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# FUSULINIDS FROM ISOLATED QARARI LIMESTONE OUTCROPS (PERMIAN), OCCURRING AMONG JURASSIC-CRETACEOUS BATAIN GROUP (BATAIN PLAIN, EASTERN OMAN)

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*Abstract*. The Batain Group of the northeastern coastal plain of Oman consists of offshore and deeper water deposits that accumulated in the Batain Basin and which were subsequently obducted onto the eastern margin of Oman. The oldest deposits of the Batain Group are the marly limestones of the Qarari Unit that have been dated as Early to Late Permian or Murgabian by different workers. Recently discovered outcrops of the Qarari Unit from the northern Batain plain are richly fossiliferous including the occurrence of fusulinids in three separate outcrops. The fusulinids represented are two species of *Skinnerella* - a subgenus of *Parafusulina*: *Parafusulina (Skinnerella) visseri* Reichel and the new taxon *P.* (*S.*) *arabica*. The most likely age of the described fusulinids is estimated as Kubergandian. The major marine transgression of the Tethyan realm that began in the Yakhtashian-Bolorian appears to have begun earlier in the Batain Basin than in other parts of Arabia and the Gulf, where it is represented by the Khuff Formation of Murgabian-Dorashamian age.

*Riassunto*. Il Batain Group della piana costiera nord-orientale dell'Oman consiste di depositi offshore e di acqua più profonda che si sono accumulati nel Batain Basin e che sono stati successivamente obdotti sul margine orientale dell'Oman. I più antichi depositi del Batain Group sono rappresentati dai calcari marnosi della Qarari Unit che sono stati datati Permiano Inferiore- Superiore o Murgabiano da diversi autori. Affioramenti recentemente scoperti della Qarari Unit della piana del Batain settentrionale sono riccamente fossiliferi e registrano la presenza di fusulinidi in tre affioramenti distinti. I fusulinidi sono rappresentati da due specie di *Skinnerella,* un sottogenere di *Parafusulina*: *Parafusulina* (*Skinnerella*) *visseri* Reichel e il nuovo taxon *P.* (*S.*) *arabica*. L'età più probabile dei fusulinidi descritti è stimata come Kubergandiana. La principale trasgressione marina della Tetide iniziata nel Yakhtashiano-Boloriano sembra essere cominciata prima nel Batain Basin che in altre parti d'Arabia e del Golfo, dove è rappresentata dalla Khuff Formation di età Murgabiana-Dorashamiana.

## Introduction

Geographically the Batain plain forms a narrow strip, extending along the Arabian sea coast of the northeastern part of the Sultanate of Oman (Fig. 1). The majority of the plain is covered by Quaternary sediments, from under which more ancient rocks of the Batain Group (Permian - Upper Cretaceous) are locally exposed. In the northern part of the plain it is possible to observe that the Batain Group consists of numerous west-north west directed thrust sheets. According to currently accepted interpretation, deposits, represented by slope and basin facies accumulated in the Batain Basin, which is considered to be a failed southern branch of the Neotethys ocean (Hauser 2002). During the latest Late Cretaceous these deposits were obducted over the margin of Arabian platform, and now they constitute a large overthrust structure called the Batain nappe (Immenhausher et al. 2000; Hauser et al. 2002).

Limestones of Qarari Unit are the oldest known deposits of the Batain Group. They form a series of tectonically isolated outcrops amongst younger rocks of the Jurassic Guwayza Formation and the Cretaceous Wahrah Formation. The Qarari limestone is estimated to be 150-180 m in its most complete section and is in tectonic contact with other units or hidden beneath recent sediments.

Pebble-boulder-sized conglomerates of the Aseelah Unit also include a variety of carbonate clasts of Permian age. The age of the Aseelah Unit is not known

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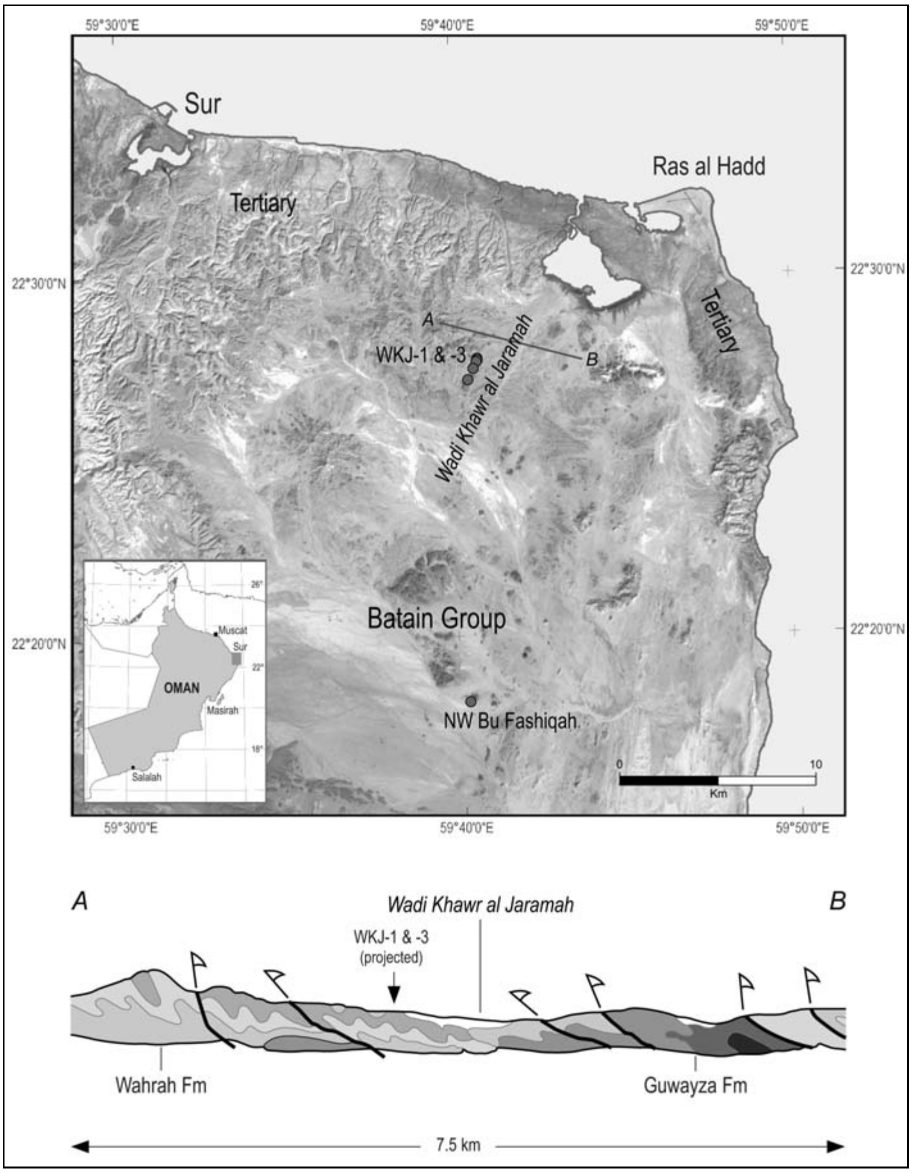


Fig. 1 - Geographical position and geological setting of the described samples. The cross-section is from Peters et al. (2001).

and it is variably placed between the Permian Qarari Unit and the overlying Triassic Sal Formation, or within the Sal Formation (Peters et al. 2001).

Fusulinids, described in the present paper, were collected from two of five small limestone outcrops located in the northern part of the Batain plain (N 22°27', E 59°40'). The largest outcrop is around 450 m$^2$ and exposes about 20 m of stratigraphic section. The outcrops form a chain, extending over 1.25 km among outcrops of oolitic limestones of Jurassic Guwayza Formation and red cherts of the Cretaceous Wahra Formation. They are clearly not part of an Aseelah-type conglomerate unit. The outcrops are of yellow, weakly lithified, marly limestones and are interpreted as offshore facies of the Qarari Unit. They are rather different than the normal grey, thinly bedded, lithified Qarari and are notably more fossiliferous. Besides fusulinids, the outcrops contain brachiopods, crinoids, blastoids, corals, trilobites, bryozoans, ammonoids and nautiloids. Work on these faunas is ongoing with various experts. The faunas are well preserved with little evidence of re-deposition. The trace fossil *Zoophycos* is present in some beds and can be used as a way-up indicator.

Fusulinids have been studied in three rock samples, which were turned into 32 oriented thin sections. They are kept in Micropaleontological laboratory of Geological Institute of Russian Academy of Science, Moscow (coll. No. 4799).

## Stratigraphy

Considering the faulted nature of the Qarari limestone outcrops, it is difficult to judge about their sequence, thickness and relations with underlying and overlying formations. In the most extensive outcrops on the south slope of Jebel Qarari and to the north-west of Bu Fasiqah, Qarari layers are represented by stratified nodular and platy micritic limestones with bands of marly shales, and intraformational conglomerates of turbidite nature (Immenhauser et al. 1998). These sediments were considered to have accumulated below wave base and above the CCD. The first faunas collected from the Qarari Unit (brachiopods, corals, bryozoans and trilobites) where interpreted to indicate ages ranging from Early to Late Permian (Shackleton et al. 1990). Conodonts and ammonoids, determined from other outcrops were more confidently identified as Murgabian (summarized in Peters et al. 2001). Fusulinids were not reported. However, numerous Permian fusulinids were recorded from clasts within the Triassic? Aseelah Unit. Limestones in pebbles and small boulders are represented by shallow-water lagoonal and reefal facies, containing well-preserved and diverse fossil algae, small foraminifera, fusulinids, corals, brachiopods, bryozoans etc. (Hauser et al. 2002). Vachard et al. (Hauser et al. 2000; Vachard et al. 2001, 2002) has described the fusulinids and small foraminifers in detail. Fusulinids indicate the age of clasts as Yakhtashian to Midian. It should be noted, however, that the Yakhtashian and Bolorian ages look doubtful. The Yakhtashian age was estimated by the specimen, identified as *Leeina kraffti* (Schellwien et Dyhrenfurth) (Hauser et al. 2000, fig. 4.1), an index species of the stage. However, we are sure that the figured specimen was incorrectly determined, and is more likely to be an oblique section of some *Parafusulina* species. A similar species to them is shown in fig. 4.2. It was named as *Parafusulina* ex gr. *japonica* (Gümbel) by Hauser et al. (2000), and considered to be of Bolorian age. However, this species is not recorded from well-defined Bolorian sections. Gümbel (1874) described it from Akasaka limestones of Japan. Topotypes of *P. japonica* were recently described by Kobayashi (2011) who proved their Murgabian age.

Summarizing the above, it can be said that the existing data on fusulinids does not provide any basis to consider the Qarari limestone outcrops to be partly of Early Permian age. Their age seems to be Kubergandian, and younger than the possible clasts of Bolorian limestone dated by Hauser et al. (2000).

## Fusulinids, Correlation, and Age

Fusulinids from the outcrops, described in the present paper, together with *Parafusulina* species described by Vachard in Hauser et al. (2000) and discussed above, are some of the oldest known from Oman. The only older fusulinids are from the upper Sakmarian Haushi Limestone in Central Oman (Angiolini et al. 2006). In our collection, from the Qarari Unit, fusulinids are represented by two species of *Skinnerella* - a subgenus of genus *Parafusulina*. *Skinerella* is distinguished from subgenus *Parafusulina* s. str. (see below) by its relatively low evolutionary level, and by less intensive and regular fluting of septa, as well as less developed and less obvious cuniculi (Coogan 1960; Skinner 1971). Correspondingly, species of *Skinnerella* are usually stratigraphically older, than that assignable to *Parafusulina* s. str. However, we should also note that differences are fairly vague. For this purpose, many researchers do not subdivide *Parafusulina* into two subgenera. Others treat *Skinnerella* as an independent genus. *Skinnerella* is treated in this paper as subgenus of *Parafusulina*.

Type material of *Skinnerella* and *Parafusulina* originate from the Permian sections of West Texas (USA). The type species of *Parafusulina (Skinnerella)* Coogan, 1960 is *Parafusulina schucherti* Dunbar & Skinner, 1937, from the Bone Spring Formation of Sierra Diablo Mountains. According to modern schemes, this formation is dated as the Cathedralian age in the American scale (Ross & Ross 1995), that is correlated to the Kungurian in the international scale and the Bolorian in the Tethyan scale (Leven & Bogoslovskaya 2006). Type species of *Parafusulina* s. str. is *Parafusulina* (*Parafusulina*) *wordensis* Dunbar et Skinner, 1931, originating from the Word Formation of the Glass Mountains. This formation corresponds to the Wordian in the international scale, and to the upper part of the Murgabian in the Tethyan scale (Leven & Bogoslovskaya 2006).

Comparing with Texas material, species from our collection [*P.* (*Sk.*) *visseri* and *P.* (*Sk.*) *arabica*] by their general appearance of the test and evolutionary level are the closest to several species described by Skinner (1971) from the Bone Spring Formation. Certain affinity can be seen with some species from Road Canyon Formation. For example, *P.* (*Sk.*) *arabica* is close to *P. glassensis* Yang et Yancey, 2000 from the middle Roadian to the lower Wordian of west Texas. The latter differs from the former only by its tighter spiral, as well as more intensive and lower fluting of septa. Based on many similarities to the Texas ones, *P.* (*Sk.*) *arabica* is considered to be late Cathedralian or may be Roadian.

Species of *Parafusulina* are widely spread around Tethyan realm and the oldest one ranges down to the Bolorian. In the Iranian sections, several *Parafusulina* (*Skinnerella*) species are associated with typical Bolorian *Misellina* (Leven & Vaziri 2004; Leven & Gorgij 2008). *Parafusulina (Skinnerella)*, which is dominant in the Kubergandian, is widely distributed from Transcaucasia and Iran to Japan and Indonesia (Kanmera 1963; Kobayashi 2008; Leven 1967, 1997, 1998; Leven & Vaziri 2004; Sheng 1963). *Parafusulina* occurs often in the lower half of the Murgabian, where it is represented by progressively evolved forms that are characterized by intensive and regular fluting of septa together

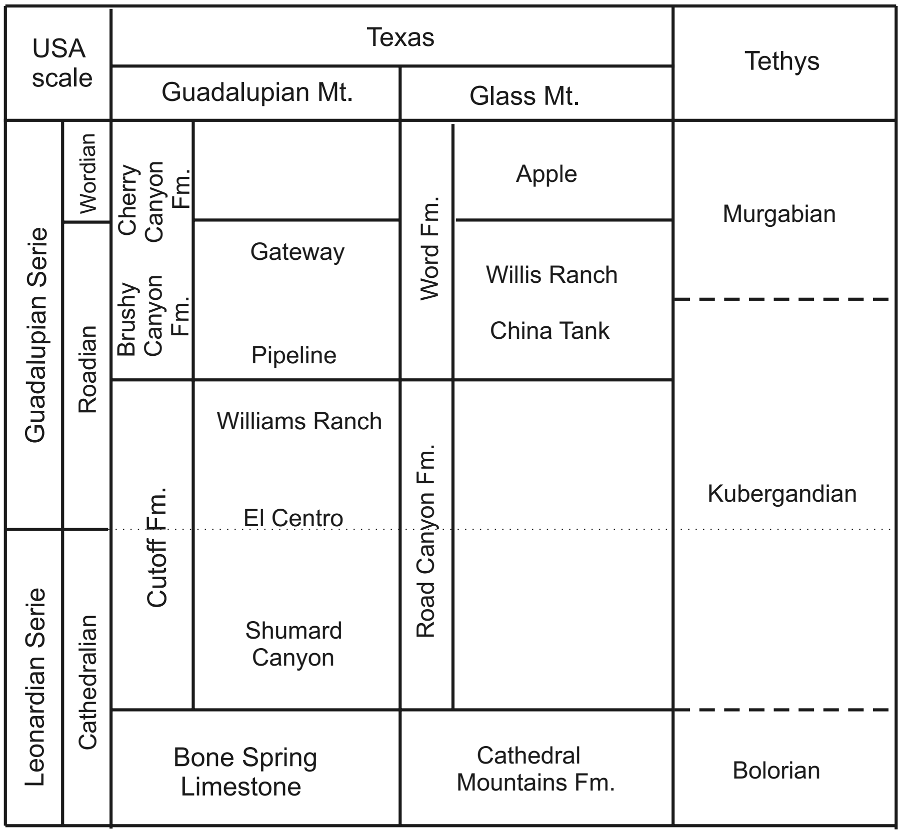


Fig. 2 - Ammonoid-based correlation of the Tethyan stages with Permian Formations of Midcontinent (Leven & Bogoslovskaya 2006).

with well-developed cuniculi (subgenus *Parafusulina*). Fusulinids of the Akasaka section in Japan (Morikawa 1958; Kobayashi 2011) can be a good example of such association.

*Parafusulina (Skinnerella) visseri* Reichel was originally described from the Permian limestones in the Shaksgam Valley in the Karakorum (Reichel 1940). It is associated with several other species of the subgenus, as well as *Yangchienia iniqua* Lee, *Minojapanella* cf. *delicata* (Colani) and *Chusenella* aff. *chihsiaensis* (Lee). All these species are characteristic of both the Kubergandian and lowermost Murgabian (Reichel 1940).

Another described species from the Qarari limestone, *P.* (*S.*) *arabica*, n. sp. is similar to *Parafusulina undulata* Chen, 1934 from the Chihsia Formation of South China. The lower part of the formation (Swine Limestone) in the stratotypic section is characterized by *Misellina claudiae* Deprat (Chen 1934; A Guide of field excursion in Tangshan, Nanjing, 1979), a typical form of the uppermost Bolorian and the lowermost Kubergandian. *Parafusulina* is distributed over the upper part of the formation (Sheng & Jin 1994; Zhu & Zhang 1994), where it is not associated with neoschwagerinids and verbeekinids, which are the marker of the Kubergandian/Murgabian boundary. Although the precise age of beds with *Parafusulina*, in terms of Tethyan scale, remains unclear, it can be said only that they characterize the boundary interval. *P.* (*Sk.*) *arabica* is closely similar to *P. nakamigawai* Morikawa & Horiguchi from Akasaka, Japan. However, the latter species was described from tectonically isolated outcrops, and is not associated with neoschwagerinids and verbeekinids (Kobayashi 2011). Either a late Kubergandian or early Murgabian age of *P. nakamigawai* might be possible.

Therefore, the comparison of *Parafusulina* from Oman with material described from other regions suggests its age of late Cathedralian to Roadian in the American scale, and Kubergandian to early Murgabian in the Tethyan scale. Though still uncertain, the Cathedralian is traditionally correlated with the Bolorian of the Tethyan scale, and Roadian - with Kubergandian and, in part, with Murgabian. However, these correlations are rather uncertain, considering the fact that Tethyan sections are very poor in conodonts useful for correlation between the Tethyan and American chronostratigraphy.

The problem of correlation between the American and Tethyan time scales was discussed by Leven (2001) and Leven & Bogoslovskya (2006). Extended analysis of ammonite, conodont and fusulinid data led the authors to conclusion that lower limit of Roadian falls within the Kubergandian of Tethyan scale (Fig. 2). In Texas sections this boundary is located inside the Road Formation of the Glass Mountains and inside the Cutoff Formation of Guadalupian Mountains (Lambert et al. 2000). The latter one overlaps the Bone Spring Limestone, which can be considered to be the analogue of the Bolorian in the Tethyan scale.

If these correlations are correct, some dualism appears in the age determination of Oman material. Comparing with Tethys data, the age should be considered Kubergandian, or, possibly, early Murgabian, while Bolorian is almost excluded. On the contrary, comparison with *Parafusulina* from Texas suggests correlation to the Bone Spring Formation, presumably of Bolorian age. The similarity with *Parafusulina* of the Roadian looks to be less obvious. Why such differences in age may occur, remains unclear. A possibility may be that similar species of *Parafusulina*, suggesting homeomorphy, have different age in U.S. Mid-Continent and in the Tethys.

## Conclusions

1) *Parafusulina* species, described in the present paper, are recognized from outcrops of Permian Qarari Unit of the Batain Group for the first time. Those previously reported from the area are from limestone clasts within conglomerates of the Aseelah Unit.

2) The age of the described *Parafusulina* can be estimated as Kubergandian, however, by comparison with the U.S. Mid-Continent the age could be from Bolorian (Cathedralian) to early Murgabian (Roadian).

3) Permian deposits of Oman can be divided into two main stratigraphic subdivisions – a lower one, represented by glacio-lacustrine, shallow-marine and alluvial deposits (Al Khlata and Gharif formations) and a transgressive upper one, represented by marine carbonates of the Khuff Formation. Within the lower unit there is a short-lived shallow marine transgression (Haushi Limestone). The Khuff Formation correlates with younger parts of Qarari and Aseelah Units of the Batain plain. This suggests that the major marine transgression of the Batain Basin started earlier, than in other parts of Oman, and can be connected with the vast transgression which took place in the Tethyan realm (Iran, Transcaucasia, Afghanistan, Pamir, Pakistan, South China) during the end of Yakhtashian - beginning of Bolorian (Leven 1994).

## Systematic descriptions

Order **Schwagerinida** Solovieva, 1985

Family Parafusulinidae Bensh, 1996

Genus *Parafusulina* Dunbar et Skinner, 1937

Subgenus *Skinnerella* Coogan, 1960

### Parafusulina (Skinnerella) visseri Reichel, 1940

Pl. 1, figs 1-3, 5; Pl. 2, fig. 4

1940 *Parafusulina visseri* Reichel, p. 112-113, pl. 24, fig. 1a-b, 2.

1940 *Parafusulina visseri* var. *lata* Reichel, p. 114-115, pl. 24, fig. 3, 4.

1963 *Parafusulina (Skinnerella) figueroai* Kanmera, p. 96-98, pl. 16, fig. 1-5.

**Material**: 15 axial sections.

**Description**. Shell large, fusiform to subcylindrical, with bluntly rounded poles. Adult specimens about 7 to 8 volutions and measure 12.6 to 14 mm in length and 4 to 4.4 mm in width; form ratio 2.78 to 3.7. Proloculus sphaerical, its outside diameter 0.45 t 0.55 mm. Coiling uniform and rather tight. Spirotheca composed of tectum and finely alveolar keriotheca 0.07 mm thick in seventh volution. Septa thin and strongly and not very regularly fluted. Septal folds low and rounded across middle part of shell and increasing in their heights toward poles. Phrenothecae developed sporadically. Low, narrow cuniculi are present in the outer whorls. Tunnel not very wide and its path irregular. Chomata weak, present only on proloculus. Secondary deposits variable in development, commonly coating septa thinly in narrow zones on both sides of tunnel.

**Discussion**. Specimens examined herein are almost identical with the original ones described by H. Reichel (1940) from the Shaksgam valley in Karakorum. This species differs from *P. yunnanica* Sheng in less regular folding of the septa and less acuminate ends of shells.

**Occurrence and age**. Oman, Wadi Khawr al Jaramah; Kubergandian.

### Parafusulina (Skinnerella) arabica Leven n. sp.

Pl. 1, fig. 4; Pl. 2, figs. 1-3; Pl. 3, figs. 1-3

**Derivation of name**: after the Arabian peninsula.

**Holotype**: GIN No. GIN 4799/1; Oman, Wadi Khawr al Jaramah, Kubergandian.

**Material:** 15 axial sections.

**Description**. Shell large, subcylindrical to cylindrical with bluntly rounded poles. First three or four volutions fusiform with sharply pointed poles. Adult specimens about 7-8 volutions and measure 15 to 19 mm in length, and 3.5 to 4.5 mm in diameter; form ratio 3.95 to 5. Proloculus spherical, its outside diameter 0.3 to 0.5 mm. Coiling rather tight in first 3 or 4 volutions but expands in adult stage. Spirotheca composed of tectum and finely alveolar keriotheca 0.075 to 0.1 mm thick in outer volutions. Septa thin, intensively fluted from pole to pole. Septal folds rounded to triangular shape in thin sections, usually low in central part of the shell. Folding becomes more intense towards poles and septal folds fill the entire space between whorls. Phrenothecae developed sporadically. Low, narrow cuniculi are present in the outer whorls. Tunnel is narrow during first 3 or 4 turns, then quickly becoming wider. Chomata low, present only on proloculus. Axial filling

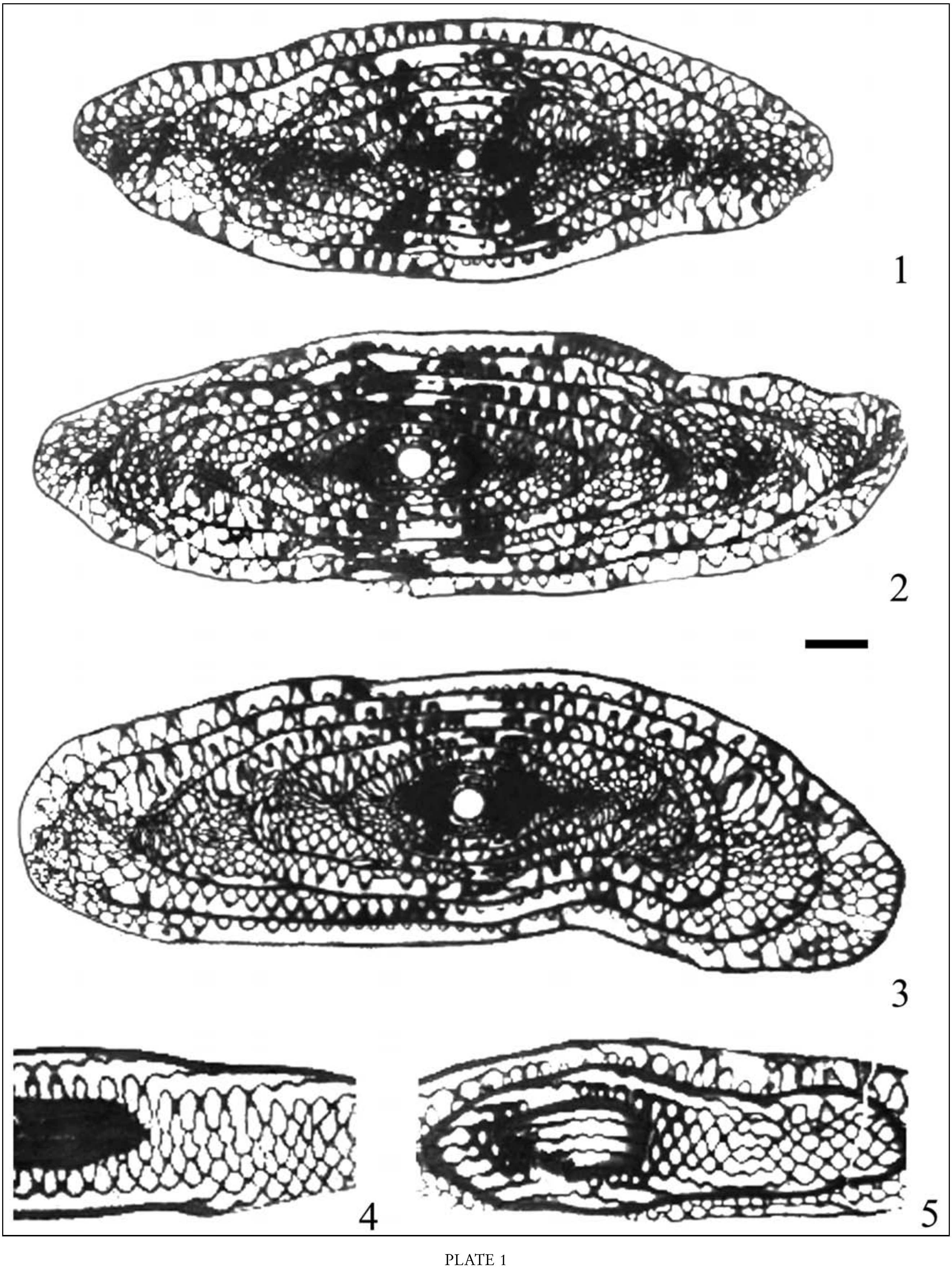


PLATE 1

Figs 1-3, 5 - *Parafusulina (Skinnerella) visseri* Reichel.
1-3) axial sections, GIN 4799/1, GIN 4799/2 and GIN 4799/3; 5) tangential sections, cuniculi visible; GIN 4799/3.
Fig. 4 - *Parafusulina (Skinnerella) arabica* n. sp. Tangential section, cuniculi visible; GIN 4799/4.
Scale bar: 1 mm.

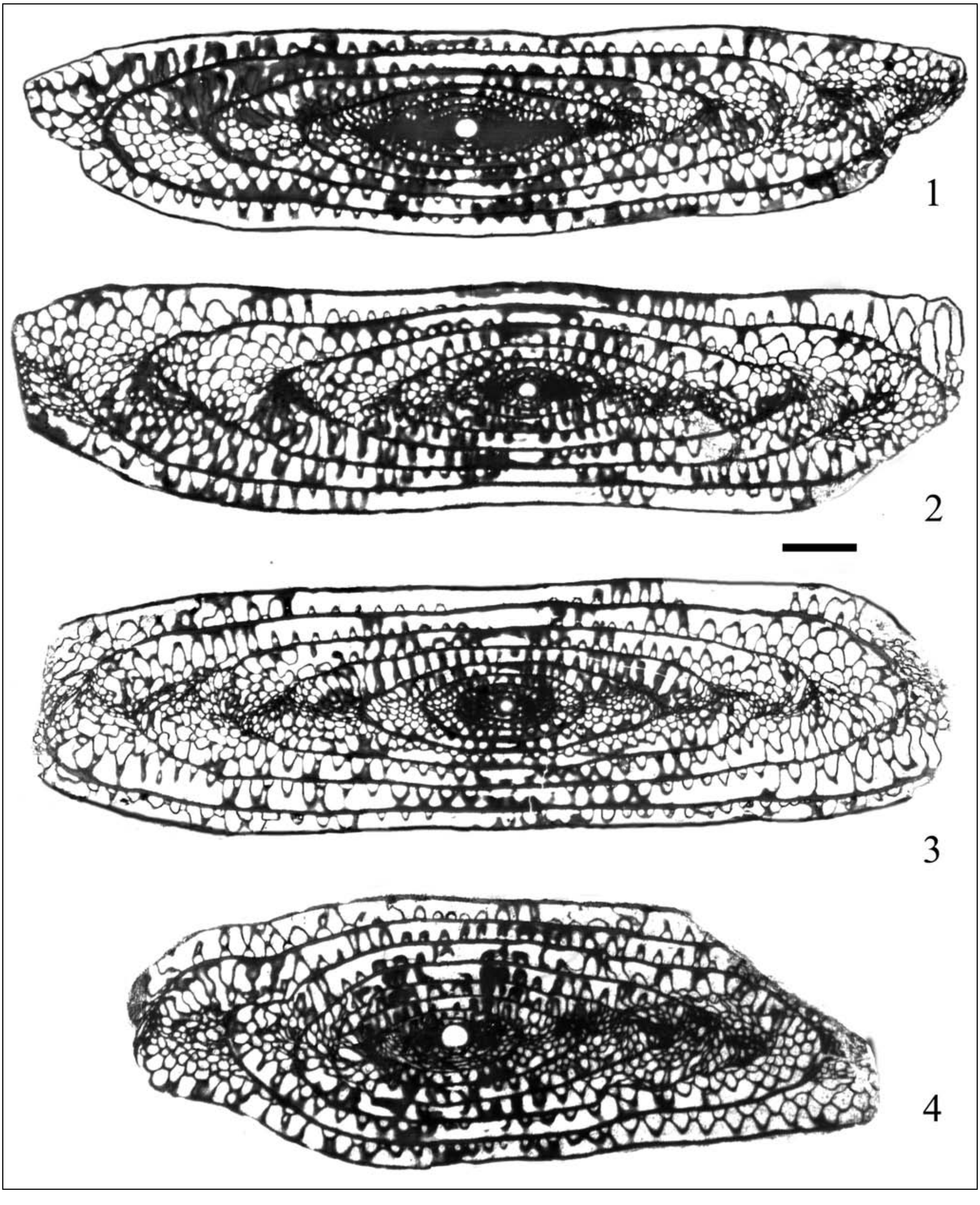


PLATE 2

Figs 1- 3 - *Parafusulina (Skinnerella) arabica* n. sp. Axial sections; GIN 4799/5, GIN 4799/6 and GIN 4799/7.
Fig. 4 - *Parafusulina (Skinnerella) visseri* Reichel. Subaxial section; GIN 4799/8.
Scale bar: 1 mm.

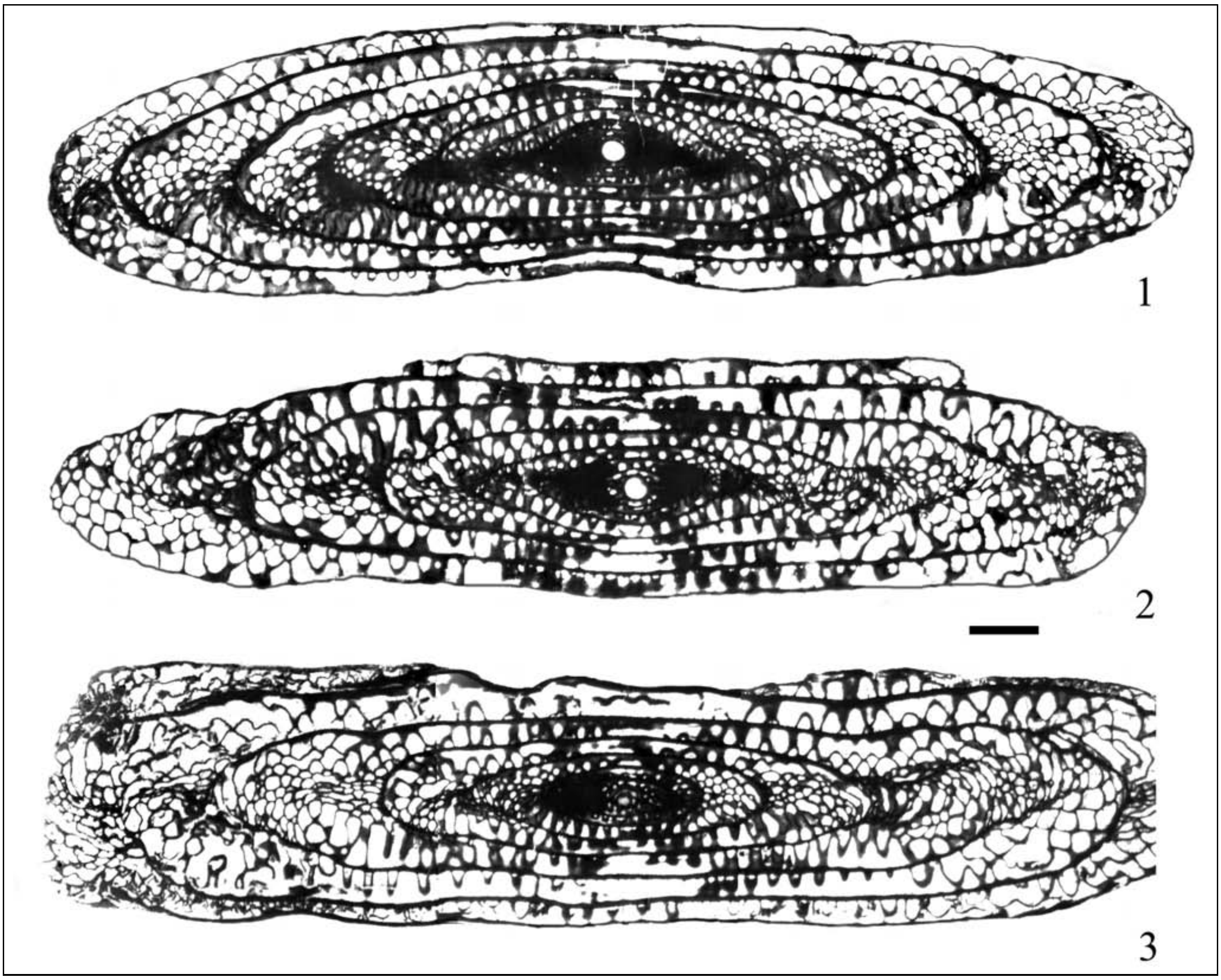


PLATE 3

Figs 1-3 - *Parafusulina (Skinnerella) arabica* n. sp. Axial sections; GIN 4799/9 (holotype), GIN 4799/10 and GIN 4799/1. Scale bar: 1 mm.

massive in first 2 to 3 volutions but absent in the outer ones.

**Discussion**. The new species described herein shows large similarity with *Parafusulina undulata* Chen, 1934, described from the Chihsia limestone in South China, however, it can be distinguished by more distinct axial filling in the inner volutions. Moreover, proloculus of *P. undulata* is irregularly shaped, while spherical in this new species. *P.* (*Sk.*) *arabica* n. sp. shows many common characters with those of *P. nakamigawai* Morikawa et Horiguchi, 1956. The former is distinguished from the latter by having lager form ratio of the test and less undulating septa.

*P.* (*Sk.*) *arabica* shows certain similarity with *P. hayashii* Igo, 1959, however, our species has larger number of volutions and larger size in corresponding volutions. Also, it has less intensive and less regular fluting of septa.

*P.* (*Sk.*) *arabica* has much in common with the some species from the Bone Spring, Cathedral Mountains and Road Canyon Formations of west United States. The highest similarity our species has with *Parafusulina fountaini* Dunbar & Skinner, 1937 from Bone Spring Formation of Guadalupe Mountains, but has a more elongated subcylindrical shell shape and larger size. From *Parafusulina glassensis* Yang & Yancey, 2000 from Road Canyon Formation of Glass and Guadalupe Mountains the here described species can be distinguished by somewhat smaller size, less form ratio, less intensive and less regular fluting of septa, as well as by less developed cuniculi. From *Parafusulina* (*Skinnerella*) *cylindrica* Skinner, 1971 from Bone Spring Formation of Sierra Diablo Mountains our species can be distinguished by smaller size, and less form ratio.

**Occurrence and age.** Oman, Wadi Khawr al Jaramah; Kubergandian.

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