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Gzhelian (latest Carboniferous) *Pseudoacutella partoazari* foraminiferal assemblage from the Tabas Block (Central Iran)

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Abstract: A foraminiferal assemblage is reported from the Zaladou Formation in the Tabas Block (Shishtu Section), Central Iran. This assemblage comprises 16 species belonging to 14 genera, and encompasses the fusulinids *Pseudoacutella partoazari*, *Grovesella tabasensis*, *Gr.* aff. *australis*, *Gr. sphaerica*, *Gr. sphaerica* var. *quadrata*, *Gr.* cf. *staffelloides*, *Schubertina* sp., *Schubertella* sp., and the smaller foraminifers *Eotuberitina* sp., *Lasiodiscus tenuis*, *Raphconilia* cf. *minor*, *R. multihelicis*, *R. modificata*, *Tetrataxis* cf. *parviconica*, *Globivalvulina* ex gr. *bulloides*, *Gl. graeca*, *Calcivertella heathi*, *Tansillites* sp., *Palaeonubecularia*? sp., *Hemigordiellina* sp., *Nodosinelloides longa*, and *N. longissima*. The age of this assemblage is considered to be Gzhelian. The assemblage is dominated by the fusulinid *Pseudoacutella partoazari* with a low total diversity of smaller foraminifers. This assemblage is compared to similar assemblages in other parts of Iran and well as the USA. An evolutionary lineage of *Pseudoacutella partoazari* is also proposed. It is confirmed that *Pseudonovella* differs from *Pseudoacutella* by the periphery rounded-carinate (carinate in *Pseudoacutella*), pseudochomata less developed, and the type of coiling (*Pseudoacutella* is truly planispiral involute). *Pseudonovella* is suggested here as the ancestor of *Pseudoacutella*. This assemblage bears one unusual attribute, the overwhelming dominance of the fusulinid *Pseudoacutella* and the relatively low total diversity, compared with similar foraminifera from Alborz, Sanandaj-Sirjan, Sabzevar and central Iran, which present warm and humid conditions during the Late Carboniferous.

Keywords:

- Ozawainelloid;
- *Pseudoacutella partoazari*;
- Gzhelian;
- Tabas Block;
- Central Iran

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Résumé : *À propos de l'association de foraminifères à* Pseudoacutella partoazari *du Gzhélien (Carbonifère terminal) du Bloc de Tabas (Iran central).-* Une association de foraminifères de la Formation de Zaladou du Bloc de Tabas (coupe de Shishtu, Iran central) est décrite. Cette association comprend 16 espèces appartenant à 14 genres ; elle réunit les fusulinides *Pseudoacutella partoazari*, *Grovesella tabasensis*, *Gr.* aff. *australis*, *Gr. sphaerica*, *Gr. sphaerica* var. *quadrata*, *Gr.* cf. *staffelloides*, *Schubertina* sp., *Schubertella* sp., et les petits foraminifères *Eotuberitina* sp., *Lasiodiscus tenuis*, *Raphconilia* cf. *minor*, *R. multihelicis*, *R. modificata*, *Tetrataxis* cf. *parviconica*, *Globivalvulina* ex gr. *bulloides*, *Gl. graeca*, *Calcivertella heathi*, *Tansillites* sp., *Palaeonubecularia*? sp., *Hemigordiellina* sp., *Nodosinelloides longa*, and *N. longissima*. Cette association, dominée par le fusulinide *Pseudoacutella partoazari* et à faible diversité totale des petits foraminifères, est comparée à celles d'autres régions de l'Iran, ainsi qu'à celles des ÉUA. Son âge est considéré comme étant gzhélien. Durant le Carbonifère supérieur, elle serait le témoin de conditions plus chaudes et plus humides que celles enregistrées par

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les associations de l'Elbourz, de Sanandaj-Sirjan, de Sabzevar et de l'Iran central. Par ailleurs, une lignée évolutive de *Pseudoacutella partoazari* est proposée. Celle-ci confirme que *Pseudonovella* diffère de *Pseudoacutella* par sa périphérie carénée-arrondie (elle est carénée chez *Pseudoacutella*), des pseudo-chomata moins développés et son type d'enroulement (seul *Pseudoacutella* est réellement planispiralé involute). Toutefois, *Pseudonovella* pourrait même être l'ancêtre de *Pseudoacutella*.

Mots-clefs :

- Ozawainelloïdes ;
- *Pseudoacutella partoazari* ;
- Gzhélien ;
- Bloc de Tabas ;
- Iran central

1. Introduction

Upper Carboniferous (Gzhelian) strata in Iran are basically widespread in the Central Iran, Sabzevar tectonic zone, Alborz Mountains, and the Sanandaj Sirjan zone (*e.g.*, Leven & Taheri, 2003; Leven & Gorgij, 2006, 2011a, 2011b; Gaetani *et al.*, 2009; Alipour *et al.*, 2013; Gorgij & Leven, 2013; Yarahmadzahi & Vachard, 2014, 2018, 2019; Badpa *et al.*, 2011, 2014, 2015; Yarahmadzahi *et al.*, 2016; Fassihi *et al.*, 2014, 2017, 2020; Niko & Badpa, 2020; Jalali *et al.*, 2021). In the northern Tabas Block (Ozbak Kuh mountains), these strata are defined as the Zaladou Formation. Fusulinids and smaller foraminiferal assemblages characterizing the latest Gzhelian were described in Zaladou Formation in central Iran (Leven & Taheri, 2003; Leven & Gorgij, 2006; Yarahmadzahi & Vachard, 2018; Jalali *et al.*, 2021). In this paper, we review the geographic distribution, stratigraphic occurrence, and taxonomy of *Pseudoacutella partoazari* Yarahmadzahi & Vachard, 2014. We further make some considerations on the paleobiogeographic and phylogenetic characters of this species.

2. Geological setting and lithostratigraphy

Upper Carboniferous deposits of north Tabas Block is well exposed in the Ozbak Kuh area (Stöcklin, 1971). Structurally, the Ozbak Kuh mountains, located in the north of the Tabas Block, are part of Central Iran (Aghanabati, 2004). The Shishtu section is situated near the Shishtu village (Fig. 1A-C). There, the Upper Carboniferous and Lower Permian foraminifera of the Zaladou Formation were accurately studied (*e.g.*, Leven & Taheri, 2003; Leven & Gorgij, 2006b; Yarahmadzahi, 2011; Yarahmadzahi & Vachard, 2018; Jalali *et al.*, 2021). Lithostratigraphically, this part of the Shishtu section corresponds to the Anarak Group including the Zaladou (Gzhelian-Asselian) and Tigh e Madanu (Sakmarian) formations. The Zaladou Formation unconformably overlies the Carboniferous (Moscovian) Absheni Formation; it is approximately 60 m thick. The Tigh e Madanu Formation is 100 m thick. The Zaladou Formation is clearly subdivided into eight units (Fig. 2) from bottom to top:

- Unit 1. (24.3 m) Gray, green and purple shale and brown, thin- and medium-bedded with interbedded green, thin-bedded microconglomerate and sandy limestone with bioclasts including smaller foraminifers, echinoderms and bryozoans;
- Unit 2. (4.9 m) Gray, thin-bedded limestone. Small foraminifers, echinoderms, bryozoans and brachiopods were observed among bioclasts;
- Unit 3. (5.6 m) Gray and brown, medium-bedded limestone and gray shale with bioclasts including smaller foraminifers and brachiopods;
- Unit 4. (2.1 m) Gray thick-bedded coral limestone (Fig. 3);
- Unit 5. (4.7 m) Gray and purple, thin and medium-bebded fusulinid limestone;
- Unit 6. (3.8 m) Gray shale including very thin-bedded brachiopods limestone;
- Unit 7. (6.8 m) Gray, medium- and thin-bedded limestone with bryozoans and echinoderms bioclasts;
- Unit 8. (7.56 m) Gray and purple, thin- and thick-bedded fusulinid limestone with interbedded gray shale with bryozoans, echinoderms and smaller foraminifers.

3. Materials and methods

The *Pseudoacutella partoazari* assemblage described in this study was sampled 1.5 km to the east of the village of Shishtu (GPS coordinates: 34°39'08.0"N 57°11'14.0"E) and 150 km to the northeast of the town of Tabas (Fig. 1B). It was collected from the middle part of Zaladou Formation, which is composed of bioclastic limestone of medium- to thick-bedded, which in some cases emerges from the rock (layer 16).

Taxonomic investigations were performed on 10 thin sections using a Leitz Wetzlar (Laborlux 11 pol) microscope. Photomicrographs were taken using Superior Statistical Analysis Pro (with version 9.0 of LIMDEP, 2008).

The material from Shishtu section is stored at the Earth Sciences Research Center, Islamic Azad University of Zahedan, Iran (collection numbers SH16a-j).

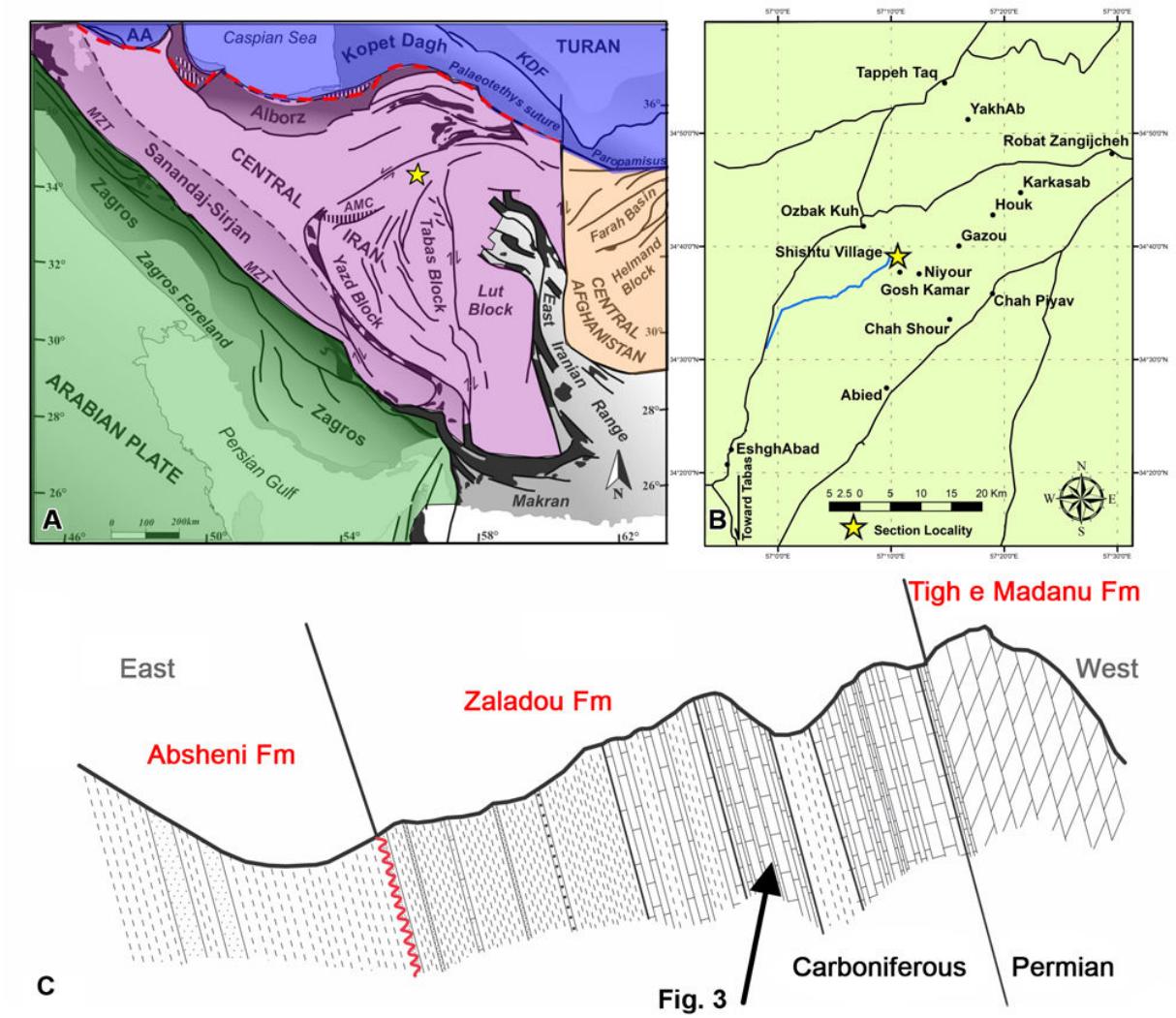


Figure 1: Geological setting of the studied area, Ozbak Kuh region (Tabas Block, east-central Iran). A) tectonic map of Iran (modified from ZANCHI *et al.*, 2009). AA = Anatolian-Armenian Block; AMC = Anarak Metamorphic Complex; KDF = Kopeh Dagh Foredeep; MZT = Main Zagros Thrust. B) geographic position (star) of the Shishtu section. C) cross-section of Zaladou Fm.

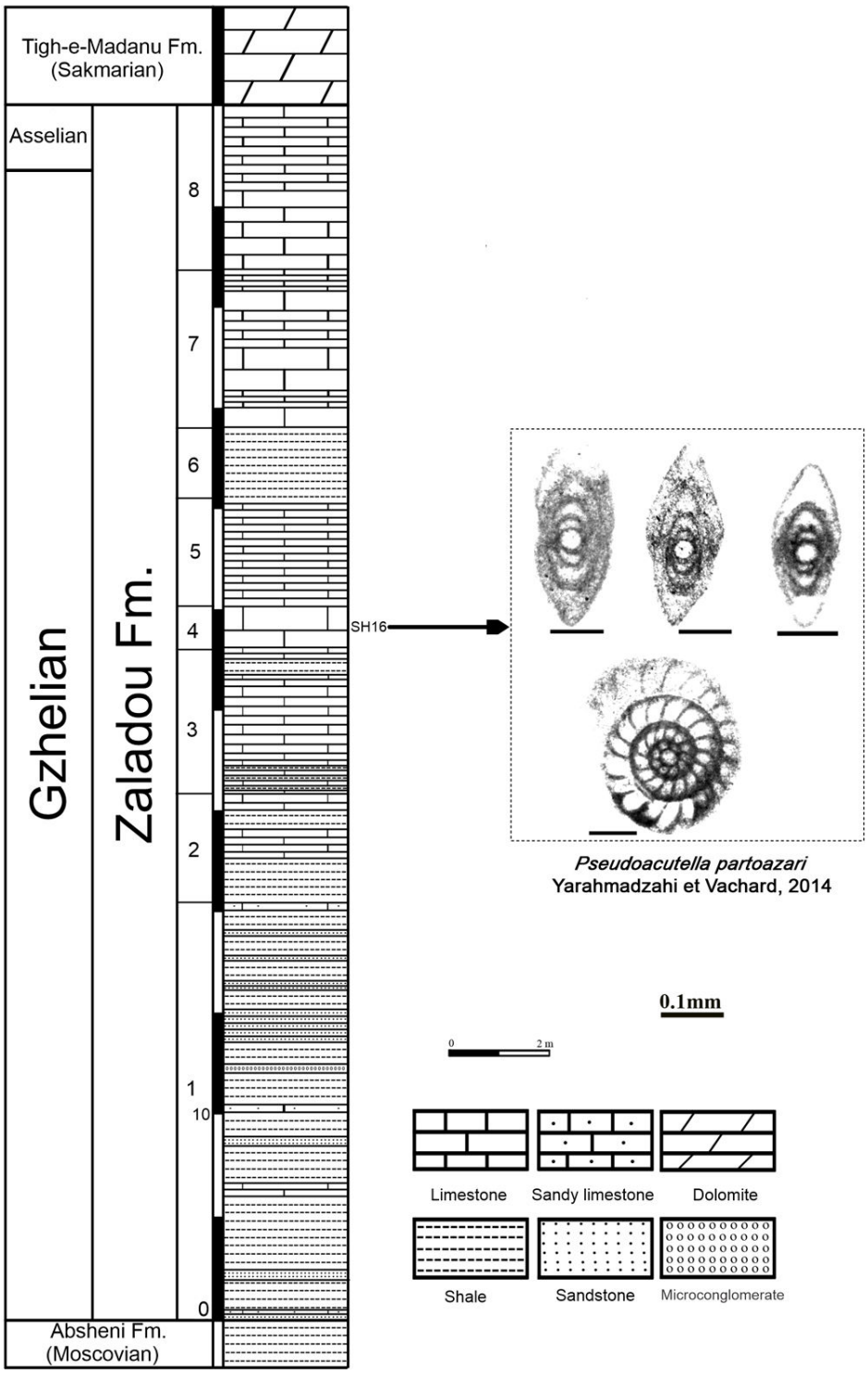
4. Gzhelian foraminifers in Iran

1. Main fusulinid markers

The Gzhelian fusulinids have been well studied in Iran (GAETANI *et al.*, 2009; LEVEN & TAHERI, 2003; LEVEN & GORGIJ, 2006, 2011a, 2011b; YARAHMADZAHI, 2011; FASSIHI *et al.*, 2019; JALALI, 2021).

Endemic fusuline species from Gzhelian in Iranian Plateau are noticeably rare in foraminiferal assemblages. Compared to similar fusuline assemblages in the Eastern European Platform, Iranian fusuline species are less diversified; still and all, Iranian fusulines have not been well studied. Furthermore, a large number of fusulinids reported from Iran belongs to *Ruzhenzevites* and *Schwageriniformis* species. In spite of their differences from typical specimens obtained from the Eastern European Platform, Iranian fusuline species have common components with the collections found in the northern part of the Tethys territory (Spain, Carnic Alps, southern Turkey, Darvaz, and Fergana).

Gzhelian fusuline assemblages which have been obtained from different tectonic blocks of Iran have specific regional characteristics (LEVEN & GORGIJ, 2011). For instance, the fusuline complex from the Yazd Block is more diverse than the Tabas, Alborz, and Sanandaj-Sirjan Blocks. In addition, the genera *Rauserites*, *Triticites*, and *Ruzhenzevites*, which are found in all tectonosedimentary blocks of Iran, are also found in the Yazd Block, in the lower part of the sequence *Schwagerina* genus and in the upper parts *Ultradaixina*, *Schellwienia*, *Anderssonites*, and *Likharevites* genera. In other blocks, either the stratigraphic intervals are absent or other fusulinids appear. Important and noticeable specimens include *Anderssonites* genus in Tuyeh Formation (Alborz zone) or *Anderssonites* and *Schellwienia* genera in Zaladou Formation (Tabas Block). In the Sanandaj-Sirjan zone, the fusuline complex is based on the abundance and diversity of *Ruzhenzevites* while this genus is less important in Yazd and Alborz blocks.



◀ **Figure 2:** Lithostratigraphic column with the main species of *Pseudoacutella partoazari* in the Zaladou Formation, Shishtu section, Ozbak Kuh region (Tabas Block, east-central Iran).

2. Gzhelian smaller foraminifers

Gzhelian smaller foraminifers have been well studied in Iran (Vachard, 1996; Alipour *et al.*, 2013; Yarahmadzahi *et al.*, 2016; Fassihi, 2017; Fassihi *et al.*, 2017, 2019, 2020; Fassihi & Shirezadeh, 2018; Yarahmadzahi & Vachard, 2018, 2019; Jalali *et al.*, 2021).

Previous studies on smaller foraminifers of Iran were more focused on Upper Carboniferous. For instance, Gzhelian smaller foraminifers described until recently (Fig. 4) comprise:

- In the Alborz Mountains:

Gadouk section (Yarahmadzahi *et al.*, 2016). The Gzhelian smaller foraminifera in section are located in the *Nodosinelloides shikhanica-Geinitzina primitiva* Zone, and the accompanying foraminifera of this zone *Geinitzina* ex gr. *uralica*.

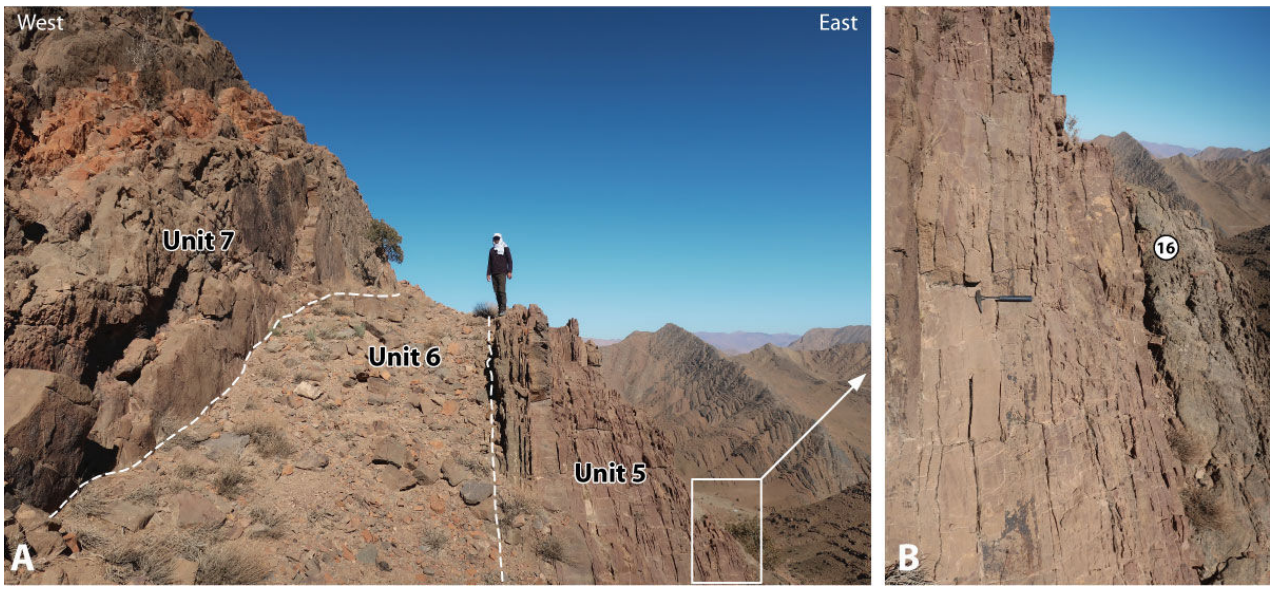


Figure 3: Unit 5 photo and sampling location.

- In the Chaman-Saver area, ALIPOUR *et al.* (2013) reported Gzhelian smaller foraminifera in two biozones:

A) *Nodosinelloides potievskayae-Vervilleina bradyi* Zone. The smaller foraminifers of this biozone are: *Nodosinelloides potievskayae* MAMET & PINARD, 1996, *Palaeotextularia bella* LIPINA, 1949, *Climacammina durabilis* KONOVALOVA, 1962, *Cribrogenerina celebrata*? LIN, 1978, *C.*? *elegans* (MÖLLER, 1879, *sensu* SCHELLWIEN, 1898, emend. VACHARD & KRAINER, 2001), *Tetrataxis conica* EHRENBERG, 1854, *T. hemiovoides*? MOROZOVA, 1949, *T. lata* SPANDEL, 1901, *Tezaquina* sp. 1, *Vervilleina bradyi* (SPANDEL, 1901), *Nodosinelloides potievskayae* MAMET & PINARD, 1996, *N.* cf. *pinardae* GROVES & WAHLMAN, 1997, '*Nodosinelloides-Geinitzina* transitional forms' *sensu* GROVES, 2000, *Geinitzina postcarbonica* SPANDEL, 1901, *Gr.* ex gr. *primitiva* POTIEVSKAYA, 1962.

B) *Calcitornella heathi-Nodosinelloides* sp. Zone. The following smaller foraminifers are associated: *Diplosphaerina inaequalis* (DERVILLE, 1931), *Tuberitina* sp., *Raphconilia damghanica* ALIPOUR & VACHARD in ALIPOUR *et al.*, 2013, *R. modificata* (POTIEVSKAYA, 1962), *Climacammina* cf. *durabilis* KONOVALOVA, 1962, *C.* ex gr. *elegans* (MÖLLER, 1879), *C.* sp., *Deckerella laheei* CUSHMAN & WATERS, 1928, *D. tenuissima* REITLINGER, 1950, *Tetrataxis* aff. *baschkirica* MOROZOVA, 1949, *T. lata* SPANDEL, 1901, *T. minuta* MOROZOVA, 1949, *T. paraconica* REITLINGER, 1950, *T. parviconica*? LEE & CHEN in LEE *et al.*, 1930, *T. planulata*? MOROZOVA, 1949, *Globivalvulina bulloides* (BRADY, 1876), *Gr.* aff. *pergrata* KONOVALOVA, 1962, *Calcivertella* sp., *Calcitornella heathi* CUSHMAN & WATERS, 1928, *Hemigordius/Rectogordius* transitional forms, *Nodosinelloides bella* (LIPINA, 1949), *N. longissima* (SULEIMANOV, 1949b), *N.* ex gr. *longissima* (SULEIMANOV, 1949b), *N. longa* (LIPINA, 1949), *N. netchajewi* (CHERDYNTSEV, 1914), *N.* sp., and *Langella* aff. *lepida* (LIN, 1984).

- In the Sanandaj-Sirjan zone:

In the Vazhnan Formation, the Gzhelian smaller foraminifera have been well studied (YARAHMADZAHI & VACHARD 2019), in two biozones:

A) *Monotaxinoides melanogaster* Zone, where the assemblage includes the following taxa: *Monotaxinoides melanogaster* (YARAHMADZAHI & VACHARD, 2019), *Turrispiroides* cf. *microsphaerica* (K.V. MIKLUKHO-MAKLAY, 1968), *Endothyra lipinae* MOROZOVA, 1949, *Bradyina lucida* MOROZOVA, 1949, *B. lepida* REITLINGER, 1950, *Tetrataxis* cf. *subconica* MOROZOVA, 1949, *T.* ex gr. *lata* SPANDEL, 1901, *Pseudonovella* aff. *carbonica* GROZDILOVA & LEBEDEVA, 1950, *Pseudoacutella* aff. *partoazari* YARAHMADZAHI & VACHARD, 2014, and *Grovesella* ex gr. *tabasensis* DAVYDOV & AREFIFARD, 2007.

B) *Raphconilia* spp., *Protonodosaria* spp., *Nodosinelloides* spp., and *Rectogordius*? *minimus* Zone. This assemblage encompasses the following taxa: *Eotuberitina reitlingerae* A.D. MIKLUKHO-MAKLAY, 1958, *Diplosphaerina inaequalis* (DERVILLE, 1931), *Turrispiroides* ex gr. *roessleri* (E. SCHMID, 1867), *Asselodiscus primitivus* MAMET & PINARD, 1992, *Raphconilia modificata* (POTIEVSKAYA, 1962), *R. minor* (PINARD & MAMET, 1998), *R.* cf. *pararecta* (PINARD & MAMET, 1998), *R.* sp., *Endothyra lipinae* MOROZOVA, 1949, *Bradyina lepida* REITLINGER, 1950, *B.* sp., *Deckerella* sp., *Climacammina* sp., Palaeotextulariidae indet., *Spireitlina* ex gr. *conspecta* (REITLINGER, 1950), *Tetrataxis* cf. *subconica* MOROZOVA, 1949, *T.* aff. *parviconica* LEE & CHEN, 1930, *T.* aff. *planulata* MOROZOVA, 1949, *T.* sp., *Globivalvulina* cf. *celebrata* ZAMILATSKAYA, 1969, *Gl.* ex gr. *bulloides* (BRADY, 1876), *Gl.* ex gr. *pulchra* REITLINGER, 1950; *Gl.* cf. *kantharensis* REICHEL, 1946; *Gl.* aff. *granulosa* REITLINGER, 1950, *Gl.* sp., *Pseudonovella* sp., *Pseudoacutella* aff. *partoazari* YARAHMADZAHI & VACHARD, 2014, *Grovesella* ex gr. *tabasensis* DAVYDOV & AREFIFARD, 2007, *Calcitornella*? sp., *Orthovertella verchojanica* SOSIPATROVA, 1970, *Hemigordius* sp.,

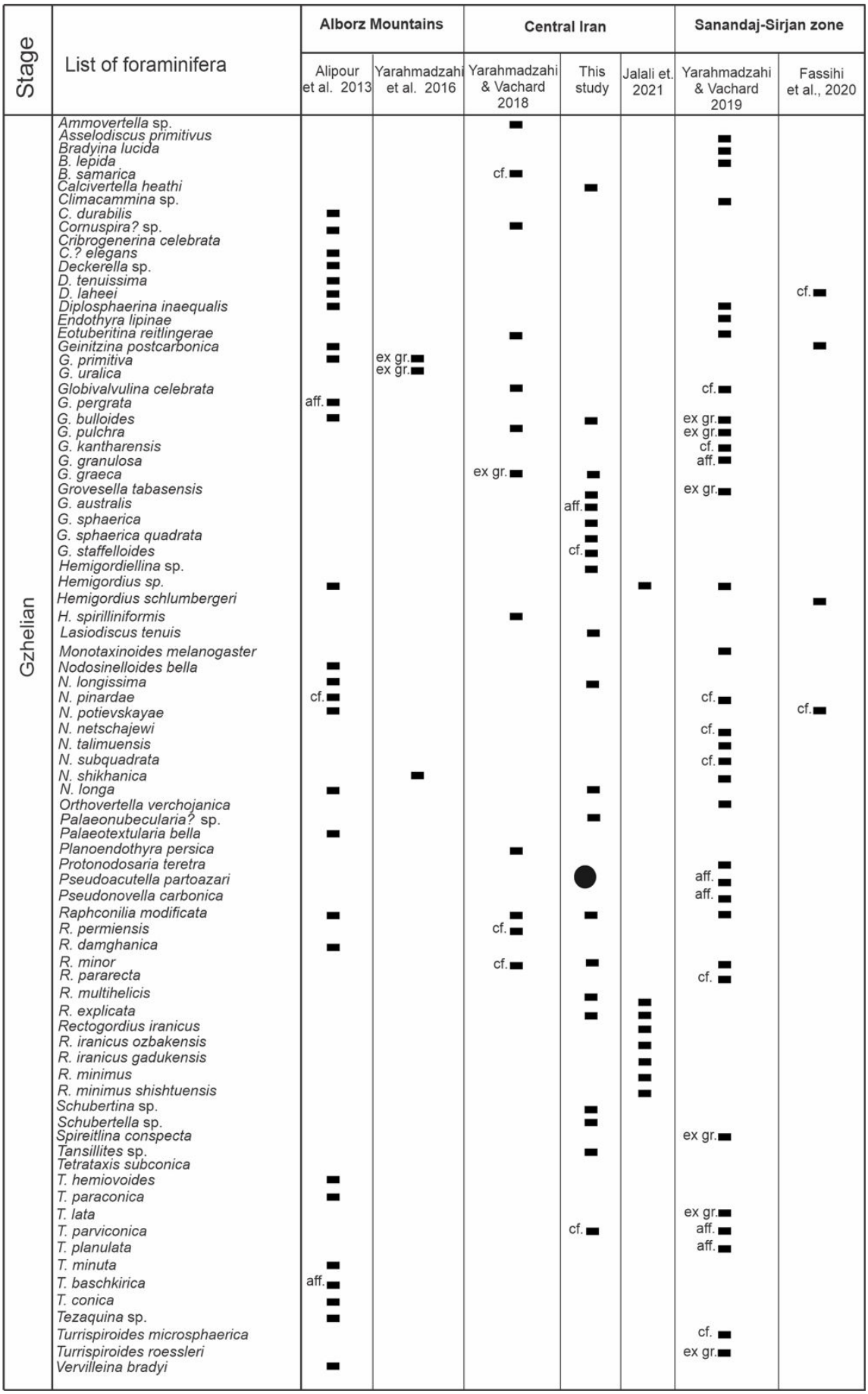


Figure 4: Gzhelian small-shelled fusulines and smaller foraminifera list from Iran.

H.? sp., *Rectogordius minimus* (YARAHMADZAHI & VACHARD, 2019), *Protonodosaria* spp., *Nodosinelloides shikhanica* (LIPINA, 1949), *N*. *talimuensis* (HAN, 1984), *N*. cf. *netschajewi* (CHERDYNTSEV, 1914), *N*. cf. *subquadrata* (LIPINA, 1949), *N*. cf. *pinardae* GROVES & WAHLMAN, 1997.

- In the Tabas area (Central Iran):

The Zaladou section (YARAHMADZAHI & VACHARD, 2018) exhibits two biozones of the Gzhelian.

A) *Hemigordius spirilliniformis Bradyina* cf. *samarica* subzone with: *Bradyina* cf. *samarica* REITLINGER, 1950, *Globivalvulina celebrata* ZAMILATSKAYA, 1969, and *Hemigordius spirollinoformis* WANG, 1982, *Eotuberitina reitlingerae* MIKLUKHO MAKLAY, 1958.

B) *Raphconilia modificata Globivalvulina* spp. Subzone including: *Eotuberitina reitlingerae*, *Raphconilia* (angulata stage) cf. *minor* PINARD & MAMET, 1998, *R*. (angulatus stage) cf. *permiensis* PINARD & MAMET, 1998, *R*. (concavus stage) *modificata* POTIEVSKAYA, 1962, *Planoendothyra persica* YARAHMADZAHI & VACHARD in YARAHMADZAHI *et al.*, 2016, *Globivalvulina celebrata* ZAMILATSKAYA, 1969, *Gl.* ex gr. *graeca* REICHEL, 1946, *Gl. pulchra* REITLINGER, 1950, *Ammovertella* sp., *Cornuspira*? sp., and *Protonodosaria teretra* CRESPIN, 1958.

In the section of Shishtu, JALALI *et al.* (2021) reported for first time the *Rectogordius* abundance zone, which contains *Rectogordius iranicus* ALIPOUR & VACHARD in ALIPOUR *et al.*, 2013, *R*. *iranicus gadukensis* YARAHMADZAHI & VACHARD, 2018, *R*. *minimus* Yarahmadzahi & Vachard, 2019, *R*. *minimus shishtuensis* YARAHMADZAHI & VACHARD in JALALI *et al.*, 2021, and *R. iranicus ozbakensis* YARAHMADZAHI & VACHARD in JALALI *et al.*, 2021.

5. *Pseudoacutella partoazari* assemblage zone

Pseudoacutella was created by VACHARD *et al.* (2013) from Cedro Peak (New Mexico, USA) and *Pseudoacutella partoazari* was found for first time by YARAHMADZAHI and VACHARD (2014) from Central Alborz (Gadouk section).

The *Pseudoacutella partoazari* assemblage consists of 16 species belonging to 14 genera: the fusulinids *Pseudoacutella partoazari*, *Grovesella tabasensis*, *Gr.* aff. *australis*, *Gr. sphaerica*, *Gr. sphaerica* var. *quadrata*, *Gr.* cf. *staffelloides*, *Schubertina* sp., *Schubertella* sp., and the smaller foraminifers *Eotuberitina* sp., *Lasiodiscus tenuis*, *Raphconilia* cf. *minor*, *R*. *multihelicis*, *R*. *modificata*, *Tetrataxis* cf. *parviconica*, *Globivalvulina* ex gr. *bulloides*, *Gl. graeca*, *Calcivertella heathi*, *Tansillites* sp., *Palaeonubecularia*? sp., *Hemigordiellina* sp., *Nodosinelloides longa*, and *N*. *longissima*.

Pseudoacutella partoazari (YARAHMADZAHI & VACHARD, 2014, Figs. 5 - 6) is an advanced species of this genus, which is characteristic of the Gzhelian to Asselian deposits (*i.e.*, the Carboniferous-Permian boundary interval) throughout the Tethys region (*e.g.*, YARAHMADZAHI & VACHARD, 2014, 2016, 2018, 2019; YARAHMADZAHI *et al.*, 2016; FASSIHI *et al.*, 2020). *P*. *partoazari* was first reported from Gadouk section (Central Alborz), and later found in Asselian limestones of Zaladou section (YARAHMADZAHI & VACHARD, 2018) and Banarizeh and Tang-e-Darchaleh sections in Sanandaj-Sirjan zone (FASSIHI *et al.*, 2020) and found in Gzhelian strata of Asad Abad section in Sanandaj-Sirjan zone (YARAHMADZAHI & VACHARD, 2019).

Grovesella tabasensis (DAVYDOV & AREFIFARD, 2007) was first identified from the Upper Sakmarian deposits of the Chili Formation in the Kalmard block, later reported from Upper Pennsylvanian-Lower Permian of Alborz, Sanandaj-Sirjan and Central Iran (YARAHMADZAHI *et al.*, 2016; YARAHMADZAHI & VACHARD, 2019; FASSIHI *et al.*, 2020), Lower Permian of Nevada (DAVYDOV, 2011) and Texas (LUCAS *et al.*, 2011), Afghanistan, and Darvaz (DAVYDOV & AREFIFARD, 2007). Middle Permian of NW Iran (EBRAHIM-NEDJAD *et al.*, 2015). *Gr.* aff. *australis* was first described from the Lower Permian of South America, Maracaibo Basin (THOMPSON & MILLER 1949), and Slovenia (RAMOVŠ & KOCHANSKY-DEVIDÉ, 1965); it resembles the Moscovian species of the genus *Eoschubertella bluensis*, *E*. *mosquensis* and *E*. *texana* (see GROVES, 1991). *Grovesella sphaerica* (SULEIMANOV, 1949) and *Gr.* cf. *staffelloides* (SULEIMANOV, 1949) described from upper Asselian and Sakmarian in the Urals-Arctic, Tethys and Kalmard area in Central Iran (DAVYDOV & AREFIFARD, 2007). *Gr. quadrata* (IVANOVA, 2000*)*, Recently, they have been found in the Gzhelian-Asselian sequence of the Sabzevar tectonic block, the Ahuban Mountains, north of Kashmar.

Globivalvulina graeca (REICHEL, 1946) described and identified from middle-upper Gzhelian of the Zaladou section in central Iran (YARAHMADZAHI & VACHARD, 2018), Lower Permian of Slovenia (KOCHANSKY-DEVIDÉ, 1970), Armenia (AKOPIAN, 1974) and South China (LIN *et al.*, 1990); it is common in Middle Permian and widespread in all the Palaeo-Tethys and Neo-Tethys: Greece, Italy, Austria, Tunisia, Hungary, Slovenia, Croatia, Montenegro, Turkey, Armenia, Iran (*e.g.*, Kuh-e Jamal: JENNY-DESHUSSES, 1983b) and Murgabian, Midian and Djulfian of Maku (EBRAHIM NEJAD *et al.*, 2015). *Gl*. ex gr. *bulloides* is reported from Serpukhovian, Bashkirian to uppermost Permian, cosmopolitan. Recently, it was described from Gzhelian-Asselian of Central Iran (YARAHMADZAHI & VACHARD, 2019, FASSIHI *et al.*, 2020) and Alborz (YARAHMADZAHI *et al.*, 2016).

Hemigordiellina sp. is complicate and controversial. The small glomospiroid porcelaneous tests were attributed to *Hemigordiellina* sp. by GAILLOT and VACHARD (2007).

Eotuberitina sp. is cosmopolitan, Silurian-Devonian, with an acme in Carboniferous- Permian, rare in lowermost Triassic (VACHARD, 2016).

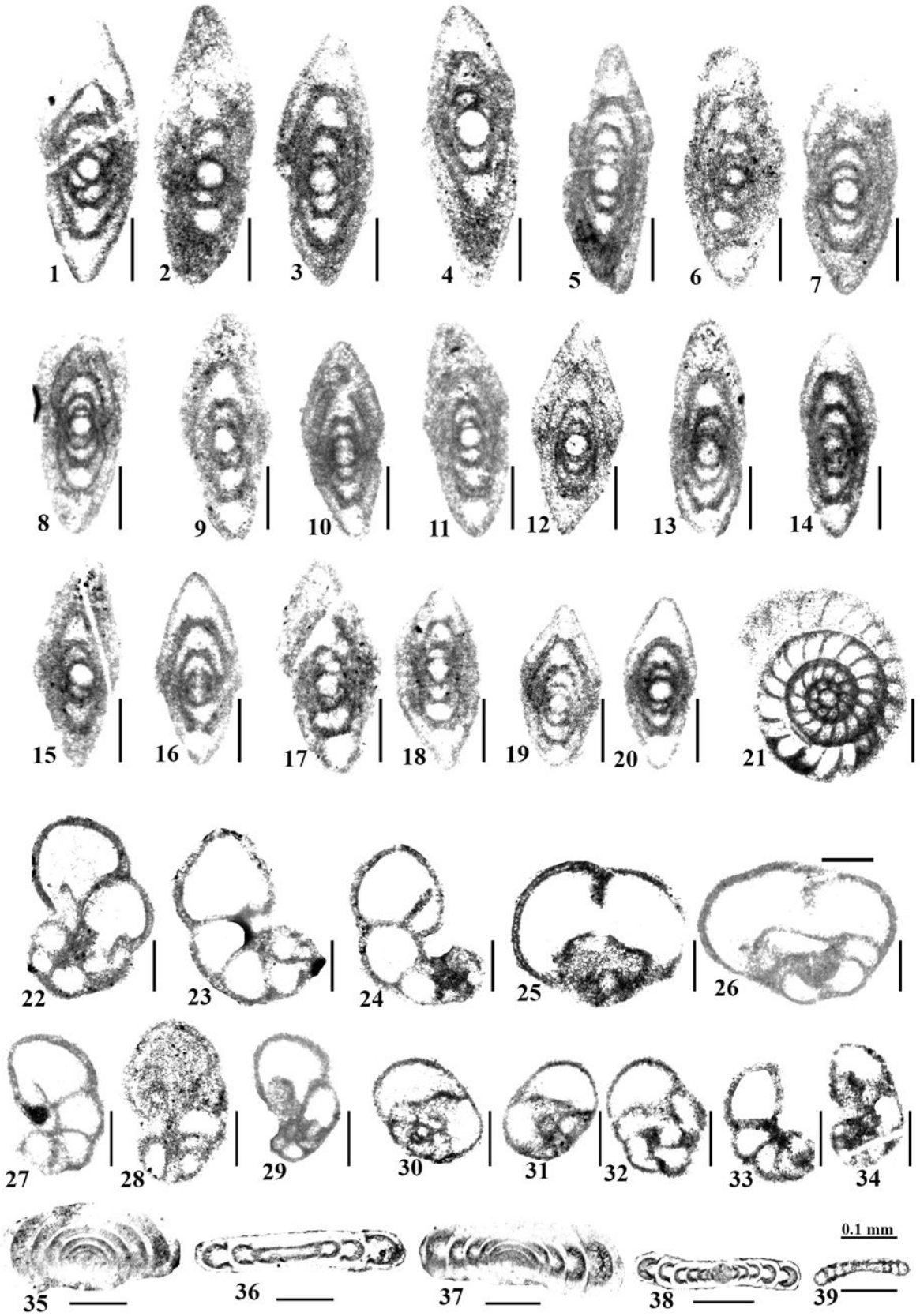


Figure 5: *Pseudoacutella partoazari* assemblage from the upper Gzhelian of the Zaladou Fm. Sample SH 16 (Scale bar = 0.1 mm). 1-21) *Pseudoacutella partoazari* (YARAHMADZAHI & VACHARD, 2014); 22-26) *Globivalvulina graeca* (REICHEL); 27-34) *Globivalvulina* ex gr. *bulloides* (BRADY)*;* 35-36) *Raphconilia* cf. *minor* (PINARD & MAMET); 37) *Raphconilia multihelicis* (PINARD & MAMET); 38) *Raphconilia modificata*; 39) *Lasiodiscus tenuis* (REICHEL).

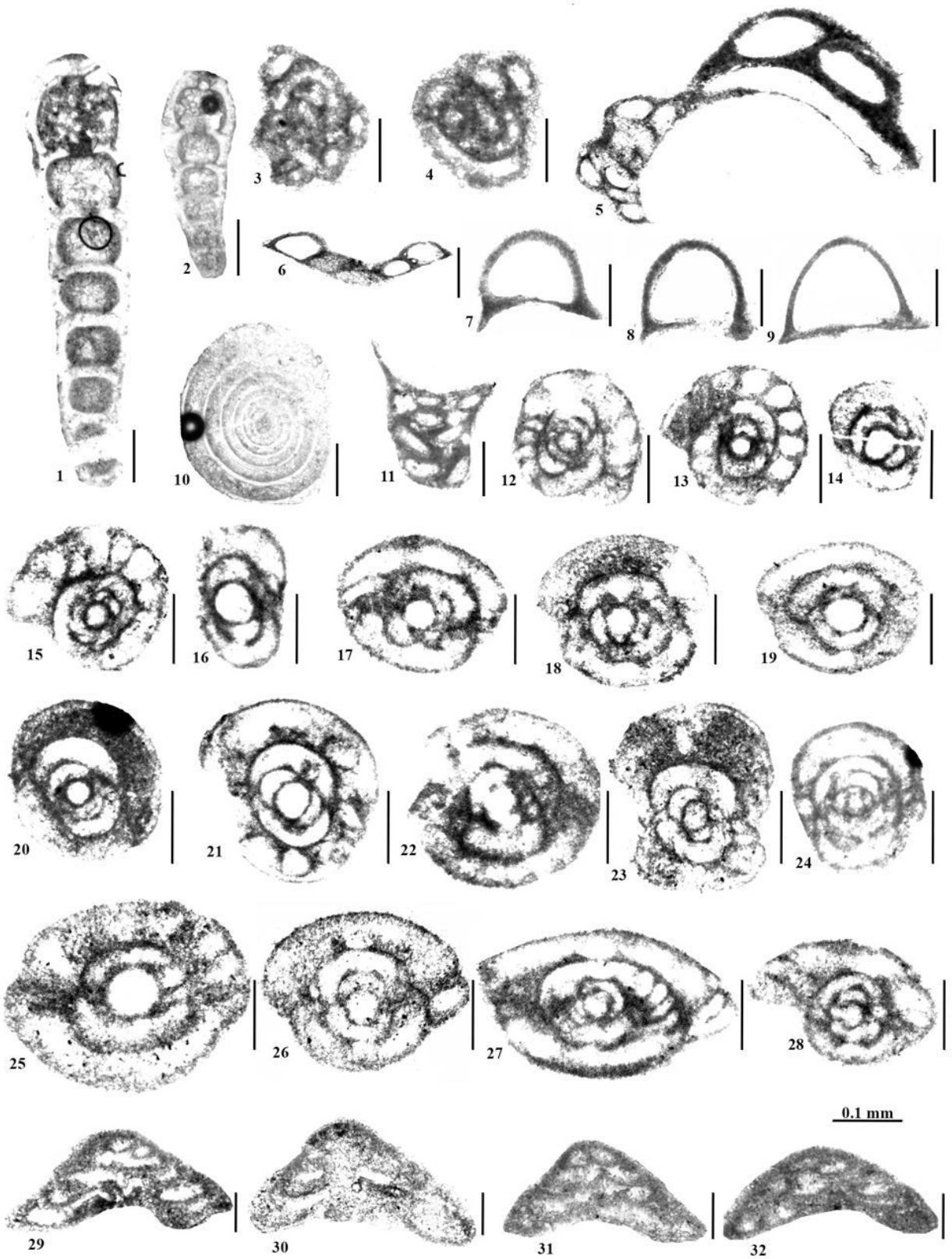


Figure 6: *Pseudoacutella partoazari* assemblage from the upper Gzhelian of the Zaladou Fm. Sample SH 16 (Scale bar = 0.1 mm). 1) *Nodosinelloides longissima* (SULEIMANOV); 2) *Nodosinelloides longa* (LIPINA); 3-4) *Hemigordiellina* sp.; 5) *Palaeonubecularia*? sp.; 6) *Calcivertella heathi* (CUSHMAN & WATERS); 7-9) *Eotuberitina* sp.; 10) *Raphconilia multihelicis* (PINARD & MAMET); 11) *Tansillites* sp.; 12-16 *Grovesella tabasensis* (DAVYDOV & AREFIFARD); 17-19) *Grovesella* aff. *australis* (Thompson & Miller); 20-22) *Grovesella sphaerica* (SULEYMANOV); 23) *Grovesella sphaerica quadrata* (IVANOVA*);* 24) *Grovesella* cf. *staffelloides* (Suleymanov); 25-27) *Schubertina* sp.; 28) *Schubertella* sp.; 29-32) *Tetrataxis* cf. *parviconica* (LEE & CHEN).

Raphconilia cf. *minor*, *R. multihelicis*, and *R. modificata* have a Gzhelian-Kungurian age, but are additionally considered as rare in Roadian, Wordian, and lower Capitanian strata and very rare in upper Capitanian and Wuchiapingian strata (ALTINER, 1988; VACHARD *et al.*, 2017). Cosmopolitan distribution and relatively widespread in America (PINARD & MAMET, 1998; VACHARD *et al.*, 2017). Discovered in the middle-upper Gzhelian to middle-upper Asselian of Iran (ALIPOUR *et al.*, 2013; YARAHMADZAHI *et al.*, 2016; YARAHMADZAHI & VACHARD, 2018, 2019; FASSIHI, 2020).

Tetrataxis cf. *parviconica* was first described by LEE and CHEN *in* LEE *et al.*, 1930. Later found in deposits on Moscovian-lower Permian of the Paleotethys and Panthalassa (UENO & NAKAZAWA, 1993). Recently, this species has been reported in Iran from Abshani Formation (LEVEN *et al.*, 2006) of Moscovian age; Vazhnan Formation in Sasandaj- Sirjan zone of Sirjan (YARAHMADZAHI & VACHARD, 2019; FASSIHI *et al.* 2020) of Gzhelian age and from Emarat in Alborz (ALIPOUR *et al.*, 2013) of late Ghzelian age.

Stratigraphic and geographic range of *Schubertella* sp. is distributed globally within the tropics-subtropics and known from Moscovian to Wordian (RAUZER-CHERNOUSOVA *et al.,* 1951; SKINNER & WILDE, 1966; LEVEN, 1998a, 1998b; DAVYDOV, 2011). Stratigraphic and geographic range of *Schubertina* sp. is distributed globally within the tropics-subtropics. It has been documented in the upper lower Bashkirian, in the Urals (SINITSYNA & SINITSYN, 1987), Donets Basin (MANUKALOVA-GREBENYUK *et al.,* 1969) and Timan-Pechora (NIKOLAEV, 2005) and lower Atokan (upper Bashkirian) in North America (GROVES, 1986, 1991). The upper range of *Schubertina* sp. is not clear at the moment (DAVYDOV, 2011). Some forms that can be considered as *Schubertina* sp. are reported from Wordian (lower Midian), Capitanian (upper Wordian) and Lopingian (SKINNER & WILDE, 1966; LEVEN, 1998a).

6. Carbonate microfacies

Pseudoacutella have been found in different microfacies from the Upper Carboniferous (Gzhelian) and Lower Permian (Asselian-Sakmarian) of Iran. YARAHMADZAHI & VACHARD (2014) and YARAHMADZAHI *et al.* (2016) suggested that *Pseudoacutella partoazari* associated with oncoid, bryozoan, brachiopod, fusulinida (schwagerinids) and smaller foraminifers characterizes a shoal sub-environment facies (Fig. 7A), Such environments and lithologies include mostly representatives of the genera *Geinitzina* sp., *Globivalvulina* sp., *Pseudovidalina* sp., *Nodosinelloides* sp., *Schubertella* sp., *Biwaella* sp., *Triticites* sp., *Tumefactus* sp., *Pseudoschwagerina* sp., *Zellia* sp., and *Praepseudofusulina* sp. (LEVEN & YARAHMADZAHI, 2020). Recently, YARAHMADZAHI & VACHARD (2018) suggested a shoal sub-environment for bioclastic, schwagerinid, brachiopod grainstone containing smaller foraminifers with a microgranular and hyaline wall, such as *Pseudonovella* sp., *Bradyina* sp., *Globivalvulina* sp., *Raphconilia* sp., *Protonodosaria* sp. and *Grovesella* sp., from the Zaladou section in the Tabas block, central Iran Zone (Fig. 7B).

YARAHMADZAHI and VACHARD (2019) reported *Pseudoacutella partoazari* in the shoal sub-environment of the Asad Abad section in Sanandaj-Sirjan zone. They observed *Pseudoacutella* together with smaller foraminifers, especially with *Bradyina* sp., *Rectogordius* sp., *Raphconilia* sp., *Nodosinelloides* sp., *Grovesella* sp., and *Endothyra* sp. in the shoal sandy bioclastic schwagerinid brachiopod grainstones (Fig. 7C).

In the present study, *Pseudoacutella* is found out in the shoal sub-environment in bryozoan, brachiopod and echinid grainstone with smaller foraminifera such as *Globivalvulina* sp., *Hemigordiellina* sp., *Eotuberitina* sp., *Raphconilia* sp., *Lasiosdiscus* sp., *Calcivertella* sp., *Tansillites* sp., *Palaeonubecularia*? sp., *Nodosinelloides* sp., *Grovesella* sp., *Schubertina* sp., *Schubertella* sp. and *Tetrataxis* sp. (Fig. 7A-D).

7. Remarks on *Pseudoacutella* and *Pseudonovella*

Pseudoacutella is regarded as a junior synonym of *Pseudonovella* by UENO (2022) with the following arguments: *Pseudoacutella* shares basic morphological features with the type species of *Pseudonovella*: *Novella* (*Pseudonovella*) *irregularis* KIREEVA, 1949, such as a slender lenticular shell with 3-3.5 volutions and a large spherical proloculus relative to the shell size. UENO (2022) suggests also that *Pseudonovella* and *Pseudoacutella* have similar stratigraphic ranges and occur commonly in the Bashkirian and Moscovian. This author, finally, admits only some subtle differences (sic) between these two genera, such as the shape of the periphery and the feature of chamber involution at umbilical regions. Furthermore, it is noticeable that *Pseudonovella* was previously considered as a subgenus of *Eostaffella* by VILLA *et al.* (2021) including UENO himself among the co-authors; hence, considered as having a coiling and growth different of *Pseudonovella sensu stricto*.

We re-illustrate here (Table 1) the differences indicated by VACHARD *et al.* (2013) and confirm that *Pseudonovella* differs from *Pseudoacutella* by the periphery rounded-carinate (carinate in *Pseudoacutella*), pseudochomata less developed, and the type of coiling (*Pseudoacutella* is truly planispiral involute). *Pseudonovella* is suggested here as the ancestor of *Pseudoacutella*.

Even if these characters may appear subtle, they are at the base of the traditional distinction between *Millerella* and *Eostaffella*. We remember that *Eostaffella* RAUZER-CHERNOUSOVA, 1948, and *Millerella* THOMPSON, 1942, were independently created and remained the children of the Cold

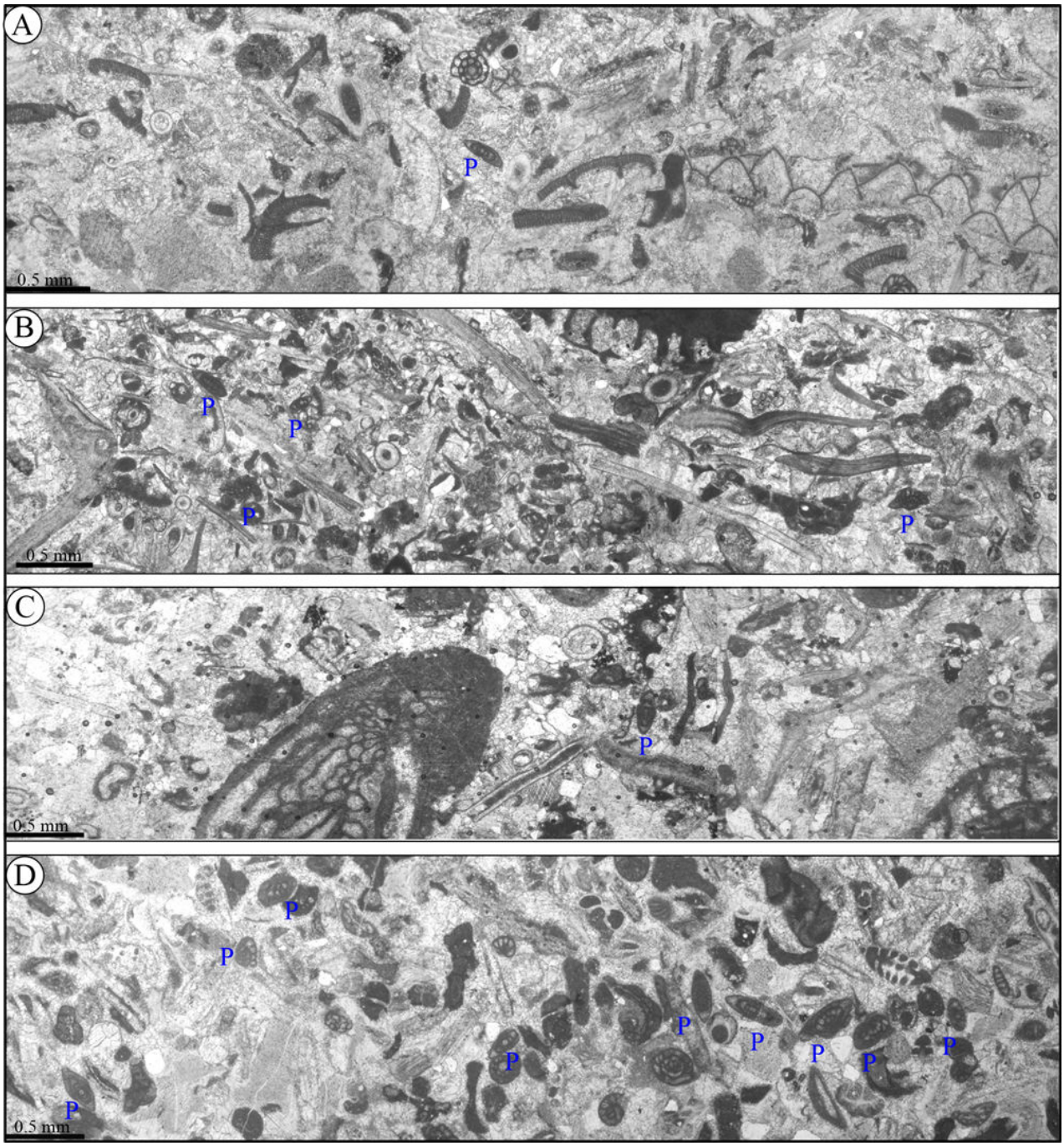


Figure 7: Photomicrographs of carbonate facies of the Zaladou Formation of the Shishtu Section in Ozbak Kuh Mountain, in northeast Tabas Block, Iran: **A)** bryozoan, brachiopod, fusulinida tests (schwagerinids) and smaller foraminifer grainstone with *Pseudoacutella partoazari* in the Emarat Formation (YARAHMADZAHI & VACHARD, 2014; sample DH 6); **B)** bioclastic, schwagerinid, brachiopod grainstone containing smaller foraminifers with a microgranular and hyaline wall with *Pseudoacutella partoazari* in the Zaladou Formation in the Zaladou section (YARAHMADZAHI & VACHARD, 2018, sample CPH 28); **C)** sandy, bioclastic, schwagerinid, brachiopod grainstone with *Rectogordius* in the Vazhnan Formation (YARAHMADZAHI & VACHARD, 2019; sample Vaa 3); **D)** bryozoan, brachiopod and echinid grainstone with smaller foraminifera with *Pseudoacutella partoazari* in the Zaladou Formation (this study; sample SH 16).

▶ **Table 1:** Morphologic and hypothetically phylogenetic evolution of Millerellinae. Abbreviations: ex gr. = ex gregae (Latin) = of the group (modified from VACHARD *et al.*, 2013).

MILLERELLINAE	PERIPHERY	INVOLUTE AND THEN EVOLUTE	ENTIRELY EVOLUTE
Advanced	Carinate	*Pseudoacutella*	*Eostaffella* ex gr. *dolixa-fragilis*
	Horse shoe	*Pseudonovella*	*Novella*
	Rounded	*Plectomillerella*	*Seminovella* *Millerella*
Primitive	Rounded	*Eostaffella* ex gr. *pseudostruvei*	*Zellerinella*

War. We remember also that the *Eostaffella* of the U.S.A. were named *Paramillerella* by THOMPSON (1951) and, finally, that the genera *Eostaffella* and *Millerella*, initially synonymized by GINKEL (1965) were, in a second time, subdivided by this author (GINKEL, 2010) in several dozens of genera and subgenera.

At first glance, *Pseudoacutella* might be considered as a subgenus of *Eostaffella*, as proposed by VILLA *et al.* (2021) because it is more similar to the millerellids than the eostaffellids. That is also the case for *Pseudonovella*. It differs from *Eostaffella* because it arises from a different lineage; nevertheless, the convergence and homeomorphy are almost perfect.

The initial mutation of *Pseudonovella* into *Pseudoacutella* seems to have taken place in the Donbass basin (Ukraine) during the deposit of the upper Bashkirian I limestone. Nevertheless, migrating *Pseudoacutella* are biostratigraphic markers for the lower Desmoinesian and/or the Atokan-Desmoinesian boundary interval in North America (VACHARD *et al.*, 2013).

The emendation of *Pseudonovella* by MASLO and VACHARD (1997) is used here for defining this latter genus, because the subsequent emendation of GINKEL (2002) seems less consistent with the generotype characters. If we can admit the text of GINKEL (2002) and his analysis of *Pseudonovella* sp. 1, we believe that the other taxa analyzed by him (*Pseudonovella* sp. 2 to sp. 6) correspond more to *Millerella* or *Seminovella*, at least in the sense of RAUZER-CHERNOUSOVA *et al.* (1951) and GINKEL (1987).

Pseudonovella differs from *Novella* by less evolute terminal whorls; consequently, *Novella pulchra* (*sensu* LEVEN, 1998, Pl. 1, fig. 5) is a *Pseudonovella* and not a *Novella*. *Pseudonovella* differs from *Millerella* and *Seminovella* by the coiling concomitantly evolute and enveloping, smaller pseudochomata and the periphery rounded-carinate (rounded in *Millerella* and *Seminovella*). It differs from *Pseudoacutella* by the periphery rounded-carinate (carinate in *Pseudoacutella*), pseudochomata less developed, and the type of coiling (*Pseudoacutella* is truly planispiral involute). *Pseudonovella* is suggested here as the ancestor of *Pseudoacutella*.

8. Conclusions

1. A foraminiferal assemblage, of 14 genera and 16 species, is reported from the Zaladou Formation in the Tabas Block (Shishtu Section), Central Iran.
2. The age of this assemblage is interpreted herein as Gzhelian (= latest Carboniferous).
3. This assemblage shows an overwhelming dominance of *Pseudoacutella* and relatively low total diversity, compared with similar foraminifera from Alborz, Sanandaj-Sirjan, Sabzevar and central Iran, which presents warm and humid conditions during the Late Carboniferous.
4. *Pseudoacutella* was recently regarded as a junior synonym of *Pseudonovella*. However, we confirm here the differences between the two genera, and conclude that *Pseudonovella* really differs from *Pseudoacutella* by the periphery rounded-carinate (carinate in *Pseudoacutella*), pseudochomata less developed, and the type of coiling (*Pseudoacutella* is truly planispiral involute).
5. *Pseudonovella* is suggested here as the ancestor of *Pseudoacutella.*

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