*? sp. 2, *19* = *Biseriella*? *exotica* sensu Rich (1980, Pl. 4, Fig. 16), Chesterian, Bangor Limestone, Alabama, USA, *20-21* = *Biseriella parva* sensu Rich, 1980. *20,* axial section = Pl. 5, Fig. 7, *21,* Transverse section = Pl. 5, Fig. 10, Chesterian, Bangor Limestone, Alabama, USA. *22-23, Dzhamansorina* sp. 2 = *Biseriella parva* sensu Rich, 1982, *22* = Pl. 1, Fig. 17, *23* = Pl. 1, Fig. 18 (compare also with "undetermined Biseriamminidae" sensu Mamet, 1970, Pl. 1, Fig. 5), latest Visean or earliest Serpukhovian, Georgia (USA). Scale bars: 0.100 mm.

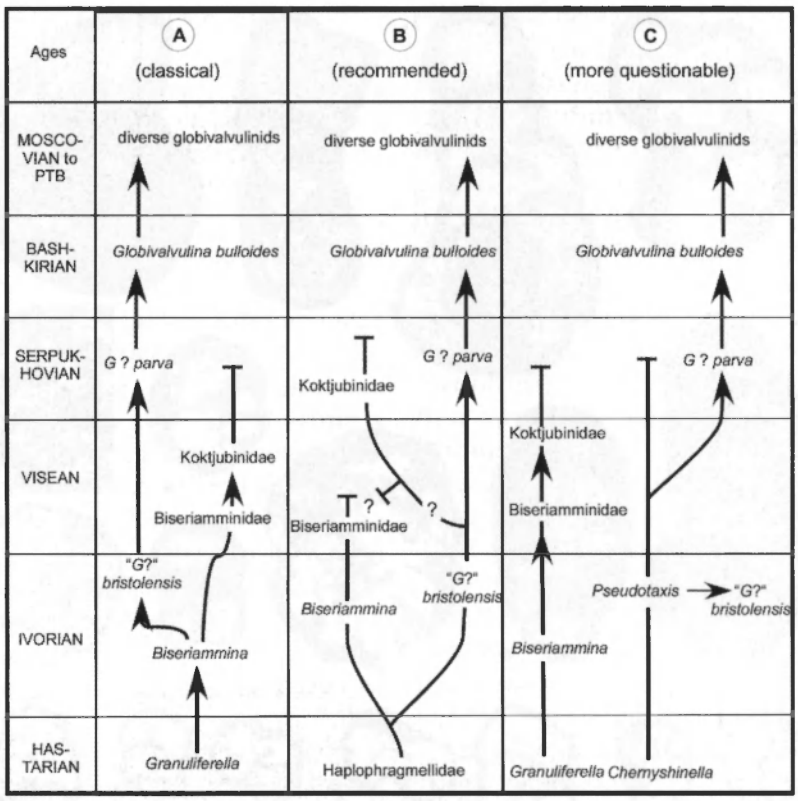


FIGURE 3–Hypotheses on the lineages of Biseriamminoidea. *A*, classical interpretation. *B*, consensual hypothesis. *C*, most probable phylogeny.

valvulina? *parva-Globivalvulina bulloides*- the diverse forms of globivalvulinids. The Koktjubinidae are not included in this lineage but can correspond to another branch diverging from *Biseriammina* (Fig. 3A). On the other hand, the transitional stages are apparently absent (a) between *Biseriammina* and *Globivalvulina*? *bristolensis*; (b) between *G.*? *bristolensis* and *G.*? *parva* (see Conil *et al.*, 1980 for this latter absence).

2) As *G.*? *bristolensis* and *G*? *parva* are very similar in coiling and size (and also herein *G.*? aff. *bristolensis*: Fig. 4. 6-8), and both distinct of *Biseriammina* (as already partly indicated by Palmieri, 1988, p. 32), a double origin can be proposed. The first lineage would comprise forms mainly with coarsely granular wall: the Biseriamminidae with the Biseriammininae and Koktjubininae. The second lineage would be composed of forms exhibiting a microgranular wall: the Globivalvulinidae. Some exceptions exist with *Dzhamansorina* in the first lineage and *Globivalvulina granulosa* in the second one. This intermediate hypothesis (Fig. 3B) is admitted here.

3) As *Pseudotaxis* is morphologically related to "*Biseriella*" (e.g., Mamet, 1974; Laloux, 1988), with a FAD slightly preceeding that of this latter, and because many confusions between *Pseudotaxis* and "*Biseriella*" exist (e.g., different illustrations of Laloux, 1988; Conil *et al.*, 1980; Vdovenko, 2001; as previously mentioned by Vachard & Beckary, 1991 and Brenckle, 2005), another filiation is possible (Fig. 3C): (a) on one hand, the late Tournaisian *Pseudotaxis eominima* is the ancestor of "*Biseriella*?" *bristolensis* (corresponding thus to an independent genus whose purely morphological characterization seems to be very difficult nowadays), (b) on other hand, the late Viséan *Pseudotaxis brazhnikovae* gave rise to the latest Viséan "*Biseriella*" *parva*, and then, to the Serpukhovian *Globivalvulina* and therefore, to the true Globivalvulinidae. Conversely, a derivation of *Biseriammina* from *Granuliferella* or another genus belonging to the Haplophragmellidae sensu Rauzer-Chernousova *et al.* (1996) is favored here. After that, from *Biseriammina* arise the other Biseriamminidae and the Koktjubinidae.

HOW MANY LINEAGES IN THE VISEAN?

After its FAD in the late Tournaisian, the group is very rarely mentioned in the early-middle Viséan interval (e.g., Mamet, 1970; Meissami *et al.*, 1978;

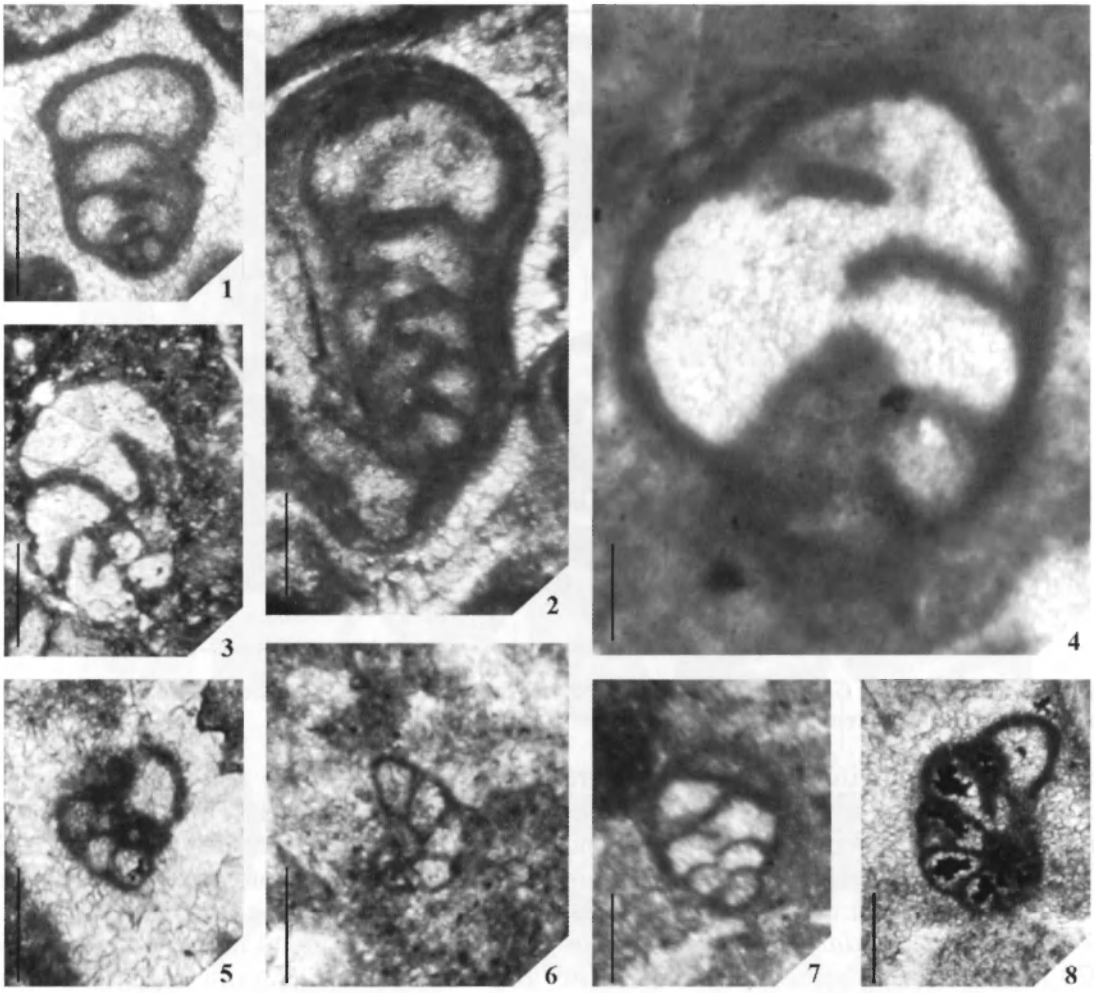


FIGURE 4–Koktjubinidae and primitive *Globivalvulina* of late Visean of southern France. Thin setions DV from collection D. Vachard (Lille, France), MA from collection Markus Aretz (Koln, Germany), and ML from samples of the collection Marie Legrand (Bordeaux, France). *1-2, Dzhamansorina* cf. *minima* (Vdovenko, 1962). *1,* axial section (Height = 0.275 mm), thin section DV293F, Lens of the road, near Roquessels (Montagne Noire), late Asbian. *2,* axial section (Height = 0.500 mm), thin section DV293H, Lens of the road, near Roquessels (Montagne Noire), late Asbian. *3, Globivalvulina*? ex gr. *parva* Chernysheva, 1948 (this section differs from the eponym species by less chambers of different shape), transverse section (Diameter = 0.330 mm), thin section ML789, photo 9.7/100, Laurens station (Montagne Noire, southern France), latest Brigantian. *4, Koktjubina* aff. *exotica* (Vdovenko, 1962), axial section (Height = 0.600 mm), thin section MAFW17, Vineyard of La Serre (Montagne Noire), latest Brigantian. *5, Dzhamansorina* aff. *kipshakensis* Marfenkova, 1991. The wall seems to be thicker and the chambers more closely arranged, axial section (Height = 0.170 mm), photo 9.8/75, thin section DV248, Vailhan (Montagne Noire), Brigantian. *6-8, Globivalvulina*? aff. *bristolensis* Reichel, 1946. *6,* transverse section (Diameter = 0.170 mm), photo 9.8/114, thin section DV327A, Vailhan (Montagne Noire). *7,* axial section, photo 9.9.6/, thin section DV328'A, Les Mentaresses (Montagne Noire), late Brigantian. *8,* transverse section, photo 9.9.6/7, Les Mentaresses (Montagne Noire), late Brigantian. Scale bars: 0.100 mm.

Conil *et al.*, 1980; Laloux, 1988; Marfenkova, 1991; Devuyst, 2006). Nevertheless, during this period, the Biseriamminidae might be represented by some poorly known genera: e.g., *Lipinella*, *Dariopsis*, and *Globochernella*.

Lipinella Malakhova, 1975b (= *Urtasella* Malakhova, 1979 nomen vanum fide Loeblich & Tappan, 1987) from the early Visean of southern Urals looks like the late Tournaisian (Kizelovsky horizon) *Biseriammina* of the same areas, because of their nautiloid, compressed tests with a weakly endothyroid, almost planispiral, biseriate, involute coiling. Their walls are brownish, calcareously agglutinated, or coarsely granular. *Lipinella* only differs from *Biseriammina* by the absence of sutures and a more inflated profile (see Conil *et al.*, 1980, p. 84). In all

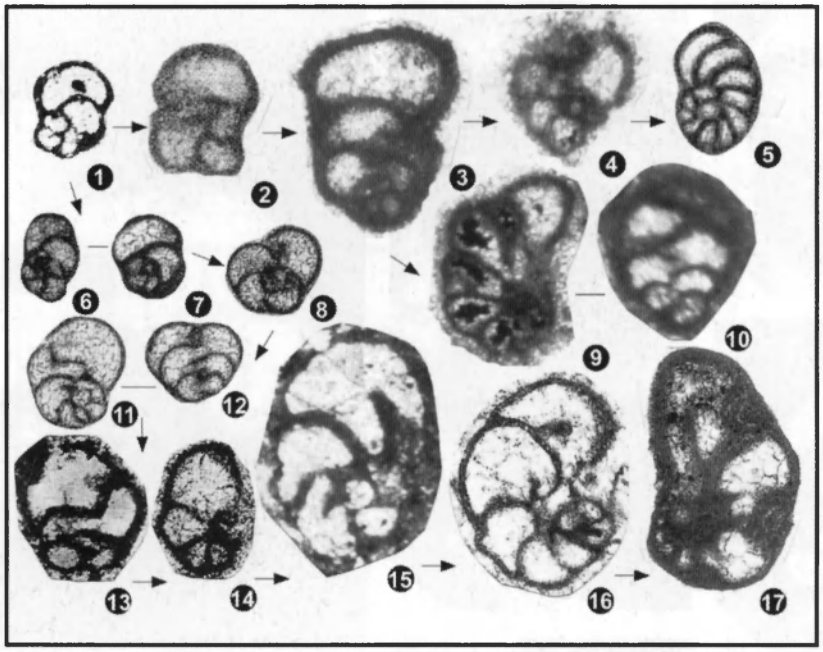


FIGURE 5–Hypothetical lineages of *Globivalvulina* and related taxa near the Viséan-Serpukhovian boundary. All the reproduced specimens are re-illustrated herein Figs. 2, 4 and 6.

the classications of Foraminifera, these criteria are considered as specific and not generic. The other *Biseriammina* or equivalents of Mamet (1970) and Brenckle (1997b, 2004) are generally late Viséan in age (early Asbian-Brigantian) and correspond to the first acme of the group. *Biseriammina*? *windsorensis* Mamet, 1970 is a late Viséan representative in Nova Scotia (eastern Canada). *Biseriammina* sp. 1 sensu Vachard, 1977 (p. 156, Pl. 6, Figs. 14-15; see also Vachard, 1974, Pl. 23, Figs. 14-16) is probably a composite of several sections of *Consobrinella* and *Latiendothyranopsis*. In the latest Viséan, these primitive small forms are more abundant (Conil *et al.*, 1980; Vachard & Berkhli, 1992; Cózar & Somerville, 2004, 2005, Somerville & Cózar, 2005; Okuyucu & Vachard, 2006). According to P. Cózar (pers. comm. October 2006), several Koktjubinidae and "*Biseriella*" are found in profusion in the late Viséan of Ireland. A detailed study of those forms would help in solving some phylogenetic problems, and defining a more complete lineage at the Viséan/Serpukhovian boundary.

Two early Viséan foraminiferal taxa are possibly linked to *Biseriammina* (or so enigmatic at least).

→

FIGURE 6–Koktjubinidae and *Globivalvulina* (late Mississippian-Pennsylvanian). *1-3, Koktjubina exotica* (Vdovenko, 1962). *1* = *Biseriella*? *exotica* (Vdovenko) sensu Rich, 1980 (= Pl. 5, Fig. 1), Chesterian, Bangor Limestone, Alabama. *2,* Holotype of Vdovenko in the original publication (Vdovenko, 1962, Pl. 3, Fig. 10) compared with the new figuration of Brenckle (2005, Pl. 10, Fig. 15), early Namurian, Kok Tyube, central Kazakhstan. *3,* The holotype, re-illustrated by Brenckle, 2005 (Pl. 10, Fig. 15), as an indication of the important re-looking of the previous Ukrainian and Russian holotypes. *4-5, Dzhamansorina minima* (Vdovenko, 1962). *4,* holotype (Pl. 3, Fig. 5 = Brenckle 2005 (Pl. 10, Fig. 16). *5,* paratype (= Vdovenko, 1962, Pl. 3, Fig. 4), early Namurian, Kok Tyube, central Kazakhstan. *6-7, Globivalvulina*? *bristolensis* Reichel, 1946 from Austin *et al.*, 1974. *6,* axial section (= Pl. 1, Fig. 6), *7,* transverse section (= Pl. 1, Fig. 8), Caninia Oolite, Great Britain. *8-12, Globivalvulina* ex gr. *parva* (*8-9* as *G. moderata* from Aisenverg *et al.*, 1958, *8* = Pl. 16, Fig. 8; *9* = Pl. 16, Fig. 9 (also illustrated in Aisenverg *et al.*, 1983, Pl. 12, Fig. 24), *10-12* as *G. parva*, Ukraine, southern slope of Voronezh Massif, early-late Serpukhovian. *13, Globivalvulina* aff. *eogranulosa* Reitlinger, 1949 (from Aisenverg *et al.*, 1958, Pl. 16, Fig. 10). Ukraine, southern slope of Voronezh Massif, early Serpukhovian. *14, Globivalvulina parva* Chernysheva, 1948. Re-illustration of a part of type material. *14,* paratype, transverse section (= Pl. 18, Fig. 1), *15* (= Pl. 18, Fig. 2 lectotype chosen herein), Syzran river (Russia), late Viséan. *16-17, Koktjubina*? *regularis* (Okimura, 1972), described as *Globivalvulina regularis*, respectively Pl. 50, Fig. 17 and Pl. 50, Fig. 16 of Okimura, 1972, Kitakami Massif, Japan, late Bashkirian.

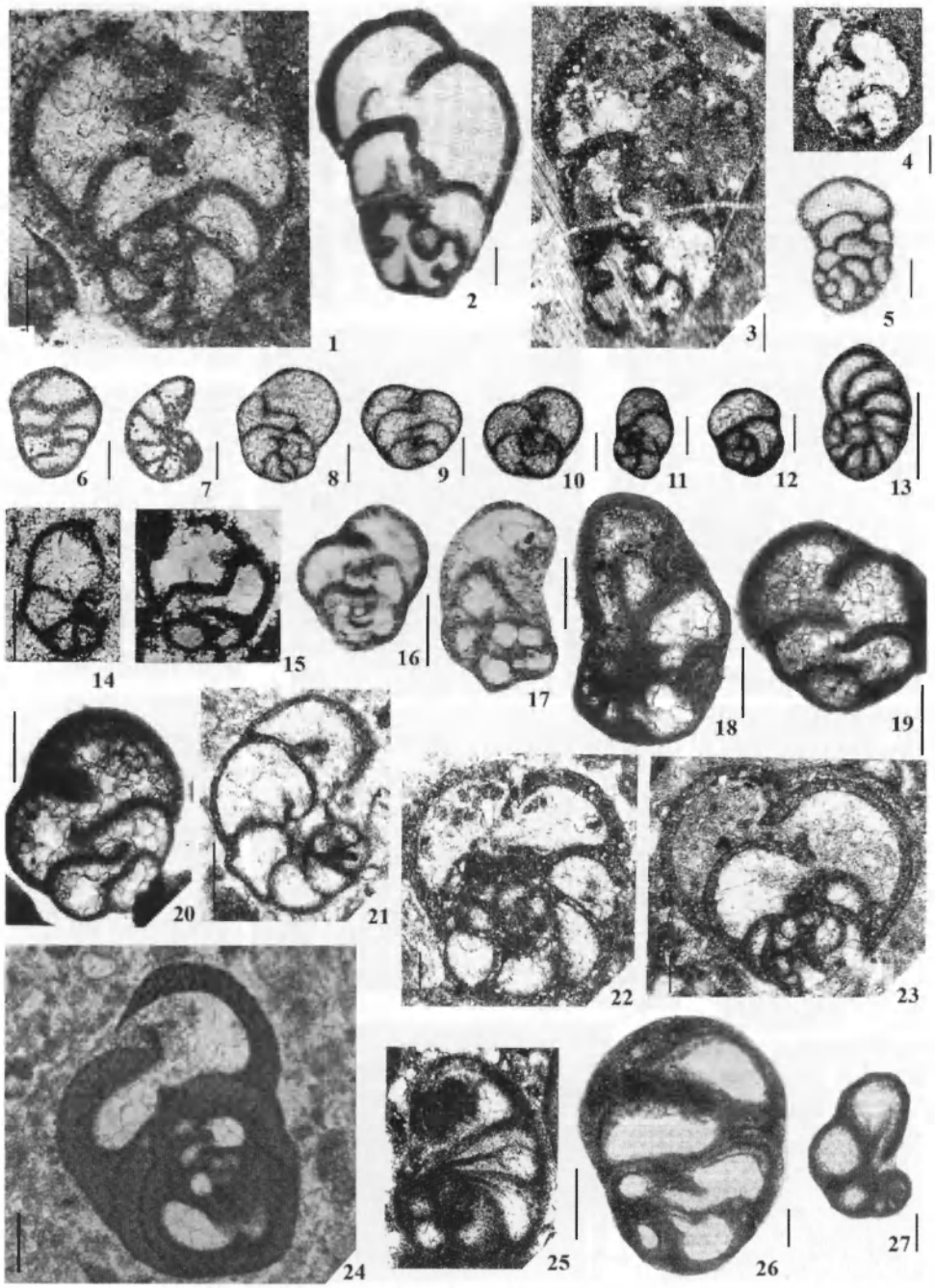


FIGURE 6–(continued). *18-20, Globivalvulina bulloides* (Brady, 1876), type material selected by Brenckle (2005, Pl. 7, figs. 18, 20 and 21 respectively). *18,* transverse section, lectotype selected by Brenckle (2005) contrary to the rules of ICZN. *19,* paralectotype, axial section. *20,* paralectotype, axial section previously illustrated by Brady (1876, Pl. 14, Fig. 4) and the logical lectotype to choose. All specimens from the Pennsylvanian of Iowa (USA). *21, Globivalvulina moderata* Reitlinger, 1949, holotype (Fig. 4a), transverse section re-illustrated by Brenckle (2005, Pl. 8, Fig. 8), Bashkirian of Bashkorotostan (Russia). *22-23, Globivalvulina granulosa* Reitlinger, 1950, *22,* holotype (Pl. 17, Fig. 5), transverse section re-illustrated by Brenckle (2005, Pl. 8, Fig. 3), *23,* paratype, axial section (see Brenckle, 2005, Pl. 8, Fig. 14 and Reitlinger, 1950, Pl. 17, Fig. 6). Myachkovian (late Moscovian) of southern Pre-Timan (Russia). *24, Tenebrosella asturica* Villa and Sánchez de Posada, 1986, holotype (= Pl. 1, Fig. 1), axial section, Villanueva de Pría, Asturias, northern Spain, early Moscovian. *25, Globivalvulina mosquensis* Reitlinger, 1950, paratype (Reitlinger, 1950, Pl. 16, Fig. 3, Brenckle, 2005, Pl. 8, Fig. 9), subtransverse section, Moscovian of Moscow Basin (Russia). *26, Globivalvulina syzranica* Reitlinger, 1950, axial section (paratype Pl. 16, Fig. 9), Syzran (Russia), Myachkovian (late Moscovian). *27, Globivalvulina minima* Reitlinger, 1950, holotype, transverse section, Rzhev river (Russia), Kashirian (early Moscovian). Scale bars: 0.100 mm.

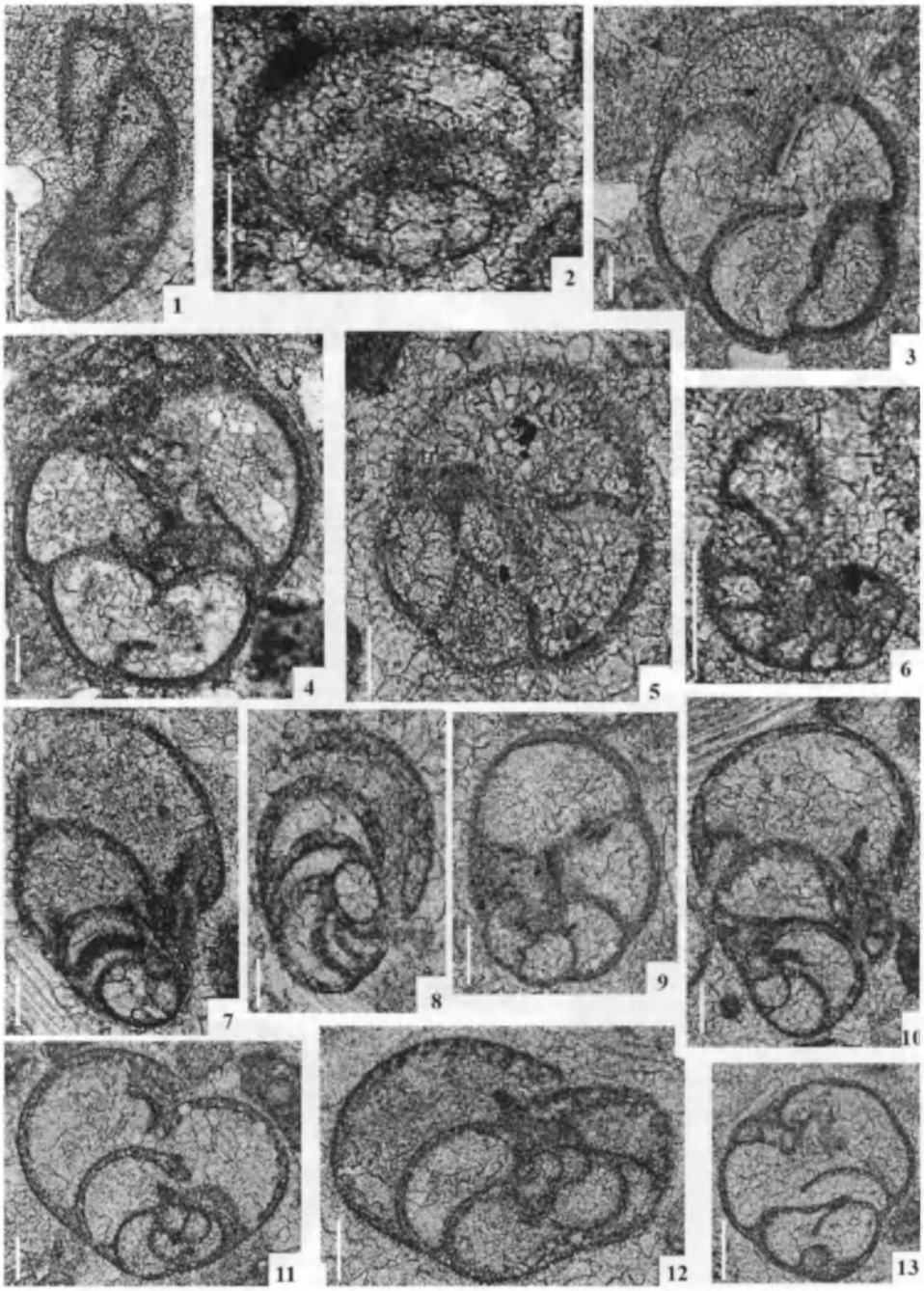


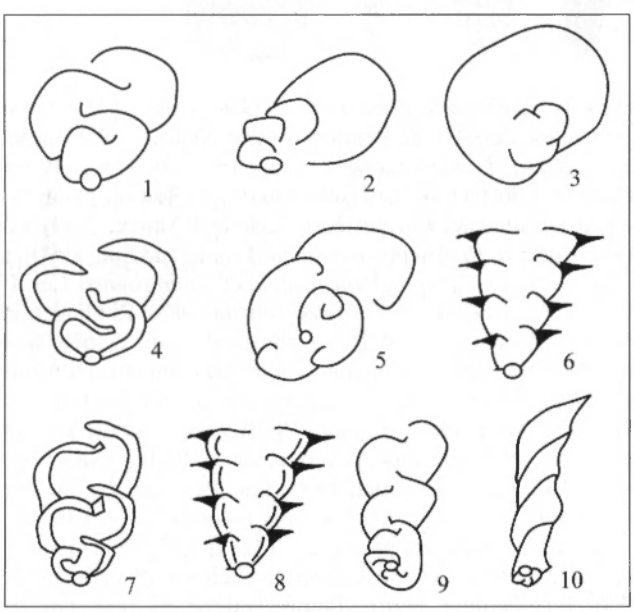
FIGURE 7–Early Permian *Globivalvulina* from Spitsbergen (*1-6*, Treskelodden Fm, Treskelen Peninsula (Creek IV), Hornsund, *7-13*, Treskelodden Fm, Hyrnefjellet Mt., Hornsund). *1, 6, Globivalvulina sikhanensis* Morozova, 1949. *1*, ZPAL F.56/V14-20, sagittal section. *6*, ZPAL F.56/V14-16, sagittal section. *2, Verispira*? sp., ZPAL F.56/V14-4, axial section. *3-5, Globivalvulina* cf. *syzranica* Reitlinger, 1950, *3*, ZPAL F.56/V14-12, tangential axial section. *4*, ZPAL F.56/V14-13, tangential axial section. *5*, ZPAL F.56/V14-1, tangential axial section. This specimen is also similar to a *G. graeca* (for example the Fig. 36C of Reichel, 1946) and the misinterpreted *G. granulosa* of Groves, 1992 (especially Pl. 4, Figs. 22 and 24). *7-8, 10-12, Globivalvulina pergrata* Konovalova, 1962. *7*, ZPAL F.56/H38-3, oblique sagittal section. *8*, ZPAL F.56/H38-6, oblique sagittal section. *10*, ZPAL F.56/H43-1, sagittal section. *11*, ZPAL F.56/H43-4, oblique section. *12*, ZPAL F.56/H41-3, oblique section. *9, 13, Globivalvulina* ex gr. *bulloides* (Brady, 1876). *9*, ZPAL F.56/H36-10, sagittal section. *13*, ZPAL F.56/H43-7, tangential axial section. The specimens of *Globivalvulina gaptankensis* Harlton, 1928 illustrated by Warthin (1930, Pl. 1, Figs. 17 a-b) seem to be very similar but their internal structures remain unknown (in the same paper *G. gaptankensis* is synonymized with *G. biserialis*, and both with *G. ovata* by Galloway and Ryniker, 1930; nevertheless, more recent revisions are missing). Scale bars: 0.100 mm.

They are *Dariopsis* Malakhova, 1975b (Fig. 2. 5-6) and *Globochernella* Hance, 1983 (Fig. 2. 7-8), from the early Viséan of the eastern slope of Southern Urals (Gumbeisky and Gusikhinsky horizons), and early-middle Viséan (Cf4-Cf5) of Belgium (Hance, 1982, 1983), respectively.

The Koktjubinidae (Figs. 4, 6) were defined by Marfenkova (1991) but remain poorly known and controversial (e.g., Brenckle, 2005). The family is transitional between the Biseriamminidae and Globivalvulinidae regarding to many characters. Due to the type of wall, the relatively slow increasing in the height size of the last chambers, and the absence of valvulae, the Koktjubinidae are considered here as closely related to the Biseriamminidae. Several Koktjubinidae: *Koktjubina* Marfenkova, 1991; *Admiranda* Marfenkova, 1991; and *Dzhamansorina* Marfenkova, 1991 were mentioned in the middle Viséan and Serpukhovian of Kazakhstan, Belgium, Ireland, SW Spain, Tarim, and U.S. Midcontinent. By contrast, they are relatively rare in southern France (Fig. 4.1-6). *Koktjubina* has only one or two uncoiled pairs of chambers and a coarsely granular wall, occasionally calcareously agglutinated. The genus is composed of *Spiroplectammina exotica* Vdovenko, 1962; *Globivalvulina* sp. 1 sensu Massa & Vachard (1979, Pl. 4, Fig. 6, Pl. 5, Fig. 6); *Globivalvulina regularis* Okimura, 1972; *Koktjubina venusta* Marfenkova, 1991; *Koktjubina* aff. *exotica* sensu Brenckle, 2004; Biseriamminide indétermine N.° 3 sensu Vachard &

FAMILY	SUBFAMILIES	GENERA
GLOBIVALVULINIDAE	Globivalvulininae	*Biseriella, Globivalvulina, Tenebrosella, Charliella, Siphoglobivalvulina, Retroseptellina*
	Paraglovivalvulininae	*Septoglobivalvulina, Paraglobivalvulina, Urushtenella, Paraglobivalvulinoides*
	Dagmaritinae	*Sengoerina, Dagmarita, Bidagmarita, Siphodagmarita, Crescentia, Louisettita*
	Paradagmaritinae	*Paradagmarita, Paradagmaritella, Paradagmaritopsis, Paradagmacrusta, Paraemiratella*

A



B

FIGURE 8–Subfamilies (8A) and cartoons (8B) of Globivalvulinidae. 1-*Globivalvulina;* 2-*Septoglobivalvulina,* 3-*Paraglobivalvulina,* 4-*Siphoglobivalvulina,* 5-*Retroseptellina,* 6-*Dagmarita,* 7-*Siphodagmarita,* 8-*Louisettita,* 9-*Paradagmarita,* 10-*Paradagmaritopsis.*

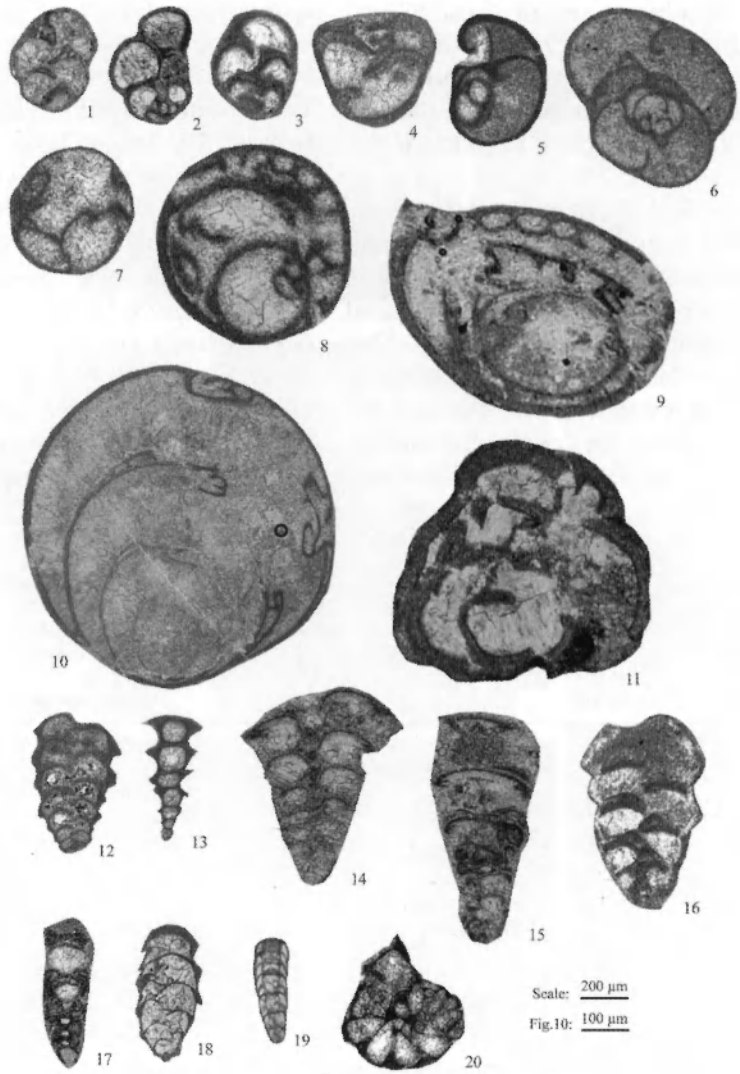


FIGURE 9–Late Permian globivalvulinids. *1-3, Siphoglobivalvulina baudi* Gaillot and Vachard in Gaillot *et al.* (submitted b), *1,* axial section, paratype (= Pl. I.43, Fig. 2 in Gaillot, 2006), Late Permian, Zagros (Iran). *2,* subaxial section, paratype (= Pl. I.43, Fig. 11 in Gaillot, 2006), Late Permian, Zagros (Iran). *3,* axial section, paratype (= Pl. VI.5, Fig. 10 in Gaillot, 2006), Late Permian, Hazro (Taurus, Turkey). *4, Charliella altineri* Gaillot and Vachard (submitted), axial section, paratype, (= Pl. II.11, Fig. 12 in Gaillot, 2006), Late Permian, Zagros (Iran). *5, Retroseptellina decrouezae* (Koylüoglu and Altiner, 1989), transverse section (= Pl. III.7, Fig. 2 in Gaillot, 2006), Late Permian, Zagros (Iran). *6, Retroseptellina nitida* (Lin, Li and Sun, 1990), transverse section, (= Pl. I.19, Fig. 18 in Gaillot, 2006), Late Permian, Zagros (Iran). *7, Septoglobivalvulina* cf. *guangxiensis* Lin, 1978, subtransverse section (= Pl. I.4, Fig. 14 in Gaillot, 2006), Late Permian, Zagros (Iran). *8, Paraglobivalvulina mira* Reitlinger, 1965, subtransverse section (= Pl. I.12, Fig. 20 in Gaillot, 2006), Late Permian, Zagros (Iran). *9, Paraglobivalvulina* sp. 1, subaxial section (= Pl. I.19, Fig. 19 in Gaillot, 2006), Late Permian, Zagros (Iran). *10, Paraglobivalvulinoides septulifera* Zaninetti and Altiner, 1981, subaxial section (= Pl. VII.1, Fig. 1 in Gaillot, 2006), late Changhsingian (latest Permian), Laren, Guangxi (South China). *11, Urushtenella* sp., axial section with a characteristic wall and a morphology of *Paraglobivalvulina* (= Pl. III.5, Fig. 5 in Gaillot, 2006), Late Permian, Zagros (Iran). *12-13, Dagmarita chanakchiensis* Reitlinger, 1965, *12,* sagittal axial section (= Pl. II.12, Fig. 2 in Gaillot, 2006), Late Permian, Zagros (Iran), *13,* frontal axial section (= Pl. II.12, Fig. 4 in Gaillot, 2006), Late Permian, Zagros (Iran). *14-15, Bidagmarita sinica* Gaillot and Vachard in Gaillot *et al.* (submitted b), *14,* sagittal axial section, holotype (= Pl. VII.3, Fig. 4 in Gaillot, 2006), Late Permian, Laren Guangxi (South China). *15,* frontal axial section, paratype (= Pl. VII.3, Fig. 5 in Gaillot, 2006), Late Permian, Laren Guangxi (South China). *16-17, Siphodagmarita vasleti* Gaillot and Vachard in Gaillot *et al.* (submitted a), *16,* sagittal axial section, paratype (= Pl. VI.6, Fig. 22 in Gaillot, 2006), Late Permian, Hazro (Taurus, Turkey), *17,* frontal axial section, paratype (= Pl. VI.6, Fig. 17 in Gaillot, 2006), Late Permian, Hazro (Taurus, Turkey). *18-19, Louisettita extraordinaria* Gaillot and Vachard in Gaillot *et al.* (submitted b), *18,* sagittal axial section, holotype (= Pl. VI.7, Fig. 10 in Gaillot, 2006), Late Permian, Hazro (Taurus, Turkey), *19,* frontal axial section, paratype (= Pl. VI.7, Fig. 13 in Gaillot, 2006), Late Permian, Hazro (Taurus, Turkey). *20, Crescentia* sp., subtransverse section (= Pl. III.13, Fig. 11 in Gaillot, 2006), Late Permian, Zagros (Iran). Scale bars indicated on the figure.

Berkhli, 1992; *Globivalvulina* sp. sensu Kulagina *et al.*, 1992, Pl. 11, Fig. 24; *Globospiroplectammina* (sic) *windsorensis* (Mamet, 1970) sensu Brenckle, 1997b (Pl. 4, Fig. 12-16); *Koktjubina* (?) sp. sensu Okuyucu & Vachard, 2006, Fig. 7.20. These taxa were found in central and southern Kazakhstan; Monteagle and Bangor Limestone (USA); Asbian of Taurus; late Visean of Nevada; Brigantian of eastern Morocco; and Asbian of Tarim (northern China).

The FAD of *Dzhamansorina* is coeval to that of *Koktjubina* (middle Visean) and it is impossible to identify the praecursor genus. *Dzhamansorina* shows a last uncoiled pair of hemispherical chambers with depressed sutures; the aperture is a large tunnel at the crossing of septa, and the microgranular wall is thin. The species of *Dzhamansorina* are: *Dzhamansorina grata* Marfenkova, 1991; *D. kipshakensis* Marfenkova, 1991; *D.* aff. *minima* (here Fig. 4. 1-2); *Spiroplectammina minima* Vdovenko, 1962; *Globivalvulina* sp. sensu Brazhnikova *et al.* (1967, Pl. 18, Fig. 13); undeterminated Biseriamminidae sensu Mamet, 1970, Pl. 1, Fig. 5; *Biseriella* sp. sensu Mamet, 1976, Pl. 81, Figs. 13 (non Fig. 12 = other species); *B.* of the group *B. parva* (Chernysheva) sensu Armstong & Mamet, 1977, Fig. 8; *Globivalvulina* aff. *bristolensis* sensu Meissami *et al.,* 1978; *Globivalvulina* cf. *parva* sensu Massa & Vachard, 1979, Pl. 4, Fig. 5.

The taxa are known from middle Visean to Serpukhovian of Kazakhstan, eastern Morocco (Jerada Basin), southern France (this study), USA (see Rich, 1982), Canada (Nova Scotia, British Columbia: Mamet, 1976), and early Serpukhovian of Libya (Massa & Vachard, 1979). Because its wall is microgranular and its coiling tends to be planispirally biseriate, *Dzhamansorina* migth be located at the beginning of the lineage, just before these primitive forms of *Globivalvulina* (e.g., *G.* ex gr. *parva*) denominated *Biseriella* by many authors. In this case, the individuality of *Biseriella* would be definitively established as a transitional stage between *Dzhamansorina* and true *Globivalvulina*. Nevertheless, as *Dzhamansorina* appears as more primitive than "*Biseriella*" *bristolensis* auctorum (by its more irregular coiling and the relatively deeply sutured chambers), the link of the *Biseriella* and primitive *Globivalvulina*, with "*G.*" or "*B.*" *bristolensis* becomes unlikely, and a new genus must be introduced to define generically "*G.*" or "*B.*" *bristolensis* (see above). From the middle Visean to late Serpukhovian, unpublished and literature data rather indicate the following lineage: *Dzhmansorina kipshakensis* (middle Visean)-*Dzhmansorina* aff. *kipshakensis* (late Asbian) (Figs. 4.5, 5.4)-*Dzhamansorina* aff. *minima* (late Asbian) (Figs. 4.1-2, 5.3)-*Globivalvulina*? ex gr. *parva* (Figs. 4.3, 5.6-13, 6.8-12) (late Brigantian)-*G.*? aff. *bristolensis* (Figs. 4.6-8, 5.9-10)-*G.*? *parva* (early Serpukhovian) (Figs. 5.11-12, 6.14-15)-*G*? spp. sensu Perret (1993) (late Serpukhovian)-*G.*? *minima* (= *kantharensis* = *scaphoidea*) (Fig. 6.27)-*Globivalvulina moderata* (Figs. 5.14, 6.21)-*G. bulloides* (Figs. 5.15, 6.18-20).

The taxonomic affinities of the genus *Admiranda* Marfenkova, 1991 (Fig. 2. 11) still remain unclear for us, although a taxon of Vachard & Berkhli (1992, Pl. 1, Fig. 1) might be included within the Marfenkova's diagnosis. The relations between *Dzhamansorina* and *Admiranda* are expected to be similar to those between *Globivalvulina* and *Dagmarita*; i.e., a secondary-uncoiled taxon lately appeared within a coiled lineage. The difference with *Ulanbela* Marfenkova, 1991 is considered here as specific and not subgeneric.

Globispiroplectammina Vachard, 1977 was interpreted as a genus of Biseriamminoidea (e.g., Conil *et al.*, 1980), and more precisely as Koktjubinidae. This interpretation is probably erroneous, because the initial part of *Globispiroplectammina* corresponds to a deviation of a biseriate test, that passes progressively to a *Spireitlina*-type of coiling with a short initial part as seen in *S. tokmovensis* (Reitlinger, 1961) sensu Vachard & Krainer (2001, Pl. 1, Figs. 8, 11). This character is pecularly obvious in a new material from southern France (Pille, Ph. D. in progress). Other genera can also be related to this informal group: *Spiroplectamminoides* Skipp, 1969; *Rectogranuliferella* Conil & Lys in Mansy *et al.,* 1989; *Palaeospiroplectammina* sensu Lipina, 1965 (pars); *Palaeospiroplectammina* (?) sensu Conil, 1980; "*Palaeospiroplectammina*" sensu Michelsen, 1971; *Spiroplectammina* sensu Chernysheva, 1940; *Spiroplectammina* (?) sensu Lebedeva, 1954 and in Grozdilova & Lebedeva, 1954; *Rectochernyshinella* sensu Ganelina, 1966; *Granuliferelloides* McKay & Green, 1963; *Corrigotubella* Ganelina, 1966; *Ammobaculites* sensu Malakhova, 1956 (pars); and *Haplophragmina* sensu Conil & Lys, 1968 (non Reitlinger, 1950).

According to Brenckle & Hance (2005); *Granuliferelloides*, *Corrigotubella* and *Lipinellina* Loeblich & Tappan, 1985 (= *Rectochernyshinella* Lipina 1965 non 1960) are synonyms; according to Lane *et al.* (2005), *Rectogranuliferella* and *Spiroplectamminoides* are synonyms. These modifications are only partly justified and remain highly subjective (revisions of the holotypes are lacking). Michelsen (1971, p. 43) interpreted the initial chambers of "*Palaeospiroplectammina*" *mellina* (Malakhova, 1956)

corresponding to a multiseriate (triseriate) initial part; in fact, this initial stage is most probably coiled with few endothyroid chambers. "*Palaeospiroplectammina*" in this case differs notably from *Palaeospiroplectammina* Lipina, 1965 emend. Conil & Lys, 1977, but looks like *Globispiroplectammina* after the emendation by Vachard & Beckary (1991) (see also Fontaine *et al.*, 1999, p. 464).

Some species analyses are presented below, concerning the plexus *Globivalvulina*?/ *Biseriella*, which appears during the late Viséan.

Globivalvulina? ex gr. *parva* (Chernysheva, 1948) (Fig. 4. 3, Fig. 6. 8-12, 14-15, 27)

?1946 *Globivalvulina kantharensis* n. sp. Reichel, p. 554, 556, Text-Figs. 40 a-d.

1948 *Globivalvulina parva* n. sp. Chernysheva, p. 249, Pl. 13, Figs.1-4.

1949 *Globivalvulina scaphoidea* n. sp. Reitlinger, p. 159, Pl. 1, Fig. 5.

1950 *Globivalvulina minima* n. sp. Reitlinger, p. 76-77, Pl. 16, Fig. 14.

1956 *Globivalvulina* sp.-Malakhova, p. 44, Pl. 4, Figs. 5-6.

non 1960 *Globivalvulina parva* n. sp. Loriga, p. 57 (= preoccupied) (in the same publication, this form is illustrated as *Globivalvulina* sp.: Text-Fig. 10 p. 157, that corresponds probably to *Siphoglobivalvulina baudi* Gaillot & Vachard in Gaillot *et al.* (submitted b), see below).

1962 *Globivalvulina parva* Chernysheva-Bogush & Juferev, p. 196, Pl. 8, Fig. 12.

1962 *Globivalvulina minima* Reitlinger-Bogush & Juferev, p. 196-197, Pl. 8, Fig. 13.

1963 *Globivalvulina* ex gr. *minima* Reitlinger-Chanton, Pl. 7, Fig. 5.

1967 *Globivalvulina moderata* Reitlinger-Brazhnikova *et al.*, Pl. 18, Fig. 12, Pl. 22, Fig. 4, Pl. 25, Fig. 5.

1967 *Globivalvulina minima* Reitlinger-Sosipatrova, Pl. 4, Fig. 15.

p. 1968 *Globivalvulina parva* Chernysheva - Aizenverg *et al.*, Pl. 16, Fig. 12 (non Figs. 11, 13 = *Dzhamansorina* aff. *minima*, herein).

1968 *Globivalvulina moderata* Reitlinger-Aizenverg *et al.*, Pl. 16, Figs. 8-9.

1969 *Globivalvulina parva* Chernysheva-Manukalova-Grebeniuk *et al.*, Pl. 13 (p. 197), Fig. 23, Pl. 8 (p. 235), Fig. 36, Pl. 13 (p. 245), Fig. 4.

1969 *Globivalvulina minima* Reitlinger-Manukalova-Grebeniuk *et al.*, Pl. 5 (p. 181), Fig. 29, Pl. 8 (p. 187), Fig. 6-7, ? Pl. 1 (p. 221), Fig. 24 (ex gr.).

1970 Primitive *Globivalvulina*? sp.-Mamet, Pl. 2, Figs. 6-7.

?1970 *Globivalvulina*? *parva* Chernysheva-Skipp & Mamet, p. B122 (no illustration).

1971 *Globivalvulina moderata* Reitlinger-Clément *et al.*, Pl. 1, Fig. 3.

?1972 *Globivalvulina kantharensis* Reichel-Okimura, p. 421, Pl. 50, Figs. 13-14.

1972 *Globivalvulina* sp. A-Okimura, p. 423, Pl. 50, Figs. 20-22.

1973 *Globivalvulina minima* Reitlinger-Ivanova, p. 196-197, Pl. 33, Fig. 13.

1973 *Globivalvulina* sp.-Ivanova, Pl. 19, Fig. 9.

v. 1973 *Globivalvulina moderata* Reitlinger-Perret, p. 321-322, Pl. 5, Figs. 4-5.

v.? 1973 *Globivalvulina parva* Chernysheva-Perret, p. 322, Pl. 5, Figs. 12-14 (with 3 references in synonymy).

v.? 1973 *Globivalvulina* aff. *bulloides* (Brady)-Perret, p. 322-323, Pl. 5, Figs. 10-11.

?1973 *Globivalvulina moderata* Reitlinger-Popova & Reitlinger, p. 55, Pl. 9, Fig. 32.

?1973 *Globivalvulina* sp. A-Brenckle, p. 67, Pl. 9, Figs. 39-40 (or *G. procera*).

1973 *Globivalvulina* sp. B-Brenckle, p. 67-68, Pl. 10, Figs. 1-5.

1973 *Globivalvulina* sp. C-Brenckle, p. 68, Pl. 10, Figs. 6-7.

1973 *Globivalvulina* sp. E - Brenckle, p. 68-69, Pl. 10, Figs. 10-11.

1974 *Globivalvulina minima* Reitlinger-Wang, p. 254, Pl. 129, Fig. 15.

v. non 1974 *Globivalvulina* cf. *parva* (Chernysheva)-Vachard, p. 335-336, Pl. 23, Figs. 2-3 (with synonymy) (= *Globivalvulina* ? aff. *bristolensis*, see herein).

non 1976 *Biseriella* of the group *B. parva* - Mamet, Pl. 76, Figs. 3-4, Pl. 92, Fig. 4 (= two Koktjubinidae).

non 1977 *Biseriella* of the group *B. parva* (Chernysheva)-Armstrong & Mamet, p. 100-101, Pl. 35 Fig. 4 (another species with more whorls), nec Fig. 8 (= *Dzhamansorina*) (with 7 references in synonymy), nec Pl. 6, Fig. 5 (= *Globivalvulina moderata*).

?1976 *Globivalvulina* aff. *minima* Reitlinger-Sosnina & Nikitina, Pl. 3, Fig. 20 (valvular projection poorly visible, may be *G.*? *parva*).

1976 *Globivalvulina* aff. *moderata* Reitlinger-Sosnina & Nikitina, Pl. 3, Fig. 14.

1976 *Globivalvulina* ex gr. *moderata* Reitlinger-Ektova, Pl. 8, Fig. 8.

1977 *Globivalvulina moderata* Reitlinger-Fomina, Pl. 4, Figs. 4-5.

1977 *Globivalvulina minima* Reitlinger-Lys & Leboulanger, Pl. 52, Fig. 12.

v. 1977 *Globivalvulina* (= *Biseriella*) ex gr. *parva* Chernysheva - Perret & Vachard, p. 90 (no illustration, but in reference to the material of Perret, 1973).

p. 1977 *Biseriella* of the group B. *parva* (Chernysheva)-Armstrong & Mamet, p. 100-101, Pl. 6, Fig. 5, Pl. 35, Fig. 4 (non Pl. 35, Fig. 8 = a koktjubinid).

v. non 1977 *Globivalvulina* cf. *parva* (Chernysheva)-Vachard, p. 156-157, Pl. 6, Figs. 16-17 (with 14 references in synonymy) (= *Globivalvulina*? aff. *bristolensis*, see herein).

1978 *Globivalvulina scaphoidea* (sic) Reitlinger-Lys *et al.*, Pl. 2, Fig. 11, Pl. 3, Fig. 6.

1979 *Globivalvulina minima* Reitlinger-Reitlinger in Wagner *et al.*, Pl. 10, Figs. 10-11.

p. 1979 *Globivalvulina minima* Reitlinger - Potievskaya in Wagner *et al.*, Pl. 12, Figs. 7, 10 (non Pl. 10, Fig. 12 = truly *G. moderata).*

p. 1979 *Globivalvulina parva* Chernysheva - Brazhnikova in Wagner *et al.*, Pl. 2, Fig. 15?, Pl. 5, Figs. 22-23 (non Pl. 3, Figs. 13-14 = *Dzhamansorina*? sp.).

v. 1979 *Globivalvulina* cf. *moderata* (Reitlinger)-Bensaïd *et al.*, Pl. 15, Fig. 14.

1980 *Globivalvulina minima* Reitlinger-Reitlinger, Pl. 4, Figs. 7-9.

non 1980 *Biseriella parva* (Chernysheva)-Rich, p. 79, Pl. 5, Figs. 2-3, 6-7, 10 (= *Koktjubina* sp.).

1980 *Biseriella* cf. *parva* (Chernysheva)-Conil *et al.*, Pl. 24, Figs. 2-4, Pl. 28, Figs. 40-41 (or another "*Biseriella*").

?1980 *Biseriella* sp.-Conil *et al.*, Pl. 26, Fig. 3 (or *Dzhamansorina*).

?1981 *Globivalvulina kantharensis* Reichel-Vachard in Vachard & Montenat, p. 70, Pl. 11, Fig. 10.

1981 *Globivalvulina parva* Chernysheva-Altiner, p. 283-284, Pl. 23, Figs. 18-23.

1981 *Globivalvulina minima* Reitlinger-Altiner, p. 281-282, Pl. 23, Figs. 36-38.

non 1981 *Biseriella parva* (Chernysheva)-Igo & Adachi, p. 107, Pl. 6, Figs. 3, 7 (= true *Globivalvulina*).

?1981 *Globivalvulina kantharensis* Reichel-Lin, Pl. 3, Fig. 17.

non 1981 *Globivalvulina parva* Chernysheva-Zhao *et al.*, p. 104, Pl. 17, Figs. 7-11 (= *G. moderata* or *G. kamensis*).

?1981 *Globivalvulina kantharensis* Reichel-Zhao *et al.*, Pl. 2, Fig. 6.

1983 *Globivalvulina* ex gr. *parva* Chernysheva - Aizenverg *et al.*, p. 14-15, Pl. 12, Figs. 12-13.

1983 *Globivalvulina moderata* Reitlinger-Aizenverg *et al.*, p. 14-15, Pl. 12, Figs. 23-25, 29.

non 1983 *Biseriella parva* (Chernysheva)-Groves, p. 381, 383, Figs. 14. 1-9 (= ?a *Globivalvulina kamensis* or *G. bulloides* sensu lato) (with incorrect synonymy).

1984 *Globivalvulina moderata* Reitlinger-Chuvashov *et al.*, Pl. 1, Fig. 25, Pl. 3, Fig. 23.

non 1984 *Biseriella parva* (Chernysheva)-Groves, Text-Fig. 6 p. 287, Text-Fig. 7 p. 289, Pl. 5, Figs. 1-6 (= ?*G. minima* and *G. scaphoidea*).

?1985 *Globivalvulina* aff. *moderata* Reitlinger-Lys, Pl. 1, Fig. 18 (or another species).

1987 *Globivalvulina minima* Reitlinger-Zheng, Pl. 2, Figs. 25-28.

1987 *Globivalvulina minima* Reitlinger-Sinitsyna & Sinitsyn, Pl. 2, Fig. 22.

1987 *Biseriella* sp.-Luo, Pl. 2, Figs. 15-17.

non 1988 *Biseriella parva* (Chernysheva)-Groves, p. 381, 383, Figs. 14. 1-9 (= ? a *Globivalvulina kamensis* or *G. bulloides* sensu lato) (with misinterpreted synonymy including *Globivalvulina moderata, G. scaphoidea, G.* sp. 1, *G. minima* and *G. kamensis).*

1988 *Globivalvulina moderata* Reitlinger-Groves, p. 381 (no illustration; with synonymy; erroneouly synonymized with "*Biseriella*" *parva).*

1988 *Globivalvulina parva* Chernysheva-Kulagina, p. 26, Pl. 2, Figs. 25-26.

1988 *Globivalvulina minima* Reitlinger-Kulagina, p. 26, Pl. 3, Figs. 11-12, Pl. 4, Fig. 31.

?1988 *Globivalvulina moderata* Reitlinger - Kulagina, p. 26, Pl. 3, Fig. 17, Pl. 4, Fig. 25.

1988 *Globivalvulina minima* Reitlinger-Kulagina & Pazukhin, p. 36, 41 (no illustration).

p. 1988 *Globivalvulina* sp.-Yanagida *et al.*, Pl. 5, Fig. 12 (only; non Figs. 1-4, 6, 10, 13-14 = *Siphodagmarita*, non Fig. 5 = *Septoglobivalvulina*? sp.; non Fig. 7 =

Retroseptellina globosa; non Figs. 8-10 = other species of *Globivalvulina*).

1989 *Biseriella parva* (Chernysheva)-Fewtrell *et al.*, p. 56, p. 64, Pl. 3. 9, Fig. 4, Pl. 3. 12, Fig. 3.

?1989 *Globivalvulina moderata* Reitlinger-Sebbar & Lys, Pl. 2, Fig. 3.

1990 *Globivalvulina minima* Reitlinger-Lin, Pl. 3, Fig. 20.

?1990 *Globivalvulina eogranulosa* Reitlinger-Postoyalko, Pl. 7, Fig. 31.

v. 1990 *Globivalvulina minima* Reitlinger-Vachard, p. 95 (no illustration).

?1990 *Globivalvulina kantharensis* Reichel-Lin *et al.*, p. 86, p. 163, Pl. 11, Figs. 30-34 (all specimens don't display the specific characters, and even might belong to *Siphoglobivalvulina*).

1991 *Biseriella parva* (Chernysheva)-Marfenkova, Pl. 9, Fig. 11.

v. 1991 *Globivalvulina parva* Chernysheva-Vachard *et al.*, p. 677, Pl. 1, Figs. 16-17.

v. 1991 *Globivalvulina moderata* Reitlinger-Vachard & Beckary, Pl. 3, Figs. 17-18.

? p. 1992 *Biseriella minima* (Reitlinger)-Kulagina *et al.*, Pl. 4, Figs. 2, 5, Pl. 13, Figs. 18?, 21?

1992 *Globivalvulina moderata* Reitlinger-Kulagina *et al.*, Pl. 11, Fig. 25.

v. 1992 Biseriamminide indetermine N.° 2-Vachard & Berkhli, Pl. 1, Figs. 10-11, Pl. 3, Fig. 5.

non 1992 *Biseriella parva* (Chernysheva)-Groves, p. 150, Pl. 4, Figs. 8-13 (all these specimens exhibit developed valvular projections and probably belong truly to *Globivalvulina*).

non 1993 *Biseriella* of the group *B. parva* (Chernysheva)-Mamet *et al.*, Pl. 13, Figs. 1-3, 5-6 (all these specimens belong truly to *Globivalvulina*: the Fig. 1, to *G. moderata;* the Figs. 2-3, 5-6 , to a larger species maybe *G. kamensis* Reitlinger, 1950).

v. 1993 *Globivalvulina moderata* Reitlinger-Perret, p. 448-449, Pl. F4, Figs. 33-59.

v. 1993 *Globivalvulina parva* Chernysheva-Perret, p. 449-450, Pl. F4, Figs. 60-64 (with 18 references in synonymy) (Fig. 61 = *Globivalvulina minima*).

1993 *Globivalvulina eogranulosa* Reitlinger-Perret, p. 450-451, Text-Figs. 136-137 p. 446-447, Pl. F.IV, Figs. 29-32, Pl. F.XII, Fig. 15 (with synonymy).

1993 *Biseriella parva* (Chernysheva)-Vdovenko & Zhulitova in Makhlina *et al.*, Pl. 4, Figs. 23-24, 28.

v. 1993 *Globivalvulina moderata* Reitlinger-Vachard *et al.*, Pl. 1, Figs. 3, 14.

1996 *Globivalvulina parva* Chernysheva-Marfenkova in Einor, Pl. 41, Fig. 35.

non 1996 *Biseriella parva* (Chernysheva)-Cózar-Maldonado, Pl. 2, Fig. 12 (maybe *Plectogyranopsis;* Cózar pers. comm., December 2006).

v. 1996 *Globivalvulina* ex gr. *moderata* Reitlinger-Proust *et al.*, p. 348 (no illustration).

1997 *Biseriella parva* (Chernysheva)-Harris *et al.*, Fig. 8. 26.

1997 *Biseriella* ex gr. *parva* (Chernysheva)-Brenckle *et al.*, Pl. 1, Fig. 22 (probably *G. minima*).

1997 *Biseriella parva* (Chernysheva)-Ueno & Igo, Pl. 1, Fig. 9 (probably *G. minima*).

1997 *Biseriella* ex gr. *parva* (Chernysheva)-Mizuno & Ueno, Tabl. 2, Pl. 3, Figs. 18-20 (probably *G. minima*).

p. 1998 *Biseriella* du groupe *B. parva* (Chernysheva)-Pinard & Mamet, p. 116-117, Pl. 27, Figs. 3?-4? (non Figs. 1-2 = *Globivalvulina*) (with 44 references in synonymy including *G. scaphoidea* and *G. moderata*).

p. 1998 *Globivalvulina kantharensis* Reichel-Pinard & Mamet, p. 118, Pl. 27, Figs. 6, 9-12 (with 6 references in synonymy) (non Fig. 7 = *G. shikhanensis*).

v. 1999 *Biseriella parva* (von Möller)-Berkhli, p. 110, 113 (no illustration).

non 2000 *Biseriella* gr. *parva* (Chernysheva)-Sebbar, Pl. 13, Fig. 17 (profile more inflated, sutures absent).

2000 *Globivalvulina moderata* Reitlinger-Sebbar, Pl. 13, Figs. 14-15, 18-19.

p.? 2000 *Biseriella* ex gr. *parva* (Chernysheva)-Cózar, Figs. 3. 7?, 8, 9?

non 2001 *Biseriella parva* (Chernysheva)-Vdovenko, Pl. 4, Figs. 47-48 (= *Pseudotaxis eominima*).

?2002 *Biseriella parva* (Chernysheva)-Kulagina & Gibshman, Text-Fig. 3 p. 186 (no illustration).

?2002 *Biseriella parva* (Chernysheva)-Marfenkova, p. 193, 195, 196 (no illustration).

?2002 *Biseriella parva* (Chernysheva)-Pazukhin *et al.*, p. 221 (no illustration).

?2002 *Globivalvulina minima* Reitlinger-Shcherbakova & Shcherbakov, p. 313 (no illustration).

?2003 *Biseriella parva* (Chernysheva)-Kulagina *et al.*, Text-Fig.7 p. 180 (no illustration).

v. 2003 *Globivalvulina parva* Chernysheva-Vachard *et al.*, p. 654 (no illlustration).

non 2003 *Biseriella* of the group *parva* (Chernysheva)-Brenckle & Milkina, Pl. 6, Figs. 1-3 (1 and 3 corresponds to another species of *Biseriella,* 2 is yet a *Globivalvulina* ex gr. *moderata* Reitlinger, 1949).

non 2003 *Biseriella* ex gr. *parva* (Chernysheva)-Cózar, Fig. 5P (= *G.*? aff. *bristolensis;* see herein).

non 2004 *Biseriella* ex gr. *parva* (Chernysheva)-Cózar & Rodríguez, Fig. 9. 7 (= *G.*? aff. *bristolensis;* see herein).

?2004 *Biseriella* cf. *parva* (Chernysheva)-Cózar & Somerville, Text-Fig. 4 p. 46 (pars), Fig. 10. 22 (oblique section, difficult to identify).

p.? 2004 *Biseriella parva* (Chernysheva)-Cózar & Somerville, Text-Fig. 6 p. 47 (pars), Text-Fig. 15 p. 61 (pars), Fig. 10. 24? (non Fig. 10-23 = *G.*? aff. *bristolensis*; see herein).

non 2004 *Globivalvulina kantharensis* Reichel-Zhang & Hong, p. 70, Pl. 1, Figs. 22-23 (= *Retroseptellina globosa*) (with 6 references in synonymy).

v. 2005 *Biseriella parva* (Chernysheva)-Saïd, p. 178, p. 182? (ex gr.), p. 184, p. 186, p. 188, p. 189, p. 191, Fig. X. 1. 17 (typical although listed as "ex gr."), 18, 22.

v. 2005 *Biseriella* sp.-Saïd, p. 180 (no illustration).

?2005 *Biseriella parva* (Chernysheva)-Brenckle, Tabl. 1 p. 170 (no illustration).

?2005 *Biseriella parva* (Chernysheva)-Orlov-Labkovsky, p. 23, 24, 25, 26 (no illustration).

2005 *Biseriella minima* (Reitlinger)-Orlov-Labkovsky, p. 24, 25, 26 (no illustration).

v. 2006 *Globivalvulina scaphoidea* Reitlinger-Insalaco *et al.*, Pl. 1, Fig. 16.

v. 2006 *Biseriella* aff. *parva* (Chernysheva)-Okuyucu & Vachard, p. 547, Fig. 5. 17-19.

Description.–Small test, planispiral and inflated. Proloculus spherical and excentred. The five first chambers are closely arranged and their height remain smaller than the proloculus diameter. The sixth to ninth chambers increase markedly in width, very rapidly in height, and constitute the median part of the last whorl. Apertural face flat or slightly inflated. Valvula well developed in the last chamber, and often present in the two or three last ones. Diameter (D) = 0.170-0240 (0.330) mm; width (w) = 0.110-0.150 mm; ratio w/D = 0.60-0.70; proloculus diameter = 0.025-0.045 mm; number of whorls: 1-1.5; number of chambers at the last whorl: 4-5 pairs; height of the last whorl = 0.060-0.110 (0.135) mm; wall thickness of the last whorl = 0.010-0.015 mm. The type of wall is not precisely known, since the type material of *G. parva* was not revised, but we dont forget that Chernysheva (1948) written: "the wall is microgranular sometimes with a thin and poorly developed radial layer " (see also Loeblich & Tappan, 1987).

Remarks.–According to Brenckle (2005), *B. scaphoidea* is difficult to distinguish from *B. parva.* According to Gaillot (2006), *G. scaphoidea* is synonym of *G. kantharensis*, a species considered as a true *Globivalvulina* by Pinard & Mamet (1998) or a *Verispira* by Palmieri (1988). If *G. kantharensis, G. scaphoidea* and *G. parva* were synonyms, *G. kantharensis* must be the prioritary name of the type-species. Furthermore, as for *G. parva*, Reichel (1946) indicated that a small clear layer was present in the wall of the last chambers of some specimens in the *G. kantharensis* type-material : "Test très finement granuleux, des traces de couche hyaline poreuse interne sont visibles dans les dernières loges ". Consequently, the three taxa seem to constitute a group of species. This latter is often misinterpreted and it can generally be used to identify all the Viséan-Serpukhovian "*Biseriella*", some unquestionable *Globivalvulina*, and even koktjubinids. That explains the relative imprecision about the biostratigraphic value of *Globivalvulina*? *parva.* It was considered as a marker of the late Serpukhovian E2/zone 18 by Mamet & Skipp (1971) and Mamet (1974), but the rare forms illustrated by Mamet, as well as those illustrated by Groves (1988) correspond to much more advanced species, already corresponding to unquestionable *Globivalvulina.* Conversely, the late Viséan "*Biseriella*" *parva* of many authors belong in fact to the genus *Pseudotaxis* (see in connection with that, the compilation of Vachard & Beckary, 1991), other species of *Biseriella* (for instance, here, *G.*? aff. *bristolensis*), or *Koktjubina* (for example, the Akerchi specimens mentioned in several publications, about central Morocco, by members of our team). Finally, the true *B. parva* can be indicative of the earliest Serpukhovian and or the latest beds of the Viséan (see references in Okuyucu & Vachard, 2006). Nevertheless, according to the literature, many similar species are distributed up to the Moscovian: e.g., *G. minima, G. moderata,* and *G. scaphoidea.* The holotype of the first one of them, *G. minima*, corresponds

probably to an equatorial transverse section of *G. parva* whose the type material is only constituted by oblique transverse sections. Consequently, the type of section of *G. minima* shows the well developed valvular projection and the closely arranged first chambers which are not obvious in *G. parva*. Moreover, some *G. minima* show a differentiated wall; notably, the Turkish specimens of Altiner (1981) and some but not all of the specimens seen by us (see for example, that of Perret, 1993, Pl. F.IV, Fig. 53). *G. scaphoidea* has the same size and differs only by the shape of the late chamber. *G. moderata* is larger (D = 0.310-0.510 mm but has more chambers: 7-9 pairs), and it is transitional to *G. bulloides* or synonym of this species (see discussion in Groves, 1984 or Brenckle, 2005).

Occurrence.–Early Namurian of England (Fewtrell *et al.*, 1989). Late Viséan of Submoscovite Basin, Uzbekistan. ?Latest Venevsky to latest Serpukhovian of southern Urals. ?C1^{v}g-earliest Serpukhovian of Donets Basin (limestones B4, B10 and CI) to early Bashkirian (D7^{2} limestone). Late Viséan of southern Spain. Latest Viséan-early Serpukhovian of USA. Early-late Brigantian of central and eastern Morocco (the populations of the Idmarrach Formation are especially interesting; see Said, 2005). Latest Brigantian of eastern Taurus (Turkey). Serpukhovian of Kazakhstan. Earliest Serpukhovian of Tien-Shan (local FAD according to Orlov-Labovsky, 2005). ?Serpukhovian of Thailand (Chiang Dao area). Latest Brigantian of South China. Early Serpukhovian-earliest late Serpukhovian of Tien-Shan. Early Serpukhovian of northwest China. Earliest Serpuhkhovian of northern England. ?Late Serpukhovian of Idaho (USA). ?Late Serpukhovian-early Bashkirian of Alaska and Hina Group of Japan. Early Serpukhovian of Montagne Noire (Laurens station and La Serre vineyard). Late Serpukhovian of Pyrenees (Ardengost).

Occurrence of G. minima.–Middle Carboniferous of Russian Platform, Kazakhstan, North Tianshan, Primorye, Algeria (Bechar, Reggan, Illizi) and South China. Protvinsky-Bashkirian of southern Urals and Alaska. Serpukhovian of Donets Basin (D_4 to D_7^2 limestones). Middle Serpukhovian-early late Serpukhovian of central Tien-Shan. Moscovian of Rhodes Island (Greece) and Ellesmere Island (Canada). Late Serpukhovian of Ardengost area (French Pyrenees). Earliest Bashkirian-early Moscovian of eastern Alborz (Iran). ? Morrowan of Idaho. Late Bashkirian-earliest Late Carboniferous in eastern Taurus (Turkey). Late Bashkirian of Thailand. Vereian of Spitsbergen.

Occurrence of G. scaphoidea/kantharensis. - Bashkirian-Early Permian of Canadian Arctic. Early Permian of Cyprus, Afghanistan, Japan. Lopingian of South China, northern Thailand, Iran (Zagros).

Globivalvulina? aff. *bristolensis* Reichel, 1946 (Figs. 4. 6-8)

v. 1974 *Globivalvulina* cf. *parva* (Chernysheva)-Vachard, p. 335-336, Pl. 23, Figs. 2-3.
v. 1977 *Globivalvulina* cf. *parva* (Chernysheva)-Vachard, p. 156-157, Pl. 6, Figs. 16-17.
p.? 2000 *Biseriella* ex gr. *parva* (Chernysheva)-Cózar, Figs. 3. 7?, 8, 9?
?2003 *Biseriella bristolensis?* (Reichel)-Brenckle & Milkina, Pl. 3, Fig. 12.
2003 *Biseriella* ex gr. *parva* (Chernysheva)-Cózar, Fig. 5P.
2004 *Biseriella* ex gr. *parva* (Chernysheva)-Cózar & Rodríguez, Fig. 9. 7.
p. 2004 *Biseriella parva* (Chernysheva)-Cózar & Somerville, Fig. 10. 23 (non? Fig. 10-24 = difficult to identify).

Comparison.–This taxon of the late Brigantian of Montagne Noire differs from *G.? bristolensis* Reichel, 1946, by the entirely planispiral coiling, the shape of the chambers (triangular in *G.? bristolensis*, see Fewtrell *et al.*, 1989, Pl. 3. 3, Fig. 2; with a less voluminous last chamber) and the different age (*G.? bristolensis* is characteristic of the late Chadian = latest Tournaisian = latest Ivorian = MFZ8).

Occurrence.–Questionable in the early Tulsky of Kazakhstan. Late Serpukhovian of southwestern Spain. Latest Brigantian of northern England. Brigantian of Montagne Noire.

HOW MANY SUBDIVISIONS OF GLOBIVALVULINA DURING THE PENNSYLVANIAN?

The Pennsylvanian-Cisuralian (Early Permian) forms are extensively described (e.g., Pinard & Mamet, 1998) and generally all attributed to the unique genus *Globivalvulina*. All these forms have a small, medium or large, subglobular test, entirely biseriate and planispiral, with a lobate periphery, undivided chambers, and an aperture simple protected by the valvular projection sometimes well developed. Based on the same criteria than *Biseriella*, many Moscovian globivalvulines must be considered as dif-

FIGURE 10 - Late Permian Iranese (Zagros) Paradagmaritinae. *1-5, 23, Paradagmarita monodi* Lys in Lys and Marcoux, 1978, *1,* frontal axial section (= Pl. I.15, Fig. 4 in Gaillot, 2006), Late Permian, Zagros (Iran). *2,* subtransverse section (= Pl. I.16, Fig. 2 in Gaillot, 2006), Late Permian, Zagros (Iran). *3,* subtransverse section (= Pl. III.5, Fig. 14 in Gaillot, 2006), Late Permian, Zagros (Iran). *4,* axial section (= Pl. III.6, Fig. 9 in Gaillot, 2006), Late Permian, Zagros (Iran). *5,* subtransverse section (= Pl. III.25, Fig. 2 in Gaillot, 2006), Late Permian, Zagros (Iran). *23,* subtransverse section with peripheric punctuations, paratype (= Pl. III.18, Fig. 3 in Gaillot, 2006), Late Permian, Zagros (Iran). *6-7, Paremiratella instabilis* Gaillot and Vachard (submitted), *6,* subtransverse section, paratype (not illustrated in Gaillot, 2006), Late Permian, Zagros (Iran), *7,* subaxial section, paratype (not illustrated in Gaillot, 2006), Late Permian, Zagros (Iran). *8-10, Paradagmaritopsis kobayashii* Gaillot and Vachard in Gaillot *et al.* (submitted a), *8,* frontal axial section, paratype, (= Pl. I.9, Fig. 9 in Gaillot, 2006), Late Permian, Zagros (Iran), *9,* sagittal axial section, paratype (= Pl. I.9, Fig. 8 in Gaillot, 2006), Late Permian, Zagros (Iran), *10,* oblique section, paratype (= Pl. I.9, Fig. 5 in Gaillot, 2006), Late Permian, Zagros (Iran). *11-13, Paradagmaritella flabelliformis* (Zaninetti, Altiner and Çatal, 1981). *11,* sagittal axial section (= Pl. III. 2, Fig. 10 in Gaillot, 2006), Late Permian, Zagros (Iran), *12,* transverse section (= Pl. I.14, Fig. 12 in Gaillot, 2006), Late Permian, Zagros (Iran). *13,* subtransverse section (= Pl. III.2, Fig. 8 in Gaillot, 2006), Late Permian, Zagros (Iran). *14-15, Paradagmaritella surmehensis* Gaillot and Vachard (submitted). *14,* transverse section, paratype (= Pl. I.7, Fig. 13 in Gaillot, 2006), Late Permian, Zagros (Iran). *15,* oblique section, paratype (= Pl. I.7, Fig. 14 in Gaillot, 2006), Late Permian, Zagros (Iran). *16-17, Paradagmaritella brevispira* Gaillot and Vachard (submitted), *16,* subtransverse section, paratype (= Pl. I.8, Fig. 14 in Gaillot, 2006), Late Permian, Zagros (Iran), *17,* subtransverse section, paratype (= Pl. I.9, Fig. 13 in Gaillot, 2006), Late Permian, Zagros (Iran). *18-19, Paradagmarita zaninettiae* Gaillot and Vachard (submitted), *18,* subtransverse section, paratype (= Pl. I.10, Fig. 15 in Gaillot, 2006), Late Permian, Zagros (Iran). *19,* subaxial section, paratype (= Pl. I.10, Fig. 16 in Gaillot, 2006), Late Permian, Zagros (Iran). *20-21, Paradagmacrusta callosa* Gaillot and Vachard (submitted), *20,* transverse section, paratype (= Pl. I.12, Fig. 10 in Gaillot, 2006), Late Permian, Zagros (Iran), *21,* subaxial section, paratype (= Pl. I.12, Fig. 17 in Gaillot, 2006), Late Permian, Zagros (Iran). (Iran). *22-23, Paradagmarita* cf. *monodi*, *22,* frontal axial section (not illustrated in Gaillot, 2006), Late Permian, Zagros (Iran), *23,* sagittal axial section (not illustrated in Gaillot, 2006), Late Permian, Zagros (Iran).

ferent genera because they have a wall distinct from that of *Globivalvulina bulloides*. Nevertheless, only the very poorly known genus *Tenebrosella* has been separated from *Globivalvulina* sensu lato, during this period.

The wall differs from black, microgranular to differentiated into two, three or four layers, but this differentiation dont affect all the chambers and/or correspond to fossildiagenetic features and cannot be admitted as generic criterion. Some groups of species exhibit sporadic addition of: (a) a yellow pseudofibrous inner layer (see *G. mosquensis* Reitlinger, 1950), or (b) are similar to the wall of an *Omphalotis* endothyroid (Vachard & Beckary, 1991), or (c) are granular with agglutinated particules: *G. granulosa* Reitlinger, 1950, and finally, (d) with an intermediary clear layer (" diaphanotheca" of authors): *G. bulloides* (Brady, 1876) of the authors. However, *G. granulosa* and *G. mosquensis* were included in the same group by Reitlinger (1950).

Some authors consider that the appearance of the "diaphanothecal" wall in *G. bulloides* is characteristic of the Early/Mid Carboniferous Boundary; nevertheless, *G. bulloides* appears in the late early Serpukhovian or Protvinsky (Kulagina & Gibshman, 2002, Text-Fig. 3 p. 186; Shcherbakova & Shcherbakov, 2002, p. 308).

Finally, the genus *Globivalvulina* is composed of several groups of species according to generally admitted foraminiferal criteria: wall structure, size, development of the valvulae, characters of the chambers, and shape of the apertural face. Unfortunately, these characters appear very variable among the specimens of the same population. The six main groups are:

First group: *G.* ex gr. *parva*. Small species (D < 0.350 mm) with unilayered dark wall, numerous chambers, few or no sutures, and valvula absent or developed only in the last chambers: *G. parva* Chernysheva, 1948; *G. minima* Reitlinger, 1950; *G. kantharensis* Reichel, 1946 = *G. scaphoidea* Reitlinger, 1949; *G. procera* Postoyalko, 1990;?*G. eogranulosa* Reitlinger, 1949; ?*G. shikhanensis* Morozova, 1949; ?*Globivalvulina bristolensis* Reichel, 1946.

Second group: *G.* ex gr. *bulloides*. Medium size species (D = 0.350-0.500 mm), generally with five chambers at the last whorl, and some wall differentiations forming very rarely and very sporadically an intermediary clear layer ("diaphanotheca" of the authors), and well-developed valvulae: *G. bulloides* (Brady, 1876); *G. bulloides minima* Zolotova in Zolotova & Baryshnikov, 1980 (*minima* is preoccupied); *G. apiciformis* Zolotova in Zolotova & Baryshnikov, 1980; *G. cora* Harlton, 1928; *G. kamensis* Reitlinger, 1950;*G. moderata* Reitlinger, 1949; *G. sossipatrovae* Baryshnikov in Zolotova & Baryshnikov, 1980; *G. unciata* Zolotova in Zolotova & Baryshnikov, 1980; *G. vulgaris* Morozova, 1949; *G. ovata* Cushman & Waters, 1928; *G. biserialis* Cushman & Waters 1928; *G. pulchra* Retlinger, 1950; *G. arguta* Konovalova 1962; *G. discrata* Wang, 1974; *G. gaptankensis* Harlton 1928; *G. neglecta* Gaillot & Vachard (submitted); *G. parascaphoidea* Gaillot & Vachard (submitted); and *G. curiosa* Gaillot & Vachard in Gaillot *et al.* (submitted a).

Third group: *G.* ex gr. *granulosa*. Medium size with agglutinated wall (difficult to distinguish from *Koktjubina* Marfenkova, 1991); *G. granulosa* Reitlinger, 1950; *G. granulosa* var. *complicata* Reitlinger, 1950; *G. granulosa* var. *compressa* Reitlinger, 1950; *G. rauserae* Reitlinger, 1950; and *G. guangdongensis* Hao & Lin, 1982.

Fourth group: *G.* ex gr. *spiralis*. Large species (D > 500μm) with unilayered dark wall and well-developed valvulae, with uncoiling and evolute last chambers. This group, relatively characteristic of the Late Pennsylvanian, is morphologically homogeneous, although the wall is microgranular in *G. nassichucki* and coarsely granular in *G. pergrata*. The members of this group are: *G. spiralis* Morozova, 1949; *G. nassichuki* Pinard & Mamet, 1998; *G. pergrata* Konovalova, 1962; *G. distensa* Wang in Zhao *et al.*, 1981; *G. glomerata* Ivanova, 1988; ?*G. orbiculata* Zolotova in Zolotova & Baryshnikov, 1980; ?*G. ovoidea* Zolotova in Zolotova & Baryshnikov, 1980; ?*G. pulchra* Reitlinger, 1950.

Fifth group: *G.* ex gr. *mosquensis*. Medium to large size species (D > 0.300 mm) with scarcely developed pseudofibrous internal layer: *G. mosquensis* Reitlinger, 1950; *G. syzranica* Reitlinger, 1950; *G. donbassica* Potievskaya, 1962; *G. cyprica* Reichel, 1946; *G. graeca* Reichel, 1946; *G. vonderschmitti* Reichel, 1946.

Sixth group: unamed. Medium size with differentiated wall similar to the endothyroid genus *Omphalotis*: *G.* sp. Vachard & Beckary, 1991. A similar differentiation of wall is visible in *G.* aff. *vonderschmitti* sensu Vachard & Ferrière, 1991, and the paraglobivalvulinin genus *Urushtenella*. Some mentioned "keriothecal" walls (Reichel, 1946) and alveolar walls (Saint-Jean, 1957) might be related to this group.

The question is to establish the real status of these groups due to the designation of the first one as the

distinct genus *Biseriella*. Theoretically, *Biseriella* differs from *Globivalvulina* by a microgranular wall versus a "diaphanothecal" wall. The generic modification was supposed take place exactly at the Mid-Carboniferous Boundary. Rapidly, some problems have cropped up: (1) the genus *Biseriella* was criticized by Vachard (1977) and Altiner (1984), although the latter author accepted the genus in subsequent studies (e.g., Altiner & Savini, 1995); (2) assignments of species to both genera vary a lot according to the authors; (3) the revision of *G. bulloides*, the type species of *Globivalvulina*, by Brenckle (2005) did not confirm the existence of a true diaphanotheca in the wall, whereas *G. parva* was never revised. According to our observations, the so-called diaphanotheca is not a constant character among the *Globivalvulina*. Similarly, the double, pseudofibrous layer, affects only a part of the specimens and in each specimen only a part of the septa; e.g., in *G. graeca, G. vonderschmitti, G. mosquensis* or *G. syzranica*. Brenckle (2005) doubted of the assignment of *G. mosquensis* and speaks about *Globivalvulina*? *mosquensis*, but the creation of a new genus for this species would be also questionable than that of *Biseriella*. Another problem: although they are very similar in coiling (last evolute chambers) and great size, and both signicantively different of *Globivalvulina bulloides*, the coeval *G. pergrata* and *G. spiralis* (and its probable synonym *G. nassichuki*) differ completely between them by their wall microstructure (granular versus microgranular). Hence, we don't know which type of objective criterion must be prioritized to create genera, subgenera, group of species, species or subspecies of Pennsylvanian *Globivalvulina*. Brenckle (2005, p. 13), with his options, must share the Reitlinger's type material between several genera; for example, among the three type specimens of *Globivalvulina eogranulosa*, one should belong to *Biseriella*, the other one to *Globivalvulina*, and the last one was not revised. Similarly, the two specimens of the type material of *G. moderata* are assigned by Brenckle (2005) to *Biseriella* and *Globivalvulina*, respectively.

Thirty years after the creation of *Biseriella*, the type material of *Globivalvulina*, *G. bulloides*, was revised. Contrary to the rules of the ICZN (International Code of Zoological Nomenclature), Brenckle (2005) has not selected an illustration of Brady (1876, Pl. 4, Fig. 14 = Brenckle, 2005, Pl. 7, Fig. 21 = herein Fig. 6. 20) as lectotype, but another specimen. Paradoxically, when the name of the species is *bulloides*, something which is only obvious in an axial section, Brenckle chosen a transverse section as lectotype. Furthermore, this lectotype don't exhibit the "clearly defined diaphanotheca" of Armstrong & Mamet (1977) because it is described as: "Wall mostly dark, microgranular, with a trace of central light colored layer, becoming appreciably thicker in the outer chambers"; or still more restrictively: "The wall of the lectotype as well as those of the paralectotypes exhibits a rudimentary, central light colored layer but that structure is difficult to discern not only by its incipient development but also because the thin sections are overly thick". Consequently, we can conclude: (1) the type material of *G. bulloides* does not exhibit clearly a diaphanotheca, but only some sectors with recrystallizations; (2) many specimens of various species present these recrystallizations (see the remarks of Reichel, 1946; Reitlinger, 1950; Altiner, 1984; and Perret, 1993); (3) these recrystallizations exist among many atypical species of *Biseriella* and in *B. parva* itself; (4) finally, the wall of the numerous species of *Globivalvulina* exhibits many microstructures and/or diageneses; (5) the systematics of *Globivalvulina* is impossible to establish clearly now with our available techniques; it is clear that *G*? *mosquensis* differs totally from *G. bulloides* if we take into account the characters used for the diagnosis of *Biseriella*, but these characters dont seem to be generically diagnostic. As well as for the pairs *Howchinia-Vissariotaxis* and *Eolasiodiscus-Hemidiscus*, the variation, in the type of wall of *Biseriella-Globivalvulina*, is intraspecific and not generic (see Perret, 1993; Vachard & Krainer, 2001; Okuyucu & Vachard, 2006). Conversely, we admit perfectly the generic character of this difference in *Quasiendothyra-Eoquasiendothyra*, *Cribrostomum-Koskinotextularia*, and *Climacammina-Koskinobigenerina*. Many variations in the wall are obvious in *Tetrataxis*, *Globoendothyra* or several archaediscids, but these variations are not used as generic in taxonomy. They correspond most to a Sigal's spectrum (Sigal, 1966). Finally, no new genera are proposed in order to share the *Globivalvulina* genus, but we recommend putting in synonymy *Biseriella* and *Globivalvulina* up to a complete revision of the genus *Globivalvulina*.

REASONS OF A POSSIBLE DECLINE IN THE EARLY/MIDDLE PERMIAN

After the Pennsylvanian-Cisuralian diversification, Artinskian to Murgabian forms did not vary a lot. Only the species *G. cyprica*, *G. graeca*, and *G. vonderschmidtti* appeared in this epoch. The difference in the evolution of the globivalvulines can be related to the warming of the Earth after the Gondwan glacia-

tion. Other hypotheses can be the deepening of the carbonate platforms (according to our observations in southern Urals), and/or the appearance of many upwellings or cold-currents as admitted by Weidlich (2002) or Samankassou (2002) in Oman and the Carnic Alps. Another explanation is the subduction of Urals, which destroyed many centers of speciation of the Pennsylvanian species and interrupted the communications between Tethys and North America. These communications and migrations of Tethyan microfauna to North America were nevertheless re-established as soon as the Midian/Capitanian with the migration of the *Neoschwagerina* up to the North American Craton, in Texas. Some recently published biseriamminoids from the Middle Permian of Texas (Nestell & Nestell, 2006) exhibit Tethyan affinities, and have entirely modified our palaeobiogeographical knowledge about this world area.

Another groups can occupy more successfully the same biotopes. This hypothesis can be confirmed by the presence of globivalvulinids in confined environments in Afghanistan (Vachard, 1980). Conversely, this adaptation could permit to the globivalvulines to survive at the PTB crisis (see below).

Species mentioned in the late Early Permian are *G. apiciformis* Zolotova in Zolotova & Baryshnikov, 1980; *G. bulloides minima* Zolotova in Zolotova & Baryshnikov, 1980; *G. kungurensis* Igonin (see Chuvashov *et al.*, 1990); *G. orbiculata* Zolotova in Zolotova & Baryshnikov, 1980; *G. ovoidea* Zolotova in Zolotova & Baryshnikov, 1980; *G. sossipatrovae* Baryshnikov in Zolotova & Baryshnikov, 1980; *G. unciata* Zolotova in Zolotova & Baryshnikov, 1980; apparently all belong to the group *G. bulloides*.

Verispira was described in the Artinskian of Queensland (Australia), but here also this unquestionable variation migth be only intraspecific.

THE LOPINGIAN DIVERSIFICATION AND THE PTB

After the Pennsylvanian-Cisuralian diversification, and the Artinskian-Murgabian impoverishment, the diversification of the globivalvulinid is maximal (e.g., Altiner, 1997, Gaillot, 2006). In the Midian-Lopingian times (late Middle to Late Permian), the family Globivalvulinidae can be subdivided into 4 subfamilies (Fig. 8): Globivalvulininae Reitlinger, 1950; Paraglobivalvulininae Gaillot & Vachard in Gaillot *et al.* (submitted b); Dagmaritinae Bozorgnia, 1973 (= Louisettitinae Loeblich & Tappan, 1984); Paradagmaritinae Gaillot & Vachard in Gaillot *et al.* (submitted b). The three latter are characteristic of the interval Midian-Lopingian, and the two latter can be generated by the unique species *G. cyprica* (as partly suggested by Altiner, 1997). The ecological tolerance of the globivalvulines was emphasized by Vachard in Vachard & Montenat (1981, p. 70). The Late Permian forms are tolerant to the hypersalinity, but the habitus is nearly always restricted to the inner platforms, where other groups are diversified.

The Midian-Wuchiapingian Globivalvulininae are composed of *Globivalvulina* Schubert, 1921; *Charliella* Altiner & Ozkan-Altiner, 2001; *Siphoglobivalvulina* Gaillot & Vachard in Gaillot *et al.* (submitted b); *Retroseptellina* Gaillot & Vachard in Gaillot *et al.* (submitted b) (Fig. 12). The *Globivalvulina* include diverse forms corresponding to new or older representatives of three of the seven groups listed above: (a) the group *G. bulloides,* (b) the group *G. parva* = *"Biseriella"* (auctorum), with *G. kantharensis* for example, and (c) sporadically bilayered taxa as such *G. cyprica, G. graeca* and *G. vonderschmitti*. Three species, still nomina nuda, will be introduced by Gaillot & Vachard (submitted): *G. neglecta, G. parascaphoidea* and *G. curiosa*. This latter appears in South China below the lithostatigraphical limit of the PTB (Gaillot *et al.*, submitted a), and, after calibration by the FAD of the conodont *Hindeodus parvus,* migth indicate that the *Globivalvulina* survive in the earliest Triassic times. *Charliella* differs by its wall and the more triangular shape of the chambers. It is likely that this group has evolved from the *G. vonderschmitti* pool (Nestell, pers. communication), developing the angular periphery and thicker wall due the high-energy tidal shoal environments during the late Wuchiapingian. This adaptation may have occurred at least twice during the Permian, firstly during the Midian with *Charliella rossae* and later during the late Wuchiapingian. This genus exists in the Midian of Turkey (northwest Anatolia), Italy (Monte Facito), Sumatra and Cambodia, early Midian of Oman, late Capitanian of central Mexico, and Late Permian of Thailand (Gaillot, 2006 with references). It is probably present in Japan (Taishaku, *Yabeina* zone), Oman and late Wuchiapingian of Zagros, Fars and Abu Dhabi; Gaillot, 2006).

Siphoglobivalvulina, with two submitted species, has a granular wall and an aperture differing from that of *Globivalvulina*. Its distribution is late Midian-Lopingian from Zagros-Fars area (Iran) and Turkey (Hazro), Transcaucasia?, Montenegro, Italy, Hungary,

South China, central Japan, northern Thailand (Gaillot, 2006). *Retroseptellina*, with three already described species: *R. globosa*, *R. decrouezae* and *R. nitida*, is characterized by (a) the horizontally elongate coiling giving abnormally broad tests than in a true *Globivalvulina*, and (b) especially, by the backward curvature of the septa. It is Midian to Changhsingian in age, in southern Turkey, Thailand and Malaysia, Batain Plain (Oman). Transcaucasia, New Zealand, central Japan, Greece, South China, northern Italy, Iran, Saudi Arabia, and Hungary (see Gaillot, 2006, with references).

The Paraglobivalvulininae are Globivalvulinidae with entirely or almost entirely enveloping last chambers; i.e., they tend to a spherical shape. They exist some endoskeletal supplementary formations at the roof of the chambers, and a wall microgranular unilayered, occasionally with an *Omphalotis*-like differentiation. The subfamily composition is: *Septoglobivalvulina* Lin, 1978; *Paraglobivalvulina* Reitlinger, 1965; *Urushtenella* Pronina-Nestell in Pronina-Nestell & Nestell, 2001; and *Paraglobivalvulinoides* Zaninetti & Jenny-Deshusses, 1985. They exist during the Midian-Changhsingian in Tethys. *Septoglobivalvulina* is morphologically transitional between *Globivalvulina* and *Paraglobivalvulina*. It begins as a *Globivalvulina* and its last chamber envelops all the preceding ones. *Paraglobivalvulina* is accurately known from the work of Jenny-Deshusses (1983). Unlike Unal *et al.* (2003), we consider *P. gracilis* as very similar to the type-species *P. mira*. *Paraglobivalvulinoides* is well separated from *Paraglobivalvulina* by the largest size and the details of the endoskeleton, while *Urushtanella* is only a *Paraglobivalvulina* with an *Omphalotis*-type wall.

The Dagmaritinae Bozorgnia, 1973 nomen translat. (ex family) are uncoiled biseriate (or exceptionally rebecomed biserially coiled) Globivalvulinidae, with chambers often with horn-like lateral expansions, and a basal, simple aperture with valvula. They are composed of *Sengoerina* Altiner, 1999; *Crescentia* Ciarapica, Cirilli, Martini & Zaninetti, 1986; *Dagmarita* Reitlinger, 1965; *Siphodagmarita* Gaillot & Vachard in Gaillot *et al.* (submitted b); *Bidagmarita* Gaillot & Vachard in Gaillot *et al.* (submitted a); and *Louisettita* Altiner & Bronnimann, 1980. The genus *Sengoerina* is a *Globivalvulina* passing to a *Dagmarita* by the modification of the shape of the chambers. The type species is Midian in age, but unpublished material is present in the Murgabian of Afghanistan. *Dagmarita* was remarkably well described by Reitlinger (1965). *Crescentia* is a *Dagmarita* which recovers a coiled growth. *Bidagmarita* is larger than *Dagmarita* with a different wall. *Louisettita* is a *Dagmarita* with some additional elements of endoskeleton, still not entirely well interpretable. *Siphodagmarita* with *Siphodagmarita vasleti* Gaillot & Vachard in Gaillot *et al.* (submitted b) as type species, has a wall and an aperture of *Siphoglobivalvulina* but is rectilinear as a dagmaritinin. The convergence with Palaeotextulariidae or Textulariidae is extreme in this case, and a possible Mesozoic form of this taxon has been denominated *Textularia tetragonica* by Arnaud-Vanneau (1980).

The Paradagmaritinae are a subfamily of Globivalvulinidae characterized by a uncoiling more or less developed after an initial coiling generally slightly trochospiral. They are composed of *Paradagmarita* Lys in Lys & Marcoux, 1978, *Paradagmaritopsis* Gaillot & Vachard in Gaillot *et al.* (submitted a), *Paradagmaritella* Gaillot & Vachard (submitted), *Paradagmacrusta* Gaillot & Vachard (submitted); and *Paremiratella* Gaillot & Vachard (submitted).

Paradagmarita is well known, and remarkably abundant in Taurus and Zagros but still mentioned in several Neo-Tethyan areas. Its type of development (trochospiral biseriate becoming biseriate uncoiled) exists also in *Paradagmaritella* (with a granular wall) and *Paradagmacrusta* (with a thick crusta on the floor of the chambers, and because this supplementary crusta is a character apparently unique among the Biseriamminoidea). The last appeared genus of the lineage (Fig. 12), *Paremiratella*, is a homeomorph of *Paradagmarita* with an internal globivalvuline (Fig. 11), a short uncoiled part and a frequently microsparitized wall. It is homeomorph of some here above suggested *Biseriammina*.

BIOSTRATIGRAPHY

Globivalvulina? *bristolensis* is characteristic of the late Tournaisian (e.g., Devuyst, 2006). The sequence from late Asbian to late Serpukhovian can probably be accurately biozoned and especially the Viséan/Serpukhovian boundary (e.g., Kulagina and Gibshman, 2002). The Bashkirian is poorly divided by this group due to the good scales provided by the fusulinids. The Moscovian is well known, as well as the Kasimovian. No many changes in species composition are recorded to the Gzhelian-Sakmarian. The Artinskian-Murgabian is poorly zoned. The Midian-Lopingian is principally characterized by a strong

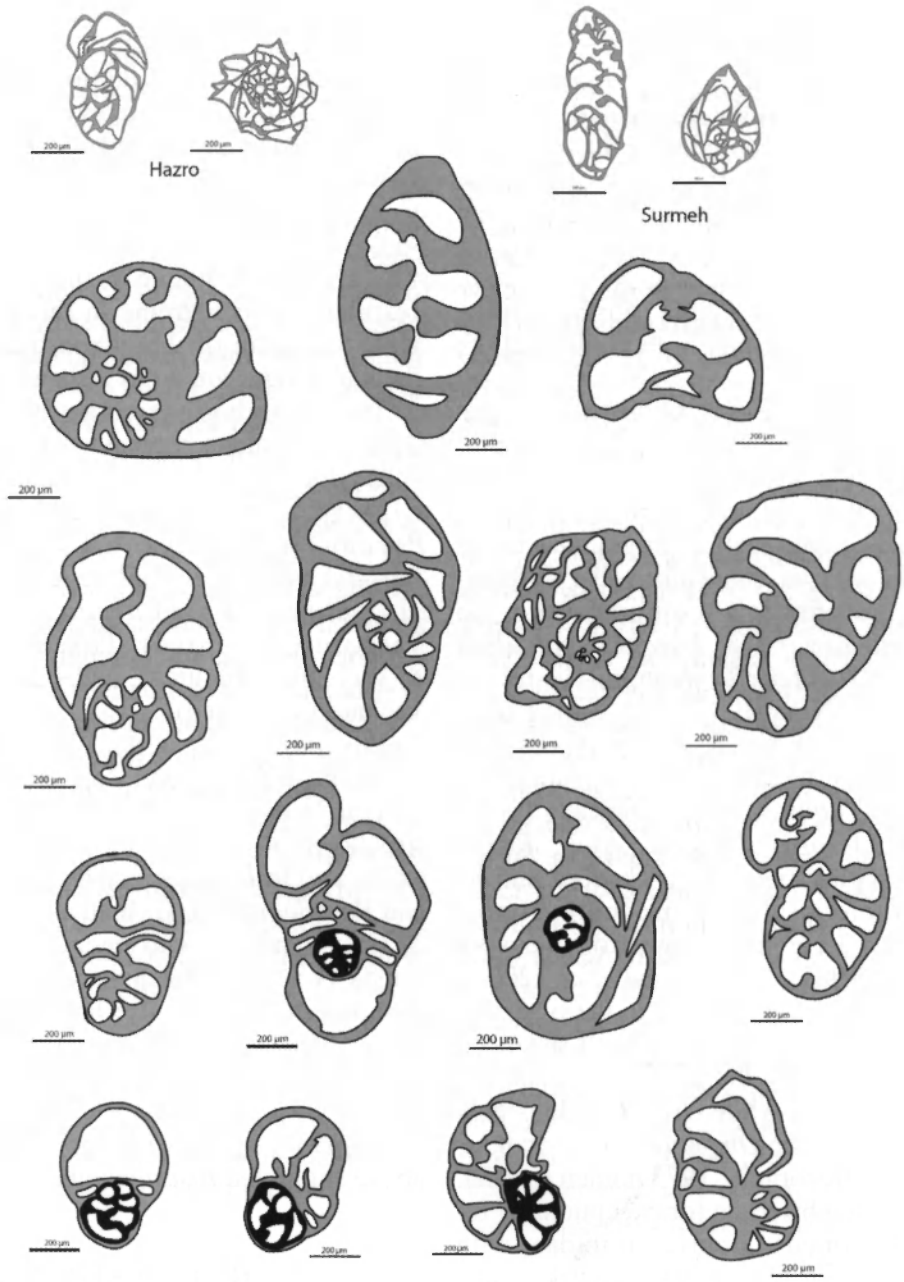


FIGURE 11–Various sections of *Paremiratella* (Zagros and United Arabian Emirates, with the internal globivalvulinin coloured in black).

diversification of the Globivalvulinidae. The last species of *Globivalvulina*, *G. curiosa* Gaillot & Vachard in Gaillot *et al.* (submitted a) attains the summit of the Permian and migth survive in the earliest Triassic? of South China at the base of the thrombolites lithostratigraphically assigned to the base of Triassic (investigation of conodonts in progress). In this species, the shape of the chambers is very irregular, hemispherical to semi-ovoid, as in the tests affected today by mechanic perturbations, hypersalinity or marine pollutions (e.g., Stouff *et al.*, 1999; Armynot du Châtelet *et al.*, 2004); abnormal chambers are located at the end of the coiling, at the beginning of the terminal whorl, or in the entire terminal whorl. According to colleagues of Lausanne, Switzerland (pers. comm.), more or less similar "crazy globivalvulines" exist in the Lopingian of Alborz (northern Iran). They migth belong to *G. curiosa*. All the coeval "normal" globivalvulines of the literature are different, as well as the "*Biseriella*". Because of their location in the PTB (Permian-

Triassic Boundary) levels, these forms are evidently upon the controls of the different geochemical shifts observed during this period.

Among the other Globivalvulininae, according to Gaillot (2006), *Charliella altineri* is characteristic of the late Wuchiapingian in Zagros and adjacent areas, and disappears just below the appearance of the Changhsingian marker *Paradagmacrusta callosa,* in southern Iran (Gaillot, 2006). *Paraglobivalvulina* is generally considered as a Late Permian indicator (Pronina, 1995), whereas in southern Iran (Zagros) the FAD of *Paraglobivalvulina mira* was suggested as late Capitanian in age (Baghbani, 1997), as well as the Hazro section (Taurus, southern Turkey), where *P. mira* is associated with the keriothecal fusulinid *Chusenella* aff. *sinensis* (Gaillot, 2006; Gaillot *et al.,* submitted b) considered as Middle Permian in age (e.g., Leven, 1998). *Paraglobivalvulinoides septulifer* indicates the latest Changhsingian in Alborz (Bozorgnia, 1973), ?Italy (Pasini, 1985), Greece (Vachard *et al.,* 1993), Himalaya (Lys *et al.,* 1980), South China (Lin *et al.,* 1990; Gaillot *et al.,* submitted a), Thailand (Sakagami & Hatta, 1982, Yanagida *et al.,* 1988), Transcaucasia (Pronina-Nestell & Nestell, 2001), Japan (Kobayashi, 1997, 1999), and Malaysia (Fontaine *et al.,* 1994). *Louisettita elegantissima*, initially considered as late Changhsingian in Turkey (Altiner & Brönnimann, 1980), has a likely earlier FAD in the middle Wuchiapingian in Zagros and was found in late Changhsingian strata in South China (Gaillot *et al.*, submitted a). An event with abundant *Louisettita elegantissima* and *Dagmarita* spp. corresponds to a major regional bloom in biseriamminoid species. *Louisettita extraordinaria* Gaillot & Vachard in Gaillot *et al.* (submitted b) has a range limited to another important event as it allows a direct correlation with sections towards the southeastern Turkey (e.g., Hazro) and possibly with the Changhsingian levels of Afghanistan (as a possible synonym of the *Paradagmarita dubreuilli* nomen nudum of Vachard, 1980). Finally in our investigations, three markers appear to be fundamental to attribute an interval to the late Changhsingian: (a) the calcareous algae *Actractyliopsis lastensis*, (b) the dagmartinin *Louisettita extraordinaria*, and (c) the last representative of the *Paradagmarita* lineage, *Paradagmarita planispiralis* Gaillot & Vachard in Gaillot *et al.* (submitted b).

The genus *Paradagmarita* and its subfamily characterize exclusively the Lopingian.

The stratigraphic distribution of *Paradagmarita* has been discussed: Dorashamian (Vachard *et al.*, 2002) or late Dzhulfian-Dorashamian (Altiner, 1981). The *Paradagmarita* zone in Taurus (Turkey) is considered as Changhsingian/Dorashamian when associated with *Louisettita* (e.g., Altiner *et al.,* 2000). Russian authors proposed an early Dzhulfian/Wuchiapingian *Paradagmarita* FAD (Kotlyar *et al.*, 1989; Pronina, 1995). Herein, according to Gaillot (2006), the early Wuchiapingian-late

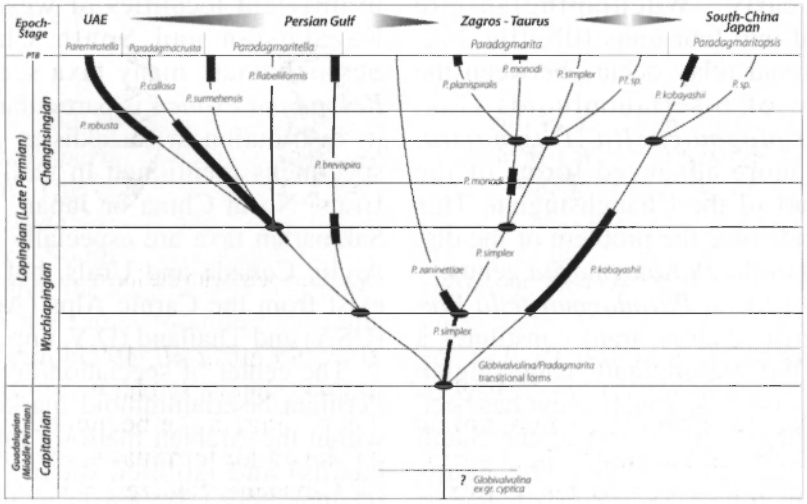


FIGURE 12–Phylogeny of Paradagmaritinae (Gaillot and Vachard, submitted). The Persian Gulf possibly acted as a radiative pole with a pool of initially endemic species that intermittently spread towards relatively closed palaebiogeographic domains. The units (Gaillot, 2006) are regional subdivisions, not used in this synthetic paper.

Changhsingian distribution of *Paradagmarita* is admitted (Fig. 10). Contrary to the previous studies, this genus is not unique in this zone, and all a lineage with diverse genera can be reconstructed in this interval (Fig. 10). *Paradagmarita simplex* occurs in the lower part of the Wuchiapingian, above the *Rectostipulina* zone; *Paradagmarita zaninettiae* could constitute the late Wuchiapingian representative of the *Paradagmarita* lineage that evolved from the early Wuchiapingian *P. simplex* to the Changhsingian *P. monodi*. This latter could be considered as the early/middle Changhsingian "turnover marker", similarly to *Paradagmaritella brevispira* for the Wuchiapingian/Changhsingian transition. *Paradagmarita planispiralis* Gaillot & Vachard (submitted) is the most advanced form, with an almost planispiral coiling, and seems to be the last representative of the *Paradagmarita* lineage. *P. monodi* and *P planispiralis* are especially abundant just before the Permian-Triassic boundary in the Zagros-Fars area and in Turkey. In these areas, the Permian-Triassic transition is characterized by abundant *Paradagmarita monodi* below the appearance of the classical thrombolites. The first appearance of Triassic fauna (such as the annelid *Spirorbis phlyctaena*) confirms the transgressive character of the sedimentary cycle through the Permian-Triassic boundary interval and correlatable character of both events. A specimen of *Paradagmarita monodi* (it does not seem reworked) was found in the Permian-Triassic turnover (the end-Permian extinction), coinciding with the base of the thrombolitic beds. These different taxa permit to divided the early Wuchiapingian-late Changhsingian interval into four units Illb, IIIa, IVc, IVb (Fig. 10). A regional relay occurs between the Wuchiapingian pool of biseriamminoids (i.e., *Paradagmarita*, *Paradagmaritella, Dagmarita, Louisettita*) and the more advanced forms of the family in the basal part of the Changhsingian. This event might explain and solve the problem of the discussion about the FAD of the *Paradagmarita* genus.

Among the brother-genera, *Paradagmaritella brevispira* at Kuh-e Surmeh (Zagros, Iran) constitutes a good marker for the Wuchiapingian/Changhsingian transition, as indicated above A similar event has been observed within the Khuff succession of the Saudi Arabian subsurface (Gaillot, 2006). The genus *Paradagmaritopsis* with *Paradagmaritopsis kobayashii* is another important taxon as it suggests that the Zagros-Fars area was palaeogeographically strongly linked to some parts of South-China and Japan during the Late Permian (see next chapter). *Paradagmaritopsis kobayashii* has been documented in the Changhsingian of Japan and South China (Gaillot, 2006), and those latter taxa are distibuted more or less abundantly up to the latest Changhsingian suggesting their belonging to a homogenous palaeogeographic unit with Iran. This homogeneity is nevertheless relative and the markers could also appear during the Wuchiapingian, with delayed appearances due to migration processes. A late Wuchiapingian age is here favored as the biseriamminoid bloom of the overlying unit is considered to be linked to a major transgressive event in the early Changhsingian. The first occurences of *Paradagmaritopsis kobayashii* and *Charliella altineri* are also validated within this unit, as well as the LAD of *Nanlingella simplex*. Both genera *Paradagmacrusta* and *Paremiratella* revealed powerful concerning the correlations within the Changhsingian levels. *Paradagmacrusta callosa*, *Louisettita ultima* and the nodosarioid *Aulacophloia martiniae* are the main early Changhsingian foraminiferal markers in Zagros (Gaillot, 2006).

PALAEOBIOGEOGRAPHY

Biseriammina is apparently limited to the Urals. Similarly, *G.? bristolensis* is nearly confined to England and adjacent countries. Kokjubinidae sensu stricto exist from Kazahkstan to the USA and Canada but are very sporadically mentioned. The lineage *Dzhamansorina-Globivalvulina* was apparently found in different localities of western Europe, Ukraine, Kazakhstan and South China. Since the late Serpukhovian, many taxa seem to be cosmopolite. *Koktjubina exotica* is particularly puzzling because of its distribution in Kazakhstan and USA, without any specimens mentioned in well known areas such as Urals, North China or Japan. Late Carboniferous to Sakmarian taxa are especially known in Spitsbergen, Arctic Canada and Urals, but the same forms seem exist from the Carnic Alps (Austria) to New Mexico (USA) and Thailand (D.V. unpublished data).

The center of speciation/diversification of the Late Permian biseriamminoid markers is probably located within the Arabian platform interior (Zagros and Fars basins) and isolated during Wuchiapingian time (Gaillot, 2006). By means of the basal Changhsingian event and subsequent bloom, those markers likely spread over a larger palaeogeographic domain (Fig. 13). Midian to Lopingian taxa are generally endemic of Zagros, Taurus and South China; i.e., relatively con-

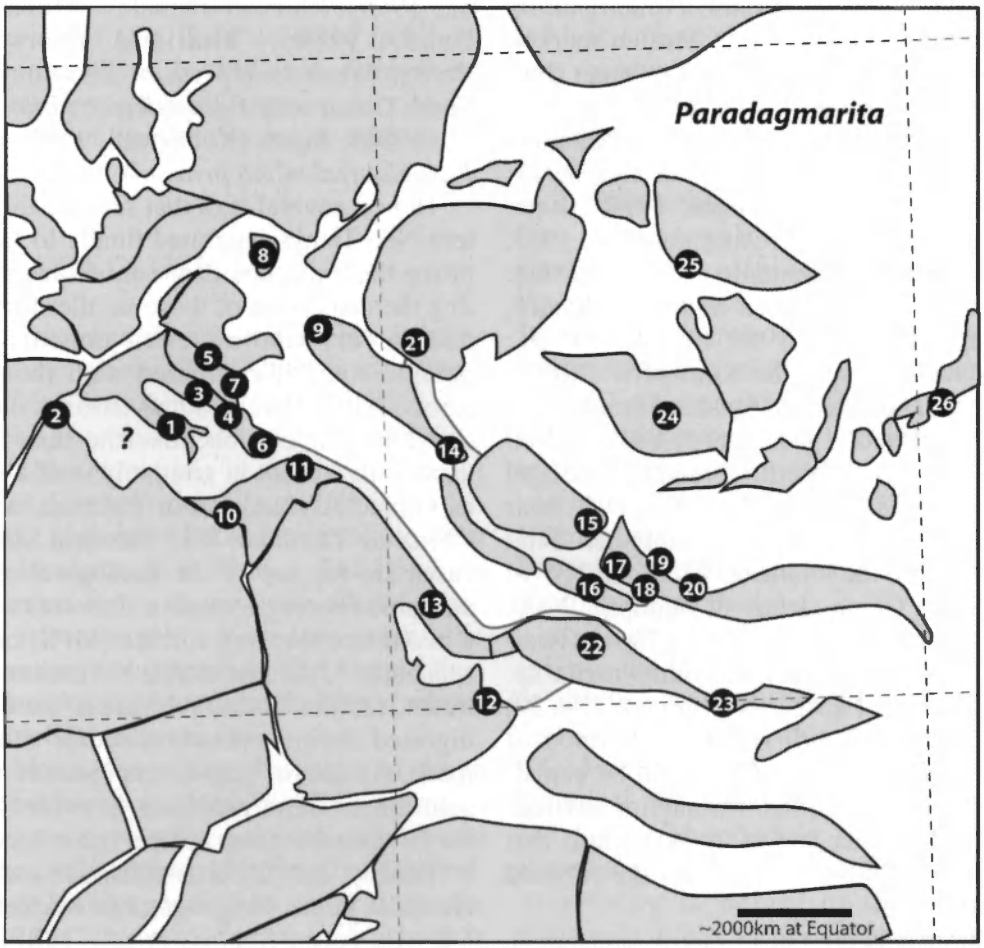


FIGURE 13–Palaeobiogeography of *Paradagmarita*. *1*, Italy, *2*, Tunisia, *3*, Croatia-Montenegro, *4*, Albania, *5*, Hungary, *6*, Greece, *7*, Cyprus, *8*, Crimea, *9*, Caucasus, *10*, Anatolia, *11*, Taurus, *12*, Oman-Saudi Arabia, *13*, Zagros, *14*, Alborz, *15*, Afghanistan, *16*, Salt Range, *17*, S.E. Pamir, *18*, Himalaya, *19*, Kashmir, *20*, Tibet, *21*, South China, *22*, Thailand-Burma, *23*, Malaysia, *24*, Indochina, *25*, Primorye-Koryak, *26*, Japan.

fined in the Neo-Tethys, and *Paradagmaritopsis* even attains the Japan. *Paradagmarita* extends to Italy, and to Thailand and Japan. The presence of the genera *Paradagmaritopsis*, *Paradagmarita* and *Louisettita* in Laren section (Guangxi, South China; Gaillot *et al.*, submitted a)) suggests that the Zagros area was periodically connected with the Laren foraminiferal fauna between two palaeogeographic domains that were relatively close to each other, without major oceanic barrier separating those domains (Fig. 13).

Because of the stenotopic and stenobath characters of its species, *Paradagmarita* indicates the continuity and the free communication in the Neo-Tethys seaway during the Changhsingian, and this latter genus seems to be characteristic of the Neo-Tethys because it is only mentioned in Italy (under some erroneous designations: *Paradagmarita evoluta* and *Paraglobivalvulina monodi*; Cirilli *et al.*, 1998, p. 99; Jenny & Stampfli, 2000); Tunisia (Bir Mastoura borehole) as *Paradagmarita* sp. (Lys, 1988); Hungary, as *Globivalvulina cyprica* (Berczi-Makk *et al.*, 1995, Pl. 5, Fig. 4); Greece: Hydra: Jenny & Stampli (2000); central, eastern and southern Turkey: *Paradagmarita* n. gen. sp. 1, 2, 3 (Argyriadis & Lys, 1977), *Paradagmarita monodi*, *P.* sp. 2, *P.* sp. 3 (Lys & Marcoux, 1978); *P. monodi*, *P. evoluta*, *P. lata* (Lys, 1988); *P. monodi*, *P. flabelliformis*, *P.* sp. (Zaninetti *et al.*, 1981; Altiner, 1981, 1984; Köyluoglu & Altiner, 1989; Altiner *et al.*, 2000; Jenny & Stampfli, 2000; Unal *et al.*, 2003); Hazro as *P.* sp. (Lys, 1988) or as *Palaeotextularia* sp. (Canuti *et al.*, 1970), and probabli Valvulinidae (Canuti *et al.*, 1970); Armenia, Dorasham 2: *Paradagmarita* sp. (Pronina, 1988, 1989; Kotlyar *et al.*, 1989); Oman *Paradagmarita* sp. (Lys in Montenat *et al.*, 1977, but

this reference is questionable, because *Paradagmarita* is here associated to *Shanita*, a late Midian marker, according to Vachard *et al.*, 2002); Trucial Oman (Lys, 1988); Saudi Arabia: *Paradagmarita flabelliformis*, *P.* sp. (Manivit *et al.*, 1986; Vaslet *et al.*, 2005; Vachard *et al.*, 2005); southern Iran (Argyriadis & Lys, 1977; Argyriadis, 1978; Lys, 1988; Baghbani, 1997; Altiner *et al.*, 2000), and northern Iran (Okimura *et al.*, 1985, Partoazar, 1995); central Mountains of Afghanistan: *Paradagmarita dubreuilli* nomen nudum (Vachard, 1980); Salt Range (Okimura, 1988, Fig. 3. 4: *P.* sp.; Fig. 2: *P. monodi;* Jenny & Stampfli, 2000); *Paradagmarita*? is mentioned in Zanskar Himalaya by Jenny-Deshusses & Baud (1989, p. 885, 886), as well as "*Crescientia*" (sic) (ibidem, p. 887); Thailand (Fontaine *et al.*, 1988: Khao Khan Ban Dai, near Prachuabkhirikhan; and Vachard, unpublished data: road N 323, just before the kilometer 22, at the NW of Kachanaburi); South China (Jenny & Stampfli, 2000; Gaillot *et al.*, submitted a). The form of Japan (Iwai-Kanyo area; Chichibu Terrane): *Paradagmarita* sp. (Kobayashi, 1997, Pl. 4, Fig. 19: 2004, Fig. 6.47-6.50) is in fact a *Paradagmaritopsis*. The absence of *Paradagmarita monodi* in South-China can be explained by strong infeodation to platform-interior environments (probably shallower and more restricted) that prevailed during the Late Permian onto the rimmed Arabian platform.

Paradagmaritopsis is present in Zagros and Japan, as well two taxa described as *Partisania* sp. and *Globivalvulina* sp. by Kobayashi (2004), and renamed *Partisania* sp. and *Floritheca variata* n. gen. n. sp. (Gaillot, 2006; Gaillot & Vachard, submitted).

Louisettita is apparently confined to eastern Taurus, Zagros (Altiner, 1981; Gaillot, 2006), and Oman (but not illustrated: Pillevuit, 1993, p. 91), and is also present in South-China (Gaillot *et al.*, submitted a). *Charliella, Sengoerina, Siphoglobivalvulina* and *Siphodagmarita* appear more endemic because they are apparently absent of South China. *Paraglobivalvulinoides* is mentioned in more localities from Italy to Japan: Italy (Tesero Member: Noë, 1987); Greece, Attica (Vachard *et al.*, 1993), Evvia (Jenny-Deshusses & Baud, 1989); northwestern Caucasus (Kotlyar *et al.*, 1999; Pronina-Nestell & Nestell, 2001); Armenia (Jenny & Stampfli, 2000); Alborz (Bozorgnia, 1973; Jenny & Stampfli, 2000); Abadeh (Baghbani, 1993; Jenny & Stampfli, 2000); Zagros (Baghbani, 1997; but not found during this study); Oman (Jenny & Stampfli, 2000); Ladakh Himalaya under the name of *Paraglobivalvulina mira* Reitlinger (Lys *et al.*, 1980); S.E. Pamir (Kotlyar *et al.*, 1999); Zanskar Himalaya (Jenny-Deshusses & Baud, 1989); Thailand (Toriyama, 1984): *Paraglobivalvulina piyasini* Sakagami & Hatta, 1982; South China with *Paraglobivalvulina spumida* (Lin *et al.*, 1990); Japan (Kobayashi, 1997: under the name *Paraglobivalvulina piyasini*).

Hence, several taxa that seemed limited to the western Neo-Tethys, migrated finally to Japan. These taxa prove the existence of a continuous platform permitting the dispersion of these smaller foraminifers infeoded to very shallow environments and devoid of pelagic stage if compared with the modern similar forms. Alternatively, some terranes can present rapid and long travels, because the taxa in question are apparently absent in relatively well known areas such as Oman, Afghanistan or Pakistan, as well as South China or Thailand. The classical solutions in these cases are (a) gap of the geological record; (b) unfavourable lithologies and/or dissolution; (c) absence of a maximum flooding surface (MFS) or a precise parasequence, (d) unfavourable environments and/or substrates, (e) the favourable areas were destroyed and digested during obduction and/or subduction phenomena, (f) data of subsoil exploration are lacking. The solution to these problems is evidently fundamental for the palaebiogeographical reconstructions.

Finally, the Globivalvulinidae can re-inforce the classical palaeobiogeographic markers, for example *Shanita* (e.g., Sengör *et al.*, 1988; Ueno, 2003), *Palaeofusulina* and *Colaniella* (e.g., Kobayashi, 1999), and *Paradagmarita* (Sengor *et al.*, 1988; Gaillot & Vachard, 2004). They indicate that the BaoShan Block (Yunnan) and Lhassa Block (Xizang) are related with to the Perigondwan border and/or a plate more or less directly related with to Gondwana. The North Chinese Tarim Basin and Kun-Lun Mountains are related to the Perihercynian Block because of the Visean foraminifers and calcareous algae palaeobiogeography, and the presence of *Eopolydiexodina* (e.g., Vachard & Bouyx, 2002). Intermediary plates of South China and Indosinia are Cimmerian (according to the nomenclature of Sengor, 1979). Well constrained in latitude, these plates are not constrained in longitude and can be located in a more western location as generally reconstructed, and consequently almost in connection with Iran (see also the palaeomagnetic data of Besse *et al.*, 1998). That explains also the many similarities between Viet-Nam and Greece, in the fusuline population of *Sphaeroschwagerina*, *Zellia*, *Neoschwagerina*, and *Verbeekina*.

If the blocks of North China and Mongolia are similarly displaced to the west, we can obtain a

Pangaea scheme (Fig. 13), also consistent with the Carboniferous and Permian distribution of foraminifers and calcareous algae. In this case, the oceans, which are the preludes to the collisions, are not necessarily wide oceans but narrow oceans, as such as the Recent Red Sea.

CONCLUSIONS

1. The biseriamminoids are considered here as monophyletic, although rapidly divided in two lineages because (a) no transitional forms were never observed between *Biseriammina* and *Globivalvulina*; (b) the wall of *Biseriammina* is similar to that of *Granuliferella* or *Haplophragmella* and entirely distinct of that of the globivalvulinds despite of the great variety of microstructures in this group. The first lineage would comprise forms mainly with coarsely granular wall: the Biseriamminidae with the Biseriammininae and Koktjubininae. The second lineage would be composed of forms exhibiting a microgranular wall: the Globivalvulinidae.

2. Some problems concerning the origin of group can modify this interpretation: (a) the coiling of *Biseriammina* is most probably a double endothyroid coiling than a biseriate coiling; (b) primitive globivalvulinids are very similar (and often confused in the literature) with the tetrataxid *Pseudotaxis* which is probably truly their ancestor.

3. The suborder Palaeotextulariina Hohengger & Piller, 1975 is not admitted here, because of the presence of a terminal biseriate stage following many unlinked initial coiled parts (e.g., endothyrid, chernyshinellid, haplophragmellid).

4. The biseriamminids sensu stricto correspond to a group which is only Tournaisian and Viséan in age and which have no descendance in the Pennsylvanian or Permian. The biseriamminids sensu stricto are probably limited to *Biseriammina* and some very poorly known genera as such *Globochernella* or *Lipinella*.

5. Although relatively similar to the Biseriamminidae and Kotjubinidae by the type of wall and the biseriate chambers, *Globispiroplectammina* and *Spireitlina* are definitively excluded of their phylogeny.

6. No new genera are proposed in order to share the *Globivalvulina* genus, but we recommend putting in synonymy *Biseriella* and *Globivalvulina* up to a complete revision of the genus *Globivalvulina* because the specimens appear very variable among the populations. Nevertheless, *Globivalvulina* appears composed of six main groups of species according to the wall structure, test size, development of the valvulae, shapes of chambers, and apertural face. The six main groups are: *G.* ex gr. *parva*, *G.* ex gr. *bulloides*, *G.* ex gr. *granulosa*, *G.* ex gr. *spiralis*, *G.* ex gr. *mosquensis*, and a unamed group.

7. The Permian globivalvulinids can be subdivided into four subfamilies: Globivalvulininae, Paraglobivalvulininae, Dagmaritinae and Paradagmaritinae. Nevertheless, the two genera *Siphoglobivalvulina* and *Siphodagmarita* seem to be phylogenetically related to each other (due to the type of wall) whereas their morphologies must be separated, and related with *Globivalvulina* and *Dagmarita* respectively. Consequently, the independence and/or reality of the subfamilies Globivalvulininae and Dagmaritinae might be questioned due to these possible polyphyletisms (based on wall structure and morphology, respectively).

8. During the Late Permian (Lopingian), and as early as the late Middle Permian, the evolutive trends in the four subfamilies of globivalvulinids are as follows. Among the Globivalvulininae, (a) *Globivalvulina* subsisted but gave rise to three morphological differentiations: *Retroseptellina*, *Charliella* and *Siphoglobivalvulina*; (b) *Retroseptellina* shows a backward curvature of septa linked to a very slow increasing in height of the last chambers; (c) *Charliella* differs from *Globivalvulina* by the complex type of wall and the triangular shape of the chambers; and (d) *Siphoglobivalvulina* exhibits fundamentally a different, but also a more granular wall. The Paraglobivalvulininae confirm the tendency, appeared with (a) *Septoglobivalvulina* where the last chamber is very high and broad, and lead to (b) *Paraglobivalvulina* with a completely sphaerical, medium-sized test and chamberlets on the roof of the chambers, and to (c) *Paraglobivalvulinoides*, where the test becomes very large and the apertural endoskeleton very complicated. The Dagmaritinae cannot derive from *Crescentia*, which is in fact, as indicated by each FAD, a secondarily coiled *Dagmarita*. Some forms without horny expansions can be mentioned, especially one form well characterized by its aperture: *Siphodagmarita*. Finally, an endoskeleton appears in this group with *Louisettita*. The Paradagmaritinae are very much diversified that indicated in the previous studies which were only concerned with *Paradagmarita*. *P. flabelliformis* was not encountered in our material indicating that the endemism is very important in this group. Similarly, some illustrations of Transcaucasia and NW Caucasus can correspond to

other unpublished taxa. However, the *Paradagmarita* of Pakistan as well as Thailand migth be an advanced form of *Charliella* and not a true *Paradagmarita*. The unique citation in Oman is doubtful, and *P. dubreuilli* in Afghanistan is most probably a *Louisettita*. Consequently, true *Paradagmarita* are limited to Saudi Arabia, Transcaucasia, NW Caucasus, and of course southern Turkey and Zagros. Nevertheless, very closely related forms are present in our material of South China (Gaillot *et al.*, submitted a). The most interesting genus is *Paradagmaritopsis* whose distribution is Zagros, South China and Japan.

9. The phylogeny of *Paradagmarita* begins in the early Wuchiapingian with *P. simplex* which is unquestionably related with *Globivalvulina* (no with *Dagmarita*, contrary to the reconstruction of Altiner, 1997). The spire and the number of pairs of chambers increase in the following species: *P. zaninettiae*, which evolves progressively into *P.* cf. *monodi*, *P. monodi* (truly characteristic of Changhsingian) and *P. planispiralis*. *Paradagmacrusta callosa* is another characteristic species of the late Changhsingian. Exceptionally among the globivalvulinids, it exhibits crustae on the roof of the chambers. Two other index species are rarer: *Paradagmaritella surmehensis* and *P. brevispira*.

10. The Mississippian Biseriamminoidea appear as endemic, or with a surprising distribution (e.g., *Koktjubina exotica*). Some areas of Kazakhstan, Morocco and Ireland appear as the most important sectors for a detailed study of the Mississippian phylogeny.

11. The palaeogeographic distribution of selected Late Permian Globivalvulinidae: *Paradagmarita*, *Paradagmaritopsis*, *Louisettita*, *Paraglobivalvulinoides*, due to the necessity of the continuity of the carbonate platforms for the migration of foraminifers living in very shallow seas, permit to conclude that South China was closely located to Zagros and Turkey during the Late Permian, and maybe since the Early Carboniferous.

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