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PERMIAN FUSULINID FAUNA OF PERI-GONDWANAN AFFINITY FROM THE KALMARD REGION, EAST-CENTRAL IRAN AND ITS SIGNIFICANCE FOR TECTONICS AND PALEOGEOGRAPHY

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ABSTRACT

Six genera and 27 species of Permian fusulinids, of which four genera and 15 species are described as new, have been recovered for the first time from the Khan Formation in east-central Iran. When compared with the fossil content of central Pamir, south Afghanistan, east Hindu Kush, Karakorum and south Tibet (north of Rutog), the fauna of the Khan Formation shows a Peri-Gondwanan affinity. The evolutionary pattern both of the Peri-Gondwanan *Perigondwania* and of *Neodutkevitchia* of late Sakmarian-early Artinskian age is quite similar to, and shows homeomorphic evolutionary similarity to the late Gzelian and Asselian *Shagonella* and *Dutkevitchia* fauna from the tropical Tethyan realm. The *Eoparafusulina* and *Perigondwania-Neodutkevitchia* faunas are widely distributed in a narrow, southern antitropical belt that surrounded Peri-Gondwana. The time of deposition of the Khan Formation corresponds to a major unconformity between the Sardar and Jamal Formations in the Shirgesht and Ozbakuh areas, and is important in interpretations of the paleogeography, paleotectonics and paleoclimate in east-central Iran and the entire Peri-Gondwanan region.

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KEY WORDS: Iran, East-Central; Cisuralian; fusulinaceans, biostratigraphy, correlation, Peri-Gondwana, new species

INTRODUCTION AND PREVIOUS WORK

Permian strata are widely distributed in the Kalmard area in East-Central Iran. The Permian sediments were first reported by Aghanabati (1977) who recognized the uniqueness of this sequence and proposed the name “Khan Formation” for it. Aghanabati (1977) divided the formation into three members (A, B and C), corresponding to Early, Middle and Late Permian, respectively. These members were correlated with the Dorud,

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Ruteh and Nessen Formations of the Alborz area in North Iran. In all, six stratigraphic sections have been studied including Abdollaho, Bakhshi, Gachal, Rahdar, Halvan and Madbeiki. The following foraminifers were reported there: Member A - *Schwagerina* sp., *Pseudofusulina* sp., *Brevaxina* sp. and *Staffella* sp. Member B - fusulininaceans (*sensu lato*) without certain taxonomy and smaller foraminifers *Geinitzina* sp., *Globivalvulina* sp., *Gl. biserialis*, *Cribrogenerina* sp., *Lunucammina* sp. and *Pachyphloia* sp. Member C - smaller foraminifers *Padangia* sp., *Lunucammina* sp., L. *perberata*, *Agathammina* sp., *Hemigordius* sp. and *Glomospira* sp. (Aghanabati 1977).

Triticites primaries isfarensis (Bensh 1972) and *Pseudofusulina alpine antique* (Schellwien 1898), attributed to the Late Carboniferous, were reported in the Kalmard region although without specific locations of the samples (Kahler 1977). The analyses of figures provided in this publication suggest that these fossils belong to the new genus *Perigondwania*.

In recent years, the biostratigraphic study of Member A of the Khan Formation by Haftlang (1998) and Gorgij (2002) showed that this member belongs to the Mississippian and includes no evidence of Permian fossils.

The current study is a part of the project "Permian stratigraphy and geochemistry in East-Central Iran" and has been carried out by the junior author for the last six years (Arefifard 2006). Four stratigraphic sections were carefully measured and sampled for paleontologic, geochemical and sequence stratigraphic analyses. The goals of this contribution are 1) to summarize the stratigraphy of the Khan Formation, 2) offer thorough taxonomic studies and analyses of fusulinids that are found in the Khan Formation and 3) provide biostratigraphic dating of Permian deposits based on fusulinids.

GEOLOGIC SETTING

Structural evolution during the Phanerozoic was complicated in Iran. The area can be divided into several tectonic provinces based on several structural and sedimentary features (Stocklin 1968; Eftekharnezhad 1980; Stampfli 1978; Berberian and King 1981; Alavi 1991). One of the most active of these provinces (especially during the Mesozoic and Cenozoic) is central Iran. This tectonic domain formed part of a broad platform through coalescence with other Iranian provinces during the Paleozoic. Prevailing structural patterns mostly include detached tectonic blocks along with major faults. A recent study by Alavi (1991) has divided central

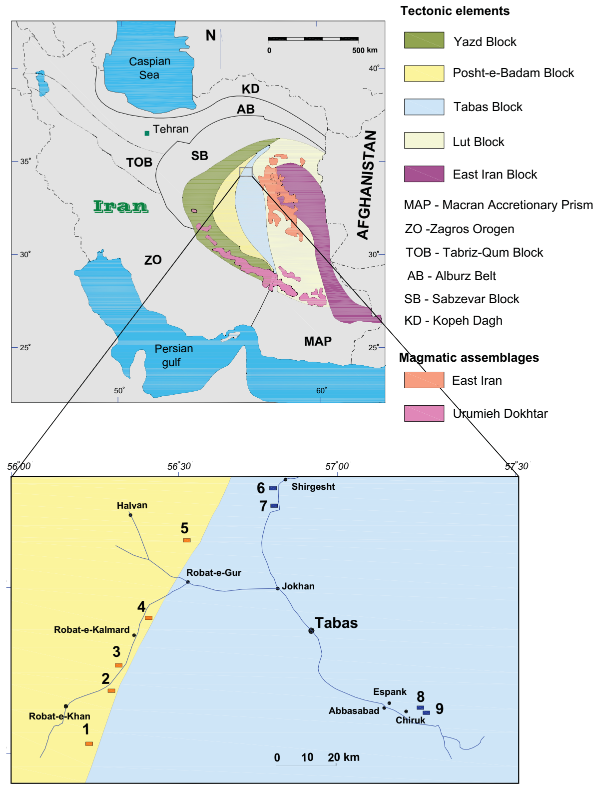

Figure 1. Generalized tectonic map of Iran (after Alavi 1991) and index map with location of studied sections. In this classification the Central Iran micro-continent is divided into four blocks. The Kalmard area is located within the Pash-e-Badam (PBB) Block.
Sections discussed in this paper: 1– Gachal, 2 – Bakhshi (type section of Khan Formation), 3 – Madbeiki, 4 – Rahdar, 5 – Halvan. Other studied sections: 6 – Shish Angosht, 7 – Bagh-e-Vang, 8 – Jamal 1, 9 – Jamal 2.

Iran into four blocks including the Lut block (LB), Tabas block (TB), Posht-e-Badam block (PBB) and Yazd block (YB) (Figure 1). The area under study for this paper, Kalmard (West Tabas), is located within the Posht-e-Badam block, which is separated from the Tabas block by the Kalard and Kuhbanan (southern continuation of Kalmard) faults. Aghanabati (2004) considered the Kalmard area part of the Tabas block based on a strong resemblance between the Precambrian basement in the Kalmard and Tabas areas. He also proposed that since the Kalmard area is situated between two active faults (Kalmard fault in the East and the covered Naeini fault in the West) it is possible to designate this area as an isolated sub-block within Tabas. The oldest rocks in Kalmard are the Kalmard Formation of Precambrian age. They are well folded and overlain by the Ordovician Shirgesht Formation, separated by an angular unconformity.

The Ordovician-Middle Triassic strata in the Kalmard area were deposited in a shallow water platform that possesses lithologic dissimilarities with the Tabas area. There is no report of upper Triassic sediments in the Kalmard area, which would be indicative of a longer hiatus than in the Tabas area resulting from early Kimmerian orogeny (Aghanabati 2004).

STRATIGRAPHY AND SEDIMENTOLOGY

The sections in our study are located on Bakhshi Mountain (92 km southwest of the town of Tabas), Madbeiki Mountain (12 km of northwest of the Bakhshi Section), Gachal Mountain (approximately 100 km southwest of Tabas), Rahdar mountain (65 km west of Tabas) and Halvan mountain (80 km northwest of Tabas) in the Kalmard area, Iran (Figure 1).

The type section of the Khan Formation was established by Aghanabati (1977) as being on Bakhshi Mountain, 8.5 km southeast of Kalmard Karavansaray. Five stratigraphic sections were measured and sampled, and more than 546 samples were collected for both geochemical and paleontological studies (Figure 2). Because the successions discussed here show minor differences from one another, their lithological features will be explained in general. The Khan Formation overlies the limestone of the Gachal Formation where Mississippian *Archaesphaera*, *Endothyra* and *Earlandia* were reported (Gorgij 2002). It mostly consists of red to brown cyclic sequences that start with gravel to cobble conglomerate or with very coarse to coarse sandstone. The size of the clasts decreases upward, and the topmost portion of each cycle are shallow water thick- to medium-bedded packstone to grainstone. The distinguishing feature of this formation is the siliciclastic material that encompasses many of the units. The lithological content of the Khan Formation suggests its deposition near a terrigenous source (Arefifard 2006).

There are several cyclic sequences present in the Khan Formation. Each starts with gravel to cobble conglomerate or with very coarse to coarse sandstone (Figure 2). The size of clastic grains decreases upward. This part of the cycle shows the transgressive phase. With increasing water depth, carbonate sediments that consist mainly of shallow water thin to medium-bedded packstone to grainstone with a few horizons of mudstone, are deposited. The fossil content of this limestone is commonly dominated by small foraminifers, fusulinids, corals, bryozoans, crinoid stems and brachiopods. It is also quite thin, suggesting a short duration stabilization within the depositional basin. Medium-bedded fusulinid-bearing limestone of the Khan Formation was found in a second sedimentary cycle in the Madbeiki, Gachal and Rahdar sections. The first cycle was present in the Halvan section (Figure 3). There was no packstone or grainstone at the Bakhshi section. Dolomite and dolomitic limestone form part of the carbonate sediments of each cycle in some sections of the Khan Formation. For example, in the Halvan section the carbonate part of the third cycle is defined by the predominance of grey medium-bedded dolomite. Petrographic studies of these dolomites demonstrate that they are secondary in origin. The topmost portion of each cycle terminates in red colored sandstone, showing a possible regressive phase.

Through the analysis of five stratigraphic sections it becomes apparent that the number of sedimentary cycles in the Khan Formation varies from section to section. The Madbeiki, Rahdar and Gachal sections possess two cycles, and Bakhshi and Halvan sections show four and three cycles, respectively. Additionally, the regressive, siliciclastic sediments of each cycle are a result of basin uplift and consequent erosion. Therefore, transgressive siliciclastic deposits of the cycle directly overlay carbonate sediments. The lower boundary of the Khan Formation is placed at a disconformity, which is recognized by channeling immediately above the Mississippian limestone of the Gachal Formation. It is overlain by Lower Triassic yellow vermiculite limestone of the Sorkh Shale Formation. The disconformity between the Khan and Sorkh Shale Formations is marked by a bauxite horizon.

The early Artinskian is marked by a regression in the Kalmard region. Continental conditions in the area remained until the early Triassic. As such, uplifting did not give way to subsidence until the end of Permian, as evidenced by the Lower Triassic Sorkh Shale Formation that unconformably overlies the late Sakmarian-early Artinskian Khan Formation. Facies analysis, petrographic studies and lithological features of the Khan Formation suggest that it was deposited in a shoreline environment with mixed siliciclastic-carbonate sediments.

SYSTEMATIC PALAEONTOLOGY

All specimens are housed at the Paleontology Repository, Department of Geosciences, University of Iowa. **SUI 102968 to 103100**

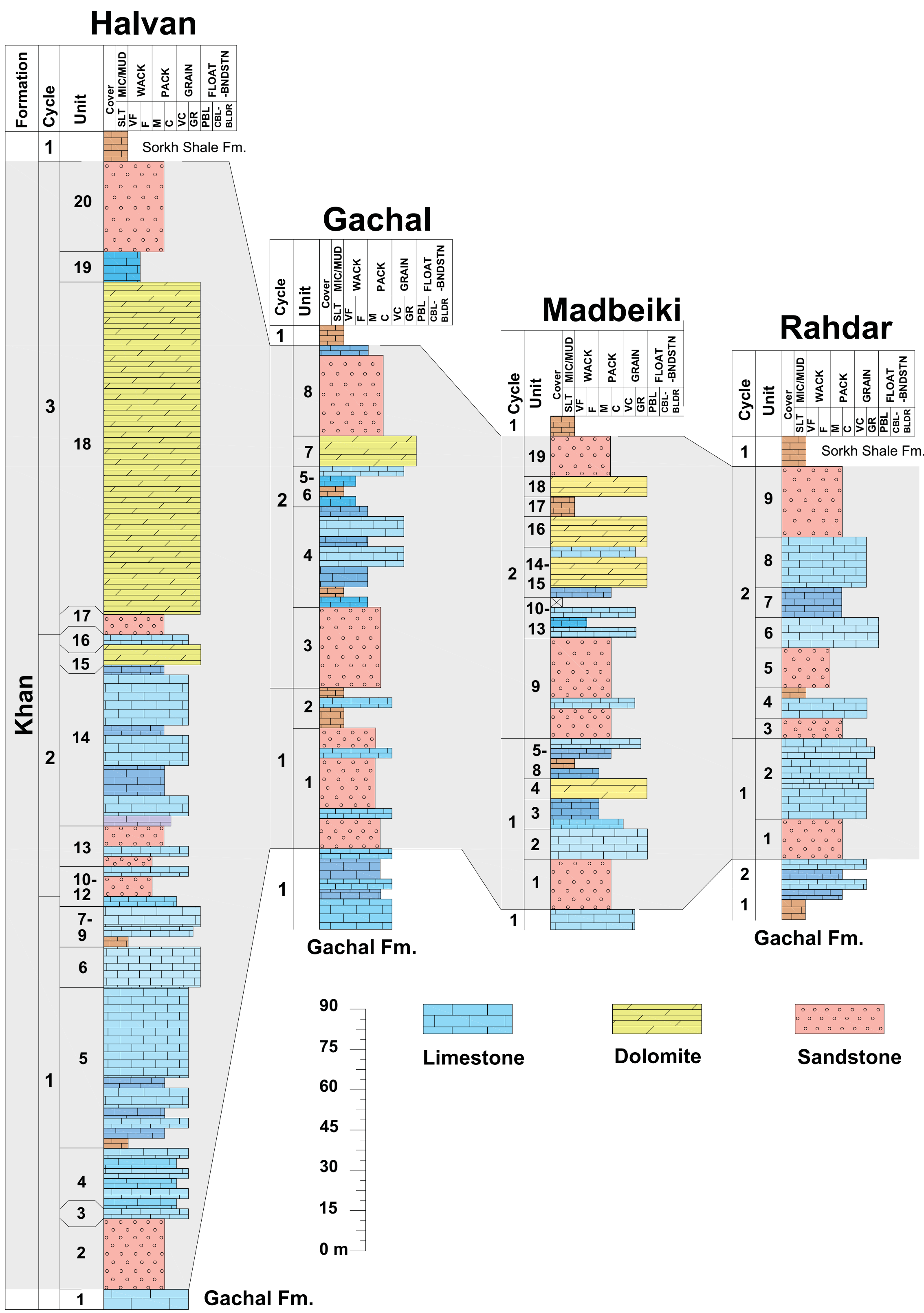

Figure 2. Stratigraphy of the Khan Formation in the Kalmard area.

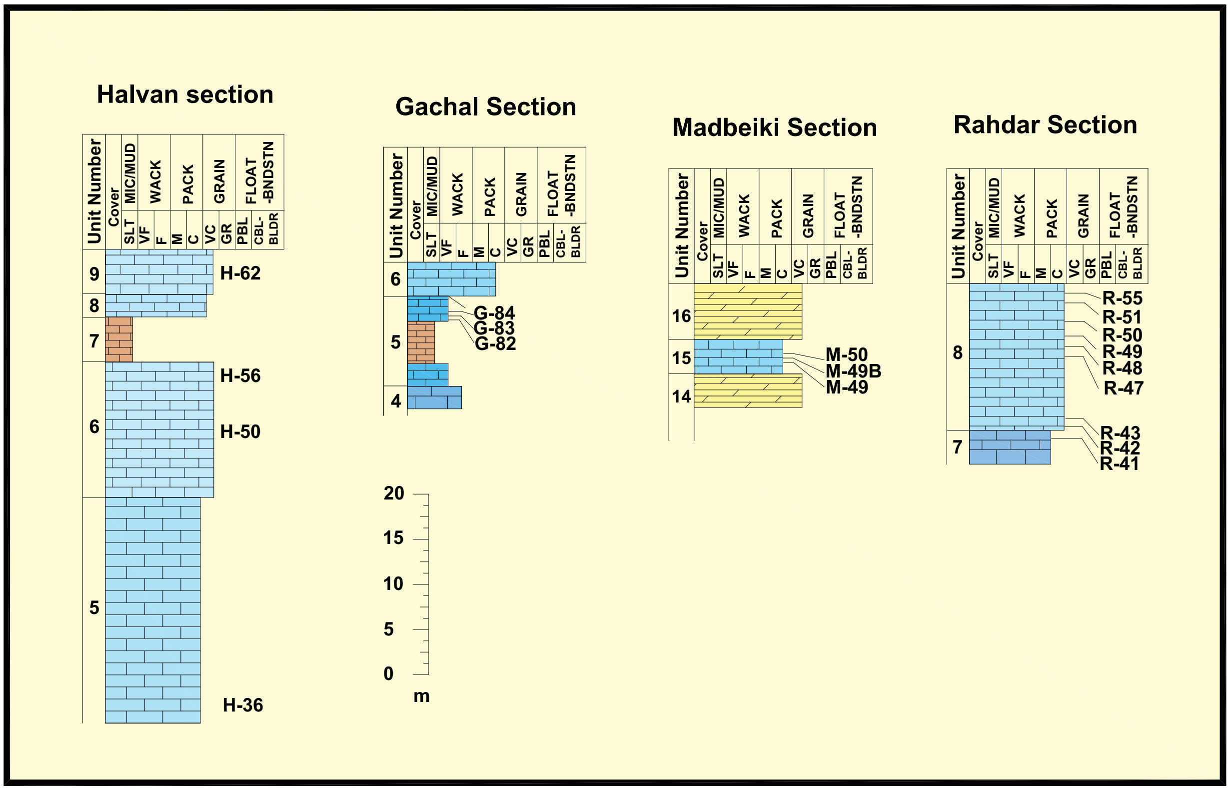

Figure 3. Correlation chart of fusulinid-bearing deposits of the Khan Formation among studied sections.

Order *FUSULINIDA* Fursenko, 1958
Family *SCHUBERTELLIDAE* Skinner, 1931
Subfamily *SCHUBERTELLINAE* Skinner, 1931
Genus *GROVESELLA*, new genus

v. 1937 *Eoschubertella* Thompson, 1937; Thompson, p. 123 (partim)

v. 1994 *Eoschubertella* Thompson, 1937; Groves et al., p. 32 (partim)

v. 1949 *Schubertella* Staff and Wedekind, 1910; Suleimanov, p. 27-28 (partim)

v. 1951 *Schubertella* Staff and Wedekind, 1910; Rauser-Chernousova, Bensh, Vdovenko, Gibshman, Leven, Lipina, Reitlinger, Solovieva and Chedia, p. 69 (partim)

v. 1969 *Schubertella* Staff and Wedekind, 1910; Manukalova-Grebenjuk, Il'ina and Serezhina p. 82 (partim)

Type species. *Grovesella tabasensis* new species, Latest Sakmarian-early Artinskian, Madbeiki section, Kalmard area, East-Central Iran.

Diagnosis. Small, nautiloid to nearly globular schubertellides with form ratio equal or less than one.

Description. Test very small to moderate in size for this group of schubertellids discoidal to nautiloid or nearly globular, with broadly rounded periphery and weakly to mildly umbilicate flanks. Coiling skewed in initial one or two volutions or can be nearly straight. Length of the test is equal or less than width and consequently the means of form ratio is equal or less than one. Wall thin, poorly visible, most probably two layered with darker and thin tectum and slightly lighter, structureless primatheca. Chomata not observed in type species, but present in the other, predominantly Pennsylvanian representatives of the genus.

Other species. *Grovesella mosquensis* (Rauser in Rauser-Chernousova et al. 1951); *Grovesella compressa* (Rauser in Rauser-Chernousova et al. 1951); *Grovesella miranda* (Leontovich, in Rauser-Chernousova et al. 1951); *Grovesella globulosa* (Safonova, in Rauser-Chernousova et al. 1951); *Grovesella pseudoglobulosa* (Safonova, in Rauser-Chernousova et al. 1951), *Grovesella borealis* (Rauser in Rauser-Chernousova et al. 1951) **–** all from Moscovian of Russian Platform and surrounding areas; *Grovesella sphaerica* (Suleimanov 1949); *Grovesella staffelloides* (Suleimanov 1949) from late Asselian and Sakmarian in the Urals-Arctic, Tethys and Kalmard area in Central Iran.

Etymology. The genus is named after John R. Groves in recognition of his contribution to the study Upper Paleozoic fusulinids and smaller foraminifers.

Remarks. The major distinguishing feature of this genus is an exceptionally small size, and a nautiloid to nearly globular shape with form ratio equal or less than one. The genus possesses a typical schubertellids feature: small size, skewed to straight coiling, thin, obscure, but differentiated wall. However, the test of *Grovosella* takes a nautiloid to spherical shape with form ratios less than one and indeed a very small size. Groves (Groves et al. 1994, p. 33) noted a significant difference of these forms from typical *Eoschubertella*.

In all likelihood, *Grovosella* derived from *Semistaffella* sometime in the early Bashkirian, since both genera possess similar coiling, test shape and a two- to three-layered (but obscure in terms of exact differentiation of the layers) wall. Probably due to its small size and rare occurrence *Grovesella* are not known from the Bashkirian. However, some of the subglobular "*Schubertella*" described from early to late Bashkirian (Manukalova-Grebenjuk et al. 1969; Nikolaev 1989) are most likely *Grovesella*. This genus becomes more abundant in the Moscovian. The second acme of the genus is late Asselian-Sakmarian through early Artinskian at least in the Urals-Arctic, Carnic Alps-Chios, Nevada and Kalmard area in Central Iran.

Range. Urals-Arctic, Carnic Alps-Chios and Kalmard area in Central Iran; Bashkirian(?)-Artinskian.

Grovesella tabasensis, new species
Figure 4.12-4.16

Holotype. SUI 102982. Axial section; sample R-49-3, Madbeiki section, Khan Formation, unit 8, 134 m above the base of the section; Kalmard area, East-Central Iran; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. Two axial, two tangential, and one saggital sections from the Khan Formation, Central Iran, and over 20 axial sections from *Eoparafusulina linearis* beds, Bird Spring Formation, Artinskian, and Arrow Canyon, Nevada.

Description. Test is very small with 3-3.5 volutions, nautiloid with broadly rounded periphery and mildly umbilicate flanks. Coiling is slightly skewed in initial one or two volutions or nearly straight. Length of the test is 165-200 microns, diameter (width) 210-290 microns, with form ratio of the last volution of 0.6-0.85. Outer diameter of proloculus is 35-50 microns. Thickness of the wall in the final volution is 7-10 microns. Wall thin, poorly visible, most probably two layered with darker and thin tectum and slightly lighter, structureless primatheca. Chomata and tunnel were not observed among the studied specimens. Chamber count was available only in one specimen and it is 12-13 in final volution.

Etymology. After the Tabas city and area where this genus has been found.

Types. The specimen illustrated in Figure 4.15 (SUI 102982) is designated as the holotype, which is from the Khan Formation of the Madbeiki section, 134.0 m above the base of measured section (Figure 4). Other illustrated specimens are designated as paratypes (Figures 4.12-5.19; SUI 102979, SUI 102980, SUI 102981, SUI 102982, SUI 102983, SUI 103062, SUI 103063, SUI 103064).

Remarks. A very small size, small number of volutions, and a nautiloid shape of the test make this species very distinct from the rest of the genus. *Grovesella tabasensis* could be compared to *Grovesella staffelloides* (Suleimanov 1949) from late Asselian and Sakmarian of Southern Urals. It has a very similar test shape, wall structure and straight coiling, but differs from *staffeloides* in the smaller size of corresponding volutions, a smaller proloculus and tighter coiling. Many specimens of *Grovesella tabasensis* have been found recently in *Eoparafusulina linearis* beds, Arrow Canyon, Nevada, i.e., eventually from the same stratigraphic level.

Stratigraphic range. Khan Formation; Madbeiki section sample M49; Permian, Cisuralian, Latest Sakmarian-early Artinskian; Bird Spring Formation, Arrow Canyon, Nevada, *Eoparafusulina linearis* beds, Artinskian.

Geographic occurrence. Kalmard area, East-Central Iran; Arrow Canyon, Nevada.

Genus *EOSCHUBERTELLA* Thompson, 1937
EOSCHUBERTELLA sp. 1
Figure 4.17

Remarks. Only one paraxial section has been found in the studied material. This specimen is very small, and because of poor preservation and orientation, the important morphological features characteristic for species taxonomy cannot be observed. An elongate fusiform outline and espe-

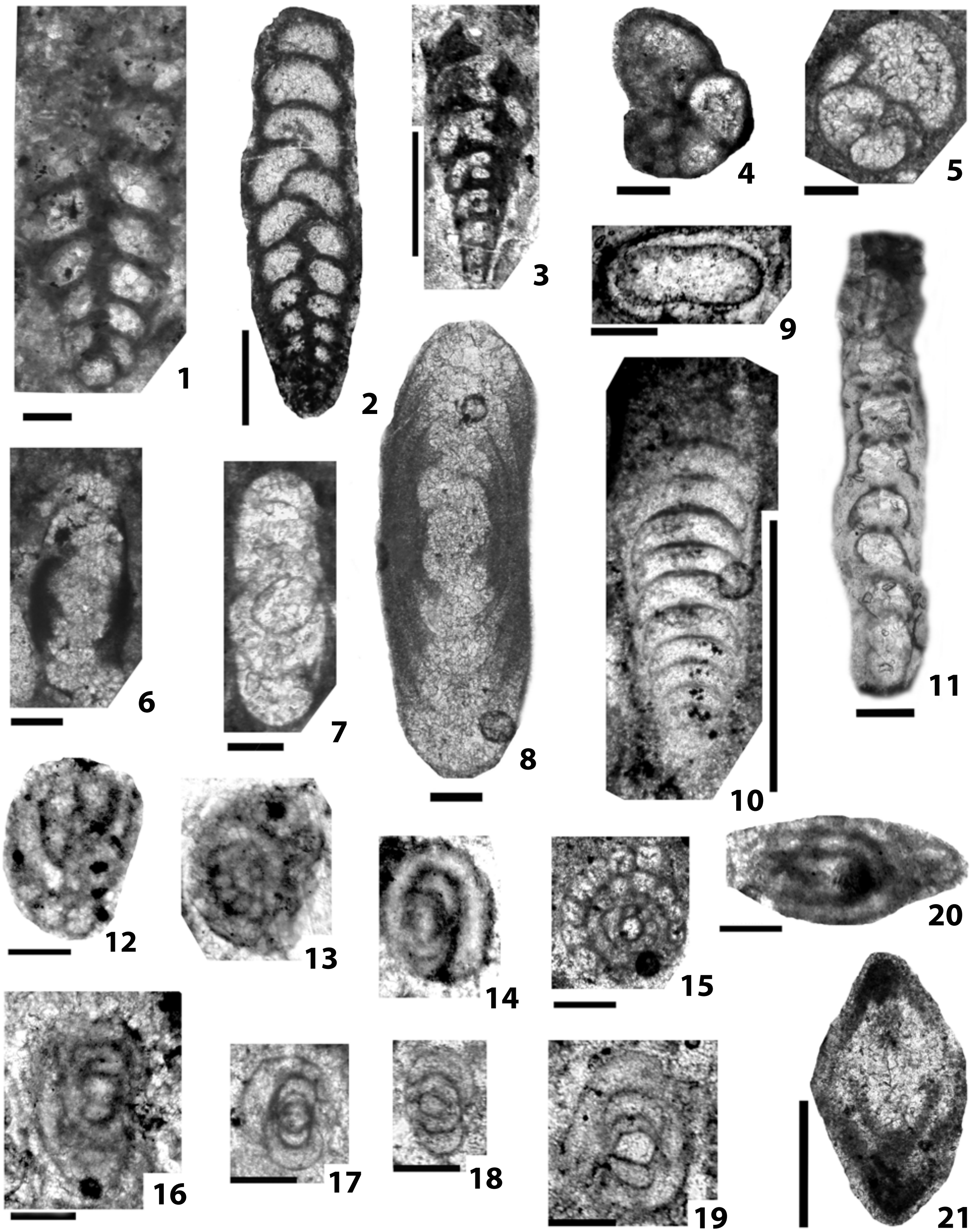
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Figure 4 (previous page). Permian smaller foraminifers and primitive fusulinids in the Kalmard area. Horizontal bars – 0.1 mm, vertical bars – 0.5 mm. 4.1, ***Palaeotextularia* sp.,** x 90, sample R-43-7, Cat. No SUI 102968; 4.2, ***Deckerella* sp**., x 35, sample R-42-3, Cat. No SUI 102969; 4.3, ***?Deckerella*** sp., x 45, sample R-49-6, Cat. No SUI 102970; 4.4-5, ***Globivalvulina* sp**., both x 100; 4.4, sample M-50-11, Cat. No SUI 102971; 4.5, sample R-43-8, Cat. No SUI 102972; 4.6-7, ***Hemigordius* sp.,** both x 100; 4.6, sample R-43-1, Cat. No SUI 102973; 4.7, sample R-42-2, Cat. No SUI 102974; 4.8, ***?Hemigordius*** sp., x 100, sample R-41-16, Cat. No SUI 102975; 4.9-10, ***Geinitzina* sp**., both x 100; 4.9, sample R-51-9, Cat. No SUI 102976; 4.10, sample R-49-13, Cat. No SUI 102977; 4.11, ***?Amphoratheca*** sp., x 100, sample H-50-2, Cat. No SUI 102978; 4.12-19, ***Grovesella tabasensis***, new species, all x 120; 4.12, oblique section of paratype, sample H-51-21, Cat. No SUI 102979; 4.13, oblique section of paratype, sample R-49-8b, Cat. No SUI 102980; 4.14, axial section of paratype, sample M-49-4b, Cat. No SUI 102983; 4.15, saggital section of paratype, sample R-42-5, Cat. No SUI 102981; 4.16, axial section of holotype, sample R-49-5, Cat. No SUI 102982; 4.17, axial section of paratype, sample Arrow_847, Cat. No SUI 103062; 4.18, axial section of paratype, sample Arrow_846, Cat. No SUI 103063; 4.19, axial section of paratype, sample Arrow_845, Cat. No SUI 103064; ***Schubertella* sp.1**, x 120, 12, paraxial section, sample M-49-8b, Cat. No SUI 102984. 5.18, ***Pseudoendothyra*** sp., x 70, paraxial section, sample M-50-13, Cat. No SUI 102985.

cially small size distinguish this form from many *Schubertella*. However, without seeing the early volutions it is difficult to designate the precise taxonomy of this specimen.

Stratigraphic range. Khan Formation; Madbeiki section, sample M49; Pennsylvanian-Permian.

Geographic occurrence. Global distribution within tropical-subtropical belts.

Family *SCHWAGERINIDAE* Skinner, 1931
Subfamily *MONODIEXODINIINAE* Kanmera, Ishii and Toriyama, 1976
Genus EOPARAFUSULINA Coogan, 1960

v. 1960 *Parafusulina* (*Eoparafusulina*) Coogan, p. 262.
v. 1965 *Eoparafusulina* Skinner and Wilde, p. 73.
v. 1966 *Alaskanella* Skinner and Wilde, p. 57.
v. 1967 *Eoparafusulina* Ross, p. 944.
v. 1975 *Eoparafusulina* Rosovskaya, p. 106.
v. 1996 *Eoparafusulina* Rauser-Chernousova, Bensh, Vdovenko, Gibshman, Leven, Lipina Reitlinger, Solovieva and Chedia, p. 141-142.

Type species. *Parafusulina gracilis* (Meek), Thompson, Wheeler and Hazzard 1946, p. 31-32, PI. 1, figs. 6-10 (neoholotype pl. 1, fig. 10).

Discussion. Although the concept of the genus and its type species has been amended and modified several times, the taxonomy is far from being clear owing to complications with designation. Skinner and Wilde (1965, p.73-74) thoroughly quoted the original concept of the genus by Coogan (1960) and the original description of the genus type by Meek (1864). They suggested that the species described by Thompson et al. (1946) differs from *Fusulina gracilis* Meek (1864) because of a considerable discrepancy between dimensions as cited by Meek and Thompson et al. It should be noted that Meek described his species based on the external study of small, slender, subcylindrical forms. Unfortunately, the specimen of *Fusulina gracilis* from Meek's collection has been lost and therefore its internal morphology, which is absolutely critical for understanding species and genus concept, can never be distinguished. Moreover, there is no certainty about the generic nature of this taxon. Meek's specimens could potentially be *Schubertella*, young specimens of *Pseudofusulina*, or the *Schwagerina*, which are reported by Thompson et al. (1946) from the type locality.

Skinner and Wilde (1965, 1966) proposed a new concept of the species based on topotypes. The dimensions closely resemble Meek's description but are two or more times smaller then the specimens described as *Parafusulina gracilis* (Meek), by Thompson et al. in 1946. The situation becomes more complex as Skinner and Wilde (1965) did not designate a neotype or neoholotype for the *Eoparafusulina gracilis* Meek (1864) when they re-described it. The majority of fusulinid workers use *Parafusulina gracilis* (Meek), *sensu* Thompson et al. (1946) as a type of the genus for the *Eoparafusulina*. Consequently, the modern concept of *Eoparafusulina* genus ties to this species (Rosovskaya 1975; Rauser-Cheronusova et al. 1996; Ueno 2006).

To avoid any further complications in regard to the taxonomic stability of *Eoparafusulina*, the following can be proposed: According to article 24.2.1. "Statement of the Principle of the First Reviser" of the International Code of Zoological nomenclature (ICZN), "When the precedence between names or nomenclatural acts cannot be objectively determined, the precedence is fixed by the action of the first author citing in a published work those names or acts and selecting from them; this author is termed the "First Reviser" (http://www.iczn.org/iczn/index.jsp)." Because Thompson and Wheller (1946) were the first who fixed the *Parafusulina gracilis* name by designation of the holotype (neoholotype in their definition) and provided adequate description, measurements and photographs that undoubtedly designate *Parafusulina gracilis* for taxonomic practice, they become authors of this species. This would meet the criteria of article 11.10 of ICZN [Deliberate employment of misidentifications. If an author employs a specific or subspecific name for the type species of a new nominal genus-group taxon, but deliberately in the sense of a previous misidentification of it, then the author's employment of the name is deemed to denote a new nominal species. The specific name is available with its own author and date as though it were newly proposed in combination with the new genus-group name (see Article 67.13 for fixation as type species of a species originally included as an expressly stated earlier misidentification, and Article 69.2.4 for the subsequent designation of such a species as the type species of a previously established nominal genus or subgenus)]. Coogan (1960) designated *Parafusulina gracilis* (Meek) Thompson et al., 1946 for his new subgenus *Eoparafusulina*. Thompson et al. become authors of this species (*Parafusulina gracilis* Thompson et al. 1946). According to article 75.5 of ICZN *Fusulina gracilis* (Meek 1864) becomes *nomen dubium* and is removed from taxonomic practice. For the species described by Skinner and Wilde (1965, p. 76, pl. 34, figs. 6-11) as *Eoparafusulina gracilis* the new name of *Eoparafusulina skinnerwildei* is proposed, new species with holotype figured on plate 34, fig. 7 (Skinner and Wilde 1965, p. 76). *Eoparafusulina thompsoni* (Skinner and Wilde 1965) becomes a junior synonym of *Parafusulina gracilis* (Thompson et al. 1946).

It is difficult to add anything to an excellent diagnosis of *Eoparafusulina* proposed by Skinner and Wilde (1965, p. 75) except the stock of subglobular fusulinids with form ratios less than 3.5 that were described as *McCloudia* (Ross 1967) and have to be excluded from the genus. As a result of the transitional character of evolution between *Eoparafusulina* and *Monodiexodina* (Ueno 2006) some species can be placed in either genus only conventionally. Consequently, the concept of the genera depends on species composition.

The following adjusted diagnosis can be proposed for *Eoparafusulina*:

Test is medium to large, elongate to short subcylindrical usually around 10 mm in length, but might exceed 15 mm. Mature individuals possess 5 to 8 volutions and are bilaterally symmetrical. Proloculus is small to large, its outside diameter in general is around 200 microns, but on some megalospheric specimens might reach up to 400 microns. Spirotheca is relatively thin, gradually increasing in thickness throughout the growth; its thickness in final volution does not usually exceed 100 microns. In addition, the spirotheca is composed of smooth and very thin tectum and fine alveolar keriotheca. The test is rather tightly coiled and expanding uniformly. Phrenotheca are absent. Septae are strongly fluted from pole to pole. Septal folds are well developed along the lower half of the septa, and opposing folds of adjacent septa meet. Low cuniculi form in the outer volutions at those places where opposing septal folds adjoin. Secondary deposits coat septal folds in all but the outer half volution and form conspicuous, sometimes significant axial deposits. Rudimentary chomata are present in proloculus, sometimes in first volution; in the rest of volutions chomata are replaced by pseudochomata that are adjacent to the tunnel.

Remarks. *Eoparafusulina* is much like *Monodiexodina* (Sosnina 1956) in many respects. In fact, these genera are evolutionarily related to each other (Ueno 2006). Still, *Eoparafusulina* has a smaller size and form ratio (> 7 in *Monodiexodina* according to Ueno 2006), less dense axial fillings and less well-developed septa. Cuniculi are mostly present in one to two outer volutions in *Eoparafusulina* as opposed to well-developed cuniculi in many volutions including the inner one in *Monodiexodina*. *Eoparafusulina* also resemble elongate subcylindrical *Parafusulina*, but are smaller in size, and have tighter coiling, as well as specific septal fluting where septal folds are developed along the lower half or less of the septa. The genera also differ in stratigraphic range. *Eoparafusulina* is found in the Sakmarian-Artinskian, wereas subcylindrical elongate *Parafusulina* are generally found post Artinskian.

A group of small *Eoparafusulina*-like fusulinids from the Arctic appear to belong to a separate and distinct group described here as a new genus *Timanites* (see below).

Stratigraphic range. Permian, Cisuralian, Late Asselian-Artinskian and ?Kungurian.

Geographic occurrence. Global distribution within tropical-subtropical belts.

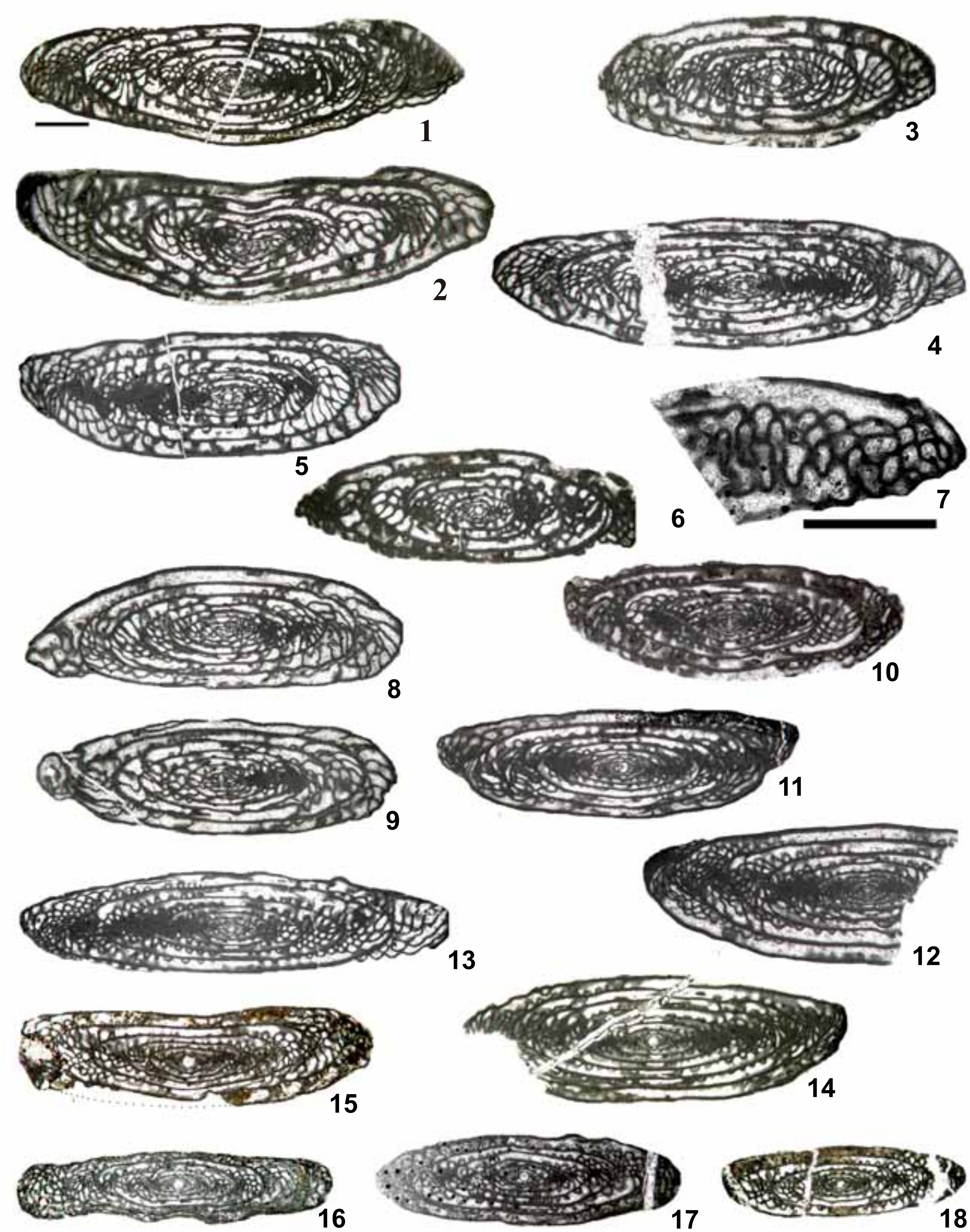
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Figure 5 (previous page). Permian advanced fusulinids in the Kalmard area. Scale bar - 1 mm, all magnifications, except 5 are x10, figure 5 x 25.5.1-5, ***Eoparafusulina grozdilovae***, new species; 5.1, axial section of holotype, sample M-50-18, Cat. No SUI 102986; 5.2, axial section of paratype, sample M-50-13, Cat. No SUI 102987; 5.3, axial section of paratype, sample M-50-6, Cat. No SUI 102988; 5.4, axial section of paratype, sample M-50-26, Cat. No SUI 102989; 5.5-10, ***Eoparafusulina stevensi***, new species; 5.5, axial section of holotype, sample M-50-4, Cat. No SUI 102990; 5.6, axial section of paratype, sample M-50-17, Cat. No SUI 102991; 5.7, paraxial section of paratype showing lower cuniculi in the final volution, sample M-50-1, Cat. No SUI 102992; 5.8, subaxial section of paratype, sample M-50-29, Cat. No SUI 102993; 5.9, axial section of paratype, sample M-50-8, Cat. No SUI 102994; 5.10, axial section of paratype, sample M-50-1, Cat. No SUI 102995. 5.11-14, ***Eoparafusulina madbeiki,*** new species; 5.11, axial section of holotype, sample M-50-19, Cat. No SUI 102996; 5.12, axial section of slightly inflated specimen, paratype, sample M-50-1b, Cat. No SUI 102997; 5.13, axial section of elongate specimen, paratype, sample M-49B-5, Cat. No SUI 102998; 5.14, axial section of paratype, sample M-50-14, Cat. No SUI 102999; 5.15-18, ***Eoparafusulina pamirensis*** Leven 1993; 5.15, axial section, sample G-84-3, Cat. No SUI 102300; 5.16, axial section of elongate specimen, sample G-83-4, Cat. No SUI 102301; 5.17, axial section, sample G-84-22, Cat. No SUI 10302; 5.18, axial section, sample G-84-4, Cat. No SUI 103003.

Eoparafusulina grozdilovae, new species
Figure 5.1-5.4

v. 1993 *Eoparafusulina tschernyschewi tschernyschewi* (Schellwien 1909), Leven, p. 178, pl. 10, figs. 7, 8, 11.

Holotype. SUI 102990. Axial section; sample M-50-26, Madbeiki section, Khan Formation, unit 15, 136 m above the base of the sections; Kalmard area, East-Central Iran; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Description. Test is large in size, subcylindrical to slightly fusiform with bluntly rounded poles. First volution is ellipsoidal to inflated fusiform. Volutions expanded along the axis gradually in early 3-4 volutions and more rapidly in the following ones. Coiling is generally moderate and gradual throughout the development, but slightly tighter in the early 3-4 volutions. Mature specimens of 6-8 volutions are 6.2-9.8 mm in length and 2.4-3.6 in diameter with form ratios of 2.5-2.7. The first volution is 0.25-1.25 mm long and 0.23-0.36 wide, giving form ratios of 1.1-2.3. The length and diameter of the fourth volution are 3-3.7 mm and 1-1.2 mm with form ratios of 2.5-3.7. Spherical proloculus is medium in size, its outside diameter 125-250 microns. Spirotheca is moderately thin and composed of thin and dark tectum and thick and coarsely alveolar keriotheca. It is thin in the early 3-4 volutions and gradually thickens in succeeding ones. The thickness of spirotheca in the first, fourth and last volutions of 5 specimens are 20-30, 40-70, 70-80 microns, respectively. Septae are thin to moderate in thickness, usually around 30-50 microns, and twice as thin as the wall in respective volutions.

The widely spaced septa are regularly and narrowly fluted throughout the length of the test, with fluting extending half or less than half as high as chambers. Tunnel is very narrow in early volutions and widens with a rather irregular path in late volutions. Chomata are very small, rounded and observed in proloculus and first volution. Chomata are not distinguishable in the other volutions, where tunnel is outlined with pseudochomata. Axial fillings vary from significant to very weak and developed in polar ends of second to fifth volutions.

Etymology. The species named in honor of Russian fusulinid worker Ljudmila P. Grozdilova, who studied *Eoparafusulina* in the Arctic.

Material examined. Ten axial and seven paraxial sections from Madbeki section in Kalmard area, East-Central Iran.

Remarks. *Eoparafusulina grozdilovae* draw a likeness to *Eoparafusulina tschernyschewi tschernyschewi* (Schellwien 1909) from Russian Arctic. Some specimens of *E. grozdilovae* from Peri-Gondwana (Central Pamir) have even been described under this name (Leven 1993, p. 178). The major difference between these two species is that *E. grozdilovae* possess a much thinner septa in all volutions. The septa of *E. tschernyschewi tschernyschewi* and related species from Russian Arctic are as thick as the wall in all volutions (Grozdilova and Lebedeva 1961, p. 219-220), whereas septa in *E. grozdilovae* (especially in the final volution) are more than two times thinner than the wall. Moreover, *E. grozdilovae* has less well-developed axial fillings, a slightly more fusiform outline and a wider tunnel, especially in the final volution. There are two other major contrasts that allow differentiation between these species. First, they appear in opposite sides of tropical belt: *E. grozdilovae* is found in the southern antitropical (subtropics) area and *E. tschernyschewi tschernyschewi* in the northern antitropical area. Second, the stratigraphic range of *E. tschernyschewi*

tschernyschewi is very narrow: it is present only in the uppermost Asselian-lowermost Sakmarian, whereas the stratigraphic range of *E. grozdilovae* is present in the uppermost Sakmarian-lower Artinskian. Finally, specimens of *E. grozdilovae* from Central Pamir are rather similar to the population from the Kalmard area and differ from the latter only in better developed axial fillings.

Stratigraphic range. Bed 6, Dangikalon Formation, samples G-83, M-49-50, Khan Formation; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Madbeki and Gachal sections in Kalmard area, East-Central Iran; Kalaktash area, Central Pamir, Tadzhikistan.

Eoparafusulina stevensi, new species
Figure 5.5-5.10

v. 1993 *Eoparafusulina tschernyschewi memoranda* (Grozdilova and Lebedeva, 1961), Leven, p. 178, pl. 11, figs. 2, 3, 6.

Holotype. SUI 102996. Axial section; sample M-50-4, Madbeiki section unit 15, 136 m above the base of the sections, Kalmard area, East-Central Iran; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. Fourteen axial and eight paraxial sections from Madbeiki section in Kalmard area, East-Central Iran.

Description. The test is large in size, sub-cylindrical with bluntly rounded poles, first volution is ellipsoidal to inflated-fusiform with lateral slopes that are sub-parallel across the central half of the shell and uniformly or irregularly convex in the end quarters. The expansion of volutions changes during growth, for it gradually increases in axial extension in the first 2-4 volutions and then attains to more expanded polar ends in later volutions. Coiling tight to moderate in the early 3-4 volutions and uniformly and gradually coiled in the late volutions. Mature tests of 6-6.5 volutions are 5.8-7.2 mm long and 1.8-2.3 wide with form ratios of 3.1-3.2. First volution is 0.4-0.7 mm long and 0.25-0.29 wide, giving form ratios of 1.6-2.4. The length and diameter of the fourth volution are 3-5 mm and 1-1.4 mm, respectively, with form ratios of 3-2.8. The proloculus is medium to large in size, spherical, with outside diameter of 150-250 microns averaging 210 microns for six specimens. Spirotheca is composed of tectum and keriotheca; it is relatively thin in early volutions and gradually thickens after the third-fourth (earlier mentioned "3-4") volution. The thickness of spirotheca in the first, fourth and last volutions of five specimens are 20-30, 40-60, 70-80 microns, respectively. Septae are thin to moderate 20-50 microns and usually twice as thin as wall in respective volutions. They are widely spaced and rather narrowly fluted throughout the length of shell, the fluting extending to half the height of chambers. Very low and poorly developed cuniculi can be observed only in the final volution. The tunnel is narrow and low in early volutions and becomes rapidly wide with a rather irregular path in late volutions. The chomata are small and rounded in theirst volution but indistinct in other volutions. It seems to be pseudochomata that outline the tunnel after first volution. Weak to very weak axial fillings are present in axial ends of 2-4 volutions.

Etymology. Species named in honor of Calvin Stevens, well-known Permian fusulinid and coral worker.

Remarks. *Eoparafusulina stevensi* shares many characteristics with *Eoparafusulina tschernyschewi memoranda* (Grozdilova and Lebedeva 1961) from the Russian Arctic, but has much thinner septa in all volutions. These septae are twice or more times thinner than the wall, as opposed to the thick septae that are equal in thickness to wall in *E. tschernyschewi memoranda*. Also, *E. stevensi* features a wider tunnel and less well-developed axial fillings. Specimens of *E. stevensi* from Central Pamir (Leven 1993) are similar to the population from the Kalmard area in all respects.

Stratigraphic range. Bed 6, Dangikalon Formation, Khan Formation samples M49-M50; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Madbeiki section in the Kalmard area, East-Central Iran; Kalaktash area, Central Pamir, Tadzhikistan.

Eoparafusulina madbeiki, new species
Figure 5.11-5.14

Holotype. SUI 103004. Axial section; sample M-50-19, Madbeiki section, Khan Formation, unit 15, 136 m above the base of the sections; Kalmard area, East-Central Iran, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. Eight axial and four paraxial sections.

Description. Test is of large size, subcylindrical to elongate fusiform with bluntly rounded to slightly pointed poles. First volution is sub-ellipsoidal to fusiform. The test expands slowly along the axis during the first 3-4 volutions, but beyond this the volutions expanded more rapidly. The test is gradu-


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Figure 6 (previous page). Permian advanced fusulinids in the Kalmard area. Scale bar - 1 mm, all magnifications are x10.6.1-5, ***Eoparafusulina ruttneri*****,** new species; 6.1, axial section of holotype, sample M-49-5, Cat. No SUI 103004; 6.2, axial section of paratype, sample M-50-28, Cat. No SUI 103005; 6.3, paraxial section of paratype, sample M-49B-9, Cat. No SUI 103006; 6.4, incomplete axial section of paratype, sample M-50-20, Cat. No SUI 103007; 6.5, axial section of paratype, sample M-49-6, Cat. No SUI 103008; 6.6-8, ***Eoparafusulina isobella,*** new species**;** 6.6, axial section of paratype, sample M-50-13, Cat. No SUI 103009; 6.7, axial section of paratype, sample M-50-21, Cat. No SUI 103010; 6.8, axial section of holotype, sample M-50-16, Cat. No SUI 103011; 6.9-13, ***Eoparafusulina shemiraniensis,*** new species; 6.9, axial section of paratype, sample M-M-49B-2, Cat. No SUI 103012; 6.10, axial section of paratype, sample M-50-25, Cat. No SUI 103013; 6.11, axial section of paratype, sample M-50-15, Cat. No SUI 103014; 6.12, axial section of paratype, sample M-49B-8, Cat. No SUI 103015; 6.13, axial section of holotype, sample M-49B-3, Cat. No SUI 103016; 6.14-18, ***Eoparafusulina minuta,*** new species; 6.14, axial section of paratype, sample G-83-7, Cat. No SUI 103017; 6.15, axial section of paratype, sample G-83-3, Cat. No SUI 103018; 6.16, axial section of paratype, sample G-83-8, Cat. No SUI 103019; 6.17, axial section of paratype, sample M-49B-6, Cat. No SUI 103020; 6.18, axial section of holotype, sample G-83-8, Cat. No SUI 103021. 6.19-24, ***Perigondwania rahdarensis,*** new species; 6.19, subaxial section of paratype, sample R-55-2, Cat. No SUI 103024; 6.20, axial section of paratype, sample R-43-5, Cat. No SUI 103027; 6.21, axial section of paratype, sample R-55-7, Cat. No SUI 103025; 6.22, axial section of holotype, sample H-56-4, Cat. No SUI 103022; 6.23, axial section of paratype, sample R-47-3, Cat. No SUI 103023; 6.24, axial section of paratype, sample R-56-2, Cat. No SUI 103026; 6.25, ***Perigondwania macilenta*** (Leven 1993), axial section, sample R-48-49, Cat. SUI 103028.

ally and moderately coiled throughout the development, but slightly tighter in the early 2-3 volutions. Mature specimens of 6.5-7.5 volutions are 7.3-8.5 mm long and 1.9-2.2 wide with form ratios of 3.4-4.5. The first volution is 0.4-0.6 mm long and 02-0.3 wide, giving form ratios of 1.5-2.2. The length and diameter of the fourth volution are 2.5-3.2 mm and 0.8-0.9 mm with form ratios of 2.7-4. Proloculus is spherical and medium to large in size with an outside diameter of 180-300 microns. Spirotheca is moderately thin and composed of thin and dark tectum and thick and coarsely alveolar keriotheca. It is thin in the early 3-4 volutions and gradually thickens in the following volutions. The thickness of spirotheca in the first, fourth and last volutions of four specimens are 20, 40 and 60 microns, respectively. Septa are thin to moderate in thickness about 30-50 microns, which is less than wall in all volutions. Septa are widely spaced, moderately and narrowly fluted throughout the length of the test, with fluting extending to half or less than half as high as chambers. The tunnel is very narrow and low in early volutions and widens in late volutions with irregular paths. Chomata are very small and rounded in proloculus and first volution, and pseudochomata outline the tunnel after the first volution. Axial fillings are moderate to light and developed in polar ends of 2-5 volutions.

Etymology. After the name of Madbeiki section where this species has been found.

Remarks. *Eoparafusulina madbeiki* can be distinguished from the comparable *Eoparafusulina stevensi* in its elongate-fusiform test outline in all volutions, slightly tighter coiling, more regularly fluted septa, better developed axial fillings and a narrower tunnel.

Stratigraphic range. Khan Formation samples M49B-M50; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Madbeiki section in the Kalmard area, East-Central Iran

Eoparafusulina pamirensis Leven, 1993
Figure 5.15-5.18

v. 1993 *Eoparafusulina pamirensis* Leven, p. 180-181, pl. 12, figs. 9-12.

Remarks. In general the population from East-Central Iran possesses a slightly larger proloculus, shorter test and narrower tunnel.

Stratigraphic range. Bed 6, Dangikalon Formation; Khan Formation samples G-83-84, M49-M50; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Kalaktash area, Central Pamir, Tadzhikistan; Madbeiki and Gachal sections in Kalmard area, East-Central Iran.

Eoparafusulina ruttneri, new species
Figure 6.1-6.5

Holotype. SUI 103004. Axial section; sample M-49-5, Madbeiki section, Khan Formation, unit 15, 135 m above the base of the sections; Kalmard area, East-Central Iran, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. Four axial and seven paraxial sections.

Description. Test is of medium size, subcylindrical with bluntly rounded poles. First volution is ellipsoidal. The shell expands gradually in the early 3-4 volutions along the axis and more rapidly in succeeding volutions. The test is moderately and uniformly coiled throughout growth. Mature specimens with 6-7 volutions are 4.9-7 mm long and 1.6-2 wide with form ratios of 3.0-4.3. The first volution is 0.4-0.6 mm long and 0.3-0.4 wide, giving form ratios of 1.4-1.6. The length and diameter of the fourth volution are 1.7-3 mm and 0.8-1.2 mm with form ratios of 2.1-2.8. Proloculus is spherical, medium in size with an outside diameter of 170-220 microns. Spirotheca is composed of thin and dark tectum and thick and coarsely alveolar keriotheca. It is thin in the early 3-4 volutions, and it increases in thickness gradually in succeeding volutions. The thickness of spirotheca in the first, fourth and last volutions of four specimens are 20-30, 40-60, 60-90 microns, respectively. Septae are thin to moderate in thickness, usually around 30-60 microns, but never reached even half of the thickness of the wall in respective volutions. Septae are widely spaced and moderately and narrowly fluted but seemingly irregularly fluted throughout the length of the test of all volutions, with fluting extending half or less than half as high as chambers. The tunnel is very narrow and low in early volutions and becomes broad in late volutions. Small and rounded chomata occur only in proloculus and first volution. They are not identifiable in other volutions, where the tunnel is outlined with septa or pseudochomata. Narrow axial fillings along axis are present in 2-5 volutions.

Etymology. The species named in honor of A.W. Ruttner, a famous Austrian geologist who extensively mapped East-Central Iran and studied the Upper Paleozoic there.

Remarks. *Eoparafusulina ruttneri* shares some of the same features as *Eoparafusulina stevensi* but has a smaller test with greater form ratio, slightly tighter coiling, better developed axial fillings that are usually present in all volutions and a narrower tunnel. This species differs from *Eoparafusulina regina* (Nie and Song 1983a) by nearly twice as much, more regular and stronger septal fluting, and better developed axial fillings in almost all volutions as opposed to weak axial fillings in *E. regina*.

Stratigraphic range. Khan Formation samples M49-M50; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Madbeiki section in Kalmard area, East-Central Iran.

Eoparafusulina isobella, new species
Figure 6.6-6.8

Holotype. SUI 103003. Axial section; sample M-50-16, Madbeiki section, Khan Formation, unit 15,136 m above the base of the sections; Kalmard area, East-Central Iran; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. Five axial and three paraxial sections.

Description. Test is medium in size, short and elongate-ellipsoidal with bluntly rounded poles. The test exhibits ellipsoidal to elongate-ellipsoidal outline starting from the first volution and continuing throughout the development. Consequently, the test is rather tightly but uniformly coiled throughout the growth. Mature specimens with 6.5-7.5 volutions are 5.3-6.3 mm long and 1.9-2.4 wide with form ratios of 2.4-3.3. The first volution is 0.5-0.8 mm long and 0.3-0.4 wide, giving form ratios 1.4-1.6. The length and diameter of the fourth volution are 1.7-3 mm and 1.4-2.3 mm with form ratios of 1.8-3.0. Proloculus is spherical to ellipsoidal, large in size with an outside diameter of 230-300 microns. The Spirotheca is composed of thin and dark tectum and thick and coarsely alveolar keriotheca. It is thin in the early 3-4 volutions and gradually thickens in following volutions. The thickness of spirotheca in first, fourth and last volutions of four specimens are 20-30, 30-40, 50-80 microns, respectively. Septae are thin, with thickness around 30-40 microns in final volution. They are usually twice as thin as wall in respective volutions. They are also closely spaced, uniformly and narrowly fluted throughout the length of the test. Flutings are rather regular and reaching the third or less than third of the height of chambers. A low tunnel is very narrow in early volutions and becomes slightly wider in late volutions. Chomata are small and rounded occurring only in proloculus and first volution. The tunnel is outlined with septal arches or pseudochomata in other volutions. Axial fillings are weak to moderately developed in polar ends of 2-5 volutions.

Etymology. Iso- and bella, Latin: perfect in all respects.

Remarks. *Eoparafusulina isobella* differs from all other species of *Eoparafusulina* described in this paper in its elongate-ellipsoidal test outline that is nearly the same in shape starting from the 2-3 volution, in very regular and intense septal fluting that is formed in axial sections and small and well rounded, low arches in all volutions.

Stratigraphic range. Khan Formation samples M49-M50; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Madbeiki section in Kalmard area, East-Central Iran.

Eoparafusulina shemiraniensis, new species
Figure 6.9-6.13

Holotype. SUI 103004. Axial section; sample M-49B-3, Madbeiki section, Khan Formation, unit 15, 135.5 m above the base of the sections; Kalmard area, East-Central Iran, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. Seven axial and four paraxial sections.

Description. Test is medium in size, elongate fusiform with narrowly rounded poles. First volution is ellipsoidal. Volutions expanded along the axis gradually in early 2-3 volutions and more rapidly in succeeding volutions. Test is moderately and gradually coiled in general throughout the growth, but slightly tighter in the early 2-3 volutions. Mature specimens of 5.5-6 volutions posses 5.4-7.5 mm in length and 1.8-2.2 in diameter with form ratios of 3.0-3.9. The first volution is 0.3-0.8 mm long and 0.3-0.4 wide, giving form ratios of 1.0-2.0. The length and diameter of the fourth volution are 2.5-4.1 mm and 1-1.2 mm with form ratios of 2.5-3.6. Proloculus spherical to ovoid, medium to large in size, having an outside diameter of 150-350 microns. The moderately thin spirotheca is composed of thin and dark tectum and thick and coarsely alveolar keriotheca. It is thin in the early 2-3 volutions and gradually thickens in following volutions. A total thickness of spirotheca in first, fourth and last volutions of five specimens are 20-30, 50-55, 60-70 microns, respectively. Septa thin to moderate in thickness, usually around 30-50 microns, twice as thin as wall in all volutions. Septa are widely spaced, moderately and narrowly fluted throughout the length of the test, with fluting extending half or less than half as high as chambers. The tunnel is very narrow and low in early volutions and widens in later volutions with slightly irregular paths. Chomata are very small, rounded and observable in proloculus and first volution but not in other volutions. Pseudochomata and septa outline the tunnel after the first volution. Axial fillings are moderate to weak and developed along the axis in the 2-5 volutions.

Etymology. The species named in honor of Professor A. Shemirani, foraminiferal specialist of Sakhid Beshesti University, Iran.

Remarks. *Eoparafusulina shemiraniensis* has many of the same features as *Eoparafusulina madbeiki* but has a shorter test and fusiform outline with sharper polar ends, slightly less regular, but stronger and deeper septal fluting and a narrower tunnel with an irregular path.

Stratigraphic range. Khan Formation samples M49B-M50; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Madbeiki section in Kalmard area, East-Central Iran.

Eoparafusulina minuta, new species
Figure 6.14-6.18

v. 1993 *Eoparafusulina depressa* Skinner and Wilde, 1965, Leven, p. 179, pl. 12, figs. 3-8.

Holotype. SUI 103021. Axial section; sample G-83-8, Gachal section, Khan Formation, unit 15, 160 m above the base of the sections; Kalmard area, East-Central Iran, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. Seventeen axial and nine paraxial sections.

Description. Test small to very small, subcylindrical to elongate fusiform with bluntly rounded poles. Coiling is moderate and uniform throughout development. Mature specimens of 5-5.5 volutions are 3.5-4.3 mm in length and 1.1-1.3 in diameter with form ratios of 3.0-3.6. The first volution is 0.4-0.7 mm long and 0.2-0.3 mm wide with form ratios of 1.9-2.5. The length and diameter of the fourth volution are 2.4-3 mm and 0.8-1 mm, respectively, with form ratios of 3.0-3.2. Proloculus is spherical, small to moderate in size, with an outside diameter of 130-200 microns. Spirotheca are thin although poorly preserved with considerable tectum and alveolar keriotheca. The thickness of spirotheca in the first, fourth and last volutions are 20, 30-50 and 50-70 microns, respectively. Septa are thin, about 30-40 microns, thinner than wall in respective volutions. Septa are widely spaced, moderately and irregularly fluted throughout the length of the test. The tunnel is low and narrow in inner volutions but expanded in outer ones with an irregular path. Chomata are small and rounded and observed only in proloculus. Axial fillings are absent or weakly developed.

Etymology. *Minute:* Latin word for small.

Remarks. *Eoparafusulina minuta* differs from many other *Eoparafusulina* in the small size of the test, with less then five volutions, and a less regular and well-developed septal fluting. It is similar to

Eoparafusulina depressa (Skinner and Wilde, 1965, but has less well-developed cuniculi that are present and well observed in two-three outer volutions in *E. depressa* (Skinner and Wilde 1965, p. 76). *E. minuta* has very poorly developed cuniculi only in the final volution. The latter also has less regular and intense fluting of septa and a complete absence of axial fillings, although very weak axial fillings are present in one specimen from Central Pamir (Leven 1993, pl. 12, fig. 3).

Stratigraphic range. Bed 6, Dangikalon Formation; Khan Formation sample M49B, Gachal section, samples G-83-84; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Central Pamir, Tadzhikistan; Gachal and Madbeiki sections in Kalmard area, East-Central Iran.

Genus *TIMANITES*, new genus

v. 1961 *Triticites* Grozdilova and Lebedeva, p. 177.
v. 1991 *Triticites* Konovalova, p. 92 (partim).
v. 1997 "*Triticites*" Remizova, pl. 1, fig. 10; pl. 2, figs.1-5.

Type of the genus. *Triticites domesticus* Grozdilova and Lebedeva 1961, p.185-186, Pl. 3, figs. 7 and 8 (holotype), Ilibey Horizon, lower Sakmarian; Volonga River, Northern Timan, Russia.

Diagnosis. Very small subcylindrical to ovoid test, four to five tightly and gradually coiled volutions, small proloculi, weakly fluted septa, chomata at least in 3-4 inner volutions.

Description. Test is small to very small and usually does not exceed 3-4 mm in length, subcylindrical to ovoid in shape. The proloculus is also small to very small, with an outside diameter of 60-90 microns, sometimes up to 130 microns. Coiling is tight in early volutions, nearly uniform. Spirotheca is thin with fine alveolar keriotheca that was observed mostly in late volutions. Septal fluting is weakly to prominently developed in axial ends; in the last volution septa are often nearly straight or just wavy. Cuniculi were not observed. Axial fillings are absent or are weakly developed in axial ends of the final volution. Very small, rounded to trapezoidal chomata developed throughout the growth, sometimes absent in one or two outer volutions.

Other species. At the moment, this genus includes species described from Arctic: *Timanites pensus* (Grozdilova and Lebedeva 1961), *Timanites dubius* (Grozdilova and Lebedeva 1961), *Timanites tersus* (Grozdilova and Lebedeva 1961), *Timanites cheni* (Grozdilova and Lebedeva 1961), *Timanites elatus* (Grozdilova and Lebedeva 1961), *Timanites mansus* (Grozdilova and Lebedeva 1961), *Timanites duplex* (Grozdilova and Lebedeva 1961), *Timanites paraduplex* (Grozdilova and Lebedeva 1961), *Timanites festus* (Grozdilova and Lebedeva 1961), *Timanites poljaricus* (Grozdilova and Lebedeva 1961), *Timanites teres* (Grozdilova and Lebedeva 1961), *Timanites komiensis* (Grozdilova and Lebedeva 1961), *Timanites recondita* (Grozdilova and Lebedeva 1961), all from Nenets and Ilibey Horizons, upper Asselian and lower Sakmarian, Volonga, Indiga and Sula Rivers, Northern Timan, Russia; *Timanites sterlitamakensis* (Grozdilova 1936), from upper Asselian and lower Sakmarian of southern Urals. One more species placed in this genus conventionally *Timanites pusilla* (Schellwien 1898) that was found together with ?*Paraschwagerina fusulinoides* (Schellwien 1898) in Uggowitzer Breccie and most probably Sakmarian in age (Forke 2007).

Etymology. The genus is named after Timan region where this group of fusulinids were first described and where they were widely distributed.

Remarks. *Timanites* includes a very specific group of forms that are considered small and primitive among the other Permian schwagerinids. Originally described as *Triticites*, they recently were questionably assigned to *Eoparafusulina* (Davydov 1995; Remizova 1997). Overall, *Timanites* are of a much smaller size and have a small proloculus, fewer number of volutions, tighter coiling, less well-developed septal fluting, and an absence of cuniculi. They also have a small but conspicuous chomata in most volutions except the one or two outer ones. *Timanites* are different from the small monodiexodinid group *Mccloudia* (Ross 1967) in having a smaller size, tighter coiling, presence of chomata in most volutions, less well-developed septal fluting and an absence of cuniculi.

Stratigraphic range. Permian, Cisuralian, Late Asselian-early Artinskian.

Geographic occurrence. Russian and Norwegian Arctic, Urals.

Subfamily *SCHWAGERININAE* Skinner, 1931
Genus *PERIGONDWANIA*, new genus

v. 1993 *Pseudofusulina* Dunbar and Skinner, 1931; Leven, p. 162 (partim)
v. 1997 *Pseudofusulina* Dunbar and Skinner, 1931; Leven, p. 67 (partim)

Type of the genus. *Perigondwania aghanabatii*, new species, Latest Sakmarian-early Artinskian, Madbeiki section, Kalmard area, East-Central Iran.

Diagnosis. Large, subcylindrical test, strongly, deeply and irregularly fluted septa, well-developed phrenotheca, lower cuniculi in the final volution.

Description. Test is large to very large and usually exceeds 7-8 mm in length, subcylindrical to cylindrical in shape. The proloculus is moderate in size, typically with an outside diameter of 100-150 microns. Coiling is moderate, nearly uniform, with early volutions coiled slightly tighter. The spirotheca is thick with coarse alveolar keriotheca and smooth and thin dark tectum. Septal fluting is well developed starting from early volutions. The septa is strongly, deeply and irregularly fluted throughout. Very low and poorly developed cuniculi are observed only in the final volutions. Well-developed phrenotheca are present in the outer 1-2 volutions. The axial fillings are weakly developed and generally absent. Very small, rounded chomata can be observed only on proloculus.

Other species. *Perigondwania pamirensis* (Leven 1993), *Perigondwania karapetovi* (Leven 1993), *Perigondwania plena* (Leven 1993), *Perigondwania curva* (Leven 1993), *Perigondwania incompta* (Leven 1993), *Perigondwania gravis* (Leven 1993), *Perigondwania inobservalis* (Leven 1993), *Perigondwania macilenta* (Leven 1993), *Perigondwania perigrina* (Leven) 1997 and *Perigondwania pseudosulcata*, new species, from Dangikalon Formation in Central Pamir from Bed Formation in Gudri-Mazar and Zone P2 of Tezak in Central Afghanistan (Leven1993, 1997), Lupghar Formation in Karakorum (Gaetani et al. 1995) and Saiwan Formation in Central Oman (Angiolini et al. 2006); *Perigondwania hordeola* (Nie and Song 1983b) from Tunlonggonba Formation of Rutog, Xinzang, Tibet, Western China; *Perigondwania rahdariensis*, new species; *Perigondwania* sp. 1 from Khan Fromation, Kalmard area, East-Central Iran.

Etymology. The genus is named after the Peri-Gondwanan region where this group of diagnostic fusulinids is distributed.

Remarks. This fusulinid group of the Peri-Gondwana affinity resembles *Pseudofusulina* in many respects and especially in the large test and its subcylindrical outline, moderate and uniform coiling, character of septal fluting, and size of proloculus. *Perigondwania*, however, have more irregular septal fluting, presence of well-developed phrenotheca in two late volutions, and a lower cuniculi in the final volution. Besides, it is still not clear whether or not *Pseudofusulina* type possess a rugosity of the tectum in the wall. The tectum of *Perigondwania* is smooth in all volutions. *Perigondwania* is most similar to *Shagonella* from Gzhelian-Asselian of western Tethys (Bensh 1972; Davydov 1986; Ueno et al. 1995) in test size, shape outline, character of coiling and especially in character of septal fluting and presence of phrenotheca and lower cuniculi in final volution of advanced forms. *Shagonella* possess a strong rugosity of the tectum that is lacking in *Perigondwania*. These genera occur in two different non-overlapped geographic areas and do not overlap in stratigraphic range. The appearance of both is a striking case of homeomorphism that is quite common in fusulinid evolution. The character of the development of *Shagonella* that has been established in great detail (Davydov 1988) suggests that species of *Perigondwania* recovered in Central Pamir and in the Kalmard area of Iran are advanced representatives of the genus. Discovery of smaller and less developed species can be predicted. However, it cannot be excluded that tendencies in *Perigondwania* evolution in Peri-Gondwana area could be different from those of *Shagonella* in the Tethys.

Stratigraphic range. Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Central Pamir, Central and Southern Afghanistan, Hindu-Kush, Karakorum, Rutog, Central Oman, and Kalmard area in Central-Eastern Iran.

Perigondwania pseudosulcata, new species

v. 1993 *Pseudofusulina sulcata* Korzhenevsky, 1940; Leven, p. 165, pl. 3, figs. 1-4.

Holotype. GGM VI-229-21 (Leven, 1993, pl. 3, fig. 4). Axial section; Dangikalon section, bed 6, Kalaktash area, Central Pamir; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. Sixteen axial sections that reported in Leven's paper (Leven, 1993, p.165).

Description. The description and all measurement for this species are based on the data from Leven (1993). The test is large to very large in size, subcylindrical with bluntly to moderately pointed poles. Early volutions are inflated-fusiform to elongate-ellipsoidal. The test expands along axis rapidly but uniformly and possesses a subcylindrical outline from 3-4 volution. Proloculus is moderate in size, its out diameter 100-120 microns. Length = 0.9-1.1 mm, diameter = 2.4-2.9 mm, form ratios = 3.3-4.0. First volution length is 0.4-1.0, diameter = 0.35-

0.45 and form ratios = 1.2-2.2. Coiling is moderate to slightly loose and uniform throughout the development. Spirotheca is thick with coarse alveolar keriotheca and smooth and thin dark tectum. The estimates of its thickness from Leven (1993) are 70-110 microns. Septa are strongly, regularly to irregularly fluted in all volutions. Fluting is slightly deeper and irregular in the final volution. Well-developed phrenotheca can be seen at least in the two outer volutions. No observation can be made regarding cuniculi, because the original material was not examined. However, the presence of cuniculi that appear in many other *Perigondwania* cannot be excluded. The narrow tunnel is present in all volutions except the final where it is wide to very wide. Axial fillings are generally absent. Very weak secondary deposits in the poles of the third volution are present in one specimen (Leven, 1993, pl. 3, fig. 3). Chomata perhaps present only in proloculus and second chamber.

Etymology. The name of the species shows a homeomorphic similarity between the true *Pseudofusulina sulcata* (Korzhenevsky 1940) from the Urals and *Perigondwania pseudosulcata*, a new species of the Kalaktash area of Central Pamir in Tadzhikistan**.**

Remarks. *Perigondwania pseudosulcata* bear a striking likeness to *Pseudofusulina sulcata* (Korzhenevsky 1940) in many important morphological features. However, the former has well-developed phrenotheca that have never been observed in *Pseudofusulina sulcata* (Korzhenevsky 1940). Several tenths of specimens of *Pseudofusulina sulcata* from the upper Asselian and lower Sakmarian in the Southern Urals were examined and no phrenotheca in any specimen was found. Moreover, *Pseudofusulina sulcata* have regular septal fluting in final volution, the tunnel uniformly widened throughout the development as opposed to irregular width throughout the development in *Perigondwania pseudosulcata*.

Stratigraphic range. Bed 6, Dangikalon Formation; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Kalaktash area, Central Pamir, Tadzhikistan.

Perigondwania rahdariensis, new species
Figure 6.19-6.24

Holotype. SUI 103022. Axial section; sample H-56-4, Halvan section, Khan Formation, unit 6, 134 m above the base of the sections, Kalmard area, east-central Iran, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. Eleven axial and six paraxial sections.

Description. Test is small in size, subcylindrical to cylindrical with bluntly rounded poles. Coiling in early two volutions is very tight, slightly looser in the rest of the volution. The first volution is ellipsoid to inflated fusiform, volutions expands very rapidly in length starting from the second volution and becoming subcylindrical in outline beginning from the 3-4 volutions. Mature tests of 4-5.5 have 5.5-8.4 mm in length and 1.5-1.9 mm in diameter giving form ratios of 3.2-4.4. First volution is 0.3-1 mm long and 0.2-0.4 mm wide with form ratios of 1.7-3.3. The length and diameter of the fourth volution are 3.2-4.2 mm and 0.8-1.2 mm with form ratios of 2.6-4.2. The proloculus is spherical, of small to medium size with an outside diameter of 150-270 microns. Spirotheca is composed of coarse alveolar keriotheca and smooth and thin dark tectum that increases in thickness with the growth of the individuals. The thickness of spirotheca in the first, fourth and final volutions are 20-30, 50-70, and 50-80 microns, respectively. The septa are thin, about 20-40 microns, half as thin as wall in all volutions. They are intensely and irregularly fluted throughout the length of shell from the middle poleward; folds are high, rounded to irregular in shape. Well-developed phrenotheca are present in the outer 1-2 volutions. The tunnel is very narrow to narrow throughout the growth with an irregular path. Chomata are small and asymmetrical, observable only in proloculus and first volution. Axial fillings are absent or very weak in early volutions.

Etymology. After the name of Rahdar section, where this species has been found.

Remarks. *Perigondwania rahdariensis* mirrors *Perigondvania macilenta* (Leven 1993) in the size of the test and proloculus, character of septal fluting and coiling. It is distinguished by its elongate fusiform test outline in the early volutions and its subcylindrical outline in the final volution as opposed to an ellipsoidal outline in the early volutions and elongate-fusiform in late volutions of *P. macilenta.* This species also differs from the latter in having looser coiling in maturity and a narrower tunnel.

Stratigraphic range. Khan Formation samples R-43-55, H-56; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Rahdar and Halvan sections in Kalmard area, East-Central Iran.


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Figure 7 (previous page). Permian advanced fusulinids in the Kalmard area. Scale bar - 1 mm, all magnifications are x10; 7.1-2, ***Perigondwania karapetovi*** (Leven 1993); 7.1, axial section, sample R-49-5, Cat. No SUI 103028; 7.2, axial section, sample H-56-10, Cat. No SUI 103029; 7.3-5, ***Neodutkevitchia psharti*** (Leven 1993); 7.3, axial section, sample R-50-20, Cat. No SUI 103030; 7.4, axial section, sample R-49-2, Cat. No SUI 103031; 7.5, axial section, sample R-49-3, Cat. No SUI 103032; 7.6-9, ***Perigondwania aghanabatei***, new species; 7.6, axial section of holotype, sample R-41-2, Cat. No SUI 103033; 7.7, axial section of paratype, sample R-41-4, Cat. No SUI 103034; 7.8, axial section of paratype, sample R-49-13, Cat. No SUI 103035; 7.9, axial section of paratype, sample R-49-7, Cat. No SUI 103036; 7.10-12, ***Perigondwania pamirensis*** (Leven; 1993); 7.10, axial section, sample R-42-4, Cat. No SUI 103037; 7.11, axial section, sample R-41-17, Cat. No SUI 103038; 7.12, axial section, sample R-49-13, Cat. No SUI 103039; 7.13-15, ***Perigondwania inobservalis*** (Leven 1993); 7.13, axial section, sample R-42-1, Cat. No SUI 103040; 7.14, axial section, sample R-49-11, Cat. No SUI 103041; 7.15, axial section, sample R-42-1, Cat. No SUI 103042; 7.16, ***Perigondwania sp.*** paraxial section showing lower cuniculi in the final volution, sample R-48-2, Cat. No SUI 103047.

Perigondwania macilenta (Leven, 1993)
Figure 6.25

v. 1993 *Pseudofusulina macilenta* Leven, p. 171, pl. 7, figs. 3-7.
v. 1997 *Pseudofusulina macilenta* Leven, p. XI, figs. 12-19.

Remarks. Specimens from East-Central Iran in general possess slightly looser coiling and a narrower tunnel.

Stratigraphic range. Bed 6, Dangikalon Formation; Khan Formation, Rahdar section samples R-48-49; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. East-Central Iran; Kalaktash area, Central Pamir, Tadzhikistan; Khaftkala arae in Central Afghanistan; Kalmard area, East-Central Iran.

Perigondwania karapetovi (Leven, 1993)
Figure 7.1-7.2

v. 1993 *Pseudofusulina karapetovi karapetovi* Leven, p. 171, pl. 1, figs. 4-9.
v. 1995 *Pseudofusulina* ex gr. *karapetovi karapetovi* Leven in Gaetani et al. pl. 8, figs. 5-10.
v. 1997 *Pseudofusulina karapetovi karapetovi* Leven, p. 67-68, pl. XI, figs. 1-5.
v. 2006 *Pseudofusulina* ex gr. *karapetovi karapetovi* Leven and Gorgij ?? in Angiolini et al., pl. 1, figs. 5-6.

Stratigraphic range. Bed 6, Dangikalon Formation; Khan Formation samples R-48-49; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. East Hindu Kush, Pakistan, Khaftkala area in Central Afghanistan, Rahdar section in Kalmard area, East-Central Iran; Kalaktash area, Central Pamir, Tadzhikistan.

Perigondwania aghanabatii, new species
Figure 7.6-7.9

Holotype. SUI 103034. Axial section; sample R-41, Rahdar section, Khan Formation, unit 7, 123 m above the base of the sections; Kalmard area, East-Central Iran; Permian, Cisuralian, Latest Sakmarian-early Artinskian.

Material. Nine axial, and three paraxial sections.

Description. The test is large, subcylindrical to elongate-fusiform with bluntly rounded to pointed poles. Early 2-3 volutions are fusiform to elongate fusiform with pointed poles. Test is uniformly and moderately coiled but tighter in the early 3 volutions. Specimens of 5-5.5 volutions are 8.2-10.3 mm long and 2.2-2.5 wide with form ratios of 3.5-4.5. First volution is 0.4-1.0 mm in length and 0.2-0.3 mm in diameter with form ratios of 1.7-2.7. The length and diameter of the fourth volution are 4.2-6.6 and 1-1.6 with form ratios of 4-4.5. Spherical proloculus is medium to large in size with an outside diameter of 150-250 microns. The spirotheca possess coarse alveolar keriotheca and smooth and thin dark tectum. The thickness of spirotheca for the first, fourth and last volutions is 20-30, 50-70 and 80-90 microns, respectively. Septa are thin, nearly 20-50 microns. They are strongly, narrowly and irregularly fluted throughout the length of the test, especially strong in the polar ends. Well-developed phrenotheca are present in the outer 1-2 volutions. The tunnel is low and very narrow in early volutions and widens in the following volutions, but still moderate in width in the final volution. Small and rounded chomata are observed only on proloculus. Axial fillings are absent or very weak and narrow along the axis in the early 2-3 volutions.

Etymology. After Iranian geologist Dr. A. Aghanabati who established the Khan Formation and proposed its Permian age.

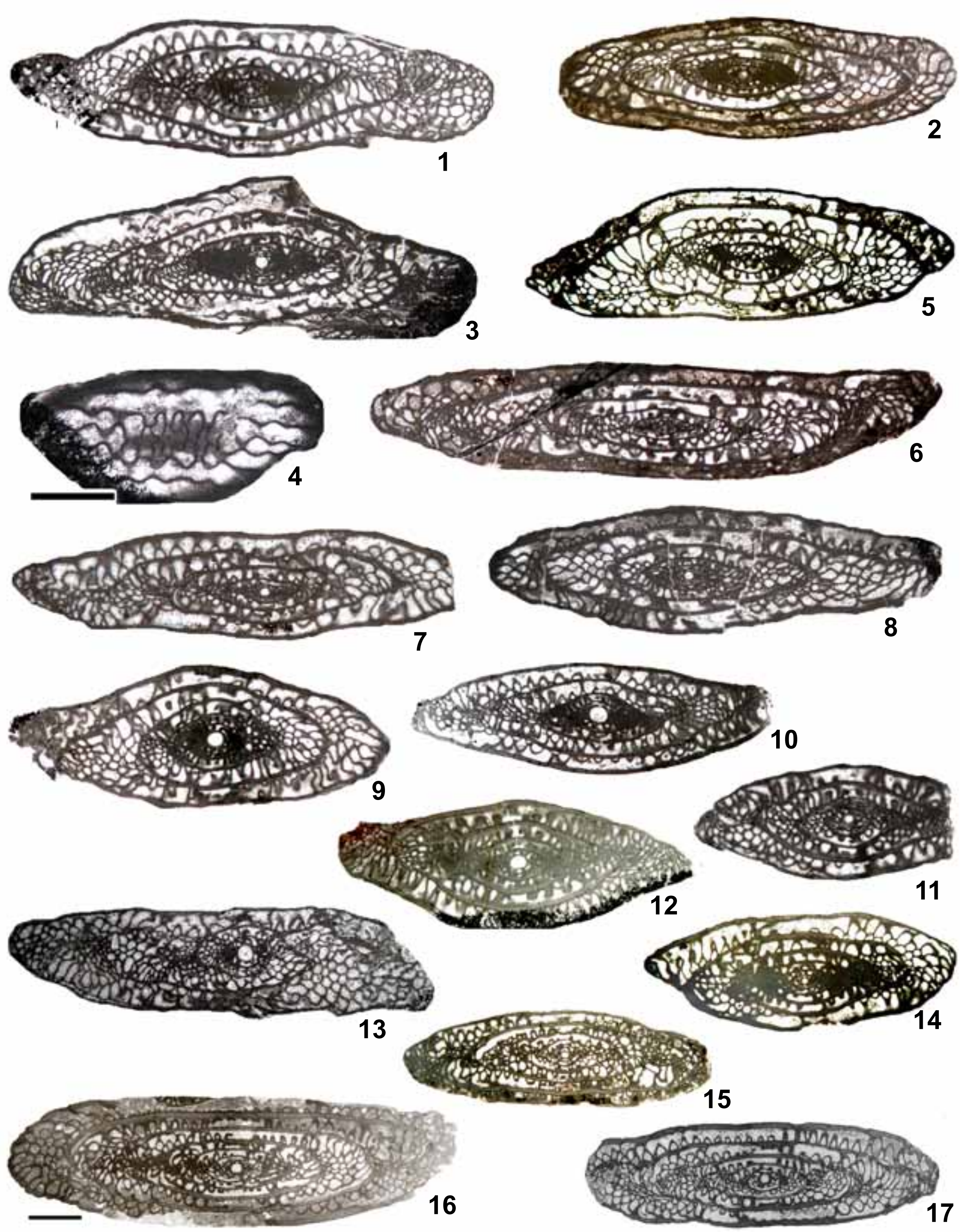
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Figure 8 (previous page). Permian advanced fusulinids in the Kalmard area. Scale bar - 1 mm, all magnifications are x10; 8.1-4, ***Neodutkevitchia spinosai***, new species; 8.1, axial section of holotype, sample M-49B-10, Cat. No SUI 103043; 8.2, axial section of paratype, sample R-49-4, Cat. No SUI 103044; 8.3, axial section of paratype, sample R-50-12, Cat. No SUI 103046; 8.4, paraxial section of paratype showing lower cuniculi in the final volution, sample R-50-9, Cat. No SUI 103047; 8.5 ***Neodutkevitchia insignis*** (Leven 1993), axial section, sample R-43-7, Cat. No SUI 103045; 8.6-7 ***Perigondwania plena*** (Leven 1993); 8.6, axial section, sample R-48-2, Cat. No SUI 103048; 8.7, axial section, sample R-41-5, Cat. No SUI 103049; 8.8, ***Perigondwania gravis*** (Leven 1993)**,** axial section, sample R-50-16, Cat. No SUI 103050; 8.9-10, ***Neodutkevitchia snyderi***, new species; 8.9, axial section of paratype, sample H-62-2, Cat. No SUI 103051; 8.10, axial section of holotype, sample R-48-1, Cat. No SUI 103052; 8.11, ***Neodutkevitchia*** sp. 1, axial section, sample H-62-1, Cat. No SUI 103053; 8.12, ***Neodutkevitchia partoazari***, new species, axial section of holotype, sample H-62-3, Cat. No SUI 103054; 8.13, ***Neodutkevitchia complicata***, new species, axial section of holotype, sample H-62-8, Cat. No SUI 103055; 8.14, ***Perigondwania* ?** sp. 1, axial section, sample R-43-6, Cat. No SUI 103056. Fusulinids from upper Asselian and Lower Sakmarian in southern Urals; 8.15-17, ***Pseudofusulina sulcata*** Korzhenevsky 1940; 8.15, axial section, sample Kond-13-30, Cat. No SUI 103057; 8.16, axial section, sample Kond-8-29, Cat. No SUI 103058; 8.17, axial section, sample Kond-3-7, Cat. No SUI 103059.

Remarks. *Perigondwania aghanabatii* strongly resembles *Perigondwania pamirensis* (Leven 1993) especially in having a large test, moderate and uniform coiling, intense and irregular septal fluting, and the size of the proloculus. However, it has elongate fusiform test outline with pointed polar ends in early volutions and subcylindrical to elongate fusiform test outline in late volutions as opposed to ellipsoidal outline in the early volutions and subcylindrical outline in the late volutions in *P. pamirensis.* Additionally, the former has a narrower tunnel and tighter coiling especially in early volutions.

Stratigraphic range. Halvand section, sample H-56, Rahdar section, sample R-41, R-43, R-49-50, Khan Formation; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Occurrence. Kalmard area, East-Central Iran.

Perigondwania pamirensis (Leven, 1993)
Figure 7.10-7.12

v. 1993 *Pseudofusulina pamirensis* Leven, p. 162-163, pl. 1, figs. 1-3, 6, 8.
v. 1993 *Pseudofusulina kalaktashensis* Leven, p. 165, pl. 2, figs 4-6.
v. 1995 *Pseudofusulina* aff. *syniensis* Konovalova and Baryshnikov, 1980, Leven in Gaetani et al., pl. 8, figs. 2, 4.
v. 2006 *Pseudofusulina kalaktashensis* Leven in Angiolini et al., pl. 1, fig. 13.

Material. Twelve axial and six oblique sections.

Remarks. *Pseudofusulina pamirensis* and *Pregondwania kalaktashiensis* are synonymized because these two species resemble each other in many morphological features such as similar large test, the size of a proloculus, shape outline, relatively loose character of coiling, intense and irregular septal fluting, well-developed phrenotheca in outer 2 volutions, a narrow tunnel in the early volutions and a wide tunnel in final one. The only difference is that *Perigondwania kalaktashensis* has a slightly more inflated fusiform test outline in two early volutions, whereas *P. pamirensis* has an ellipsoidal outline in the early volutions.

Stratigraphic range. Bed 6, Dangikalon Formation; Khan Formation, Rahdar section, sample R-50; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Kalaktash area, Central Pamir, Tadzhikistan; Rahdar section in Kalmard area, East-Central Iran.

Perigondwania inobservabilis (Leven, 1993)
Figure 7.13-7.15

v. 1993 *Pseudofusulina inobservabilis* Leven, p. 164, pl. 2, figs. 1-3.

Material. Six axial, two oblique sections and three paraxial sections.

Remarks. Specimens of *Perigondwania inobservabilis* from East-Central Iran compare well to those from central Pamir. *P. inobservabilis* is a little different, having a slightly larger test, being slightly looser in the last volution, having a narrower tunnel and stronger septal flutings, especially in last stage of development.

Stratigraphic range. Warfa-6 well sample WA6-11, Haushi Lm; bed 6, Dangikalon Formation; Khan Formation, Rahdar section, samples R-41, R-42, R-49, R-50, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Central Oman; Kalaktash area, Central Pamir, Tadzhikistan; Rahdar section in Kalmard area, East-Central Iran.

Perigondwania plena (Leven, 1993)
Figure 8.6-8.7

v. 1993 *Pseudofusulina plena* Leven, p. 164, pl. 2, figs. 1-3.

Material. Six axial and two paraxial sections.

Stratigraphic range. Bed 6, Dangikalon Formation; Lupghar Fm., sample KK20, Khan Formation Rahdar section, samples R-41, R-42, R-48, R-50; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. East Hindu Kush, Pakistan; Khaftkala area in Central Afghanistan, Rahdar section in Kalmard area, East-Central Iran; Kalaktash area, Central Pamir, Tadzhikistan.

Perigondwania gravis (Leven, 1993)
Figure 8.8

v. 1993 *Pseudofusulina gravis* Leven, p. 170, pl. 6, figs. 6-8,10.

Material. One axial and two oblique sections.

Stratigraphic range. Bed 6, Dangikalon Formation; Khan Formation, Rahdar section, sample R-50; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Kalaktash area, Central Pamir, Tadzhikistan; Rahdar section in Kalmard area, East-Central Iran.

Perigondwania? sp.1
Figure 8.14

Material. One axial and two paraxial sections from sample R-43, Rahdar section.

Description. Test is medium in size, short subcylindrical with bluntly rounded to slightly pointed poles. The first volution is ellipsoidal, the second-fourth volutions are inflated fusiform; and the fifth and six volutions are subcylindrical in outline. The proloculus is small, spherical with an outside diameter of 145 microns. The last volution is 5.8 mm in length and 2.1 mm in diameter with a form ratio of 2.8. Coiling in early two volutions is tight to moderate; the rest of the volutions are coiled slightly looser. Spirotheca in early two volutions is thin, 25-30 microns, its structure obscure; coarse alveolar keriotheca observed in two outer volutions where spirotheca is 120-140 microns thick. Septal flutings are irregular and widely spaced. Septa are strong and narrowly fluted throughout their length, fluting reaches almost the entire chamber's height and increases toward the polar ends. Phrenotheca are rare and observed only in the final volution. The tunnel is very narrow in early volutions and narrow elsewhere. Very small chomata is observed only on proloculus and first volution. Axial fillings are quite strong in the polar ends of the early four volutions.

Remarks. The described species possesses many features that separate it from the rest of *Perigondwania*. It has a smaller test and proloculus, tight coiling in early volutions, narrow tunnel and strong axial fillings. Because of limited material this species cannot be described as new, especially because of the small proloculus and tight coiling that occurs in the early volutions. This may represent microspheric reproductive generations of other known species or other species described in this study.

Stratigraphic range. Khan Formation, samples R-43, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Kalmard area, eastern-central Iran, Rahdar sections.

Genus *NEODUTKEVITCHIA*, new genus

v. 1993 *Pseudofusulina* Dunbar and Skinner, 1931; Leven, p. 162 (partim)

Type of genus. *Neodutkevitchia snyderi* new species, latest Sakmarian-early Artinskian, Rahdar section, Kalmard area, East-Central Iran.

Diagnosis. Large, subcylindrical to inflated fusiform test with large proloculus and loose coiling, strongly and deeply fluted septa, well-developed phrenotheca, lower cuniculi in the final volution.

Description. Test is large to very large in size, usually exceeds 7-8 mm, but sometimes can be slightly smaller in length. Its shape varies from subcylindrical and cylindrical to inflated-fusiform. Proloculus is large to very large, its outside diameter usually exceeds 200 microns. The coiling is loose, especially starting from third-fourth volutions, early volutions coiled slightly tighter. The spirotheca is thick with coarse alveolar keriotheca and smooth and thin dark tectum. Septa are strongly, deeply and irregularly fluted throughout the development of the test. In early volutions septa are fluted more regularly than in late volutions. Well-developed phrenotheca are present in the outer 1-2 volutions. Lower cuniculi are observed in final volution. Axial fillings are well developed only in early volutions where septal fluting is regular. On some species axial fillings might be weakly developed or absent. Chomata are absent.

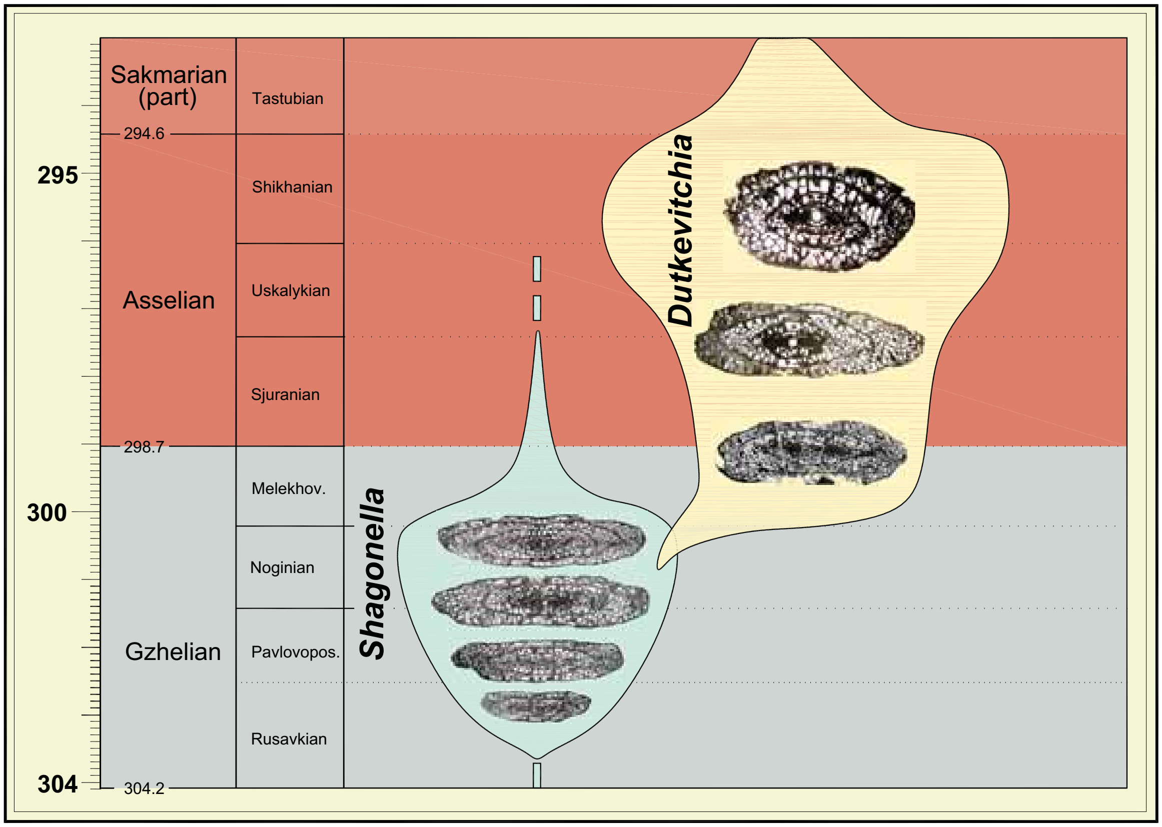

Figure 9. The evolutionary pattern of Tethyan late Gzhelian-Asselian warm-water tropical *Shagonella* and *Dutkevitchia* .

Other species. *Neodutkevitchia tezakensis* (Leven 1997), *Neodutkevitchia curteus* (Leven 1993), *Neodutkevitchia psharti* (Leven 1993), *Neodutkevitchia insignis* (Leven 1993), *Neodutkevitchia granuliformis* (Leven 1993), *Neodutkevitchia memoralis* (Leven 1993), *Neodutkevitchia neglectens* (Leven 1993)

Neodutkevitchia licis (Leven 1993), *Neodutkevitchia tumidiscula* (Leven 1993), *Neodutkevitchia vulgara* (Leven 1993), *Neodutkevitchia curta* (Leven 1993), from Dangikalon Formation of Central Pamir; *Neodutkevitchia spinosai,* new genus and species, *Neodutkevitchia partoazari,* new genus and species, *Neodutkevitchia complicata,* new genus and species, *Neodutkevitchia* sp. 1 from Khan Formation in the Kalmard area of Central-Eastern Iran. Because of the transitional character of morphologies between *Perigondwania* and *Neodutkevitchia*, this genus included: *Neodutkevitchia? curteum* (Leven 1993), *N.*? *gravis* (Leven 1993), and *N.*? *perrara* (Leven 1993).

Etymology. The name of the genus *Neodutkevitchia* of Peri-Gondwanan affinity came from homeomorphic genus *Dutkevitchia* that is Tethyan affinity that strongly resemble each other.

Remarks. Like *Perigondwania*, the genus *Neodutkevitchia* distributed in Peri-Gondwana has also been described as *Pseudofusulina* (Leven 1993, see synonymy). However, it is different from *Pseudofusulina* in several important features such as loose coiling, a large proloculus, a well-developed phrenotheca and presence of cuniculi in final volution. *Neodutkevitchia* is very similar to *Dutkevitchia* from the late Gzhelian-Sakmarian of Tethys (Leven and Scherbovich 1978) in test size and shape outline, in character of septal fluting, presence of phrenotheca, a lower cuniculi in the final volution and especially in having a large proloculus and loose coiling that separate *Neodutkevitchia* as well as *Dutkevitchia* from the rest of the *Schwagerinidae* genera (Figure 9 and Figure 10). The most notable contrast between these two genera is that *Dutkevitchia* possess strong rugosity of tectum that is lacking in *Neodutkevitchia*. Though genera occur in two different non-overlapped geographic areas, they partially overlap stratigraphically. Again, as in the case with *Shagonella* and *Perigondwania*, the strong homeomorphism can be noted between *Dutkevitchia* and *Neodutkevitchia*. However, tendencies in evolution

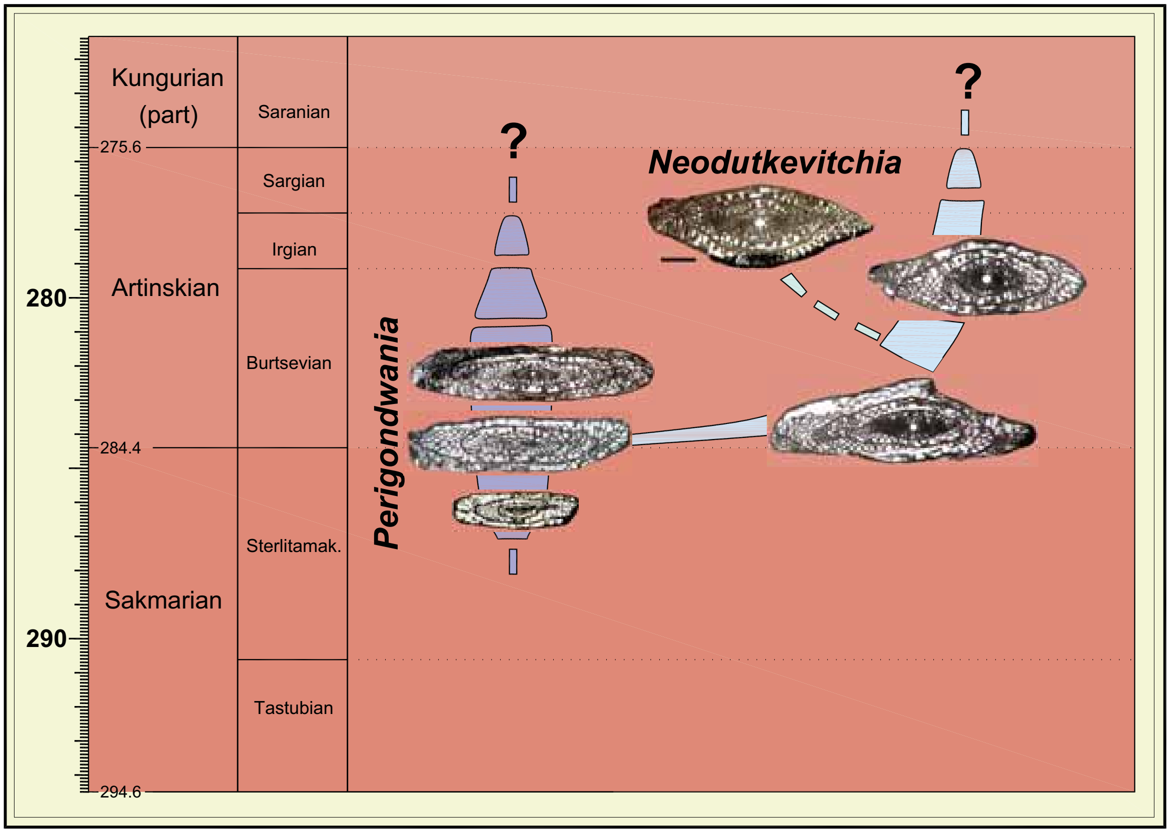

Figure 10. Evolutionary pattern of Peri-Gondwanan late Sakmarian-early Artinskian cool-water, antitropical *Perigondwania* and *Neodutkevitchia*. The trend of morphological evolution in these two genera shows striking similarities to the trend in evolution *Shagonella* and *Dutkevitchia*. See text for details.

of *Neodutkevitchia* seem somewhat different from what is known in *Dutkevitchia* (Davydov 1988). In general, however, evolution within the lineage *Perigondwania-Neodutkevitchia* is quite similar to the evolution within the lineage of *Shagonella-Dutkevitchia*. Increases of strong and chaotic septal fluting in development *Shagonella* give rise to genus *Dutkevitchia*. There is an opposite tendency in the development of septal fluting where it has become more and more regular to give rise to genus *Ruzhenzevites* (Davydov 1986, 1988). Similarly, two groups that most likely derived from *Perigondwania* can be separated among *Neodutkevitchia*. The first one, having irregular septal fluting, represents *Neodutkevitchia* itself. The second group that is unfortunately limited in our material seems to represents a tendency toward increasing more regular septal fluting. Unfortunately, our material on this group is limited. Typically it is included in *Neodutkevitchia*.

Stratigraphic range. Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Central Pamir, Central and Southern Afghanistan and the Kalmard area in Central-Eastern Iran.

Neodutkevitchia psharti (Leven, 1993)
Figure 7.3-7.5

v. 1993 *Pseudofusulina psharti* Leven, p. 166, pl. 3, fig.7, pl. 4, figs. 1-4.

Material. Nine axial and six paraxial sections.

Description. Test is large in size, elongate-fusiform with bluntly rounded poles. First volution is fusiform. Coiling is moderate to loose after tight inner 2-3 volutions. Proloculus is spherical, medium to large in size, with an outside diameter of 170-250 microns. Specimens of 4.5-6 volutions are 7.5-9 mm in length and 1.6-2.4 mm in diameter, giving form ratios of 3.4-4.6. First volution is 0.5-0.8 mm long and 0.2-0.3 wide with a form ratio of 2-2.3. The length and diameter of the fourth volution are 3.6-5.2 mm and 1.2-1.6 mm with form ratios of 2.6-4.6. Spirotheca is thick and composed of thick, coarse alveolar keriotheca and thin and smooth, dark tectum. The thickness of spirotheca in first, fourth and last volutions are 20-30, 60-70 and 70-120, respectively. Septa are thin, around 20-40 microns. They are strongly, narrowly and irregularly fluted throughout. Flutings start from early volutions and extend more than half of the chamber heights. Well-developed phrenotheca present in the outer 1-2 volutions. Chomata are absent. Well-developed axial fillings occur in early 2-3 volutions but are lacking in the rest of the volutions.

Remarks. Specimens from the Kalmard area differ from those in Central Pamir in slightly tighter coiling.

Stratigraphic range. Bed 6, Dangikalon Fm., Central Pamir; Khan Formation samples R-49-50; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Kalaktash area, Central Pamir, Tadzhikistan; Rahdar section in Kalmard area, East-Central Iran.

Neodutkevitchia spinosai, new species
Figure 8.1-8.4

Holotype. SUI 103045. Axial section; sample M-49B-10, Madbeiki section, Khan Formation, unit 15, 135.5 m above the base of the sections, Kalmard area, east-central Iran, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. Five axial and three paraxial sections.

Description. Test is large, subcylindrical to fusiform with bluntly pointed poles. It is loosely coiled but early 3-4 volutions are fairly tighter. The first volution is ellipsoidal. Mature test of 4.5-5.5 volutions are 7.3-9.6 mm long and 2.2-2.5 mm wide, giving form ratios of 3.3-3.8. The first volution is 0.4-0.8 mm in length and 0.3-0.4 mm in diameter with form ratios of 1.5-2.1. The length and diameter of the fourth volutions are 5.3-6.6 mm and 1.4-2.2 mm with form ratios of 2.9-3.8. Proloculus is medium to large with an outside diameter of 150-280 microns. Spirotheca is thick with coarse alveolar keriotheca and smooth and thin dark tectum. It is thin in the early 2-3 volutions and gradually thickens throughout the growth. The thickness of spirotheca in first, fourth and last volutions are 20-30, 50-80 and 90-120 microns, respectively. Septa are thin to moderate in thickness, usually about 20-50 microns. Septa are intensely, narrowly and irregularly fluted in outer volutions but more regularly fluted in inner volutions. Well-developed phrenotheca are present in the outer 1-2 volutions. Chomata are absent. The tunnel is very narrow in early volutions, but gradually and slowly widens throughout the test development. Axial fillings well developed in the early two, tighter coiled volutions that separate them from the later volutions. Lower cuniculi are observed only in the final volution.

Etymology. The species is named in honor of Prof. Claude Spinosa, a well-known Permian ammonoid worker, our good colleague, and First Co-Director of the Permian Research Institute at Boise State University.

Remarks. *Neodutkevichia spinosai* resembles *Neodutkevichia insignis* (Leven 1993) in general outline, and character of coiling throughout the growth, but differs from the latter in stronger septal fluting and particularly in the outer volutions and in narrow tunnels. Cuniculi are observed in *N. spinosai*, but it is not clear if they are present in *N. insignis*.

Stratigraphic range. Khan Formation samples M-49B, R-43,49-50; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Madbeiki and Rahdar sections in the Kalmard area, East-Central Iran.

Neodutkevitchia insignis (Leven, 1993)
Figure 8.5

v. 1993 *Pseudofusulina insignis* Leven, p. 167, pl. 4, figs. 6-8.

Material. Two axial and two oblique sections.

Stratigraphic range. Bed 6, Dangikalon Formation; Khan Formation, Rahdar section, samples R-43, R-50, R-51, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Kalaktash area, Central Pamir, Tadzhikistan; Rahdar section in the Kalmard area, East-Central Iran.

Neodutkevitchia snyderi, new species
Figure 8.9-8.10

Holotype. SUI 103054. Axial section; sample R-48-1, Rahdar section, Khan Formation, unit 7, 133 m above the base of the sections, the Kalmard area, east-central Iran, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. Three axial and two paraxial sections.

Description. The test is of moderate size, fusiform to inflated-fusiform with narrowly rounded poles. The first volution is ellipsoidal to inflated-fusiform. Coiling is relatively loose, but slightly tighter in the early two volutions. Proloculus is spherical to subspherical, very large, with an outside diameter of 300-420 microns. Specimens of 4-4.5 volutions are

6.7-6.9 mm in length and 2.1-2.4 mm in diameter, giving form ratios of 2.9-3.2. The first volution is 1.1-1.2 mm long and 0.6-0.7 wide with a form ratio of 1.6-1.8. Spirotheca is thick and composed of coarse alveolar keriotheca and smooth and thin dark tectum. The thickness of spirotheca in first, fourth and last volutions are 25-35, 50-60 and 90-115 microns, respectively. Septa are thin, usually about 20-25 microns. They are strongly, narrowly and very irregularly fluted throughout the length of the volutions. Septal fluting is deep and regular in the early two volutions. Folds are sharp and quite irregular in shape in three outer volutions, but high and sub-square in the early two volutions. Well-developed phrenotheca are present in the outer two volutions. Chomata are lacking. Axial fillings are well developed in early two volutions. The tunnel is very narrow and low throughout the growth. Lower cuniculi are observed in two outer volutions.

Etymology. This species is named in honor of Prof. W.S. Snyder, Co-Director of Permian Research Institute, at Boise State University. Prof. Snyder is a well-recognized stratigrapher, paleontologist and sedimentologist who researches the Upper Paleozoic globally.

Remarks. Characteristic features of this species are an inflated fusiform test with a large proloculus and loose coiling and rather irregular septal fluting in outer volutions. **Stratigraphic range.** Khan Formation samples H-62, R-48; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Halvan and Rahdar sections in the Kalmard area, East-Central Iran.

Neodutkevitchia partoazari, new species
Figure 8.12

v. 1993 *Pseudofusulina curta* Leven (partim), p. 173, pl. 7, fig. 14 (only)

Holotype. SUI 103054. Axial section; sample H-62-3, Halvan section, Khan Formation, unit 9, 145 m above the base of the sections, the Kalmard area, east-central Iran, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. One axial and one oblique section in our collection and one axial section from Leven (1993).

Description. The test is moderate in size, inflated fusiform to sub-rhomboidal with narrowly rounded to sharply pointed poles. Coiling is loose and uniformly expended from the first volution, where it is moderate in height. The first volution is ellipsoidal to sub-rhomboidal. Mature test of 4-5 volutions is 5.0-5.6 mm in length and 1.7-2.0 mm in diameter, giving a form ratio of 2.8-3.0. The first volution is 0.7-1.1 mm in length and 0.4-0.6 in diameter with form ratios of 1.7-1.8. Proloculus is large with an outside diameter of 220-320 microns. Spirotheca is thick, up to 110 microns, with coarse alveolar keriotheca and smooth and thin dark tectum. The thickness gradually increased throughout the growth of test. Septa are thin, usually about 20-30 microns. They are deeply, strongly and regularly fluted throughout the length of shell and form high and nearly sub-square arches that are thickened at the top. Chomata are lacking. Axial fillings are weakly developed and present in the early 2-3 volutions. Rare phrenotheca observed in two outer volutions. Presence of cuniculi was not documented.

Etymology. This species is named after Iranian geologist and paleontologist Dr. H. Partoazar from Geological Survey of Iran, who studied the Permian in Iran.

Remarks. *Neodutkevichia partoazari* are similar to *Neodutkevichia snyderi*, a new species, in many respects but have a smaller and sub-rhomboidal test, slightly tighter and more uniform coiling, and more regular septal fluting.

Stratigraphic range. Bed 6, Dangikalon Formation; Khan Formation, Halvan section, sample H-62; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Kalaktash area, Central Pamir, Tadzhikistan; Halvan section in Kalmard area, East-Central Iran.

Neodutkevitchia complicata, new species
Figure 8.13

Holotype. SUI 103057. Axial section; sample H-62-8, Halvan section, Khan Formation, unit 9, 145 meters above the base of the sections, Kalmard area, east-central Iran, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. 1 axial and one oblique sections.

Description. Test is large in size, subcylindrical with bluntly rounded to slightly pointed poles, loosely coiled. First volution is subspherical. Proloculus is spherical and large with outside diameter of 320 microns. Mature test of 3-3.5 volutions is 8.8-9.0 mm long and 1.9-2.1 mm wide with form ratio 4.3-4.6. Spirotheca is thin (20-25 microns) in first volution, gradually and uniformly thickens up to 100 microns in final volution. Septa are thin, 20-25 microns, closely spaced, very intensely, highly and very irregularly fluted throughout the length of shell. Closed chamberlets extendsto tops of chambers in all volutions. Chomata are lacking. Tunnel is very narrow and very low throughout. Very weak axial fillings are present only in first volution. Rare phrenotheca present in final volution only.

Etymology. Complicata (latin) - complex, and is given in respect of complex character of septal fluting in this species.

Remarks. *Neodutkevichia complicata* differs from all other *Neodutkevichia* in having a subcylindrical test outline, loose and uniform coiling, as well as a strong and very irregular septal fluting.

Stratigraphic range. Khan Formation samples H-62; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Halvan section in Kalmard area, East-Central Iran.

Neodutkevitchia sp. 1
Figure 8.11

Holotype. SUI 103055. Axial section; sample H-62-1, Halvan section, Khan Formation, unit 9, 145 meters above the base of the sections, Kalmard area, east-central Iran, Permian, Cisuralian, latest Sakmarian-early Artinskian.

Material. One axial and one sagittal section.

Description. Test is moderate in size, sub-rhomboidal with narrowly rounded to slightly pointed poles, loosely and uniformly coiled. First volution is subspherical. Proloculus is spherical and large with an outside diameter of 260 microns. Mature test of 4.5-5 volutions is 5.8 mm long and 2.2 mm wide with a form ratio of 2.6. Spirotheca is moderate in thickness, 50 microns the first volution, and very gradually and uniformly thickens up to 80-90 microns in the final volution. Septa are thin, 20-25 microns, closely spaced, very intensely, highly and relatively regularly fluted throughout the length of the shell. Closed chamberlets extend nearly to the tops of the chambers in all volutions. The tunnel is very narrow and low throughout. Axial fillings and chomata are lacking. No phrenotheca is observed in the studied specimen.

Remarks. *Neodutkevichia* sp. 1 closely resembles *Neodutkevichia partoazari* in sub-rhomboidal test outline, loose and uniform coiling and strong septal fluting, but differs in less regular septal fluting, lacking axial fillings and phrenotheca. It cannot be excluded that *Neodutkevichia* sp. 1 might fall within the variation among the population of *N. partoazari*, but limited material does not allow us to clarify this problem.

Stratigraphic range Khan Formation samples H-62; Permian, Cisuralian, latest Sakmarian-early Artinskian.

Geographic occurrence. Halvan section in the Kalmard area, East-Central Iran.

CORRELATION AND BIOSTRATIGRAPHY OF THE KHAN FORMATION WITH CORRELATIVE PERI-GONDWANA DEPOSITS

Twenty-one samples were collected from four sections at 1 m intervals, and 352 oriented thin-sections with fusulinids were prepared. The recovered assemblage of fusulinids consists of six genera and 24 species. Six genera of smaller foraminifera were found as well (Table 1). The most abundant taxa in the assemblage are diverse *Eoparafusulina*, and *Perigondwania*; the *Neodutkevitchia* are much less diverse. Schubertellides (*Eoschubertella* and *Grovesella*) and staffellids are very rare but present in the assemblage. Smaller foraminifera in the studied material are very rare.

Eoparafusulina, *Perigondwania*, and *Neodutkevitchia* that are distributed within Peri-Gondwana appear there as the earliest, relatively warm water marine assemblage above cool water carbonates. They are associated with brachiopods and bryozoans and cold/cool-water siliciclastic deposits including glacial diamictites (Angiolini et al. 2006; Leven 1993, 1997; Ueno 2003; Shi and Grunt 2000). This assemblage represents the transition between non-fusulinid cold-water communities and typical warm-water fusulinid communities of a tropical area. Accordingly, a stressful environment can be expected in this transition that is marginal for fusulinids. These conclusions are based on the following observations. First, the diversity of the assemblage is relatively low relative to the assemblages in the Tethys of a comparible age (e.g., Afghanistan, North and South China). Second, an abnormally large number of the specimens (>5% of the total population) have a double proloculi. A similar phenomenon was observed in the published data from Central Pamir (Leven 1993). From the 102 figured specimens of *Eoparafusulina*, *Perigondwania* and *Neodutkevitchia* in this paper, six specimens have a double proloculi (Leven 1993, Plate 1, figure 7; Plate 2, figure 5; Plate 5, figure 9; Plate 7, figure 16; Plate 11, figures 6 and 14). The unusually large number of specimens with a double proloculi might indicate a stressful environment that is marginal for these surviving fusulinids. In normal warm-water conditions the number of specimens with double proloculi never exceeds 0.1% of the population.

Table 1. Distribution of smaller foraminifers and fusulinids in Khan Formation, Kalmard area, East-Central Iran. Note NS = new species; L = Leven, 1993.

Species name		Sections: Gachal			Halvan				Madbeiki			Rahdar								
		G-82	G-83	G-84	H-36	H-50	H56	H-62	M-49	M49B	M50	R-41	R-42	R-43	R-47	R-48	R-49	R-50	R-51	R-55
Smaller foraminifers		159mab	160mab	161mab	97mab	127mab	133mab	145mab	135mab	135.5mab	136mab	123mab	124mab	125mab	132mab	133mab	134mab	136mab	138mab	139mab
Palaeotextularia sp														x						
Deckerella sp.													x							
?*Deckerella* sp.																	x			
Globivalvulina sp.											x			x						
Hemigordius sp.													x	x						
?*Hemigordius* sp.												x								
Geinitzina sp																	x		x	
?*Amphoratheca* sp						x														
Fusulinids																				
Grovesella tabasensis	NS					x			x				x				x			
Eoschubertella sp.1																	x			
Pseudoendothyra sp.											x									
Eoparafusulina grosdilovae	NS	aff.							x		x									
Eoparafusulina madbeikii 2	NS						x			x	x									
Eoparafusulina shermaniensis 3	NS									x	x									
Eoparafusulina isobella 4	NS								x	x	x									
Eoparafusulina ruttneri 5	NS								x	x	x									
Eoparafusulina stevensi	NS								x		x									
Eoparafusulina pamirensis	L		x	x					x	x										
Eoparafusulina minuta	NS		x	x						x										
Perigondwania macilenta	L															x	x			
Perigondwania karapetovi	L				cf.	x	x					x	x	x	aff.	x	x			
Perigondwania rahdariensis 6	NS						x							x	x	x				x
Perigondwania pamirensis	L											x	x	x	x		x	x		x
Perigondwania plena	L											x	x			x		x		
Perigondwania inobservalis	L											x	x				x	x		
Perigondwania gravis	L																	x		
Perigondwania aghanabati 7	NS						x					x		x	cf.		x	x		
Perigondwania sp. 1														x				x		
Neodutkevitchia snyderi 8	NS							x								x				
Neodutkevitchia complicata	NS							x												
Neodutkevitchia partoazari	NS							x												
Neodutkevitchia psharti	L										cf.						x	x		
Neodutkevitchia insignis	L													x				x	aff.	
Neodutkevitchia spinosai 10	NS									x				x	cf.		x	x		
Neodutkevitchia sp. 1								x												

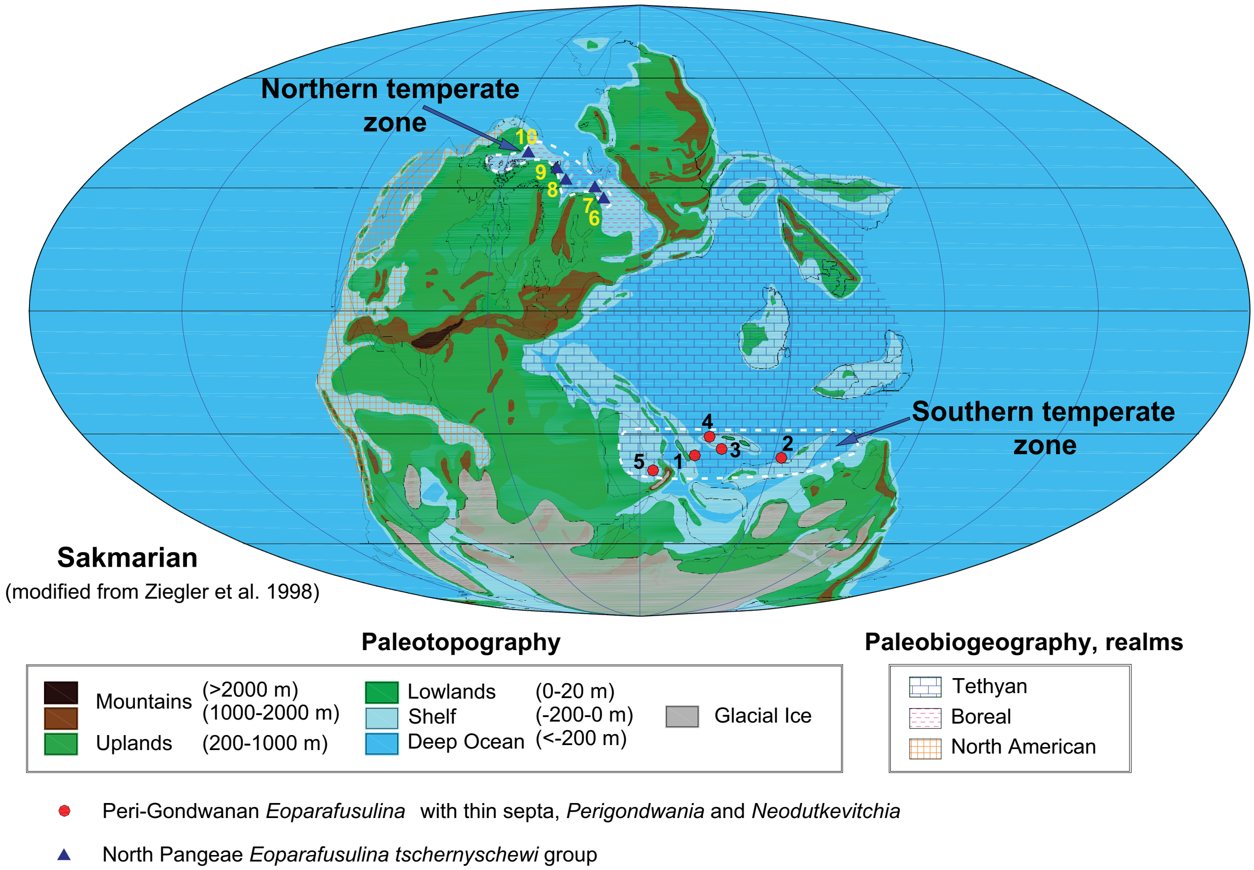

Figure 11. Distribution Peri-Gondwanan *Eoparafusulina* with thin septa and *Perigondwania* - *Neodutkevitchia* stocks and Arctic *Eoparafusulina tschernyshevi* group with thick septa in Sakmarian, Early Permian. Map slightly modified from Ziegler et al. 1998. Note the presence of bridge between Pangaea and Kazakhstania plates south from Uralian sea that prevent connections between Boreal and Tethyan faunas starting from early Sakmarian. Occurrences:1, Posht-e-Badam block, Kalmard area, East-Central Iran; 2, Baoshan, Sibumasu, Tengchong Blocks, Indo-China (Cimmerian) Blocks; 3, Quangtang Block (including South Tibet, East Hindu Kush, Karakorum and south Afghanistan); 4, Central Pamir; 5, Central Oman; 6, North Timan; 7, Kolguev; 8, Barents Sea subsurface; 9, Spitsbergen; 10, Canadian Arctic.

Two assemblages can be recognized in the Kalmard area. One is *Eoparafusulina*-dominated and found in Gachal and Madbeiki sections. The second, a *Perigondwania*-*Neodutkevitchia*-dominated assemblage is found in the Halvan and Rahdar sections. The *Eoparafusulina*-dominated assemblage consists of eight species of Eoparafusulina, seven of which are new, and one species of *Neodutkevitchia* (Table 1). One previously known species is *E. pamirensis* (Leven 1993). It has been found in the Kalmard area and was originally described from bed 6 of Dangikalon Fm in Central Pamir (Leven 1993), where it appears in an assemblage with several other *Eoparafuslina*, numerous *Perigondwania*, less diverse *Neodutkevitchia* and perhaps rare *Pseudoendothyra, Schubertella* and *Pseudoreichelina* (Leven 1993). Unfortunately, no documentation about species distribution in each section/sample nor ecological or environmental information were provided in this publication. It is hard to judge whether *Eoparafusulina* in Central Pamir appear together with *Perigondwania* and *Neodutkevitchia* or whether these two assemblages occur separately as in the Kalmard area (Figure 11).

Two new species of *Eoparafusulina* (*E. grozdilovae* and *E. stevensi*) that are found in the Kalmard area also occur in bed 6 of Dangikalon Fm in Central Pamir and were designated there as *Eoparafusulina tschernyschewi tschernyschewi* and *Eoparafusulina tschernyschewi memoranda* (Leven 1993). The latter two species were originally described from late Asselian-early Sakmarian of Timan (Schellwien 1909; Grozdilova and Lebedeva 1961). It is plausible that neither population of *E. grozdilovae* nor *E. stevensi* from Central Pamir or from the Kalmard areas belong to species from the Arctic for several reasons. First, they differ from Arctic *Eoparafusulina* in morphology. The thickness of septa in all *Eoparafusulina* from the Arctic is as thick as a spirotheca (Grozdilova and Lebedeva 1961), whereas septa in *Eoparafusulina* from Central Pamir and the Kalmard areas are twice or more thinner than spirotheca. It seems that thin septa are characteristic for all other *Eoparafusulina* in the Peri-Gondwana regions (Premoli-Silva 1965; Leven 1993, 1997; Gaetani et al. 1995; Ueno 2003). Second, *Eoparafusulina* from the Arctic, Central Pamir and Kalmard areas possess a different stratigraphic range: late Asselian-early Sakmarian vs. latest Sakmarian-early Artinskian. Third, these two groups of *Eoparafusulina* are distributed within two separate antitropical temperate high latitude belts on opposite sides of the tropical belt (Figure 11). That is, *Eoparafusulina* from the Arctic occur in the northern antitropical belt, whereas *Eoparafusulina* from the Peri-Gondwana regions occur in the southern antitropical belt. In early Sakmarian, the northern transitional temperate zone of the Arctic became completely isolated from either Tethys and/or Peri-Gondwana (Davydov and Leven 2003) and consequently Arctic *Eoparafusulina* had no path for migration into Peri-Gondwana during the latest Sakmarian-early Artinskian. An independent origin of *Eoparafusulina* in Peri-Gondwana is the most probable scenario. However, no direct evidence is available.

Eoparafusulina is widely distributed in the Peri-Gondwana and known from the Baoshan and Tengchong Blocks in Yunnan (Ueno 2003; Shi Yukun personal commun., 2006), the Rutog area, South Tibet (Nie and Song 1983a), East Hindu Kush (Gaetani et al. 1995), Karakorum (Premoli Silva 1965), South and Central Afghanistan (Leven 1997), central Pamir (Leven 1993) and Oman (Angiolini et al. 2006). Leven also reported several species of *Eoparafusulina* in Central Pamir that were originally described in Alaska and the Shasta Lake Area of North America (Petocz 1971; Skinner and Wilde 1965). Although they possess remarkable similarity to some specimens from Central Pamir (Leven 1993), these are most probably different and new species. For example, *Eoparafusulina depressa* Skinner and Wilde 1965 and *E. laudoni* Skinner and Wilde 1965 from Shasta Lake Area possess much better developed cuniculi in 2-3 outer volutions whereas cuniculi in *Eoparafusulina* from Peri-Gondwana are always less well developed and can be barely observed only in final volution.

The *Perigondwania-Neodutkevitchia* dominated assemblage is distributed within Peri-Gondwana approximately in the same regions as the *Eoparafusulina*-dominated assemblage. In the Kalmard area the diversity of this assemblage is relatively poor. Six species of *Perigondwania* are found there and are also known in South Tibet (Nie and Song 1983b), East Hindu Kush (Gaetani et al. 1995), Karakorum (Premoli Silva 1965), South and Central Afghanistan (Leven 1997), central Pamir (Leven 1993) and Oman (Angiolini et al. 2006). The two species of *Perigondwania* from the Kalmard area (P.*rahdariensis* and *P. aghanabati*) as well as all *Neodutkevitchia* are new.

AGE OF PERI-GONDWANAN *EOPARAFUSULINA* AND *PERIGONDWANIA-NEODUTKEVITCHIA* ASSEMBLAGES

The age and stratigraphic range of the species in the *Eoparafusulina* and *Perigondwania-Neodutkevitchia* Peri-Gondwana assemblage is not clear because of endemism and a limited geographic distribution of these faunas within Peri-Gondwana (Figure 12). In Central Pamir, where this assemblage is taxonomically most diverse, the presence of *Robustoschwagerina*, *Paraschwagerina tianshaniensis* (Chang 1963), *Zellia nunosei* (Hanzawa 1938) and *Sphaeroschwagerina zhongzanica* (Zhang 1982) were reported, and a Sakmarian age for the assemblage has been proposed (Leven 1993). The latter species were compared with similar taxa from the Trogkofel and Rattendorf Stages of Carnic Alps (Kahler and Kahler 1980), from Sakmarian rocks in North Afghanistan (Leven 1971, 1997), Darvaz (Leven and Scherbovich 1980) the Kelping Mountains of Xinjiang (Chang 1963), and from the lower part of Sakamotozawa Stage of Japan (Choi 1973). The FAD of *Robustoschwagerina*, *Paraschwagerina tianshaniensis*, *Zellia nunosei* is Sakmarian. However, in the Carnic Alps the acme of these taxa is in the Artinskian as they occur together with typical Artinskian conodont *Sweetognathus whitei* (Forke 1995, 2002).

The *Eoparafusulina* and *Perigondwania-Neodutkevitchia* Peri-Gondwana assemblage is also reported in Central and South Afghanistan (Leven 1997). In the Khaftkala tectonic zone several typical Artinskian species from the Urals were mentioned in association with *Perigondwania-Neodutkevitchia*. However, none of these important for age control species from the Urals were described or figured and thus no observation can be made regarding the age of the assemblage in the Khaftkala tectonic zone. In the Khoja Murod

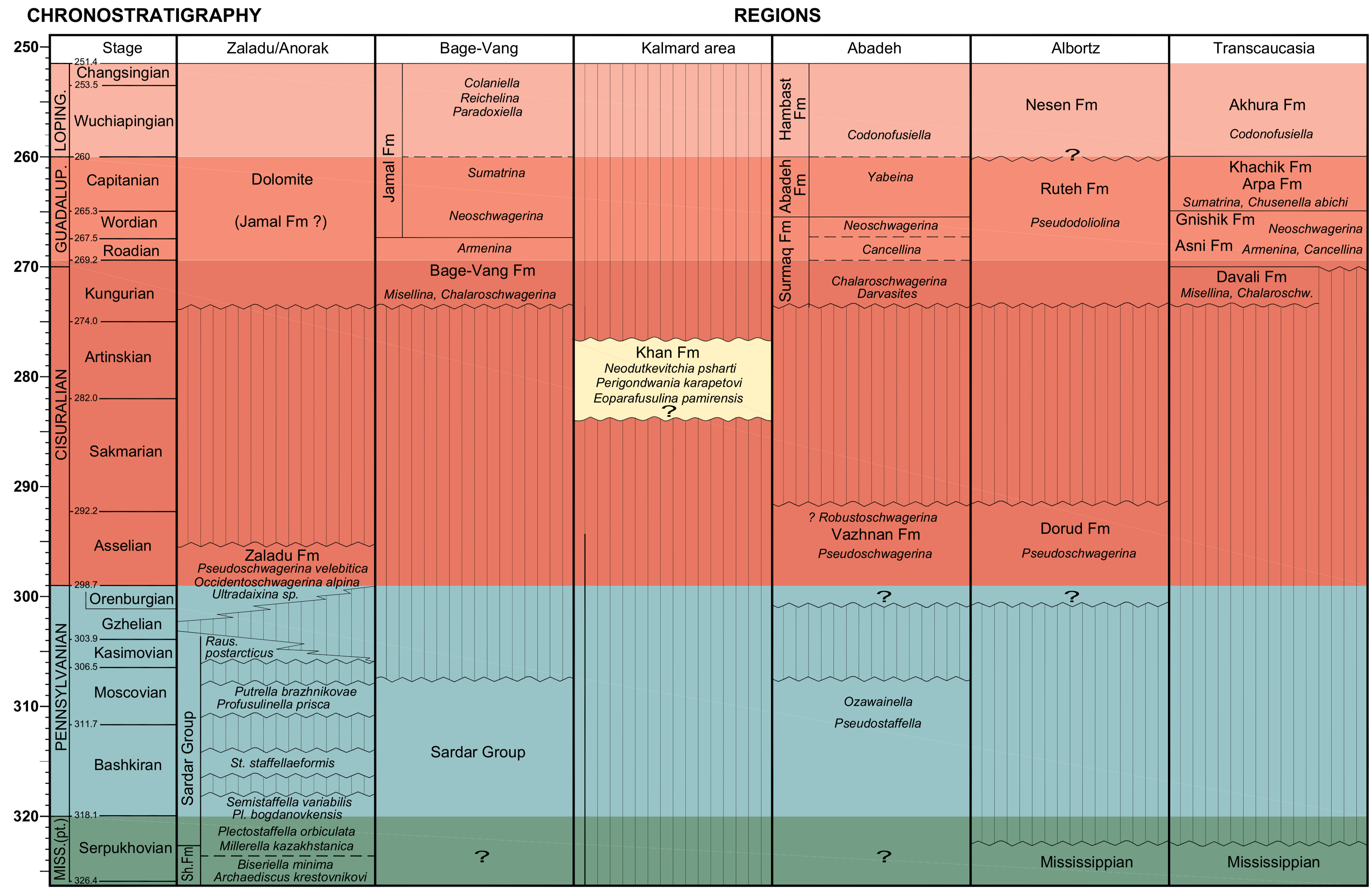

Figure 12. Correlation chart of the main Carboniferous-Permian sections in Northern, Central, Eastern Iran and Transcaucasia. Zaladu, Anorak and Bage-Vang - Leven and Moghaddam (2004), Leven and Gorgij 2006; Leven et al. (2006); Abadeh - Baghbani 1993, 1997; Albortz - Jenny-Deshusses 1983; Transcaucasia - Leven 1998.

tectonic zone typical Artinskian (Yakhtashian) species *Pamirina* cf. *evoluta* Sheng have been reported together with *Perigondwania karapetovi* and *P. peregrina*. Again, neither a description nor figure of these important taxa has been provided (Leven 1997). In the other localities in Central Afghanistan the *Eoparafusulina* and *Perigondwania-Neodutkevitchia* Peri-Gondwana assemblage occurs between sequences with staffellids, bryozoans and brachiopods of probable Sakmarian age below and typical Artinskian (Yakhtashian) *Pseudofusulina kraffti, Ps. exiqua, Ps. fusiformis, Darvasites contractus, Chalaroschwagerina vulgaris* fusulinids above (Leven 1997).

In Northern Karakorum *Pseudofusulina* aff. *sedujachensis* Konovalova and Barishnikov 1980 and *Ps*. aff. *synensis* Konovalova and Barishnikov 1980 that were originally described from lower Artinskian in Timan-Pechora Basin (Konovalova and Barishnikov 1980) were reported in association with *Perigondwania plena* (Leven 1993), *Pr. incomperta* (Leven 1993), *Pr*. ex gr. *karapetovi* (Leven 1993) and *Eoparafusulina* aff. *pamirensis* Leven 1993, i.e., with typical Peri-Gondwana fusulinid assemblage (Gaetani et al. 1995). Although specimens from Northern Karakorum are quite similar to Uralian species, they differ from the latter by a presence of phrenotheca that are typical for *Perigondwania* and that have never been described in these Uralian *Pseudofusulina*. Thus, these "*Pseudofusulina*" from Northern Karakorum are most probably a new species of *Perigondwania*.

Brevaxina sp. has been reported from Member A of the Khan Formation (Aghanabati 1977). This would suggest a Kungurian (Bolorian) or a younger age for the basal part of the formation. However, we did not find *Brevaxina* in our studies, and we think that most probably Grovesella was erroneously identified as *Brevaxina*. Our analyses of fusulinid assemblages from the Khan Formation and similar fusulinids from Peri-Gondwana show that they may not be younger than Artinskian.

Two conodont occurrences are known to appear together with *Eoparafusulina* and *Perigondwania-Neodutkevitchia* fusulinids in Peri-Gondwana. In Central Pamir *Neogondolella bisseli* (Clark and Behnken 1971) have been reported immediately below the Peri-Gondwana fusulinid assemblage (Leven 1993). This species is an index of Sterlitamakian (Upper Sakmarian) conodont zone *Sweetognathus anceps-Mesogondolella bisseli* recently established in the Urals (Chernykh 2005). However, the species ranges up to the top of Artinskian.

In the Baoshan block, west Yunnan, Southwest China, the occurrence of *Sweetognathus whitei* in association with *Eoparafusulina* and *Perigondwania* has been reported (Ueno et al. 2002). V.V. Chernykh (personal commun., January 2007) confirmed that forms from the Baoshan block closely resemble *Sweetognathus whitei*, the index species of the lower Artinskian conodont zone in the Urals (Chernykh 2005).

Within the whole area of Iran, the time of deposition of the Khan Formation corresponds to a major unconformity between the Sardar and Jamal Formations in the Shirgesht and Ozbakuh areas (Figure 12).

Summarizing everything above, the following can be proposed regarding the age of *Eoparafusulina* and *Perigondwania-Neodutkevitchia* Peri-Gondwana assemblage: In many areas this assemblage appears immediately above glacial deposits that are most probably late Sakmarian in age. The appearance of this fusulinid assemblage corresponds with a relatively warmer climatic episode. Some recent models suggest the middle Sakmarian age for the warming episode (Montañez et al. 2007), whereas others suggest a latest Sakmarian-early Artinskian age (Schneider et al. 2006). Fusulinid data support warming during the late Sakmarian-Artinskian transition (Davydov et al. 2003). Fusulinids *Robustoschwagerina, Zellia* and *Paraschwagerina* and conodont *Sweetognathus whitei* that are found together with *Eoparafusulina* and *Perigondwania-Neodutkevitchia* suggest an early Artinskian age, although it cannot be excluded that the FAD of some fusulinid species might be in the latest Sakmarian. The youngest fusulinid species reported from this assemblage is *Pamirina* cf. *evoluta* (Leven 1997) of Artinskian (Yaktashian) age. However, it has not been described and/or figured and therefore its presence in the assemblage is somewhat questioned here. Artinskian fusulinid species from the Urals that were reported in association with *Perigondwania-Neodutkevitchia* assemblage (Leven 1993, 1997; Gaetani et al. 1995) most likely belong to *Perigondwania* and cannot clarify the age model for the assemblage.

PALEOBIOGEOGRAPHIC AND PALEOTECTONIC IMPLICATIONS OF THE *PERIGONDWANIA-NEODUTKEVITCHIA* ASSEMBLAGES FROM KHAN FORMATION

Three major biogeographic realms are usually recognized in the distribution of the Late Paleozoic foraminifers: North American or Midcontinent-Andean, Boreal or Uralian-Franklinian, and Tethyan (Reitlinger 1975; Ross and Ross 1985). Two antitropical transitional realms (or provinces) periodically appear in the north and south from the Tethyan realm. The northern transitional zone that has been tentatively called the Arctic province (Rui et al. 1991) appears in response to cooler-water environments and possesses somewhat endemic biotas and has a low-diversity taxonomic composition. It extends along the northern margin of Pangaea, from the Northern Urals in the east up to the Canadian Arctic and Alaska in the west (Figure 11). This province exists only in the Late Moscovian-Kasimovian through Gzhelian and the late Asselian-early Sakmarian. Beginning from the late Sakmarian through Artinskian and the early Kungurian, the entire Boreal realm became completely isolated from other realms. At the time it had relatively cooler water, but was in general very similar to the entire area from the Pre-Caspian, along the Urals to the Canadian Artic. The southern transitional zone or, the Peri-Gondwanan province (Australian by Miklukho-Maclay 1963), does exhibit cooler climate faunas. This leads to observations of biogeographic differences with other realms that have been proposed and recently accepted (Leven 1993; Kalvoda 2002; Ueno 2006). It exists from the latest Sakmarian and Artinskian through Guadalupian (Figure 11). One more transitional zone, sometimes called the “McClaude realm,” includes several accreted terranes of western North America (Ross 1997). In the late Carboniferous and early Cisuralian, the fauna there closely resembled fusulinids of the North American realm. During the late Cisuralian it possessed significant Tethyan elements but many of these elements of the North American fauna can still be found today (Skinner and Wilde 1965).

Fusulinaceans were distributed in different carbonate to mixed carbonate-siliciclastic shallow water conditions in tropical-subtropical belts (up to 40-45° south/north latitude; Belasky 1996) and often formed foraminiferal limestone with numerous specimens that are collected and studied in many sections throughout the globe. As a result, foraminifers are a great indicator of paleoclimate/paleoenvironments within a high-resolution spatial and temporal framework. It is assumed that the majority of the fusulinaceans host the photosynthetic symbionts that are found in many of the larger living foraminifera (Ross 1982). Because large, extant tropical foraminifera with symbionts live in conditions with temperature ranges between 35-15°C, which never fall below 14°C for several weeks (Hohenegger 2004) it seems reasonable that fusulinaceans may have lived under similar conditions (Ross 1972; Murray 1991). Temperature appears to control the diversity of extant larger foraminifera assemblages. Shallow water assemblages with optimal water temperature (30-20°C) for foraminifera are generally much more diverse than those with temperatures greater than approximately 31°C and/or less than approximately 20°C (Murray 1991; Beavington-Penney and Racey 2004).

Perigondwania-Neodutkevitchia fauna that are found in the Khan Formation in the Posht-e-Badam block, Central Iran, also occur in South Tibet, East Hindu Kush, Karakorum, South and Central Afghanistan, central Pamir and Oman (Nie and Song 1983b; Gaetani et al. 1995; Angiolini et al. 2006; Premoli Silva 1965; Leven 1993, 1997) and strictly indicate the southern antitropical temperate zone. The fusulinid assemblages in these regions appear to be restricted taxonomically and include either *Eoparafusulina* with thin septa or *Perigondwania-Neodutkevitchia* faunas. Furthermore, these assemblages contain an unusually large number of specimens with double proloculi that might indicate a stressful environment, which is marginal for these surviving fusulinids. Based on these observations, it is suggested that this temperate zone was geographically and climactically quite narrow. It probably represents a narrow climatic belt (30-40° southern hemisphere) where environmental conditions were marginal for fusulinids with an annual temperature range around 14-20°C. Thus, it is hard to overestimate the biogeographic significance of the *Perigondwania-Neodutkevitchia* fauna.

This fauna might also have an important paleotectonic significance. The petrographic and sedimentologic studies of the Gachal and Khan Formations, and especially the transition between these formations, which are critical for understanding details of paleotectonics of the area, were beyond the scope of the current project. Nevertheless, some general paleotectonic observations can be suggested. On most of the paleotectonic models, the Iran microcontinent has the northernmost position within the Cimmerian Continent. The

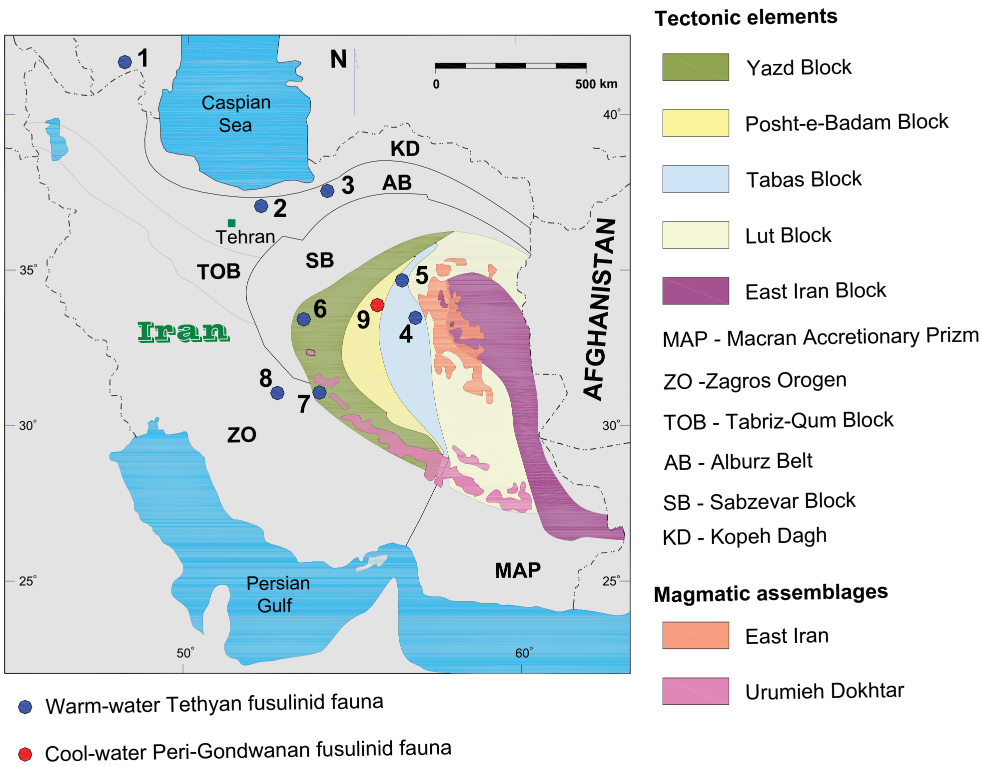

Figure 13. Geographic occurrences of warm-water Tethyan and cool-water Peri-Gondwanan fususlinid faunas in Iran and surrounding areas. 1 - Transcaucasia (Leven 1998); 2, 3 - Albortz; 4 - Jamal (Jenny-Deshusses 1983); 5 - Ozbak Kuh; 6 - Anorak (Leven and Moghaddam 2004; Leven and Gorgij 2006; Leven et al. 2006); 7 - Abadeh; 8 - Zagros (Baghbani 1993, 1997); 9 - Kalmard area, Posht-e-Badam block (present paper).

Posht-e-Badam block was a part of the Cimmerian Plates (terranes) that were proposed to have separated from Gondwana in the Late Carboniferous (Golonka and Ford 2000; Stampfli and Borel 2002). Detailed petrographic, biostratigraphic and taphoniomic studies of the Pennsylvanina-Cisuralian glacial-postgacial transition in Oman were interpreted as recording continental breakup and the onset of Neotethyan spreading between northern Gondwana and the Cimmerian terranes at mid-Sakmarian times, as constrained by brachiopod assemblages (Angiolini et al. 2003). Similar brachiopod assemblages associated with *Perigondwania-Neodutkevitchia* fusulinid fauna were recovered in Central Oman (Angiolini et al. 2006) and so this continental breakup and onset of Neotethyan spreading is probably latest Sakmarian-early Artinskian in age as suggested by the fusulinids and conodonts.

The biostratigraphic and paleontologic data from the Khan Formation can also be applied in an effort to gain better understanding of the local and regional tectonic framework and post-Permian tectonic development of the area. Figure 13 shows the distribution of fusulinid assemblages of different affinities in Iran and the surrounding areas. Fusulinids in localities 1-8 are typical Tethyan, whereas fusulinids from the Posht-e-Badam block belong to temperate transitional cool to cold water fauna of higher latitude. There are no common forms in Tethyan and Peri-Gondwanan assemblages, and taxonomically they are sharply different. This might suggest that in the early Permian, the Posht-e-Badam block was far south in comparison to the rest of the locations that formed recent Iran.

CONCLUSIONS

1. A well-defined assemblage of Permian Peri-Gondwanan fusulinids occurs in the Khan Formation in East-Central Iran.
2. Six genera and 27 species were designated in this assemblage, in which three genera and 14 species are new. In addition, two new species were established from (Leven 1993).
3. The evolutionary pattern of Peri-Gondwanan early Artinskian *Perigondwania* and *Neodut-*

kevitchia are quite similar and homeomorphic to the evolution of Late Gzhelian and Asselian *Shagonella* and *Dutklevitchia* from the tropical Tethyan realm.

4. The *Eoparafusulina, Perigondwania-Neodutkevitchia* assemblage is widely distributed in a narrow southern antitropical belt surrounding Peri-Gondwana and has important applications in understanding the paleogeography, paleotectonics and paleoclimate in East-Central Iran and Peri-Gondwana.

5. The Pennsylvanian-Permian correlation chart provided in this paper shows that the time of deposition of the Khan Formation corresponds to a major unconformity between the Sardar and Jamal Formations in the Shirgesht and Ozbakuh areas and has important applications for paleotectonic reconstruction of the tectonic history of the whole of Iran.

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