MISSISSIPPIAN-ASSELIAN (EARLY CARBONIFEROUS-EARLY PERMIAN) FORAMINIFERAL FAUNAS AND BIOSTRATIGRAPHY OF THE SHAHREZA-ABADEH REGIONS (THE SANANDAJ-SIRJAN ZONE), IRAN

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ABSTRACT

The Mississippian–Asselian (Early Carboniferous–Early Permian) foraminiferal faunas and biostratigraphy were studied in three sections of the Shahreza–Abadeh regions, in the Sanandaj-Sirjan Zone, in Iran. These sections with a thickness of about 528–1180 m are mainly composed of the siliciclastics and fossiliferous carbonates carbonates, apparently deposited in a shallow-water environment. The studied successions consist of Carboniferous Shishtu and Sardar groups and the uppermost Carboniferous–Lower Permian Anarak Group. The sequence in question contains 217 species belonging to 75 genera within the six foraminiferal zones; namely, (1) the *Uralodiscus rotundus - Glomodiscus miloni* zone of a Viséan age, (2) the *Plectostaffella jakhensis - Eostaffella pseudostruvei* zone of a Voznesenian (earliest Bashkirian) age, (3) the *Tikhonovichiella tikhonovichi - Profusulinella* (*Depratina*) *prisca - Aljutovella* spp. zone of a Melekessian–Vereian (latest Bashkirian–earliest Moscovian) age, (4) the *Beedeina samarica - Taitzehoella mutabilis* zone of a late Kashirian age, (5) the *Fusulinella* (*Fusulinella*) *pseudobocki* zone of an early Podolskian age, and (6) the *Praepseudofusulina kljasmica* zone of a latest Gzhelian–Asselian age. Among the identified foraminifers, 21 genera and 37 species are reported for the first time in the Sanandaj-Sirjan Zone. The foraminiferal zones and their characteristic index species allow to correlate the Mississippian–Asselian sequence in the Sanandaj-Sirjan Zone with the foraminiferal biozonation acknowledged for the Mississippian–Asselian in the the Russian Platform, Southern and Northern Urals, Istanbul Terrane, Eastern and Central Taurides (Turkey), and Western Europe. These new foraminiferal faunas, furthermore, share some common species with the concurrent faunas of the Alborz, East Iran, and Central Iran. In this study, the foraminiferal assemblages of the Voznesenian (earliest Bashkirian) age, the Melekessian–Vereian (latest Bashkirian–earliest Moscovian) age, and also the Biozone MFZ11B (late early Viséan) are reported for the first time in the Sanandaj-Sirjan Zone. The study also presents the occurrence of 19 species of foraminifers for the first time in Iran.

Keywords: Foraminiferal faunas, Iran, Sanandaj-Sirjan Zone, Mississippian, Asselian.

FAUNA FORAMINIFERA BERUSIA MISSISSIPPIAN-ASSELIAN (KARBON AWAL-PERMIAN AWAL) DAN BIOSTRATIGRAFI KAWASAN SHAHREZA-ABADEH (ZON SANANDAJ-SIRJAN), IRAN

ABSTRAK

Foraminifera dan biostratigrafi berusia Mississippian–Asselian (Karbon Bawah–Permian Bawah) dikaji pada tiga seksyen di wilayah Shahreza–Abadeh, dalam Zon Sirjan, Iran. Seksyen-seksyen ini mempunyai ketebalan 528–1180 m dan terdiri daripada silisiklastik dan karbonat yang kaya dengan fosil, dan diendapkan di kawasan laut cetek. Jujukan ini terdiri daripada Kumpulan Shishtu dan Sardar yang berusia Karbon dan Kumpulan Anarak yang berusia Karbon Lewat-Permian Bawah. Jujukan ini mengandungi 217 spesis yang terdiri daripada 75 genera dalam enam zon-zon foraminifera; iaitu, (1) zon *Uralodiscus rotundus - Glomodiscus miloni* yang berusia Viséan, (2) zon *Plectostaffella jakhensis - Eostaffella pseudostruvei* yang berusia Voznesenian (Bashkirian Awal), (3) zon *Tikhonovichiella tikhonovichi - Profusulinella* (*Depratina*) *prisca - Aljutovella* spp. yang berusia Melekessian–Vereian (Bashkirian Lewat – Moscovian Awal), (4) zon *Beedeina samarica - Taitzehoella mutabilis* Kashirian Lewat, (5) zon *Fusulinella* (*Fusulinella*) *pseudobocki* yang berusia Podolskian Awal, dan (6) zon *Praepseudofusulina kljasmica* yang berusia Gzhelian–Asselian Lewat. Diantara foraminifera yang dikenalpasti, 21 genera dan 37 spesis adalah yang pertama dilaporkan di Zon Sanandaj-Sirjan. Zon-zon foraminifera dan ciri-ciri yang terdapat pada spesis index membolehkan korelasi dibuat antara jujukan Mississippian–Asselian di Zon Sanandaj-Sirjan dengan foraminifera biozon lain yang juga berusia Mississippian–Asselian di Platfom Rusia, selatan dan utara Urals, Istanbul Terrane dan Taurides Tengah (Turki), dan barat Eropah. Foraminifera tersebut juga menunjukkan spesis-spesis yang sama yang terdapat di Alborz, Iran Timur, dan Iran Tengah. Kajian ini juga pertama kali melaporkan himpunan-himpunan foraminifera yang berusia Voznesenian (earliest Bashkirian), dan juga Biozon MFZ11B (Viséan Lewat Awal) di Zon Sanandaj-Sirjan. Kajian ini turut melaporkan buat pertama kali kewujudan 19 spesis foraminifera.

Kata kunci: Foraminifera, Iran, Sanandaj-Sirjan Zon, Mississippian, Asselian.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Since the foraminifers are very sensitive to the different environmental conditions (e.g. water temperature, light, depth, and salinity), they are considered as the useful tools for paleoenvironmental and paleogeographic reconstructions. The evolution of the structure, shape, and size of the mineralized shells of foraminifers indicates the variation of these factors through geologic time. Besides, their biostratigraphic values have been widely appreciated. In this respect, the ecological behaviour, evolution, and systematics of the first mineralized Paleozoic foraminifers are principal to demonstrate the former shallow marine environments, and also to reveal the distributions of the foraminifers through space and time (Vachard et al. 2010).

Fusulinids are an extinct group of foraminifers within the larger benthonic foraminiferal faunas. They are among the most widespread and abundant groups of fossils in the Carboniferous and Permian deposits, where they have been well studied, and are thus of great stratigraphic significance. For example, fusulinids have been used to describe the International stage scale of the Carboniferous that is now receiving authorization, and the stage scale of the Permian in the Tethys (Leven & Gorgij, 2011c). Although fusulinids were largely confined to the carbonate facies, they have a broad geographic dispersal and include many taxa which evolved relatively rapidly. As a result, particularly in recent years, they have received much attention and numerous species have been reported (e.g. Davydov & Leven, 2003; Leven & Taheri, 2003; Leven & Gorgij, 2005, 2006a,b, 2007, 2008a,b, 2009, 2011a,b,c; Dzhenchuraeva & Okuyucu, 2007; Okuyucu, 2008, 2009; 2013; Gaetani et al. 2009; Okuyucu & Göncüoğlu, 2010). Fusulinids principally lived in shallow marine carbonate environments. However, storms, sea-flow streams, and turbidity currents re-distributed them in a notably broader range of environmental conditions, including the outer ramp and slope facies.

As a subject of scientific investigation for over two centuries, fusulinids are one of the best studied microfossil groups with thoroughly established taxonomy, systematics, and phylogeny (Davydov & Leven, 2003). They give the valid foundation for dating and correlation of the Upper Carboniferous and Permian marine strata for regional and global correlations (Boardman et al. 1998; Chernykh & Ritter, 1997; Chernykh et al. 1997; Wardlaw et al. 1999). The Early Carboniferous fusulinids that originated in the Viséan age were of low diversity and low abundance (Leven & Gorgij, 2011c). In the Iranian sections, they are described by some simple genera of identical morphology, which differ from each other mainly in spirotheca structure, in many cases having slight distinctions (Leven & Gorgij, 2011c). Besides Iran, fusulinids of close morphology are found not only in the Lower, but also in the Upper Carboniferous deposits. The same is true of concurrent fusulinid species found from the Iranian sections. Their minor morphological features make these fusulinids of low value for dating their host deposits. Smaller foraminifers are more important in this respect (Leven & Gorgij, 2011c).

1.2 Purposes and scopes

This study is devoted to enhance the understanding of the Mississippian–Asselian (Lower Carboniferous–Lower Permian) biostratigraphy of the Sanandaj-Sirjan Zone in Iran. For this purpose three stratigraphic sections have been measured for a total thickness of about 1600 meters. The objectives of this study are:

- To provide new biostratigraphic zonation to the Mississippian–Asselian (Lower Carboniferous–Lower Permian) strata to the Sanandaj-Sirjan Zone in Iran.
- To provide further information of the smaller foraminifer and fusulinid faunas of a late Paleozoic age from the Shahreza and Abadeh regions in the Sanandaj-Sirjan Zone, where only small part of the faunas were previously studied by earlier researchers for example Baghbani (1993) and Leven and Gorgij (2008a, 2011b,c).
- To make correlation of the identified local biozones with the coeval assemblages of the other tectonic blocks in Iran and with the foraminiferal biozonations acknowledged for the Mississippian–Asselian in the Russian Platform, Southern and Northern Urals, Istanbul Terrane and Central Taurides (Turkey), and Western Europe.

1.3 Study area

Iran has a complex geological structure and is divided into several tectonic units, such as the Zagros, the Alborz, Central Iran (Yazd Block), East Iran (Lut and Tabas blocks), and the Sanandaj-Sirjan Zone of Middle–Late Paleozoic basements (Arfania & Shahriari, 2009; Ruban, 2007; Torsvik & Cocks, 2004) (Figure 1.1). The Sanandaj-Sirjan Zone, where the biostratigraphic sections studied carried out, is composed of mainly of the metamorphic complexes and granitoid intrusions. It includes Carboniferous−Permian strata that exhibit different lithological characteristics in comparison with the tectonic blocks of East Iran and Central Iran (Ahadnejad, 2013; Alavi & Kishvar, 1991; Bahrami et al. 2014).

In the Sanandaj-Sirjan Zone, three locations; namely, the Banarizeh, Asad Abad II, and Tang-e-Darchaleh sections have been investigated for this study (Figures 1.1 & 1.2). These three sections belong to a belt of the Carboniferous and Permian strata that distribute almost continuously from Esfahan to Sirjan along the Sanandaj-Sirjan Zone (Leven & Gorgij, 2008a). The Banarizeh Section is situated approximately 40 km northeast of the Abadeh town and its starting point is at the coordinates: N31˚34′25.9″; E52˚22′30.9″. The Asad Abad II Section is situated approximately 35 km southeast of the Shahreza town, and its starting point is at the coordinates: N31˚46′13.4″; E52˚08′56.9″. Note that it is not equal to the original Asad Abad Section of Boncheva et al. (2007), but was newly introduced *in* Fassihi et al. (2017). The Tang-e-Darchaleh Section is situated approximately 18 km northeast of the Shahreza town and its starting point is at the coordinates: N32˚02′39.7″; E52˚02′24.2″. The base maps are from the Izadkhast Map, 1:100.000 series Sheet No. 6453 (Hamzehpour & Nazari, 1998), and from the Esfahan Map, 1:250.000 series Sheet No. J7 (Zahedi et al. 1978).

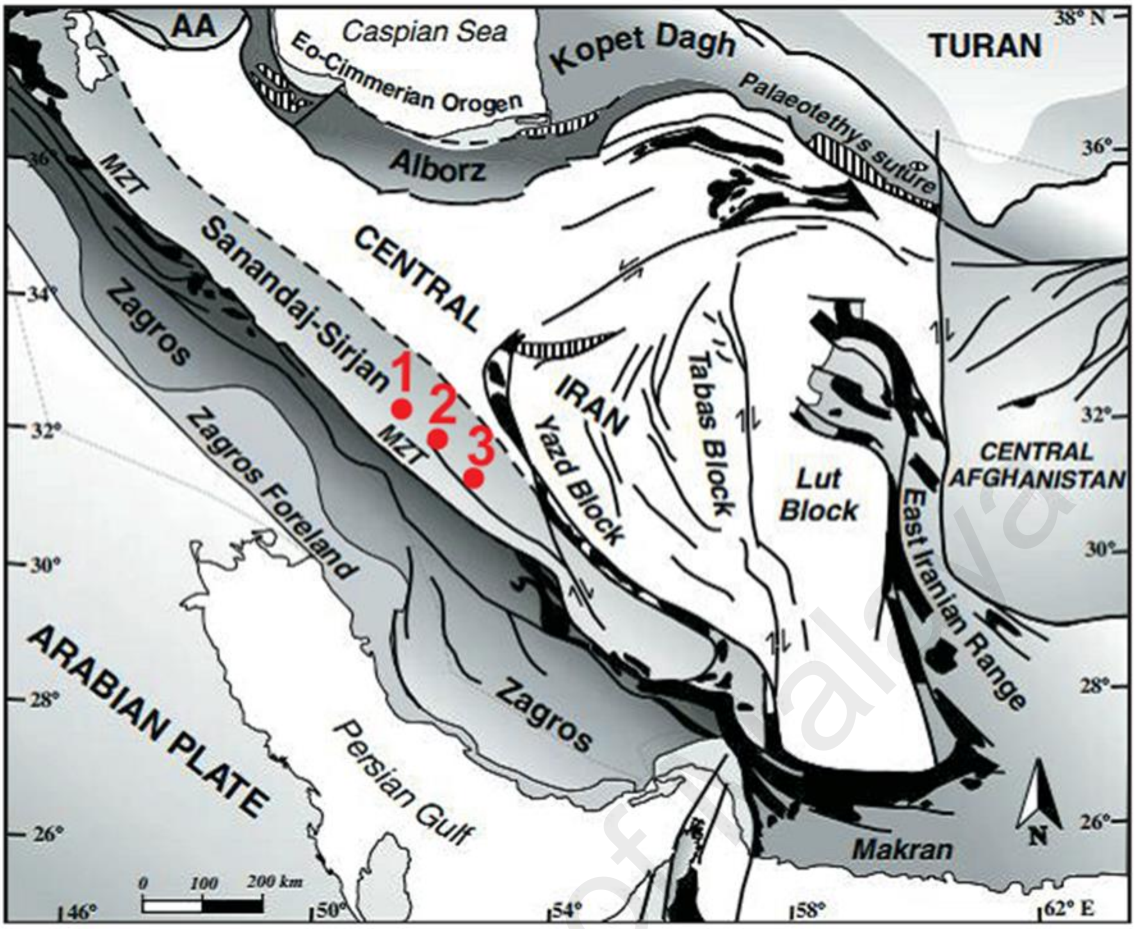

Figure 1.1: Tectonic subdivisions of Iran (base map after Angiolini et al. 2007). (1): Tang-e-Darchaleh Section; (2): Asad Abad II Section; (3): Banarizeh Section.

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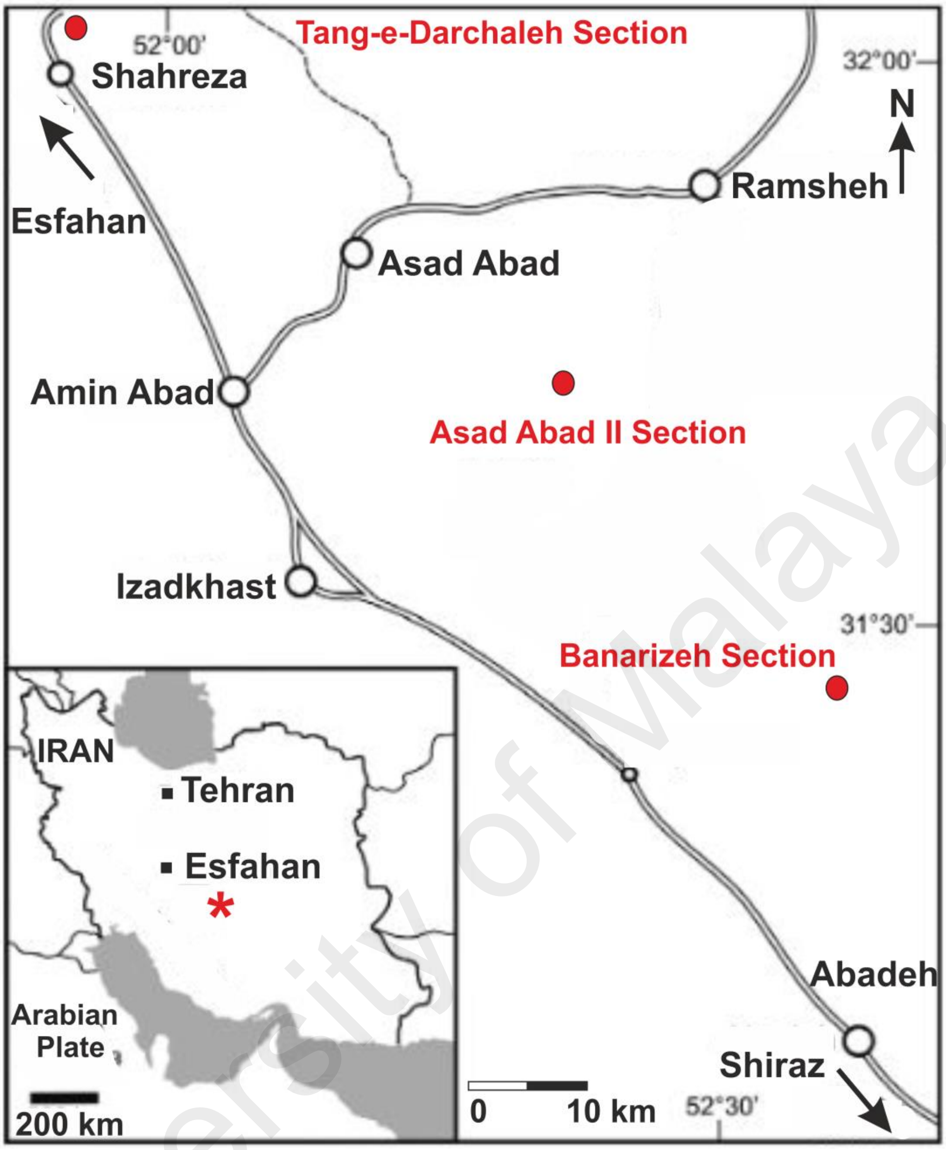

Figure 1.2: Map of the Shahreza-Abadeh areas showing the location of the three sections under studied in this research (modified after Hampe et al. 2013).

CHAPTER 2: LITERATURE REVIEW

The presence of the continuous Carboniferous and Permian carbonate and siliciclastic sequences has long been known from Iran. Some information about Early Carboniferous foraminifers in Iran can be found in Gaetani (1968), Vachard (1996), Bozorgnia (1973), Lys et al. (1978), Kalantari (1986), and Ueno et al. (1997). Recently, the Early Carboniferous foraminiferal faunas from the Alborz and Central Iran were studied in detail by Devuyst (2006), Brenckle et al. (2009), Zandkarimi et al. (2014), Vachard and Arefifard (2015), and Falahatgar et al. (2015). Over recent years, on the other hand, the Carboniferous and Permian fusulinids and stratigraphy were comprehensively investigated in predominantly Central Iran, East Iran, Alborz, and the Sanandaj-Sirjan Zone (Leven & Taheri, 2003; Leven et al. 2006d; Leven & Gorgij, 2006a,b, 2007, 2008a,b, 2009, 2011a,b,c; Davydov & Arefifard, 2007; Gaetani et al. 2009; Leven et al. 2011).

Despite the fairly common occurrence of Bashkirian and Moscovian deposits in Iran, their fusulinids have not been investigated in detail until recent years. The fusulinid-bearing Bashkirian strata have been identified in the Alborz, Central Iran, East Iran, and the Sanandaj-Sirjan Zone by Leven and Gorgij (2011c). Bashkirian fusulinids of the Ghaleh Formation of Central Iran and East Iran have been studied in detail by Leven et al. (2006d). A typical Syuranian fusulinid assemblage (earliest Bashkirian) is known from the Zaladou section of East Iran (Leven & Gorgij, 2011c). The Syuranian species *Plectostaffella jakhensis* Reitlinger also occurs in the Dozdehband Formation of the Central Alborz (Gaetani et al. 2009). Leven and Gorgij (2011c) presented new data for Akavassian (early Bashkirian) fusulinid assemblages from the Zaladou Section of East Iran and the Anarak sections of Central Iran. Representatives of the Akavassian assemblage also occur in the East Alborz, and they are confined to the Qezelgaleh Formation that yields *Pseudostaffella antiqua* (Dutkevich), *Ps. grandis* Schlykova, and

Ps. compressa Rauser-Chernousova (Lys et al. 1978). Askynbashian (late Bashkirian) fusulinids have not been found in Central Iran (Leven & Gorgij, 2011c). Recently, Gaetani et al. (2009) carried out the detailed study on the Pennsylvanian–Early Triassic stratigraphy of the Alborz. According to their study, two representatives of the Askynbashian fusulinids are present in the Qezalgaleh Formation of the eastern Alborz: they are *Profusulinella* (*Depratina*) aff. *parva* (Lee & Chen) and *Pr.* (*Depratina*) *convoluta* (Lee & Chen).

In the Anarak Section of Central Iran, fusulinids of the late Bashkirian–early Moscovian transition beds are characterized by species of *Profusulinella* (*Depratina*) ex gr. *parva* Lee & Chen, *Pr.* (*Depratina*) *pseudoparva* Leven & Davydov, *Pr.* (*Depratina*) *omiensis* Watanabe, *Pr.* (*Depratina*) aff. *subovata* Safonova, *Pr.* (*Depratina*) *prisca* (Deprat), *Pr.* (*Depratina*) *beppensis* Toriyama, *Aljutovella* aff. *artificalis* Leontovich, *Al.* cf. *cybaea* Leontovich, *Al. tumida* Bensh, *Al. cafirniganica* Bensh, *Al.* aff. *stocklini* Leven & Davydov, *Al. conspecta* Leontovich, *Al. iranica* Leven & Davydov, *Ozawainella fergaensis* Dzhentchuraeva, *Oz. kurakhovensis* Manukalova, *Oz. vozhgalica* Safonova, *Oz.* cf. *mosquensis* Rauser Chernousova, *Oz. paracompressa* Grozdilova & Lebedeva, *Oz.* aff. *paratingi* Manukalova, *Oz. eoangulata* Manukalova, *Oz.* aff. *grandis* Putievskaja, and *Tikhonovichiella pseudoaljutovica* (Rauser-Chernousova) (Leven et al. 2006d). They occur in association with species of *Pseudostaffella, Fusiella, Eostaffella, Novella*, and *Seminovella* (Leven et al. 2006d).

In the Sanandaj-Sirjan Zone of Iran, the occurrence of fusulinids from the Bashkirian–Moscovian transition beds was not known previously. The present findings from the upper Ghaleh Formation can therefore fill in this gap.

The first data on the Moscovian fusulinids of Iran were published by Lys et al. (1978) and Jenny et al. (1978), who both studied the Moscovian Stage in the Qezelqaleh Formation of the East Alborz. Later, deposits of the Moscovian Stage were established by Baghbani (1993) in the Tang-e-Darchaleh Section of the Sanandaj-Sirjan Zone. Illustrations of few poorly oriented Moscovian fusulinids from J. Jenny's collections of the Qeselqaleh Formation of the East Alborz can also be found in Vachard (1996). Moscovian fusulinids from Central Iran and East Iran have been described recently by Leven et al. (2006d). The Moscovian fusulinids in the Qezelqaleh Formation of the Alborz have also been discovered and described by Gaetani et al. (2009).

As pointed out by Leven and Gorgij (2011c), the Moscovian sections of Iran are not studied as detailed as those of the East European Platform, so they cannot be subdivided to the same degrees of biostratigraphic resolution. Nevertheless, Moscovian fusulinid assemblages characterizing the lower three of the four Moscovian substages, namely, the Vereian, Kashirian, and Podolskian are recognizable in Iran with sufficient information (see Leven & Gorgij, 2011c). Only Myachkovian (latest Moscovian) fusulinids have not yet been found in Iran.

Based on the results of recent investigations, the Vereian fusulinid assemblages occur in the lowermost parts of the Absheni Formation in Central Iran and East Iran (Leven et al. 2006d). Representatives of the Vereian assemblage also occur in the lower part of the Qezelqaleh Formation in Alborz. The Kashirian fusulinid assemblages are well known in Central Iran and East Iran, and they are confined to the middle parts of the Absheni Formation (Leven et al. 2006d). Sparse fusulinids of the Kashirian age are also known from the Qezelqaleh Formation of the East Alborz (Gaetani et al. 2009; Lys et al. 1978; Vachard, 1996).

Recently, new fusulinids of Moscovian age, corresponding to the Kashirian and Podolskian substages, were reported by Leven and Gorgij (2008a) from the Sanandaj-Sirjan Zone. The assemblage of Podolskian fusulinids in Iran is so far only known in the Sanandaj-Sirjan Zone. Beyond the Sanandaj-Sirjan Zone Podolskian and Myachkovian fusulinids are not yet been known in Iran so far.

In previous years, the latest Pennsylvanian and Permian fusulinids were also extensively investigated in the Zagros, Central Iran, East Iran, the Sanandaj-Sirjan Zone, and the Alborz (e.g. Douglas, 1950; Taraz, 1969, 1971, 1973, 1974; Iranian-Japanese Research Group, 1981; Baghbani, 1993, 1997; Partoazar, 1995; Kalantari, 1995; Leven & Taheri, 2003; Leven & Gorgi, 2006a,b, 2007, 2008b, 2009, 2011a,b,c; Davydov & Arefifard, 2007; Gaetani et al. 2009; Leven et al. 2011).

In the Sanandaj-Sirjan Zone, the fusulinids and biostratigraphy of the Carboniferous–Permian sequence were investigated by several earlier researchers. The Abadeh region and the area to the southwest were mapped and were investigated by geologists of the former Anglo-Iranian Oil Company in 1935–1936 and the results were published in the 1:250.000 Geological Map Series of Iran by the British Petroleum Company, Ltd. in 1963 and 1969 (Iranian-Japanese Research Group, 1981). Douglas (1950) was the first who reported some fusulinid species from the Sanandaj-Sirjan Zone (Leven & Gorgij, 2011c). Later, Taraz (1971, 1974) identified in the Abadeh area the limestones of the Lower Carboniferous, sandstones probably of the Upper Carboniferous, and the Permian deposits. He subdivided the Carboniferous strata into two informal groups; namely, the ‘Limestone Group’ of Lower Carboniferous and the ‘Sandstone Group’ of a probable the Upper Carboniferous age. The underlying ‘Limestone Group’ of Taraz (1971, 1974) has generally been left in open lithostratigraphic nomenclature, often referred to as ‘Carboniferous beds’ (e.g. Baghbani, 1993).

In the Permian succession, Taraz (1974) distinguished Artinskian and Guadalupian strata, the Abadeh Formation and the beds corresponding to the Dzhulfian Stage (Leven & Gorgij, 2011c). Later, the Permian succession of the Abadeh region was studied in detail by the Iranian-Japanese Research Group (1981). According to the conclusions of that group, the Permian succession in the Abadeh region spans the stratigraphic interval from the Bolorian to Dorashamian stages. This interval from the base upward is subdivided into three formations; namely, the Surmaq Formation (beds 1–3), the Abadeh Formation (beds 4a, 4b and 5) and the Hambast Formation (beds 6 and 7) (Iranian-Japanese Research Group (1981). Baghbani (1993) after reinvestigation of several sections in the Abadeh and Shahreza regions introduced the Vazhnan Formation for the Lower Permian strata. Besides he changed, to some extent, the stratigraphic ranges of the Abadeh and Hambast formations. Based on the fusulinids, Baghbani (1993) assigned a Sakmarian age to the Vazhnan Formation, although a large part (his units 3–7) of the formation was reported to be barren of diagnostic fossils. Lately, this age determination was revised: the Vazhnan Formation was attributed to the late Gzhelian–Asselian age, rather than the Sakmarian (Leven & Gorgij, 2011b,c). Fassihi (1998) described the Permian sequence in the Shahreza area. Kobayashi and Ishii (2003a,b) delineated Permian fusulinids collected by Iranian-Japanese Research Group (1981) from the Abadeh region. The fusulinids of the Bolorian and Kubergandian age in the Sanandaj-Sirjan Zone were studied by Leven and Gorgij (2008b). The Carboniferous–Permian boundary interval in the Sanandaj-Sirjan Zone was also studied by Fassihi et al. (2014, 2017).

As a result, the characteristics of fusulinids from all the Carboniferous and Permian stages of Iran have been shown, except for the Kasimovian Stage. So far, more than 400 fusulinid species have been identified from the Iranian sections (Leven & Gorgij, 2011c).

CHAPTER 3: METHODOLOGY

This study consisted of the field and laboratory investigations. In the field work, three sections; namely, the Banarizeh (630 m thick), the Asad Abad II (Pennsylvanian strata; 678 m thick), and the Tang-e-Darchaleh sections (528 m thick) were measured on the successions mainly composed of calcareous or terrigenous units (Figure 3.1). These sections were measured and samples taken using the tape and compass method. Samples were collected throughout the sections at different intervals at lithologic changes, and rock textures were recorded using the general field textural classification of Dunham (1962). About 750 samples have been collected from nearly each bed of the three sections under consideration. Collection of the rock samples was carried out with the special focus on the lithological changes observed in the field, and sampling was carried out in the intervals ranging from several centimeters to maximum three meters.

Laboratory investigation includes microscope study. About 960 thin sections have been prepared for micropaleontological analysis of the carbonate samples. In the micropaleontological investigations, the thin sections were studied under polarized light with an Olympus BX51 polarizing binocular microscope and the images have been taken in x4, x5, and x10 objectives. Most of thin sections contained foraminifers, calcareous algae, and some other fossils such as crinoids, brachiopods, gastropods, and bryozoans. Biostratigraphic and paleontological data were collected about the foraminiferal assemblages with the traditional methods of preparation and examination. The dimensions of the fusulinids and smaller foraminifers from the studied sections were determined. Individuals belonging to each species were photographed and classified according to the taxonomical hierarchy. After identification and discrimination of foraminifers, by using their distributions, the foraminiferal zones for the three sections in question were recognized.

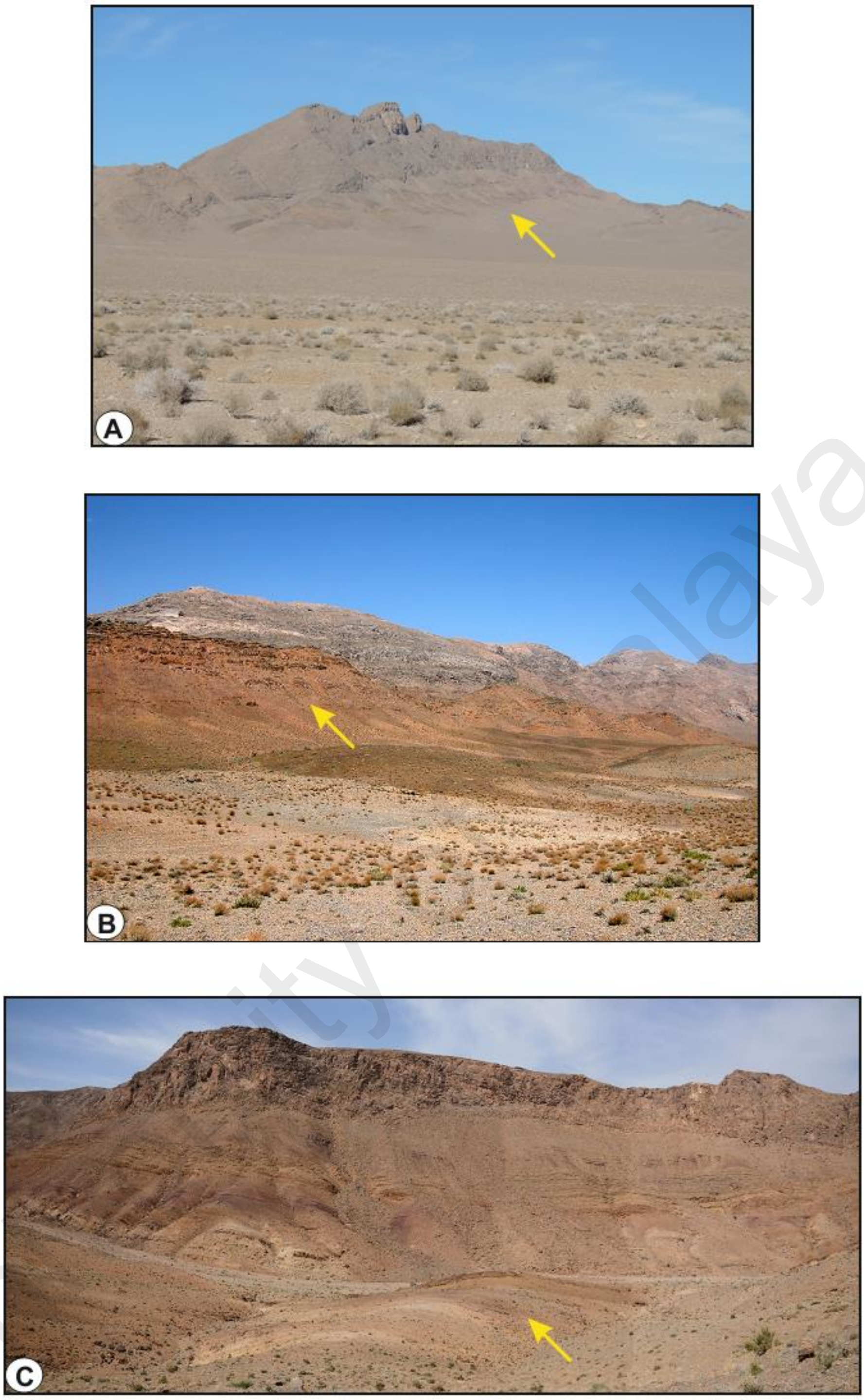

Figure 3.1: Photographs from the three sections under studied in this project.

(A) The view of the Banarizeh Section (630 m thick); **(B)** The view of the Asad Abad II Section (1180 m thick); **(C)** The close up view of the Tang-e-Darchaleh Section (528 m thick).

CHAPTER 4: RESULTS

In the Sanandaj-Sirjan Zone, Carboniferous–Permian strata are widely exposed with a nearly complete succession. The traditional lithostratigraphic subdivisions of the Carboniferous strata are as follows:

First, the Mississippian strata are represented by the sequences of limestone intercalated with shale and sandstone in the upper part. The strata of the Tournaisian, Viséan, and Serpukhovian ages correspond to the Shishtu Group of the Tabas block sections in East Iran. According to recent studies, the Shishtu Group consists of the Shishtu 1 and Shishtu 2 formations (Leven & Gorgij, 2011c). The Shishtu 1 Formation of Frasnian–early Tournaisian age is composed of sandstones and shale intercalated with the limestones. The Shishtu 2 Formation is mostly composed of the carbonate strata. Stocklin (1971) assigned the late Tournaisian–Viséan age to this formation that most likely spans the upper Viséan and Serpukhovian (Leven & Gorgij, 2011c).

Second, the Sardar Group of Pennsylvanian age unconformably overlies the Shishtu Group. It consists of the Ghaleh and Absheni formations which correspond roughly to the Bashkirian and Moscovian stages (Leven & Gorgij, 2011c). However, the conodont data of Boncheva et al. (2007) and the present results show that the stratigraphic range of the Ghaleh Formation is revised and the formation in question is now shown to be of the uppermost Serpukhovian–Moscovian (Vereian substage), rather than the Bashkirian. The Ghaleh Formation is composed chiefly of limestone, with argillite, aleurolite, and sandstone intercalations. Basal conglomerates of this formation rest on the sandy limestone of the Shishtu Group. The Absheni Formation of Moscovian age is dominated by the limestone in the lower part and by shale in the upper part. Abundant fusulinids in this formation are characteristic of the Kashirian and Podolskian substages (Leven & Gorgij, 2011c). This is overlain by a conglomerate bed of the

Anarak Group. The conglomerate bed was considered by Baghbani (1993) as the basal part of the Vazhnan Formation (now known to be of Gzhelian–Asselian in age, see Leven & Gorgij, 2011b).

The Vazhnan Formation belonging to the Anarak Group was first established by Baghbani (1993). It includes conglomerates, sandstone, shale, and limestone beds. Conglomerates or red laterites occurring at the formation base overlie the Moscovian deposits (Leven & Gorgij, 2011c). Based on the small numbers of fusulinids that have been found, Baghbani (1993) attributed the formation to the Asselian–Sakmarian stages. However, because the representative fusulinids are poorly preserved, the presence of the Sakmarian rocks in the formation is uncertain (Leven & Gorgij, 2011b,c). Recently, the age of the Vazhnan Formation is revised by Leven and Gorgij (2011b). Accordingly, the fusulinids from the formation lower part belong to Gzhelian age and are of the Asselian Stage in the higher interval. Hence, the Sakmarian Stage is acceptable only for the uppermost part of the formation, though this still needs confirmation (Leven & Gorgij, 2011c).

At the Sanandaj-Sirjan Zone, the succession of an upper Lower–Upper Permian age is introduced as the Tabas Group (Leven & Gorgij, 2011c), that consists of the Surmaq, Abadeh and Hambast formations in ascending order. The Surmaq Formation consists of Bed 1 (limestones), Bed 2 (calcareous–cherty rocks), and Bed 3 (limestones) (Iranian-Japanese Research Group, 1981). Fusulinids occur all over the formation sequence, as described by Baghbani (1993) and Kobayashi and Ishii (2003a,b). The fusulinids found in Bed 1 are characteristic of the Bolorian, Kubergandian, Murgabian, and the lower part of the Midian stages. Stratigraphic ranges of the fusulinids suggest Beds 2 and 3 span an interval of Middle Permian, corresponding to the Midian (Leven & Gorgij, 2011c). The Abadeh Formation includes Beds 4a and 4b of shale with subordinate limestone interlayers and Bed 5 of limestone with interlayers of shale

(Leven & Gorgij, 2011c). The fusulinids such as *Chusenella abichi* and *Chusenella longa* found in Bed 4a indicate a late Midian age (Leven & Gorgij, 2011c). Bed 4b is devoid of fusulinids, its Midian age is based on the ammonoids and conodonts (Iranian Japanese Research Group, 1981). Bed 5 of the basal Dzhulfian is dated based on the distribution of the conodonts (Korte et al. 2004).

The Hambast Formation including Beds 6 and 7 is designated principally by limestone with thin interlayers of argillaceous shale. Plentiful conodonts found in this formation are characteristic of the late Dzhulfian and Dorashamian stages. The Hambast Formation is overlain conformably by the lower Triassic deposits. As a matter of fact, the Sanandaj-Sirjan Zone is one of few areas in the world, where the Permian succession continues into the Triassic sediments.

This study focuses on the Lower Carboniferous–Lower Permian sequence, in which three sections; namely, the Asad Abad II, Banarizeh, and Tang-e-Darchaleh sections have been defined and examined in order to delineate the Mississippian–Asselian foraminifers and biostratigraphy of the Sanandaj-Sirjan Zone.

4.1 Asad Abad II Section

The Asad Abad II Section was introduced by Fassihi et al. (2017) separate from the original Asad Abad Section of Boncheva et al. (2007). The Asad Abad II Section (coordinates: N31˚46′13.4″; E52˚08′56.9″), structurally belongs to the Shahreza-Hambast-Abadeh Belt and is situated approximately 35 km southeast of the Shahreza town (Figure 4.1). At the Asad Abad II Section a sequence of 1180 m thick displays the carbonate deposits in the lower part, whereas the upper part is composed of alternating siliciclastic and carbonate deposits. The contact of the lower part of this interval is not exposed, and the upper part is overlain unconformably by the Surmaq Formation (upper

Lower Permian–Middle Permian). In lithological composition, a section of the Mississippian–Asselian interval is divided, from the base upward into three groups; namely, the Shishtu, Sardar, and Anarak groups (Figures 4.2 & 4.3).

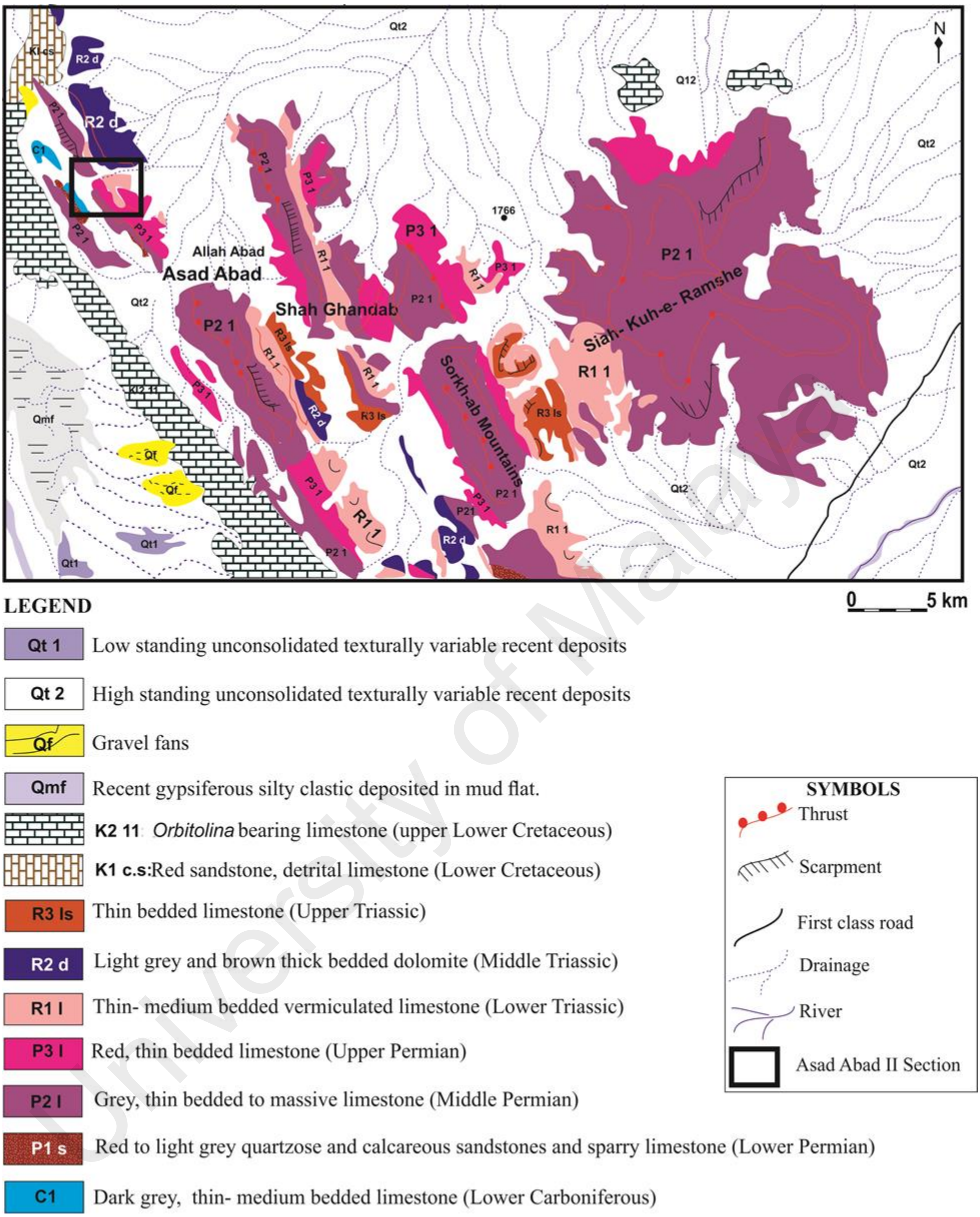

Figure 4.1: The geological map of the Shahreza area, showing the location of the Asad Abad II Section (adapted after Fassihi et al. 2017). The base map from the Esfahan Map, 1:250.000 series sheet, No. J7 (Zahedi et al. 1978).

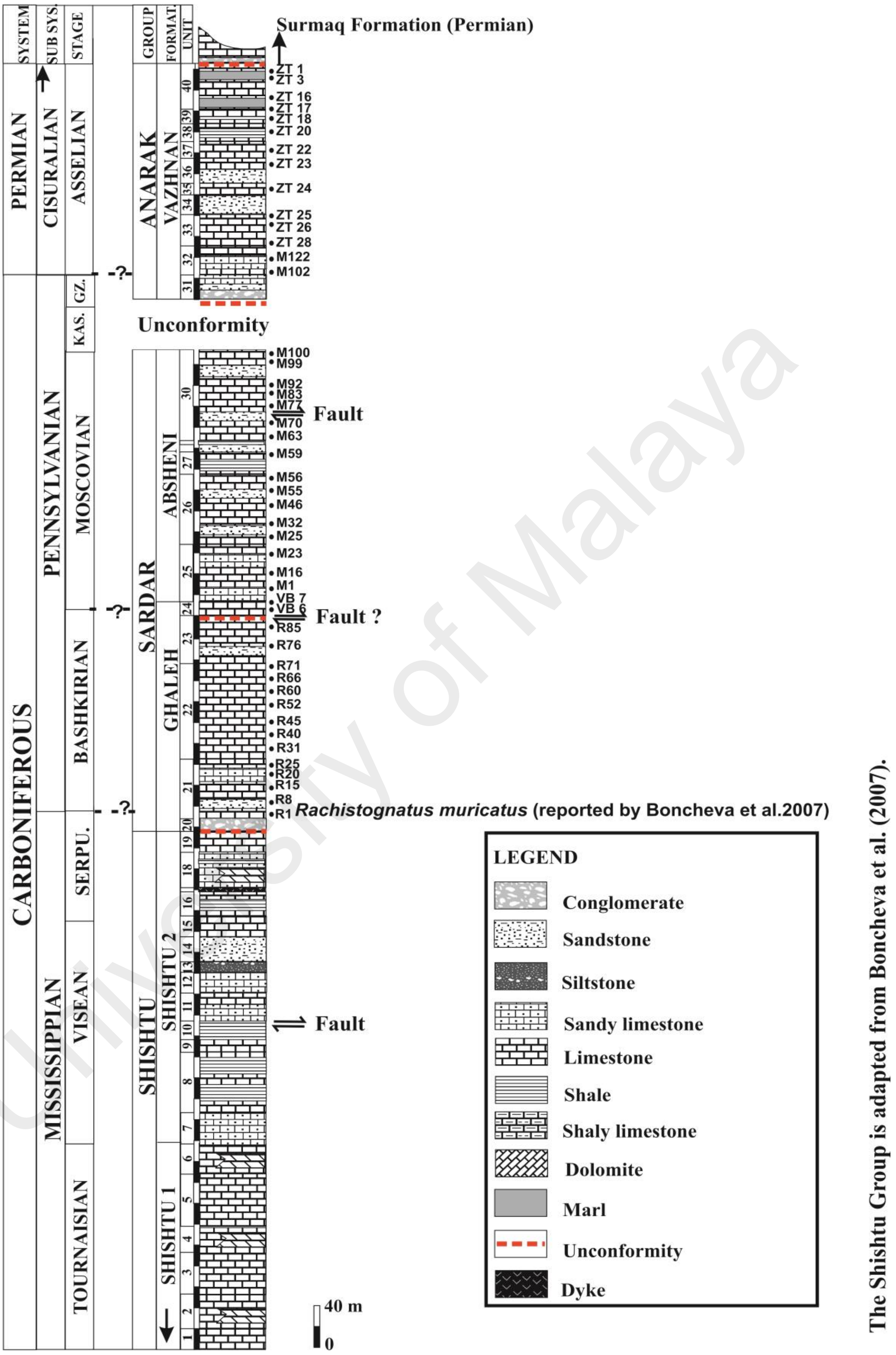

Figure 4.2: The stratigraphic log of the Asad Abad II Section in the Shahreza area. **Note:** Abbreviations: **(GZ.)** = Gzhelian; **(KAS.)** = Kasimovian; **(SERPU.)** = Serpukhovian; **(SUB SYS.)** = Subsystem; **(FORMAT.)** = Formation.

Figure 4.3: Field photograph of the Carboniferous sequence in the Asad Abad II Section of the Shahreza area (view: Northwest).

The following units are exposed in the Asad Abad II Section from base to the top:

4.1.1 Shishtu Group

The lithostratigraphic subdivisions of the Shishtu Group in the Asad Abad II Section are adapted from the Boncheva et al. (2007). In the original Asad Abad Section, a sequence of the Shishtu Group (Mississippian), 497 m thick, starts with limestones intercalated in the upper part with the shale and sandstone (Boncheva et al. 2007). Because of the absence of index conodonts, Viséan and probably most of Serpukhovian cannot be recognized in details, on the conodont base (Boncheva et al. 2007). However, the ammonoids such as *Neoglyphioceras yazdii* and *Dombarites* sp. from the siltstone bed above the base of the section, suggest the latest Viséan age (Hairapetian et al. 2006).

The contact of the lower part of this interval with the underlying strata is unexposed or more likely faulted. The upper part of the succession is overlain unconformably by the Ghaleh Formation corresponding in age to the latest Serpukhovian–earliest Moscovian.

According to Boncheva et al. (2007) the following units of the Shishtu Group are exposed in this section from base to top:

- Unit 1 (20 m). Grey, thin bedded micritic limestone, containing corals and bryozoans.
- Unit 2 (33 m). Grey, thin–medium bedded limestone, interbedded with dolomite.
- Unit 3 (40 m). Grey, medium–thick bedded limestone with brachiopods and conodonts.
- Unit 4 (25 m). Grey, medium bedded limestone interbedded with dolomite.
- Unit 5 (50 m). Grey, thin bedded limestone, containing gastropods.
- Unit 6 (29 m). Alternating grey, massive limestone and thin bedded dolomite, barren of fossils.
- Unit 7 (30 m). Sandy limestone interbedded with shale, rich in brachiopods, crinoids, bryozoans, and conodonts.
- Unit 8 (58 m). Alternating green, thin–medium bedded limestone and shale, bearing crinoids, brachiopods, and holothurian remains.
- Unit 9 (12 m). Grey, medium–thick bedded limestone, bearing brachiopods and sponge spicules.
- Unit 10 (18 m). Brownish–reddish shale, with iron nodules.

- Unit 11 (27 m). Green–yellow, thick bedded sandy limestone with crinoids, brachiopods, and conodonts.
- Unit 12 (20 m). Yellowish sandy limestone with bioclasts.
- Unit 13 (10 m). Red, thin bedded siltstone, containing brachiopods, and ammonoids.
- Unit 14 (24 m). Alternating cream, thin bedded sandstone and thin bedded limestone.
- Unit 15 (20 m). Alternating, cream, medium–thick bedded limestone and dolomite with corals and rarely trilobites.
- Unit 16 (23 m). Alternating red limestone and shale, interbedded with dolomite.
- Unit 17 (4 m). Volcanic rocks.
- Unit 18 (34 m). Alternating grey sandy limestone, shale, and dolomite.
- Unit 19 (20 m). Alternating brown, thin–medium bedded limestone and sandstone.

4.1.2 Sardar Group

In our Asad Abad II Section, the total thickness of the sediments of the Sardar Group (uppermost Mississippian–Pennsylvanian) is about 458 m. This group includes deposits of the Ghaleh and Absheni formations. Conglomerate, sandstone, and sandy limestone are dominated in the lower part, whereas most part of the section displays alternating siliciclastic and carbonate deposits. The conglomerate of the basal part of this succession rests unconformably on the alternating limestone and sandstone of Unit 19 of the Shishtu Group. The upper part is overlain unconformably by the basal conglomerate of the Vazhnan Formation (uppermost Gzhelian–Asselian). The lithological units in the Sardar Group, including the Ghaleh and Absheni formations, are as follows (from base to top):

4.1.2.1 Ghaleh Formation

In the Asad Abad II Section, the Ghaleh Formation (uppermost Serpukhovian–lowermost Moscovian) of 217 m thick starts with a polymictic limestone conglomerate that is composed largely of carbonate clasts and minor sandstone., and sandy limestone, but most part of the formation is composed of limestones occasionally intercalated with sandstone. The microfacies of the Ghaleh Formation are represented by mudstone, sandy oolitic grainstone, and bioclastic wackestone, packstone, and grainstone (Figure 4.4). The conglomerate in the basal part of this unit rests unconformably on the alternating limestone and sandstone of the Shishtu Group.

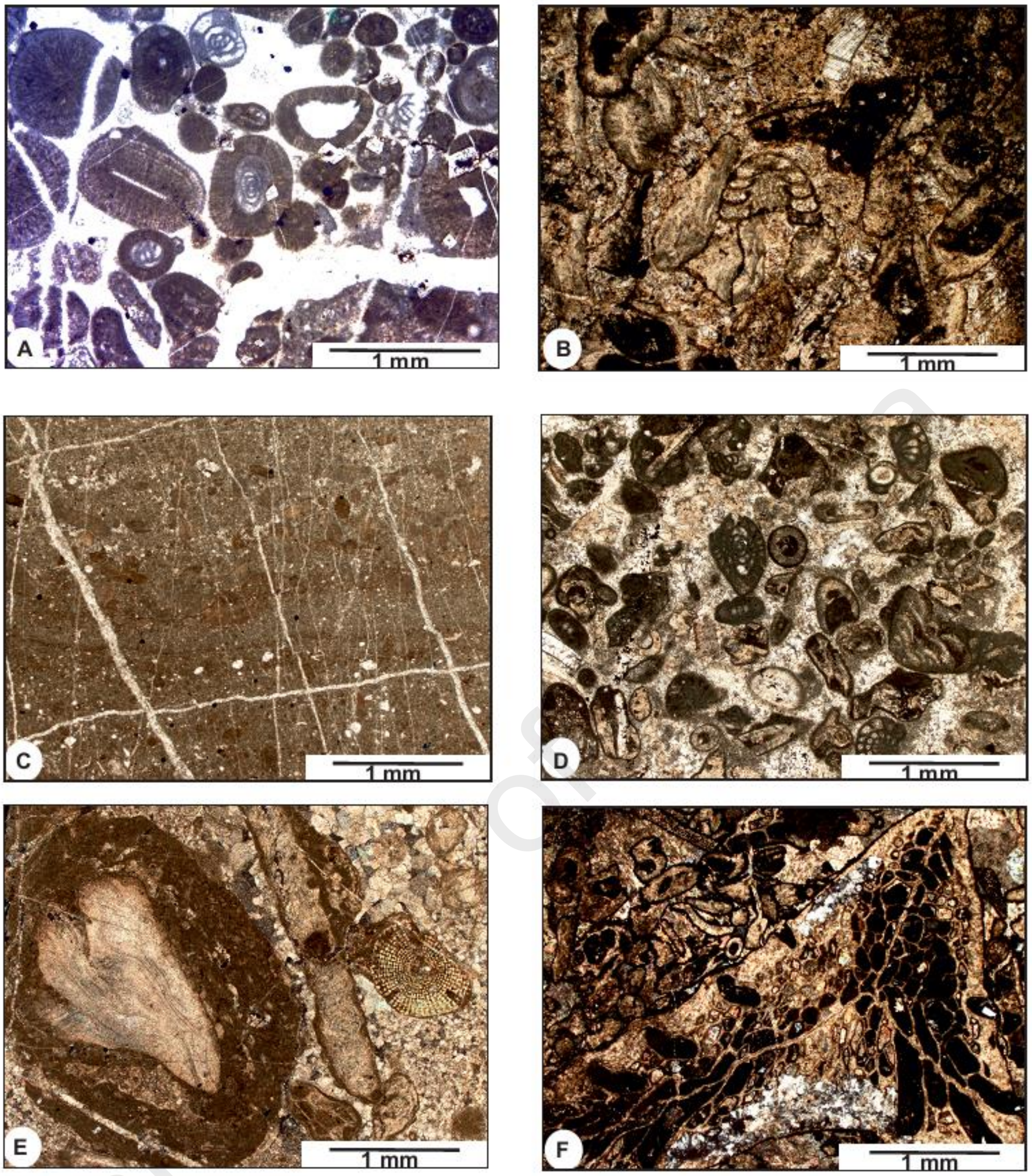

Figure 4.4: Photomicrographs of the carbonate facies of the Ghaleh Formation in the Asad Abad II Section in the Shahreza area. **Note:** Abbreviation: Spl. = Sample Number.

(A) Sandy oolitic grainstone with ooid, foraminifers, and quartz grains, Spl. R28; **(B)** Bioclastic wackestone–packstone with foraminifers and crinoids, Spl. R71; **(C)** Mudstone, Spl. R70; **(D)** Bioclastic grainstone with foraminifers, Spl. R69; **(E)** Bioclastic packstone–grainstone with algae, bryozoans, and brachiopods, Spl. R70; **(F)** Bioclastic packstone with bryozoans and crinoids, Spl. R23.

The following units are defined in this formation from base to the top:

- Unit 20 (12 m). A pebbly polymictic conglomerate with coarse carbonate clasts and minor sandsone.
- Unit 21 (57 m). Sandstone and the grey, medium bedded wackestone–packstone and sandy oolitic grainstone containing bryozoans, crinoids, corals, brachiopods, and foraminifers, changing upward into the sandy limestone (Samples R1–R30).
- Unit 22 (93 m). Grey, medium–thick bedded mudstone, wackestone, packstone, and grainstone (Samples R31–R71), containing foraminifers, algae, bryozoans, and brachiopods.
- Unit 23 (42 m). Alternating sandstone and wackestone–grainstone, containing brachiopods, crinoid fragments, and fusulinids (Samples R72–R85, VB1–VB4).
- Unit 24 (12.8 m). Grey, thin bedded wackestone–grainstone changing upward into the marly limestone, containing brachiopods, corals, crinoid fragments, and fusulinids (Samples VB5, VB6, VB6.1, and VB7).

4.1.2.2 Absheni Formation

In the Asad Abad II Section, the Absheni Formation (Moscovian) of 241 m thick is composed mainly of alternating siliciclastic and carbonate deposits occasionally intercalated with the shale. The limestones of the Absheni Formation are represented by mudstone, oolitic grainstone, and bioclastic wackestone–packstone–grainstone (Figures 4.5 & 4.6).

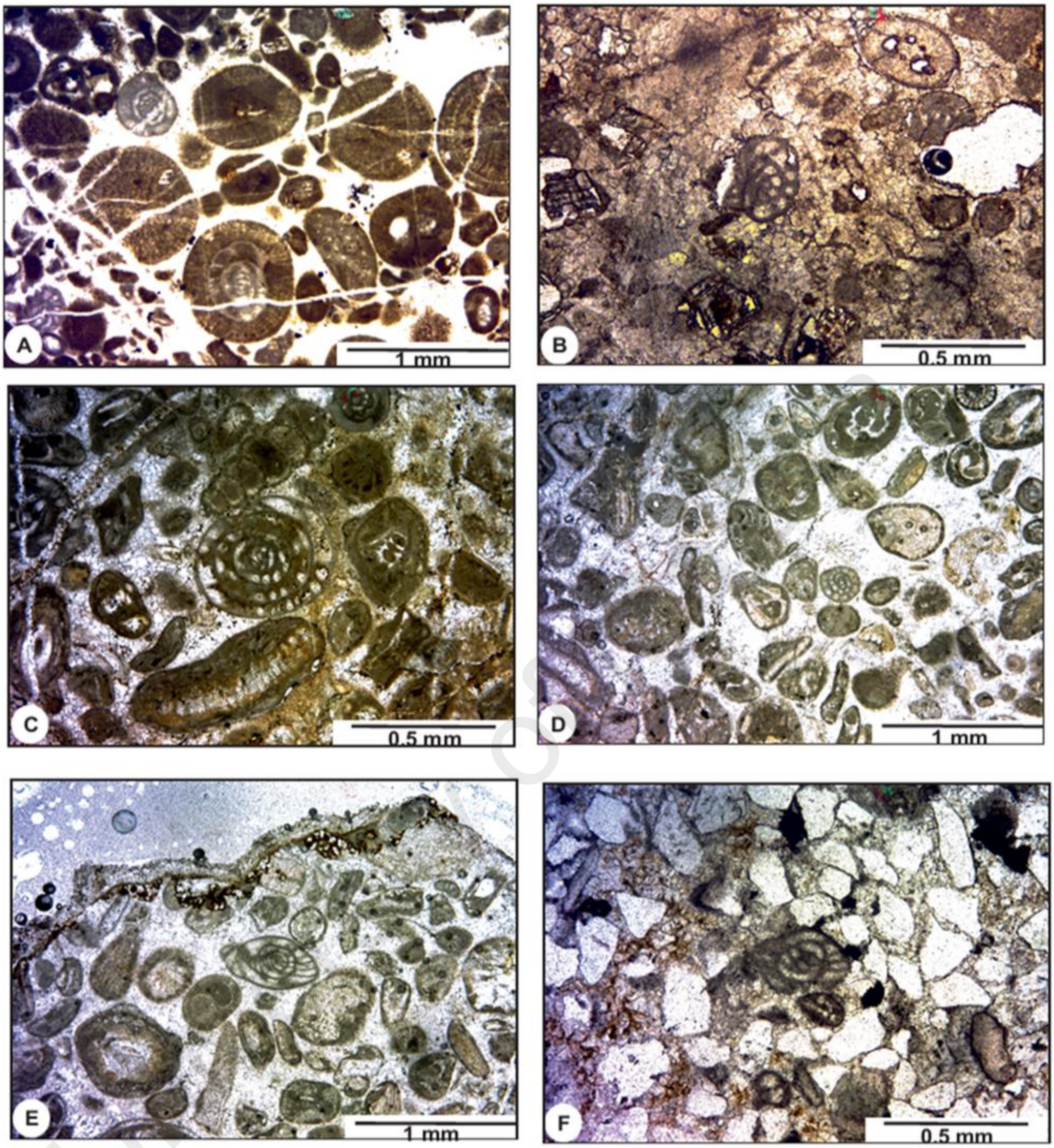

Figure 4.5: Photomicrographs of the carbonate facies of the lower part of the Absheni Formation in the Asad Abad II Section in the Shahreza area. **Note:** Abbreviation: Spl. = Sample Number.

(A) Oolitic grainstone with foraminifers and peloids, Spl. M47 ; **(B)** Bioclastic wackestone with foraminifers and crinoids, Spl. M38; **(C)** Bioclastic packstone–grainstone with foraminifers, Spl. M21; **(D, E)** Bioclastic grainstone with foraminifers, intraclasts, and coated grains, Spl. M23, M16 ; **(F)** Sandy packstone with foraminifers, Spl. M31.

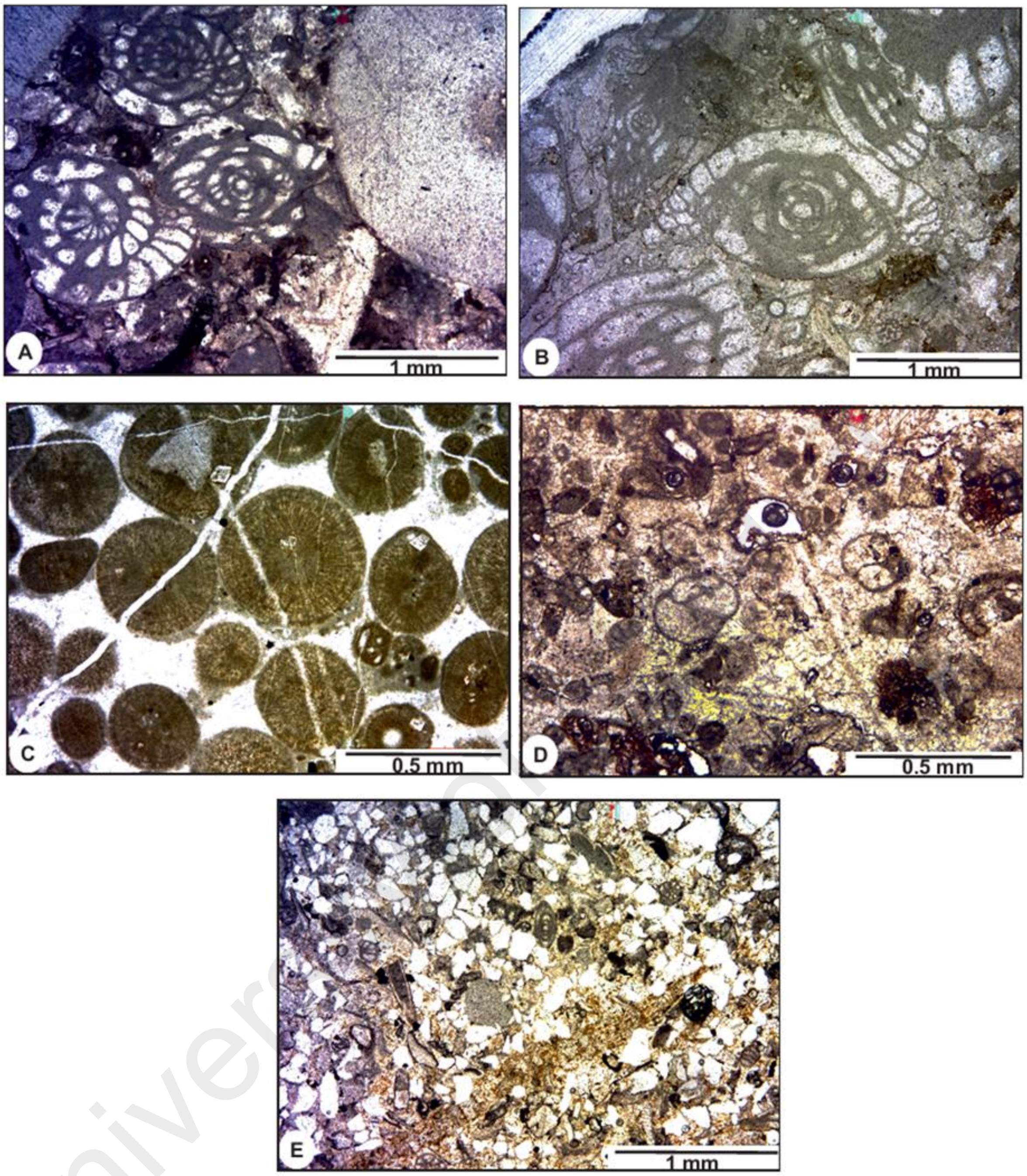

Figure 4.6: Photomicrographs of the sandstone and carbonate facies of the middle and upper parts of the Absheni Formation in the Asad Abad II Section in the Shahreza area. **Note:** Abbreviation: Spl. = Sample Number.

(A, B) Bioclastic packstone with foraminifers and crinoids, Spl. FM3, M59; **(C)** Oolitic grainstone with foraminifers and quartz grains, Spl. M64; **(D)** Bioclastic wackestone–packstone with foraminifers, Spl. FM7; **(E)** Sandy packstone with foraminifers, Spl. M60.

The lithological units in the Absheni Formation from base to the top are defined as follows:

- Unit 25 (55 m). Grey, medium bedded wackestone, packstone, grainstone intercalated with sandy limestone, containing foraminifers, algae, and brachiopods (Samples M1–M24).
- Unit 26 (67 m). Alternating purple–white sandstone and grey, medium bedded mudstone, wackestone, packstone, and oolitic grainstone, containing crinoids, brachiopods, bryozoans, and foraminifers (Samples M25–M56).
- Unit 27 (21.5 m). Cream, thin bedded wackestone, packstone, and grainstone intercalated with shale, rich in brachiopods, crinoids, foraminifers, and bryozoans (Samples M57–M59, FM1–FM9).
- Unit 28 (7 m). Purple sandstone changing upward into the cream, medium bedded sandstone (Sample M60).
- Unit 29 (4 m). Shale, containing brachiopods, bryozoans, and crinoids (Samples M61 and M62).
- Unit 30 (87 m). Grey, medium–thick bedded wackestone, packstone, and oolitic grainstone intercalated with the purple, medium bedded sandstone, containing corals, foraminifers, brachiopods, bryozoans, and crinoids (Samples M63–M100).

4.1.3 Anarak Group

4.1.3.1 Vazhnan Formation

In the Asad Abad II Section, the total thickness of the Vazhnan Formation (uppermost Gzhelian–Asselian) is about 226 m. The succession starts with the conglomerate, sandstone, sandy limestone, but most part of the section is composed of the alternating siliciclastic and carbonates changing upward into marl and shale. The microfacies of the Vazhnan Formation are represented by mudstone, bioclastic wackestone, packstone, and grainstone (Figure 4.7). This interval is overlain unconformably by the Surmaq Formation (upper Lower Permian–Middle Permian). The deposits of this interval rest directly on the Sardar Group. The presence of the siliciclastic sequence in the base of the Vazhnan Formation implies a hiatus at the formation boundary. No angular unconformity was observed.

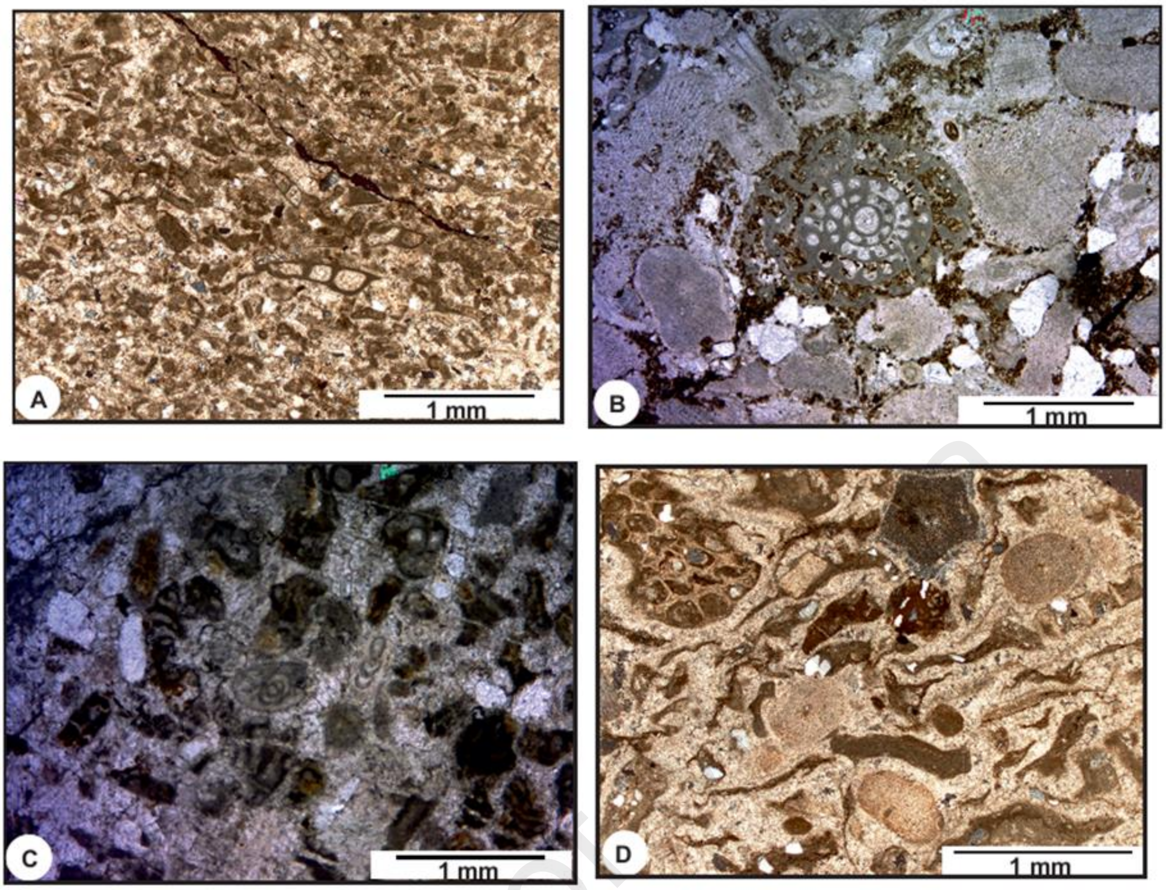

Figure 4.7: Photomicrographs of the carbonate facies of the Vazhnan Formation in the Asad Abad II Section in the Shahreza area. Note: Abbreviation: Spl. = Sample Number.

(A) Bioclastic packstone–grainstone with foraminifers, algae Spl. ZT28; **(B)** Bioclastic sandy packstone with foraminifers, crinoids, echinoderms, and bryozoans, Spl. ZT3; **(C)** Bioclastic grainstone with foraminifers and echinoderms, Spl. ZT23; **(D)** Bioclastic grainstone with foraminifers, echinoderms, and crinoids, Spl. ZT15.

The following units of the Vazhnan Formation are exposed in this section from base to the top:

- Unit 31 (23 m). A polymictic limestone conglomerate that is composed largely of carbonate clasts and minor sandstone, changing upward to sandstone, and sandy limestone (Figure 4.8: A).
- Unit 32 (28 m). Grey, medium bedded mudstone, wackestone, and packstone intercalated with the shale and sandy limestone, containing oncoids, fusulinids,

brachiopods, gastropods (*Bellerophon*), and crinoid fragments (Samples M101–M122).

- Unit 33 (30 m). Cream, medium bedded bioclastic packstone–grainstone, containing foraminifers and algae (Samples ZT25– ZT28).
- Unit 34 (19 m). Cream, medium bedded sandstone.
- Unit 35 (11 m). Grey bioclastic wackestone, containing the gastropods (Sample ZT24).
- Unit 36 (24 m). Purple, medium bedded sandstone with intercalations of brownish bioclastic packstone–grainstone, containing echinoderms and foraminifers (Samples ZT23).
- Unit 37 (16 m). Grey, medium bedded grainstone, rich in calcite veins and fractures in the base, changing into grey, medium bedded bioclastic wackestone–packstone, containing foraminifers, crinoids, and silicified brachiopod fragments (Samples ZT21–ZT22).
- Unit 38 (17 m). Alternating green, thin bedded, argillaceous limestone and shale, containing ammonoids (Samples ZT19–ZT20).
- Unit 39 (14 m). Grey–black, thin–medium bedded mudstone–wackestone intercalated with marl, changing upward into the medium bedded mudstone with rarely bioclastic fragments and chert nodules, with 2-m thick volcanic sills (Samples ZT17–ZT18).
- Unit 40 (44 m). Cream–grey, thin-medium bedded packstone–grainstone, interbedded with marl, and sandstone containing brachiopods, echinoderms, foraminifers, crinoids, and bryozoans (Samples ZT1–ZT16).

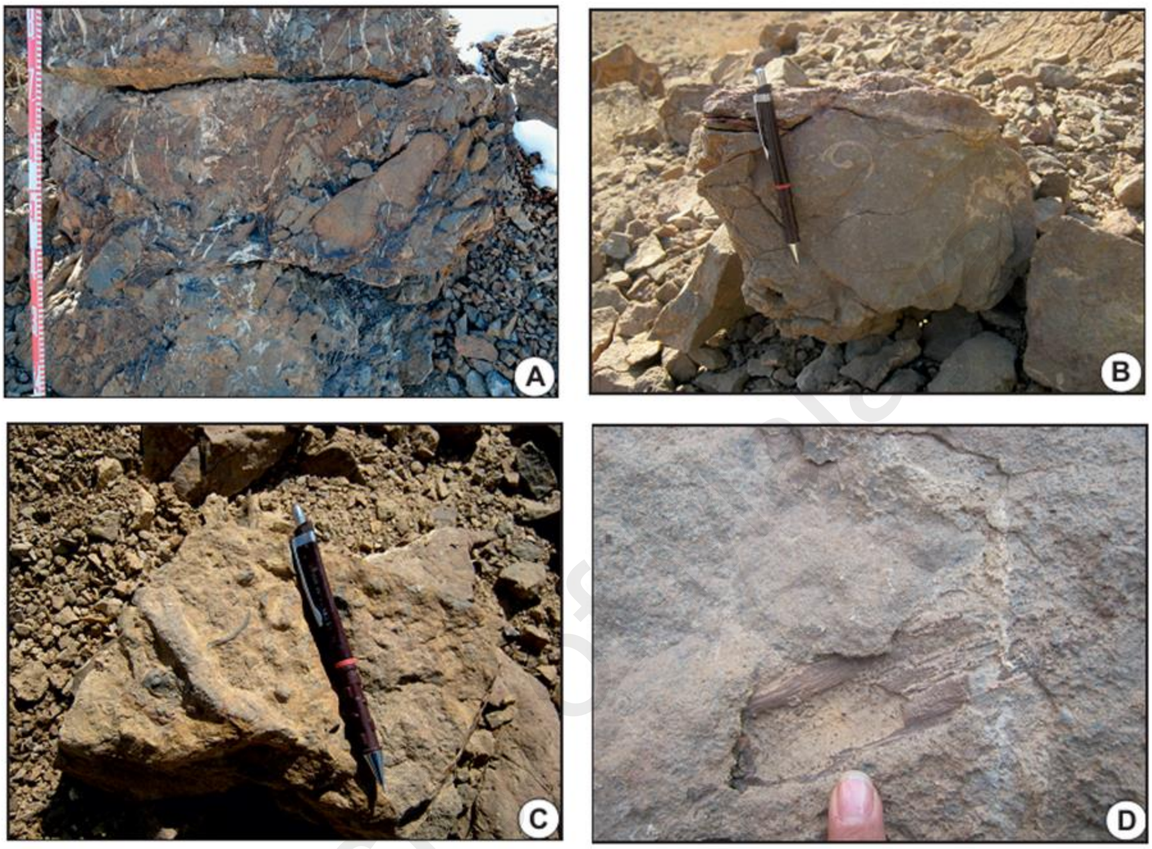

Figure 4.8: The photographs of the conglomerate, *Bellerophon*, brachiopods, and piece of the wood in the Asad Abad II Section in the Shahreza area.

(A) = The conglomerate of Unit 31 at the base of the Vazhnan Formation; **(B) =** The limestone bearing the *Bellerophon* in the Vazhnan Formation; **(C) =** The limestone bearing the brachiopods in the Vazhnan Formation; **(D) =** Close up view of the piece of the wood found in the Absheni Formation.

4.2 Banarizeh Section

The Banarizeh Section (coordinates: N31˚34′25.9″; E52˚22′30.9″), structurally belongs to the Shahreza-Hambast-Abadeh Belt and is located about 40 km northeast of the Abadeh town (Figure 4.9). At the Banarizeh Section a continuous sequence of 630 m thick is composed mainly of alternating siliciclastic and carbonate deposits. The contact of the lower part of this interval is not exposed, and the upper part is overlain unconformably by the Surmaq Formation (upper Lower Permian–Middle Permian). In lithological composition, a section of the Mississippian–Asselian interval, from the base upward, is divided into three parts; namely, the Shishtu 2 Formation, and the Sardar and Anarak groups (Figures 4.10 & 4.11).

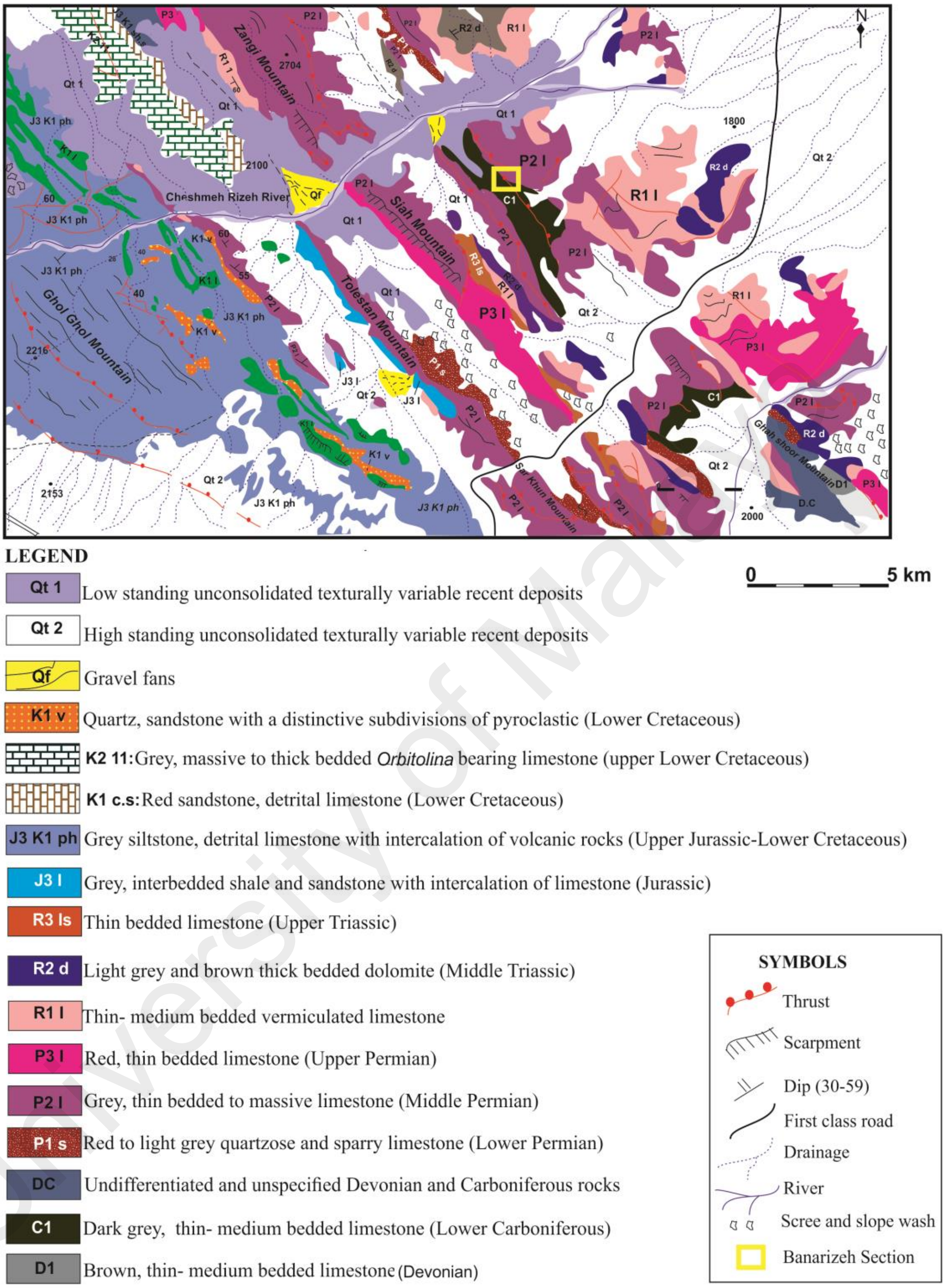

Figure 4.9: The geological map of the Abadeh area showing the location of the Banarizeh Section. The base map from the Izadkhast Map, 1:100.000 series sheet, No. 6453 (Hamzehpour & Nazari, 1998).

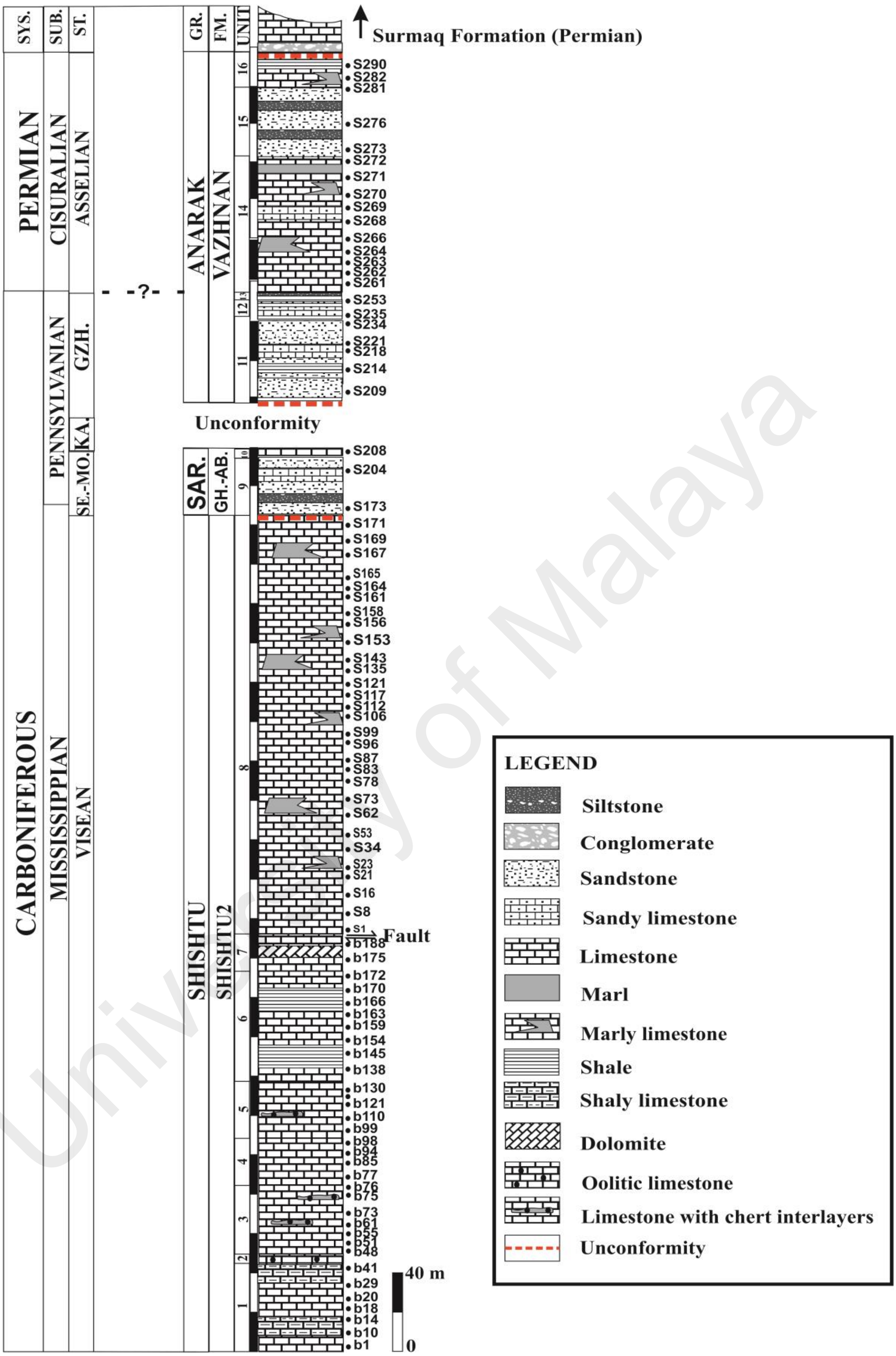

Figure 4.10: The stratigraphic log of the Banarizeh Section in the Abadeh area. **Note:** Abbreviations: **(SE.-MO.)** = uppermost Serpukhovian–Moscovian; **(KAS.)** = Kasimovian; **(GZH.)** = uppermost Gzhelian; **(GH.)** = Ghaleh; **(AB.)** = Absheni; **(SAR.)** = Sardar; **(SYS.)** = System; **(SUB.)** = Subsystem; **(GR.)** = Group; **(FM.)** = Formation.

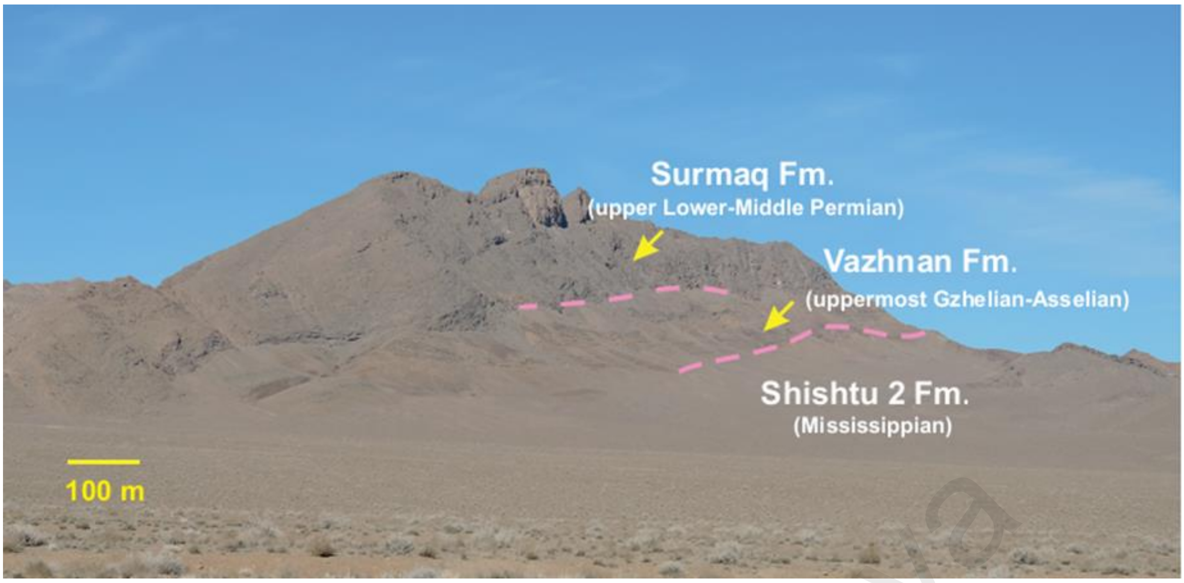

Figure 4.11: Field photograph of the Banarizeh Section in the Abadeh area (view: Northwest).

The following units are exposed in the Banarizeh Section from base to the top:

4.2.1 Shishtu 2 Formation

In the Banarizeh Section, the Shishtu 2 Formation (Mississippian), 425 m thick, starts with the limestone, shaly limestone, and shale, but most part of the section is composed of the limestones intercalated with the marl. The limestones of the Shishtu 2 Formation are represented by mudstone, bioclastic wackestone, packstone, grainstone, and oolitic grainstone (Figure 4.12). The contact of the lower part of this interval with the underlying strata is unexposed or more likely faulted. The upper part of the succession is overlain unconformably by the purple sandstone of the basal part of uppermost Mississippian–Pennsylvanian succession (Sardar Group).

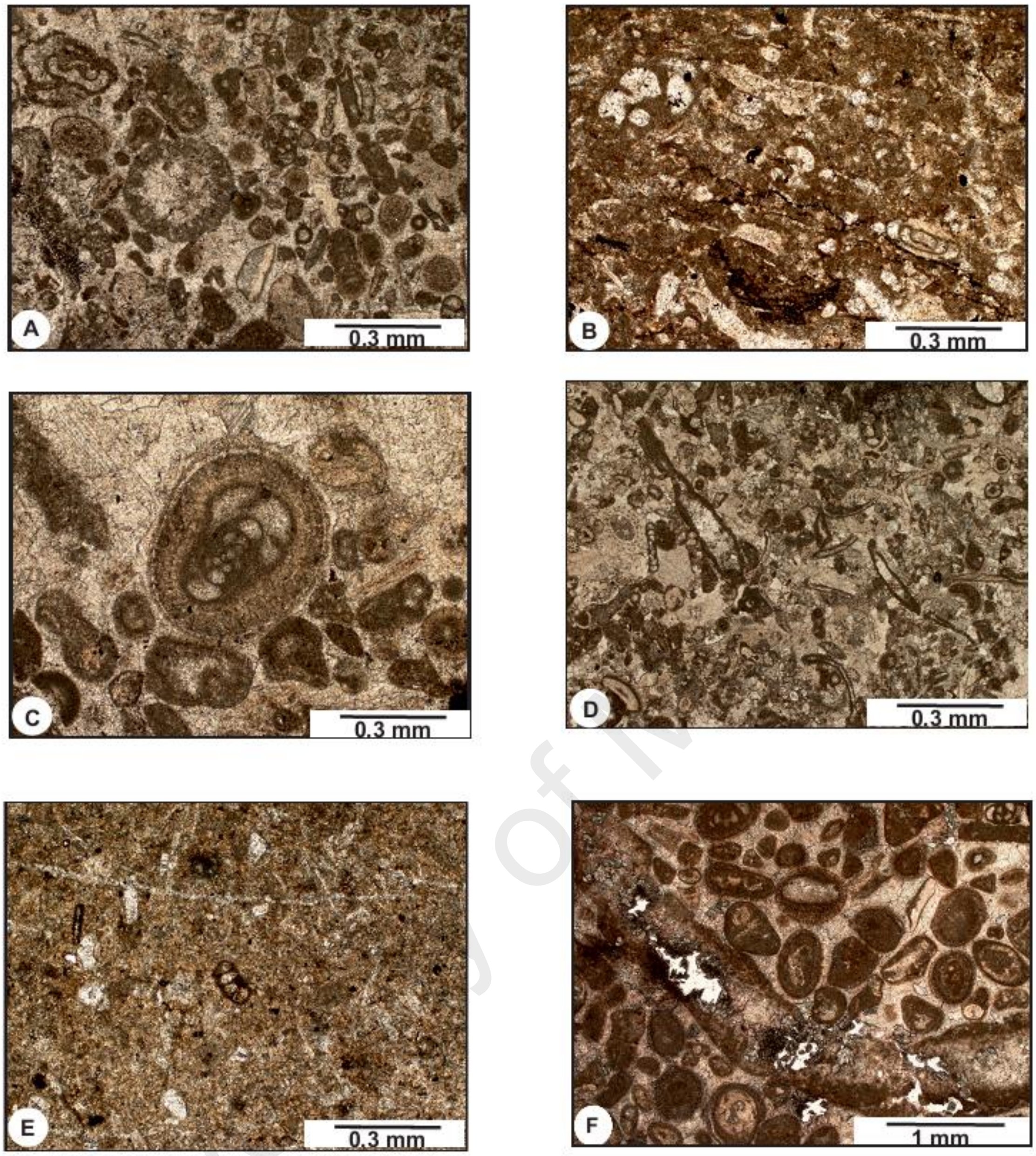

Figure 4.12: Photomicrographs of the carbonate facies in the Shishtu 2 Formation in the Banarizeh Section. **Note:** Abbreviation: Spl. = Sample Number.

(A) Bioclastic grainstone with foraminifers and algae, Spl. b44; **(B)** Bioclastic wackestone–packstone with foraminifers, Spl. b77; **(C)** Oolitic grainstone with foraminifers, Spl. b46; **(D)** Bioclastic grainstone with foraminifers, Spl. b111; **(E)** Bioclastic wackestone with foraminifers and quartz grains, Spl. S147; **(F)** Oolitic grainstone, Spl. b42.

The following units of the Shishtu 2 Formation are exposed in this section from base to top:

- Unit 1 (45 m). Dark grey, medium bedded mudstone, wackestone, packstone, and grainstone with intercalations of shaly limestone, containing foraminifers, and the medium bedded packstone–grainstone in the middle and upper part of the unit, containing the crinoids, brachiopods, bryozoans, and corals (Samples b1–b41).
- Unit 2 (4.5 m). Grey, medium bedded packstone and oolitic grainstone, containing foraminifers, crinoids, algae, brachiopods, and corals (Samples b42–b47).
- Unit 3 (35 m). Dark grey, thin bedded wackestone, packstone, and grainstone with intercalations of chert lenses, containing crinoids, corals, and brachiopods (Samples b48–b76).
- Unit 4 (24 m). Grey, medium–thick bedded wackestone–packstone with foraminifers, crinoids, corals, and brachiopods (Samples b77–b98).
- Unit 5 (29 m). Grey, massive–thick bedded packstone–grainstone with intercalations of chert layers, containing foraminifers, crinoids, and brachiopods (Samples b99–b131).
- Unit 6 (56 m). Grey, thin–thick bedded bioclastic wackestone with intercalations of shale, containing foraminifers, organic remains, corals, brachiopods, and bryozoans (Samples b132–b172).
- Unit 7 (19 m). Grey, medium bedded bioclastic packstone–grainstone changing upward into the thick bedded, dolomitic limestone and dolomite, containing corals, brachiopods, crinoids and organic remains (Samples b173–b188).
- Unit 8 (213 m). Dark grey, thin–medium bedded mudstone, wackestone, packstone, and grainstone with intercalations of marly limestone. Its contact

with the limestone of Unit 7 is complicated by a fault. This bed contains brachiopods, silicified corals, crinoids, bryozoans, and foraminifers (Samples S1–S172).

4.2.2 Sardar Group

In the Banarizeh Section, the total thickness of deposits of the Sardar Group (uppermost Mississippian–Pennsylvanian) is about 33 m. Quartz sandstone, and siltstone are dominated in the lower part, whereas the upper part of the section is composed of bioclastic limestone. The purple sandstone of the basal part of this succession rests unconformably on the limestones of Unit 8 of the Shishtu 2 Formation. The upper part is overlain unconformably by the purple sandstone and sandy limestone of the Vazhnan Formation (uppermost Gzhelian–Asselian). The lithological units in the Sardar Group from base to top are as follows:

- Unit 9 (29 m). Purple, fine–medium grained sandstone interbedded with siltstone and sandy limestone, containing brachiopods, crinoids, and bryozoans (Samples S173–S204).
- Unit 10 (4 m). Cream, thin bedded mudstone, wackestone with bryozoans, and crinoids (Samples S205–S208).

4.2.3 Anarak Group

4.2.3.1 Vazhnan Formation

In the Banarizeh Section, the total thickness of the Vazhnan Formation (uppermost Gzhelian–Asselian) is about 168 m (Figure 4.10). Sandstone, sandy limestone, marl, and siltstone are dominated in the lower part, whereas the middle and upper parts are mostly composed of the limestone intercalated with the shale and marl, changing upward into the sandstone, siltstone, marly limestone, and shale. The microfacies of the Vazhnan Formation are represented by mudstone, wackestone, packstone, and grainstone (Figure 4.13). This formation is overlain unconformably by the basal conglomerate of the Surmaq Formation (upper Lower Permian–Middle Permian). The deposits of this interval rest directly on the Carboniferous Sardar Group (Figure 4.14: A). The presence of the siliciclastic sequence in the base of the Vazhnan Formation implies a hiatus at the formation boundary.

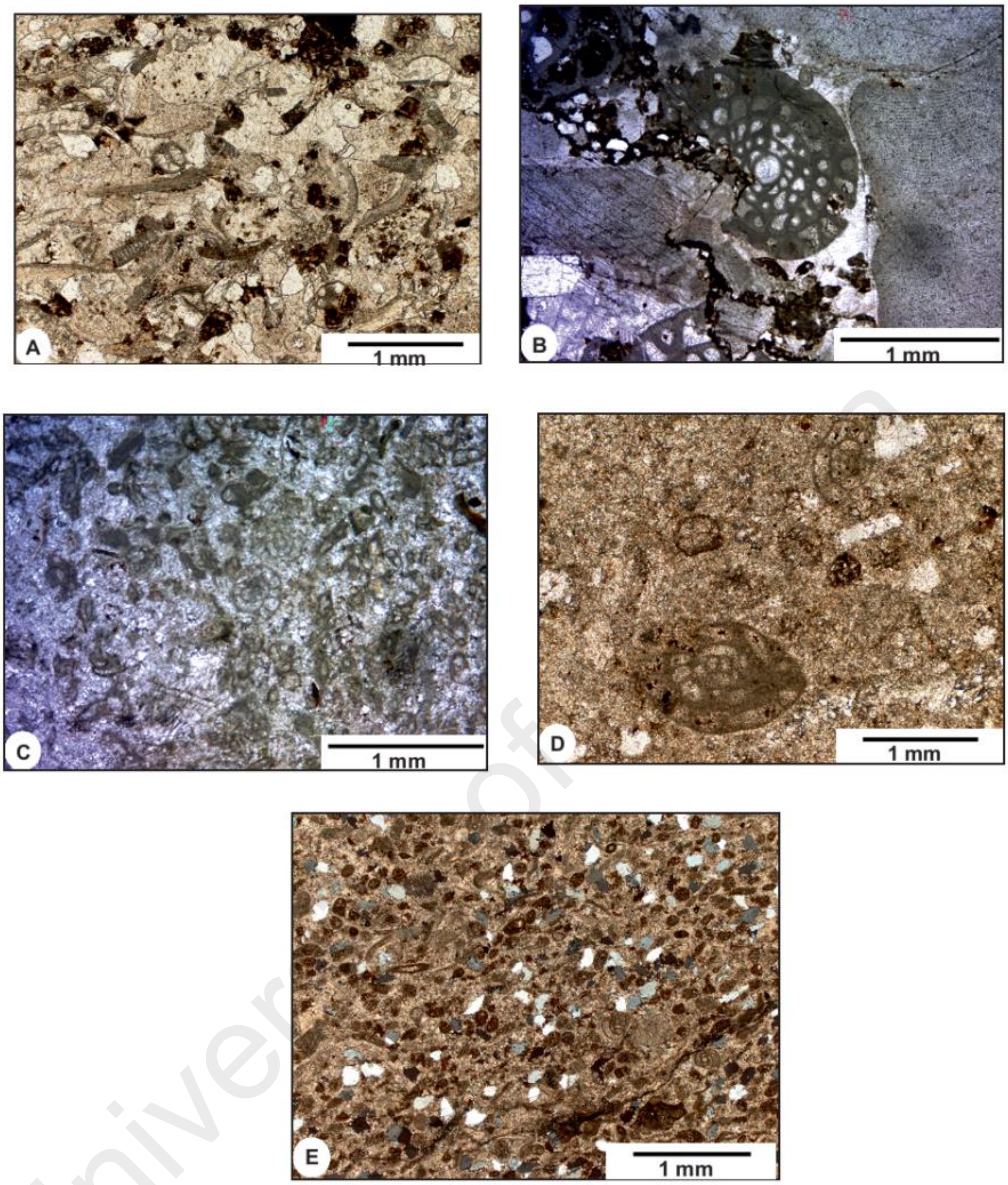

Figure 4.13: Photomicrographs of the sandstone and carbonate facies in the Vazhnan Formation in the Banarizeh Section. **Note:** Abbreviation: Spl. = Sample Number.

(A) Bioclastic grainstone with brachiopods, crinoid stems, and peloids, Spl. S243**; (B)** Bioclastic grainstone with foraminifers and echinoderms, Spl. S241; **(C)** Bioclastic packstone–grainstone with foraminifers, Spl. S251; **(D)** Bioclastic wackestone with foraminifers, Spl. S267.5; **(E)** Sandy packstone with foraminifers and peloids, Spl. S279.

The following units of the Vazhnan Formation are exposed in this section from base to the top:

- Unit 11 (32 m). Alternating white–purple, medium–fine grained sandstone and siltstone interbedded with sandy limestone and shale (Samples S209–S234).
- Unit 12 (10 m). White sandstone and sandy limestone, grading into the cream, thin bedded bioclastic packstone–grainstone, containing corals, bryozoans, crinoids, foraminifers, and brachiopods (Samples S235–S253).
- Unit 13 (4 m). Alternating white, thin–medium bedded, fine grained sandstone and siltstone enclosing interlayers of shale, containing brachiopods, *Bellerophon*, and crinoid fragments (Samples S254–S260).
- Unit 14 (69 m). Cream, thin–medium bedded bioclastic wackestone, packstone, and grainstone intercalated with the marl and sandy limestone rich in brachiopods, crinoids, *Bellerophon*, and foraminifers (Samples S261–S272).
- Unit 15 (35 m). Alternating purplish–greenish, thin–medium bedded, fine grained, sandstone and siltstone (Samples S273–S281).
- Unit 16 (18 m). Dark grey, thin–medium bedded mudstone, wackestone, and packstone intercalated with the shale, marl, and volcanic sills, containing bryozoans and brachiopods (Samples S282–S290).

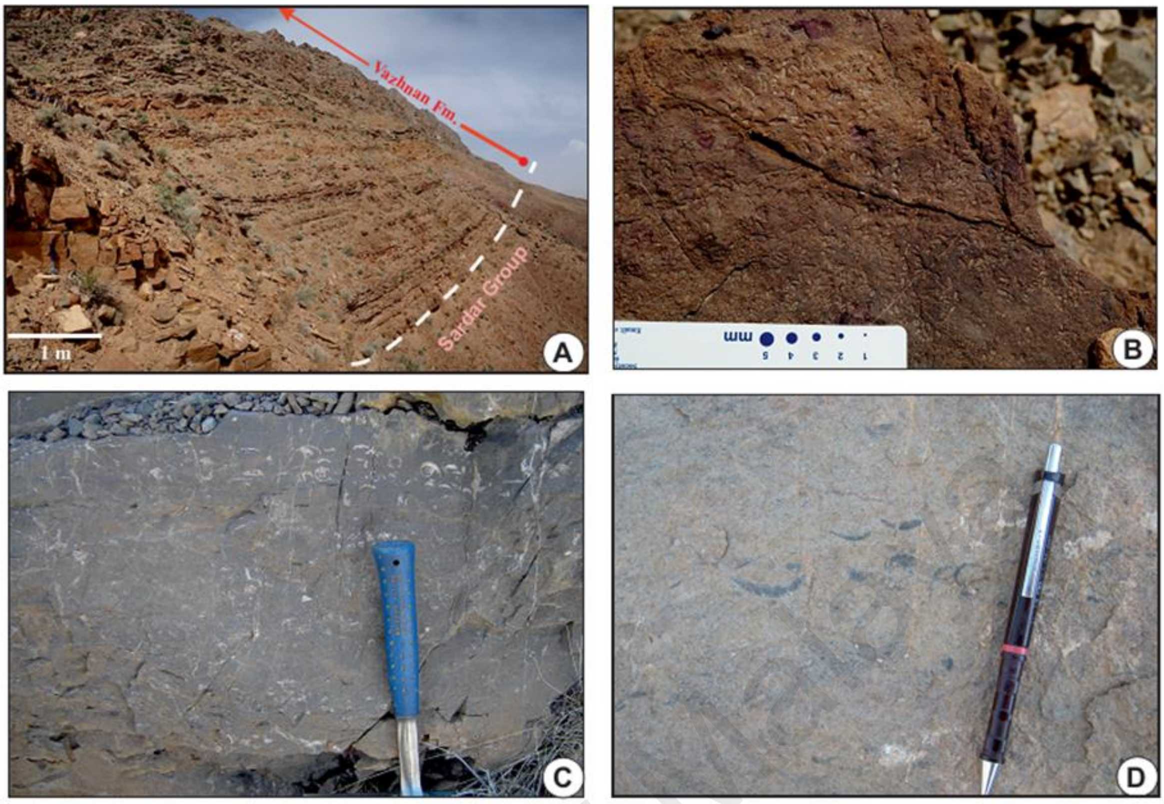

Figure 4.14: The photographs of the Vazhnan Formation, fusulinids, *Bellerophon*, and brachiopods in the Banarizeh Section in the Abadeh area.

(A) General view of the Vazhnan Formation; **(B)** Limestone bearing fusulinids; **(C)** Limestone bearing the *Bellerophon*; **(D)** Limestone bearing brachiopods.

4.3 Tang-e-Darchaleh Section

The Tang-e-Darchaleh Section (coordinates: N32˚02′39.7″; E52˚02′24.2″) structurally belongs to the Shahreza-Hambast-Abadeh Belt, and is situated approximately 18 km northeast of the Shahreza town (Figure 4.15). At the Tang-e-Darchaleh Section a continuous sequence of 528 m thick displays the alternating layers of carbonates and siliciclastic deposits. The basal part of this unit is not exposed, and the upper part is overlain unconformably by the Surmaq Formation (upper Lower Permian–Middle Permian). In lithological composition, section of the Mississippian–Asselian interval is divided from the base upward into three parts; namely, the Shishtu 2 Formation, and the Sardar and Anarak groups (Figures 4.16 & 4.17).

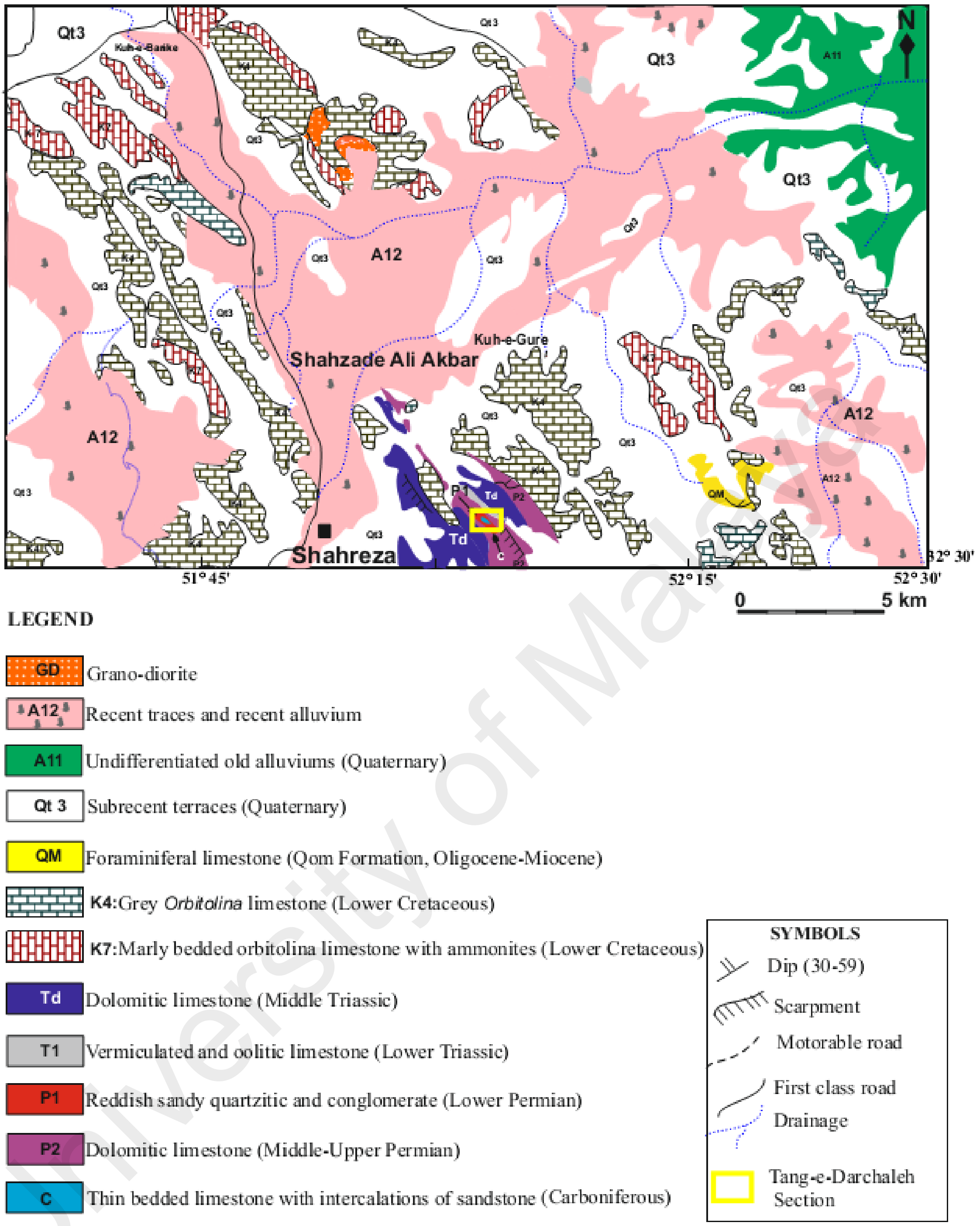

Figure 4.15: The geological map of the Shahreza area showing the location of the Tang-e-Darchaleh Section. The base map from the Esfahan Map, 1:250.000 series sheet, No. J7 (Zahedi et al. 1978).

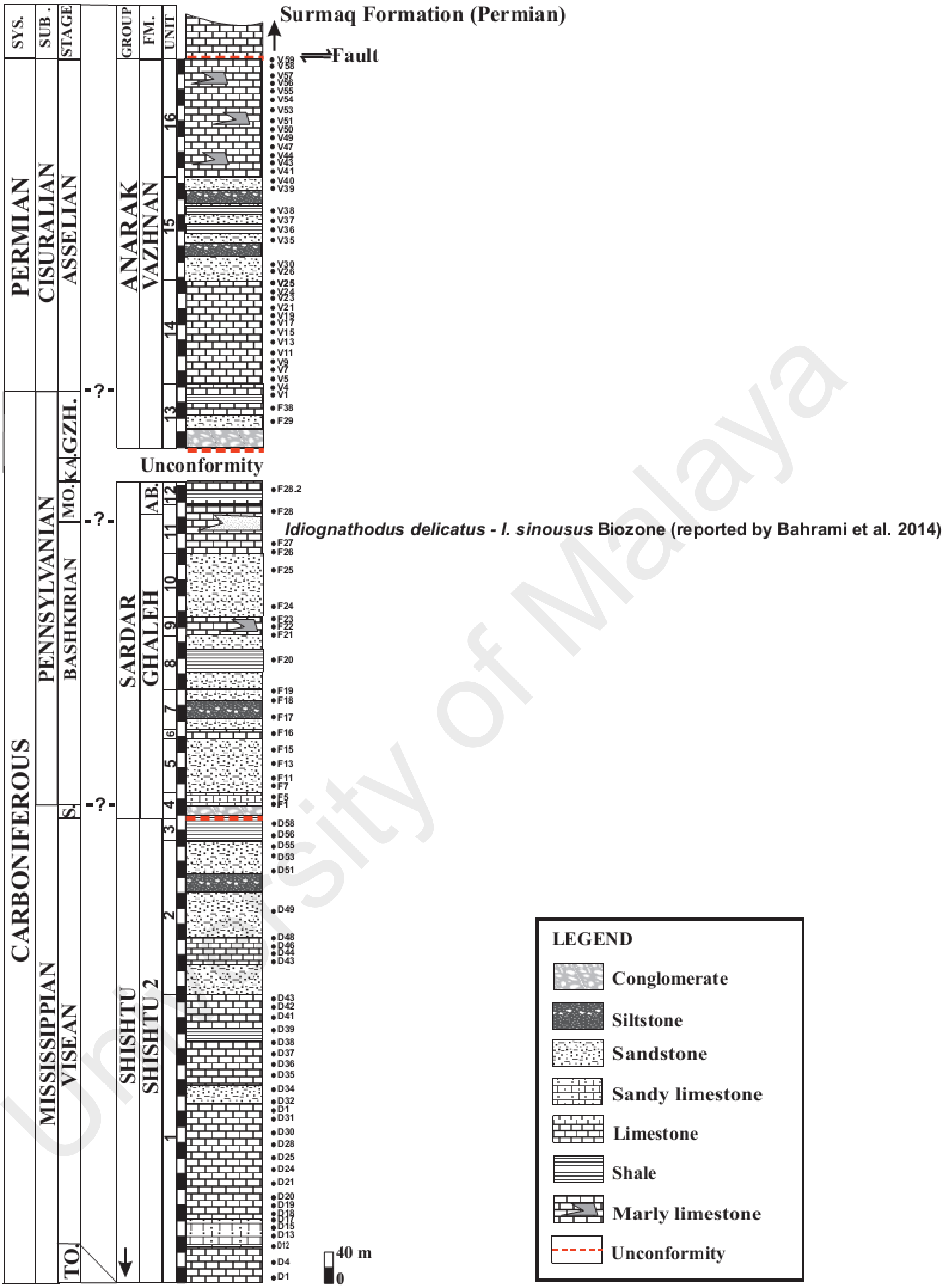

Figure 4.16: The stratigraphic log of the Tang-e-Darchaleh Section in the Shahreza area. **Note:** Abbreviations: **(KA.)** = Kasimovian; **(MO.)** = Moscovian; **(GZH.)** = uppermost Gzhelian; **(S.)** = uppermost Serpukhovian; **(TO.)** = Tournaisian; **(SYS.)** = System; **(SUB.)** = Subsystem; **(FM.)** = Formation; **(AB.)** = Absheni.

Figure 4.17: Field photograph of the Tang-e-Darchaleh Section in the Shahreza area (view: west).

The following units are exposed in the Tang-e-Darchaleh Section from base to the top:

4.3.1 Shishtu 2 Formation

The Shishtu 2 Formation (Mississippian) in the Tang-e-Darchaleh Section with a thickness of about 206 m starts with the sequence of limestone changing upward to the shale and sandstone. The microfacies of the Shishtu 2 Formation are represented by mudstone, wackestone, packstone, grainstone, and oolitic grainstone (Figure 4.18). The contact of the lower part of this interval with the underlying strata is not exposed. The upper part of the succession is overlain unconformably by the Sardar Group (uppermost Serpukhovian–Moscovian).

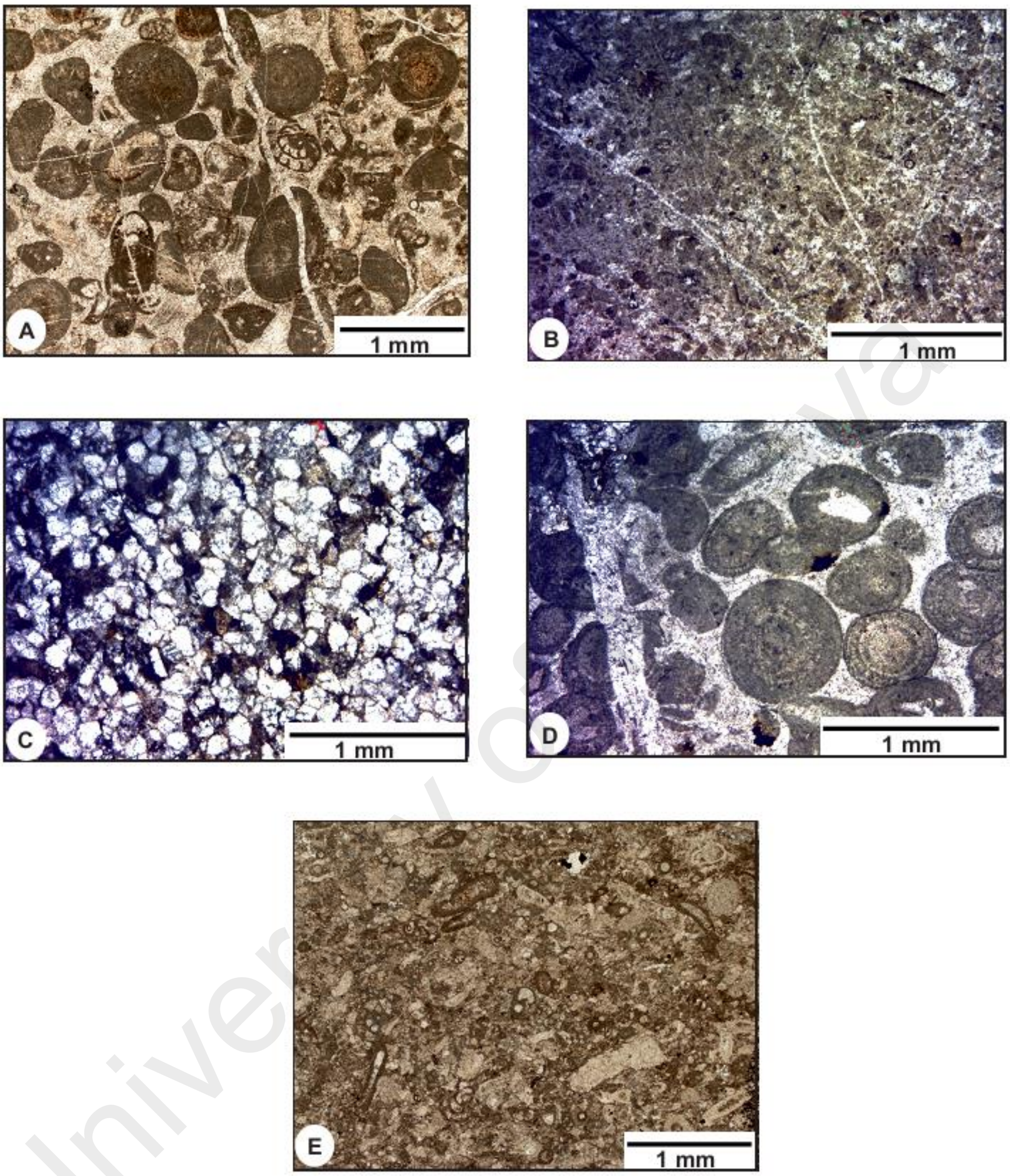

Figure 4.18: Photomicrographs of the sandstone and carbonate facies in the Shishtu 2 Formation in the Tang-e-Darchaleh Section. **Note:** Abbreviation: Spl. = Sample Number.

(A) Bioclastic grainstone with crinoids, and foraminifers, intraclasts, and coated grains, Spl. D20; **(B)** Mudstone–wackestone, Spl. D14 ; **(C)** Quartz arenitic sandstone with opal mineral, Spl. D53; **(D)** Oolitic grainstone, Spl. D41; **(E)** Bioclastic wackestone–packstone with foraminifers and coated grains, Spl. D20.

The following units of the Shishtu 2 Formation are defined for this section from base to top:

- Unit 1 (128 m). Grey–cream, medium–thick bedded bioclastic mudstone, wackestone, and oolitic grainstone, intercalated with sandy limestone and sandstone, changing upward into the thin bedded mudstone, wackestone, and packstone intercalated with the marl, and grey shale, containing the foraminifers, crinoids, corals, brachiopods, and trace fossils (*Zoophycos*) (Samples D1–D43).
- Unit 2 (68 m). Alternating thin–medium bedded sandstone, siltstone, and cream, thin–medium bedded wackstone (Samples D44–D55).
- Unit 3 (10 m). Shale (Samples D56–D58).

4.3.2 Sardar Group

In the Tang-e-Darchaleh Section, the total thickness of the deposits of the Sardar Group (uppermost Mississippian–Pennsylvanian) is about 149 m. The limestone pebble conglomerate, sandstone, and sandy limestone are dominated in the lower part, whereas most part of the section is composed of alternating siliciclastic and carbonates deposits. The microfacies of the Sardar Group are represented by sandstone, mudstone, bioclastic wackestone, and packstone. The conglomerate of the basal part of this succession rests unconformably on the shale and marly limestone of Unit 3 of the Shishtu 2 Formation. The upper part is overlain unconformably by the basal limestone pebble conglomerate of the Vazhnan Formation.

The lithological units in the Sardar Group from base to top are as follows:

- Unit 4 (11.5 m). A pebbly polymictic conglomerate with coarse carbonate clasts and lenses and layers of white, thick–medium bedded, medium grained sandstone, changing upward into conglomerate and sandy limestone and medium bedded oolitic limestone (Samples F1–F5).
- Unit 5 (24 m). Brown, thin–medium bedded, fine grained sandstone (Samples F6–F15).
- Unit 6 (4 m). Grey, medium bedded mudstone (Sample F16).
- Unit 7 (18 m). Alternating sandstone and silt (Samples F17–F19).
- Unit 8 (24 m). Alternating sandstone and shale (Sample F20).
- Unit 9 (8 m). Grey, medium bedded bioclastic wackestone–packstone intercalated with the purple marly limestone, rich in crinoids, bryozoans, and brachiopods (Samples F21–F23).
- Unit 10 (28 m). White, fine grain sandstone (Samples F24 & F25).
- Unit 11 (22 m). Grey, medium bedded bioclastic wackestone–packstone intercalated with marly limestone, containing the corals, crinoid fragments, bryozoans, and foraminifers (Samples F26– F28).
- Unit 12 (10 m). Grey, medium bedded bioclastic wackestone intercalated with the shale (Sample F28.2).

4.3.3 Anarak Group

4.3.3.1 Vazhnan Formation

In the Tang-e-Darchaleh Section, the total thickness of the Vazhnan Formation (uppermost Gzhelian–Asselian) is about 173 m. The succession starts with the conglomerate, sandstone, sandy limestone, but most part of the section is composed of alternating limestone and marly limestone. The microfacies of the Vazhnan Formation are represented by sandstone, mudstone, bioclastic wackestone, packstone, and grainstone (Figure 4.19). This interval is overlain unconformably by the limestone beds of the Surmaq Formation (upper Lower Permian–Middle Permian). The deposits of this interval rest directly on the Sardar Group of early Moscovian age. The presence of the siliciclastic sequence in the base of the Vazhnan Formation implies a hiatus at the formation boundary.

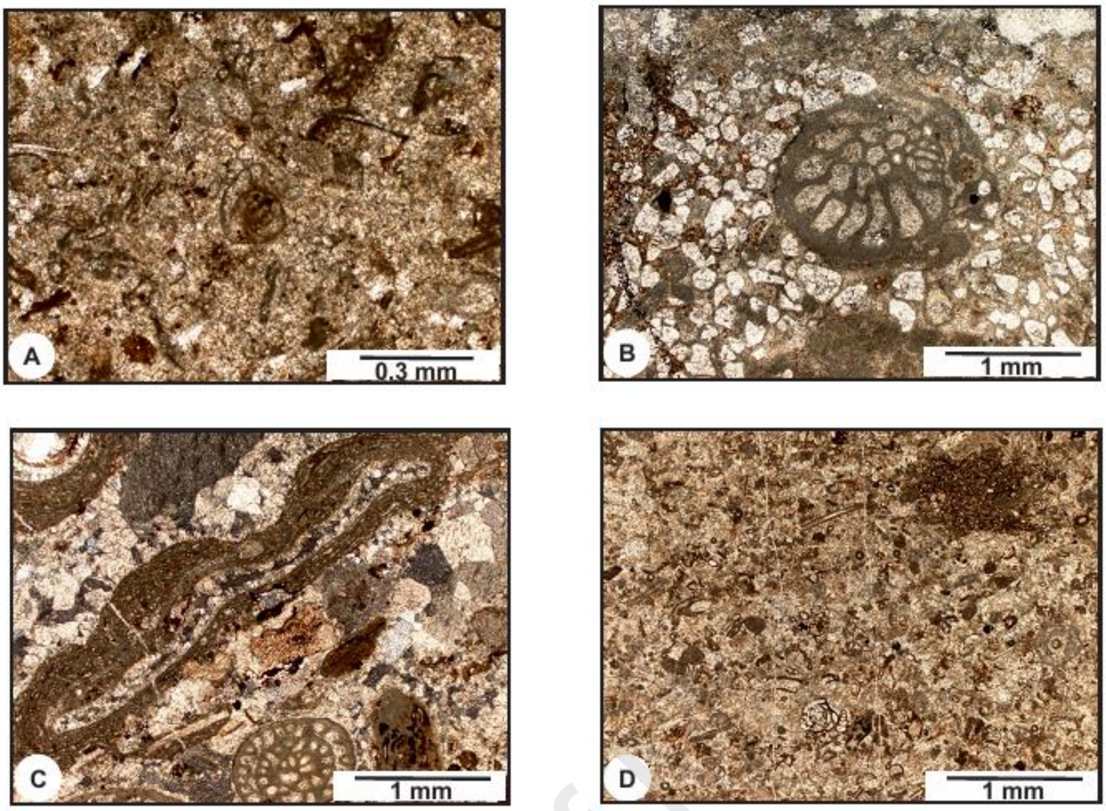

Figure 4.19: Photomicrographs of the sandstone and carbonate facies in the Vazhnan Formation in the Tang-e-Darchaleh Section. **Note:** Abbreviation: Spl. = Sample Number.

(A) Bioclastic wackestone with foraminifers, Spl. V21; **(B)** Sandy packstone with foraminifers, Spl. F38; **(C)** Bioclastic grainstone with foraminifers, and algae, Spl. V6.; **(D)** Bioclastic wackestone with foraminifers and peloids, Spl. V58.

The following units of the Vazhnan Formation are exposed in this section from base to the top:

- Unit 13 (29 m). The basal limestone pebble conglomerate (Figure 4.20) and alternation of the medium–fine grained sandstone, marl, and bioclastic, cream, thin–medium bedded mudstone, bioclastic wackestone, and packstone, containing brachiopods, bryozoans, crinoids, and foraminifers (Samples F29–F38, and V1–V4).

- Unit 14 (46 m). Grey, medium–thick bedded bioclastic wackestone, packstone, grainstone, containing the foraminifers, algae, and *Bellerophon* (Samples V5–V25).
- Unit 15 (46 m). Alternating thin–medium grained sandstone and siltstone interbedded with thin–medium bedded shale (Samples V26–V40).
- Unit 16 (52 m). Dark grey, thin–medium bedded packstone and grainstone intercalated with marly limestone, containing the foraminifers and algae (Samples V41–V59).

Figure 4.20: Conglomerate at the base of the Vazhnan Formation in the Tang-e-Darchaleh Section in the Shahreza area.

CHAPTER 5: DISCUSSIONS

5.1 Systematic Paleontology

The fusulinid forms of biostratigraphic significance to the present results are examined herein. The taxonomic classification here used principally follows that of the Rauser-Chernousova et al. (1996). In synonyms of the species described, only the holotype and important names are listed. The main taxonomic parameters for identification of the fusulinids contain the form of coiling, the diameter of proloculus, wall thickness (thickness of the primary wall, protheca, at each volution measured as close to the center of the tunnel as possible), radius vector (specimen height from the center of the proloculus to the top of the tectum of each volution, measured as close to the center of the tunnel as possible), half-length (diameter, normally maximum, of the initial chamber measured from top to top of tectum across the center of the chamber), the form ratio (half-length/radius vector), the number of volutions, peripheral shape, secondary deposits, the degree of development of chomata, and weak, moderate, or strong septal fluting (Figure 5.1).

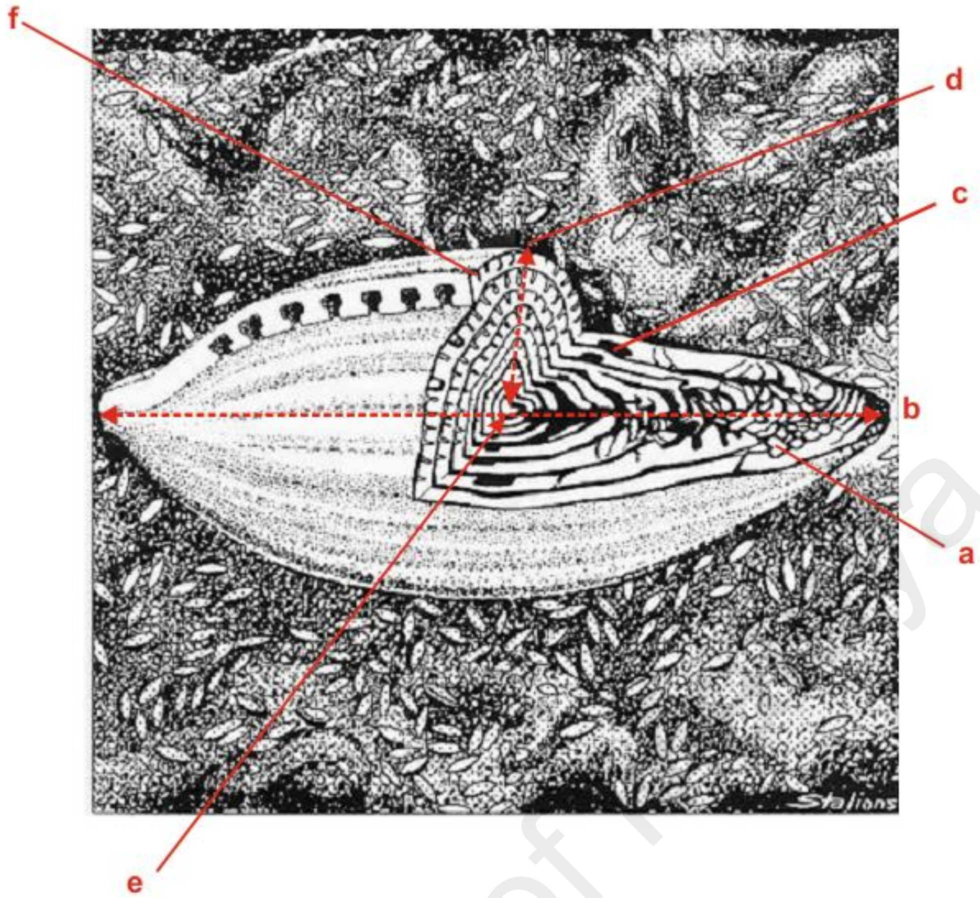

Figure 5.1: The schematic diagram of the fusulinid showing its morphological parameters (the base illustration is adapted from Armstrong & Brasier, 2013). **(a)** = Septal fluting; **(b)** = Length; **(c)** = Secondary deposits; **(d)** = Radius vector for the last volution; **(e)** = Proloculus; **(f)** = Wall or spirotheca.

The fusulinid specimens with the prefix UM are to be used in Fassihi et al. (2017) and Fassihi et al. (in press), and are stored in the Department of Geology, University of Malaya (Kuala Lumpur). The other described specimens with the prefix SF are planned to be published in a future: they will be deposited in appropriate museum(s)/institute(s) accordingly.

The following abbreviations are used for description of the fusulinids: **(No. of V.)** = Number of volutions; **(L.)** = Length; **(W)** = Width; **(FR.)** = Form Ratio; **(PR.)** = Proloculus.

Class **Foraminifera** d’Orbigny, 1826

Superorder **Fusulinoida** Fursenko, 1958

Order **Endothyrida** Brady, 1884

Family **Endostaffellidae** Loeblich & Tappan, 1984

Genus ***Mediocris*** Rozovskaya, 1961

Type species.- *Eostaffella mediocris* Vissarionova, 1948

Mediocris mediocris **(Vissarionova, 1948)**

Figure 5.2 (A, B)

Synonyms.-

1948 *Eostaffella mediocris* Vissarionova; p. 222−223, pl. 14, figs 7−9.

1960 *Eostaffella mediocris* Vissarionova; Grozdilova & Lebedeva, p. 109, pl. 13, fig.13

1963 *Eostaffella mediocris* Vissarionova; Conil & Pirlet, pl. 3, fig. 42.

1963 *Mediocris mediocris* (Vissarionova); Rozovskaya, p. 103−104, pl. 18, figs 26−33.

1981 *Mediocris mediocris* (Vissarionova); Altiner, p. 440, pl. 28, figs 15−18.

1982 *Mediocris mediocris* (Vissarionova); Strank, p. 105, pl. 9, fig. 14.

1999 *Mediocris breviscula* (Ganelina); Özkan, p. 222, pl. 10, figs 21−27.

2005 *Mediocris mediocris* (Vissarionova); Zhijun et al., p. 343, pl. 2, figs 22−26.

Material examined.- Two specimens illustrated; SF001, SF002.

Description.- The specimens of three to four volutions, 0.32–0.47 mm in diameter, 0.162–0.20 mm in width, and a W/D ratio of 0.42–0.5. Shells are small in size, lenticular in axial view, and rounded periphery, with the secondary deposits in umbilical regions. The inner volutions are skewed, and the outer volutions are planispiral. The last volution is wider and longer than the others. The wall is dark microgranular.

Occurrence.- Tang-e-Darchaleh Section; Shishtu 2 Formation; Samples D3, D4; late early Viséan; Mississippian; Carboniferous.

Discussion.- The specimens are described based on their morphological features, such as size, shape, and internal features are assignable to *Mediocris mediocris* (Vissarionova). They are distinguished from *Mediocris breviscula* (Ganelina) by having the greater form ratio and less compressed test.

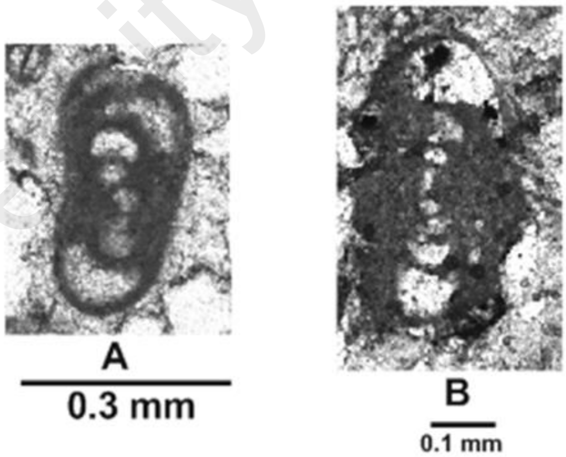

Figure 5.2: *Mediocris mediocris* (Vissarionova, 1948); A: SF001, axial section; B: SF002, axial section.

***Mediocris breviscula* (Ganelina, 1951)**

Figure 5.3 (A–D)

Synonyms.-

1951 *Eostaffella mediocris* var. *breviscula* Ganelina; p. 197–198, pl. 3, figs 1–3.

1954 *Eostaffella breviscula* Ganelina; Grozdilova & Lebedeva, p. 121–122, pl. 13, figs 12, 13.

1963 *Mediocris breviscula* (Ganelina); Rozovskaya, p. 108, pl. 19, figs 14–17.

1969 *Mediocris mediocris* var. *breviscula* (Ganelina); Manukalova-Grebeniuk et al., p. 24–25, pl. 6, figs 3–4.

1973 *Mediocris breviscula* (Ganelina); Mamet, p. 119, pl. 7, figs 15–16.

1981 *Mediocris breviscula* (Ganelina); Altiner, p. 440, pl. 28, figs 20–25.

1993 *Mediocris breviscula* (Ganelina); Mamet et al., pl. 10, figs 19–22.

1999 *Mediocris breviscula* (Ganelina); Özkan, p. 222, pl. 10, figs 9–20.

2005 *Mediocris breviscula* (Ganelina); Zhijun et al., p. 343, pl. 2, figs 16–21.

Material examined.- Four specimens illustrated; SF003, SF004, SF005, SF006.

Description.- Four specimens of three to four volutions, 0.31–0.46 mm in diameter, 0.11–0.21 mm in width, and a W/D ratio of 0.35–0.45. The shells are small in size, discoidal in axial view, with the broadly rounded periphery and shallow umbilical regions. Coiling is planispiral and involute, the last volution expands more rapidly than the inner ones. The wall is thin microgranular.

Occurrence.- Banarizeh and Asad Abad II sections; Shishtu 2 and Ghaleh formations; Samples S108, S124, R71, S104; late early Viséan–earliest Bashkirian; Mississippian–Pennsylvanian; Carboniferous.

Discussion.- The specimens under question, based on their morphological features, can be assigned to *Mediocris breviscula* (Ganelina). They are distinguished from *Mediocris mediocris* (Vissarionova) by having the rapid expansion of coiling, more compressed test, and the smaller form ratio.

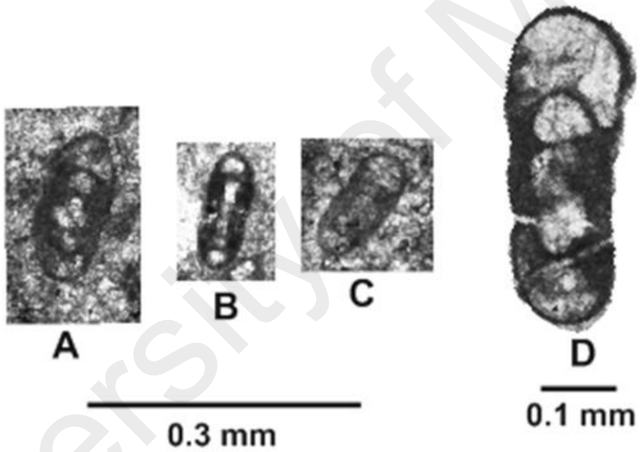

Figure 5.3: *Mediocris breviscula* (Ganelina, 1951). A: SF003, axial section; B: SF004, axial section; C: SF005, axial section; D: SF006, axial section.

Order **Ozawainellida** Solovieva, 1980

Family **Eostaffellidae** Mamet, 1970

Genus ***Eostaffella*** Rauser-Chernousova, 1948

Type species.- *Staffella (Eostaffella) parastruvei* Rauser-Chernousova, 1948

Eostaffella pseudostruvei **(Rauser-Chernousova & Belyaev *in* Rauser-Chernousova et al. 1936)**

Figure 5.4

Synonyms.-

1936 *Staffella pseudostruvei* Rauser-Chernousova & Beliaev *in* Rauser-Chernousova et al., p. 79, pl. 1, fig. 7.

1981 *Eostaffella pseudostruvei* (Rauser-Chernousova & Beliaev); Altiner, p. 440, pl. 27, figs 18–20.

2008 *Eostaffella pseudostruvei* (Rauser-Chernousova & Beliaev); Cozar et al., p. 473, text fig. 8, fig. 22.

2011 *Eostaffella pseudostruvei* (Rauser-Chernousova & Beliaev); Atakul & Özdemir et al., p. 713, text fig. 5, figs j–r.

Material examined.- One specimen illustrated; SF008.

Description.- One specimen of four volutions, 0.31 mm in diameter, 0.14 mm in width, and a W/D ratio of 0.45. The shell is small in size, discoidal in axial view, involute, with the broadly rounded periphery and narrow umbilical regions. The spire expands gradually, except for the last volution which expands more rapidly than the inner ones. The wall is dark microgranular. The chomata are weakly developed.

Occurrence.- Asad Abad II Section; Ghaleh Formation; Sample R71; Voznesenian (earliest Bashkirian); Pennsylvanian; Carboniferous.

Discussion.- The specimen is identified to *Eostaffella pseudostruvei* (Rauser-Chernousova & Beliaev) based on its small size, discoidal shape, and the narrow umbilical regions. It is easily distinguished from the other forms of *Eostaffella* in this assemblage; for example from *Eostaffella ikensis* Vissarionova by having the smaller size and discoidal shape and by lacking the convex lateral slopes and the sharp keel in the two last volutions. It is distinguished from *Eostaffella parastruvei* (Rauser- Chernousova) by its smaller form ratio and size, and having the deep umbilical regions.

Figure 5.4: *Eostaffella pseudostruvei* (Rauser-Chernousova & Belyaev, 1936). SF008, axial section.

***Eostaffella ikensis* Vissarionova, 1948**

Figure 5.5 (A–D)

Synonyms.-

1948 *Eostaffella ikensis* Vissarionova, p. 219, pl. 13, figs 8–10; pl. 14, fig. 1.

1990 *Eostaffella ikensis* Vissarionova; Vdovenko et al., p. 188, text fig. 1, fig. 23.

1999 *Eostaffella ikensis* Vissarionova; Özkan, p. 225, pl. 11, figs 4–5.

Material examined.- Four specimens illustrated; SF009, SF0010, SF0011, SF0012.

Description.- Four specimens of four volutions, 0.57–0.88 mm in diameter, 0.39–0.62 mm in width, and a W/D ratio of 0.68–0.7. The shells are large in size, lenticular in axial view, with the convex lateral slopes and no umbilical regions, with many chambers and the small acute keel in the outer volution. Coiling is planispiral and involute. The wall is dark microgranular. The pseudochomata are weakly developed because of the secondary deposits.

Occurrence.- Asad Abad II Section; Ghaleh Formation; Samples R71, R72, R76; Voznesenian (earliest Bashkirian); Pennsylvanian; Carboniferous.

Discussion.- The Iranian forms are identified to *Eostaffella ikensis* Vissarionova, based on their lenticular shape with the angular periphery, the complete absence of the umbilical regions, and their size. They are distinguished from *Eostaffella pseudostruvei* (Rauser-Chernousova & Beliaev) in having the larger size, convex lateral slopes, the angular periphery, and no umbilical regions and from *Eostaffella* *parastruvei* (Rauser- Chernousova) in lacking the umbilical regions and having the greater form ratio.

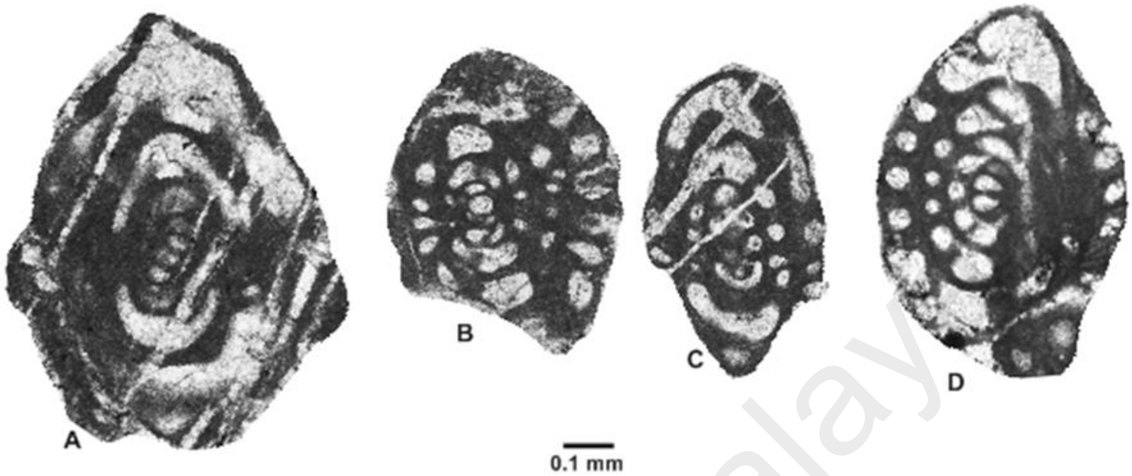

Figure 5.5: *Eostaffella ikensis* Vissarionova, 1948. A: SF009, subaxial section; B: SF0010, axial section; C: SF0011, subaxial section; D: SF0012, oblique section.

***Eostaffella parastruvei* (Rauser-Chernousova, 1948)**

Figure 5.6 (A–G)

Synonyms.-

1948 *Staffella (Eostaffella) parastruvei* Rauser-Chernousova, p. 15, pl. 3, figs 16–18.

1963 *Eostaffella parastruvei* (Rauser-Chernousova); Conil & Pirlet, pl. 3, fig. 41.

1981 *Eostaffella parastruvei* (Rauser-Chernousova); Altiner, p. 440, pl.27, figs 1–5.

1989 *Eostaffella parastruvei* (Rauser-Chernousova); Athersuch & Strank, p. 17, pl. 4, fig. 11.

1989 *Eostaffella* cf. *parastruvei* (Rauser-Chernousova); Skompski et al., p. 473, pl. 7, fig. 24.

1998 *Eostaffella parastruvei* (Rauser-Chernousova); Gallagher, p. 202, pl. 2, fig. 2.

2004 *Eostaffella parastruvei* (Rauser-Chernousova); Cózar, p. 381, pl. 2, fig. 14.

2004 *Eostaffella parastruvei* (Rauser-Chernousova); Cózar & Somerville, p. 56, text fig. 14, fig. 30.

2005 *Eostaffella parastruvei* (Rauser-Chernousova); Somerville & Cózar, p. 138, pl. 3, fig. 28.

Material examined.- Seven specimens illustrated; SF0013, SF0014, SF0015, SF0016, SF0017, SF0018, SF0019.

Description.- Seven specimens of four volutions, 0.38–0.76 mm in diameter, 0.2–0.42 mm in width, and a W/D ratio of 0.52–0.55. The shells are medium in size, lenticular in axial view, with a rounded periphery in the inner volutions, and the angular periphery in the penultimate or last volutions, and shallow umbilical regions. The spire expands gradually, except for two last volutions which expand more rapidly than the inner ones. The wall is dark microgranular; it is composed of a tectum and lower and upper tectorium for Specimen SF0013 (Figure 5.6A), a single structureless layer for Specimen SF0014 (Figure 5.6B), a tectum and lower and upper tectorium for Specimen SF0015 (Figure 5.6C), a tectum and lower and upper tectorium for Specimen SF0016 (Figure 5.6D), a thin tectum and structureles lower layer for Specimen SF0017 (Figure 5.6E), a single structureless layer for Specimen SF0018 (Figure 5.6F), and the dark and structureless layer which is thik in the inner volutions for Specimen SF0019 (Figure

5.6G). The secondary deposits are present in two or three inner volutions as the massive and symmetric chomata.

Occurrence.- Asad Abad II Section; Ghaleh Formation; Samples R63, R70, R76; Voznesenian (earliest Bashkirian); Pennsylvanian; Carboniferous.

Discussion.- Present species are identified to *Eostaffella parastruvei* (Rauser-Chernoussova) based on their lenticular shape, narrow umbilical regions, and the angular periphery in the final volutions. They are distinguished from *Eostaffella ikensis* Vissarionova by lacking the convex lateral slopes. They are also distinguished from *Eostaffella pseudostruvei* (Rauser-Chernousova & Beliaev) by having the larger shell, greater form ratio, and the angular periphery.

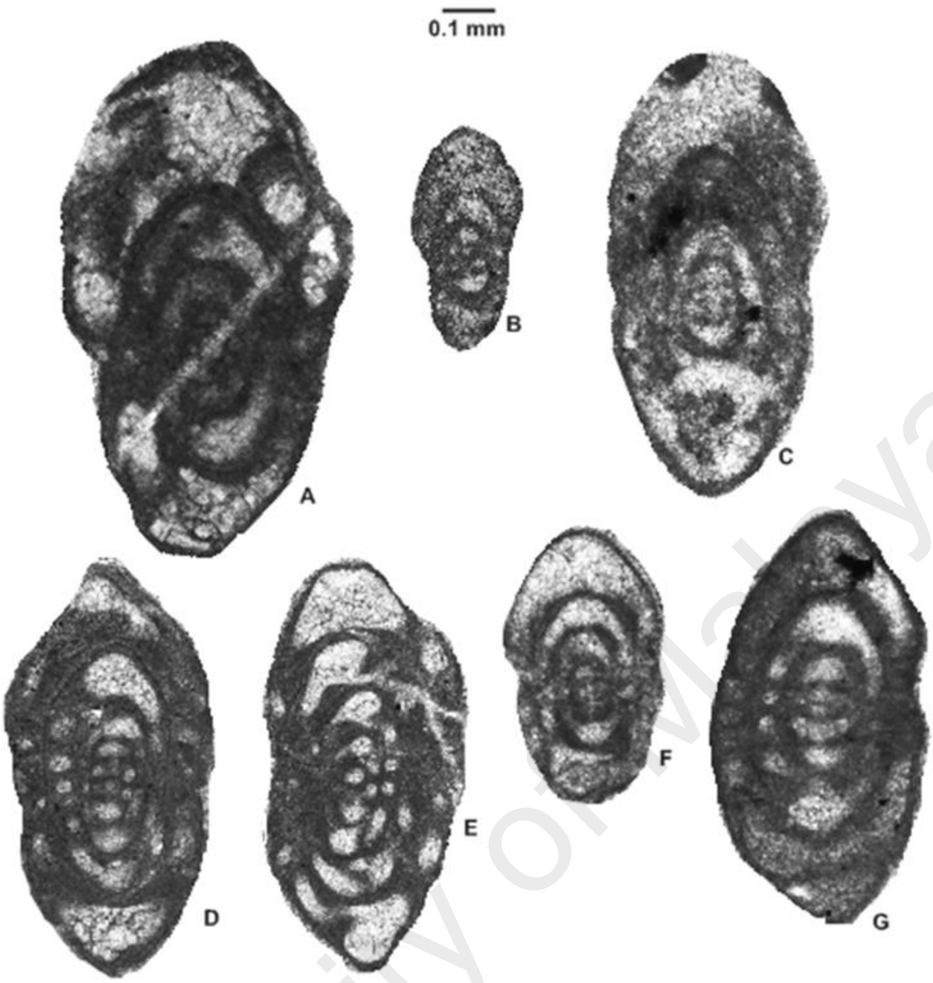

Figure 5.6: *Eostaffella parastruvei* (Rauser-Chernoussova, 1948). A: SF0013, axial section; B: SF0014, axial section; C: SF0015, axial section; D: SF0016, subaxial section; E: SF0017, subaxial section; F: SF0018, axial section; G: SF0019, tangential section.

Family **Ozawainellidae** Thompson & Foster, 1937

Subfamily **Ozawainellinae** Thompson & Foster, 1937

Genus ***Ozawainella*** Thompson, 1935

Type species.- *Fusulinella angulata* Colani, 1924

***Ozawainella* cf. *fragilis* Safonova, 1951**

Figure 5.7

Synonym.-

cf. 1951 *Ozawainella fragilis* Safonova *in* Rauser-Chernousova et al., p. 139, pl. 11, fig. 5.

Material examined.- One specimen illustrated; SF0039.

Description.- One specimen of four volutions and loosely coiled is 1.1 mm in axial length, 0.45 mm in diameter, and a form ratio of 2.44. The shell is lenticular, with acutely pointed periphery. The spirotheca is three layered, composed of a tectum, upper tectorium, and lower tectorium. The low and asymmetrical chomata exist in the inner volutions.

Occurrence.- Asad Abad II Section; Absheni Formation; Sample M18; late Kashirian (early Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The specimen resembles to *Ozawainella fragilis* Safonova based on the four layered wall, lenticular shape, and pointed poles, but because of the presence just one subaxial section, it cannot be attributed to a definite species.

Figure 5.7: *Ozawainella* cf. *fragilis* Safonova, 1951; SF0039, subaxial section.

Family **Pseudostaffellidae** Putrja, 1956

Genus ***Pseudostaffella*** Thompson, 1942

Type species.- *Pseudostaffella needhami bocki* Thompson, 1942

Pseudostaffella subquadrata **(Grozdilova & Lebedeva, 1950)**

Figure 5.8 (A–D)

Synonym.-

1950 *Neostaffella subquadrata* Grozdilova & Lebedeva

Material examined.- Four specimens illustrated; SF0042, SF0043, SF0044, SF0045.

Description.- Four specimens of four to six volutions are 0.9–1.2 mm in axial length, 0.8–0.9 mm in diameter, and a form ratio of 1–1.5. Spherical proloculus of large size, its outer diameter is 0.1–0.2 mm. The shells are quadratic in axial view. The spirotheca is thin consists of a thin tectum, lower and upper tectorium. The distinct chomata are present in all volutions.

Occurrence.- Asad Abad II Section; Ghaleh Formation; Samples VB6.1, VB7; Melekessian–Vereian (latest Bashkirian–early Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The current specimens are comparable with *Pseudostaffella subquadrata* (Grozdilova & Lebedeva) from Urals (Grozdilova & Lebedeva, 1950) based on the proloculus size, shell size, and the presence of chomata. The Iranian form is distinguishable from the other forms of *Pseudostaffella* in this study; for example, from *Pseudostaffella* cf. *gorskyi* (Dutkevich) by having the larger shell and proloculus, quadratic shape, and distinct chomata. It differs from *Pseudostaffella paracompressa* Safonova by having the distinct chomata in all the volutions.

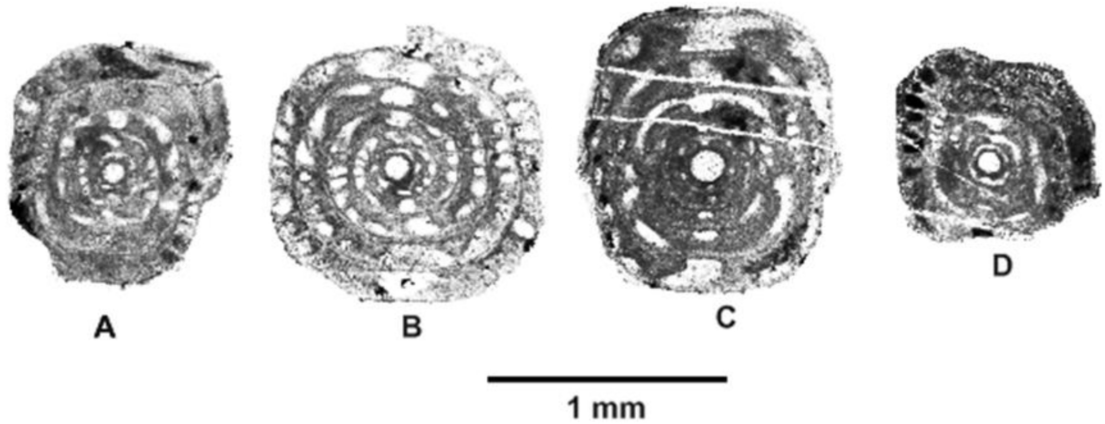

Figure 5.8: *Pseudostaffella subquadrata* (Grozdilova & Lebedeva, 1950). A: SF0042, axial section; B: SF0043, axial section; C: SF0044, axial section; D: SF0045, axial section.

Order **Schubertellida** Skinner, 1931

Family **Schubertellidae** Skinner, 1931

Genus ***Eoschubertella*** Thompson, 1937

Type species.- *Schubertella lata* Lee & Chen *in* Lee et al. 1930

Discussion.- The *Eoschubertella* forms are one of the groups of the *Schubertella*-related forms. *Eoschubertella* is characterized by its small ovoid test (less than 0.3 mm in length), poorly differentiated wall, and having 3–4 volutions with 2–3 initial skewed inner volutions (Davydov, 2011). The morphological separation of the genus *Eoschubertella* from *Schubertella* Staff and Wedekind, 1910 is for years the subject to debate. The main distinction between *Eoschubertella* and *Schubertella* is related to their wall structures and the taxonomic separation between these two genera is still the subject of controversy (Okuyucu & Goncuoglu, 2010). According to Ueno *in* Fohrer et al. (2007), in most cases, the small schubertellids from the middle Pennsylvanian are regarded as *Eoschubertella* bearing the spirotheca composed of a tectum, lower tectorium, and upper tectorium. On the other hand, those Permian forms reported as *Schubertella* have a spirotheca consisting of a tectum and a distinct lower lighter layer (Ueno *in* Fohrer et al. 2007).

In this study, the genus *Eoschubertella* is accepted, following Davydov (2011).

***Eoschubertella lata* (Lee & Chen *in* Lee et al. 1930)**

Figure 5.9 (A–C)

Synonyms.-

1930 *Schubertella lata* Lee & Chen *in* Lee et al., p. 111, pl. 6, figs, 9–11.

1934b *Schubertella* cf. *lata* Lee et al., p. 39, pl. 6, figs. 5, 21.

1957 *Schubertella lata* (Lee & Chen). IGO, p. 186–187, pl. 3, figs. 6–8.

1958 *Schubertella lata* var. *elliptica* SHENG, p. 20, 87, pl. 2, figs. 13–20.

1975*Schubertella (Schubertella) lata* Lee & Chen. ROZOVSKAYA, pl. 3, fig. 5

1984 *Schubertella lata elliptica* Sheng. ZHANG & JIANG, pl. 1, fig. 25.

1987 *Schubertella* cf. *lata elliptica* Sheng. VAN GINKEL, p. 210–221, figs. 4.7–4.12.

1995 *Schubertella* ex gr. *lata* Lee & Chen. VILLA, p. 114–115, pl. 7, figs. 20–21, 24.

Material examined.- Three specimens illustrated; SF0047, SF0048, SF0049.

Description.- Three specimens of four volutions are 0.27–0.36 mm in axial length, 0.15–0.21 mm in diameter, and a form ratio of 1.28–2.00. The proloculus is spherical, small, 0.03 mm in outer diameter. The shells are small, ovoid with the broadly arched periphery and rounded poles. The inner volution is skew-coiled and then coiling becomes planispiral in outer volutions. The septa are nearly plane. The spirotheca is composed of a thin tectum, lower and upper tectorium.

Occurrence.- Banarizeh Section; Vazhnan Formation; Samples S251, S267.5; latest Gzhelian–Asselian; Late Carboniferous–Early Permian.

Discussion.- The current specimens are comparable with *Eoschubertella lata* (Lee & Chen) from China (Lee et al. 1930), no detailed description seems to be necessary.

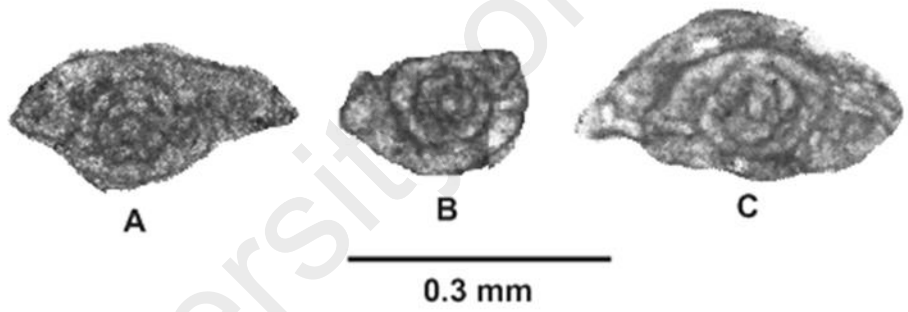

Figure 5.9: *Eoschubertella lata* (Lee & Chen, 1930). A: SF0047, axial section; B: SF0048, axial section; C: SF0049, axial section.

Order **Fusulinida** Fursenko, 1958

Family **Profusulinellidae** Solovieva *in* Rauser-Chernousova et al. 1996

Genus ***Profusulinella*** Rauser-Chernousova & Belyaev *in* Rauser-Chernousova et al. 1936

Type species.- *Profusulinella pararhomboides* Rauser-Chernousova & Belyaev *in* Rauser-Chernousova et al. 1936

Discussion.- As pointed out by Kobayashi (2011), *Profusulinella* and related genera are important in the early evolution of the family Fusulinidae. In the scheme proposed by Rauser-Chernousova et al. (1996), the newer genera were erected from the *Profusulinella* species groups that were placed under two new families; namely, Profusulinellidae and Aljutovellidae. Among the new genera is *Depratina* Solovieva, 1996 which is established from the *Profusulinella prisca* (Deprat, 1912) group (Kobayashi, 2011; Villa & Merino, 2016).

Taxonomic interpretations concerning these primitive fusulinids, nevertheless, differ broadly among the experts. For example Ueno *in* Fohrer et al. (2007), Kobayashi (2011), and Villa & Merino (2016) presume such branching of genera makes it difficult to establish the phylogenetic relationships among the profusulinellid taxa. They prefer to maintain *Profusulinella* in the broader sense of Rauser-Chernousova et al. (1951). In this study it is treated as *Profusulinella* (*Depratina*) as following Solovieva *in* Rauser-Chernousova et al. (1996).

***Profusulinella* (*Depratina*) *prisca* (Deprat, 1912)**

Figure 5.10

Synonyms.-

1912 *Schwagerina prisca* Deprat

1936 *Profusulinella prisca* (Deprat); Rauser-Chernousova et al., p. 176–177, pl. 1, fig. 1.

Material examined.- One specimen illustrated; UM10633.

Description.- The specimen with five and a half volutions is 1.3 mm in axial length, 1.1 mm in width, and a form ratio of 1.18. The height of the volutions gradually increases to outer volutions. The shell is small in size, inflated fusiform in axial view, with convex lateral slopes, and broadly arched periphery. The septa are plane and gently fluted near the poles. The chomata are asymmetric, massive, and exist in almost all the volutions. The radius vectors from the first to fifth volutions of the specimen are 0.02, 0.08, 0.16, 0.25, and 0.41 mm, respectively. The spirotheca is thin, consisting of three layered, and is composed of the tectum, upper tectorium, and lower tectorium. The thickness of the spirotheca from the first to fifth volutions of the specimen is 0.014, 0.014, 0.016, 0.014, and 0.025 mm, respectively.

Occurrence.- Asad Abad II Section; Ghaleh Formation; Sample VB6; Melekessian–Vereian (latest Bashkirian–earliest Moscovian); Pennsylvanian; Carboniferous.

Discussion.- This Iranian form is identified with *Profusulinella* (*Depratina*) *prisca* (Deprat, 1912) originally known from the Moscovian of Yunnan, southwest China. This identification is based on its globose shape, massive chomata, plane to weakly fluted septa, number of volutions, and size. The current specimen can be distinguished from other forms of *Profusulinella* in this assemblage; for example, from *Profusulinella* (*Depratina*) cf. *subovata* Safonova by having the larger shell (greater form ratio), more globose shape, and more massive chomata. It is distinguished from *Profusulinella* (*Depratina*) *parva* (Lee & Chen, 1930) in having the smaller L/W ratio, thinner wall, more volutions and less massive chomata in the last volution.

Figure 5.10: *Profusulinella* (*Depratina*) *prisca* (Deprat, 1912). UM10633, subaxial section.

***Profusulinella* cf. (*Depratina*) *prisca* (Deprat, 1912)**

Figure 5.11

Synonyms.-

cf. 1912 *Schwagerina prisca* Deprat

cf. 1936 *Profusulinella prisca* (Deprat); Rauser-Chernousova et al., p. 176–177, pl. 1, fig. 1.

Material examined.- One specimen illustrated; SF0020.

Description.- One specimen of four volutions is 1.4 mm in axial length, 1.1 mm in width, and a form ratio of 1.27. The height of the volutions gradually increases in outer volutions. The shell is small in size, inflated fusiform with convex lateral slopes, and broadly arched periphery. The septa are plane and gently fluted near poles. The chomata are asymmetric and massive in the inner volutions. The radius vectors from the first to fourth volutions of the specimen are 0.16, 0.26, 0.4, and 0.53 mm, respectively. The spirotheca is thin consisting of three layered, and is composed of the tectum, upper tectorium, and lower tectorium. The thickness of the spirotheca from the first to fourth volutions of the specimen is 0.014, 0.029, 0.028, and 0.029 mm, respectively.

Occurrence.- Asad Abad II Section; Ghaleh Formation; Sample VB6; Melekessian–Vereian (Bashkirian–earliest Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The present form is assignable to *Profusulinella* (*Depratina*) *prisca* (Depart), based on its globose shape, high and massive chomata, and unfluted septa. Because only one oblique section of this specimen is available, however, it is tentatively identified as the *Profusulinella* (*Depratina*) cf. *prisca* (Deprat).

Figure 5.11: *Profusulinella* cf. (*Depratina*) *prisca* (Deprat, 1912). SF0020, tangential section.

***Profusulinella* (*Depratina*) *parva* (Lee & Chen, 1930)**

Figure 5.12

Synonym.-

1930 *Fusulinella* (*Neofusulinella*) *parva* Lee & Chen *in* Lee et al., p. 118–119, pl. 7, figs 22–27.

Material examined.- One specimen illustrated; UM10634.

Description.- The single specimen of four and a half volutions is 1.2 mm in axial length, 0.9 mm in width, and a form ratio of 1.33. The shell is small in size, globose in shape with broadly rounded periphery. The chomata are massive, high, and asymmetric in the fourth to the fourth and a half volutions, where their height exceeds half the chamber height. The radius vectors from the first to fourth volutions of the specimen are 0.05, 0.1, 0.23, and 0.36 mm, respectively. The spirotheca thin, consists of three layered, composed of the tectum, upper tectorium, and lower tectorium (less dense layer). The thickness of the spirotheca from the first to fourth volutions is 0.03, 0.03, 0.05, and 0.03 mm, respectively.

Occurrence.- Asad Abad II Section; Ghaleh Formation; Sample VB7; Vereian (earliest Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The globose shape and intensity of septal fluting of *Profusulinella* (*Depratina*) *parva* resemble *Profusulinella* (*Depratina*) *prisca*. However, some features such as having the fairly longer shell (greater L/W ratio), thicker wall, less volutions, and more massive chomata in the last volutions, distinguish *Profusulinella* (*Depratina*) *parva* from *Profusulinella* (*Depratina*) *prisca*.

Figure 5.12: *Profusulinella* (*Depratina*) *parva* (Lee & Chen, 1930). UM10634, subaxial section.

Genus ***Taitzehoella*** Sheng, 1951

Type species.- *Taitzehoella taitzehoensis* Sheng, 1951

***Taitzehoella mutabilis* (Safonova, 1951)**

Figure 5.13 (A–C)

Synonym.-

1951 *Profusulinella mutabilis* Safonova *in* Rauser-Chernousova et al., p. 179–180, pl. 19, figs 1–3.

Material examined.- Three specimens illustrated; SF0021, SF0022, SF0023.

Description.- The specimens of three and a half volutions are 1.25–1.35 mm in axial length, 0.5–0.6 mm in width, and a form ratio of 2.25–2.60. The shells are small in size, fusiform in shape with the skew coiled juvenarium, broadly rounded periphery, and straight or concave lateral slopes. The chomata are distinguished in all volutions. The radius vectors from the first to fourth volutions of the specimen are 0.04, 0.11, 0.20, and 0.28 mm for Specimen SF0021 (Figure 5.13A), 0.03, 0.11, 0.21, 0.23 mm for SF0022 (Figure 5.13B), and 0.04, 0.11, 0.22, 0.26 for SF0023 (Figure 5.13C). The spirotheca thin composed of tectum and lower tectorium. The thickness of spirotheca from the first to fourth volutions of the specimen is 0.014, 0.013, 0.013, and 0.014 mm for Specimen SF0021 (Figure 5.13A), 0.014, 0.014, 0.015, and 0.014 mm for SF0022 (Figure 5.13B), and 0.013, 0.012, 0.015, and 0.015 mm for SF0023 (Figure 5.13C).

Occurrence.- Asad Abad II Section; Absheni Formation; Samples M1, M9, M57; late Kashirian–early Podolskian (early–late Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The specimens are identified with *Taitzehoella mutabilis* (Safonova) based on fusiform shape, rounded poles, straight or almost concave lateral slopes, prominent chomata, skew coiled juvenarium, and plane septa.

Figure 5.13: *Taitzehoella mutabilis* (Safonova, 1951). A: SF0021, axial section; B: SF0022, axial section; C: SF0023, axial section.

Family **Fusulinellidae** Staff & Wedekind, 1910

Subfamily **Fusulinellinae** Staff &Wedekind, 1910

Genus ***Fusulinella*** von Moeller, 1878

Subgenus ***Fusulinella*** **(*Fusulinella*)** von Moeller, 1878

Type species.- *Fusulinella bocki* von Moeller, 1878, designated in Douville (1907)

Fusulinella **(*Fusulinella*)** ***pseudobocki*** **Lee & Chen *in* Lee et al. 1930**

Figure 5.14 (A, B)

Synonym.-

1930 *Fusulinella* (*Neofusulinella*) *pseudobocki* Lee & Chen *in* Lee et al., pp. 122–123, pl. 9, figs 10–14, pl. 10, figs 1–7.

Material examined.- Two specimens illustrated; SF0031, SF0032.

Description.- Two axial sections of five to six volutions are 2.7–4 mm in axial length, 1.1–1.7 mm in diameter, and a form ratio of 2.35–2.45. Proloculus of moderate size, its outer diameter is 0.04–0.07 mm. The shells are fusiform, rather large in size, with slightly convex lateral slopes and rounded poles. The chomata are asymmetric and massive, most distinct in first four volutions, reaching the half-height of respective volutions. Thin septa are slightly fluted in the sagittal area, forming rather simple interlacement near poles. The radius vectors from the first to sixth volutions of the specimens are 0.042, 0.014, 0.28, 0.5, 0.71, and 0.92 mm, for Specimen SF0031 (Figure

5.14A), and 0.057, 0.17, 0.285, 0.457, and 0.6 mm for SF0032 (Figure 5.14B). The spirotheca is four layered, composed of a tectum, upper tectorium, and lower tectorium, and diaphanotheca. The thickness of spirotheca from the first to the last volutions of the specimens is 0.014, 0.028, 0.019, 0.014, 0.014, and 0.018 mm for Specimen SF0031 (Figure 5.14A) and 0.014, 0.012, 0.019, 0.014, and 0.014 mm for SF0032 (Figure 5.14B).

Occurrence.- Asad Abad II Section; Absheni Formation; Samples M57, M61; early Podolskian (early late Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The current specimens are assigned to *Fusulinella* (*Fusulinella*) *pseudobocki* Lee & Chen, based on their four layered wall, fusiform shape, rounded poles, and massive chomata. They can be distinguished from other forms of *Fusulinella* in this assemblage; for example from *Fusulinella* (*Moellerites*) cf. *paracolaniae* Safonova by their larger size, having the greater form ratio, more elongated fusiform shape, and also having the diaphanotheca in all volutions and from *Fusulinella* (*Fusulinella*) ex gr. *bocki* Moeller by having the smaller proloculus, larger size, the greater form ratio, and more elongated fusiform shape.

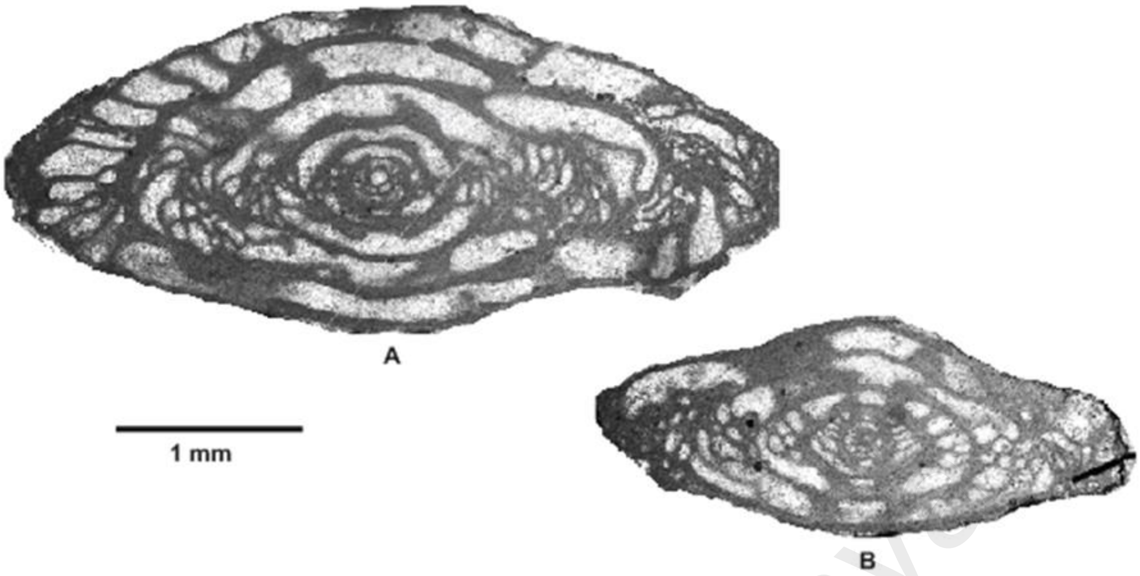

Figure 5.14: *Fusulinella* (*Fusulinella*) *pseudobocki* Lee & Chen 1930. A: SF0031, axial section; B: SF0032, subaxial section.

***Fusulinella* (*Fusulinella*) ex gr. *bocki* von Moeller, 1878**

Figure 5.15 (A–D)

Synonym.-

ex gr. 1878 *Fusulinella bocki* Moeller, pp. 104–107, pl. 5, figs 3a–g, pl. 14, figs1–4.

Material examined.- Four specimens illustrated; SF0035, SF0036, SF0037, SF0038.

Description.- Four specimens of three and a half to five volutions, with almost globular inner volutions are 1.6–1.75 mm in axial length, 0.85–1.1 mm in diameter, and a form ratio of 1.65–2.05. Proloculus spherical, 0.1–0.11 mm in outer diameter. The shells are small in size, ovoid or short fusiform with rounded poles. The septa are plane and gently fluted near poles. The chomata are symmetric and massive. The radius vectors from the first to last volutions of the specimens are 0.14, 0.22, 0.36, and 0.5 mm for Specimen SF0035 (Figure 5.15A), 0.07, 0.1, 0.28, 0.42, and 0.58 mm for SF0036 (Figure 5.15B), 0.076, 0.2, 0.28, 0.5, and 0.67 for SF0037 (Figure 5.15C), and 0.1, 0.2, 0.35, and 0.5 for SF0038 (Figure 5.15D). The spirotheca is four layered, composed of a tectum, upper tectorium, lower tectorium, and diaphanotheca. The thickness of the spirotheca from the first to fourth volutions is 0.142, 0.28, 0.014, and 0.14 mm for Specimen SF0035 (Figure 5.15A), 0.014, 0.014, 0.02, 0.014, and 0.014 mm for SF0036 (Figure 5.15B), 0.15, 0.3, 0.1, 0.12 and 0.14 mm for SF0037 (Figure 5.15C), and 0.15, 0.28, 0.2, and 0.16 mm for SF0038 (Figure 5.15D).

Occurrence.- Asad Abad II Section; Absheni Formation; Samples M59, M63, M66, M93; early Podolskian (early late Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The current specimens are comparable with *Fusulinella* (*Fusulinella*) *bocki* von Moeller from the Russian Platform (Moeller, 1878). The Iranian forms, however, differ by having the less massive chomata and more ovoid shape in the inner volutions. This form can be distinguished from other forms of *Fusulinella* in this assemblage; for example, from *Fusulinella* (*Moellerites*) cf. paracolaniae Safonova by its more ovoid shape and having the diaphanotheca in all volutions and from *Fusulinella* (*Fusulinella*) *pseudobocki* Lee & Chen by having the smaller size, more ovoid shape, smaller form ratio, and larger proloculus.

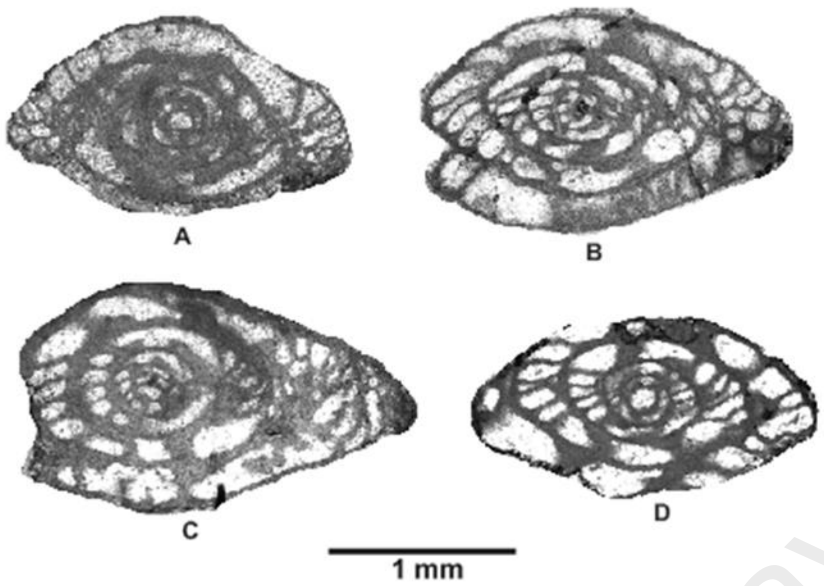

Figure 5.15: *Fusulinella* (*Fusulinella*) ex gr. *bocki* von Moeller, 1878. A: SF0035, axial section; B: SF0036, subaxial section; C: SF0037, subaxial section; D: SF0038, axial section.

Subgenus ***Fusulinella* (*Moellerites*)** Solovieva, 1986

***Fusulinella* (*Moellerites*) cf. *paracolaniae* Safonova, 1951**

Figure 5.16 (A, B)

Synonym.

cf. 1951 *Fusulinella paracolaniae* Safonova *in* Rauser-Chernousova et al., p. 219, pl. 30, figs 7–9.

Material examined.- Two specimens illustrated; SF0033, SF0034.

Description.- Two specimens of four loosely coiled volutions are 1.8–2.4 mm in axial length, 1.02–1.25 mm in width, and a form ratio of 1.764–2. Proloculus is large, its outer diameter is 0.05–0.07 mm. The shells are moderate in size, inflated fusiform with convex lateral slopes, and broadly arched periphery. The septa are plane and gently fluted near poles. The chomata are symmetric and massive. The radius vectors from the first to fourth volutions of the specimens are 0.014, 0.021, 0.036, and 0.071 mm for Specimen SF0033 (Figure 5.16A) and 0.014, 0.021, 0.046, and 0.078 mm for SF0034 (Figure 5.16B). The spirotheca in most volutions consists of a tectum and upper tectorium. The diaphanotheca presents in the last volution. The thickness of the spirotheca from the first to fourth volutions of the specimen is 0.014, 0.011, 0.01, and 0.014 mm for SF0033 (Figure 5.16A) and 0.014, 0.014, 0.013, and 0.014 mm for Specimen SF0034 (Figure 5.16B).

Occurrence.- Asad Abad II Section; Absheni Formation; Samples M71, M73; early Podolskian (early late Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The present specimens are assignable to *Fusulinella* (*Moellerites*) *paracolaniae* Safonova described in the Russian Platform (Rauser-Chernousova, 1951), based on their inflated fusiform shape, wall structure, massive chomata, and loosely coiled volutions. Because of their larger shell and poor preservation, however, they are tentatively assigned to *Fusulinella* (*Moellerites*) cf. *paracolaniae* Safonova. This form can be distinguished from other forms of *Fusulinella* in this assemblage; for example, from *Fusulinella* (*Fusulinella*) ex gr. *bocki* Moeller, by having the loosely coiled volutions, less ovoid shape, smaller proloculus, and lacking the diaphanotheca in the inner volutions and from *Fusulinella* (*Fusulinella*) *pseudobocki* Lee & Chen by having the smaller size, more convex lateral slopes, lacking the diaphanotheca in the inner volutions, and the smaller form ratio.

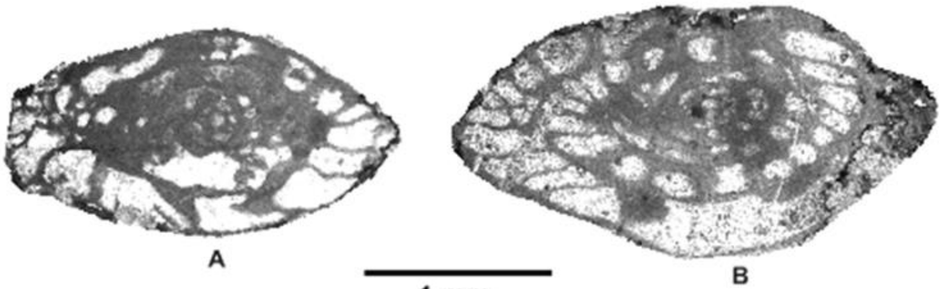

Figure 5.16: *Fusulinella* (*Moellerites*) cf. *paracolaniae* Safonova, 1951. A: SF0033, axial section; B: SF0034, subaxial section.

Family **Aljutovellidae** Solovieva *in* Rauser-Chernousova et al. 1996

Genus ***Aljutovella*** Rauser-Chernousova *in* Rauser-Chernousova et al. 1951

Type species.- *Profusulinella aljutovica* Rauser-Chernousova, 1938

***Aljutovella* cf. *aljutovica* (Rauser-Chernousova, 1951)**

Figure 5.17 (A, B)

Synonym.-

cf. 1938 *Profusulinella aljutovica* Rauser-Chernousova, p. 97 & 98, pl. 1, figs 10–12.

Material examined.- Two specimens illustrated; UM10635, UM10636.

Description.- Two specimens of four volutions are 2–2.4 mm in axial length, 0.9–1.1 mm in diameter, and the form ratio of 2–2.22. The shells are moderate in size, fusiform with slightly convex lateral slopes, and rounded poles. The septa are thin and slightly fluted along the axial region. The chomata are asymmetric, subquadrangular, and fairly massive. The radius vectors from the first to fourth volutions are 0.11, 0.2, 0.34 and 0.51 mm for Specimen UM10635 (Figure 5.17A) and 0.06, 0.16, 0.33, and 0.5 mm for UM10636 (Figure 5.17B). The spirotheca is three layered, composed of a tectum, upper tectorium, and lower tectorium. The thickness of spirotheca from the first to fourth volutions is 0.029, 0.014, 0.023, and 0.021 mm for Specimen UM10635 (Figure 5.17A) and 0.025, 0.033, 0.014, 0.016 mm for UM10636 (Figure 5.17B).

Occurrence.- Asad Abad II Section; Ghaleh Formation; Sample VB7; Melekessian–Vereian (latest Bashkirian–earliest Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The current form is comparable with the type species of *Aljutovella;* that is *Profusulinella aljutovica* Rauser-Chernousova, 1938, from the Russian Platform. The Iranian form, however, differs by having the almost plane septa along the axial region, more elongate shape, and less volutions. They can be easily distinguished from other forms of *Aljutovella* in this assemblage; that is from *Aljutovella* cf. *subaljutovica* Safonova by having the much lesser inflated fusiform shape; and from *Aljutovella* cf. *skelnevatica* (Putrja) by having the smaller proloculus, less inflated fusiform shape, and rounded poles.

Figure 5.17: *Aljutovella* cf. *aljutovica* Rauser-Chernousova, 1938. A: UM10635, subaxial section; B: UM10636, axial section.

Genus ***Tikhonovichiella*** Solovieva *in* Rauser-Chernousova et al. 1996

Type species.- *Aljutovella tikhonovichi* Rauser-Chernousova *in* Rauser-Chernousova et al. 1951

Discussion.- Solovieva *in* Rauser-Chernousova et al. (1996) originally described the *Tikhonovichiella* genus with the *Aljutovella tikhonovichi* Rauser-Chernousova type species. She attributed to that genus the small and inflated fusiform fusulinids with three layers spirotheca (including the tectum, upper tectorium, and lower tectorium), the sub rhomboidal inner volutions, massive chomata, and more or less regular septal fluting. According to Rauser-Chernousova et al. (1996) *Tikhonovichiella* can be distinguished from *Aljutovella* by having the massive chomata, the smaller number of volutions, sub rhomboidal inner volutions, and shortened and inflated shell shape. It differs from *Profusulinella* in having the wavy septa.

However, the taxonomic independence of the genus *Tikhonovichiella* from *Profusulinella* and *Aljutovella* has long been the subject to debate. For example Kobayashi (2011) considers this taxonomic treatment as a controversial issue, stating that almost all what is treated by Solovieva *in* Rauser-Chernousova et al. (1996) as *Tikhonovichiella* are not easily distinguished from *Aljutovella* and *Profusulinella* and should be synonymous with the aforementioned genera. According to Kobayashi (2011), in her new genus, Solovieva *in* Rauser-Chernousova et al. (1996) includes a large number of species that all of them are thought to be junior synonyms of *Aljutovella* and *Profusulinella*.

In this study, the genus *Tikhonovichiella* is accepted, following Solovieva in Rauser-Chrnousova et al. (1996).

Tikhonovichiella tikhonovichi **(Rauser-Chernousova, 1951)**

Figure 5.18 (A, B)

Synonym.-

1951 *Aljutovella tikhonovichi* Rauser-Chernousova *in* Rauser-Chernousova et al., p.185–186, pl. 19, figs 12, 13.

Material examined.- Two specimens illustrated; UM10637, UM10638.

Description.- Two specimens of three and a half to four and a half volutions are available. They are 1.5–1.7 mm in axial length, 0.8–1 mm in diameter, with the form ratio of 1.5–2 and outside diameter of 0.057–0.11 mm. The chomata are massive, vary between 0.028–0.057 mm for Specimen UM10637 (Figure 5.18A) and 0.057–0.085 mm for UM10638 (Figure 5.18B). The radius vectors from the first to fourth volutions are 0.03, 0.13, 0.25, and 0.41 mm for Specimen UM10637 [Figure 5.18 (A)] and 0.06, 0.16, 0.26, and 0.45 mm for UM10638 [Figure 5.18 (B)]. The spirotheca is three layered, composed of a tectum, upper tectorium, and lower tectorium. The thickness of spirotheca from the first to fourth volutions is 0.016, 0.016, 0.025, and 0.03 mm for Specimen UM10637 (Figure 5.18A) and 0.014, 0.016, 0.025, and 0.05 mm for UM10638 (Figure 5.18B).

Occurrence.- Asad Abad II Section; Ghaleh Formation; Samples VB6.1, VB7; Melekessian–Vereian (latest Bashkirian–earliest Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The specimens are identified to *Tikhonovichiella tikhonovichi* (Rauser-Chernousova), based on their three layered wall, inflated fusiform shape, pointed poles, massive chomata, and sub rhomboidal inner volutions. These specimens can be easily distinguished from other forms of *Tikhonovichiella* in this assemblage. They are very similar to *Tikhonovichiella* aff. *grozdilovae* Ektova by their inflated fusiform shape, massive chomata, and intensity of septal fluting. But they differ from the latter by having the more pointed poles and the smaller proloculus. They are also distinguished from *Tikhonovichiella pseudoaljutovica* (Rauser-Chernousova) by having the more pointed poles and the wavier septa in the middle part of the shell. The present specimens can also be distinguished from *Tikhonovichiella* cf. *gracilis* Ektova by their larger size, inflated fusiform shape, and bluntly pointed poles.

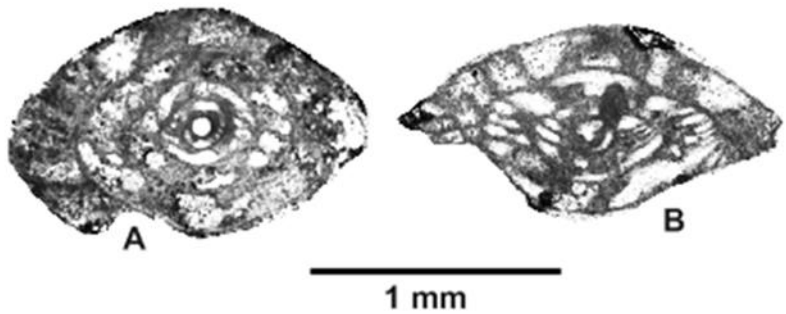

Figure 5.18: *Tikhonovichiella tikhonovichi* (Rauser-Chernousova, 1951). A: UM10637, axial section; B: UM10638, axial section.

***Tikhonovichiella* cf. *tikhonovichi* (Rauser-Chernousova, 1951)**

Figure 5.19 (A, B)

Synonym.-

cf. 1951 *Aljutovella tikhonovichi* Rauser-Chernousova *in* Rauser-Chernousova et al., p.185–186, pl. 19, figs 12, 13.

Material examined.- Two specimens illustrated; SF0024, SF0025.

Description.- Two axial sections of four to four and a half volutions is 1.6–1.9 mm in axial length, 0.9–1.1 mm in diameter, and a form ratio of 1.72–1.77. Proloculus is relatively large, its outer diameter is 0.11–0.17 mm. The chomata are massive, vary between 0.056–0.083 mm for Specimen SF0024 (Figure 5.19A) and 0.032–0.052 mm for SF0025 (Figure 5.19B). The shells are inflated fusiform, small in size, with slightly convex lateral slopes and pointed poles. The chomata are asymmetric and massive. The septa are almost perpendicular to spirotheca or slightly anteriorly directed. The radius vectors from the first to fourth volutions of the specimens are 0.088, 0.205, 0.382, and 0.47 mm, for Specimen SF0024 (Figure 5.19A) and 0.058, 0.205, 0.323, and 0.44 mm for SF0025 (Figure 5.19B). The spirotheca is three layered, composed of a tectum, upper tectorium, and lower tectorium. The thickness of the spirotheca from the first to fourth volutions of the specimens are 0.044, 0.058, 0.029, and 0.058 mm for Specimen SF0024 (Figure 5.19A) and 0.014, 0.044, 0.029, and 0.029 mm for SF0025 (Figure 5.19B).

Occurrence.- Asad Abad II Section; Ghaleh Formation; Sample VB6.1; Melekessian–Vereian (latest Bashkirian–earliest Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The present form is close to *Tikhonovichiella tikhonovichi* (Rauser-Chernousova) described earlier. Because of the poor preservation, however, this is tentatively identified as *Tikhonovichiella* cf. *tikhonovichi* (Rauser-Chernousova).

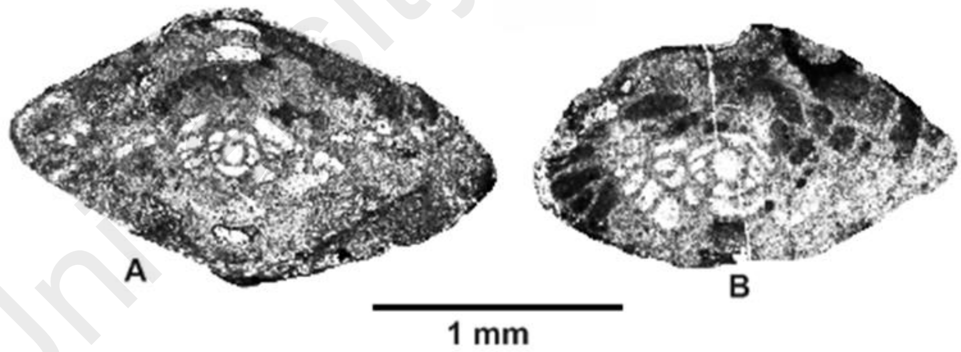

Figure 5.19: *Tikhonovichiella* cf. *tikhonovichi* (Rauser-Chernousova, 1951). A: SF0024, axial section; B: SF0025, axial section.

Tikhonovichiella pseudoaljutovica **(Rauser-Chernousova, 1951)**

Figure 5.20 (A, B)

Synonym.-

1951 *Aljutovella pseudoaljutovica* Rauser-Chernousova *in* Rauser-Chernousova et al., p. 186–187, pl. 20, Fig. 12

Material examined.- Two specimens illustrated; SF0026, SF0027.

Description.- Two axial sections of three and a half volutions are 1.5–1.6 mm in axial length, 0.8–0.88 mm in diameter, and a form ratio of 1.81–1.87. The shells are inflated fusiform, small in size, with slightly convex lateral slopes and nearly pointed poles. The proloculus is relatively large its outer diameter is 0.17–0.18 mm. The chomata are massive, vary between 0.057–0.086 mm for Specimen SF0026 (Figure 5.20A) and 0.057–0.071 mm for SF0027 (Figure 5.20B). The radius vectors from the first to fourth volutions are 0.088, 0.147, 0.264, and 0.411 mm for Specimen SF0026 (Figure 5.20A) and 0.088, 0.151, 0.28, and 0.48 mm for SF0027 (Figure 5.20B). The height of the volutions is gradually increasing in outer volutions. The spirotheca is three layered, composed of a tectum, upper tectorium, and lower tectorium. The thickness of spirotheca from the first to fourth volutions is 0.029, 0.014, 0.058, and 0.029 mm for Specimen SF0026 (Figure 5.20A) and 0.020, 0.011, 0.05, and 0.03 mm for SF0027 (Figure 5.20B). The chomata are asymmetrical and not well-developed in the outer volutions. Septal fluting is weak in the middle part of the shell and is almost perpendicular to spirotheca.

Occurrence.- Asad Abad II Section; Ghaleh Formation; Sample VB7; Melekessian–Vereian (latest Bashkirian–earliest Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The current specimens are assigned to *Tikhonovichiella pseudoaljutovica* (Rauser-Chernousova) based on their three layer spirotheca and inflated fusiform tests with slightly convex lateral slopes and nearly pointed poles. This form can be distinguished from other forms of *Tikhonovichiella* in this assemblage; that is, from *Tikhonovichiella tikhonovichi* (Rauser-Chernousova) by having less and straighter septa in the middle part of the shell, and nearly rounded poles and from *Tikhonovichiella* aff. *grozdilovae* Ektova by having the less well-developed chomata, smaller proloculus, and less septal fluting in the middle of the shell.

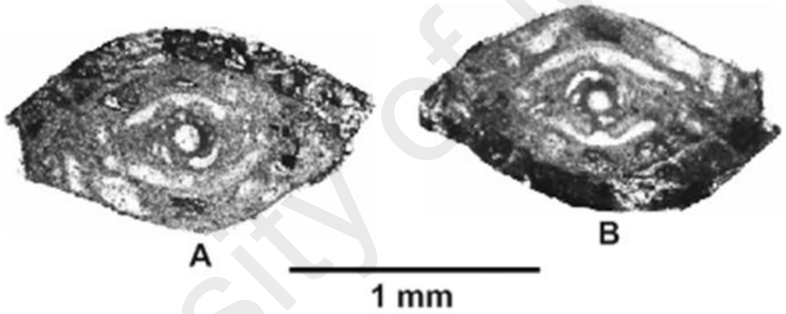

Figure 5.20: *Tikhonovichiella pseudoaljutovica* (Rauser-Chernousova, 1951). A: SF0026, axial section; B: SF0027, axial section.

***Tikhonovichiella* aff. *grozdilovae* (Ektova, 1972)**

Figure 5.21

Synonym.-

aff. 1972 *Aljutovella grozdilovae* Ektova

Material examined.- One specimen illustrated; SF0028.

Description.- One specimen of four volutions is 1.6 mm in axial length, 0.9 mm in width, and a form ratio of 1.649. The proloculus is large, its outer diameter is 0.2 mm. The shell is small in size, inflated fusiform with convex lateral slopes, and broadly arched periphery. The septa are plane and gently fluted near poles. The chomata are symmetric and massive in the inner volutions with the diameter between 0.072–0.085 mm. The radius vectors from the first to fourth volutions of the specimen are 0.058, 0.176, 0.323, and 0.47 mm, respectively. The spirotheca is thin, consists of three layered; tectum, upper tectorium, and lower tectorium. The thickness of the spirotheca from the first to fourth volutions of the specimen is 0.029, 0.029, 0.044, and 0.029 mm, respectively.

Occurrence.- Asad Abad II Section; Ghaleh Formation; Sample VB7; Melekessian–Vereian (latest Bashkirian–earliest Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The specimen is assignable to the *Tikhonovichiella grozdilovae* Ektova based on the massive chomata, inflated fusiform shape, three layered wall, moderate septal folding, and nearly rounded poles. Because of its larger shell, however, the Iranian species is tentatively identified as *Tikhonovichiella* aff. *grozdilovae*. This form is distinguishable from other forms of *Tikhonovichiella* in this assemblage; that is, from *Tikhonovichiella tikhonovichi* (Rauser-Chernousova) by having the fairly symmetrical chomata, larger proloculus, and nearly rounded poles and from *Tikhonovichiella pseudoaljutovica* (Rauser-Chernousova) by having the larger proloculus, rounded poles and wavier septa in the middle part of the shell.

Figure 5.21: *Tikhonovichiella* aff. *grozdilovae* Ektova, 1972. SF0028, axial section.

Family **Fusulinidae** von Moeller, 1878

Subfamily **Beedeininae** Solovieva, 1996

Genus ***Beedeina*** Galloway, 1933

Type species.- *Fusulinella girtyi* Dunbar & Condra, 1927

***Beedeina samarica* Rauser-Chernousova & Belyaev *in* Rauser-Chernousova et al. 1940**

Figure 5.22 (A, B)

Synonym.-

1940 *Fusulina samarica* Rauser-Chernousova & Belyaev *in* Rauser-Chernoussova et al., p. 19–21, p. 72, pl. 3, figs 4–9; pl. 4, figs 1–3.

Material examined.- Two specimens illustrated; SF0029, SF0030.

Description.- Two specimens of five to six volutions are 3.1–3.57 mm in axial length, 1.64–2 mm in diameter, and a form ratio of 1.78–1.87. Proloculus of moderate size, its outer diameter is 0.06 mm. The shells are inflated fusiform, rather large in size, with convex lateral slopes and rounded poles. The chomata are asymmetric and massive, most distinct in first four volutions, with the diameter between 0.095–0.19 mm for Specimen SF0029 (Figure 5.22A) and 0.047–0.14 mm for SF0030 (Figure 5.22B). Thin septa are slightly fluted in the middle area of the shell they are rather strongly fluted in the ends and poles. The radius vectors from the first to sixth volutions of the specimens are 0.28, 0.57, 0.85, 1.2, 1.5, and 1.7 mm, for Specimen SF0029 (Figure 5.22A) and 0.14, 0.21, 0.28, 0.48, 0.64, and 0.86 mm for SF0030 (Figure 5.22B). The spirotheca is four layered, composed of a tectum, upper tectorium, lower tectorium, and diaphanotheca. The thickness of spirotheca from the first to the last volutions of the specimens is 0.028, 0.021, 0.028, 0.028, 0.025, and 0.042 mm for Specimen SF0029 (Figure 5.22A) and 0.014, 0.014, 0.014, 0.028, 0.028, and 0.030 mm for SF0030 (Figure 5.22B).

Occurrence.- Asad Abad II Section; Absheni Formation; Samples M38 and M52; late Kashirian (early Moscovian); Pennsylvanian; Carboniferous.

Discussion.- The current form is identified with *Beedeina samarica* Rauser-Chernousova & Belyaev (Rauser-Chernousova et al. 1940) from the Russian Platform based on its size, massive chomata, inflated fusiform shape, and rounded poles. It differs from other species of *Beedeina*, for example from *B. schwellwieni* (Staff) in having the larger size, the smaller form ratio, and more pointed poles. *Beedeina samarica* is also distinguished from *B. elegans* (Rauser-Chernousova & Beljaev) in having the smaller size, more inflated fusiform shape, and more sharply pointed poles.

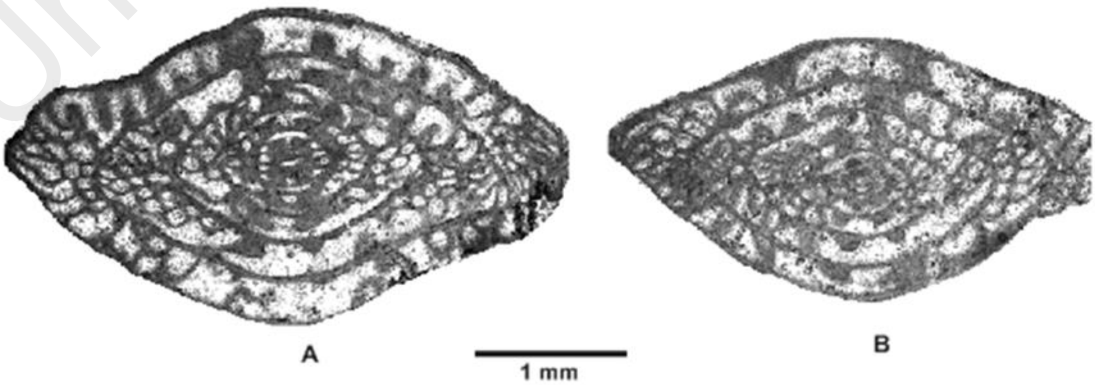

Figure 5.22: *Beedeina samarica* Rauser-Chernousova & Belyaev. A: SF0029, subaxial section; B: SF0030, axial section.

Order **Schwagerinida** Solovieva, 1985

Family **Schwagerinidae** Dunbar & Henbest, 1930

Subfamily **Psedoschwagerininae** Chang, 1963

Genus ***Pseudoschwagerina*** Dunbar & Skinner, 1936

Type species.- *Schwagerina uddeni* Beede & Knicker, 1924

***Pseudoschwagerina* ? sp.**

Figure 5.23

Material examined.- One specimen illustrated; UM10685.

Description.- Two inner volutions are closely coiled, the later one is loosely coiled and the last volution has the lower height than the penultimate volution. The shell is subspherical with rounded polar poles and convex lateral slopes. Chomata is absent. The septa are plane and slightly fluted near the base. The proloculus is large of 0.13 mm in diameter. The radius vectors from the first to fourth volutions of the specimen are 0.13, 0.3, 0.6, and 1 mm, respectively. The spirotheca is thick, consists of tectum and keriotheca. The thickness of spirotheca from the first to fourth volutions of the specimen is 0.01, 0.02, 0.08, and 0.08 mm, respectively.

Occurrence.- Banarizeh Section; Vazhnan Formation; Sample S267.3; middle Asselian; Early Permian.

Discussion.- The current specimen is comparable with *Pseudoschwagerina*. The Iranian form, however, differs by lacking the tightly coiled juvenarium and having the smaller shell with less volution.

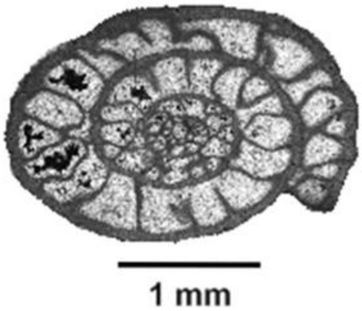

Figure 5.23: *Pseudoschwagerina* ? sp. (UM10685, oblique section).

Family **Pseudofusulinidae** Dutkevitch, 1934

Subfamily **Pseudofusulininae** Dutkevich, 1934

Genus ***Praepseudofusulina*** Ketat & Zolotukhina, 1984

Type species.- *Pseudofusulina* ? *fastuosa* Ketat, 1971

Praepseudofusulina kljasmica **(Sjomina, 1961)**

Figure 5.24 (A–C)

Synonym.-

1961 *Pseudofusulina* ? *pusilla* subsp. *kljasmica* Sjomina, p. 50–51, pl. 2, figs 1, 2.

Material examined.- Three specimens illustrated; UM10661, UM10662, UM10663.

Description.- Three specimens of six to seven volutions are 4.5–5.5 mm in axial length, 1.7–2.2 mm in diameter, and a form ratio of 2.54–2.64. Two or three inner volutions are tightly coiled, the coils gradually enlarging to the outer whorls. The proloculus is spherical, 0.04–0.12 mm in outer diameter. The shells are rather large, ovoid or short fusiform with rounded poles. The septal fluting is intensive. The chomata are indistinct, rudimentary chomata may be present in the two or three inner volutions. The radius vectors from the first to last volutions of the specimens are 0.1, 0.2, 0.3, 0.3, 0.4, 0.7, and 0.9 mm for Specimen UM10661 (Figure 5.24A), 0.15, 0.38, 0.6, 0.76, 1.07, 1.38 mm for UM10662 (Figure 5.24B), and 0.07, 0.3, 0.46, 0.76, 0.9, 1.53 mm for UM10663 (Figure 5.24C). The spirotheca is composed of a thin tectum and moderately coarse keriotheca. The thickness of spirotheca is 0.055, 0.055, 0.083, 0.11, 0.11, 0.11, and 0.055 mm for Specimen UM10661 (Figure 5.24A), 0.071, 0.085, 0.072, 0.071, 0.142, and 0.078 mm for UM10662 (Figure 5.24B), and 0.038, 0.038, 0.076, 0.077, 0.076, and 0.11 mm for UM10663 (Figure 5.24C).

Occurrence.- Banarizeh Section; Vazhnan Formation; latest Gzhelian–Asselian; Samples S248, S267.5, S270; late carboniferous–Early Permian.

Discussion.- Inflated fusiform shape, rounded poles, and septal fluting of the Iranian form agree well with *Praepseudofusulina kljasmica* (Sjomina) from the Russian Platform (Sjomina, 1961). This form can be distinguished from other forms of *Praepseudofusulina* in this assemblage; that is, from *Praepseudofusulina* cf. *saratovensis* (Chernova) by having the plane septa in the mid region of the shell, more elongated shape, and somewhat pointed poles. It is distinguished from *Praepseudofusulina incomperta* (Scherbovich) by having the tight two or three inner volutions, larger size, more fusiform shape, and the smaller proloculus.

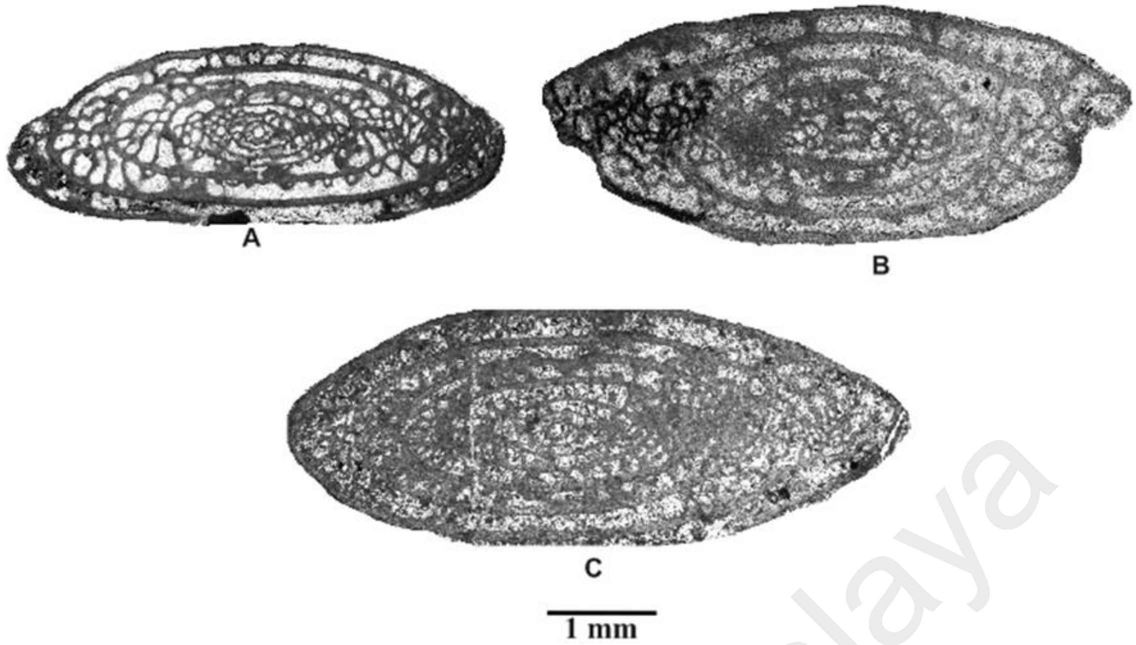

Figure 5.24: *Praepseudofusulina kljasmica* (Sjomina, 1961). A: UM10661, axial section; B: UM10662, subaxial section; C: UM10663, axial section.

***Praepseudofusulina incomperta* (Scherbovich, 1971)**

Figure 5.25 (A, B)

Synonym.-

Pseudofusulina incomperta Scherbovich, 1971, p. 80, pl.2, figs 5–7.

Material examined.- Two specimens illustrated; UM10675, UM10676.

Description.- Two specimens of four and a half to five volutions are 2.3 mm in axial length, 1.2–1.4 mm in diameter, and a form ratio of 1.92. The proloculus is spherical, medium, 0.1–0.14 mm in outer diameter. The shells are small in size,

inflated fusiform with rounded poles. The septa are irregularly fluted in the inner volutions and regularly and strongly fluted in the outer ones. The radius vectors from the first to last volutions of the specimens are 0.08, 0.13, 0.2, 0.33, and 0.51 mm for Specimen UM10675 (Figure 5.25A), and 0.08, 0.17, 0.25, 0.37, and 0.45 mm for UM10676 (Figure 5.25B). The spirotheca is thin composed of a thin tectum and moderately coarse keriotheca. The thickness of the spirotheca is 0.011, 0.022, 0.022, 0.044, and 0.044 mm for Specimen UM10675 (Figure 5.25A) and 0.014, 0.022, 0.028, 0.042, and 0.028 mm for UM10676 (Figure 5.25B).

Occurrence.- Banarizeh Section; Vazhnan Formation; Samples S267.4, S267.5; latest Gzhelian–Asselian; Late Carboniferous– Early Permian.

Discussion.- The present specimens can be easily distinguished from other forms of *Praepseudofusulina* in this assemblage; for example, from *Praepseudofusulina kljasmica* (Sjomina) by having the smaller shell and intensive septal fluting in the outer volutions, from *Praepseudofusulina* cf. *saratovensis* (Chernova) by having the smaller shell and less convex lateral slopes. It is also distinguishable from *Praepseudofusulina* cf. *impercepta* (Jagofarova) by having the larger form ratio and smaller test. The present specimens are very similiar to *Pseudofusulina mikhailovi* Leven, 1971; however, the Iranian forms are distinguished from *P. mikhailovi* by having the shorter test.

Figure 5.25: *Praepseudofusulina incomperta* (Scherbovich, 1971). A: axial section, UM10675; B: axial section, UM10676.

***Praepseudofusulina* cf. *saratovensis* (Chernova, 1971)**

Figure 5.26

Synonym.-

cf. 1971 *Pseudofusulina saratovensis* Chernova, p. 80, pl. 2, figs. 5–7.

Material examined.- One specimen illustrated; UM10677.

Description.- One axial section of seven volutions is 5.4 mm in axial length, 2.6 mm in diameter, and a form ratio of 2.07. The proloculus is moderate in size; its outer diameter is 0.13 mm. The shell is rather large in size, inflated fusiform with rounded poles and convex lateral slopes. The septa are rather weakly fluted in the middle part of the shell and strongly fluted in the poles of the three inner volutions. The test coiled a little tightly in inner two or three volutions and gradually expanded in succeeding whorls. The chomata are not distinct, the rudimentary chomata may be present in the inner volutions. The radius vectors from the first to the last volutions of the specimen are 0.11, 0.22, 0.36, 0.55, 0.7, 0.1, and 1.2 mm. The spirotheca is thin, varies between 0.03–0.1 mm, and is composed of a thin tectum and keriotheca.

Occurrence.- Banarizeh Section; Vazhnan Formation; Sample S267.5; latest Gzhelian–Asselian; Late Carboniferous– Early Permian.

Discussion.- The present specimen agrees in major diagnostic characters such as the inflated fusiform shell, rounded poles, number of volutions, septal fluting and proloculus diameter to *Praepseudofusulina saratovensis* (Chernova) from the Russian Platform. The Iranian form, however, cannot be assigned to a definite species because of having the less septal fluting in the poles. This form can be easily distinguished from other forms of *Praepseudofusulina* in this study; that is, from *Praepseudofusulina kljasmica* by having the more convex lateral slopes in its shape and rounded poles, from *Praepseudofusulina incomperta* (Scherbovich) by having the smaller proloculus, more convex lateral slopes, a larger overall shell size, and more intense septal fluting in the inner volutions and from *Praepseudofusulina* cf. *impercepta* (Jagofarova) by having the larger form ratio and stronger septal fluding in the three inner volutions.

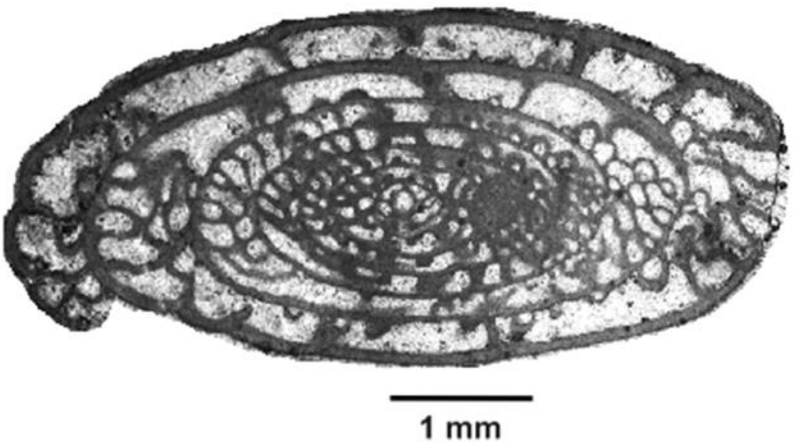

Figure 5.26: *Praepseudofusulina* cf. *saratovensis* (Chernova, 1971). UM10677, axial section.

***Praepseudofusulina* cf. *impercepta* (Jagofarova, 1971)**

Figure 5.27

Synonym.-

cf. 1971 *Pseudofusulina*? *impercepta* Kireeva et al., p.89, pl. 4, figs. 7 & 8.

Material examined.- One specimen illustrated; UM10678.

Description.- One axial section of six and a half volutions is 4.1 mm in axial length, 2.3 mm in diameter, and a form ratio of 1.78. The shell is rather large in size, inflated fusiform with rounded poles. The proloculus is large, its outer diameter is 0.2 mm. The radius vectors from the first to the last volutions of the specimen are 0.1, 0.3, 0.5, 0.7, 1, 1.3, and 1.6 mm, respectively. The septa are regularly fluted throughout the shell. The spirotheca is thin, composed of a thin tectum and keriotheca. The thickness of spirotheca from the first to the last volutions is 0.01, 0.01, 0.01, 0.1, 0.1, 0.1, and 0.1 mm.

Occurrence.- Banarizeh Section; Vazhnan Formation; Sample S270; latest Gzhelian–Asselian; Late Carboniferous– Early Permian.

Discussion.- The current specimen is comparable with *Praepseudofusulina impercepta* (Jagofarova) from the Russian Platform. The Iranian form, however, differs by having the more inflated shape and weaker septal fluting in the inner volutions. This form can be easily distinguished from other forms of *Praepseudofusulina* in this assemblage; that is, from *Praepseudofusulina kljasmica* (Sjomina) by having the more inflated fusiform shape, smaller form ratio, and larger proloculus and from *Praepseudofusulina incomperta* (Scherbovich) by having the larger shell, regular septal fluting throughout the shell, more convex lateral slopes, and larger proloculus. It is also distinguished from *Praepseudofusulina* cf. *saratovensis* (Chernova) by having the smaller shell and form ratio, regular septal fluting throughout the shell, and larger proloculus.

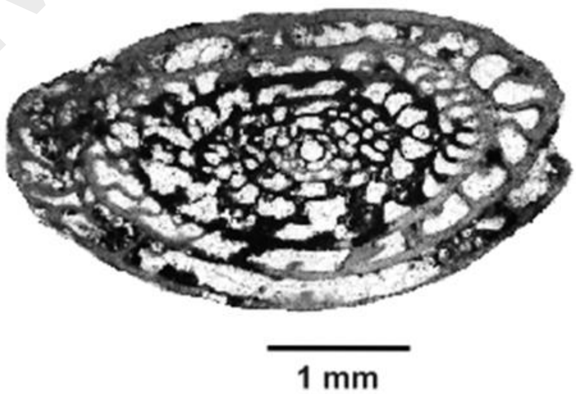

Figure 5.27: *Praepseudofusulina* cf. *impercepta* (Jagofarova, 1971). UM10678, axial section.

Genus *Nonpseudofusulina* Leven, 2008

Type species.- *Pseudofusulina blochini* Korzhenevsky, 1940

Discussion.- The *Pseudofusulina* genus with the *Pseudofusulina huecoensis* as the type species was first described by Dunbar and Skinner (1931) from the Hueco Limestone of the North American Wolfcampian of Early Permian age (Ueno et al. 2011). The genus is characterized by the elongated fusiform fusulinoids, with the tectum and keriothecal structure in the wall, and more or less regular septal fluting (Dunbar and Skinner 1931). Skinner and Wilde (1965, 1966) further pointed out that *Pseudofusulina huecoensis* exhibits the rugosity in its wall. Based on these features, Rauser-Chernousova managed to tell apart the *Rugosofusulina* genus that was known to be the younger synonym of the *Pseudofusulina* genus. However, ignoring this fact and as per Dunbar and Skinner (1931), Rauser-Chernousova (1996) described the *Pseudofusulina* genus in the "Reference Book on the Systematics of Paleozoic Foraminifers" (Leven & Gorgij, 2009).

The description by Rauser-Chernousova et al. (1996) encompasses a large group of fusulinids which possess all features of *Pseudofusulina huecoensis* Dunbar and Skinner, 1931, except for the rugosity of the wall.

On the other hand, according to Ueno et al. (2011), after the evolution of Pangaea, which was approximately estimated at the Middle Carboniferous time, the Schwagerinid faunas, which could potentially be separated between North America and Eurasia, exhibit the paleobiogeographic difference of both areas. Accordingly, in some cases, the Eurasian forms could have completely different origins with the type species of the genus from North America. It is therefore possible that pseudofusulinids with large variability are polyphyletic.

These opinions raise doubts about the definition of the Eurasian forms of *Pseudofusulina*, which are characterized by regularly fluted septa, obvious secondary deposits, and the absence of rugosity. Accordingly, the usage of the generic name *Pseudofusulina* for the Eurasian forms is the subject to debate and the fusulinids in question cannot be in the same class of that genus.

Fusulinids of this kind were highlighted by Leven (2008), who suggested a new name for the species described from Eurasia under *Pseudofusulina*. He proposed *Nonpseudofusulina* (not *Pseudofusulina*) with *Pseudofusulina blochini* Korzhenevsky 1940, as the type species for the majority of species lacking rugosity, which are not included in *Praepseudofusulina*, *Pseudochusenella*, *Rugosochusenella*, and *Anderssonites*. Leven (2008), although, states that *Nonpseudofusulina* has a very large variability in terms of its basic morphology. It is therefore possible that a number of distinct lineages can be included within *Nonpseudofusulina*.

Ueno et al. (2011), however, consider this taxonomic treatment as a controversial issue, stating that almost all what is treated by Leven (2008) as *Nonpseudofusulina* lacks the heavy axial fillings, and is barren of clearly recognizable juvenile volutions. Therefore, in his new genus, Leven (2008) includes a large number of species that are commonly regarded as *Pseudofusulina* by most fusulinoid workers. Ueno et al. (2011) specify that although this taxonomic problem on *Pseudofusulina* could be partly solved via the introduction of *Nonpseudofusulina* by Leven (2008), the basic premise of whether or not *Nonpseudofusulina* is monophyletic is still up for debate.

In this study, the genus *Nonpseudofusulina* is accepted, following Leven (2008).

Nonpseudofusulina cf. _modesta_ (Scherbovich, 1971)

Figure 5.28

Synonym.-

cf. 1971 *Pseudofusulina modesta* Kireeva et al., p. 80, pl. 2, figs 5–7.

Material examined.- One specimen illustrated; UM10681.

Description.- One specimen of four volutions is 3.8 mm in axial length, 1.5 mm in width, and a form ratio of 2.53. The height of the volutions gradually increases in outer volutions. The shell is rather large in size, fusiform with broadly arched periphery. The septa are regularly fluted throughout the shell and makes chamberlets in the polar regions. The radius vectors from the first to fourth volutions of the specimen are 0.176, 0.294, 0.47, and 0.882 mm, respectively. The spirotheca consists of a thin tectum and moderately coarse keriotheca. The thickness of the spirotheca from the first to fourth volutions of the specimen is 0.058–0.117 mm.

Occurrence.- Banarizeh Section; Vazhnan Formation; Sample S262; latest Gzhelian–Asselian; Late Carboniferous– Early Permian.

Discussion.- *Nonpseudofusulina* is distinguished from *Praepseudofusulina* by its elongated to swollen fusiform shell, loosely coiled spiral in the inner volutions and regularly expanding coiled in the outer ones, and distinct keriotheca. Besides, the stratigraphic range of *Nonpseudofusulina* is confined from the late Gzhelian to Midian inclusive while *Praepseudofusulina* is limited to the latest Gzhelian and Asselian stages.

The current Iranian form is comparable with *Nonpseudofusulina modesta* from the Russian Platform (Rauser-Chernousova et al. 1996). It, however, differs by having the cuniculi, more elongated inner volutions, somewhat pointed poles, smaller size, and lower and less uniform septal fluting.

Figure 5.28: *Nonpseudofusulina* cf. *modesta* (Scherbovich, 1971). UM10681, subaxial section.

***Nonpseudofusulina* sp.**

Figure 5.29 (A, B)

Material examined.- Two specimens illustrated; UM10682, UM10683.

Description.- Two axial sections of five volutions are 4.9–5.1 mm in axial length, 1.4–1.7 mm in diameter, and a form ratio of 3–3.5. The shells are medium, long fusiform with rounded poles. The proloculus is large, its outer diameter is 0.16–0.19 mm. The radius vectors from the first to the last volutions of the specimens are 0.05, 0.23, 0.3, 0.46, and 0.73 mm for Specimen UM10682 (Figure 5.29A) and 0.05, 0.27, 0.46, 0.65, and 0.96 mm for UM10683 (Figure 5.29B). The septa are regularly fluted throughout the shell. The spirotheca consists of a thin tectum and keriotheca. The thickness of spirotheca from the first to the last volutions is 0.01, 0.016, 0.016, 0.07, and 0.08 mm for Specimen UM10682 (Figure 5.29A) and 0.01, 0.02, 0.012, 0.08, and 0.02 for UM10683 (Figure 5.29B).

Occurrence.- Banarizeh Section; Vazhnan Formation; Sample S251; latest Gzhelian–Asselian; Late Carboniferous– Early Permian.

Discussion.- These specimens resemble some species of *Nonpseudofusulina*, but the exact identification cannot be made due to their poor preservation.

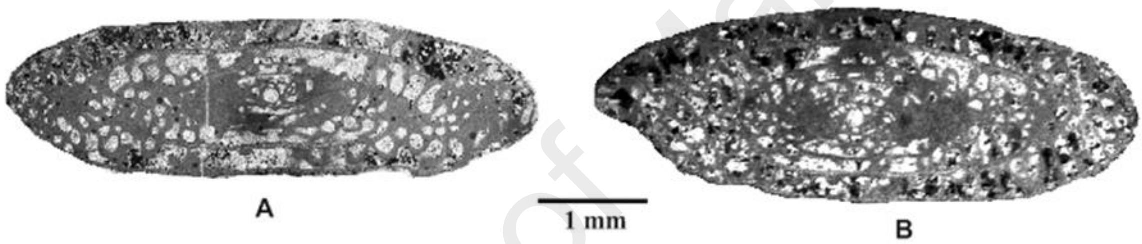

Figure 5.29: *Nonpseudofusulina* sp. A: UM10682, axial section; B: UM10683, axial section.

***Nonpseudofusulina* ? sp.**

Figure 5.30

Material examined.- One specimen illustrated; SF0052.

Description.- One subaxial section of four volutions is 6.6 mm in axial length, 1.6 mm in diameter, and a form ratio of 4.12. The shell is large in size, long fusiform with rounded poles. The radius vectors from the first to the last volutions of the specimen are 0.25, 0.4, 0.6, and 0.8 mm, respectively. The septa are regularly fluted throughout the shell and make the cuniculi. The spirotheca consists of a thin tectum and keriotheca. The thickness of the spirotheca from the first to the last volutions is 0.03, 0.05, 0.05, and 0.03 mm, respectively.

Occurrence.- Banarizeh Section; Vazhnan Formation; Sample S241; latest Gzhelian–Asselian; Late Carboniferous–Early Permian.

Discussion.- The present form is similar to *Nonpseudofusulina* based on its elongated fusiform shape, loosely coiled spiral in the inner volutions and regularly expanding in the outer ones, and bluntly pointed poles. However, due to the insufficient material, a definite species could not be assigned to this form.

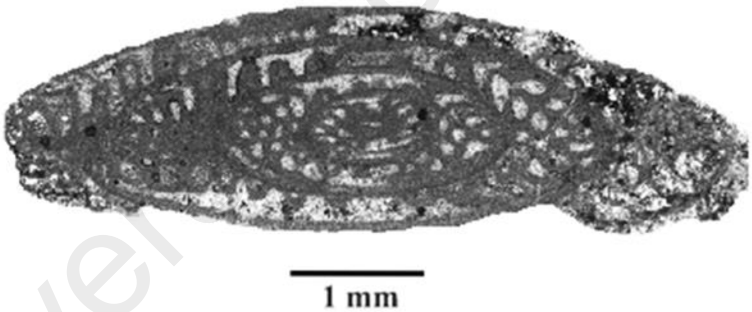

Figure 5.30: *Nonpseudofusulina* ? sp. SF0052, subaxial section.

5.2 Subdivisions of the Carboniferous and Permian Systems

The traditional scales of the Carboniferous and Permian Systems used for the sedimentary sequences of the Western and Eastern Europe are mostly based on the foraminifers and ammonoids. However, recently the scales have been updated by coordinating them with the conodont zonations (e.g. Weddige, 1987; Menning et al. 2003; Chlupac & Hladil, 2000). According to recent decision, the Carboniferous System is divided into two parts; namely, the Mississippian, and Pennsylvanian Subsystems with the approved boundaries (GSSPs; i. e. the Global Stratotype Section and Point). Nevertheless, about the division of the subsystems into the series and stages, there has not been made the final decision so far (Leven & Gorgij, 2011c). The Permian Tethyan chronostratigraphy which is based on the fusulinid evolution is divided into two parts; namely, the Cisuralian and Tethysian Subsystems (Leven, 1980a, 2003). In the chronozanation of Jin et al. (1997), the Permian deposites were compared within the three great subcontinents; namely, Russia, USA, and China. According to this scale, the Permian System is divided into three Series: Cisuralian, Guadalupian, and Lopingian.

The Tournaisian–Changhsingian stages of the Carboniferous and Permian Systems correspond to different chronostratigraphic subdivisions in different regions such as the Russian Platform, Southern Urals, Western Europe, North America, and China (Leven, 1980a, 2003; Jin et al. 1997; Kulagina et al. 2009; Richards, 2013). Figures 5.31–5.34 outline the global and regional subdivisions of the Carboniferous and Permian Systems.

In this research, for the Mississippian Series, the chronostratigraphic subdivisions in Western Europe and for the Pennsylvanian–earliest Permian, the chronostratigraphic subdivisions of the Russian Platform are followed.

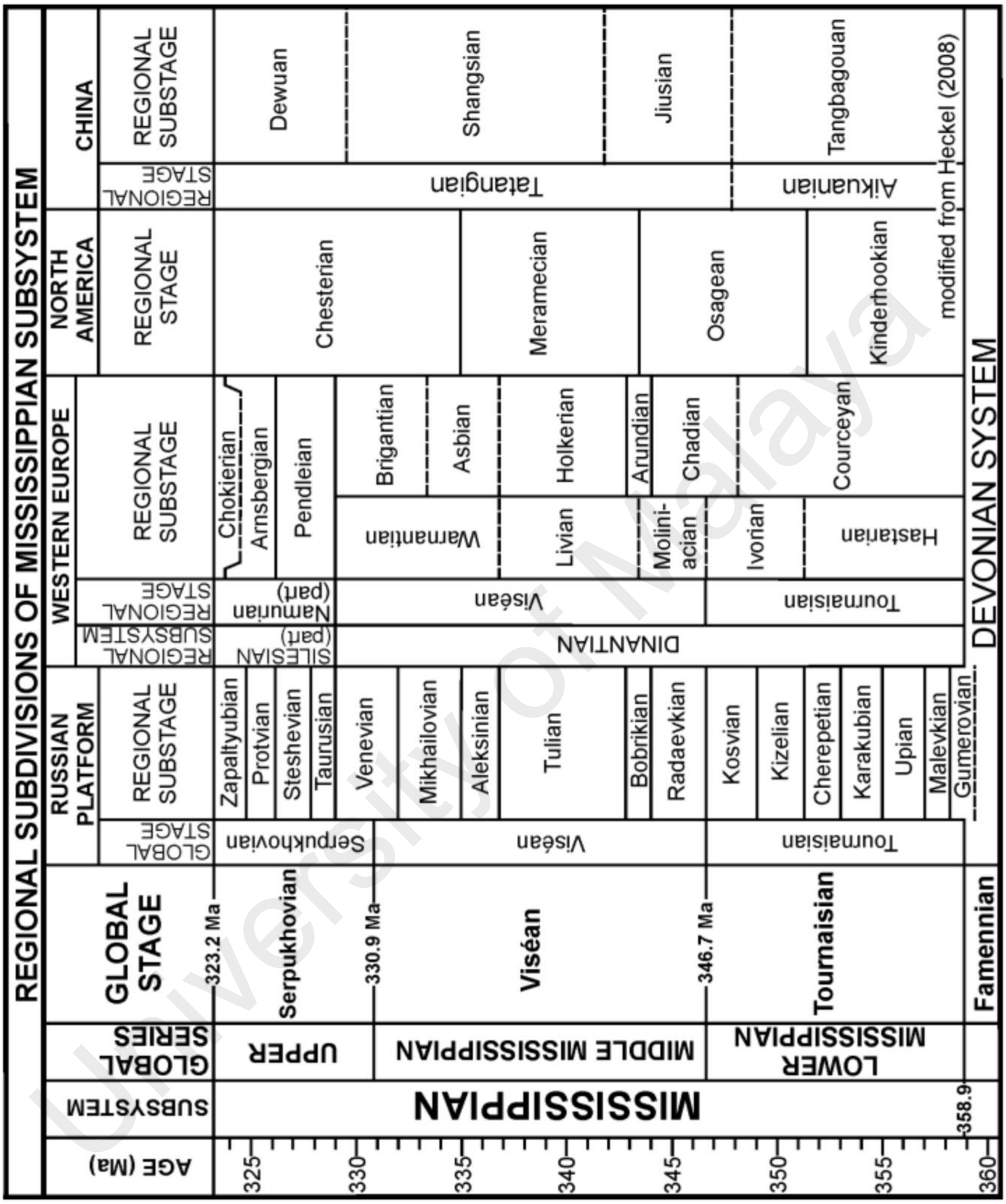

Figure 5.31: Global and regional subdivisions of the Mississippian Subsystem of the Carboniferous System (adapted after Richards, 2013).

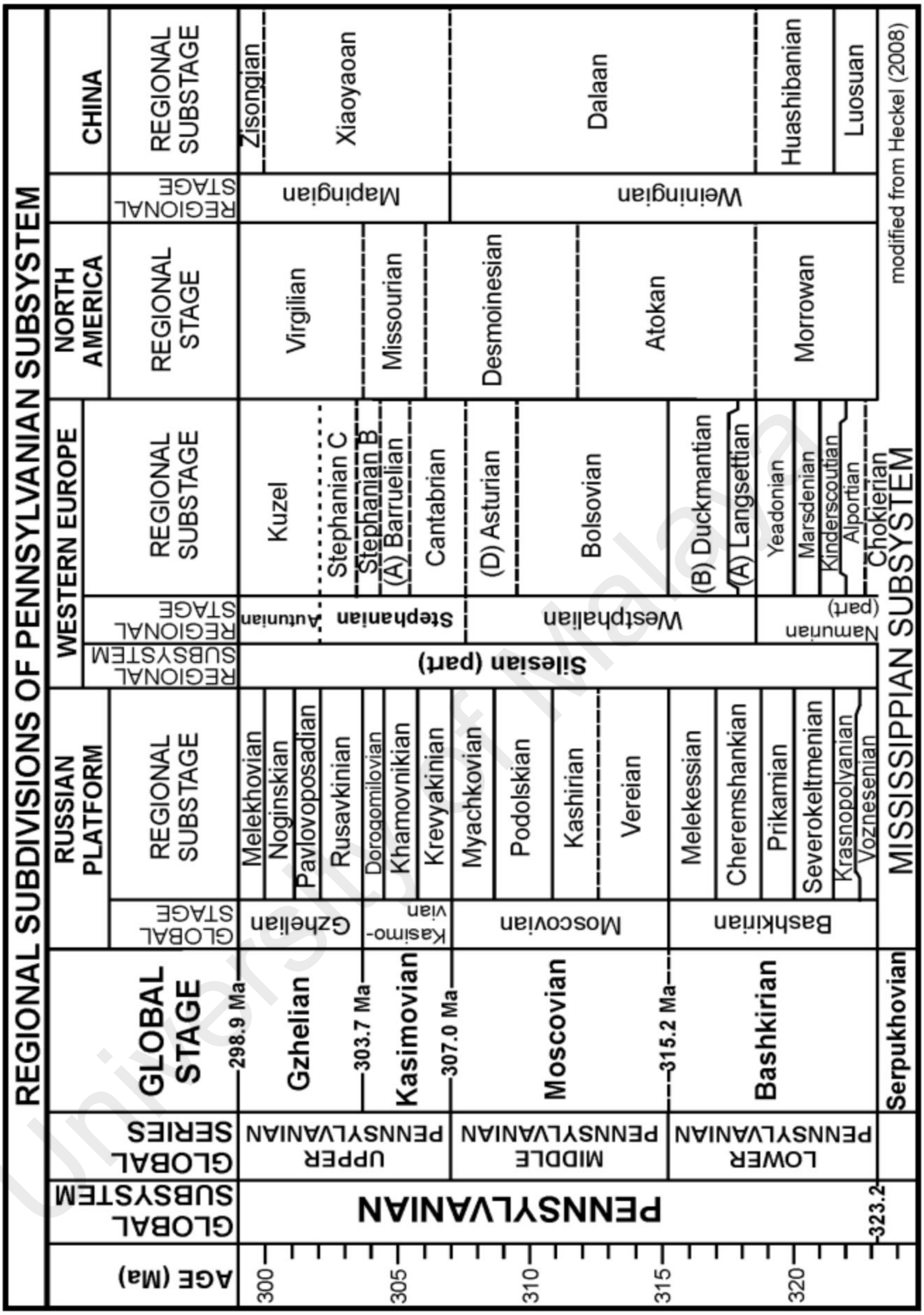

Figure 5.32: Global and regional subdivisions of the Pennsylvanian Subsystem of the Carboniferous System (adapted after Richards, 2013).

GSS			General stratigraphic scale of Russia, 2003, 2006				Local units of South Urals
Subsystem	Series	Stage	Substage	Ammonoids	Foraminifers	Conodonts	
Upper Carboniferous (Pennsylvanian)	Upper Pennsylvanian	Gzelian		Shumardites - Vidrioceras	Daixina bosbytauensis - Globifusulina robusta	Str. wabaunsensis	Martukian
					Daixina sokensis	Str. bellus	
					Jigulites jigulensis	Str. virgilicus	Azantashian
					Triticites rossicus - Rauserites stuckenbergi	Streptognathodus vitali	
						Str. simulator	
						Str. firmus	
		Kasimovian		Dunbarites - Parashu-mardites	Rauserites quasiarcticus	Str. toretzianus	Kerzhakovian
					Montiparus montiparus	Str. cancellosus	Orlovian
						Idiognathodus sagitalis	
					Protriticites pseudomontiparus - Obsoletes obsoletes	Str. makhlinae	
						Str. subexcelsus	
	Middle Pennsylvanian	Moscovian	Myachkovian	Pseudopara-legoceras - Wellerites	Fusulina cylindrica - Protriticites oyatus	Neognathodus roundyi	Tashlian
					Fusulinella bocki	Neognathodus inaequalis	Zilimian
			Podolskian		Fusulinella colaniae - F. vozhgalensis - Beedeina kamensis		
						I. podolskensis - N. medexultimus	
			Kashirian	Paralegoceras - Eowellerites	Fusulinella subpulchra	S. concinnus - I. robustus	Imendiashevian
					Priscoidella priscoidea	Neognathodus medadultimus	
						Neognathodus bothrops	
			Vereian	Diaboloceras - Winslowoceras	Aljutovella aljutovica	Streptognathodus transitivus	Soloncian
						D. donetzianus - Id. postsulcatus	
	Lower Pennsylvanian	Bashkirian	Archangel-skian	Diaboloceras - Axinolobus	Verella spicata - A. tikhonovichi	Declinognathodus marginodosus	Asatauian
				Branneroceras - Gastrioceras	Pr. rhombiformis		Tashastian
					Pr. primitiva- Ps. gorskyi		
			Askynbashian	Bilinguites - Cancelloceras	Ps. praegorskyi - St. staffelaeformis	Idiognathodus sinuosus	Askynbashian
			Akavassian		Pseudostaffella antiqua	Neognathodus askynensis- N. symmetricus	Akavassian
			Sjuranian	Reticuloceras - Bashkortoceras	Semistaffella variabilis	Idiognathoides sinuatus	Kamennogorian
				Homoceras - Hudsonoceras	S. minuscularia Plectostaffella bogdanovkensis	Declinognathodus noduliferus Later / Early	Bogdanovkian

Figure 5.33: Regional subdivisions of the Bashkirian and Moscovian stages in the Southern Urals (adapted after Kulagina et al. 2009).

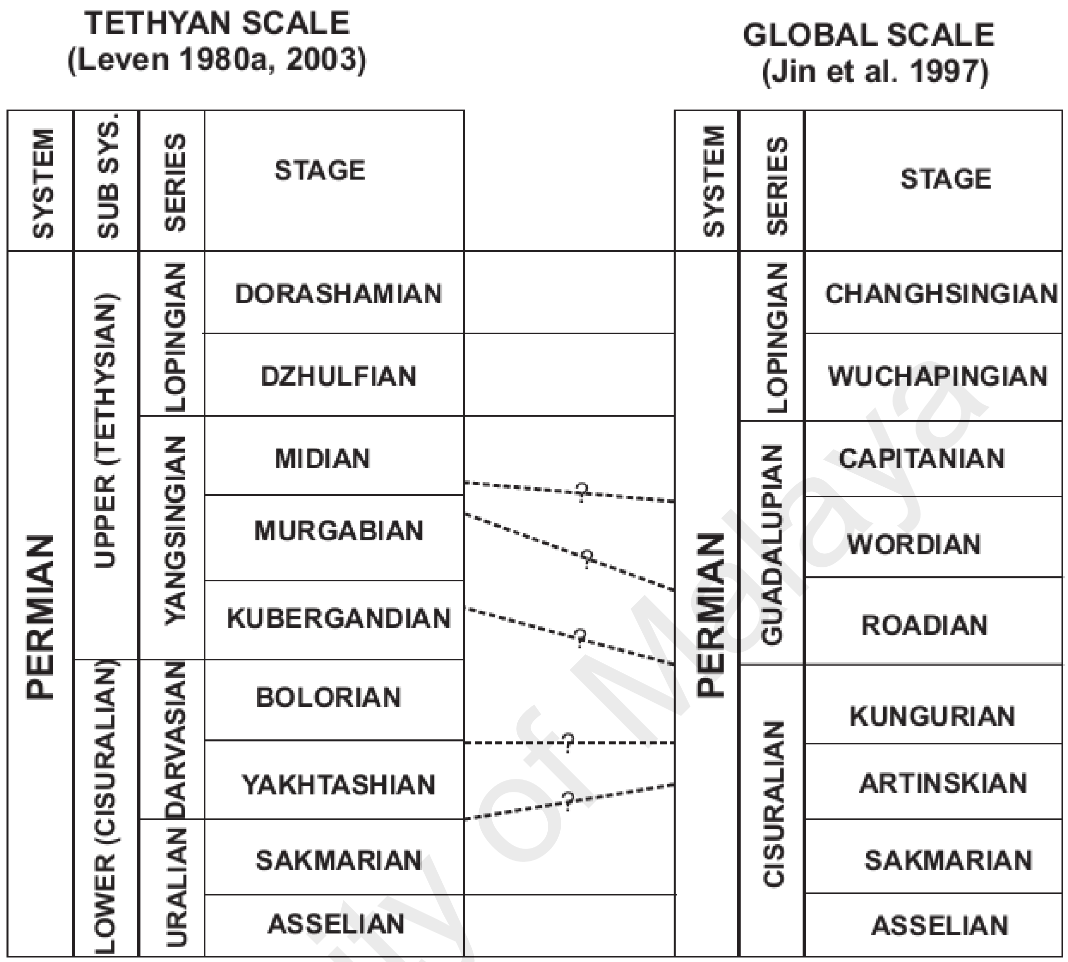

Figure 5.34: Global and Tethyan subdivisions of the Permian System (modified after Leven & Gorgij, 2011c).

5.3 Foraminiferal Assemblages

According to the available data, the biostratigraphic characters of the three sections in question; namely, the Banarizeh, Asad Abad II, and Tang-e-Darchaleh sections will be discussed as follows.

5.3.1 Foraminiferal Biostratigraphy in the Banarizeh Section

Taxonomic composition and the stratigraphic distribution of the foraminiferal assemblages in the Banarizeh Section (Units 1–16) indicate an age range of the early Viséan–Asselian for their host deposits (Figure 5.35). Fossils occurring in the bioclastic limestones in Units 1–8 of the Shishtu 2 Formation include gastropods, corals, conodonts, brachiopods, bryozoans, and crinoids. The interval also encloses fusulinids and smaller foraminifers including the species of *Endothyra, Dainella, Laxoendothyra*?, *Eoparastaffella*, *Inflatoendothyra*?, *Eogloboenothyra Viseidiscus, Omphalotis, Mediocris, Glomodiscus, Lapparentidiscus, Brunsia, Valvulinella, Forschia,* and *Tetrataxis* (Samples b1–b188, S1–S172).

The most meaningful components in the assemblage in question are the species of *Glomodiscus* (Samples b42, b44) and *Uralodiscus rotundus* (Chernysheva) (Sample b84) which are among the characteristic smaller foraminifers to define the Viséan age.

The assemblage includes some of the common taxa found in Biozone MFZ11 of Poty et al. (2006) in Western Europe (MFZ=Mississippian Foraminiferal Zone). In the Belgium stratotypes, MFZ11 is represented by the Neffe Limestone (Conil & Naum, 1977; Conil et al. 1977; Hance, 1988). This biozone is located between the base of the range zone of *Uralodiscus rotundus* Chernysheva and the base of the interval zone of *Pojarkovella nibelis* (Durkina) (Okuyucu et al. 2013). The representative foraminifer is

Uralodiscus rotundus or sometimes the assemblages of *Viseidiscus primaevus* and *Uralodiscus rotundus* (e.g., Kagarmanov & Donakova, 1990; Einor, 1996). Biozone MFZ11 is also marked by numerous first appearance datum (FAD) and the last appearance datum (LAD) of foraminifers: for example the first appearance datum of various subspecies of *Uralodiscus rotundus*, *Cribranopsis*, *Conilidiscus*, and *Paraarchaediscus* and last appearance datum of *Eoendothyranopsis*, *Eoparastaffella*, *Pseudolituotubella*, *Condrustella*, and *Eotextularia* (Okuyucu et al. 2013). New findings in South China, on the other hand, allowed subdividing MFZ11 into two subzones; namely, MFZ11A and MFZ11B; the second of which is distinguished by the first appearance of *Archaediscus* sp. and rare *Pojarkovella* sp. (Hance et al. 2011; Zandkarimi et al. 2014).

It is difficult to determine the age of the sandstones and sandy limestones of Units 9–10, as the paleontological characterization of the interval is inadequate for precise dating. The interval contains fragmentary brachiopods, bryozoans, and crinoids, and is devoid of any foraminifers (Samples S173–S208). Only one indeterminable Eostaffellidae is recovered in the middle part of Unit 10 (Sample S206) which is of low value for age determination. This is also the principal obstacle for confident biostratigraphic subdivision of the succession in question. Nevertheless, the interval by its stratigraphic position is assigned to the Sardar Group of the latest Serpukhovian–early late Moscovian age.

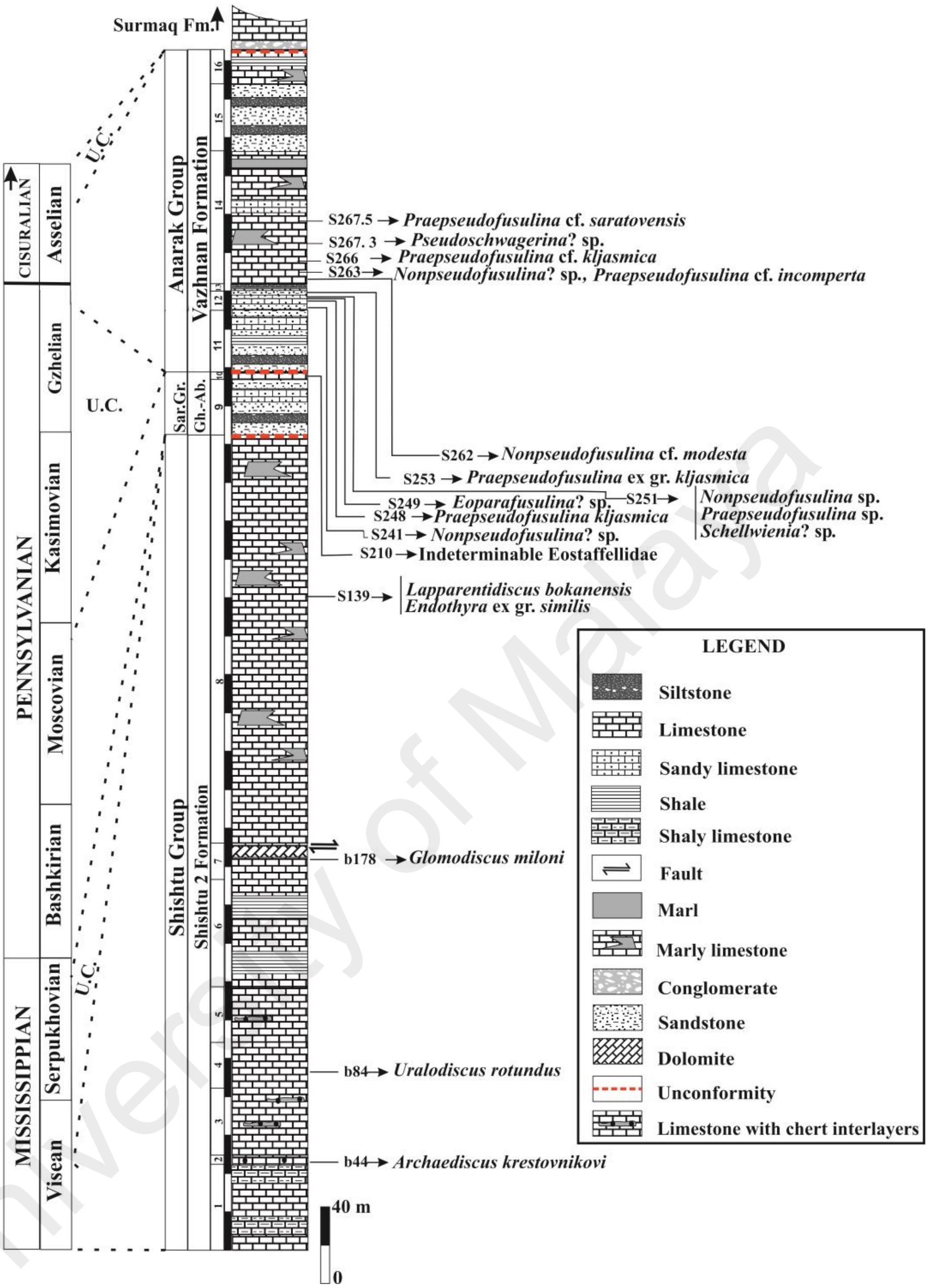

Figure 5.35: The stratigraphic log of the Banarizeh Section showing the occurrence of some of the index species identified in this study. **Note:** Abbreviations: **(Sar. Gr.) =** Sardar Group; **(Gh.Ab.) =** Ghaleh-Absheni formations; **(U.C.) =** unconformity.

The Sardar Group in the Banarizeh Section rests directly on the carbonate rocks of Unit 8 bearing the foraminifers of the upper part of early Viséan age. It implies the existence of a stratigraphic unconformity between the Shishtu 2 Formation and Sardar Group, which corresponds to the upper Viséan Stage and most of the Serpukhovian Stage.

At the Banarizeh Section, the youngest foraminiferal faunas appearing in the Mississippian–Asselian interval occur in Units 11–16 of the Vazhnan Formation (Samples S209–S290). The mixed terrigenous-carbonate interval includes the bryozoans, corals, brachiopods, crinoid fragments, smaller foraminifers, and fusulinids. The smaller foraminifers are represented by the species of *Nodosinelloides*, *Pseudovidalina*, *Rectogordius*, *Cornuspira*, *Eolasiodiscus*, *Pseudoacutella*, *Hemigordius*, *Globivalvulina*, *Hemidiscus*, *Pseudoagathammina*, *Protonodosaria*, *Geinitzina*, *Syzrania*, and *Hemigordiellina*. The fusulinids are dominated by the species of *Preaepseudofusulina*, *Nonpseudofusulina*, *Anderssonites*, *Schubertella*, *Grovesella*, and *Pseudoschwagerina*? belonging to the Pseudofusulinidae, Schwagerinidae, Pseudostaffellidae, and Schubertellidae. Based on the occurrence of characteristic species such as *Praepseudofusulina kljasmica* (Sjomina), *Pseudoschwagerina*? sp., and *Nonpseudofusulina* cf. *modesta* (Scherbovich), the Vazhnan Formation can be assigned to the uppermost Gzhelian–Asselian age.

Biostratigraphic analysis of the latest Gzhelian–Asselian foraminiferal assemblage.- As specified previously, the species composition of the fusulinids in the Vazhnan Formation indicates a Late Carboniferous–Early Permian age. The genus *Grovesella* occurring in the lower part of Unit 12 (Sample S241, about 36 m above the base of the Vazhnan Formation) is of low value for age determination. *Grovesella* is often ignored by workers in the Permian rocks, since, (1) due to its very small size (less than 0.3 mm), the researchers who mostly seek large fusulinids disregard this genus, (2) *Grovesella* is considered as a juvenile form of Schubertella by some workers (Davydov, 2011), and (3) it is of wide stratigraphic range, that is from Bashkirian up to Murgabian (Davydov, 2011).

Nonpseudofusulina? is another genus of the fusulinid assemblage in Sample S241. The lifetime of *Nonpseudofusulina* is confined from the late Gzhelian to Midian inclusively (Leven & Gorgij, 2009), so it is also of low value for the purpose of age determination.

The fusulinid assemblage from the middle and upper parts of Unit 12 and lower part of Unit 14 (Samples S248–S266) was collected from levels of 2–12.5 m above the first occurrence level of *Nonpseudofusulina*? sp. These fusulinids represent an assemblage which is devoid of genera of schwagerinid. The most important fusulinids of this assemblage are *Praepseudofusulina kljasmica* (Sjomina), and *Nonpseudofusulina* cf. *modesta* (Scherbovich) which occur in association with *Schubertella* sp., *Nonpseudofusulina* sp., *Praepseudofusulina* sp., *P.* sp. 1, *P.* ex gr. *kljasmica* (Sjomina), *P.* cf. *incomperta* (Scherbovich, 1971), *Schellwienia*? sp, and *Anderssonites*? sp.

Praepseudofusulina kljasmica is the meaningful component of this assemblage. The genus *Praepseudofusulina* was originally suggested by Ketat (1971) with *Pseudofusulina* (?) *fastuosa* as the type species. In many sections of the Russian Platform and the Southern Urals, this genus is characteristic of the uppermost Gzhelian and Asselian stages (Kireeva et al. 1971; Ketat & Zolotukhina, 1984; Rauser-Chernousova et al. 1996; Leven & Gorgij, 2011b,c). *Praepseudofusulina kljasmica* (Sjomina) was first reported by Sjomina (1961) as a subspecies of *Pseudofusulina pusilla*, and was introduced as *Pseudofusulina kljasmica* (*Pseudofusulina pusilla* var. *kljasmica*). Later on, it was assigned to *Praepseudofusulina kljasmica* (Loeblich &

Tappan, 1988). *Praepseudofusulina kljasmica* is one of the most characteristic fusulinid taxa of the uppermost Gzhelian–Asselian stages in sections of the Russian Platform, Tethyan realm, and Southern Urals (Leven & Gorgij, 2006b, 2011b,c).

In this assemblage, only one indeterminate species of *Schellwienia*? sp. was found from Sample S251 in Unit 12. The genus *Schellwienia* is characteristic of the second half of the Gzhelian and lowermost Asselian stages in the Southern Urals, Russian Platform, and Tethyan realm (Leven & Gorgij, 2006a). If the genus in question can be correctly referable to *Schellwienia*, it also suggests the age of latest Gzhelian–early Asselian for the assemblage.

The next younger assemblage occurring in Unit 14 (Samples S267.3–S272, i.e. in levels 53–58 m above the base of Vazhnan Formation) is characterized by *Pseudoschwagerina*? sp. and a few indeterminate genera of schwagerinids. They occur in association with *Praepseudofusulina* species, including *Praepseudofusulina kljasmica* (Sjomina), *P.* ex gr. *kljasmica* (Sjomina), *P.* cf. *kljasmica* (Sjomina), *P*. cf. *saratovensis* (Chernova), *P. incomperta* (Scherbovich), *P.* cf. *incomperta* (Scherbovich), *P*. cf. *impercepta* (Jagofarova), *P*. sp. 2, *P*. sp. 3, *P*. sp. 4, *P*. sp. 5, and also the species of *Eoschubertella*, and *Grovesella*. The deposits containing this fusulinid assemblage are most likely of middle Asselian age. As the assemblage displays the schwagerinid faunas, which are unknown in the beds older than middle Asselian (e.g. Leven & Scherbovich, 1978; Leven & Taheri, 2003).

Considering the above information, the following two assemblages of the foraminiferal faunas are characterized in the Banarizeh Section: (1) the late early Viséan foraminiferal Assemblage, (2) the latest Gzhelian–Asselian foraminiferal Assemblage.

The Vazhnan Formation is situated directly obove the sediments of the Sardar Group. It indicates the existence of a stratigraphic unconformity, i.e., a paraconformity between the Sardar Group and Vazhnan Formation, which corresponds to the uppermost Moscovian–lower Gzhelian age. Up to now, no evidence of the Kasimovian Stage has been reported in the Sanandaj-Sirjan Zone (Leven & Gorgij, 2008a, 2011c; Boncheva et al. 2007). This hiatus may be related to the epeirogenic movements, uplifting phenomena, or the Gondwana ice-age of lacuna Veevers and Powell (1987) which influenced most parts of Iran during the Late Pennsylvanian (Kasimovian–middle Gzhelian) to Early Permian (late Sakmarian) (Leven & Taheri, 2003). The foraminiferal faunas occurring in the overlying layers of the Surmaq Formation are of the upper Lower Permian–Middle Permian (Iranian-Japanese Research Group, 1981; Kobayashi & Ishii, 2003a,b; Leven & Gorgij, 2011c). It implies the existence of a stratigraphic unconformity between the Lower Permian and upper Lower Permian deposits corresponding to the upper Asselian–Sakmarian.

5.3.2 Foraminiferal Biostratigraphy in the Asad Abad II Section

The Asad Abad II Section consists of separate and frequently displaced blocks (Units 1–40). According to Boncheva et al. (2007) the Shishtu Group (Units 1–19) with a thickness of about 500 m is devoid of any foraminifers. The conodont data suggest the age of Early Carboniferous for the interval, corresponding to the Tournaisian–upper Serpukhovian stages (Boncheva et al. 2007). It is necessary to note here that in the Asad Abad II Section, the Viséan Stage not designated based on conodont data (Boncheva et al. 2007).

Taxonomic composition of the foraminiferal assemblages and their distribution throughout the Sardar Group and Vazhnan Formation of the Asad Abad II Section suggest the latest Serpukhovian–Asselian age for the succession (Figure 5.36). The Pennsylvanian fusulinid assemblages, more abundant than the Banarizeh and Tang-e-

Darchaleh sections, are represented in the Asad Abad II Section. The fusulinid assemblages of the latest Serpukhovian–earliest Moscovian and Moscovian age occur in the Ghaleh and Absheni formations, respectively. The mixed terrigenous-carbonate deposits of Units 20–23 of the Ghaleh Formation include the gastropods, corals, conodonts, brachiopods, bryozoans, and crinoid fragments. In addition the listed faunas, the interval includes the smaller foraminifers and fusulinids (Samples R1–R85, VB1–VB4). The smaller foraminifers are characterized by the species of *Bradyina*, *Paraarchaediscus, Earlandia, Globivalvulina, Biseriella, Howchinia, Tetrataxis, Pseudoglomospira, Consobrinella, Deckerella, Koskinotextularia, Palaeotextularia,* and *Climacammina*. In the fusulinid assemblage, the genera *Mediocris, Eostaffella, Planoendothyra, Endothyra,* and *Millerella*, occur in association with genus *Plectostaffella*. Most of the species occurring in the Units 20–23 range from the Serpukhovian to earliest Bashkirian. However, the presence of *Eostaffella pseudostruvei* (Rauser-Chernousova) and *Plectostaffella jakhensis* Reitlinger in this interval allows the correlation to the *Eostaffella pseudostruvei* Zone in Southern Urals (Kulagina and Sinitsyna, 1997), which corresponds to Voznesenian Substage (earliest Bashkirian).

The fusulinid assemblages occurring in Unit 24 of the Ghaleh Formation are rather poor both in occurrence and preservation. Smaller foraminifers in this interval are very rare. The identified fusulinids are dominated by the species of *Aljutovella, Tikhonovichiella, Profusulinella, Pseudostaffella,* and *Ozawainella*. In addition to the listed taxa, the assemblage includes the species of *Staffellaeformis, Eoschubertella, Schubertella, Pseudostaffella, Ozawainella, Millerella,* and *Eostaffella* (Samples VB5–VB7). The taxonomic composition of the fusulinids listed above and their distribution throughout the interval indicate the latest Bashkirian–earliest Moscovian age corresponding to the Melekessian–Vereian stages.

Biostratigraphic analysis of the Melekessian–Vereian foraminiferal assemblage.- Some forms of *Eostaffella* occur in Unit 23 (Samples VB3–VB4) and the lower part of Unit 24 (Samples VB5–VB6) but not in a higher level. In general, *Eostaffella* is of wide stratigraphic range that is from Viséan to Moscovian, but it is rare in the late Bashkirian and Moscovian (Grozdilova et al. 1954; Groves et al. 1999; Leven & Gorgij, 2011c).

The fusulinid assemblage in Sample VB6 is relatively diversified. The fusulinids identified in Sample VB6 are species of *Thikhonovichiella, Profusulinella, Ozawainella, Pseudostaffella, Schubertella, Eostaffella*, and *Aljutovella*. Most characteristic fusulinids among this assemblage are the *genera Profusulinella, Aljutovella*, and *Tikhonovichiella.* These genera are indicative of the uppermost fusulinid zone of the Bashkirian (i.e., the Melekessian Substage) and the lowermost zone of the Moscovian (i.e., the Vereian Substage) in many sections of the Urals and East European Platform (Leven & Gorgij, 2011c). *Profusulinella* recovered in this assemblage is represented by the species such as *Pr.* (*Depratina*) *prisca, Pr.* (*Depratina*) *parva*, and *Pr. postpararhombiformis* (Fassihi et al. 2017).

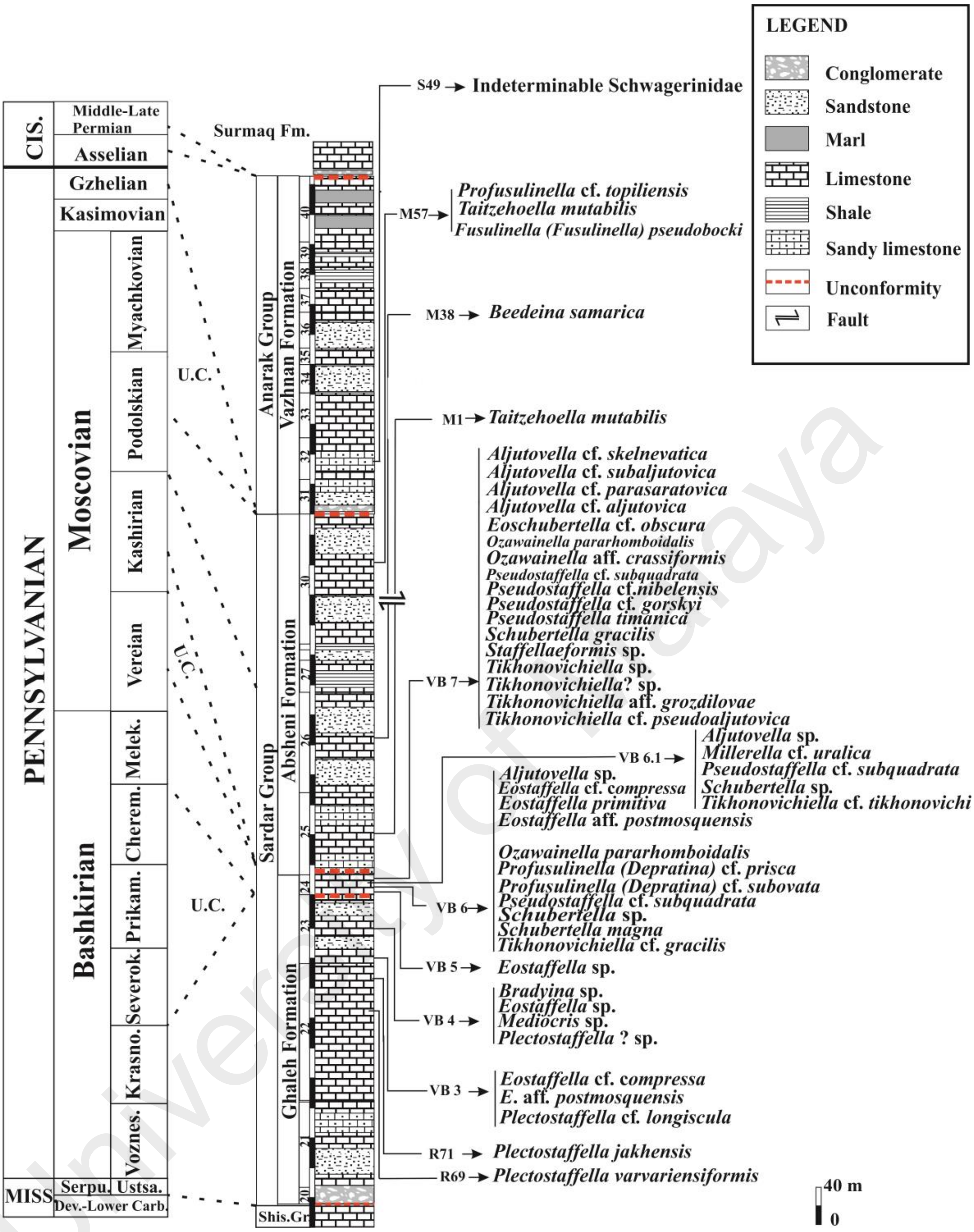

Figure 5.36: The stratigraphic log of the Sardar Group and Vazhnan Formation in the Asad Abad II Section showing the occurrence of some of the index species identified in this study. **Note:** Abbreviations: **(CIS.)** = Cisuralian; **(MISS.)** = Mississippian; **(Voznes.)** = Voznesenian; **(Krasno.)** = Krasnopolyanian; **(Severok.)** = Severokeltmenian; **(Prikam.)** = Prikamian; **(Cherem.)** = Cheremshankian; **(Melek.)** = Melekessian; **(Ustsa.)** = Ustsarbasky; **(Surmaq Fm.)** = Surmaq Formation; **(Dev.–Lower Carb.)** = Devonian–Lower Carboniferous; **(Shis. Gr.)** = Shishtu Group; **(U.C.)** = unconformity.

In many sections of the Russian Platform near the boundary between the Bashkirian and Moscovian stages, the first representatives of *Profusulinella* such as *Pr.* (*Depratina*) *praeprisca* Solovieva and *Pr.* (*Depratina*) ex gr. *prisca* occurred in the latest Bashkirian, but they continued to the Moscovian Stage (Kulagina, 2009; Leven & Gorgij, 2011c; Rauser-Chernousova, 1954). The conodont species *Declinognathodus donetzianus* Nemirovskaya has been also proposed as an index species to define the base of the Moscovian in the Southern Urals (Groves, 2006). In the sections containing *D. donetzianus*, the first appearance of *Pr.* (*Depratina*) *prisca* is noted a few meters below that of *D. donetzianus* (Kulagina et al. 2009).

The next assemblage in Sample VB6.1 consists of *Millerella*, *Pseudostaffella*, *Tikhonovichiella*, *Schubertella*, and *Ozawainella* species. This assemblage suggests the latest Bashkirian–earliest Moscovian age (the Melekessian–Vereian transition in the Russian Platform). This age is supported by the occurence of *Tikhonovichiella tikhonovichi*. In sections of the Urals and East European Platform, *T. tikhonovichi* appears in the uppermost Bashkirian, but it continues to the earliest Moscovian (Leven & Gorgij, 2011c).

The fusulinid assemblage from Sample VB7 was collected 2.5 meters above the first occurrence level of *T. tikhonovichi*. This assemblage is dominated by species of *Aljutovella* and *Tikhonovichiella* which occur in association with species of *Ozawainella*, *Schubertella*, *Staffellaeformis*, *Profusulinella*, and *Pseudostaffella*. In this assemblage, some different forms of *Aljutovella*, namely, *Al.* cf. *aljutovica*, *Al.* cf. *subaljutovica*, *Al.* cf. *parasaratovica*, and *Al.* cf. *skelnevatica* are present. The fusulinids in Bed VB7 are most likely of early Moscovian (Vereian) age, as this is suggested by the occurrence of a relatively diverse assemblage of *Aljutovella* (including *Al.* cf. *aljutovica*) which are associated with the large *Pseudostaffella* species. The assemblage also includes the species of *Tikhonovichiella* and *Profusulinella* that originated in the latest Bashkirian (Fassihi et al. 2017).

In the General Stratigraphic Scale of the Russian Platform (GSSR), the lower Moscovian boundary is defined at the base of the *Declinognathodus noduliferous - Idiognathoides postsulcatus* conodont zone and the base of the *Aljutovella aljutovica* fusulinid zone (Makhlina et al. 2001). Davydov (2009) designates the fusulinids *Al. aljutovica* Rauser-Chernousova and *Schubertella pauciseptata* Rauser-Chernousova are practical indexes to define the base of the Moscovian Stage in the western Tethys. In Southern Uralian sections, the typical *Aljutovella* with distinct fluted septal folding in axial regions of the test appears above the appearance of *Profusulinella* (*Depratina*) *prisca* (Kulagina, 2009). The same sequence of foraminiferal appearance is reported in the upper Petchora Basin, where *Al.* ex gr. *aljutovica* appears 15 meters above the first appearance of *Pr.* (*Depratina*) *prisca* (Kulagina, 2009).

Staffellaeformis is another genus characteristic of the fusulinid assemblage in Sample VB7. In Eurasia, the genus ranges commonly from the upper Bashkirian into the lower Moscovian (Kulagina, 2009). The *Staffellaeformis - Depratina* lineage has been recorded in complete successions across the Bashkirian–Moscovian transition layers in the Southern Urals (Kulagina, 2009). The large *Pseudostaffella* species such as *Pseudostaffella subquadrata* and *Ps.* cf. *gorskyi* are also the important components of this assemblage. These species are among the index species of the latest Bashkirian–early Moscovian assemblage in the Russian Platform (Leven & Gorgij, 2011c).

A stratigraphic unconformity between Unit 23 of the lowermost Bashkirian age, and Unit 24 of the Melekessian−Vereian age is quiet possible, as the middle and upper Bashkirian Stage are missing from the section in question (Figure 5.37). However, since the presence of the upper Bashkirian strata in the Sanandaj-Sirjan Zone is confirmed by the conodont data (Boncheva et al. 2007), a fault contact between the Melekessian−Vereian fusulinids-bearing deposits and the underlying beds cannot be excluded.

ASAD ABAD II SECTION

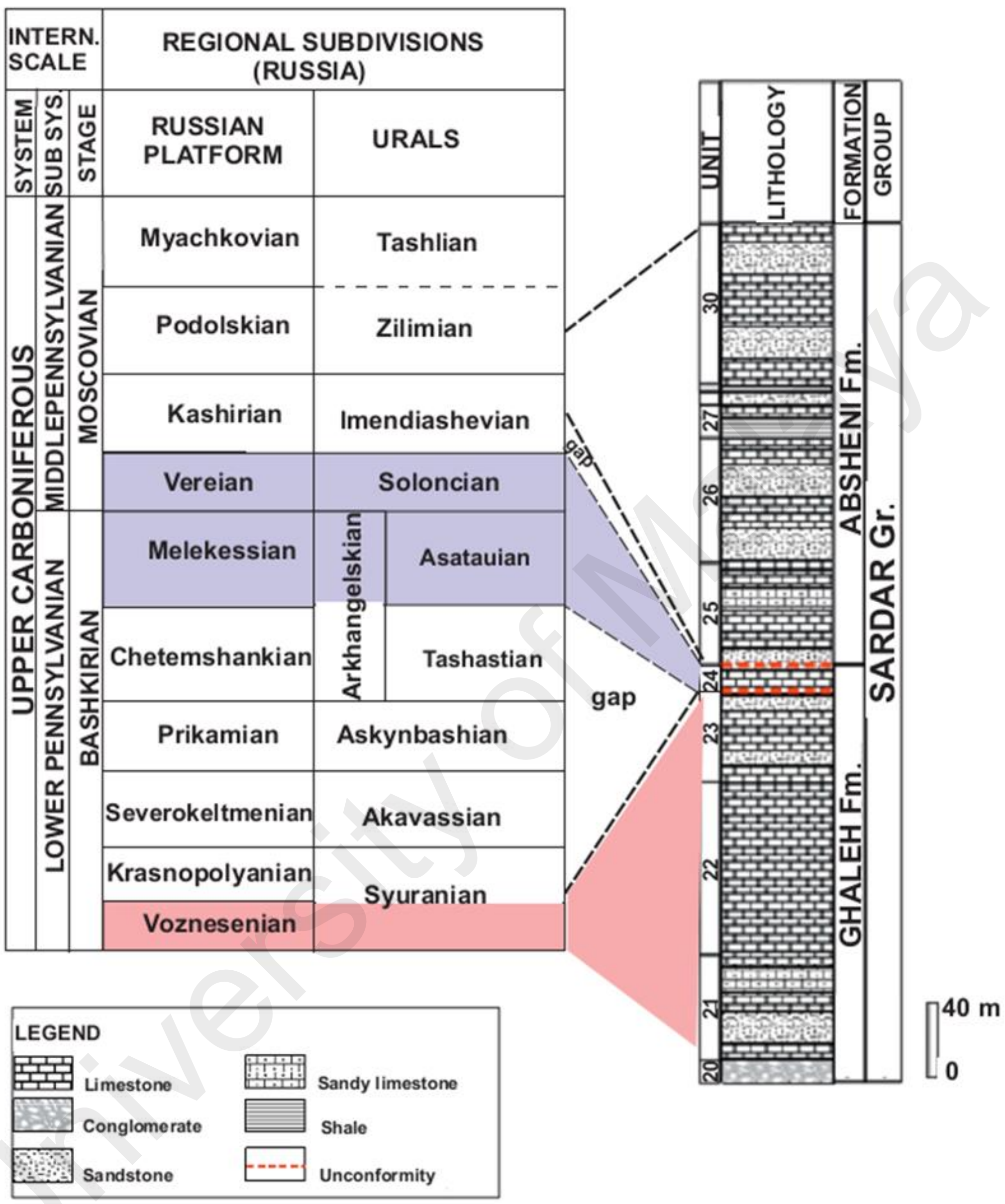

Figure 5.37: Lithostratigraphic subdivisions of the Bashkirian–Moscovian sequence in the Asad Abad II Section, together with the subdivisions of the Bashkirian and Moscovian stages in the Russian Platform and the Southern Urals (age of Unit 4 revised from Fassihi et al. 2017).

The late Kashirian fusulinid assemblage occurs in the mixed terrigenous-carbonate deposits of Units 25 and 26 of the Absheni Formation (Samples M1–M56). In this interval, the succession of displaced Melekessian–Vereian deposits and the Kashirian–Podolskian beds is reconstructed by means of fusulinid data. The interval besides the fusulinids contains brachiopods, corals, and crinoid fragments. An important feature of the Kashirian fusulinid assemblage is the first appearance of the fusulinids with four layered spirotheca, which implies a new phase in their evolution (Leven & Gorgij, 2011c). The *Aljutovella* with three layered spirotheca give place here to *Beedeina samarica* Rauser & Belyaev (Sample M38) with four layered. Another meaningful component in our Kashirian fusulinid assemblage is the species *Taitzehoella mutabilis* (Safonova) (Sample M1). In sections of the Russian Platform, the boundary between the Vereian and Kashirian substages is tentatively determined by the first occurrence of *Taitzehoella, Aljutovella priscoidea*, and *Hemifusulina* (Leven & Gorgij, 2008a, 2011c).

As the Vereian deposits, the fusulinids of *Pseudostaffella* are significant components of the Kashirian interval. Representatives of *Ozawainella* and *Profusulinella* have also been identified in the assemblage.

The fusulinid assemblage from the limestone and oolitic limestones of Units 27–30 of the Absheni Formation appears to be of early Podolskian in age (Samples M57–M100, FM1–FM9). Fusulinid species supporting this age are the abundant representatives of the *Fusulinella* which known from many sections of the Podolskian Substage in the Russian Platform and Southern Urals (Leven & Gorgij, 2011c). Since, some *Profusulinella* species, which are atypical of the Moscovian upper part, are also found here, the assemblage is attributed to the basal part of the Podolskian Substage. *Profusulinella* in this assemblage is characterized by the species such as *Profusulinella* sp. (Sample M63), *Profusulinella beppensis* Toriyama (Sample M59), and

Profusulinella topiliensis Putrja (Sample M66). Moreover, *Taitzehoella*, *Ozawainella*, and *Fusiella* are among the genera that transit into the Podolskian assemblage from the Kashirian one. The associated species *Taitzehoella mutabilis* (Safonova) (Sample M57), *Fusiella pulchella* Safonova (Sample M61), and also the species of *Ozawainella* are among the characteristic fusulinid taxa of the Podolskian Substage. In this assemblage, the number of fusulinids with four layered structure of the spirotheca gradually increases. In general, these are fusulinids such as *Fusulinella* (*Fusulinella*) *pseudobocki* Lee & Chen (Samples M57 and M61), *Fusulinella* (*Fusulinella*) *ginkeli* Villa (Sample M96), *Fusulinella* (*Moellerites*) *praebocki* Rauser-Chernousova, (Sample M75), *Fusulinella* (*Fusulinella*) ex gr. *bocki* Moeller (Samples M63, M59), and *Fusulinella* (*Moellerites*) cf. *paracolaniae* Safonova (Samples M71 and M73). The uppermost part of the Moscovian Stage, corresponding to the Myachkovian Substage, is absent from the Asad Abad II Section.

At the Asad Abad II Section, the Kasimovian deposits are absent. In point of fact, in Iran, the deposits of the Kasimovian age are only distinguished in the lower part of the Zaladou Formation of Tabas Block, where the conodonds *Idiognathodus trigonolobatus*, *I.* cf. *neverovensis*, *I.* ex gr. *sagittalis*, and Rhachistognathus sp. have been found. It appears that Kasimovian sediments did not accumulate over the greater part of the Iranian territory (Leven & Gorgij, 2011c).

The youngest foraminiferal faunas appearing in the Mississippian–Asselian interval of this section occur in Units 31–40 of the Vazhnan Formation. The mixed terrigenous-carbonate interval includes the gastropods (*Bellerophon*), corals, brachiopods, bryozoans, ammonoids, crinoids, and rare smaller foraminifers and fusulinids (Samples ZT1–ZT28). The fusulinids are represented by the scanty *Praepseudofusulina* and indeterminable schwagerinid faunas, which are representatives to define the latest Gzhelian–Asselian stages in the Russian Platform and Southern

Urals. It implies the existence of a stratigraphic unconformity between the Absheni and Vazhnan formations, which corresponds to the uppermost Moscovian–lower Gzhelian age.

Leven and Gorgij (2011b) described the latest Gzhelian–Asselian fusulinids from the Vazhnan Formation of the same area. According to their conclusions, this assemblage is characterized by the fusulinids of *Schwageriniformis acutatus* Leven, *Rauserites baghbanii* Leven & Gorgij, *R. karlensis* Rosovskaya, *R. ishimbaji* (Rosovskaya), *Ruzhenzevites ferganensis ferganensis* (Dutkevich), *R.* aff. *ferganensis* curtus Leven, *R. ferganensis grandiusculus* Leven, *Quasifusulina eleganta* Shlykova, *Anderssonites anderssoni* (Schellwien), *A.* aff. *zarjae* Potievskaya, *Schellwienia* ex gr. *stocklini* Leven, *Ferganites*? aff. *obessus* Villa & Ueno, in association with *Praepseudofusulina kljasmica* (Sjomina), *P.* ex gr. *kljasmica* (Sjomina) *P.* aff. *cara* (Dobrokhotova), *P. impercepta* (Jagofarova), *Nonpseudofusulina* aff. *modesta* (Scherbovich), *Nonpseudofusulina* sp., *Sphaeroschwagerina*? sp. and two species of *Pseudoschwagerina*; namely, *P.* aff. *ozguli* Kobayashi & Altiner and *P.* ex gr. *beedei* Dunbar & Skinner (Leven & Gorgij, 2011b).

Considering the above information, the following five assemblages of the foraminiferal faunas are characterized in the Asad Abad II Section: (1) the earliest Bashkirian (Voznesenian) foraminiferal Assemblage, (2) the latest Bashkirian–earliest Moscovian (Melekessian–Vereian) foraminiferal Assemblage, (3) the late Kashirian foraminiferal Assemblage, (4) the early Podolskian foraminiferal Assemblage, and (5) the latest Gzhelian–Asselian foraminiferal Assemblage. The foraminifers occurring in the superior layers of the Surmaq Formation are of the late Early–Middle Permian age. It implies the existence of a stratigraphic unconformity between the Lower Permian and upper Lower Permian deposits corresponding to the upper Asselian–Sakmarian.

5.3.3 Foraminiferal Biostratigraphy in the Tang-e-Darchaleh Section

Taxonomic composition of the foraminiferal assemblages and their distribution throughout the Carboniferous–Lower Permian succession in the Tang-e-Darchaleh Section (Units 1–16) designate the late early Viséan–Asselian age (Figure 5.38).

The oldest foraminiferal fauna of the interval occurs in the mixed carbonate and siliciclastic sediments of Units 1–3 of the Shishtu 2 Formation (Samples D1–D58). The interval contains the fusulinids and the smaller foraminifers; mainly the species of *Uralodiscus, Omphalotis, Bessiella, Mediocris, Viseidiscus, Endothyranopsis, Plectogiranopsis, Rhodesinella*?, *Inflatoendothyra*?, *Eoparastaffella*?, *Glomodiscus, Paraarchaediscus, Lapparentidiscus,* and *Endothyra*. The most characteristic fauna identified in this assemblage are *Paraarchaediscus* cf. *dubitabilis* Orlova, Sample D1, *Uralodiscus rotundus* (Chernysheva) (Samples D12, D17, and D48), *Glomodiscus miloni* (Pelhate) (Samples D47 and D1), and *Glomodiscus oblongus* (Conil & Lys) (Samples D1 and D2). These species indicate the age of Viséan for the assemblage (see section 5.3.1 of this dissertation). Besides the foraminifers, the interval encloses the marine macro faunas belonging to the crinoids, corals, and brachiopods.

Age diagnostic fossils are scanty in the mixed terrigenous-carbonate deposits of Units 4–12 of this interval. Being lateral equivalent of Units 20–30 of the Asad Abad II Section, Units 4–12 of the Tang-e-Darchaleh Section are most likely to be the uppermost Serpukhovian–Moscovian in age. Besides the scarce foraminifers, the succession contains fragmentary brachiopods, corals, and crinoids (Samples F1–F28.2). Bahrami et al. (2014) studied the Carboniferous deposits in the Tang-e-Darchaleh Section based on the conodont fauna. According to their conclusions, the upper portion of the Sardar Group, which corresponds to the lower and middle parts of Unit 11 in this study, can be assigned to the Bashkirian. Conodonts suggesting this age are

Idiognathodus delicatus and *Idiognathodus sinousus*. Moscovian deposits occur in the upper part of Unit 11 and Unit 12 (Samples F28, F28.2). Foraminifers identified in this interval are characterized by the species of *Fusiella, Taitzehoella*, *Millerella*, and *Ozawainella.* The early Moscovian (rather upper Kashirian than Vereian) of this interval is indicated by the occurence of *Fusiella* cf. *typica* Lee and Chen (Sample F28.2) and *Taitzeholla* sp. (Sample F28).

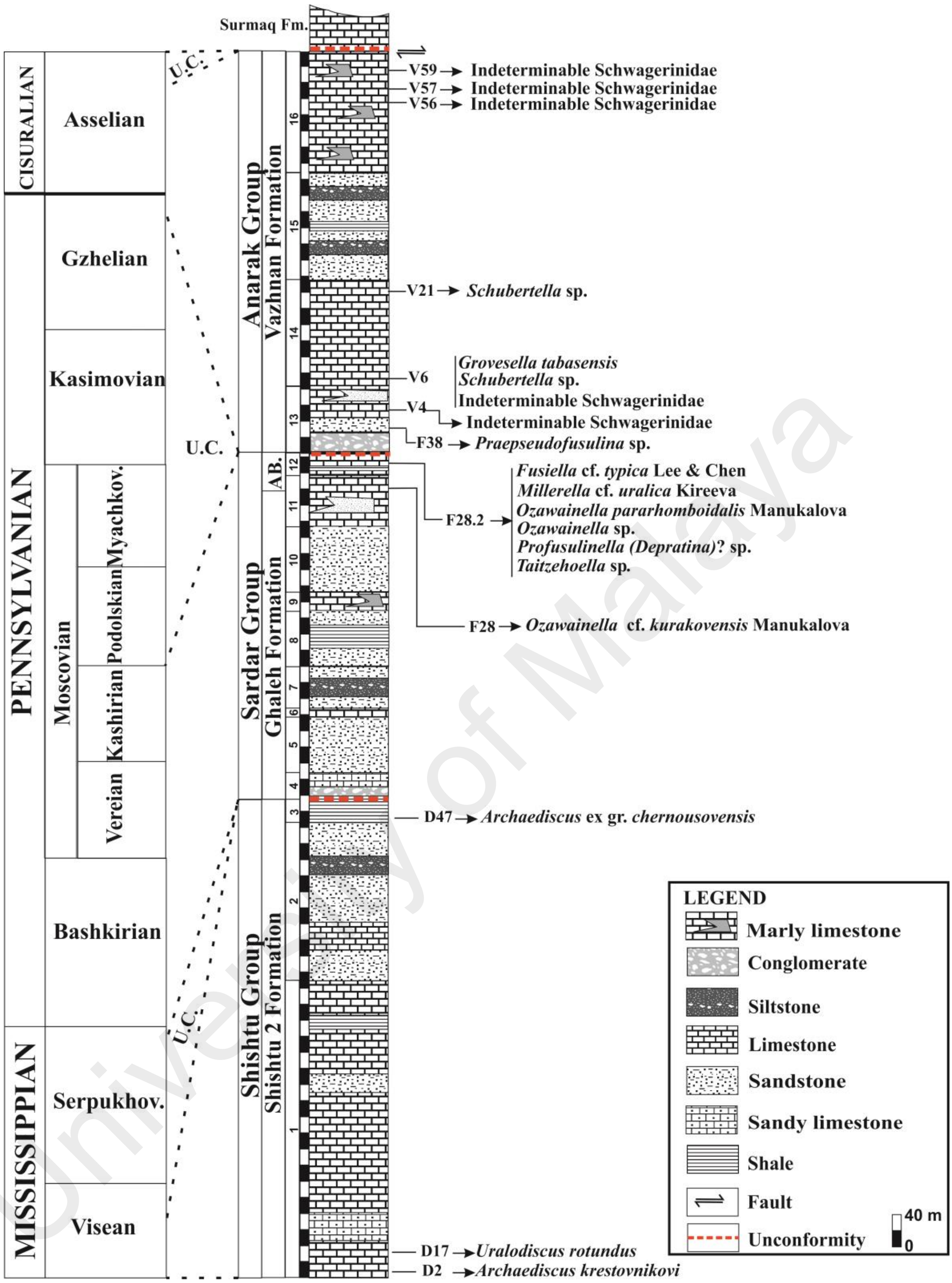

Figure 5.38: The stratigraphic log of the Tang-e-Darchaleh Section showing the occurrence of some of the index species identified in this study. **Note:** Abbreviations: **(Myachkov.)** = Myachkovian; **(Serpukhov.)** = Serpukhovian; **(Surmaq Fm.)** = Surmaq Formation; **(AB.)** = Absheni Formation; **(U.C.)** = unconformity.

In the Tang-e-Darchaleh Section the youngest foraminiferal fauna of the Mississippian–Lower Permian succession occurs in the mixed terrigenous-carbonate deposits of Units 13–16 of the Vazhnan Formation. Besides the scarce fusulinids, the deposits enclose bryozoans, corals, brachiopods, crinoid fragments, and fish remains (Samples F29–F38; V1–V59). Comparing to the identified fusulinids, only *Praepseudofusulina* sp. is useful for age determination, and suggests the latest Gzhelian–Asselian. Other recovered fusulinids include *Schubertella* sp., *Grovesella* sp., and *G. tabasensis* Davydov & Arefifard, all of long stratigraphic range. Hence, they are of low value for age determination. The layers bearing this assemblage can be correlated with the Asselian–Sakmarian fusulinids-bearing strata described by Baghbani (1993) in the same section. The Vazhnan Formation is situated directly on the sediments of Sardar Group. It indicates the existence of a stratigraphic unconformity between the Sardar Group and Vazhnan Formation, which corresponds to the upper Moscovian–lower Gzhelian age.

Considering the above information, the following three assemblages of the foraminiferal faunas are characterized in the Tang-e-Darchaleh Section: (1) the late early Viséan foraminiferal Assemblage, (2) the late Kashirian foraminiferal Assemblage, and (3) the latest Gzhelian–Asselian foraminiferal Assemblage.

The Vazhnan Formation is overlain unconformably by the Surmaq Formation, corresponding in age to the upper Lower Permian–Middle Permian. The contact between the two formations is sharp, likely of faulting. It is evident from brecciated character of rocks in the contact zone (Leven & Gorgij, 2008b).

5.4 Definitions of the Recognized Foraminiferal Assemblages

In the Sanandaj-Sirjan Zone, except for the Kasimovian and Tournaisian Stages, the characteristic foraminiferal assemblages of Early Carboniferous–Early Permian age exist in the almost entire Viséan–Asselian sequence. These assemblages permitted a detailed biozonation and comparison with reference biozones acknowledged for the Mississippian–Asselian in the Western Europe, Turkey, Urals, and the Russian Platform (e.g. Altiner & Özgul, 2001; Poty et al. 2006; Leven et al. 2006d; Leven & Gorgij, 2008a, 2011b,c; Okuyucu et al. 2013).

5.4.1 The late early Viséan Foraminiferal Assemblage

The sediments bearing the late early Viséan foraminiferal fauna are represented by quartz arenitic sandstone, mudstone, bioclastic wackestone, packstone, grainstone, and oolitic grainstone (see Figures 4.12 & 4.18). The foraminiferal assemblage in these strata is dominated by the species of *Endothyra*, *Dainella*, *Laxoendothyra*, *Eoparastaffella*, *Inflatoendothyra*, *Eogloboenothyra*, *Omphalotis*, *Mediocris*, *Glomodiscus*, *Lapparentidiscus*, *Brunsia*, *Valvulinella*, *Forschia*, *Uralodiscus*, *Bessiella*, *Viseidiscus*, *Endothyranopsis*, *Plectogiranopsis*, *Rhodesinella*?, *Inflatoendothyra*?, *Eoparastaffella*?, *Paraarchaediscus*, and *Tetrataxis*. The species composition within this assemblage permits to recognize a local biozone, that is, the *Uralodiscus rotundus* - *Glomodiscus miloni* zone.

The *Uralodiscus rotundus - Glomodiscus miloni* zone:

Definition.- The zone (with a thickness of about 425 m in the Banarizeh Section and 207 m in the Tang-e-Darchaleh Section) is characterized by the first appearance of

Paraarchaediscus cf. *dubitabilis* Orlova, *Uralodiscus rotundus* Chernysheva, and *Glomodiscus miloni* (Pelhate). The top of this zone is limited by an unconformity followed by sequence belonging to the earliest Bashkirian (*Plectostaffella jakhensis* - *Eostaffella pseudostruvei* zone).

Distribution.- This zone occurs in Units 1–8 of the Shishtu 2 Formation in the Banarizeh Section (Samples b1–b188 and S1–S172) and in Units 1–3 of the Shishtu 2 Formation in the Tang-e-Darchaleh Section (Samples D1–D58).

Composition.- The assemblage includes *Uralodiscus rotundus* (Chernysheva), *Uralodiscus* ex gr. *rotundus* (Chernysheva), *Omphalotis* sp., *Omphalotis* cf. *minima* (Rauser & Reitlinger), *Omphalotis* aff. *explicata* (Ganelina), *Omphalotis chariessa* (Conil & Lys), *Bessiella*? sp., *Endothyranopsis crassiformis* Vdovenko, *Plectogiranopsis* sp., *Plectogiranopsis convexa* Rauser-Chernousova, *Rhodesinella*? sp., *Inflatoendothyra*? sp., *Eoparastaffella*? sp., *Eoparastaffella* cf. *vdovenkoae* Devuyst1 & Kalvoda, *Eoparastaffella* ex gr. *simplex* Vdovenko, *Glomodiscus miloni* (Pelhate), *Glomodiscus oblongus* (Conil & Lys), *Glomodiscus* cf. *biarmicus* Malakhova, *Glomodiscus* sp., *Paraarchaediscus* cf. *dubitabilis* Orlova, *Dainella chomatica* (Dain),) *Dainella* cf. *grandis* (Grozdilova & Lebedeva), *Dainella staffelloides* Vdovenko, *Endothyra elegia* Malakhova, *Endothyra* ex gr. *similis* Rauser-Chernoussova & Reitlinger, *Endothyra* ex gr. *obsoleta* Rauser-Chernousova, *Endothyra* sp., *Laxoendothyra*? sp., *Eogloboenothyra*? sp., *Eogloboenothyra* sp., *Lapparentidiscus bokanensis* Vachard, *Lapparentidiscus* sp., *Lapparentidiscus* sp.1, *Lapparentidiscus* sp. 2, *Pseudoammodiscus* sp., *Mediocris mediocris* (Vissarionova), *Mediocris breviscula* (Ganelina), *Mediocris* sp., *Viseidiscus umbogmaensis* (Omara & Conil),*Viseidiscus* sp. 1, *Viseidiscus* sp. 2, *Viseidiscus* sp. 3, *Viseidiscus* sp. 4, *Brunsia spirillinoides* (Grozdilova & Glebovskaya), *Planoarchaediscu*s ex gr. *spirillinoides* (Rauser-Chernousova), *Planoarchaediscus* sp. 1, *Planoarchaediscus* sp. 2, *Rhodesinella*? sp., *Pseudoplanoendothyra* sp., *Mediendothyra wjasmensis* (Ganelina), *Valvulinell*a sp., *Forschia parvula* Rauser-Chernousova, *Eoparastaffella* cf. *vdovenkoae* Devuyst1 & Kalvoda, and *Tetrataxis* sp. (Figures 5.39–5.43).

Remarks.- The age of this assemblage is the late early Viséan that is the uppermost of Moliniacian Substage. It is close to the lowermost of the late Viséan, but because of the presence of Dainellids, this assemblage cannot be younger than the late early Viséan.

This study presents, for the first time, the occurrence of Biozone MFZ11 (subzone MFZ11B) in the Sanandaj-Sirjan Zone of Iran. Moreover, the species of the current fauna; namely, *Brunsia spirillinoides* (Grozdilova & Glebovskaya), *Endothyranopsis crassiformis* Vdovenko, *Endothyra elegia* Malakhova, *Plectogiranopsis convexa* Rauser-Chernousova, *Omphalotis chariessa* (Conil & Lys), *Glomodiscus miloni* (Pelhate), *Dainella staffelloides* Vdovenko, and *Forschia parvula* (Rauser-Chernousova) are reported from Iran for the first time.

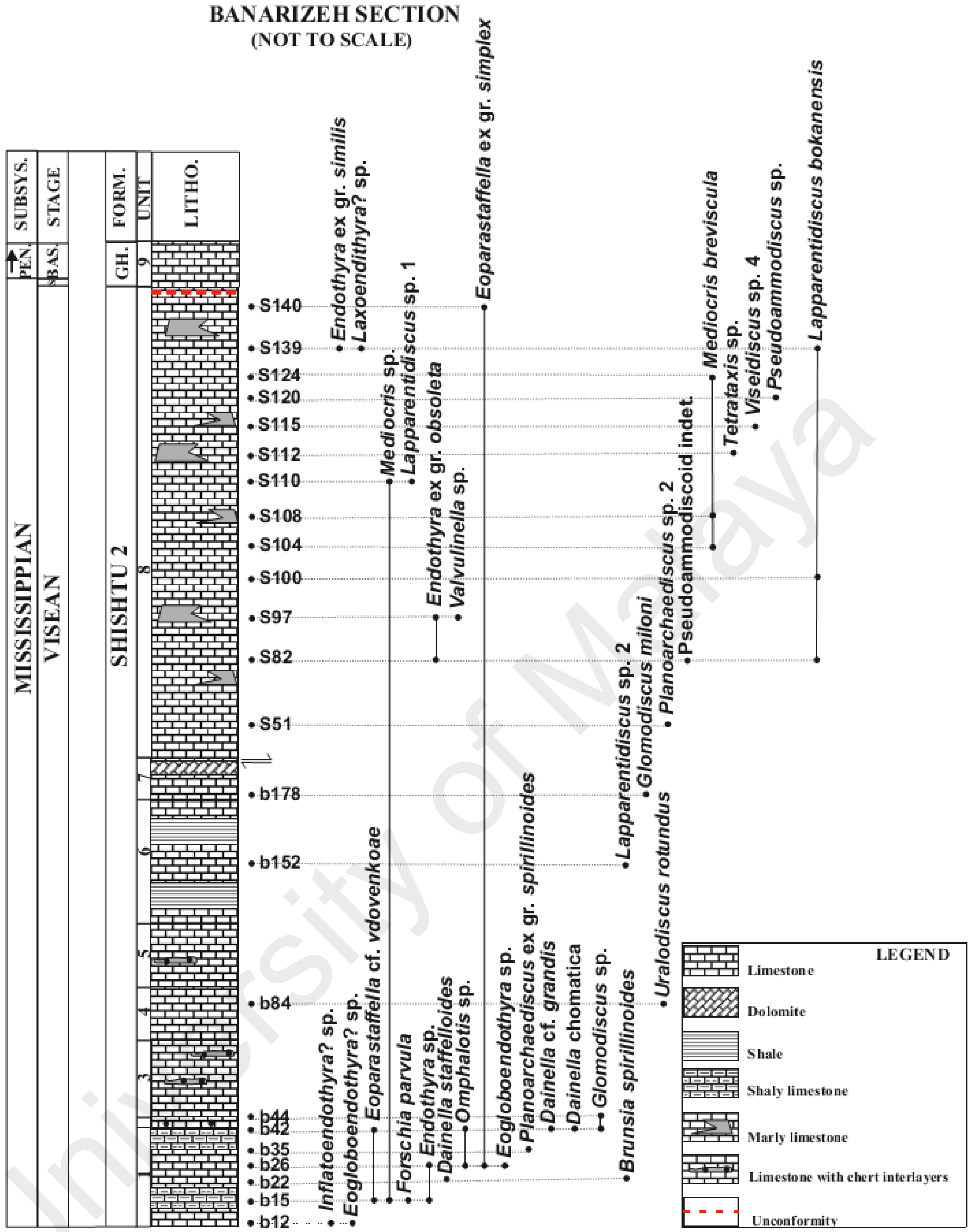

Figure 5.39: The stratigraphic occurrence of the foraminiferal fauna of a late early Viséan age in the Banarizeh Section. **Note:** Abbreviation: **(PEN.)** = Pennsylvanian; **(s.)** = uppermost Serpukhovian; **(BAS.)** = Bashkirian; **(GH.)** = Ghaleh; (**SUB SYS.)** = Subsystem; **(FORM.)** = Formation; **(LITHO.)** = Lithology.

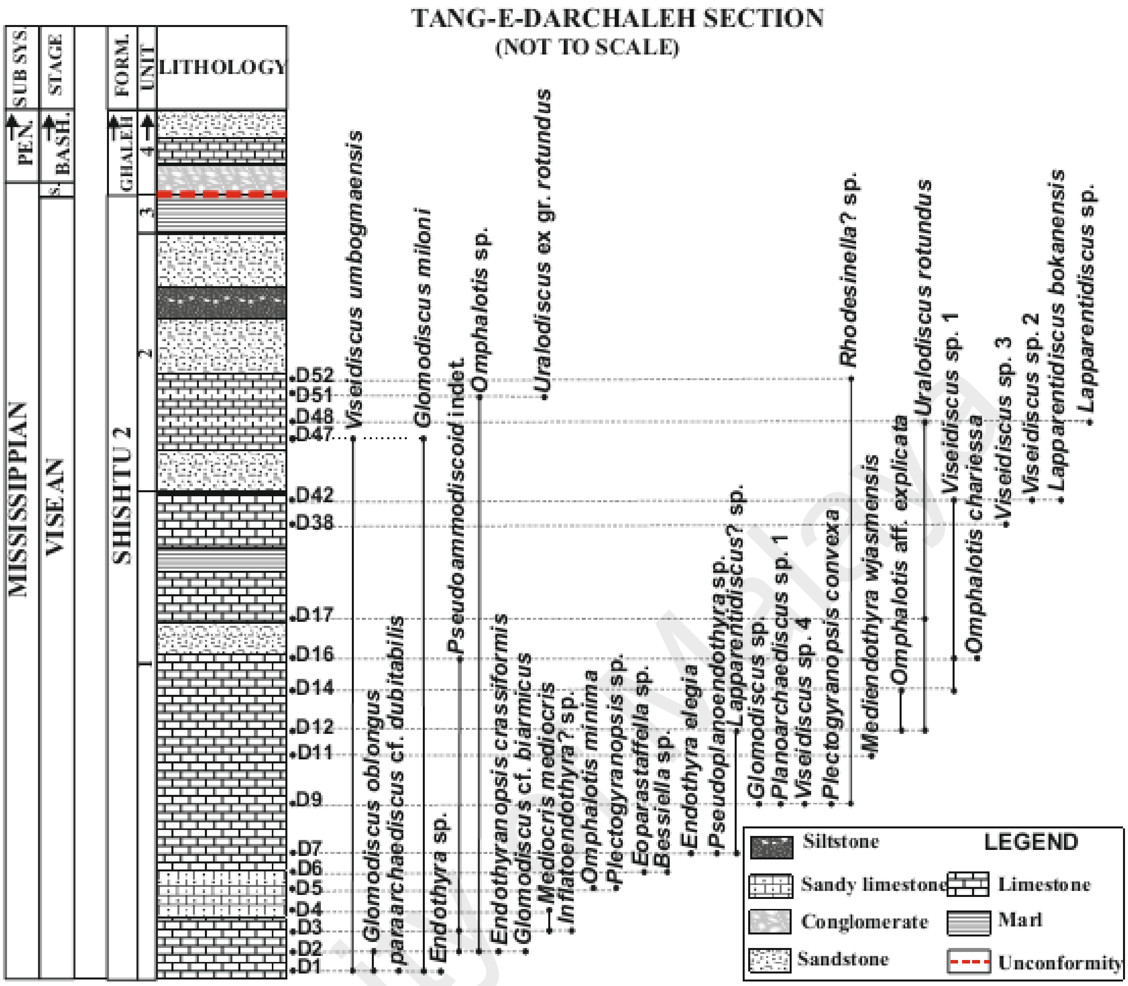

Figure 5.40: The stratigraphic occurrence of the foraminiferal fauna of a late early Viséan age in the Tang-e-Darchaleh Section. **Note:** Abbreviation: **(s.)** = uppermost Serpukhovian; **(PEN.)** = Pennsylvanian; **(BASH.)** = Bashkirian; **(FORM.)** = Formation; **(SUB SYS.)** = Subsystem.

Figure 5.41: Fusulinids and smaller foraminifers of a late early Viséan age, from the Shishtu 2 Formation in the Tang-e-Darchaleh Section. Spl.= Sample number.

(1) *Omphalotis* sp., Spl. D2; **(2)** *Omphalotis* cf. *minima* (Rauser & Reitlinger), Spl. D5; **(3)** *Bessiella*? sp., Spl. D6; **(4)** *Omphalotis* aff. *explicata* (Ganelin), Spl. D14; **(5)** *Mediocris mediocris* (Vissarionova), SF001, Spl. D3; **(6)** *Planoarchaediscus* sp. 1, Spl. D9; **(7, 8)** Pseudoammodiscoid indet., Spl. D2, D3; **(9, 12)** *Glomodiscus* sp., Spl. D9; **(10)** *Viseidiscus* sp. 1, Spl. D42; **(11)** *Viseidiscus* sp. 2, Spl. D42; **(13)** *Lapparentidiscus*? sp., Spl. D12; **(14)** *Viseidiscus* sp. 3, Spl. D38; **(15, 17)** *Viseidiscus* sp. 4, Spl. D9; **(16)** *Lapparentidiscus bokanensis* Vachard, Spl. D42.

Figure 5.42: Fusulinids and smaller foraminifers of a late early Viséan age, from the Shishtu 2 Formation in the Tang-e-Darchaleh Section. Spl.= Sample number.

(1) *Endothyranopsis crassiformis* Vdovenko, Spl. D2; **(2)** *Endothyra elegia* Malakhova**,** Spl. D7; **(3)** *Plectogiranopsis* sp., Spl. D5; **(4)** *Plectogiranopsis convexa* Rauser-Chernousova, Spl., D9; **(5)** *Omphalotis chariessa* (Conil & Lys), Spl. D16; **(6, 12)** *Rhodesinella*? sp., Spl. D9, D52; **(7)** *Endothyra* sp., Spl. D1; **(8)** *Pseudoplanoendothyra* sp., Spl. D7; **(9)** *Mediocris mediocris* (Vissarionova), SF002, Spl. D4; **(10)** *Inflatoendothyra*? sp, Spl. D3; **(11)** *Eoparastaffella*? sp., Spl. D6; **(13)** *Omphalotis* aff. *explicata* (Ganelina), Spl. D12; (**14, 15)** *Glomodiscus miloni* (Pelhate), Spl. D47, D1; **(16, 17)** *Glomodiscus oblongus* (Conil & Lys), Spl. D1, D2; **(18)** *Omphalotis* sp., Spl. D51; **(19)** *Mediendothyra wjasmensis* (Ganelina), Spl. D11; **(20)** *Paraarchaediscus* cf. *dubitabilis* Orlova, Spl. D1; **(21, 27, 29)** *Uralodiscus rotundus* (Chernysheva), Spl. D12, D17, D48; **(22, 32)** *Viseidiscus umbogmaensis* (Omara & Conil), Spl. D1, D47; **(23)** *Lapparentidiscus* sp., Spl. D48; **(24)** *Glomodiscus* cf. *biarmicus* Malakhova, Spl. D2; **(25, 31)** *Viseidiscus* sp. 1, Spl. D14, D16; **(26)** *Lapparentidiscus*? sp., Spl. D7; **(28)** Pseudoammodiscoid indet, Spl. D16; **(30)** *Uralodiscus* ex gr. *rotundus* (Chernysheva), Spl. D51.

Figure 5.43: Fusulinids and smaller foraminifers of a late early Viséan age, from the Shishtu 2 Formation in the Banarizeh Section. Spl.= Sample number**.**

(1) *Dainella* cf. *grandis* (Grozdilova & Lebedeva), Spl. b42; **(2, 7)** *Endothyra* ex gr. *obsoleta* Rauser-Chernousova, Spl. S82, S97; **(3)** *Endothyra* ex gr. *similis* Rauser-Chernoussova & Reitlinger, Spl. S139; **(4)** *Laxoendothyra*? sp., Spl. S139; **(5)** *Dainella chomatica* (Dain), Spl. b42; **(6)** *Valvulinella* sp., Spl. S97; **(8)** *Forschia parvula* Rauser-Chernousova, Spl. b15; **(9, 24)** *Endothyra* sp., Spl. b15, b26; **(10, 29)** *Eoparastaffella* ex gr. *simplex* Vdovenko, Spl. S140, b26; **(11)** *Dainella staffelloides* Vdovenko, Spl. b22; **(12)** *Viseidiscus* sp. 4, Spl. S115; **(13)** *Inflatoendothyra*? sp., Spl. b12; **(14, 31)** *Eoparastaffella* cf. *vdovenkoae* Devuyst1 & Kalvoda, Spl. b15, b42; **(15)** *Eogloboenothyra*? sp., Spl. b12; **(16, ?30)** *Omphalotis* sp., Spl. b26, b42; **(17, 18)** *Glomodiscus* sp., Spl. b42, b44; **(19)** *Glomodiscus miloni* (Pelhate), Spl. b178; **(20, 22)** *Mediocris* sp., Spl. S110, b15; **(21)** *Lapparentidiscus* sp. 1, Spl. S110; **(23)** *Eogloboenothyra* sp., Spl. b26; **(25)** *Planoarchaediscus* ex gr. *spirillinoides* (Rauser-Chernousova), Spl. b35; **(26)** *Planoarchaediscus* sp. 2, Spl.S51; **(27)** *Lapparentidiscus* sp. 2, Spl. b152; **(28)** *Brunsia spirillinoides* (Grozdilova & Glebovskaya), Spl. b22; **(32, 36, 37, 38)** *Mediocris breviscula* (Ganelina), (32): SF003, Spl. S104, (36): SF004, Spl. S108, (37): SF005, Spl. S124, (38): SF006, Spl. S124; **(33)** *Tetrataxis* sp., Spl. S112; **(34)** Pseudoammodiscoid indet, Spl. S82; **(35)** *Uralodiscus rotundus* (Chernysheva), Spl. b84; **(39, 40, 43)** *Lapparentidiscus bokanensis* Vachard, Spl. S139, S82, S100; **(41, 42)** *Pseudoammodiscus* sp., Spl. S120.

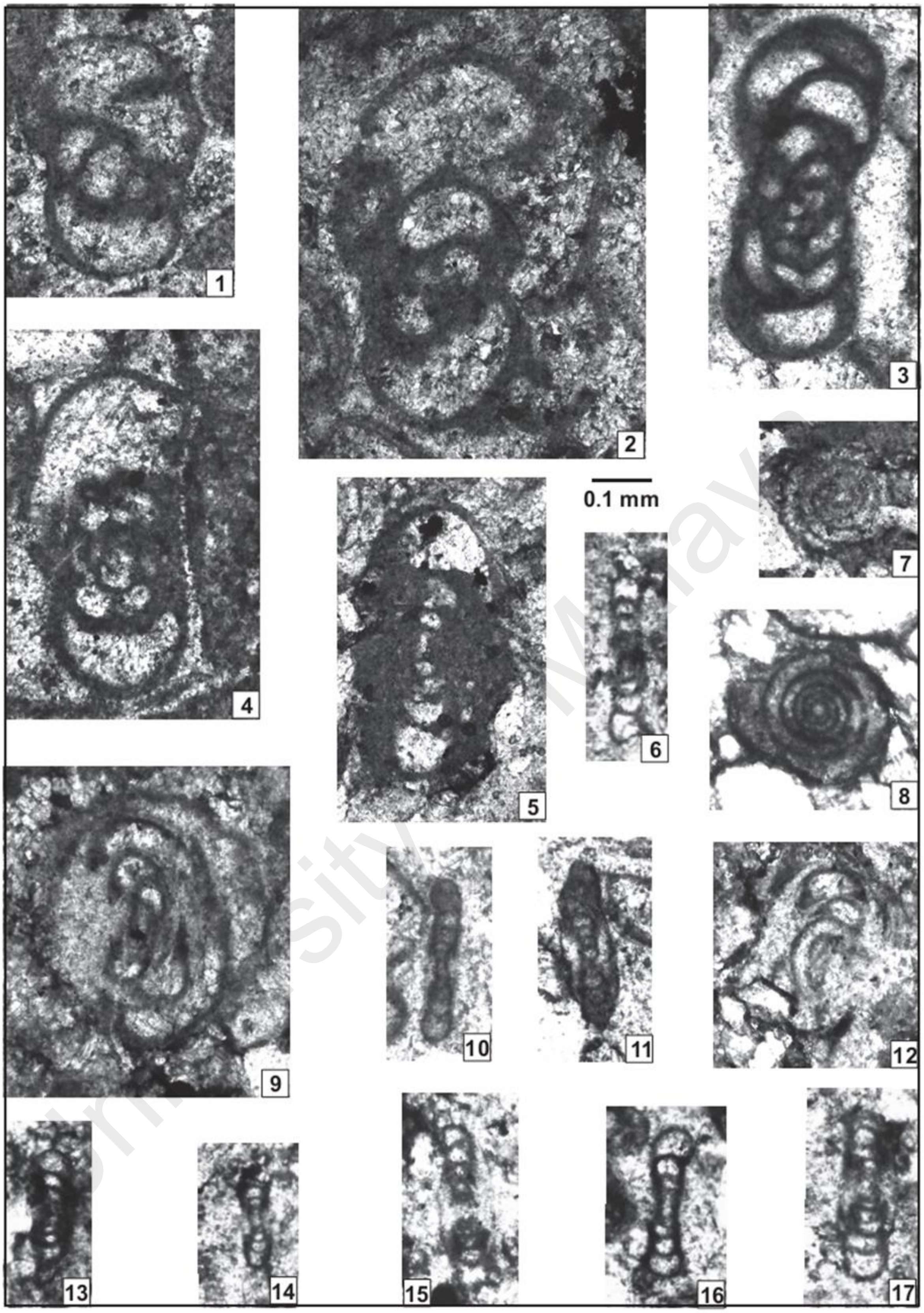

Figure 5.41: Fusulinids and smaller foraminifers of a late early Viséan age, from the Shishtu 2 Formation in the Tang-e-Darchaleh Section.

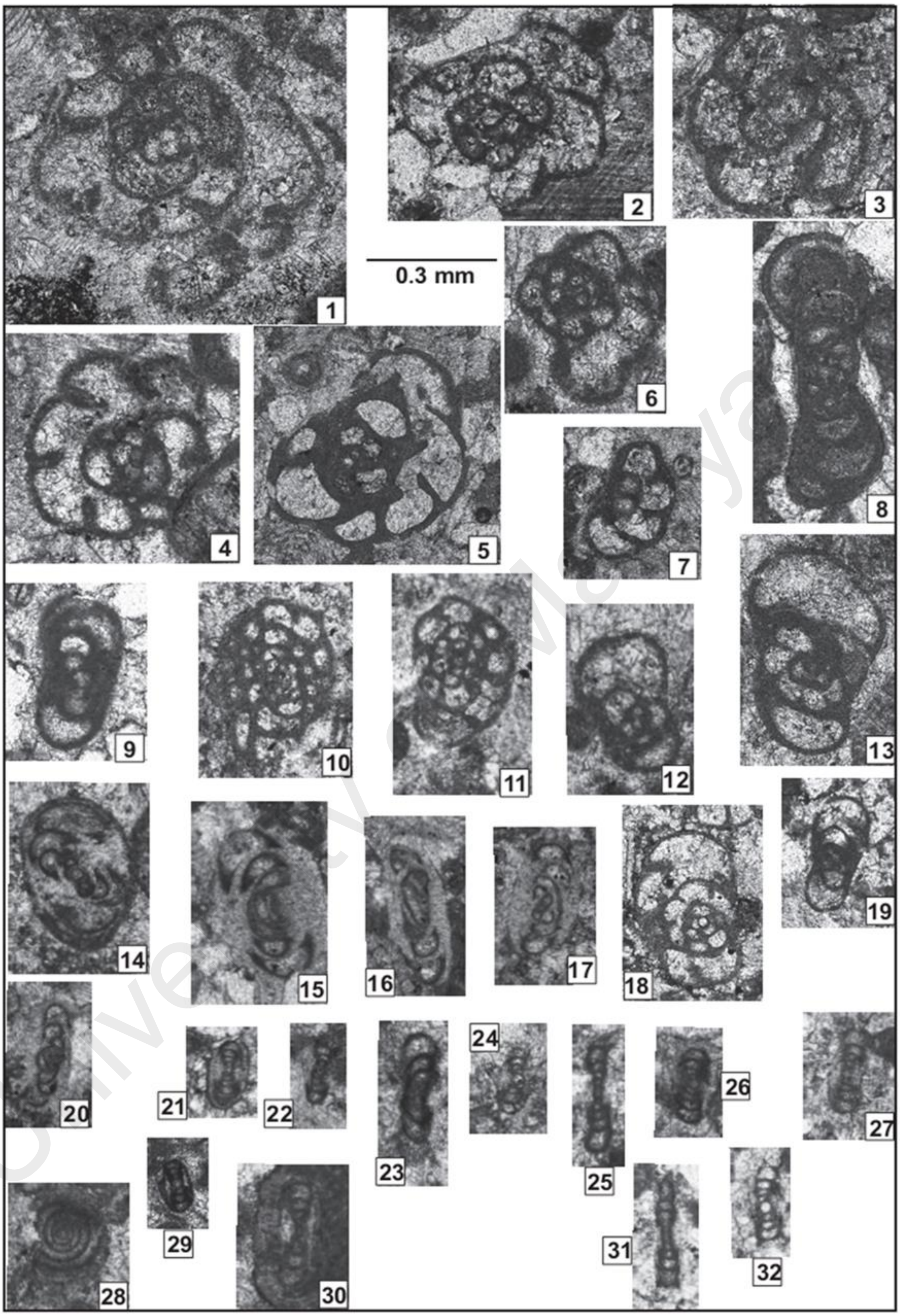

Figure 5.42: Fusulinids and smaller foraminifers of a late early Viséan age, from the Shishtu 2 Formation in the Tang-e-Darchaleh Section.

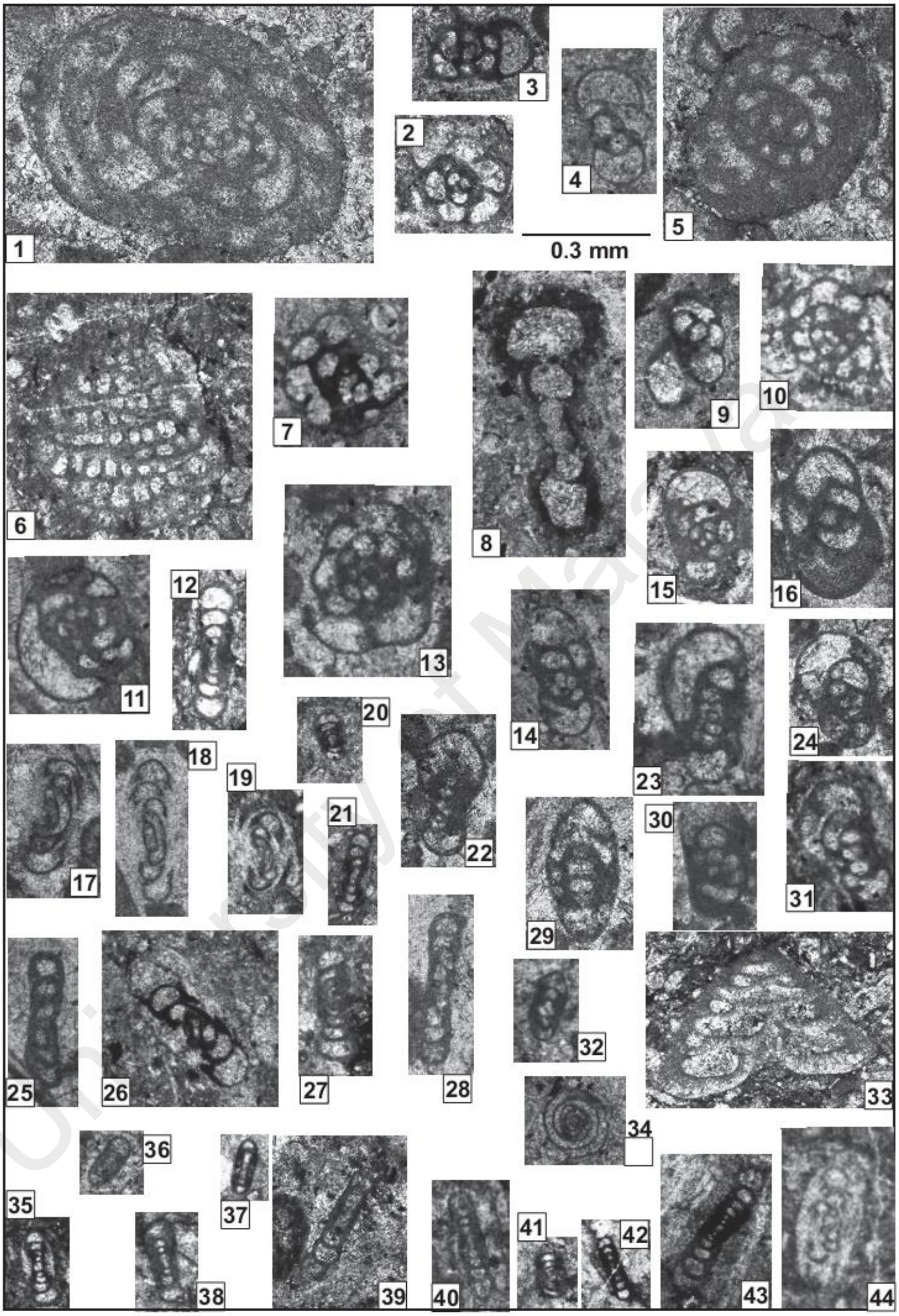

Figure 5.43: Fusulinids and smaller foraminifers of a late early Viséan age, from the Shishtu 2 Formation in the Banarizeh Section.

5.4.2 The Voznesenian (earliest Bashkirian) Foraminiferal Assemblage

The sediments bearing the Voznesenian (earliest Bashkirian) foraminifers are represented by quartz arenitic sandstone, sandy oolitic grainstone, mudstone, bioclastic wackestone, packstone, and grainstone (see Figure 4.4). The foraminiferal assemblage in this interval is dominated by species of *Paraarchaediscus*, *Earlandia*, *Globivalvulina*, *Biseriella*, *Howchinia*, *Tetrataxis*, *Pseudoglomospira*, *Consobrinella*, *Deckerella*, *Koskinotextularia*, *Palaeotextularia*, *Climacammina*, *Plectostaffella*, *Eostaffella*, *Planoendothyra*, *Endothyra*, and *Mediocris*. The species composition within this assemblage permits to recognize a biozone that is the *Plectostaffella jakhensis* - *Eostaffella pseudostruvei* zone.

The *Plectostaffella jakhensis* - *Eostaffella pseudostruvei* zone:

Definition.- The zone with a thickness of about 204 m is defined as the body of strata between the first appearance of *Plectostaffella jakhensis* Reitlinger, *Eostaffella pseudostruvei* (Rauser-Chernousova), and *Eostaffella* aff. *postmosquensis* Kireeva and the first occurrence of *Profusulinella* (*Depratina*) *prisca*, *Aljutovella* cf. *aljutovica* and *Tikhonovichiella tikhonovichi* of Melekessian–Vereian age (latest Bashkirian–earliest Moscovian stages).

Distribution.- The assemblage has been identified in Units 20–23 of the Ghaleh Formation in the Asad Abad II Section (Samples R1–R85, VB3, and VB4).

Composition.- The following species have been identified within the assemblage: *Endothyra* sp., *Planoendothyra* sp., *P.* sp. 1, *P.* sp. 2, *P.* sp. 3, *Mediocris* sp., *M. breviscula* (Ganelian), *Eostaffella parastruvei* (Rauser-Chernousova), *E.* cf. *parastruvei* (Rauser-Chernousova), *E. kasakhstanica* Rauser-Chernousova, *E. angularis*

Brazhnikova et al., *E. pseudostruvei chomtatifera* Kireeva, *E.* cf. *pseudostruvei* Rauser-Chernousova, Beljaev & Reitlinger, *E. mirifica Brazhnikova*, *E.* sp., *E.* sp. 1, *E.* sp. 2, *E. ikensis* Vissarionova, *E.* cf. *ikensis* Vissarionova, *E.* ex gr. *ikensis* Vissarionova, *E.* aff. *postmosquensis* Kireeva, *E.* cf. *raguschensis* Ganelina, *E. oblonga* Ganelina, E. *ex gr. oblonga* Ganelina, *Plectostaffella* sp., *Pl.* sp.1, *Pl. varvariensiformis* Brazhnikova & Vdovenko, *Pl. longa* Rauser-Chernousova, *Pl. jakhensis* Reitlinger, *Pl.* cf. *ovalis*, *Pl. (Plectostaffella)* cf. *bogdanovkensis* Reitlinger, *Pl. minima* Rumyantseva, *Pl. posochovae* , and *Pl.* cf. *longiscula* Rumjanzeva & O. Orlova.

In addition to the listed taxa the assemblage includes the species of the smaller foraminiferal fauna such as *Paraarchaediscus* cf. *koktjubensis* (Rauser-Chernousova), *Earlandia vulgaris* (Rauser & Reitlinger), *Globivalvulina* sp., *G. granulosa* Reitlinger, *G. scaphoidea* Reitlinger, *G.* cf. *scaphoidea* Reitlinger, *Biseriella parva* Chernysheva, *Pseudoglomospira* sp., *P. subquadrata* (Potievskaya & Vakarchuk), *Tetrataxis* sp., *T. pallae* (Coni & Lys), *Palaeotextularia* sp., *Palaeotextularia*? sp., *Climacammina* sp., *Howchinia gibba* (Moeller), *Consobrinella* sp., *Palaeobigenerin*a? sp., *Koskinotextularia* sp. (Figures 5.44–5.50).

Remarks.- The foraminiferal assemblage of this zone differs from the underlying assemblage by the appearance of several distinct genera of fusulinids, such as *Eostaffella pseudostruvei* (Rauser-Chernousova), *Plectostaffelle jakhensis* Reitlinger, *Pl. (Plectostaffella)* cf. *bogdanovkensis* Reitlinger, and *Eostaffella* aff. *postmosquensis* Kireeva which are characteristic for the earliest Bashkirian (Voznesenian) in the sections of the Russian Platform (Leven et al. 2006d).

The foraminiferal fauna of the Voznesenian age are reported from the Sanandaj-Sirjan Zone of Iran for the first time. This study also presents the first occurrence of species *Eostaffella mirifica* Brazhnikova, *E. angularis* Brazhnikova et al., *Plectostaffella varvariensiformis* Brazhnikova & Vdovenko, and *Pl. longa* Rauser-Chernousova in Iran.

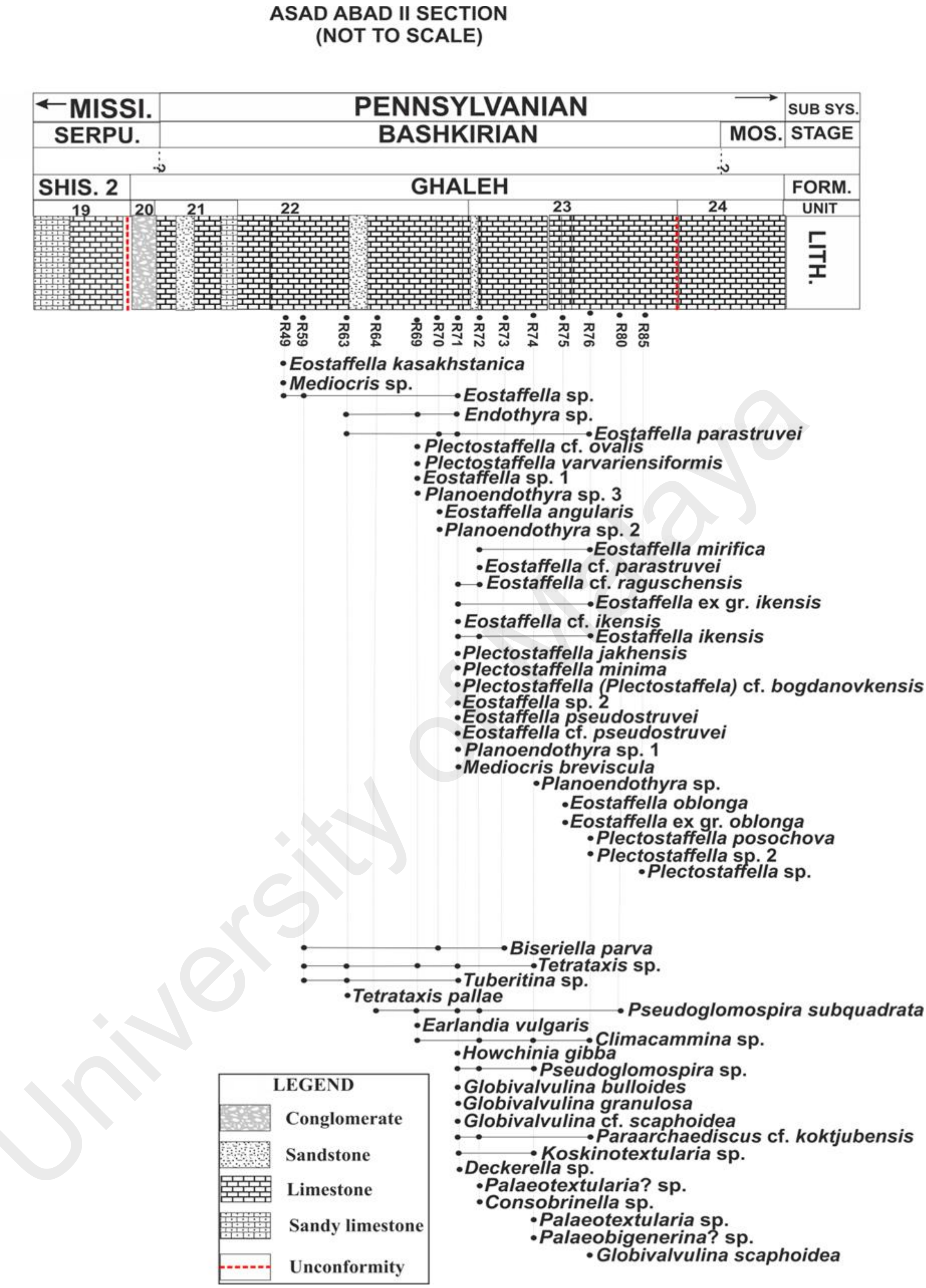

Figure 5.44: The stratigraphic occurrence of the fusulinids and smaller foraminifers of a Voznesenian (earliest Bashkirian) age from the Ghaleh Formation in the Asad Abad II Section. **Note:** Abbreviations: **(MOS.)** = lowermost Moscovian; **(MISSI.)** = Mississippian; **(SERPU.)** = Serpukhovian; **(SHIS. 2)** = Shishtu 2; **(SUB SYS.)** = Subsystem; **(FORM.)** = Formation; **(LTH.)** = Lithology.

Figure 5.45: Fusulinids of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section. Spl.= Sample number.

(1–4) *Endothyra* sp., Spl. R63, R69, R71; **(5)** *Planoendothyra* sp., Spl. R74; **(6)** *Planoendothyra* sp. 1, Spl. R71; **(7)** *Planoendothyra* sp. 2, Spl. R70; **(8)** *Planoendothyra* sp.3, Spl. R69; **(9)** *Mediocris* sp., Spl. R49; **(10, 12)** *Eostaffella kasakhstanica* Rauser-Chernousova Spl. R49; **(11)** *Mediocris breviscula* (Ganelian), SF007, Spl. R71.

Figure 5.46: Fusulinids of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section. Spl.= Sample number.

(1, 3) *Eostaffella parastruvei* (Rauser-Chernousova), (1): SF0013, Spl. R63, (3): SF0014, R70 **(2)** *Plectostaffella varvariensiformis* Brazhnikova & Vdovenko Spl. R69; **(4)** *Plectostaffella* cf. *ovalis,* Spl. R69; **(5)** *Eostaffella angularis* Brazhnikova et al., Spl. R70; **(6)** *Eostaffella* ex gr. *ikensis* Vissarionova, Spl. R71; **(7)** *Eostaffella* sp. 1, Spl. R69; **(8)** *Plectostaffella jakhensis* Reitlinger, Spl. R71; **(9)** *Plectostaffella minima* Rumyantseva, Spl. R71; **(10)** *Plectostaffella (Plectostaffella)* cf. *bogdanovkensis* Reitlinger, Spl. R71; **(11)** *Plectostaffella* sp., Spl. R85; **(12, 15)** *Eostaffella* sp., Spl. R49, R59; **(13)** *Eostaffella* sp. 2, Spl. R71; **(14)** *Eostaffella* cf. *ikensis* Vissarionova, Spl. R71; **(16)** *Eostaffella ikensis* Vissarionova, SF009, Spl. R71; **(17)** *Plectostaffella posochovae,* Spl. R76; **(18)** *Plectostaffella* sp. 1, Spl. R76.

Figure 5.47: Fusulinids of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section. Spl.=Sample number.

(1–3) *Eostaffella ikensis* Vissarionova, (1): SF0010, Spl. R71, (2): SF0011, Spl. R72, (3): SF0012, Spl. R76; **(4, 6)** *Eostaffella* ex gr. *ikensis* Vissarionova, Spl. R71, R76; **(5)** *Eostaffella* sp. Spl. R71; **(7–9)** *Eostaffella parastruvei* Rauser-Cherrnousova, (7): SF0015, Spl. R63, (8): SF0016, Spl. R63, (9): SF0017, Spl. R76.

Figure 5.48: Fusulinids of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section. Spl.=Sample number.

(1, 2) *Eostaffella* cf. *raguschensis* Ganelina, Spl. R71, R72; **(3)** *Eostaffella oblonga* Ganelina, Spl. R75; **(4)** *Eostaffella* ex gr. *oblonga* Ganelina, Spl. R75; **(5, 7, 8)** *Eostaffella mirifica* Brazhnikova, Spl. R72, R76; **(6, 12)** *Eostaffella parastruvei* (Rauser-Chernousova), (6): SF0018, Spl. R71, (12): SF0019, Spl. R71; **(9)** *Eostaffella* cf. *pseudostruvei* Rauser-Chernousova, Spl. R71; **(10)** *Eostaffella* cf. *parastruvei* (Rauser-Chernousova), Spl. R72; **(11)** *Eostaffella pseudostruvei* Rauser-Chernousova et al., SF008, Spl. R71.

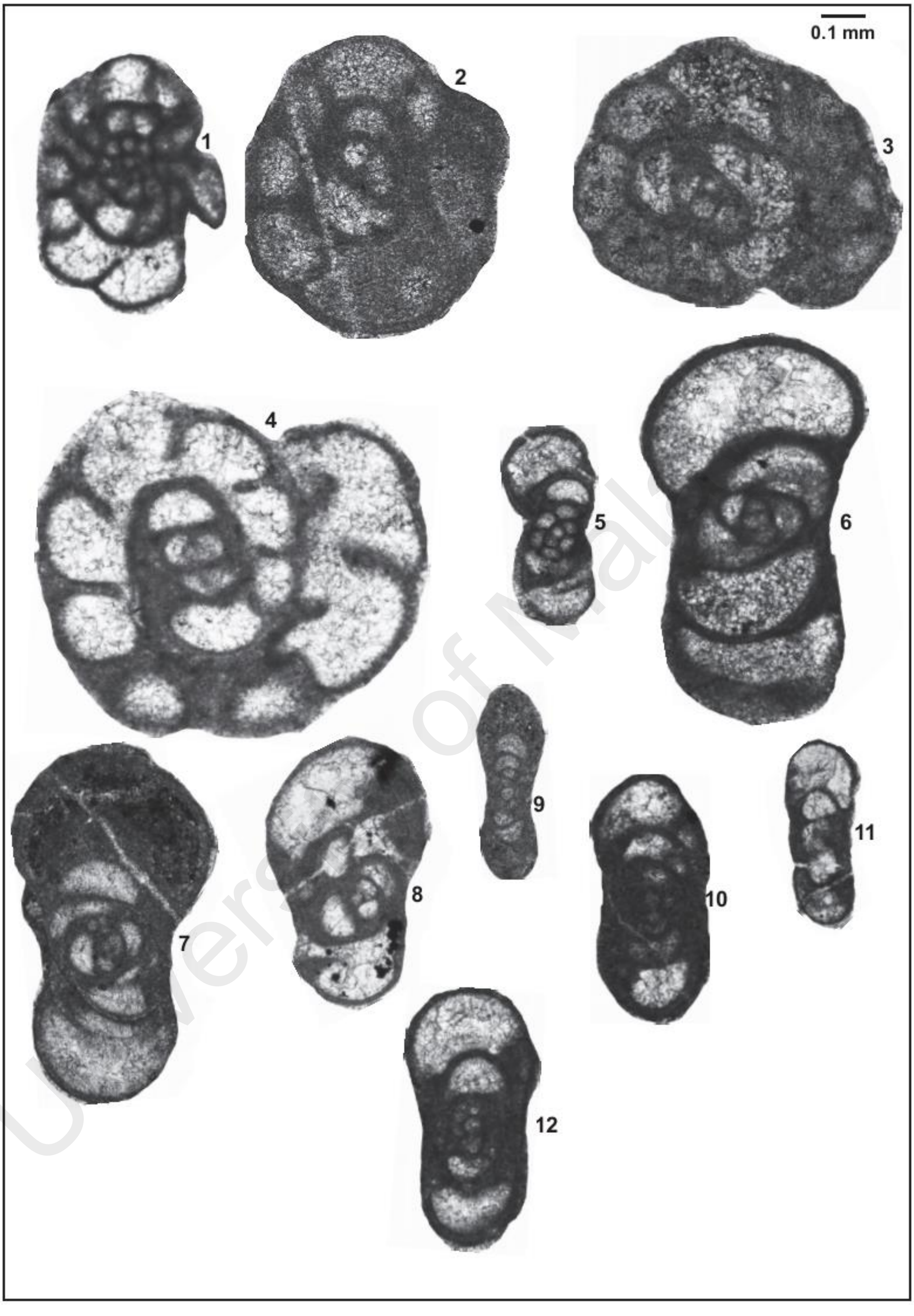

Figure 5.45: Fusulinids of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section.

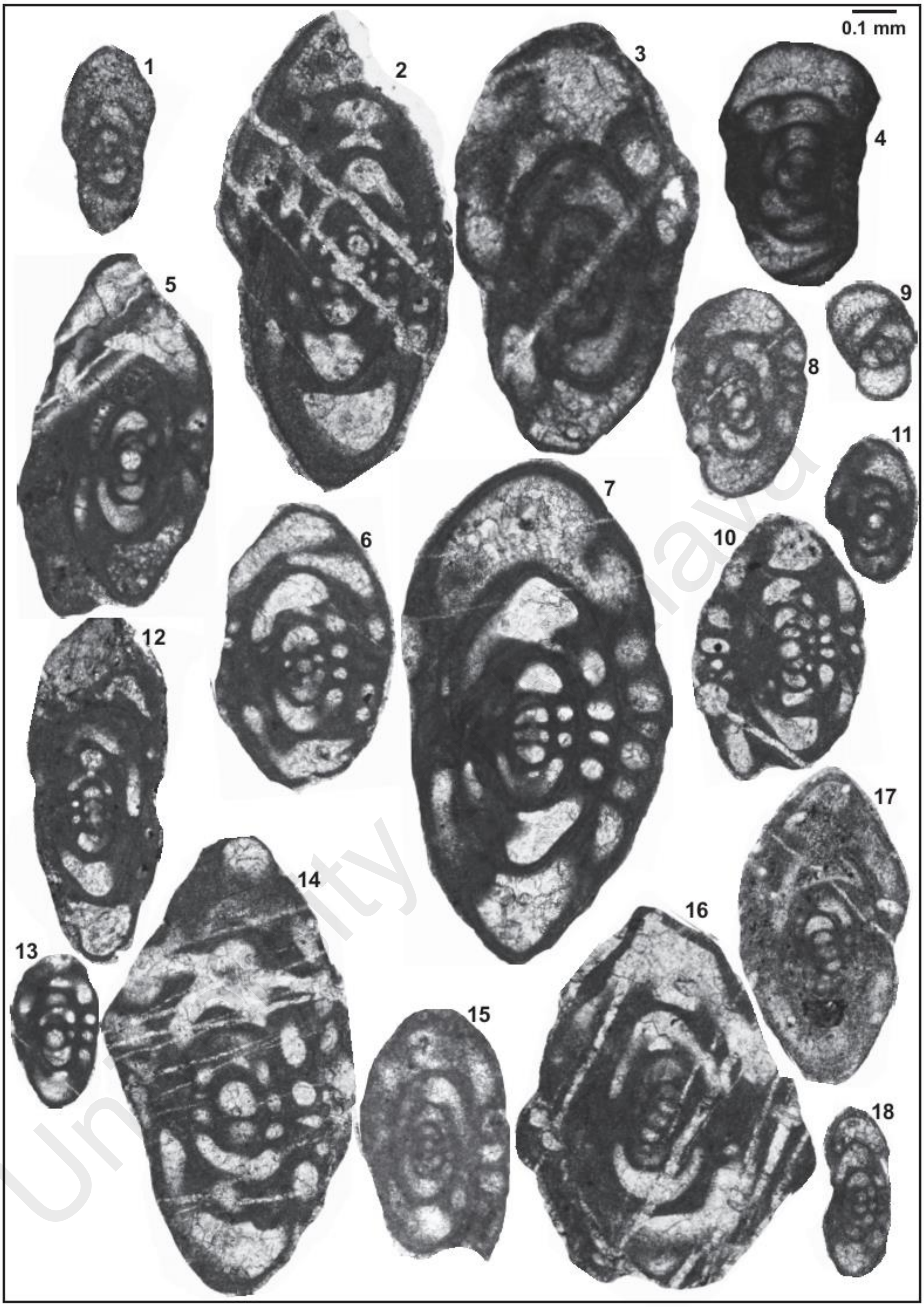

Figure 5.46: Fusulinids of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section.

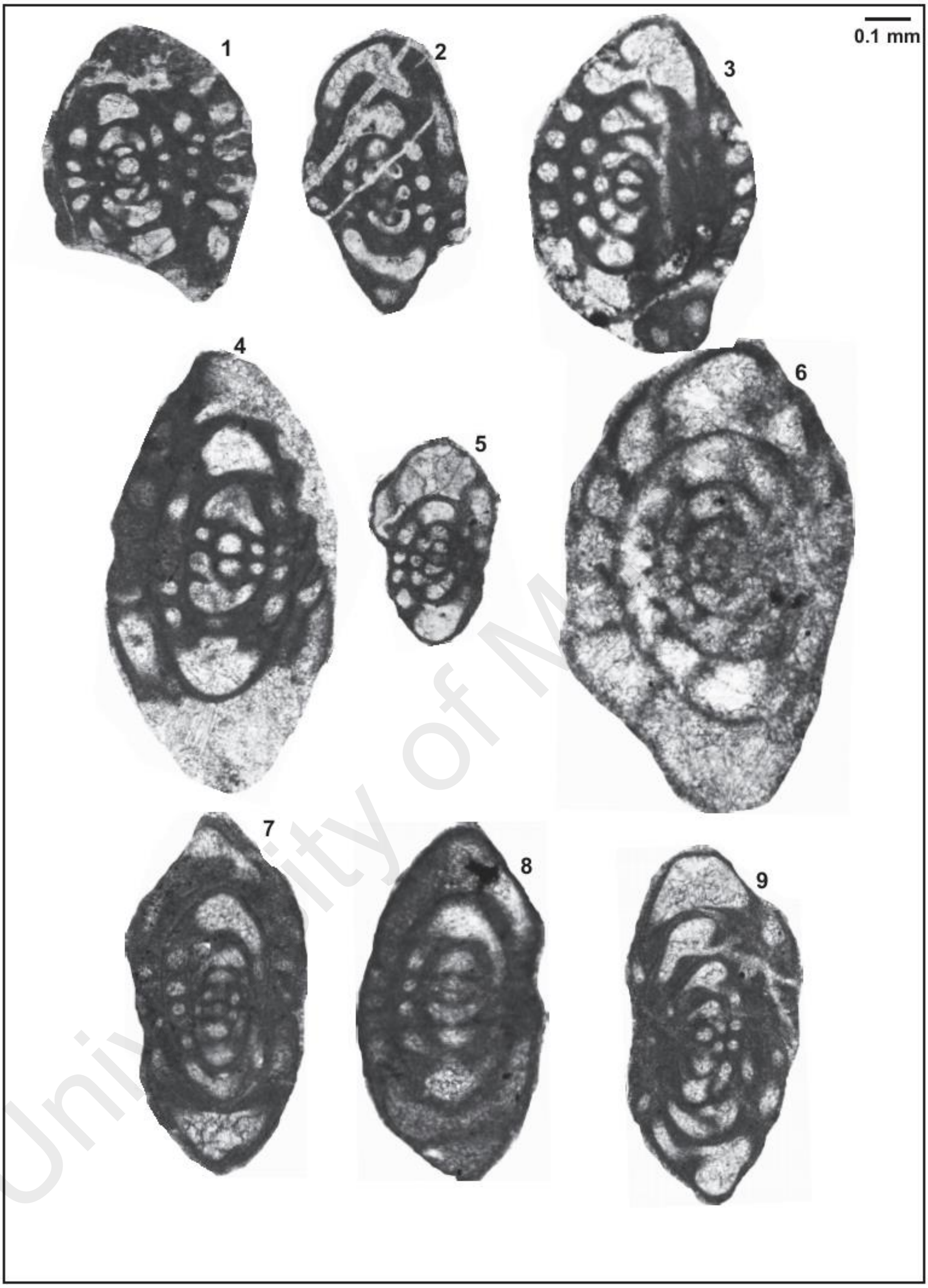

Figure 5.47: Fusulinids of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section.

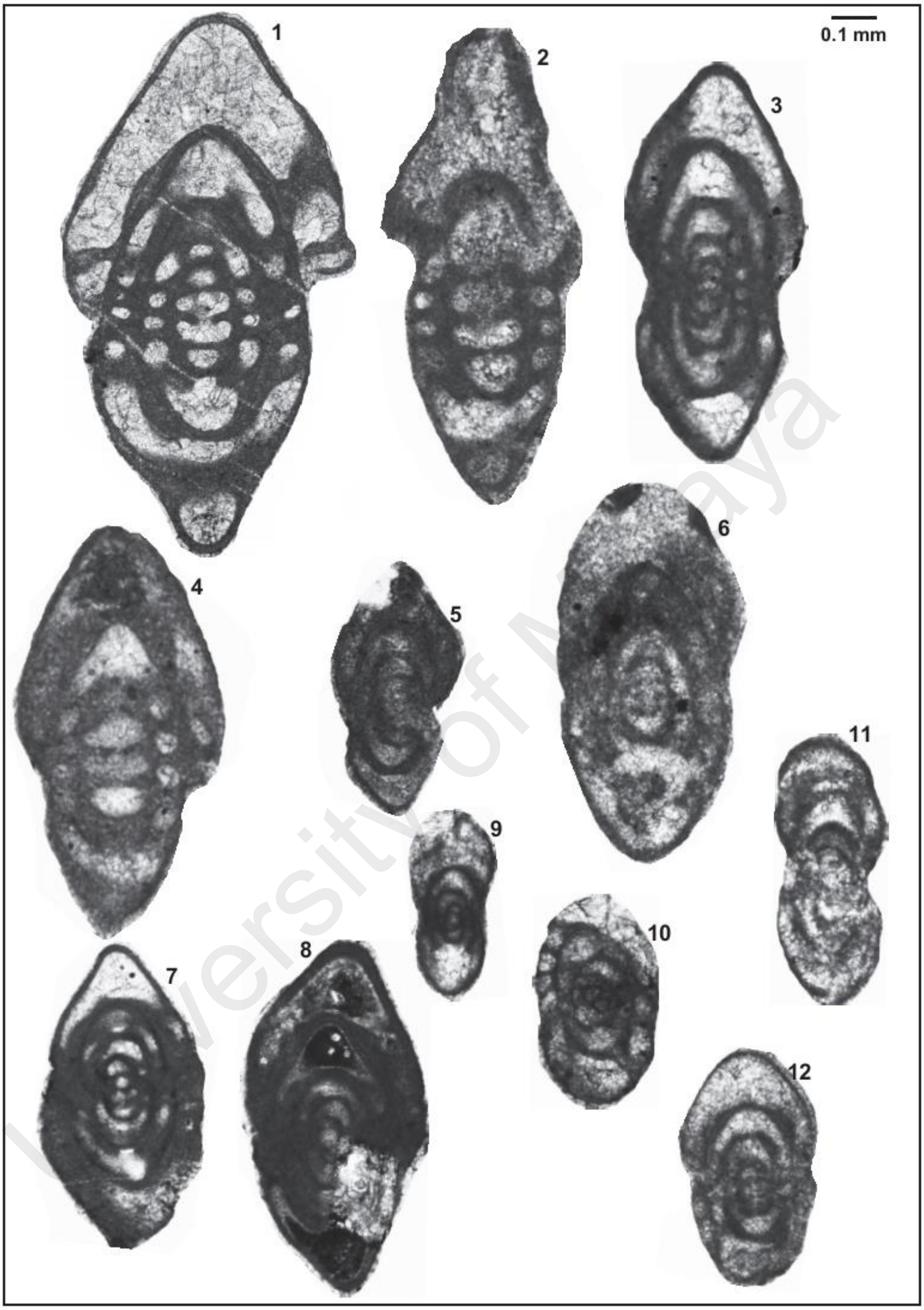

Figure 5.48: Fusulinids of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section.

Figure 5.49: Smaller foraminifers of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section. Spl.=Sample number.

(1) *Paraarchaediscus* cf. *koktjubensis* (Rauser-Chernousova), Spl. R71; **(2, 3)** *Paraarchaediscus koktjubensis* (Rauser-Chernousova), Spl. R72, R76; **(4, 5, 10)** *Tuberitina* sp. Spl. R59, R63, R71; **(6)** *Globivalvulina scaphoidea* Reitlinger, Spl. R76; **(7, 12)** *Globivalvulina granulosa* Reitlinger, Spl. R69, R71; **(8)** *Globivalvulina* cf. *scaphoidea* Reitlinger, Bed R71; **(9)** *Earlandia vulgaris* (Rauser & Reitlinger), Spl. R69; **(11)** *Eotuberitina* sp., Spl. R72; **(13, 14)** *Biseriella parva* Chernysheva, Spl. R70, R73; **(15, 16, 18, 19, 20, 22, 23, 26)** *Pseudoglomospira subquadrata* (Potievskaya & Vakarchuk), Spl. R64, R69, R71, R72, R80; **(17, 21, 24, 25)** *Pseudoglomospira* sp., Spl. R71, R72, R74.

Figure 5.50: Smaller foraminifers of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section. Spl.=Sample number.

(1) *Globivalvulina bulloides* (Brady), Spl. R71; **(2, 3, 5, 6, 11)** *Tetrataxis* sp., Spl. R59, R63, R69, R71, R74; **(4)** *Biseriella parva* (Chernysheva), Spl. R59; **(7)** *Tetrataxis pallae* (Coni & Lys), Spl. R63; **(8, 14)** *Palaeotextularia*? sp., Spl. R63, R72; **(9)** *Palaeotextularia* sp., Spl. R74; **(10, 15, 16, 22)** *Climacammina* sp., Spl. R69, R72, R74, R76; **(12, 13)** *Howchinia gibba* (Moeller), Spl. R71; **(17)** *Consobrinella* sp., Spl. R72; **(18)** *Palaeobigenerina*? sp., Spl. R74; **(19)** *Deckerella*? sp., Spl. R71; **(20, 21)** *Koskinotextularia* sp., Spl. R71, R74.

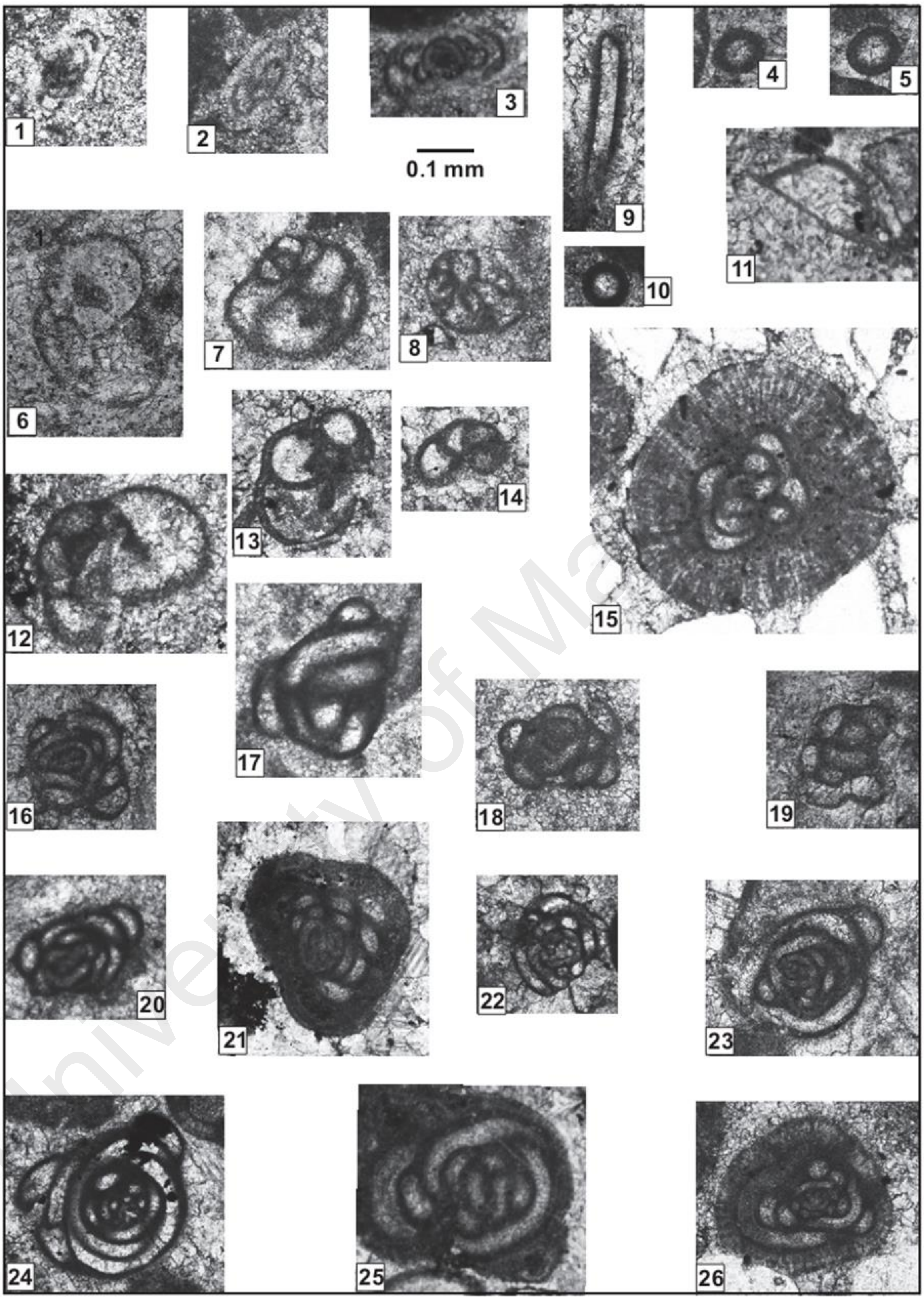

Figure 5.49: Smaller foraminifers of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section.

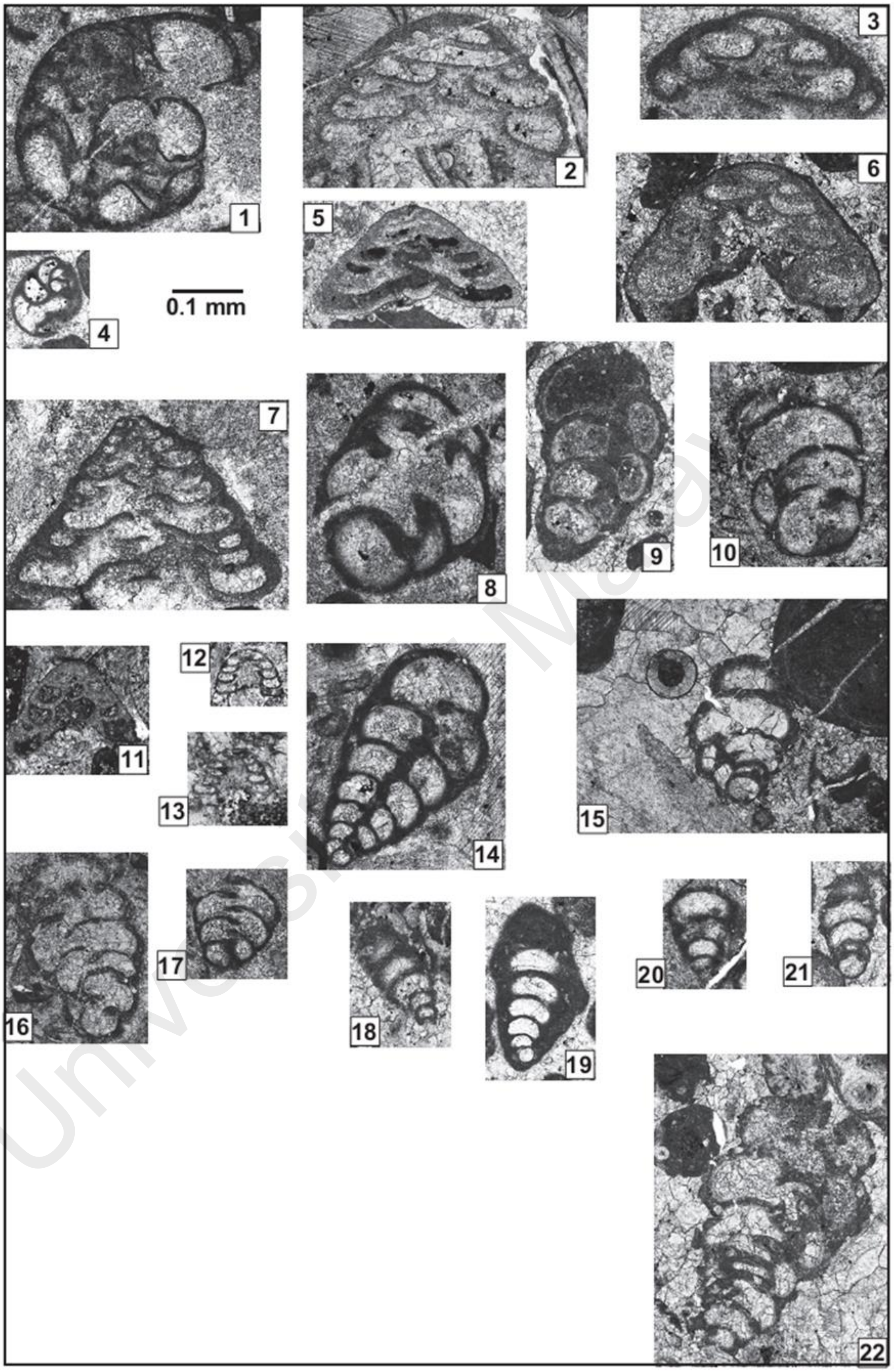

Figure 5.50: Smaller foraminifers of an earliest Bashkirian (Voznesenian) age, from the Ghaleh Formation in the Asad Abad II Section.

5.4.3 The latest Bashkirian–earliest Moscovian Foraminiferal Assemblage

The sediments bearing the latest Bashkirian–earliest Moscovian foraminiferal assemblage are represented by bioclastic wackestone, and grainstone. The smaller foraminifers in this assemblage are very rare. The fusulinids in this interval are dominated by species of *Aljutovella, Tikhonovichiella, Profusulinella, Pseudostaffella*, and *Ozawainella*. The species composition within the assemblage permits to recognize a local biozone that is the *Tikhonovichiella tikhonovichi* - *Profusulinella* (*Depratina*) *prisca* - *Aljutovella* spp. zone (Fassihi et al. 2017).

The *Tikhonovichiella tikhonovichi* - *Profusulinella* (*Depratina*) *prisca* - *Aljutovella* spp. zone:

Definition.- The zone with a thickness of about 13 m is defined between the first occurences of *Pr.* (*Depratina*) *prisca* (Deprat), *Tikhonovichiella tikhonovichi* (Rauser-Chernousova), and *Aljutovella* cf. *aljutovica* (Rauser-Chernousova), and the first appearance of *Beedeina samarica* (Rauser-Chernousova) and *Taitzehoella mutabilis* (Safonova). *Beedeina samarica* and *Taitzehoella mutabilis* are characteristic of the late Kashirian in the sections of the Russian Platform and Southern Urals (Leven & Gorgij, 2008a).

Distribution.- The assemblage has been recognized in the uppermost part of the Ghaleh Formation that is the uppermost portion of Unit 24, in the Asad Abad II Section (Beds VB5, VB6, VB6.1, and VB7).

Composition.- The assemblage is characterized by *Aljutovella* sp., *Al*. cf. *aljutovica* Rauser-Chernousova, *Al.* aff. *intermixta* Safonova, *Al.* cf. *subaljutovica* (Safonova), *Al.* aff. *subaljutovica, Al*. cf. *skelnevatica* (Putrja), *Al.* cf. *parasaratovica* Safonova, *Profusulinella* sp., *Pr.* (*Depratina*) *prisca* (Deprat), *Pr.* (*Depratina*) cf. *prisca, Pr. postpararhombiformis* Dzhenchuraeva, *Pr.* (*Depratina*) cf. *subovata* Safonova, *Pr.* (*Depratina*) *parva* (Lee & Chen), *Tikhonovichiella pseudoaljutovica* (Rauser-Chernousova), *T. tikhonovichi* (Rauser-Chernousova), *T.* cf. *tikhonovichi, T.* cf. *gracilis* Ektova, *T.* sp., *T.*? sp., and *T.* aff. *grozdilovae* Ektova. In addition to the above taxa, the current fauna includes *Staffellaeformis* sp., *Eoschubertella* cf. *obscura* Lee & Chen, *Schubertella* sp., *Sc. gracilis* Rauser, *Sc. magna* Lee & Chen, *Pseudostaffella subquadrata* Grozdilova & Lebedeva, *Ps.* cf. *subquadrata, Ps.* aff. *pseudoquadrata* Menukalova, *Ps.* cf. *nibelensis* Rauser, *Ps.* cf. *gorskyi* (Dutkevich), *Ps.* aff. *gorskyi, Ps. timanica* Rauser- Chrnousova, *Ps.* aff. *proozawai* Kireeva, *Ozawainella* sp., *Oz. pararhomboidalis* Manukalova, *Oz.* cf. *pararhomboidalis, Oz.* ex gr. *mosquensis* Rauser-Chernousova, *Oz.* aff. *crassiformis* Putrja, *Millerella* cf. *uralica* Kireeva, *Eostaffella* sp., *E. primitiva* (Dutkevich), *E.* aff. *postmosquensis* Kireeva, and *E. compressa* Brazhnikova (Figures 5.51–5.53). The assemblage also includes the rare smaller foraminifers such as *Pseudoglomospira* sp., *Globivalvulina* sp., and *Bradyina* sp.

Remarks.- The fusulinid assemblage of this zone differs from the underlying assemblage by the first appearance of several distinct genera of fusulinids including *Aljutovella, Tikhonovichiella,* and *Profusulinella* which are characteristic for the Melekessian–Vereian substages in the sections of the Russian Platform and Southern Urals (see section 5.3.2 of this dissertation). The preservation of fusulinids which define the zone is rather poor, however, they clearly indicate the Melekessian–Vereian age.

The foraminifers of the Melekessian–Vereian age are reported from the Sanandaj-Sirjan Zone of Iran for the first time. The six species of the current fauna; namely, *Eostaffella compressa* Brazhnikova, *E. primitiva* (Dutkevich), *Pseudostaffella timanica* Rauser-Chernosouva, *Schubertella gracilis* Rauser-Chernousova, *Sc. magna*

Lee & Chen, and *Profusulinella postpararhombiformis* Dzhenchuraeva are reported from Iran for the first time. This study also presents the first occurrence of the genera *Aljutovella* and *Tikhonovichiella* in the Sanandaj-Sirjan Zone of Iran.

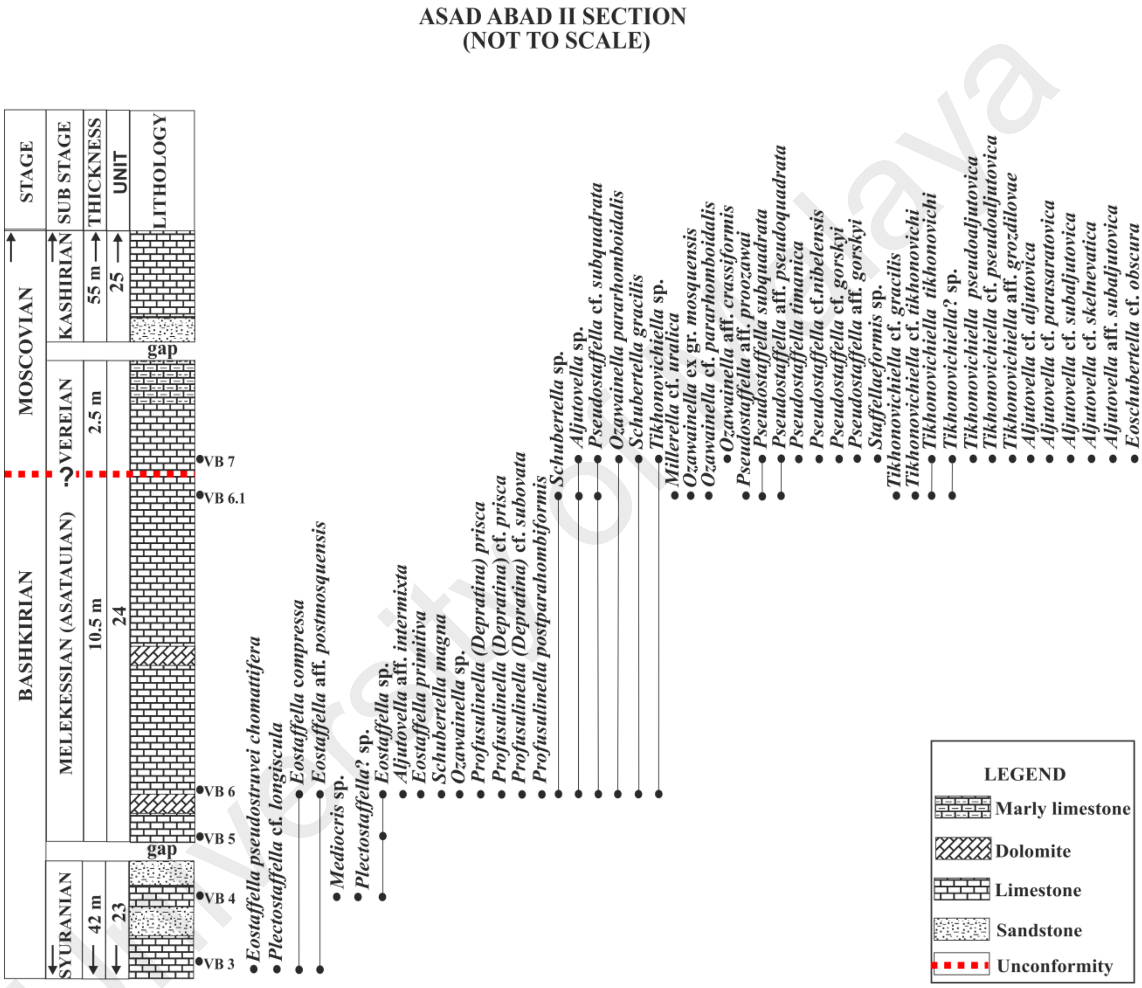

Figure 5.51: The stratigraphic occurrence of the fusulinids in the Bashkirian–Moscovian transition layers from the Ghaleh Formation, in the Asad Abad II Section (modified after Fassihi et al. 2017).

Figure 5.52: Fusulinids of a latest Bashkirian–earliest Moscovian (Melekessian─Vereian) age, from the Ghaleh Formation in the Asad Abad II Section. Figs 1–8 : scale bar A= 0.5 mm. Figs 9–36 scale bar B= 1 mm. Figs 1, 2, and 4 are of the earliest Bashkirian (Syuranian) age. Spl.=Sample number.

(1) *Plectostaffella* cf. *longiscula* Rumjanzeva & O. Orlova, Spl. VB3; **(2, 3)** *Eostaffella* aff. *postmosquensis* Kireeva, Spl. VB3, VB6; **(4)** *Eostaffella pseudostruvei* chomatifera Kireeva, Spl. VB3; **(5)** *Eostaffella* sp., Spl. VB6; **(6)** *Eostaffella primitiva* (Dutkevich), Spl. VB6; **(7)** *Millerella* cf. *uralica* Kireeva, Spl.VB6.1; **(8)** *Eostaffella compressa* Brazhnikova, Spl. VB6; **(9, 10)** *Ozawainella pararhomboidalis* Manukalova, Spl. VB6, VB7; **(11)** *Ozawainella* cf. *pararhomboidalis* Manukalova, Bed VB6.1; **(12, 13)** *Ozawainella* aff. *crassiformis* Putrja, Spl. VB7; **(14, 15)** *Ozawainella* ex gr. *mosquensis* Rauser-Chernousova, Spl. VB6.1; **(16, 17)** *Schubertella gracilis* Rauser-Chernousova, Spl. VB6, VB7; **(18)** *Eoschubertella* cf. *obscura* Lee & Chen, Spl. VB7; **(19)** *Schubertella magna* Lee & Chen, Spl. VB6; **(20)** *Pseudostaffella* cf. *nibelensis* Rauser-Chernousova, Spl. VB7; **(21, 24, 25, 26)** *Pseudostaffella subquadrata* Grozdilova & Lebedeva, (21): SF0042, Spl. VB6.1, (24): SF0043, Spl. VB7, (25): SF0044, Spl. VB7, (26): SF0045, Spl.VB6.1; **(22)** *Pseudostaffella* cf. *subquadrata* Grozdilova & Lebedeva, Spl. VB7; **(23)** *Pseudostaffella timanica* Rauser, Spl. VB7; **(27)** *Pseudostaffella* aff. *gorskyi* (Dutkevich), Spl. VB7; **(28)** *Pseudostaffella* cf. *gorskyi* (Dutkevich), SF0040, Spl. VB7; **(29)** *Pseudostaffella* aff. *proozawai* Kireeva, Spl.VB6.1; **(30, 31, 32)** *Pseudostaffella* aff. *pseudoquadrata* Menukalova, Spl. VB6.1, VB7; **(33, 34)** *Tikhonovichiella tikhonovichi* (Rauser-Chernousova), (33): UM10637, Spl. VB6.1, (34): UM10638, Spl. VB6.1; **(35, 36)** *Tikhonovichiella* cf. *tikhonovichi* (Rauser-Chernousova), (35): SF0024, Spl. VB6.1, (36): SF0025, Spl. VB6.1.

Figure 5.53: Fusulinids of a latest Bashkirian–earliest Moscovian (Melekessian─Vereian) age, from the Ghaleh Formation in the Asad Abad II Section. Spl.=Sample number.

(1, 2) *Tikhonovichiella pseudoaljutovica* (Rauser-Chernousova), (1): SF0026, Spl. VB7, (2): SF0027, Spl. VB7; **(3, 5)** *Tikhonovichiella*? sp., Spl. VB6.1, VB7; **(4)** *Tikhonovichiella* aff. *grozdilovae* Ektova, SF0028, Spl. VB7; **(6)** *Tikhonovichiella* cf. *gracilis* Ektova, Spl. VB6.1; **(7)** *Staffellaeformis* sp., Spl. VB7; **(8)** *Aljutovella* aff. *intermixta* Safonova, Spl. VB6; **(9)** *Aljutovella* aff. subaljutovica Safonova, Spl. VB7; **(10)** *Aljutovella* cf. *skelnevatica* (Putrja), Spl.VB7, **(11, 12)** *Aljutovella* cf. *aljutovica* (Rauser), (11): UM10635, Spl. VB7, (12): UM10636, Spl. VB7; **(13)** *Aljutovella* sp., Spl. VB7; **(14, 15)** *Aljutovella* cf. *subaljutovica* Safonova, Spl.VB7; **(16, 17)** *Aljutovella* cf. *parasaratovica* Safonova, Spl.VB7; **(18, 19)** *Profusulinella*? sp., Spl. VB7; **(20)** *Profusulinella postpararhombiformis* Dzhenchuraeva, Spl. VB6; **(21)** *Profusulinella* (*Depratina*) *parva* (Lee & Chen), UM10634, Spl. VB7; **(22)** *Profusulinella* (*Depratina*) *prisca* (Deprat), UM10633, Spl. VB6; **(23)** *Profusulinella* (*Depratina*) cf. *prisca* (Deaprat), SF0020, Spl. VB6; **(24)** *Profusulinella* (*Depratina*) cf. *subovata* Safonova, Spl.VB6.

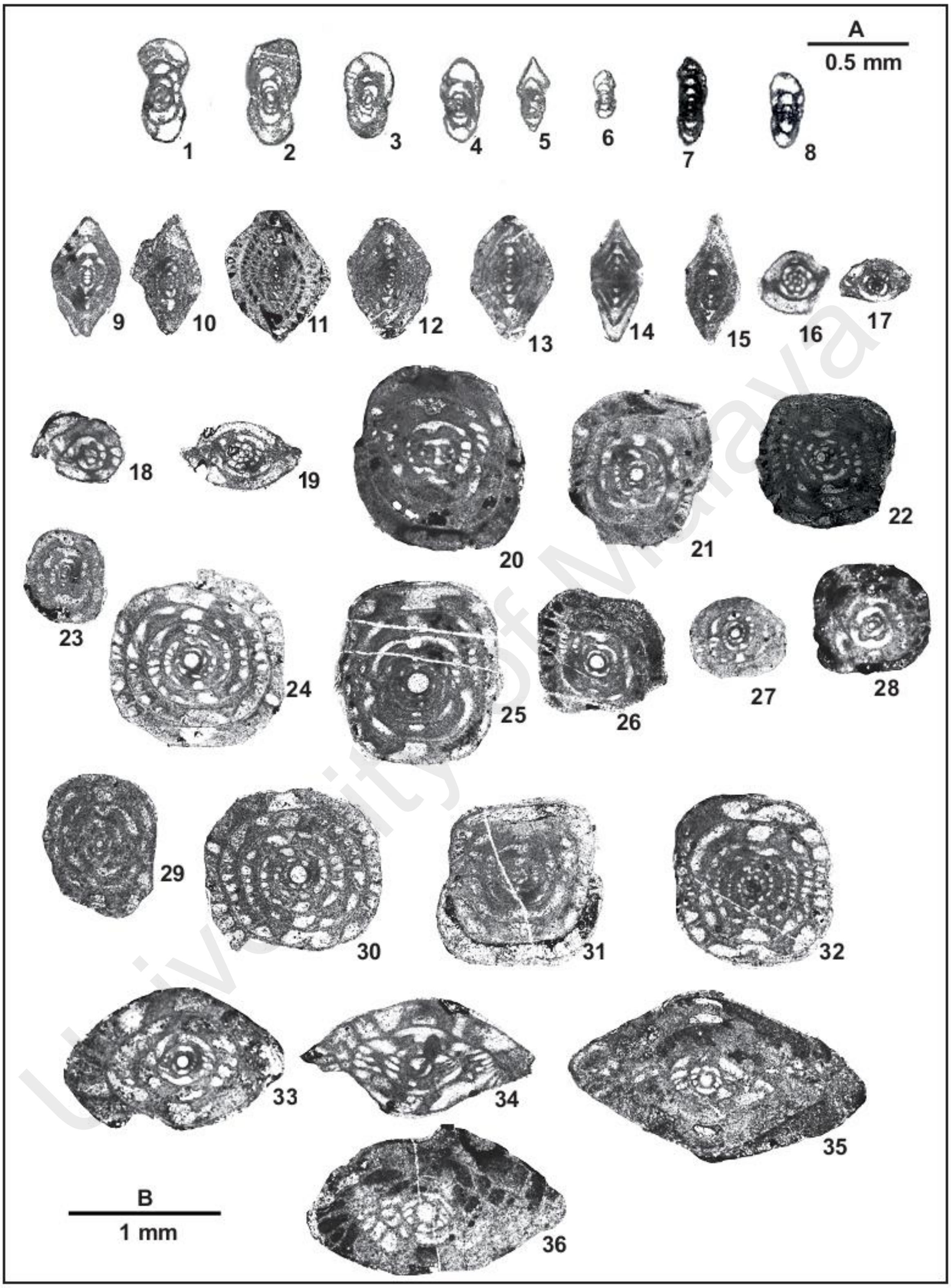

Figure 5.52: Fusulinids of a latest Bashkirian–earliest Moscovian (Melekessian─Vereian) age, from the Ghaleh Formation in the Asad Abad II Section.

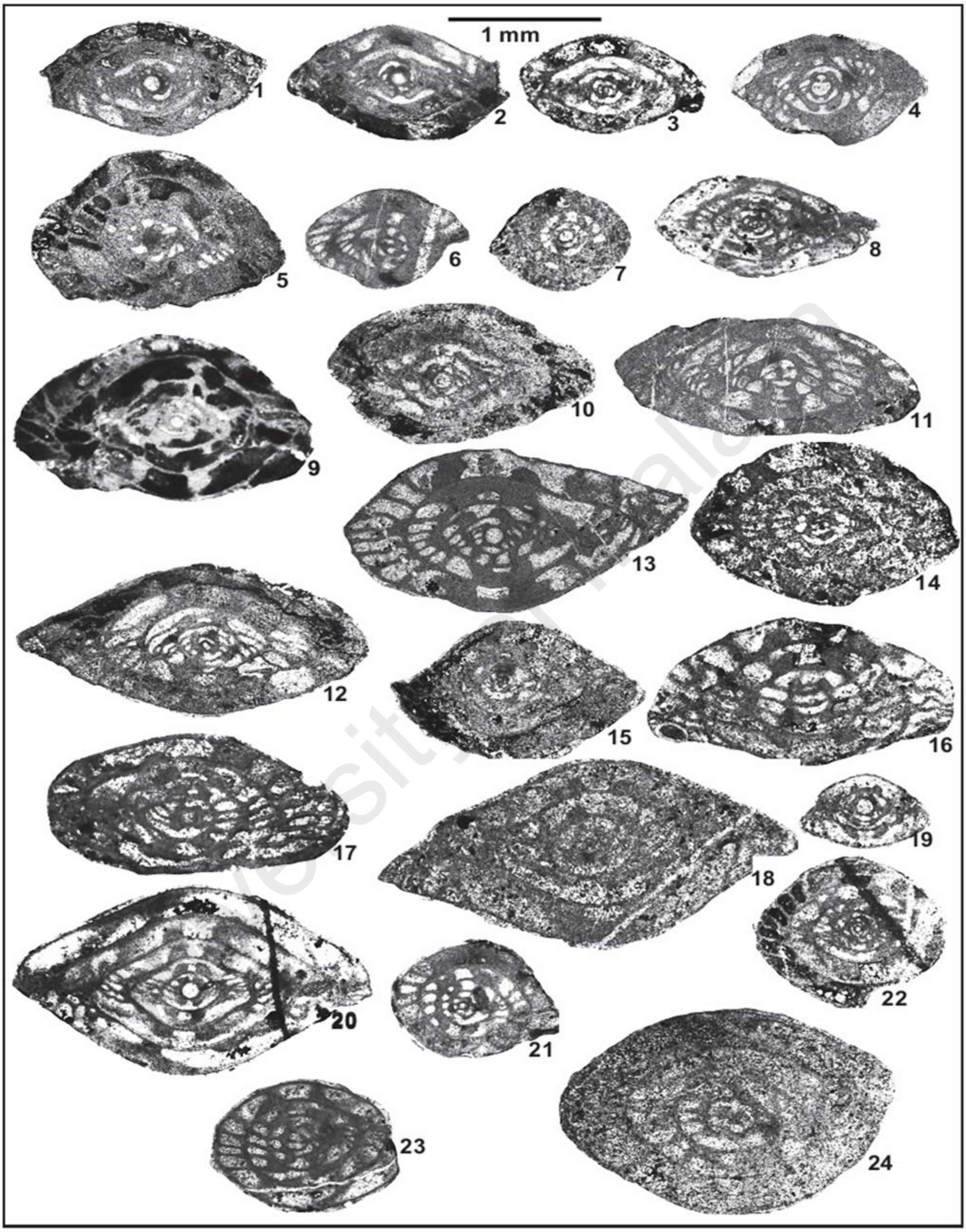

Figure 5.53: Fusulinids of a latest Bashkirian–earliest Moscovian (Melekessian–Vereian) age, from the Ghaleh Formation in the Asad Abad II Section.

5.4.4 The late Kashirian Foraminiferal Assemblage

The sediments bearing the late Kashirian foraminiferal assemblage occur in the Absheni Formation. They are represented by sandstone, oolitic grainstone, bioclastic wackestone, packstone, and grainstone (see Figure 4.5).

The rare smaller foraminifers in this assemblage are characterized by *Earlandia* sp., *Palaeotextularia* sp., and *Globivalvulina* sp. The fusulinids in this interval are distinguished by species of *Taitzehoella, Beedeina, Ozawainella, Pseudostaffella, Millerella,* and *Fusiella.* The species composition within this assemblage permits to recognize a local biozone that is *Beedeina samarica - Taitzehoella mutabilis* zone.

The *Beedeina samarica - Taitzehoella mutabilis* zone:

Definition.- The zone (with a thickness of about 122 m in the Asad Abad II Section and 14 m in the Tang-e-Darchaleh Section) is defined as the body of strata between the first appearance of *Taitzehoella mutabilis* (Safonova) and *Beedeina samarica* Rauser & Belyaev and the first appearance of *Fusulinella* (*Fusulinella*) *pseudobocki* Lee & Chen. *Fusulinella* (*Fusulinella*) *pseudobocki* is characteristic of the early Podolskian age in sections of the Russian Platform and Southern Urals (Leven & Gorgij, 2008a).

Distribution.- The assemblage occurs in Units 25 and 26 of the Absheni Formation in the Asad Abad II Section (Samples M1–M56) and the uppermost part of Unit 11 and Unit 12 of the Absheni Formation in the Tang-e-Darchaleh Section (Samples F28 & F28.2).

Composition.- The characteristic taxa in the assemblage encompass *Taitzehoella* sp., *T. mutabilis* (Safonova), *T.* cf. *pseudolibrovich atelica* Rauser-Chernousova, *Pseudostaffella kremsi* (Rauser-Chernousova), *Beedeina samarica* Rauser & Belyaev, *B.* ex gr. *samarica* Rauser & Belyaev, *Pseudostaffella* cf. *vozhgalica* Safonova, *Ps. paracompressa* Safonova, *Ps.* cf. *gorskyi* (Dutkevich), *Fusiella* sp., *F.* cf. *typica* Lee & Chen, *Millerella* aff. *uralica* Kireeva, *Millerella* sp., *Ozawainella* sp., *Oz.* cf. *kurachovensis* Manukalova, *Oz. fragilis* Safonova, *Oz. pararhomboidalis* Manukalova, *Oz. paratingi* Manukalova, and *Profusulinella* (*Depratina*) ? sp. (Figures 5.54 & 5.55).

Remarks.- The assemblage defining this zone is fairly low in abundance and diversity. The fusulinids in this assemblage differ from the underlying fusulinid assemblage by the appearance of several distinct genera such as *Taitzehoella* and *Fusiella* which are characteristic of the Kashirian Substage upper part in the Russian Platform (Leven & Gorgij, 2008a). Most characteristics are *Beedeina samarica* and *Taitzehoella mutabilis* (Safonova) first appearing in this zone. In sections of Moscow Basin *Beedeina samarica* is characteristic of the Podolskian Substage. Hence, the assemblage under consideration could be considered at first glance, to the Podolskian age. However according to Leven and Gorgij (2008a) the Iranian forms of *Beedeina samarica* and topotype are inadequately similar. On the other hand, the presence of *Profusulinella* in this assemblage, which is atypical of the Podolskian Stage, confirm the age of the late Kashirian, rather than Podolskian, for the considered assemblage.

Figure 5.54: Fusulinids of a late Kashirian age, from the Absheni Formation in the Asad Abad II Section (Figs 1–13), and the Tang-e-Darchaleh Section (Figs 14–19). Figs 1–13: scale bar A= 1 mm. Figs 14–19 scale bar B= 0.3 mm. Spl.=Sample.

(1, 4) *Beedeina samarica* Rauser-Chernoussova & Belyaev, (1): SF0029, Spl. M38, (4): SF0030, Spl. M52; **(2, 3)** *Beedeina* ex gr. *samarica* Rauser-Chernoussova & Belyaev, Spl. M47, M55; **(5, 6)** *Taitzehoella mutabilis* Safonova, (5): SF0021, Spl. M1, (6): SF0022, Spl. M9; **(7)** *Taitzehoella* cf. *pseudolibrovich atelica* Rauser-Chernousova, M44; **(8)** *Pseudostaffella paracompressa* Safonova, SF0046, Spl. M26; **(9)** *Pseudostaffella* cf. *gorskyi* (Dutkevich), SF0041, Spl. M17; **(10)** *Pseudostaffella kremsi* (Rauser-Chernousova), Spl. M29; **(11)** *Pseudostaffella* cf. *vozhghalica* Safonova, Spl. M26; **(12)** *Ozawainella* sp., Spl. M29; **(13)** *Ozawainella* cf. *fragilis* Safonova, SF0039, Spl. M18; **(14, 16)** *Ozawainella paratingi* Manukalova, Spl. F28; **(15)** *Ozawainella* cf. *pararhomboidalis* Manukalova, Spl. F28; **(17)** *Millerella* aff. *uralica* Kireeva, Spl. F28; **(18)** *Millerella* sp., Spl. F28; **(19)** *Taitzehoella* sp., Spl. F28.

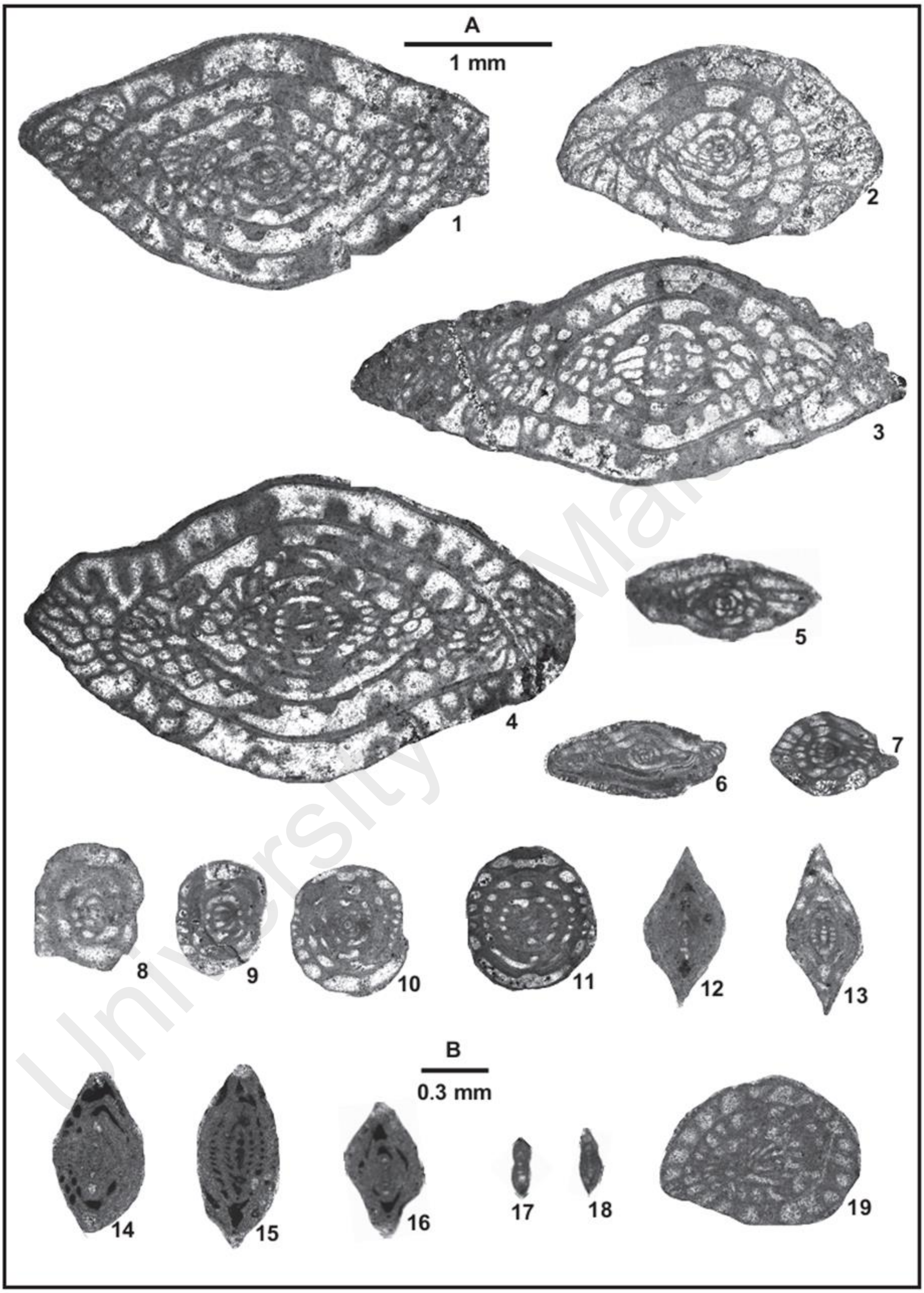

Figure 5.54: Fusulinids of a late Kashirian age, from the Absheni Formation in the Asad Abad II and Tang-e-Darchaleh sections.

5.4.5 The early Podolskian Foraminiferal Assemblage

The sediments bearing the early Podolskian foraminiferal assemblage are represented by sandstone, mudstone, oolitic grainstone, bioclastic wackestone, packstone, and grainstone (see Figure 4.6).

The sparse smaller foraminifers are characterized by the species of *Tetrataxis* and *Globivalvulina*. The fusulinids in this interval are dominated by the species of *Fusulinella*, *Taitzehoella*, *Fusiella*, *Schubertella*, *Ozawainella*, and *Profusulinella*. The species composition within the assemblage permits to recognize a local biozone that is the *Fusulinella* (*Fusulinella*) *pseudobocki* zone.

The *Fusulinella* (*Fusulinella*) *pseudobocki* zone:

Definition.- This zone with a thickness of about 119 m includes the strata between the first appearance of *Fusulinella* (*Fusulinella*) *pseudobocki* and the first appearance of *Praepseudofusulina kljasmica* (Sjomina). The top of this zone is limited by a hiatus followed by sequence belonging to latest Gzhelian–Asselian (*Praepseudofusulina kljasmica* zone).

Distribution.- The assemblage has been recognized in Units 27–30 of the Absheni Formation in the Asad Abad II Section (Samples M57–M100 and FM1–FM9).

Composition.- Characteristic fusulinids include *Fusulinella (Fusulinella) pseudobocki* Lee & Chen, *F. (F.)* ex gr. *bocki* Moeller, *F. (F.)* ex gr. *delepinei* V. Ginkel, *F. (F.) ginkeli* Villa, *F. (F.)* cf. *tokmovensis* Rauser-Chernousova & Beljaev, *Fusulinella* (*Moellerites*) cf. *paracolaniae* Safonova, *F.* (*M.*) *praebocki* Rauser-Chernousova, *F.* (*M.*) sp., *F.* (*F.*) aff. *propria* R. Ivanova, *F.* (*F.*) sp., *Taitzehoella mutabilis* (Safonova), *Fusiella pulchella* Safonova, *Fu.* ex gr. *praetypica* Safonova, *Ozawainella turgida*

Sheng, *Pulchrella*? sp., *Pulchrella*? ex gr. *orbicularia* (Bensh), *Profusulinella* sp., *P.* cf. *topiliensis* Putrja, *P. topiliensis* Putrja, P. *beppensis* Toriyama, and *P.* ex gr. *beppensis* Toriyama (Figures 5.55–5.57).

Remarks.- It is interesting to note the occurrence of the Podolskian fusulinids in Iran is so far only known in the Sanandaj-Sirjan Zone (Leven & Gorgij, 2008a, 2011c). Beyond the Sanandaj-Sirjan Zone, the Podolskian fusulinids have not been found in Iran (Leven & Gorgij, 2008a, 2011c).

Due to the presence of the relatively diversified species of *Fusulinella,* the biozone in question could be attributed, at first glance, to the late Podolskian age. However, because of the presence of the species of *Profusulinella,* which is uncommon in the late Podolskian (Leven & Gorgij, 2008a), the considered assemblage is preferably attributed to the basal interval of the Podolskian Substage.

The species *Fusiella pulchella* Safonova identified in this biozone is reported for the first time in the Sanandaj-Sirjan Zone.

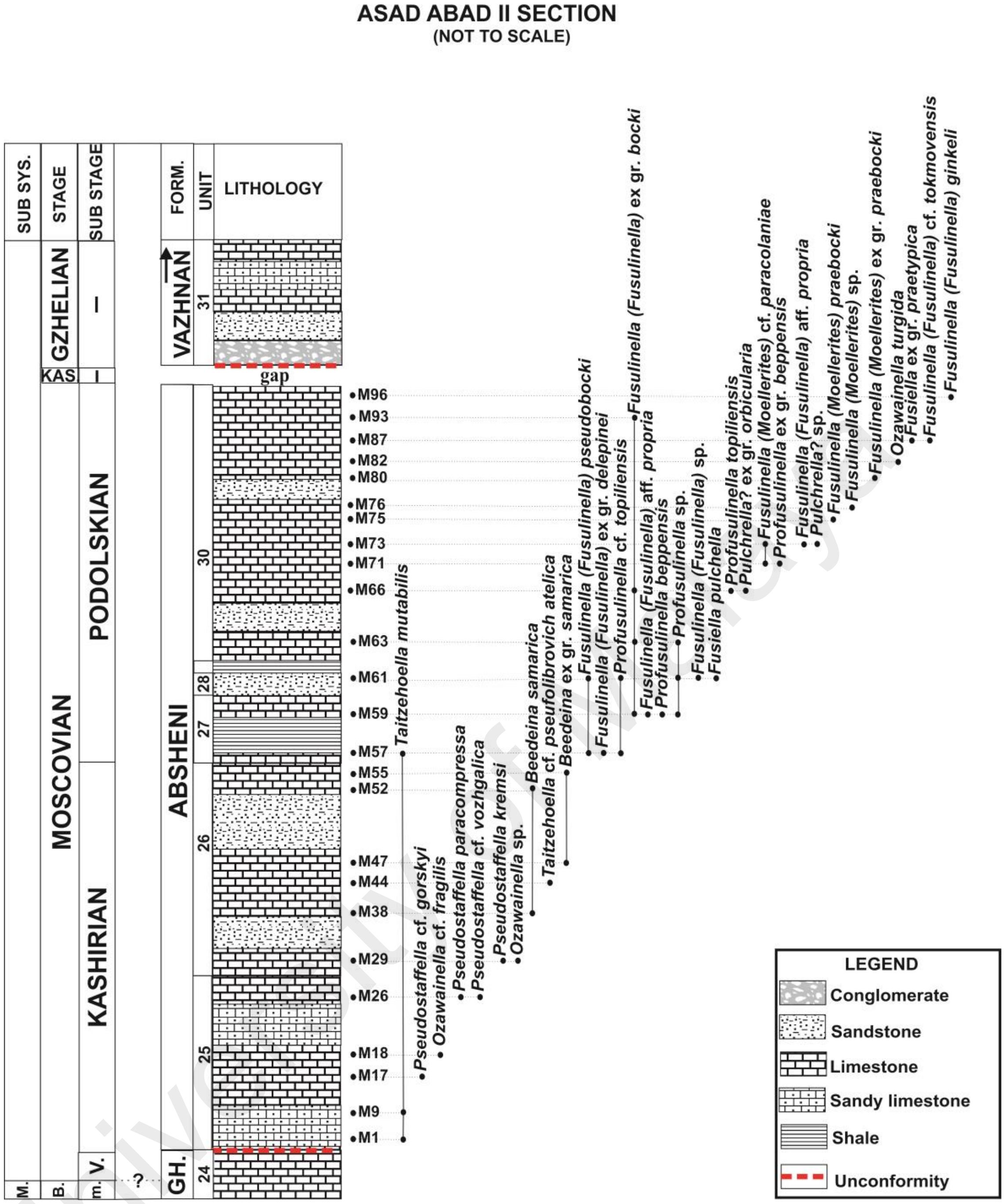

Figure 5.55: The occurrence levels of the fusulinids of the Kashirian and Podolskian age of the Absheni Formation in the Asad Abad II Section. **Note:** Abbreviation: **(m.) =** Melekessian; **(V.) =** Vereian; **(B.) =** uppermost Bashkirian; **(M.) =** uppermost Mississippian; **(KAS.) =** Kasimovian; **(GH.)** = Ghaleh.

Figure 5.56: Fusulinids of a Podolskian age, from the Absheni Formation in the Asad Abad II Section. Spl.=Sample number.

(1, 6) *Fusulinella* (*Fusulinella*) *pseudobocki* Lee & Chen, (1): SF0031, Spl. M57, (6): SF0032, Spl. M61; **(2)** *Taitzehoella mutabilis* (Safonova), SF0023, Spl. M57; **(3)** *Profusulinella* sp., Spl. M63; **(4, 7, 12)** *Fusulinella* (*Fusulinella*) ex gr. *bocki* Moeller, (4): SF0035, Spl. M59, (7): SF0036, Spl. M66, (12): SF0037, Spl. M93; **(5)** *Fusiella pulchella* Safonova, SF0050, Spl. M61; **(8)** *Fusulinella* (*Moellerites*) cf. *paracolaniae* Safonova, SF0033, Spl. M73; **(9, 14, 18)** *Profusulinella* cf. *topiliensis* Putrja, Spl. M57, M61; **(10)** *Fusulinella* (*Fusulinella*) ex gr. *delepinei* V. Ginkel, Spl. M57; **(11)** *Ozawainella turgida* Sheng, Spl. M82; **(13)** *Profusulinella topiliensis* Putrja, Spl. M66; **(15)** *Pulchrella*? sp., Spl. M73; **(16)** *Fusulinella* (*Fusulinella*) *ginkeli* Villa, Spl. M96; **(17)** *Fusiella* ex gr. *praetypica* Safonova, Spl. M87; **(19)** *Fusulinella* (*Fusulinella*) cf. *tokmovensis* Rauser-Chernousova & Beljaev, Spl. M87.

Figure 5.57: Fusulinids of a Podolskian age, from the Absheni Formation in the Asad Abad II Section. Spl.=Sample number.

(1) *Fusulinella* (*Moellerites*) *praebocki* Rauser-Chernousova, Spl. M75; **(2, 8)** *Fusulinella* (*Fusulinella*) aff. *propria* R. Ivanova, Spl. M73, M59; **(3)** *Fusulinella* (*Moellerites*) cf. *paracolaniae* Safonova, SF0034, Spl. M71; **(4)** *Fusulinella* (*Fusulinella*) ex gr. *bocki* Moeller, SF0038, Spl. M63; **(5)** *Fusulinella* (*Fusulinella*) sp., Spl. M61; **(6)** *Fusulinella* (*Moellerites*) ex gr. *praebocki* Rauser-Chernousova, Spl. M80; **(7, 11)** *Profusulinella* sp., Spl. M59, M61; **(9)** *Fusulinella* (*Moellerites*) sp., Spl. M76; **(10)** *Profusulinella beppensis* Toriyama, Spl. M59; **(12)** *Profusulinella* ex gr. *beppensis* Toriyama, Spl. M71; **(13)** *Pulchrella*? ex gr. *orbicularia* (Bensh), Spl. M66.

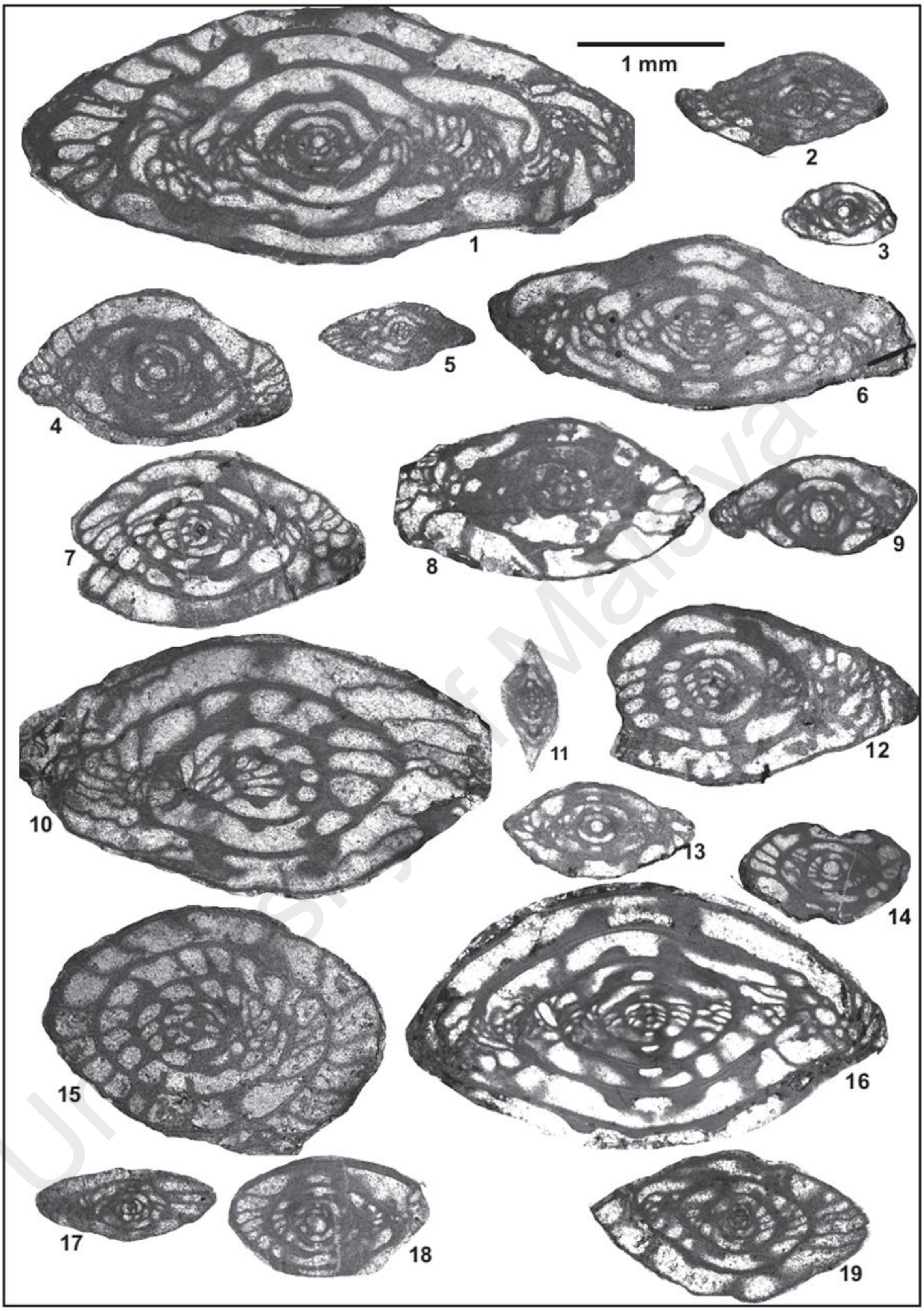

Figure 5.56: Fusulinids of a Podolskian age, from the Absheni Formation in the Asad Abad II Section.

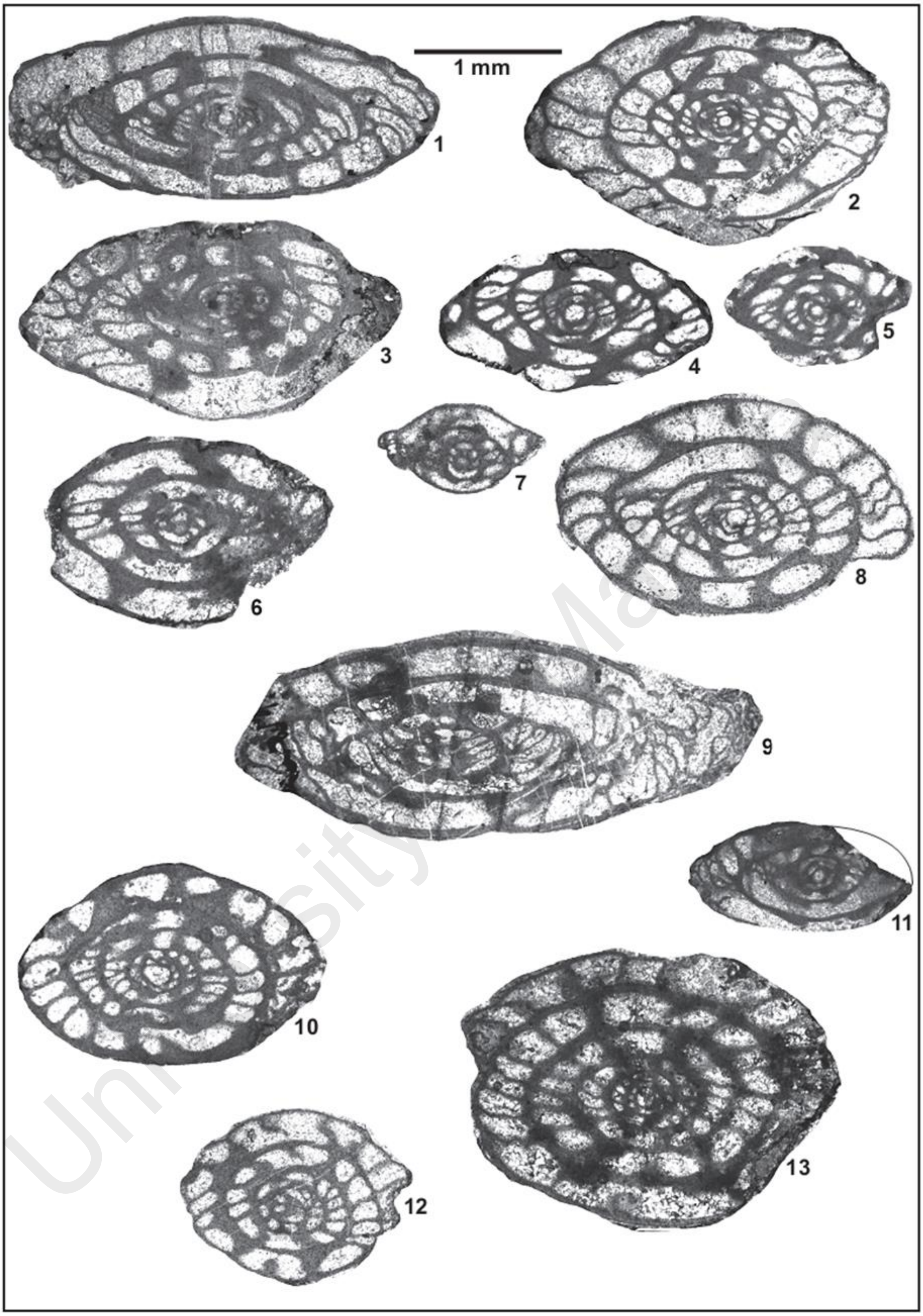

Figure 5.57: Fusulinids of the Podolskian age, from the Absheni Formation in the Asad Abad II Section.

5.4.6 The latest Gzhelian–Asselian Foraminiferal Assemblage

The sediments bearing the latest Gzhelian–Asselian foraminiferal assemblage are represented by sandstone, mudstone, bioclastic wackestone, packstone, and grainstone (see Figures 4.7, 4.13, & 4.19).

The foraminifers in this interval are dominated by the species of *Praepseudofusulina, Pseudoschwagerina*?, *Nonpseudofusulina, Anderssonites, Schubertella*, and others. Besides the listed fauna, the assemblage includes the species of smaller foraminefers such as *Nodosinelloides, Pseudovidalina, Rectogordius, Cornuspira, Eolasiodiscus, Pseudoacutella, Hemigordius, Globivalvulina, Hemidiscus, Pseudoagathammina, Protonodosaria, Geinitzina, Syzrania*, and *Hemigordiellina*. The species composition within the assemblage permits to recognize a local biozone that is the *Praepseudofusulina kljasmica* zone.

The *Praepseudofusulina kljasmica* zone:

Definition.- The zone (with a thickness of about 136 m in the Banarizeh Section, 240 m in the Asad Abad II Section, and 173 m in the Tang-e-Darchaleh Section) is defined as the body of strata between the first occurrence of *Praepseudofusulina kljasmica* (Sjomina), and the first appearance of the Yakhtashian (late early Permian) elements in the Surmaq Formation (Kobayashi & Ishii, 2003a,b). The sediments bearing this zone represent the youngest strata from the Mississippian–Asselian sequence in the Sanandaj-Sirjan Zone.

Occurrence.- The assemblage has been identified in the Vazhnan Formation; Units 12–16 of the Banarizeh Section (Samples S241–S299), Units 31–40 of the Asad Abad II

Section (Samples ZT1–ZT28 and M101–M122), and Units 13–16 of the Tang-e-Darchaleh Section (Samples F29–F38 and Samples V1–V59).

Composition.- The characteristic taxa in this interval include *Praepseudofusulina kljasmica* (Sjomina), *Pr.* sp., *Pr.* sp. 1, *Pr.* sp. 2, *Pr.* sp. 3, *Pr.* sp. 4, *Pr.* sp. 5, *Pr.* cf. *kljasmica* (Sjomina), *Pr.* aff. *kljasmica* (Sjomina), *Pr.* ex gr. *kljasmica* (Sjomina), *Pr.* cf. *saratovensis* (Chernova), *Pr. incomperta* (Scherbovich), *Pr.* cf. *incomperta* (Scherbovich), *Pr.* cf. *impercepta* (Jagofarova), and *Pseudoschwagerina*? sp. In addition to the listed taxa the assemblage includes *Nonpseudofusulina* sp., *N.* cf. *modesta* (Scherbovich), *Eoparafusulina*? sp., *Schellwienia*? sp., *Schubertella* sp., *Eoschubertella*? sp., *E. lata* Lee & Chen, *Grovesella* sp., *Gr. tabasensis* Davydov & Arefifard, and *Anderssonites* sp. The smaller foraminiferal fauna identified in this zone is dominated by the species of *Pseudovidalina* sp., *Pse.?* sp., *Pse. damghanica* Alipour & Vachard, *Rectogordius iranicus* Alipour & Vachard, *Rectogordius iranicus gadukensis* Yarahmadzahi & Vachard, *Cornuspira* sp., *Eolasiodiscus* sp., *Pseudoacutella partoazari* Yarahmadzahi & Vachard, *Hemigordius schlumbergeri* (Howchin), *Hemigordiellina* sp., *Hemidiscus* sp., *Globivalvulina* sp., *G.* cf. *celebrata* Zamilatskaya, *G. bulloides* (Brady), *G.* ex gr. *arguta* Konovalova, *G. kantharensis* Reichel, *Pseudoagathammina regularis* (Lipina), *Nodosinelloides* sp., *N. longissima* (Suleimanov), *N.* cf. *longissima* (Suleimanov), *N. camerata* (Miklukho−Maklay), *N. netschajewi* (Cherdyntsev), *N.* cf. *netschajewi* (Cherdyntsev), *N. bella* (Lipina), *N.* cf. *potievskayae* Mamet & Pinard, N. *pinardae* Groves & Wahlman, *Geinitzina* sp., *G.* cf. *longa* Suleimanov, and *Syzrania* sp. (Figures 5.58–5.63).

Remarks.- The fusulinid assemblage identified in the zone in question seems to be atypical to some extent. As it is of low taxonomic diversity and is dominated by the species of *Praepseudofusulina.* In this study, this genus is represented by four species; namely, (1) *Pr. kljasmica* (Sjomina), (2) *Pr.* cf. *saratovensis* (Chernova), (3) *Pr.*

incomperta Scherbovich, and (4) *Pr.* cf. *impercepta* Jagofarova. Among the four species, *Pr. kljasmica* is the most abundant in the fususlinid assemblage in the Vazhnan Formation. The index taxa of the considered biozone; that is, *Pr. incomperta* Scherbovich is reported for the first time in the Sanandaj-Sirjan Zone. This study also presents the first occurrence of the *Eochubertella lata* Lee & Chen in Iran.

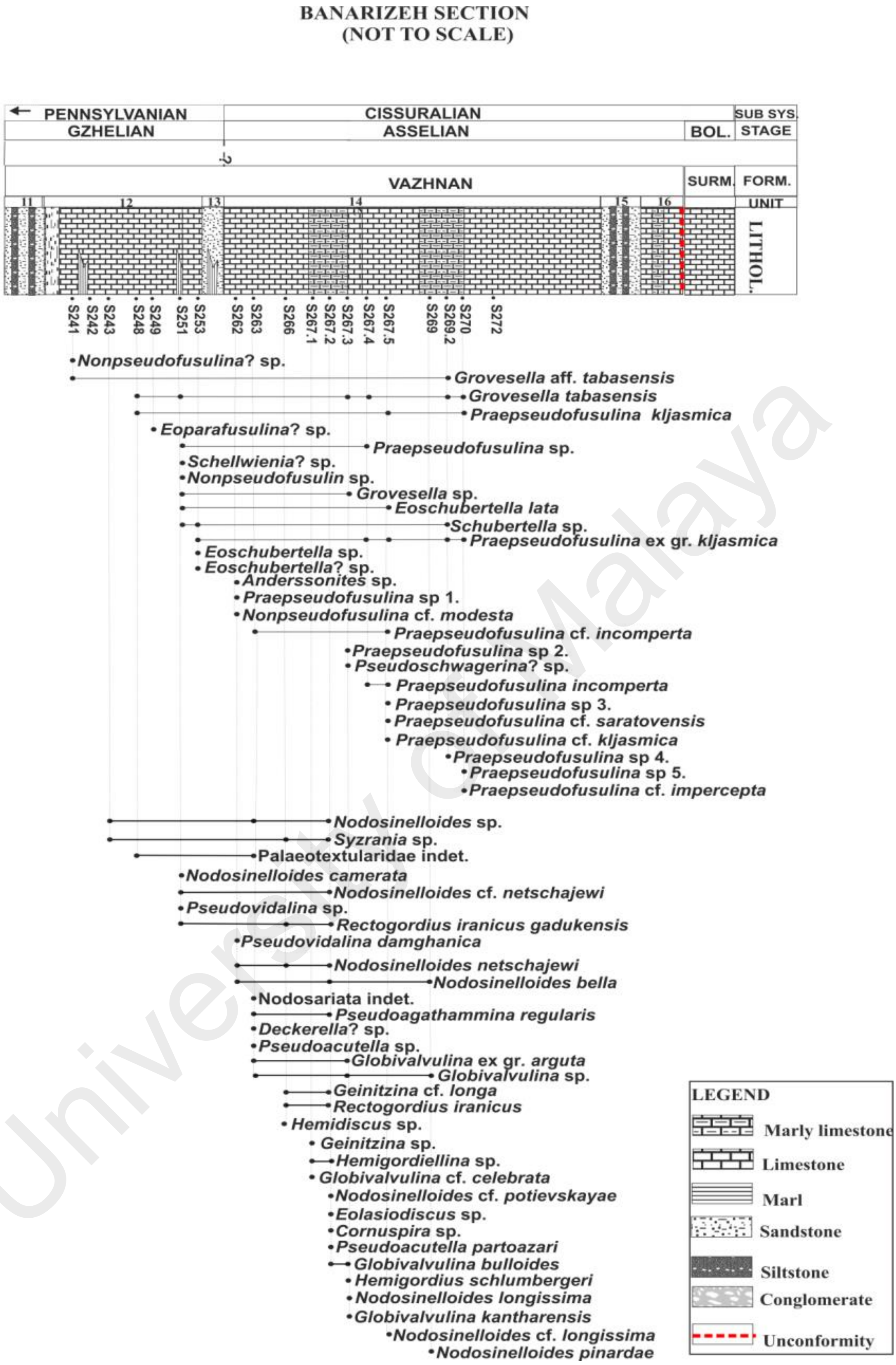

Fig. 5.58: The stratigraphic occurrence of a latest Gzhelian–Asselian fusulinids and foraminifers from the Vazhnan Formation in the Banarizeh Section. **Note**: Abbreviations: **(SURM.)** = Surmaq; **(BOL.)** = Bolorian; (**SUB SYS.)** = Subsystem; **(FORM.)** = Formation; **(LITHOL.)** = Lithology.

Figure 5.59: Fusulinids of a latest Gzhelian─Asselian age, from the Vazhnan Formation in the Banarizeh Section. Spl.=Sample number.

(1) *Praepseudofusulina* cf. saratovensis (Chernova), UM10677, Spl.S267.5; **(2)** *Praepseudofusulina* cf. *impercepta* (Jagofarova), UM10678, Spl. S270.; **(3, 4)** *Praepseudofusulina incomperta* (Scherbovich), (3): UM10675, Spl. S267.4, (4): UM10676, Spl. S267.5; **(5)** *Anderssonites* sp., SF0051, Spl. S262; **(6, 10)** *Praepseudofusulina* sp., Spl. S251, S267.4; **(7)** *Praepseudofusulina* sp. 1, Spl. S262; **(8, 11, 12)** *Praepseudofusulina* cf. *incomperta* (Scherbovich), Spl. S263, S267.5; **(9)** *Praepseudofusulina* sp. 2, Spl. S267.3; **(13)** *Praepseudofusulina* sp. 3, Spl.S267.5**; (14)** *Praepseudofusulina* sp. 4, Spl. S269.2; **(15)** *Praepseudofusulina* sp. 5, Spl.S270; **(16)** *Schellwienia*? sp., UM10680, Spl. S251; **(17)** *Eoparafusulina*? sp., Spl. S249; **(18)** *Pseudoschwagerina*? sp., UM10685, Spl. S267.3.

Figure 5.60: Fusulinids of a latest Gzhelian─Asselian age, from the Vazhnan Formation in the Banarizeh Section. Spl.=Sample number.

(1, 2) *Nonpseudofusulina* sp., (1): UM10682, Spl. S251, (2): UM10683, Spl. S251; **(3)** *Nonpseudofusulina*? sp., SF0052, Spl. S241; **(4)** *Nonpseudofusulina* cf. *modesta* (Scherbovich), UM10681, Spl. S262; **(5, 7, 8)** *Praepseudofusulina kljasmica* (Sjomina), (5): UM10661, Spl. S248, (7): UM10662, Spl. S267.5, (8): UM10663, Spl. S270; **(6)** *Praepseudofusulina* cf. *kljasmica* (Sjomina), UM10664, Spl. S267.5; **(9–13)** *Praepseudofusulina* ex gr. *kljasmica* (Sjomina), Spl. S253, S267.4, S267.5, S269.2, S270.

Figure 5.61: Fusulinids from the Vazhnan Formation in the Asad Abad II, Banarizeh, and Tang-e-Darchaleh sections. Figs 1–25: scale bar A= 0.3 mm. Figs 26–27 scale bar B= 1 mm. Spl.=Sample number.

(1, 15) *Grovesella* aff. *tabasensis* Davydov & Arefifard, Spl. S241, S269.2; **(2–8, 11, 13, 14, 16, 17, 18)** *Grovesella tabasensis* Davydov & Arefifard, Spl. S248, S251, S267.3, S267.4, S269.2, S270; **(9)** *Eoschubertella* sp., Spl. S253; **(10, 12)** *Grovesella* sp., Spl. S251, S267.3; **(19–21)** *Eoschubertella lata* Lee & Chen, (19): SF0047, Spl. S251, (20): SF0048, Spl. S251, (21): SF0049, Spl. S267.5; **(22, 23, 25)** *Schubertella* sp., Spl. S251, S253, S269.2 ; **(24)** *Eoschubertella*? sp., Spl. S253; **(26)** Gen Indt. Spl. M102; **(27)** Gen Indt. Spl. V14.

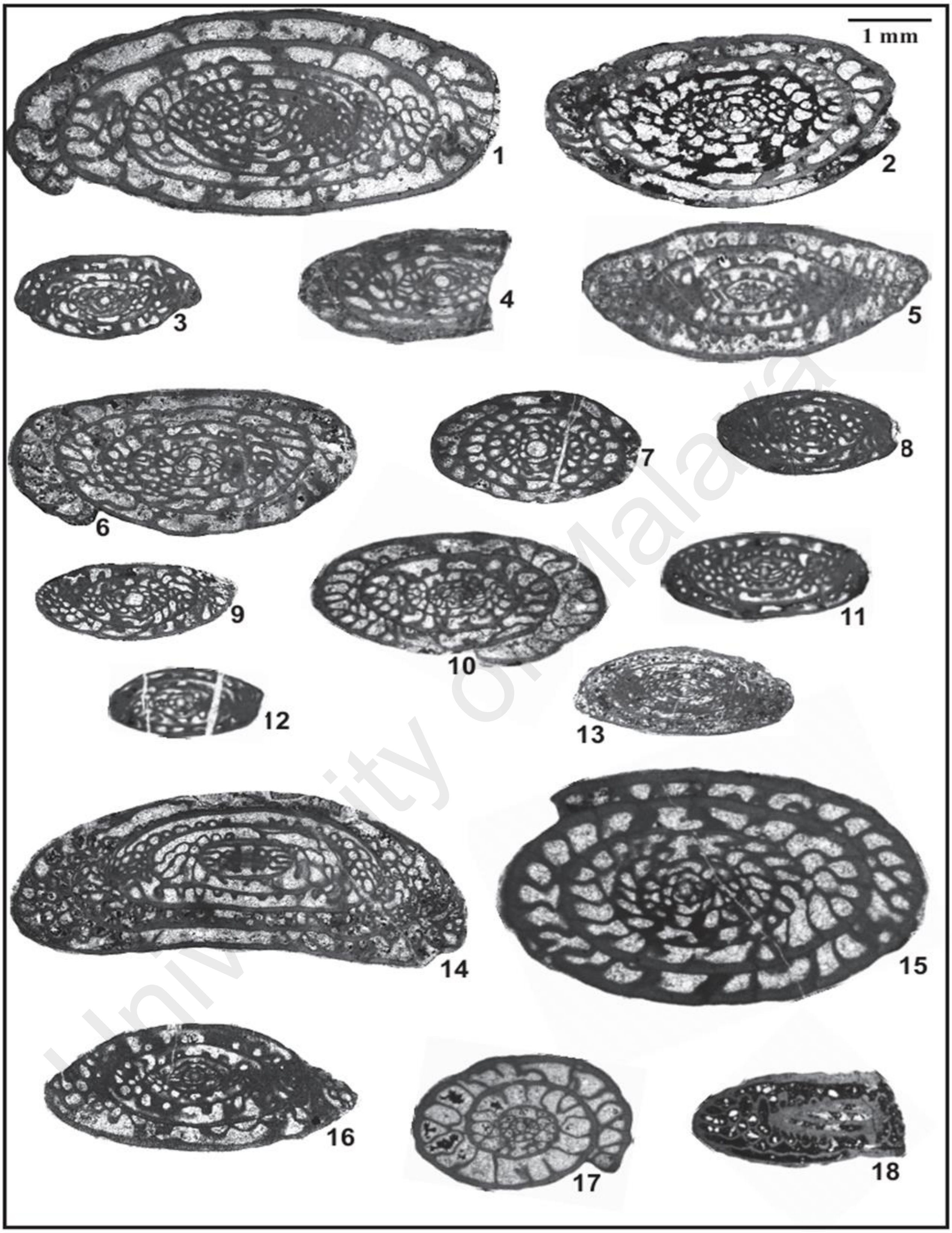

Figure 5.59: Fusulinids of a latest Gzhelian–Asselian age, from the Vazhnan Formation in the Banarizeh Section.

Figure 5.60: Fusulinids of a latest Gzhelian─Asselian age, from the Vazhnan Formation in the Banarizeh Section.

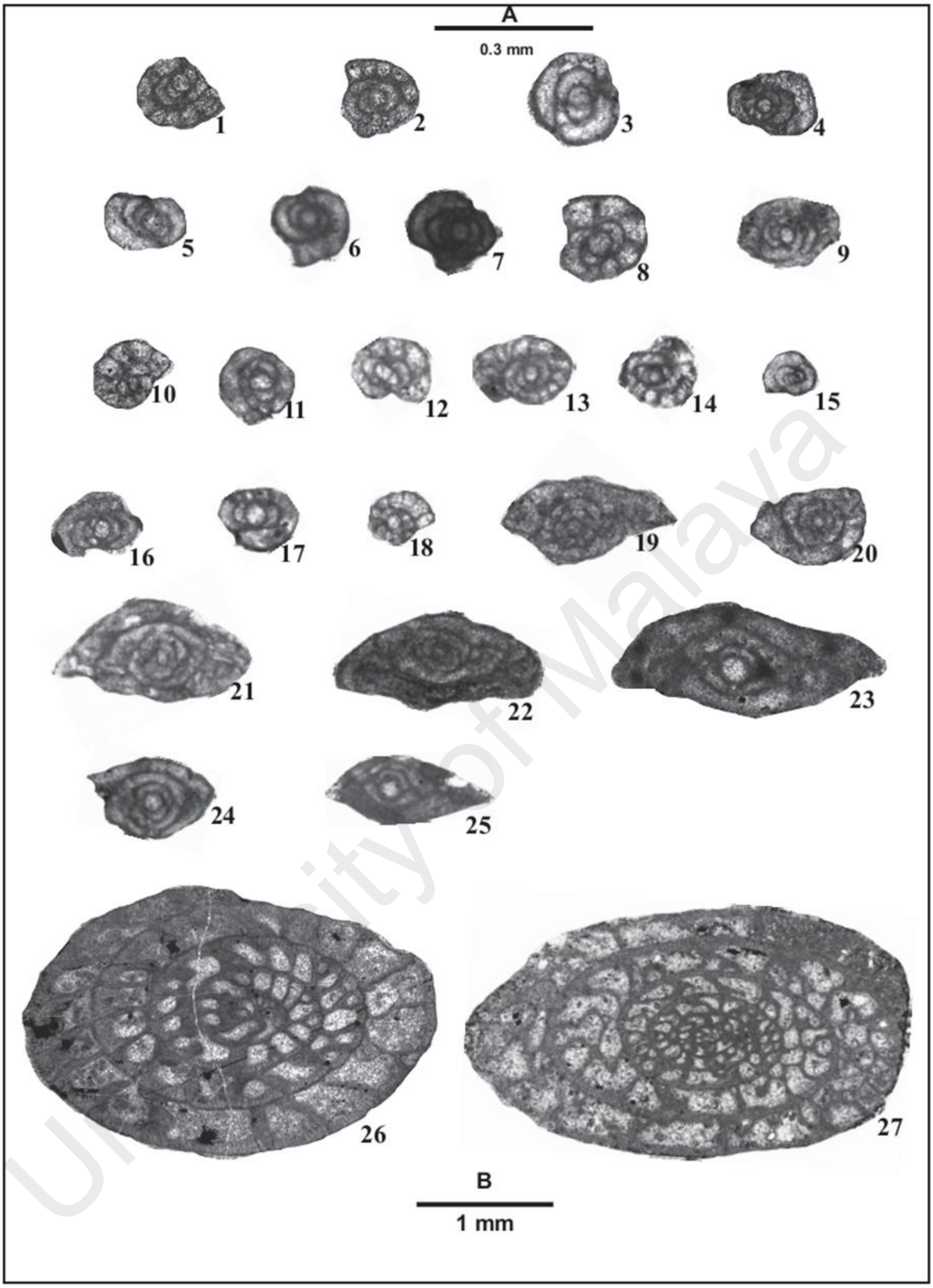

Figure 5.61: Fusulinids from the Vazhnan Formation in the Asad Abad II, Banarizeh, and Tang-e-Darchaleh sections.

Figure 5.62: Smaller foraminifers of a latest Gzhelian─Asselian age, from the Vazhnan Formation in the Banarizeh Section. Spl.=Sample number.

(1, 2, 7, 10, 14, 18, 20, 21) *Nodosinelloides netschajewi* (Cherdyntsev), Spl. S262, S266, S267.2; **(3, 15, 19)** *Nodosinelloides bella* (Lipina), Spl. S262, S267.2, S269; **(4, 6, 12)** *Nodosinelloides* sp., Spl. S243, S263, S267.2; **(5, 9)** *Nodosariata* indet., Spl. S263; **(8)** *Nodosinelloides camerata* (Miklukho−Maklay), Spl. S251; **(11, 17)** *Geinitzina* cf. *longa* Suleimanov, Spl. S266, S267.2; **(13)** *Geinitzina* sp., Spl. S267.1; **(16)** *Nodosinelloides* cf. *longissima* (Suleimanov), Spl. S267.5; **(22, 26, 27)** *Syzrania* sp., Spl. S243, S266, S267.2; **(23)** *Nodosinelloides* cf. *potievskayae* Mamet & Pinard, Spl. S267.2; **(24, 31)** *Nodosinelloides* cf. *netschajewi* (Cherdyntsev), Spl. S251, S267.2; **(25)** *Nodosineloides pinardae* Groves & Wahlman, Spl. S269; **(28, 33)** *Hemigordiellina* sp., Spl. S267.1, S267.2; **(29, 34)** *Pseudoagathammina regularis* (Lipina), Spl. S263, S267.2; **(30, 36)** Palaeotextularidae indet., Spl. S248, S263; **(32)** *Nodosinelloides longissima* (Suleimanov), Spl. S267.3; **(35)** *Deckerella*? sp. S263.

Figure 5.63: Smaller foraminifers of a latest Gzhelian─Asselian age, from the Vazhnan Formation in the Banarizeh Section (Figs 1─27) and Tang-e-Darchaleh Section (Figs 28–34). Figs 1─27: scale bar A=0.1 mm. Figs 27─34: scale barb=0.3 mm. Spl.=Sample number.

(1) *Pseudovidalina* sp., Spl. S251; **(2, 3, 7, 19)** *Rectogordius iranicus* Alipour & Vachard, Spl. S266, S267.2; **(4, 14, 15, 20, 32)** *Rectogordius iranicus gadukensis* Yarahmadzahi & Vachard, Spl.S251, S266, S267.2, V22; **(5, 6)** *Pseudovidalina damghanica* Alipour & Vachard, Spl. S262; **(8, 13)** *Eolasiodiscus* sp., Spl. S267.2; **(9)** *Cornuspira* sp., Spl. S267.2; **(10, 30)** *Pseudoacutella partoazari* Yarahmadzahi & Vachard, Spl. S267.2, V14; **(11)** *Hemigordius schlumbergeri* (Howchin), Spl. S267.3; **(12)** *Pseudoacutella* sp., Spl. S263; **(16, 34)** *Globivalvulina bulloides* (Brady), Spl. S267.2, V23; **(17, 25)** *Globivalvulina* ex gr. *arguta* Konovalova, Spl. S263, S267.3; **(18)** *Hemidiscus* sp., Spl. S266; **(21, 23, 26, 33)** *Globivalvulina* sp., Spl. S263, S267.3, S269, V47; **(22)** *Globivalvulina kantharensis* Reichel, Spl. S276.3; **(24, 27)** *Globivalvulina* cf. *celebrata* Zamilatskaya, Spl. S267.1; **(28)** *Pseudoagathammina regularis* (Lipina), Spl. V43; **(29)** *Nodosinelloides* cf. *netschajew*i (Cherdyntsev), Spl. V47; **(31)** *Nodosinelloides* sp., Spl. V43.

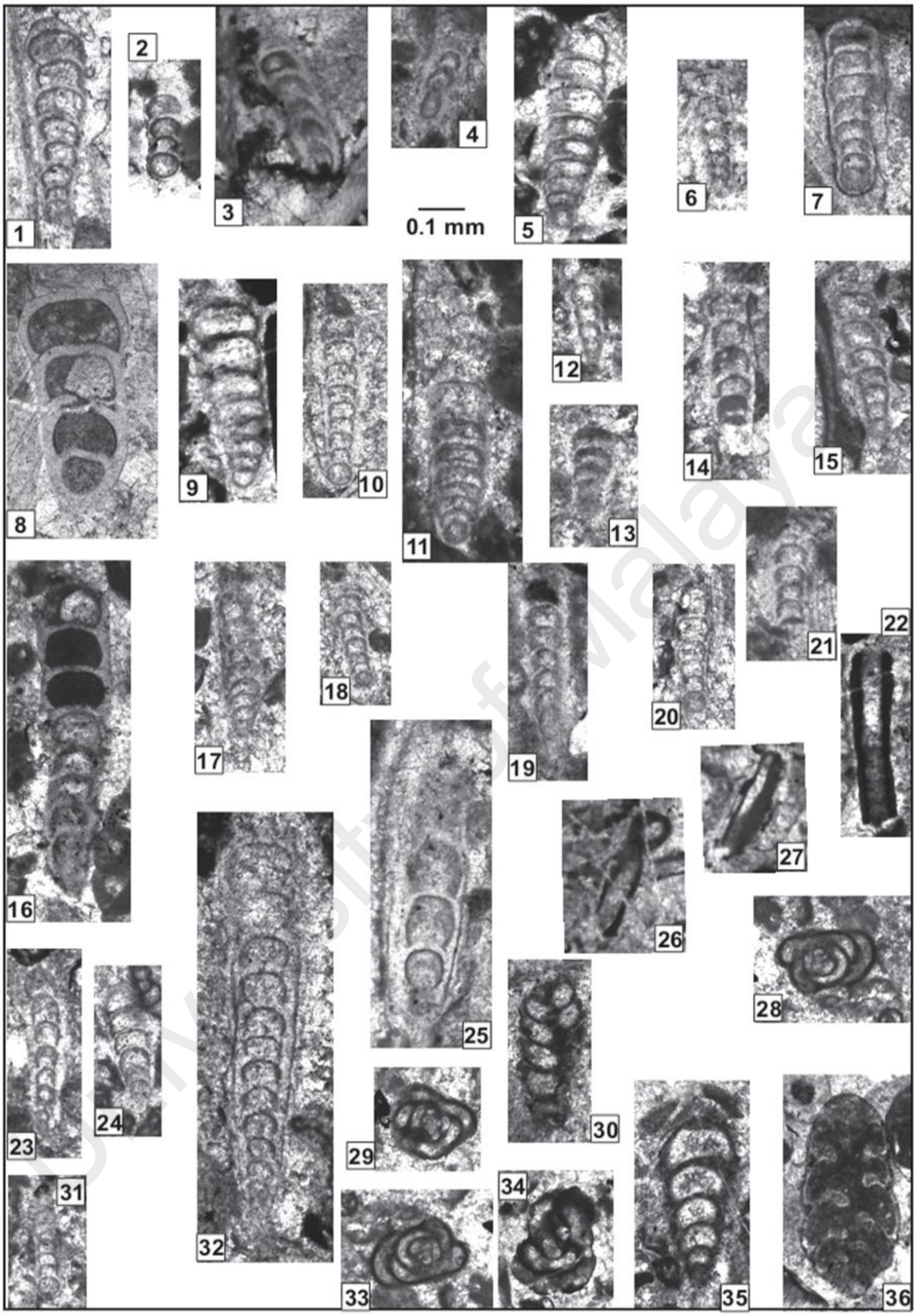

Figure 5.62: Smaller foraminifers of a latest Gzhelian─Asselian age, from the Vazhnan Formation in the Banarizeh Section.

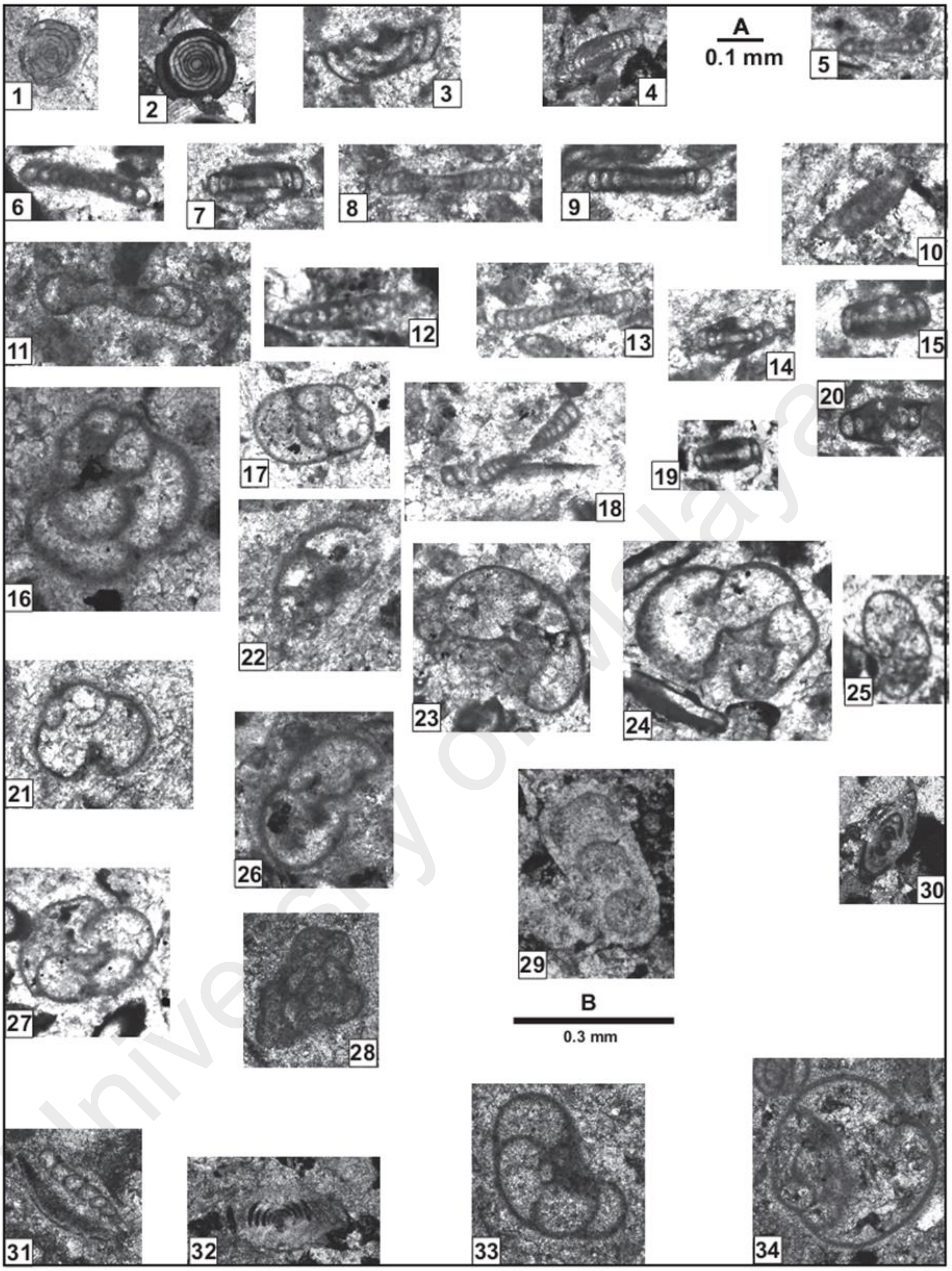

Figure 5.63: Smaller foraminifers of a latest Gzhelian─Asselian age, from the Vazhnan Formation in the Banarizeh and Tang-e-Darchaleh sections.

5.5 Mississippian–Asselian Stratigraphy in the Sanandaj-Sirjan Zone

The lithostaratigraphic and biostratigraphic frameworks established for the three sections in question are the useful aids for describing the Mississippian–Asselian sequence of the Sanandaj-Sirjan Zone in Iran. In sum, a great similarity as follows is recognized among the Banarizeh, Asad Abad II, and Tang-e-Darchaleh sections (Figure 5.64).

5.5.1 Shishtu Group

The base of the Mississippian–Asselian sequence is usually unexposed or more likely faulted. Units 1–3 of the Tang-e-Darchaleh Section, Units 1–8 of the Banarizeh Section, and Units 7–19 of the Asad Abad II Section can be correlated with each other by means of documents in the field and paleontological evidence. These intervals correspond to the Shishtu 2 Formation of the upper Tournaisian–Serpukhovian age.

Lithology and thickness.- The Shishtu 2 Formation consists mostly of limestones intercalated in the upper part with siltstone, sandstone, marl, and shale. Bioclastic wackestone, packstone, grainstone, and oolitic grainstone contain fragmentary brachiopods, bryozoans, crinoids, and foraminifers, in which bioclasts mainly display micritic coatings, with micritic matrix to spary cement. The thickness ranges from 206 m in the Tang-e-Darchaleh Section to almost 300 m in the Asad Abad II Section. In the Tang-e-Darchaleh and Banarizeh sections, the contact of the lower boundary of the Shishtu 2 Formation with the underlying beds is unexposed or more likely faulted. In the Asad Abad II section, the formation is underlain by the Shishtu 1 Formation. The upper part of the Shishtu 2 Formation is unconformably overlain by the Sardar Group.

Biostratigraphy.- Among the studied intervals of the Shishtu 2 Formation, the foraminiferal fauna has been discriminated from the Banarizeh and Tang-e-Darchaleh sections. The foraminifers are characterized by a biozone that is the *Uralodiscus rotundus* - *Glomodiscus miloni* zone. This assemblage is considered to be equivalent to the upper part of Biozone MFZ11 of Poty et al. (2006) in Western Europe.

Environment.- The prevalence of the carbonates in the Shishtu 2 Formation suggests periods of general marine transgression. The interval was essentially deposited in the shallow marine environments, rich in the micro faunas belonging to foraminifers and conodonts, and the macro faunas including crinoids, brachiopods, corals, and micro vertebrate remains. The abundance of the marine faunas suggests currents with moderate energy in normal salinity conditions. This assemblage is referred to the upper slope and outer shelf environments.

5.5.2 Sardar Group

The Sardar Group of the uppermost Mississippian–Pennsylvanian age encompasses Units 4–12 of the Tang-e-Darchaleh Section, Units 9–10 of the Banarizeh Section, and Units 20–30 of the Asad Abad II Section. The Sardar Group in the Sanandaj-Sirjan Zone has the different thicknesses, being extremely reduced to the south. Predominantly, depocenters were situated to the north, whilst reduced sedimentation or emergent areas were situated to the south. Typically, it is bipartite, that is a lower mostly terrigenous unit or the Ghaleh Formation and the carbonate unit in the top or the Absheni Formation. These two units are very thin toward the south (33 m thickness in the Banarizeh Section) while in the Asad Abad II Section the thickness of the Sardar Group is about 458 m. The Sardar Group spans the uppermost Serpukhovian–upper Moscovian stages.

5.5.2.1 Ghaleh Formation

Lithology and thickness.- In the Sanandaj-Sirjan Zone, the interval is dominated by a basal polymictic limestone conglomerate, changing upward to the sandstone, sandy limestone and limestone. The microfacies consist of oolitic grainstone, bioclastic wackestone, packstone, and grainstone. Thin intercalations of mudstone may occur. The subordinate quartz content is also observed. The Ghaleh Formation is identified just in the Asad Abad II Section and has a thickness of about 217 m. The basal conglomerate of this formation unconformably and on an erosional surface caps the underlying beds of the Shishtu 2 Formation. The Ghaleh Formation is unconformably overlain by the Absheni Formation of the lower Moscovian–upper Moscovian age.

Biostratigraphy.- The Voznesenian–earliest Moscovian fusulinid assemblages of the Ghaleh Formation are characterized mostly by the genera belonging to the Eostaffellidae, Aljutovellidae, Ozawainellidae, Schubertellidae, and Fusulinidae. The interval is represented by the biostratigraphic zones; namely, *Plectostaffella jakhensis* - *Eostaffella pseudostruvei* zone and *Tikhonovichiella tikhonovichi* - *Profusulinella* (*Depratina*) *prisca* - *Aljutovella* spp. zone, corresponding in age to the Voznesenian, and Melekessian–Vereian substages, respectively. The species composition within these assemblages permits to correlate them with the standard fusulinid biozonations acknowledged for the earliest Bashkirian Stage and Melekessian–Vereian substages in the Russian Platform and Southern Urals.

Environment.- Judging from the diversity of macro and micro fauna remains, the Ghaleh Formation has been deposited in the shallow marine and moderate energy environments, more likely the near shore with water of normal salinity conditions.

5.5.2.2 Absheni Formation

Lithology and thickness.- In the Sanandaj-Sirjan Zone, the interval consists of alternating siliciclastic and carbonate deposits. Sandstone, oolitic grainstone, and bioclastic wackestone, packstone, and grainstone contain the fusulinids, crinoids, fragmentary brachiopods, and bryozoans. The Absheni Formation has a maximum thickness of about 241 m in the Asad Abad II Section. This interval is underlain by the uppermost Serpukhovian–lowermost Moscovian deposits of the Ghaleh Formation, and overlain unconformably by the uppermost Gzhelian–Asselian succession of the Vazhnan Formation.

Biostratigraphy.- In the Absheni Formation of the Asad Abad II and Tang-e-Darchaleh sections, fusulinids are dominated by the species belonging to the families Ozawainellidae, Pseudostaffellidae, and Fusulinidae. The presence of species of *Taitzehoella, Fusiella, Profusulinella, Fusulinella, Ozawainella,* and *Beedeina* suggests the age of lower Moscovian–upper Moscovian for the interval. The species composition within this assemblage permits to recognize the local biozones; namely, *Beedeina samarica - Taitzehoella mutabilis* zone and *Fusulinella* (*Fusulinella*) *pseudobocki* zone of the late Kashirian and early Podolskian age, respectively. These assemblages can be correlated with the standard fusulinid biozonations acknowledged of Kashirian and early Podolskian age in the Russian Platform.

Environment.- The presence of the fusulinids specially the *Ozawainella* (Khodjanyazova, 2013) forms suggests the shallow water and high energy environments. Besides the fusulinids, the interval encloses the wood remains and the marine fragments including brachiopods and crinoids. The better markers are observed in the oolitic limestones, which according to Flügel (2004) indicate the high energy environments of oolitic shoals, tidal bars, and not deeper than the outer ramp.

5.5.3 Anarak Group

5.5.3.1 Vazhnan Formation

Units 11–16 of the Banarizeh Section, Units 31–40 of the Asad Abad II Section, and Units 13–16 of the Tang-e-Darchaleh Section are correlated with each other. These strata are attributed to the Vazhnan Formation of the Anarak Group, corresponding in age to the uppermost Gzhelian–Asselian.

Lithology and thickness.- The basal layer of the Vazhnan Formation in the Sanandaj-Sirjan Zone is usually a polymictic limestone conglomerate including the carbonate clasts and minor sandstone which unconformably caps the underlying layers of the Moscovian (Podolskian) age with a stratigraphic unconformity corresponding to the uppermost Moscovian–lower Gzhelian age (Baghbani, 1993, this study). The basal conglomerate is overlain by sandstone, siltstone, limestone, sandy limestone, and marly limestone. The Vazhnan Formation is characterized by sandstone, mudstone, bioclastic wackestone, packstone, and grainstone containing the gastropods (*Bellerophon*), corals, conodonts, brachiopods, bryozoans, ammonoids, fish remains, crinoid fragments, and foraminifers. The top of the stratigraphic succession in the three considered sections is overlain unconformably by the Surmaq Formation (upper Lower Permian–Middle Permian) (Iranian-Japanese Research Group, 1981; Baghabaini, 1993; Kobayashi & Ishii, 2003a,b; Leven & Gorgij, 2008a, 2011c). The total thickness of the Vazhnan Formation is varied between 168 m, in the Banarizeh section and 226 m, in the Asad Abad II Section.

Biostratigraphy-. The foraminifers in this interval are dominated by the species of the fusulinids and smaller foraminefers. The species composition within the foraminiferal assemblage in this interval permits to recognize a local biozone that is th*Praepseudofusulina kljasmica* zone. assemblage can be correlated with the fusulinid biozonation acknowledged for the latest Gzhelian–Asselian stages in the Russian Platform and Southern Urals.

Environment.- The interval was essentially deposited in shallow marine and high energy environments in normal salinity conditions, more likely the lagoons. The better markers are observed in the oncolithic limestones, which indicate the high energy environments of shoals, probably reef and lagoonal conditions, and not deeper than the outer ramp.

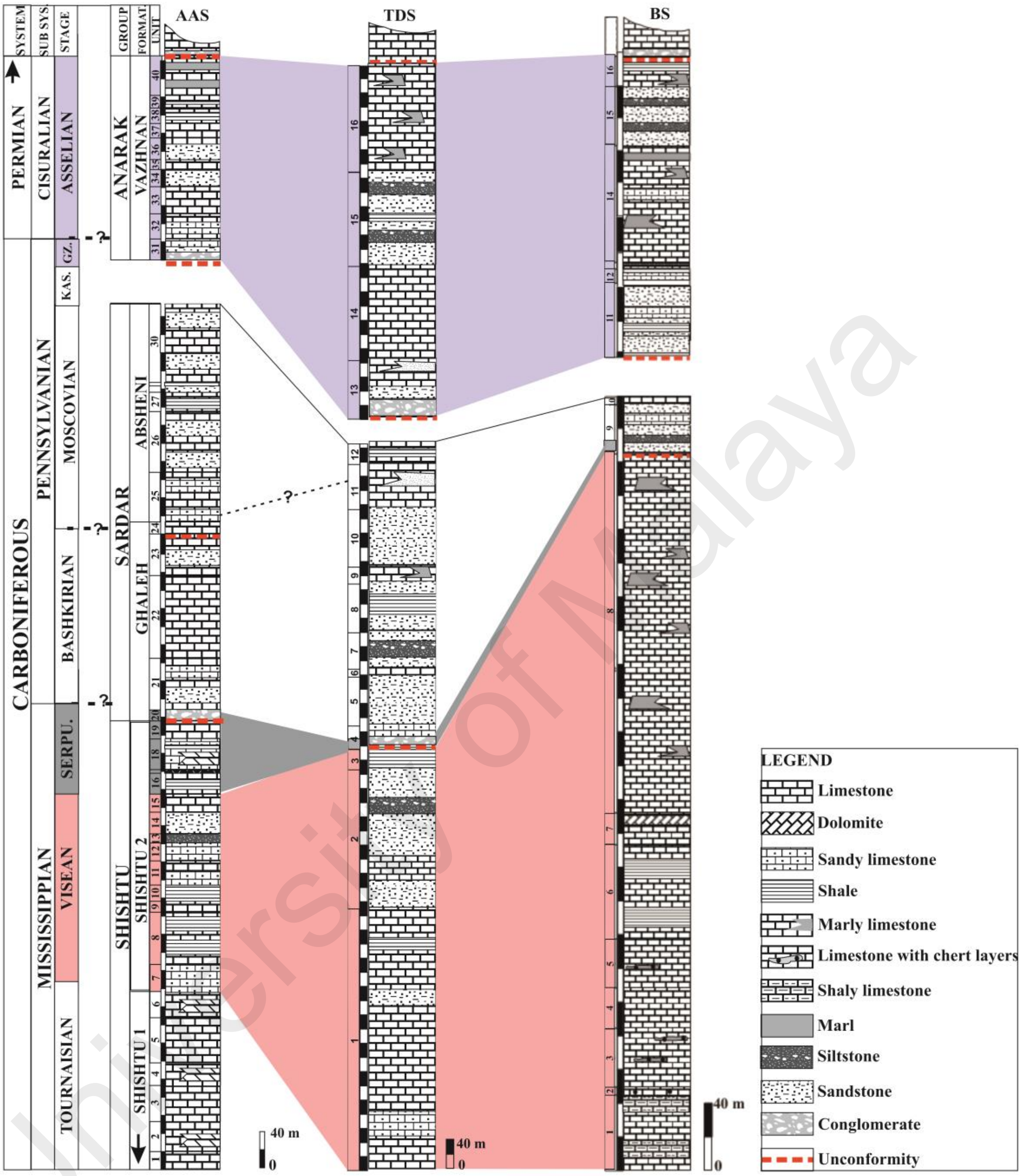

Figure 5.64: The correlation between the three stratigraphic logs under studied. **Note:** Abbreviations: **(SYS.) =** System; **(SUBSYS) =** Subsystem; **(FM.) =** Formation; (SE.) =uppermost Serpukhovian; **(MO.)** = Moscovian; **(AB.) =** Absheni Formation; **(TDS) =** Tang-e-Darchaleh Section; **(AAS) =** Asad Abad II Section; **(BS) =** Banarizeh Section.

5.6 Correlations

The foraminiferal zones and their characteristic index species allow to correlate the Mississippian–Asselian foraminiferal biozones in the Sanandaj-Sirjan Zone with the foraminiferal biozonation acknowledged for the Mississippian–Asselian in the Russian Platform, Southern and Northern Urals, Istanbul Terrane, Eastern and Central Taurides (Turkey), and Western Europe (e.g. Sjomina, 1961; Mamet et al. 1966; Makhlina et al. 1984; Solovieva, 1986; Chernykh & Reshetkova, 1987; Vdovenko et al. 1990; Davydov et al. 1992; Vachard & Maslo, 1996; Davydov, 1997; Chernykh & Ritter, 1997; Kulagina & Sinitsyna, 1997; Isakova, 1998, 2001; Ivanova, 2000, 2002; Altiner & Özgül, 2001; Kulagina et al. 2001; Poty et al. 2006; Dzhenchuraeva & Okuyucu, 2007; Okuyucu et al. 2013; Leven & Gorgij, 2011c).

5.6.1 The *Uralodiscus rotundus - Glomodiscus miloni* zone (late early Viséan):

The Mississippian strata of the Sanandaj-Sirjan Zone are dated as belonging to the *Uralodiscus rotundus - Glomodiscus miloni* zone which correlates to the late early Viséan.

The *Uralodiscus rotundus - Glomodiscus miloni* zone at the Sanandaj-Sirjan Zone can be correlated with Biozone MFZ11 in Western Europe (Mamet et al. 1966; Poty et al. 2006) (Figure 5.65). The *Uralodiscus rotundus* (Chernysheva) is common within these areas. In this study, the biozone in question is correlated with Subbiozone MFZ11B in South China by the presence of the species of *Archaediscus* and *Glomodiscus*. The presence of *Uralodiscus rotundus* (Chernysheva), *Brunsia spirillinoides* (Grozdilova & Glebovskaya), *Forschia parvula* Rauser-Chernousova, *Mediocris breviscula* (Ganelian), and *Endothyra* ex gr. *similis* Rauser-Chernoussova &

Reitlinger in the described biozone, moreover, permits the correlation with Biozone MFZ11 in the Istanbul Terrane, northwest Turkey (Okuyucu et al. 2013).

On the other hand, as a result of the detailed analysis of the Mississippian strata from several Iranian sections during recent years, so far the late early Viséan foraminiferal fauna has only been known in the Alborz (e.g. Bozorgnia, 1973; Lys et al. 1978; Vachard, 1996; Brenckle et al. 2009; Zandkarimi et al. 2014), and the Sanandaj-Sirjan Zone (this study). The *Uralodiscus rotundus* - *Glomodiscus miloni* zone can be correlated with the *Archaediscus* - *Glomodiscus* zone of Alborz (Zandkarimi et al. 2014) by the presence of index-taxa such as *Uralodiscus rotundus* (Chernysheva), *Glomodiscus oblongus* (Conil & Lys), *Lapparentidiscus bokanensis* Vachard, *Mediocris mediocris* (Vissarionova), and *Glomodiscus* sp.

SYSTEM	SUBSYSTEM	SERIES	STAGE		Western Europe Substage	Foraminiferal zones (Poty et al. 2006)	this Study (Sanandaj-Sirjan Zone)
CARBONIFEROUS	MISSISSIPPIAN	MIDDLE	Visean	Upper	Warnantian	MFZ15	
						MFZ14	
						MFZ13	
					Livian	MFZ12	
				Lower	Moliniacian	MFZ11	MFZ11B
						MFZ10	
						MFZ9	
		LOWER	Tournaisian	Upper	Ivorian	MFZ8	
						MFZ7	
						MFZ6	
						MFZ5	
						MFZ4	
				Lower	Hastarian	MFZ3	
						MFZ2	
						MFZ1	

Figure 5.65: Correlation of the described biozone from the Viséan layers in the Sanandaj-Sirjan Zone with Belgian Substages and biozonations (modified after Zandkarimi et al. 2014).

5.6.2 The *Plectostaffella jakhensis - Eostaffella pseudostruvei* zone (Voznesenian; earliest Bashkirian):

The lowermost Pennsylvanian strata of the Sanandaj-Sirjan Zone are dated as belonging to the *Plectostaffella jakhensis - Eostaffella pseudostruvei* zone, which correlates to the earliest Bashkirian; Voznesenian Substage. The fusulinid zone and its characteristic index species allow correlating the recognized biozone in the Sanandaj-Sirjan Zone with the fusulinid biozonation acknowledged for the earliest Bashkirian in the Russian Platform, Turkey, Donets Basin, and Southern Urals (Altiner & Özgül, 2001; Kulagina & Sinitsyna, 1997; Vdovenko et al. 1990; Vachard & Maslo, 1996) (Figure 5.66). The *Plectostaffella jakhensis - Eostaffella pseudostruvei* zone at the Sanandaj-Sirjan Zone can be correlated with the *Eostaffella pseudostruvei* zone in the

Southern Urals (Kulagina & Sinitsyna, 1997) by the presence of *Eostaffella pseudostruvei* (Rauser-Chernousova). If the species *Eostaffella* aff. *postmosquensis* Kireeva identified in this study can be correctly referable to *Eostaffella postmosquensis*, then the lower part of the *Plectostaffella jakhensis* - *Eostaffella pseudostruvei* zone at the Sanandaj-Sirjan Zone is correlated with the *Eostaffella postmosquensis* - *Plectostaffella* ex gr. *bogdanovkensis* zone in Taurus of Turkey (Altiner & Özgül, 2001). The recognized biozone in this study can also be correlated with the *Semistaffella* - *Plectostaffella jakhensis* zone in Taurus of Turkey (Altiner & Özgül, 2001). The *Plectostaffella jakhensis* Reitlinger is common in both areas. The *Plectostaffella jakhensis* - *Eostaffella pseudostruvei* zone at the Sanandaj-Sirjan Zone is also correlated with the *Plectostaffella bogdanovkensis* zone in the Russian Platform (Vdovenko et al.1990) and Donets Basin (Vachard & Maslo, 1996) by the presence of the species of *Plectostaffella.*

On the other hand, the Voznesenian fusulinids in Iran are distinguished in the Alborz and East Iran (Gaetani et al. 2009; Leven et al. 2006d; Leven & Gorgij, 2011c). In East Iran, the earliest Bashkirian foraminifers occurring in the lower of the Ghaleh Formation are represented by species of *Eostaffella* and *Plectostaffella* (Leven et al. 2006d; Leven & Gorgij, 2011c). Comparing the *Plectostaffella jakhensis* - *Eostaffella pseudostruvei* zone of the Sanandaj-Sirjan Zone with the coeval assemblages in East Iran, it is apparent that the assemblages of both areas are characterized mainly by species of *Plectostaffella*. The *Plectostaffella jakhensis* - *Eostaffella pseudostruvei* zone of the Sanandaj-Sirjan Zone can also be correlated with the coeval assemblage occurring in the uppermost of the Dozdehband Formation in the Alborz by the presence of the index specie *Plectostaffella jakhensis* Reitlinger.

SYSTEM	SUBSYSTEM	STAGE	SUBSTAGE	RUSSIAN PLATFORM (Vdovenko et al. 1990)	ASKYN SECTION (Kulagina and Sinitsyna, 1997)	DONETS BASIN (Vachard & Maslo, 1996)	TURKEY (Altiner & Ozgul, 2001)	SANANDAJ-SIRJAN ZONE (IRAN) (this study)
CARBONIFEROUS	PENNSYLVANIAN	BASHKIRIAN	VOZNESENIAN	*Plectostaffella bogdanovkensis* zone	*Eostaffella pseudostruvei* zone	*Semistaffella variabilis Semistaffella* sp. zone *Millerella marblensis* zone *Plectostaffella bogdanovkensis* zone	*Semistaffella – Plectostaffella jakhensis* zone *Eostaffella postmosquensis – Plectostaffella* ex gr. *bogdanovkensis* zone	*Plectostaffella jakhensis - Eostaffella pseudostruvei* zone

Figure 5.66: Biostratigraphic correlation of the Voznesenian standard fusulinid zones with the Sanandaj-Sirjan Zone.

5.6.3 The *Tikhonovichiella tikhonovichi - Profusulinella* (*Depratina*) *prisca - Aljutovella* spp. zone (latest Bashkirian–earliest Moscovian):

The fusulinid zone and its characteristic index species allow correlating the Bashkirian–Moscovian transition layers in the Sanandaj-Sirjan Zone with the fusulinid biozonation acknowledged for the latest Bashkirian–earliest Moscovian in the Russian Platform, Southern and Northern Urals, and Central Taurides (Altiner & Özgül, 2001; Dzhenchuraeva & Okuyucu, 2007; Isakova, 1998; 2001; Ivanova, 2000, 2002; Kulagina et al. 2001; Solovieva, 1986). The biostratigraphic correlation of the current latest Bashkirian–earliest Moscovian sequence in the Sanandaj-Sirjan Zone with the concurrent reference assemblages is shown in Figure 5.67.

The *Tikhonovichiella tikhonovichi - Profusulinella* (*Depratina*) *prisca - Aljutovella* spp. zone identified in this study is correlated with the *Al. aljutovica - Pr.*

prisca zone of the Southern and Northern Urals, which corresponds to the Vereian in age (Ivanova, 2000; 2002; Kulagina et al. 2001). The *Profusulinella* (*Depratina*) *prisca* and *Schubertella gracilis* are common in both areas.

If the species *Aljutovella* cf. *aljutovica* identified in this study can be correctly referable to the *Al. aljutovica*, then the *T. tikhonovichi* - *Pr.* (*Depratina*) *prisca* - *Al.* spp. zone is partly correlated with the *Al. aljutovica* - *Schubertella pauciseptata* zone of the Russian Platform (Isakova, 1998, 2001; Solovieva, 1986). The age of *Al. aljutovica* - *Sc. pauciseptata* zone is confirmed to be the earliest Moscovian, based on the occurrence of the conodont *Declinognathodus donetzianus* and the ammonoids of *Diaboloceras*-*Winslowceras* zone (Kulagina et al. 2009). *Sc. pauciseptata*, however, has not been reported in the Sanandaj-Sirjan Zone. At the same time the large subspherical *Profusulinella* species recovered in the Sanandaj-Sirjan Zone, are not known from the *Al. aljutovica* - *Sc. pauciseptata* zone in the Moscow Basin (Makhlina et al. 2001). The *T. tikhonovichi* - *Pr.* (*Depratina*) *prisca* - *Al.* spp. zone can also be correlated with the *Profusulinella* zone (latest Bashkirian) of the Central Taurides (Altiner & Özgül, 2001) by the presence of the species *Pr.* (*Depratina*) *parva*. The main faunal difference between the *T. tikhonovichi* - *Pr.* (*Depratina*) *prisca* - *Al.* spp. zone (Sanandaj-Sirjan Zone) and *Profusulinella* zone (Central Taurides) is the presence of the index species *Tikhonovichiella tikhonovichi* in the former.

The presence of *T. tikhonovichi* in the recognized biozone in this study, on the other hand, permits the correlation with the *Verella spicata* - *Aljutovella tikhonovichi* zone recognized by some authors (Solovieva, 1986; Isakova, 1998, 2001; Kulagina et al. 2001; Ivanova, 2000, 2002; Dzhenchuraeva & Okuyucu, 2007). The age of this zone in the Russian Platform is confirmed as the latest Bashkirian, based on the presence of conodonts in the *Declinognathodus marginodosus* zone and ammonoids in the *Diaboloceras* - *Axinolobus* zone (Kulagina et al. 2009). However, *Verella spicata*

Dalmatskaya was not found in the Sanandaj-Sirjan Zone. The *Tikhonovichiella tikhonovichi - Profusulinella (Depratina) prisca - Aljutovella* spp. zone identified in this study is also correlated with the *Verella spicata* zone (Melekessian age) and the *Al. aljutovica* zone (Vereian) of the eastern Taurides (Southern Turkey) (Dzhenchuraeva & Okuyucu, 2007). *Profusulinella* (*Depratina*) *prisca, Pr*. (*Depratina*) *parva*, *Tikhonovichiella tikhonovichi, Schubertella gracilis, Sc. magna,* and *Ozawainella pararhomboidalis* are common in both areas.

SYSTEM	SUBSYSTEM	STAGE	SUBSTAGE	SOUTHERN & NOTHERN URALS (Kulagina et al. 2001; Ivanova, 2000, 2002)	RUSSIAN PLATFORM (Solovieva, 1986; Isakova, 1998, 2001)	CENTRAL TAURIDES Altiner & Özgul 2001	EASTERN TAURIDES, SOUTHERN TURKEY (Dzhenchuraeva & Okuyucu, 2007)	SANANDAJ-SIRJAN ZONE (IRAN) (this study)
CARBONIFEROUS	PENNSYLVANIAN	MOSCOVIAN	VEREIAN	*Aljutovella aljutovica*-*Profusulinella prisca* zone	*Aljutovella aljutovica*-*Schubertella pauciseptata* zone	*Eostaffella mutabilis*-*Profusulinella prisca*-*Eofusulina* (*Paraeofusulina*) zone	*Aljutovella aljutovica* zone	*Tikhonovichiella tikhonovichi* - *Profusulinella* (*Depratina*) *prisca*-*Aljutovella* spp. zone
		BASHKIRIAN	MELEKESSIAN	*Verella spicata*-*Aljutovella tikhonovichi* zone	*Verella spicata*-*Aljutovella tikhonovichi* zone	*Profusulinella* zone	*Verella spicata* zone	

Figure 5.67: Biostratigraphic correlation of the Melekessian–Vereian standard fusulinid zones with the Sanandaj-Sirjan Zone.

On the other hand, as a result of the detailed analysis of fusulinids from several Iranian sections during recent years, the Bashkirian and Moscovian stages have been well distinguished in the Alborz (Gaetani et al. 2009; Jenny et al. 1978; Lys et al. 1978; Vachard, 1996), the Yazd Block (Leven et al. 2006d; Leven & Gorgij, 2011c), the Tabas Block (Leven et al. 2006d; Leven & Gorgij, 2011c), and the Sanandaj-Sirjan

Zone (Leven & Gorgij, 2008a, 2011c). Apart from these regions, these strata might not be deposited or be eroded away during the Late Pennsylvanian (Kasimovian–middle Gzhelian) to Early Permian (late Sakmarian) (Leven & Taheri, 2003). This may be also related to the Gondwana ice-age lacuna of Veevers and Powell (1987). Consequently, it is now shown that strata of both stages are fair widespread in some parts of Iran, and their fusulinid assemblages can be correlated with each other in general (Table 5.1). Correlation of the sections in different tectonic blocks of Iran that is based on the distribution of fusulinid faunas is described below.

Central and East Iranian blocks.- Fusulinids from the *T. tikhonovichi* - *Pr.* (*Depratina*) *prisca* - *Al.* spp. zone in this report can be partly correlated with the Vereian assemblages of Central and East Iranian blocks. In Central Iran, Vereian fusulinids in the lowermost part of the Absheni Formation are represented by species of *Eostaffella, Millerella, Novella, Pseudostaffella, Neostaffella, Ozawainella, Profusulinella,* and *Aljutovella* (Leven et al. 2006d; Leven & Gorgij, 2011c). A similar assemblage occurs in the lowermost part of the Absheni Formation in East Iran, which is represented by species of *Aljutovella* and *Profusulinella* (Leven et al. 2006d; Leven & Gorgij, 2011c).

Comparing the *T. tikhonovichi* - *Pr.* (*Depratina*) *prisca* - *Al.* spp. zone of the Sanandaj-Sirjan Zone with the coeval assemblages in the East and Central Iranian blocks, it is apparent that these assemblages are characterized mainly by species of *Aljutovella* and *Profusulinella*. The following species are common in these assemblages: *Al.* cf. *subaljutovica, Pr.* (*Depratina*) *prisca, Pr.* (*Depratina*) *parva,* and *Pseudostaffella subquadrata.* The main difference between the faunal compositions encountered in the Sanandaj-Sirjan Zone and the Central and East Iranian blocks is the absence of *Al*. cf. *aljutovica* and the *Tikhonovichiella* species in the latter blocks.

Alborz.- The *T. tikhonovichi* - *Pr.* (*Depratina*) *prisca* - *Al*. spp. zone in the Sanandaj-Sirjan Zone is partly correlative with the lower part of the Qezelgaleh Formation of the Alborz. According to Lys et al. (1978) and Gaetani et al. (2009), the Qezelgaleh fauna is represented mainly by *T. tikhonovichi*, *Pr.* (*Depratina*) *prisca*, and *Oz. mosquensis*. The following species are common to both Alborz and the Sanandaj-Sirjan Zone: *T. tikhonovichi*, *Pr.* (*Depratina*) *parva*, and *Pr.* (*Depratina*) *prisca*. The main faunal difference between the Sanandaj-Sirjan Zone and the Alborz is the absence of the genus *Aljutovella* in the latter.

Table 5.1: Distribution of the Melekessian–Vereian fusulinids in Iran.

FUSULINIDS	SANANDAJ-SIRJAN ZONE (this study)	ZALADOU SECTION (EAST IRAN) Leven et al. 2006	ANARAK SECTION (CENTRAL IRAN) Leven et al. 2006	ALBORZ Gaetani et al. 2009
Aljutovella aljutovica (Rauser-Chernousova)	cf.			
Al. subaljutovica Safonova	cf.	ex gr.	o	
Al. sp.	o			
Al. skelnevatica (Putrja)	cf.			
Al. parasaratovica Safonova	cf.			
Al. cybaea Leontovich		cf.	cf.	
Al. tumida Bensh			o	
Al. cafirniganica Bensh		o	o	
Al. artificialis Leontovich		o	aff.	
Al. intermixta Safonova	aff.			
Al. stocklini Leven & Davydov		o	aff.	
Al. conspecta Leontovich			o	
Al. pseudoaljutovica (Safonova)		ex gr.		
Al. iranica Leven & Davydov			o	
Al. gorgiji Leven & Davydov		o		
Ozawainella sp.	o		o	
Oz. pararhomboidalis Manukalova	o			
Oz. crassiformis Putrja	aff.			
Oz. pararhomboidalis Manukalova	cf.			
Oz. fergaensis Dzhentchuraeva		o	o	
Oz. kurakhovensis Manukalova			o	
Oz. vozhgalica Safonova			o	
Oz. mosquensis Rauser-Chernousova	ex gr.	cf.	cf.	o
Oz. paratingi Manukalova				o
Oz. paracompressa Grozdilova & Lebedeva			o	
Oz. angulata laxa Grozdilova & Lebedeva				o
Oz. paratingi Manukalova			aff.	
Oz. eoangulata Manukalova		o	o	
Oz. grandis Putievskaja			aff.	
Tikhonovichiella sp.	o			
T. grozdilovae Ektova	aff.			
T. tikhonovichi (Rauser-Chernousova)	cf.			
T. gracilis Ektova	cf.			
T. tikhonovichi (Rauser-Chernousova)	o			
T. pseudoaljutovica (Rauser-Chernousova)	cf.			
T. pseudoaljutovica (Rauser-Chernousova)			o	
Pseudostaffella nibelensis Rauser-Chernousova	cf.			
Ps. subquadrata Grozdilova & Lebedeva	o	cf.	o	
Ps. timanica Rauser-Chernousova	o		o	
Ps. pseudoquadrata Menuka	aff.			
Ps. gorskyi (Dutkevich)	cf.			
Ps. paracompressa Safonova		cf.	aff.	
Neostaffella rotundata (Bensh)		o	o	
Fusiella pulchella Safonova		o		
F. paraventricosa Rauser-Chernousova		o	o	
Schubertella sp.	o			
Pr. (Depratina) prisca (Deprat)	o	cf.	o	aff.
Pr. (Depratina) subovata Safonova	cf.		aff.	
Pr. (Depratina) pseudoparva Leven & Davydov		o	o	
Pr. (Depratina) beppensis Toriyama		o	o	
Pr. (Depratina) omiensis (Deprat)		o	o	
Pr. (Depratina) parva (Lee & Chen)	o	o	ex gr.	o

Table 5.1, Continued.

FUSULINIDS	SANANDAJ-SIRJAN ZONE (this study)	ZALADOU SECTION (EAST IRAN) Leven et al. 2006	ANARAK SECTION (CENTRAL IRAN) Leven et al. 2006	ALBORZ Gaetani et al. 2009
Pr. pseudorhomboidea Putrja		o	aff.	
Pr. postparahombiformis Dzhenchuraeva	o			
Eostaffella compressa Brazhnikova	o			
E. sp.	o			
E. primitiva (Dutkevich)	o			
E. acuta Grozdilova & Lebedeva			o	
E. mutabilis Kireeva			ex gr.	
Millerella uralica Kireeva	cf.			
M. variabilis Rauser-Chernousova		o	o	
M. marblensis Thompson		ex gr.	ex gr.	
M. pressa Thompson			o	
Novella primitive (Dutkevich)		o	o	
Seminovella nana (Kireeva)		o	o	
S. carbonica Grozdilova & Lebedeva		o	o	
S. aperta Grozdilova & Lebedeva		o	o	
Schubertella magna Lee & Chen	o			
Schubertella gracilis Rauser-Chernousova	o			
Eoschubertella obscura Lee & Chen	cf.	o		
Staffellaeformis sp.	o			
Pseudostaffella proozawai Kireeva	aff.			

Note: cf. –conformis; aff.- affinis; ex gr.- ex grege; o.- occurrence.

5.6.4 The *Beedeina samarica - Taitzehoella mutabilis* zone (late Kashirian):

The *Beedeina samarica - Taitzehoella mutabilis* zone recognized in the Sanandaj-Sirjan Zone can be correlated with the standard fusulinid biozonation acknowledged for the Kashirian Substage in the Russian Platform (Rauser Chernousova et al. 1979; Ivanova et al. 1979; Davydov & Leven, 2003), Turkey (Altiner, 1981), and Darvaz (Leven, 1998) (Figure 5.68). The biozone in question can also be correlated with the *Beedeina bona anarakensis - Putrella persica* zone distinguished in the Central Iran (Leven et al. 2006d) by the presence of species of *Beedeina*, and with the *Beedeina* ex gr. *samarica - B. bona anarakensis - Citronites* aff. *apokensis* at the Asad Abad section (Leven & Gorgij, 2008a) by the presence of *Beedeina samarica* Rauser-Chernousova & Belyaev.

SYSTEM	SUBSYSTEM	STAGE	SUBSTAGE	RUSSIAN PLATFORM (Rauser Chernousova et al. 1979; Ivanova et al. 1979; Davydov & Leven, 2003)	TURKEY (Altiner, 1981)	DARVAZ (Leven, 1998)	ASAD ABAD SECTION (Leven & Gorgij, 2008a)	SANANDAJ-SIRJAN ZONE (IRAN) (this study)
CARBONIFEROUS	PENNSYLVANIAN	MOSCOVIAN	KASHIRIAN	*Fusulinella subpulchra* zone	*Fusulinella* (*F.*) *asiatica* zone	*Citronites retuculatus-paraeofusulina subtilissima* zone	*Beedeina* ex gr. *samarica- B. bona anarakensis-Citronites* aff. *apokensis* zone	*Beedeina samarica-Taitzehoella mutabilis* zone
					Profusulinella ovata zone	*Hemifusulina*? *splendida-Depratina timanica* zone	*Neostaffella umbiicata-Putrella primaris* zone	–
				Priscoidella priscoidea zone	*Fusiella praecursor* zone	*Aljutovella znensis-Ovatella constans* zone	*Pseudostaffella gorskyi-Neostaffella ozawai-Putrella* sp. zone	–

Figure 5.68: Biostratigraphic correlation of the Kashirian standard fusulinid zones with the Sanandaj-Sirjan Zone (modified from Leven & Gorgij, 2008a).

5.6.5 The *Fusulinella* (*Fusulinella*) *pseudobocki* zone (early Podolskian):

The fusulinid zone and its characteristic index species allow correlating the early Podolskian assemblage in the Sanandaj-Sirjan Zone with the fusulinid biozonation acknowledged for the Podolskian Substage in the Russian Platform (Rauser Chernousova et al. 1979; Ivanova et al. 1979; Davydov & Leven, 2003), Spain (van Ginkel, 1965), and Turkey (Okuyucu, 2013) (Figure 5.69). The *Fusulinella* (*Fusulinella*) *pseudobocki* zone at the Sanandaj-Sirjan Zone can be correlated with the *Fusulinella* (*F.*) *pseudobocki* - *Fusulinella* (*M.*) ex gr. *praebocki* in Spain (Leven & Gorgij, 2008a). The *Fusulinella* (*Fusulinella*) *pseudobocki* Lee & Chen, and *Fusulinella* (*M.*) *praebocki* Rauser-Chernousova are common to both areas. If the species *Fusiella* ex gr. *praetypica* identified in this study can be correctly referable to the *Fu. praetypica*, then the *Fusulinella* (*Fusulinella*) *pseudobocki* zone is partly correlated with the *Fusulinella* (*F.*) *colaniae-Fusiella praetypica* zone (Okuyucu, 2013) in Turkey. Except for the Sanandaj-Sirjan Zone, so far, the Podolskian fusulinids have not been reported in Iran.

SYSTEM	SUBSYSTEM	STAGE	SUBSTAGE	RUSSIAN PLATFORM (Rauser Chernousova et al. 1979; Ivanova et al. 1979; Davydov & Leven, 2003)	TURKEY (Okuyucu, 2013)	SPAIN (van Ginkel, 1965)	ASAD ABAD SECTION (Leven & Gorgij, 2008a)	SANANDAJ-SIRJAN ZONE (IRAN) (this study)
CARBONIFEROUS	PENNSYLVANIAN	MOSCOVIAN	PODOLSKIAN	*Fusulinella colaniae- F. vozhgalensis – Fusulina kamensis* zone	*Fusulinella* (*F.*) *colaniae-Fusiella paretypica*	*Beedeina* ex gr. *elegans-Kamaina* ex gr. *ozawai* *Fusulinella* (*F.*) cf. *Pseudobocki-Fusulinella* (*M.*) ex gr. *praebocki*	*Beedeina keltmensis - Kamaina* ex gr. *ozawai* zone *Fusulinella* (*M.*) *bedakensis - F.* (*F.*) *pseudobocki - F.* (*F.*) aff. *fluxa* zone	*Fusulinella* (*Fusulinella*) *pseudobocki* zone

Figure 5.69: Biostratigraphic correlation of the Podolskian standard fusulinid zones with the Sanandaj-Sirjan Zone.

5.6.6 The *Praepseudofusulina kljasmica* zone (latest Gzhelian–Asselian):

The fusulinid zone and its characteristic index species allow correlating the latest Gzhelian–Asselian transition layers in the Sanandaj-Sirjan Zone with the fusulinid biozonation acknowledged for the latest Gzhelian–Asselian in the Russian Platform, and the Southern Urals (Sjomina, 1961; Makhlina et al. 1984; Chernykh & Reshetkova, 1987; Davydov et al. 1992; Davydov, 1997; Chernykh & Ritter, 1997; Leven & Gorgij, 2011c). This indicates additional information about the Late Carboniferous–Early Permian paleobiogeography of the Sanandaj-Sirjan Zone in the Middle East.

These assemblages are represented by the same genera and species, suggesting the free connection between the aforementioned basins with similar sedimentation conditions. The following index taxa are common within these assemblages: *Praepseudofusulina* sp., *P. kljasmica* (Sjomina), *P. incomperta* (Scherbovich), and *Nonpseudofusulina* sp. The main difference between the faunal compositions encountered in the *Praepseudofusulina kljasmica* zone and in the coeval assemblages of the Southern Urals and the Russian Platform is a lower diversity of the latest Gzhelian–Asselian fusulinoids in the Sanandaj-Sirjan Zone. The biostratigraphic correlation of the current the latest Gzhelian–Asselian sequence in the Sanandaj-Sirjan Zone with the concurrent reference assemblages are shown in Figures 5.70 and 5.71.

SYSTEM	STAGE	HORIZON	MOSCOW SYNECLISE (Makhlina *et al.* 1984; Sjomina, 1961; Davydov, 1997)	HORIZON	SOUTHERN URALS (Davydov *et al.* 1992; Chernykh & Reshetkova, 1987; Chernykh & Ritter, 1997)	DONETS BASIN (Kireeva, 1949a, Davydov, 1990b)	CARNIC ALPS (Kahler, 1989; Krainer, 1992; Forke, 1995; Forke *et al.* 1998; Krainer & Davydov, 1998)	SANANDAJ–SIRJAN ZONE IRAN (This study and Leven & Gorgij, 2011b)
PERMIAN	ASSELIAN	Shikhan.	*Sphaeroschwagerina sphaerica gigas,* *Schwagerina firma*	Shikhan.	*Sphaeroschwag. sphaerica gigas,* *Schwagerina firma*	*Sphaeroschwagerina sphaerica gigas*	*Sphaeroschwag. sphaerica gigas* *Sphaeroshwag. glomerosa* *Pseudoschw. aequalis*	?
		Kholodnolozhskian	*Sphaeroschwagerina molleri,* *Schwagerina fecunda,* *Paraschwagerina ishimbajica*	Uskalyk.	*Pseudoschwag. robusta* *Sphaeroschwag moelleri,* *Paraschwagerina akhunovi*	*Sphaeroschwagerina moelleri*		*Pseudoschwagerina beedei*
		Kholodnolozhskian	*Sphaeroschwagerina* sp., *Likharevites inglorius*	Sjuren.	*Sphaeroschwag. fusiformis,* *Schwagerina subnathorsthy* *Sphaeroschwag. vulgaris aktjubensis*	*Occidentoschwagerina "fusulinoides"*	*Zigarella panjiensis* *Likharevites inglorius* *Schellwienia bornemani*	? *Praepseudofusulina kljasmica*

Figure 5.70: Biostratigraphic correlation of the Asselian standard fusulinid zones with the Sanandaj-Sirjan Zone.

SYSTEM	STAGE	HORIZON	MOSCOW SYNECLISE (Makhlina *et al.* 1984; Sjomina, 1961; Davydov, 1997)	HORIZON	SOUTHERN URALS (Davydov *et al.* 1992; Chernykh & Reshetkova, 1987; Chernykh & Ritter, 1997)	DONETS BASIN (Kireeva, 1949a, Davydov, 1990b)	CARNIC ALPS (Kahler, 1989; Krainer, 1992; Forke, 1995; Forke *et al.* 1998; Krainer & Davydov, 1998)	SANANDAJ¬SIRJAN ZONE IRAN (This study and Leven & Gorgij, 2011b)
CARBONIFEROUS	GZHELIAN	Melekhov.	*Schwagerina robusta*	Aidaralash.	*Ultradaixina postgallowayi*		*Ultradaixina postgalloway* *Occidentoschwag. alpina*	*Anderssonites-Schellwienia*
							Rugosofusulina sp.	
					U. bosbytauensis		*Ultradaixina postokensis* *Schellwienia ulukensis*	
					U. postsokensis			
		Noginsk.	*Daixina sokensis*	Martuk.	*Daixina vasylkovskyi*	*Schellwienia modesta*, *Daixina vasylkovskyi*	*Boultonia europaea* *Ruzhenzevites parasolidus*	*Ruzhenzevites-Rauserites*
					Daixina enormis		*Schagonella gigatea* *Dukevitchia dastarensis*	

Figure 5.71: Biostratigraphic correlation of the late Gzhelian standard fusulinid zones with the Sanandaj-Sirjan Zone.

On the other hand, as a result of the detailed analysis of fusulinids from several Iranian sections during recent years, the Gzhelian and Asselian fusulinids have been well distinguished in Central and East Iran (Leven & Taheri, 2003; Leven & Gorgij, 2006b; Leven & Gorgij, 2011c), Alborz (Gaetani et al. 2009), and the Sanandaj-Sirjan Zone (Leven & Gorgij, 2011b,c, this study). Consequently, it is now shown that fusulinids of both stages are fair widespread in some parts of Iran, and they can be correlated with each other in general (Tables 5.2 & 5.3).

Correlation of the sections that is based on distribution of fusulinid faunas is substantiated below.

Central and East Iranian blocks.- Fusulinids from the *Praepseudofusulina kljasmica* zone in this report can be partly correlated with the coeval assemblages of Central and East Iranian blocks. In Central Iran, the latest Gzhelian–Asselian fusulinids in the Zaladou Formation are represented by species of *Triticites, Rauserites, Schwageriniformis, Jigulites, Ruzhenzevites, Likharevites, Praepseudofusulina, Nonpseudofusulina*, *Anderssonites*, *Sphaeroschwagerina,* and *Pseudoschwagerina* (Leven & Gorgij, 2006a,b; Leven & Gorgij, 2011b,c). A similar assemblage occurs in the lowermost part of the Zaladou Formation in East Iran (Leven & Taheri, 2003; Leven & Gorgij, 2011b).

Comparing the *Praepseudofusulina kljasmica* zone of the Sanandaj-Sirjan Zone with the coeval assemblages in the East and Central Iranian blocks, it is apparent that the assemblage in question does not share common genera and species with the former blocks. The main difference between the faunal compositions encountered in the Sanandaj-Sirjan Zone and the Central and East Iranian blocks is the almost absence of the species of *Praepseudofusulina* in the fusulinid assemblages of the latter blocks (Leven & Taheri, 2003; Leven & Gorgij, 2006b), whereas they are abundant in the Sanandaj-Sirjan Zone.

On the other hand, the diversified species of *Ruzhenzevites* (including *R. zaladuensis* Leven, and *R. subcylindricus* Bensh), occurring in Central and East Iran (Leven & Taheri, 2003; Leven & Gorgij, 2006b), are completely absent in the *Praepseudofusulina kljasmica* zone in the Banarizeh section.

Alborz.- The *Praepseudofusulina kljasmica* assemblage of the Vazhnan Formation in the Sanandaj–Sirjan Zone can be correlated with the *Anderssonites*-bearing strata of the uppermost part of the Toyeh Formation and *Praepseudofusulina* assemblage in the lowermost part of the Emarat Formation in the Alborz. *Anderssonites* assemblage is composed of *Anderssonites* cf. *subovata* (Konovalova), *Dutkevitchia*? sp., *Rauserites* sp., *Nankinella* sp., and *Eostaffella* sp. This assemblage is probably assignable to the very latest Gzhelian–earliest Asselian (Gaetani et al. 2009). Among the fusulinids in the *Anderssonites* assemblage, *Anderssonites* cf. *subovata* is originally described from the early Asselian of Timan (Zolotova et al. 1977), however, the genus is generally characteristic in the latest Gzhelian and earliest Asselian (Gaetani et al. 2009). The *Praepseudofusulina* assemblage in the lowermost part of the Emarat Formation is characterized by the occurrence of the diverse *Praepseudofusulina* forms and the lack of *Sphaeroschwagerina* species. This assemblage is generally represented by *P. kljasmica* (Sjomina), *P. urmarensis* (Scherbovich), *P. incomperta* (Scherbovich), *Nankinella* sp., and *Schubertella* sp. Comparing the latest Gzhelian–Asselian fusulinid assemblage of the Sanandaj-Sirjan Zone with the coeval assemblages in the Alborz, it is apparent that the fusulinid assemblage in the former lacks the diverse *Anderssonites*, *Dutkevitchia*, and *Rauserites* species. In addition, the fusulinid assemblages in both blocks are dominated by the diverse species of *Praepseudofusulina*.

Table 5.2: Correlation of distribution of the Gzhelian fusulinid fauna in Iran.

FUSULINIDS	SANANDAJ - SIRJAN ZONE (this study)	SANANDAJ-SIRJAN ZONE (Leven & Gorgij 2011b)	CENTRAL IRAN (Leven & Gorgij 2006a)	EAST IRAN (Leven & Taheri 2003)	ALBORZ (Gaetani et al. 2009)
Shellwienia sp.	•				
S. ex gr. *stoecklini* Leven		•	•		
S. anarakensis Leven			•		
S. delicate (Alksne)			•		
S. orenburensis (Dobrokhotova)				•	
S. aff. *dissimilis* (Scherbovich)				•	
S. aff. *modesta* (Scherbovich)				•	
Likharevites aff. *paranitidus* (Bensh)			•		
L. esetensis (Davydov)			•		
Rugosofusulina aff. *elliptica* Rozovskaya			•		
R. uralica Z. Mikhailova			•		
R.? *iranica* Leven			•		
R.? *anarakensis* Leven			•		
R.? *elongate* Leven			•		
R. directa Bensh			•		
R. mutabilis Bensh			•		
R. sp.			•		
R.? *alpine communis* (Schellwien)			•		
R. paralatioralis Suleimanov			•		
Nonpseudofusulina aff. *modesta*				•	
Triticites ex gr. *simplex* (Schellwien)			•		
T. ex gr. *ohioensis* Thompson			•		
T. aff. *ishimbaji* Rozovskaya			•		
T. aff. *shikhanensis* Rozovskaya			•		
T. samaricus Rauser Chernousova			•		
T. karlensis Rozovskaya			•		
T. globoides Z. Mikhailova			•		
T. ex gr. *simplex* Schellwien			•		
T. ex gr. *secalicus* Say			•		
T. nefandus Grozdilova			•		
Quasifusulina cayeuxi (Deprat)			•		
Q. longissima (Moeller)			•		
Q. eleganta Shlykova			•		
Q. sp.			•		
Daixina rugosa Rozovskaya			•		
D. aff. *osinovkensis* Scherbovich			•		
Jigulites cf. *formosus* Rozovskaya			•		
Schwageriniformis acutatus Leven		•	•		
S. aff. *gissaricus depressa* (Bensh)			•		
S. aff. *perstabilis* (Scherbovich)			•		
S. cf. *perlongus* (Bensh)			•		
S. ex gr. *kairakensis* (Bensh)			•		
Ultradaixina bosbytauensis distincta Leven			•		
U. ? *kozui* (Deprat)			•		
U. ? *kosvaensis* (Echlakov)			•		
U. cf. *bosbytauensis* (Bensh)			•		
Ruzhenzevites ferganensis ferganensis		•	•	•	•
R. ferganensis curtus Leven		•		•	
R. ferganensis grandiusculus Leven		•	•		
Anderssonites cf. *subovatus* (Konovalova)					•
A. anderssoni (Schellwien)		•	•		
A. aff. *anderssoni simplex* (Konovalova)				•	

Table 5.2, Continued.

FUSULINIDS	SANANDAJ - SIRJAN ZONE (this study)	SANANDAJ - SIRJAN ZONE (Leven & Gorgij, 2011b)	CENTRAL IRAN (Leven & Gorgij, 2006a)	EAST IRAN (Leven & Taheri, 2003)	ALBORZ (Gaetani et al. 2009)
Anderssonites anderssoni latiteminosa			•		
A. aff. *zarjae* Potievskaya		•			
A. pseudoanderssoni (Sjomina)			•		
Paraschwagerina primaeva fortificata			•		
Ferganites? aff. *obessus* Villa et Ueno		•			
Rauserites? *persicus* Leven			•		
R. aff. *postarcticus* Rauser Chernousova			•		
R. elongatissimus (Rozovskaya)			•	•	
R. cf. *erraticus* Rozovskaya			•		
R. stepanovi Leven			•		
R. variabilis (Rozovskaya)			•	•	
R. aff. *postarcticus* (Rauser Chernousova)			•		
R. rossicus (Schellwien)			•		
R. ishimbaji (Rozovskaya)		•	•	•	
R. aff. *stuckenbergi* (Rauser Chernosova)			•		
R. aff. *dictiophorus* Rozovskaya			•		
R. aff. *bashkiricus* Rozovskaya			•		
R. aff. *ovalis* (Rozovskaya)			•		
R. noinskyi (Rauser Chernosova)			•		
R. infrequentis Leven			•		
R. fusoideus Leven			•	•	
R. aff. *varibilis* (Rozovskaya)			•		
R. infrequentis Leven				•	•
R. tabasensis Leven				•	•
R. baghbani Leven & Gorgij		•			
R. karlensis Rosovskaya		•			
R. primitivus (Rozovskaya)				•	
R. immutabilis (Scherbovich)				•	
R. jucundus Leven				•	
R. lucidus (Rauser Chernosova)				•	
R. postarcticus (Rauser Chernosova)				•	
R. quentillus (Zolotova)				•	
R. exilis Rozovskaya				•	
R. aff. *pseudolaxus* (Igo)				•	
R. samaricus (Rauser Chernosova)				•	
R. aff. *samaricus* (Rauser Chernosova)				•	
R. inobservabilis Leven				•	
R. sp.				•	
R.? *persicus persicus* Leven				•	
R. persicus compactus Leven				•	
Kushanella? sp.				•	
Nonpseudofusulina? sp.	•				
N. sp.	•				
Praepseudofusulina kljasmica (Sjomina)	•				
P. ex gr. *kljasmica* (Sjomina)	•				
P. sp.	•				

Table 5.3: Correlation of distribution of the Asselian fusulinid fauna in Iran.

FUSULINIDS	SANANDAJ - SIRJAN ZONE (this study)	SANANDAJ-SIRJAN ZONE (Leven & Gorgij 2011b)	CENTRAL IRAN (Leven & Gorgij 2006a)	EAST IRAN (Leven & Taheri 2003)	ALBORZ (Gaetani et al. 2009)
Sphaeroschwagerina ? sp.		•		•	
S. pavlovi (Scherbovich)			•		
S. ex gr. *sphaerica* (Scherbovich)					•
S. shamovi primitiva (Leven & Scherbovich)			•		•
S. moelleri (Rauser & Chernousova)			•		
S. notabilis (Grozdilova)			•		
S. ellipsoidalis (Rauser & Chernosova)			•		
S. vulgaris (Scherbovich)					•
S. ex gr. *sphaerica* Scherbovich			•		
S. fusiformis (Krotowi)			•		
S. sp.				•	
Rhuzhenzevites zaladuensis Leven			•	•	
R. subcylindricus (Bensh)			•	•	
Pseudoschwagerina ? sp.	•				
P. turbida Fet G. Kahler			•		
P. extensa Fet G. Kahler			•		
P. velebitica Kochansky & Devide			•	•	
P. uddeni (Beede & Kniker)			•	•	
P. parabeedei Ross				•	
P. cf. *aequalis* Kahler & Kahler					•
P. muongthensis (Deprat)					•
P. truncata Rauser & Chernosova					•
P. aff. *beedei* Dunbar & Skinner					•
P. robusta (Meet)			•		
P. aff. *ozguli* Kobayashi & Altiner		•			
P. ex gr. *beedei* Dunbar & Skinner		•			
Andessonites ? sp.	•				
A. pseudoanderssoni pseudoanderssoni Sjomina			•		
Praepseudofusulina kljasmica (Sjomina)	•	•	•		•
P. cf. *saratovensis* (T. Tschernova)	•				•
P. cf. *impercepta* (Jagofarova)	•	•			•
P. incomperta (Scherbovich)	•				•
P. aff. *cara* (Dobrokhotova)		•			
P. netkatchensis Kireeva			•		
P. urmarensis (Scherbovich)					•
P. ikensis (Dobrokhotova)				•	
P. ex gr. *kljasmica* (Sjomina)	•	•			
P. aff. *kljasmica* (Sjomina)	•				
P. sp.	•	•			
P. ? sp.	•	•			
P. cf. *kljasmica* (Sjomina)	•				
P. pseudoanderssoni (Sjomina)			•		
Nonpseudofusulina sp.		•			
N. aff. *modesta* (Scherbovich)		•			
N. cf. *modesta* (Scherbovich)	•				
N. macilenta Leven				•	
Eoparafususlina ? sp.	•				
Rugosofusulina paralatioralis			•		
Likharevites gracilis Leven			•		
L. kokpektensis (Scherbovich)			•		
L. inglorious (Bensh)			•		

Table 5.3, Continued.

FUSULINIDS	SANANDAJ - SIRJAN ZONE (this study)	SANANDAJ-SIRJAN ZONE(Leven & Gorgij, 2011b)	CENTRAL IRAN (Leven & Gorgij, 2006a)	EAST IRAN (Leven & Taheri, 2003)	ALBORZ (Gaetani et al. 2009)
Sphaeroschwagerina shamovi gerontica			•		
Darvasites? *eocontructus* Leven & Scherbovich					•
Biwaella sp.			•	•	
Pseudofusulina? *macilenta* Leven				•	
P.? aff. *macilenta* Leven				•	
Quasitriticites iranicus Leven				•	
Ruzhenzevites ferganensis ferganensis				•	
R. parasolidus (Bensh)				•	
Eoparafusulina aff. *pusilla* (Schellwien)					•
Anderssonites aff. *anderssoni* (Schellwien)			•		
A.anderssoni (Schellwien)					•
Praepseudofusulina sp.1	•				
P. sp.2	•				
P. sp.3	•				
P. sp.4	•				
P. sp.5	•				
P. cf. *incomperta* (Scherbovich)	•				

CHAPTER 6: CONCLUSIONS

The Mississippian–Asselian successions in Sanandaj-Sirjan Zone of the Shahreza and the Abadeh regions have been studied in three sections. Based on the lithostratigraphic, biostratigraphic and foraminiferal assemblages the following conclusions can be drawn:

- The Mississippian–Asselian succession in the Sanandaj-Sirjan Zone consists of the Shishtu and Sardar groups of the Carboniferous and the Anarak Group of the uppermost Carboniferous–Lower Permian.
- At the Sanandaj-Sirjan Zone, deposits of the Mississippian series correspond to the Shishtu Group, including the Shishtu 1 and Shishtu 2 formations, and are represented by the sequence of silisiclastic and calcareous units.
- The uppermost Mississippian–Pennsylvanian strata in the Sanandaj-Sirjan Zone are represented by the Sardar Group, which consists of the Ghaleh and Absheni formations. The Serpukhovian-Moscovian Ghaleh Formation is composed of conglomerate, limestone, sandstone, and sandy limestone. Basal conglomerate of this sequence is underlain by the limestones of the Shishtu 2 Formation. The Absheni Formation is early Moscovian–late Moscovian in age and is composed of oolitic limestone, sandstone, and sandy limestone with intercalation of shale.
- The recently established uppermost Gzhelian–Asselian of the Vazhnan Formation belonging to the Anarak Group is of particular significance, as it presents the Carboniferous–Permian boundary (CPB). The Vazhnan Formation unconformably overlies to the Absheni Formation. This formation includes conglomerate, sandstone, shale, marl, and limestone beds. The Vazhnan Formation is unconformably overlain by the Surmaq Formation corresponding in age to the late Early Permian-Middle Permian.

- The Mississippian–Asselian interval in this study contains 217 species belonging to 75 genera within the six foraminiferal zones; namely, (1) the *Uralodiscus rotundus* - *Glomodiscus miloni* zone of a Viséan in age, (2) the *Plectostaffelle jakhensis* - *Eostaffella pseudostruvei* zone of a Voznesenian (earliest Bashkirian) in age, (3) the *Tikhonovichiella tikhonovichi* - *Profusulinella* (*Depratina*) *prisca* - *Aljutovella* spp. zone of a Melekessian–Vereian (latest Bashkirian–earliest Moscovian) in age, (4) the *Beedeina samarica* - *Taitzehoella mutabilis* zone of a late Kashirian age, (5) the *Fusulinella* (*Fusulinella*) *pseudobocki* zone of an early Podolskian in age, and (6) the *Praepseudofusulina kljasmica* zone of a latest Gzhelian–Asselian in age.
- The foraminiferal zones and their characteristic index species allow to correlate the Mississippian–Asselian sequence in the Sanandaj-Sirjan Zone with the foraminiferal biozonation acknowledged for the Mississippian–Asselian in the Russian Platform, Southern and Northern Urals, Istanbul Terrane and central and eastern Taurides (Turkey), and Western Europe (Sjomina, 1961; Makhlina et al. 1984; Solovieva, 1986; Chernykh & Reshetkova, 1987; Vdovenko et al. 1990; Davydov et al. 1992; Vachard & Maslo, 1996; Davydov, 1997; Chernykh & Ritter, 1997; Kulagina & Sinitsyna, 1997; Isakova, 1998, 2001; Ivanova, 2000, 2002; Altiner & Özgül, 2001; Kulagina et al. 2001; Poty et al. 2006; Dzhenchuraeva & Okuyucu, 2007; Okuyucu et al. 2013; Leven & Gorgij, 2011c).
- The new foraminiferal faunas, furthermore, share some common species with the concurrent faunas of the Alborz, East Iran, and Central Iran (Leven & Taheri, 3003; Gaetani et al. 2009; Leven & Gorgij, 2011c).
- In this study, the foraminiferal assemblages of the Voznesenian (earliest Bashkirian) age, the Melekessian–Vereian (latest Bashkirian–earliest

Moscovian) age, and also Biozone MFZ11B (late early Viséan) are reported for the first time in the Sanandaj-Sirjan Zone.

- Among the identified foraminifers, the following 21 genera and 37 species are reported for the first time in the Sanandaj-Sirjan Zone:

The genera: *Plectogiranopsis, Eoparastaffella, Glomodiscus, Dainella, Eogloboenothyra, Eogloboenothyra, Lapparentidiscus, Pseudoammodiscus, Brunsia, Mediendothyra, Valvulinella, Forschia, Archaediscus, Uralodiscus, Omphalotis, Pseudoplanoendothyra, Endothyranopsis, Eostaffella, Plectostaffella, Aljutovella,* and *Tikhonovichiella.*

The species: *Uralodiscus rotundus* (Chernysheva), *Omphalotis chariessa* (Conil & Lys), *Endothyranopsis crassiformis* Vdovenko, *Plectogiranopsis convexa* Rauser-Chernousova, *Glomodiscus miloni* (Pelhate), *G. oblongus* (Conil & Lys), *Dainella staffelloides* Vdovenko, *Endothyra elegia* Malakhova, *Lapparentidiscus bokanensis* Vachard, *Mediocris mediocris* (Vissarionova), *M. breviscula* (Ganelina), *Viseidiscus umbogmaensis* (Omara & Conil), *Brunsia spirillinoides* (Grozdilova & Glebovskaya), *Mediendothyra wjasmensis* (Ganelina), *Forschia parvula* Rauser-Chernousova, *Eostaffella parastruvei* (Rauser-Chernousova), *E. kasakhstanica* Rauser-Chernousova, *E. angularis* Brazhnikova et al., *E. pseudostruvei chomtatifera* Kireeva, *E. mirifica* Brazhnikova, *E. ikensis* Vissarionova, *E. oblonga* Ganelina, *E. primitiva* (Dutkevich), *E. compressa* Brazhnikova, *Plectostaffella varvariensiformis* Brazhnikova & Vdovenko, *Pl. jakhensis* Reitlinger, *Profusulinella* (*Depratina*) *prisca* (Deprat), *Pr. postpararhombiformis* Dzhenchuraeva, *Pr.* (*Depratina*) *parva* (Lee & Chen), *Tikhonovichiella pseudoaljutovica* (Rauser-Cherniusova), *T. tikhonovichi* (Rauser-Chernousova), *Schubertella gracilis* Rauser-Chernousova, *Sc. magna* Lee & Chen, *Pseudostaffella subquadrata* Grozdilova

& Lebedeva, , *Ps. timanica* Rauser, *Fusiella pulchella* Safonova, and *Praepseudofusulina incomperta* (Scherbovich).

- The study also presents the occurrence of the following 19 species of the foraminifers for the first time in Iran: *Brunsia spirillinoides* (Grozdilova & Glebovskaya), *Endothyranopsis crassiformis* Vdovenko, *Endothyra elegia* Malakhova, *Plectogiranopsis convexa* Rauser-Chernousova, *Omphalotis chariessa* (Conil & Lys), *Glomodiscus miloni* (Pelhate), *Dainella staffelloides* Vdovenko, *Forschia parvula* (Rauser-Chernousova), *Eostaffella mirifica* Brazhnikova, *E. angularis* Brazhnikova et al., *E. primitiva* (Dutkevich), *E. compressa* Brazhnikova, *Plectostaffella varvariensiformis* Brazhnikova & Vdovenko, *Pl. longa* Rauser-Chernousova, *Pseudostaffella timanica* Rauser-Chernosouva, *Schubertella gracilis* Rauser-Chernousova, *Sc. magna* Lee & Chen, *Eochubertella lata* Lee & Chen, and *Profusulinella postpararhombiformis* Dzhenchuraeva.

FURTHER STUDIES

Studying the Late Paleozoic foraminiferal faunas in Malaysia and the adjacent areas such as Thailand, and then making the correlation between the Late Paleozoic foraminifers from the Western Tethys (including the Iranian forms) and the ones from the Eastern Tethys (including the Malaysian and Thai foraminifers) are among my plan for the future.

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LIST OF PUBLICATIONS AND PAPERS PRESENTED

1. Fassihi, S., Sone, M., Hairapetian, V., & Esfahani, F. S. (in press). Fusulinoids from the Carboniferous–Permian transition beds from the Abadeh Region (Sanandaj-Sirjan Zone, Iran). Carbonates and Evaporates Journal (ISI indexed).

2. Fassihi, S., Sone, M., Hairapetian, V., & Esfahani, F. S. (2017). Fusulinoids from the Bashkirian–Moscovian transition beds of the Shahreza region in the Sanandaj–Sirjan Zone, Iran. International Journal of Earth Sciences, 106 (4), 1205-1221. (Springer) 10.1007/s00531-016-1435-8 (ISI-Indexed).

3. Fassihi, S., Kulagina, E., & Shirezadeh, F. (2017). Foraminifers of a late early Visean age (MFZ11B), in the Sanandaj-Sirjan Zone, Iran. Kazan Golovkinsky Stratigraphic Meeting and Fourth All-Russian Conference "Upper Palaeozoic of Russia". Abstract Volume, 19–23 September 2017, Kazan, Russia: 45–46.

4. Fassihi, S. & Shirezadeh, F. (2017). Mississippian–Asselian (Early Carboniferous–Early Permian) foraminiferal faunas and biostratigraphy of the Shahreza-Abadeh regions (the Sanandaj-Sirjan Zone), Iran. Kazan Golovkinsky Stratigraphic Meeting and Fourth All-Russian Conference "Upper Palaeozoic of Russia". Abstract Volume, 19–23 September 2017, Kazan, Russia: 47–48.

5. Fassihi, S., Sone, M., Hairapetian, V., & Shirezadeh, F. (2015). A new Asselian (basal Permian) fusulinid fauna from the the Abadeh region, the Sanandaj-Sirjan Zone, Iran. The XVIII International Congress on Carboniferous and Permian, August 7–15, Kazan, Russia. Abstract Volume: p. 56.

6. Fassihi, S., Sone, M., Hairapetian, V., & Shirezadeh, F. (2015). First find of a late Vereian (Moscovian) fauna from the basal part of the Absheni Formation, in the Shahreza area, the Sanandaj-Sirjan Zone, Iran. The XVIII International Congress on Carboniferous and Permian, August 7–15, Kazan, Russia. Abstract Volume: p. 57.

7. Shirezadeh, F., Hairapetian, V., Kangazian, A., Kohansal, N., Hejazi, H., Akbari Mohamadi, A., Fassihi, S., Sadri, M. (2015). Revision of the Carboniferous–Early Permian succession based on the new lithostratigraphic data in the Western edge of the Central Iran Microcontinent. The XVIII International Congress on Carboniferous and Permian, August 7–15, Kazan, Russia. Abstract Volume: p. 176.

8. Fassihi, S., Sone, M., Hairapetian, V., Shirezadeh, F. (2014) The Carboniferous–Permian Boundary in the Sanandaj–Sirjan Terrane, Central Iran: Preliminary report. Permophiles 59: 23–25.

9. Shirezadeh, F., Hairapetian, V., Kangazian A., Kohansal, N., S. Hejazi H., Fassihi, S., Akbari Mohamadi, A. (2014) Preliminary notes on lithostratigraphic revision of Carboniferous-Early Permian deposits in the Sanandaj-Sirjan Block, central Iran. The Third International Symposium of the International Geosciences Programme Project 589, Proceedings volume. 131–133.