Upper Carboniferous–Permian stratigraphy and fusulinids from the Anarak region, central Iran

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[1] The section of Upper Carboniferous (Gzhelian) and Lower Permian (Asselian–Sakmarian) sediments in the Anarak region of central Iran was first thoroughly studied. The sediments are subdivided into two units, the lower, 95-m-thick, significantly calcareous Zaladou Formation and the upper, 100-m-thick, dolomitic Tighe-Maadanou Formation. The formations are united in the Anarak Group separated from the under- and overlying deposits by stratigraphic hiatuses. The Zaladou Formation contains fusulinids from top to bottom. At the base they are represented by species characteristic equally of the uppermost Kasimovian and the lower zone of the Gzhelian. The middle Gzhelian species were encountered at 70 m above the base and still higher the typical uppermost Gzhelian forms referred to the Ultradaixina bosbytauensis Zone, occur. The upper 6 m of the section are assigned to the Asselian including its lower and middle zones. Dolomites of the Tighe-Maadanou Formation lack faunal remains. According to the position in the section they are referred to the uppermost Asselian and to the Sakmarian. The described section is similar to that in the Ozbak-Kuh Mountains north of Tabas, where the both formations of the Anarak Group are recognized. West of Tabas, in the Kalmard region, the Khan Formation can be correlated with the group; in the Alborz, the Dorud Formation; and in northern Zagros (Abadeh region), the Vazhnan Formation, respectively. The fusulinid assemblage recorded in the studied section includes 70 species referred to 21 genera and 12 families. They are illustrated in 10 paleontological plates. Seven new species and subspecies *Schwageriniformis acutatus, Rauserites stepanovi, R.* (?) *persicus, Rugosofusulina* (?) *iranica, R.* (?) *anarakensis, Ultradaixina bosbytauensis distincta, and Likharevites gracilis* are described. *INDEX TERMS:* 0999 Exploration Geophysics: General or miscellaneous; 1165 Geochronology: Sedimentary geochronology; 1705 History of Geophysics: Biogeosciences; *KEYWORDS:* Carboniferous, Permian, stratigraphy, fusulinids, Iran.

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Introduction

[2] The area of investigation is situated nearby a small town Anarak, between the Dashte Kavir Desert in the north and the Kuh Rud Range in the south, and occurs within the Yazd block, one of the large, curved to the west submeridional fault blocks recognized in the structure of central Iran (Figure 1). The Carboniferous and Permian sediments were discovered there during the geological survey conducted in the 1970s by geologists from the USSR under the contract with the Iran government. Findings of brachiopods, bryozoans, cephalopods, and foraminifers permitted the recognition of the Visean–Namurian, the nonidentified more precisely Carboniferous–Permian, and Lower and Upper Permian units. By analogy with the sections of eastern Iran [*Stepanov,* 1971; *Stöklin,* 1971], the Shishtu (Famennian–Namurian), Sardar (Carboniferous–lowermost Permian), and Jamal (Asselian–Upper Permian) formations were distinguished [*Sharkovski et al.,* 1984]. We started a thorough investigation of the discussed section few years ago.

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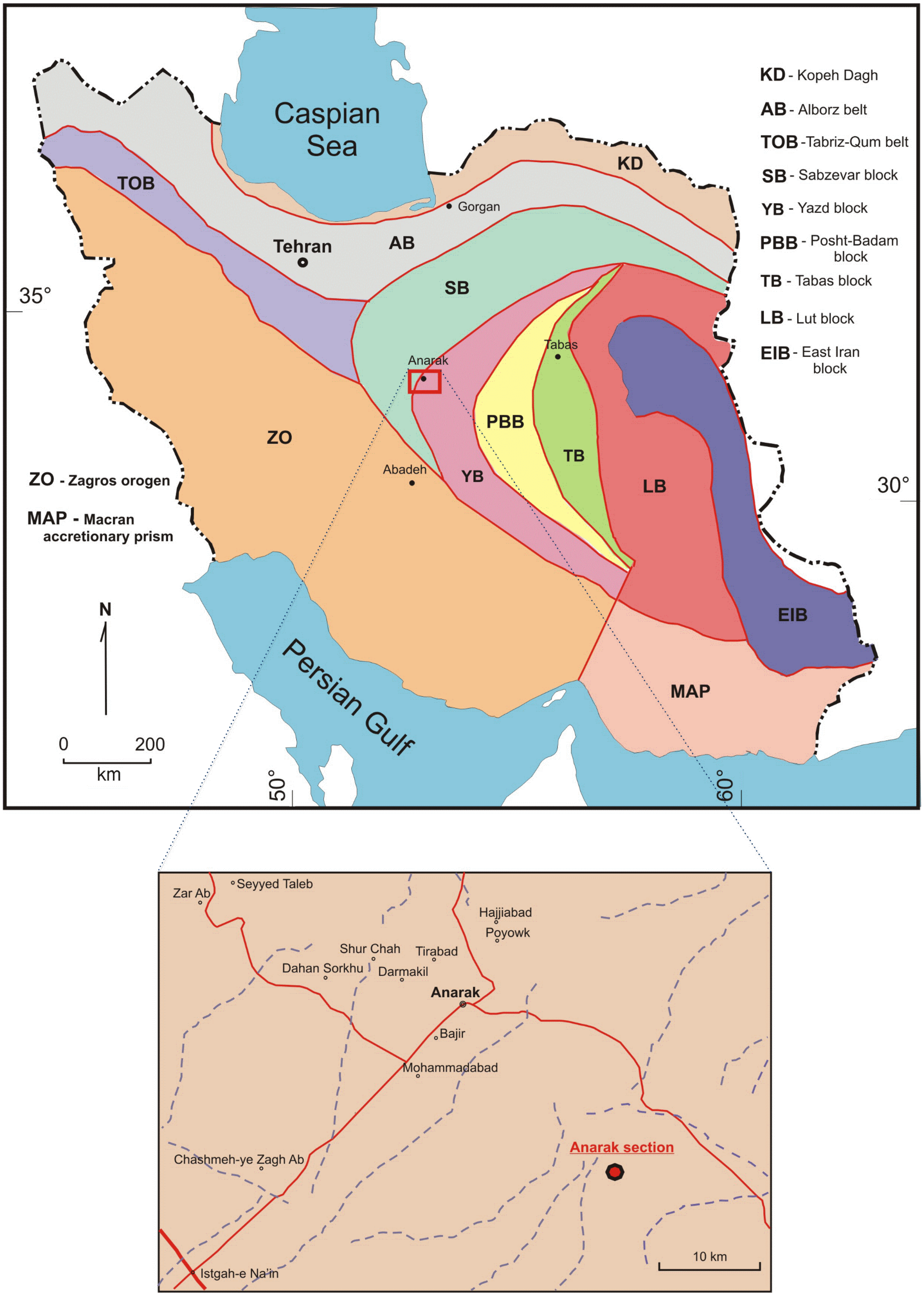


Figure 1. Area of investigation on the schematic tectonic map of Iran [*Alavi,* 1991].

Table 1. Generalized scheme of subdivision of the Carboniferous and Permian in Iran

SYST.	SUB SYST.	SERIES	STAGE	GROUP	FORMATION
PERMIAN	TETHYSIAN	Lopingian	Dorashamian	Shirgesht	Jamal
			Dzhulfian		
		Yangsingian	Midian		
			Murgabian		
			Kubergandian		
	CYSURALIAN	Darvasian	Bolorian		Baghe-Vang
			Yakhtashian	Hyatus	
		Uralian	Sakmarian	Anarak	Tighe-Maadanou
			Asselian		Zaladou
CARBONIFEROUS	PENNSYLVANIAN		Gzhelian		
			Kasimovian	Hyatus	
			Moskovian	Sardar	Absheni
			Bashkirian		Ghaleh
	MISSISSIPPIAN		Serpukhovian	Hyatus	
			Visean	Shishtu	Shishtu 2
			Tournaisian		Shishtu 1

In so doing a large stratigraphic hiatus was recorded within the Sardar Formation. Therefore it was subdivided into two separate units, namely, the Ghaleh (upper Serpukhovian?–Bashkirian) and Absheni (Moscovian) formations [*Leven et al.,* 2006]. The Gzhelian sediments were also recognized and united together with the Asselian rocks in the Zaladou Formation. It was believed that the Kasimovian Stage is missing in the section [*Leven and Gorgij,* 2006]. Upward from the base the new dolomitic, presumably Sakmarian, Tighe-Maadanou Formation was distinguished. It is overlain by the Upper Permian Jamal Formation and is separated from it by a thin sandstone and shale sequence conventionally correlated with the Baghe-Vang Formation of eastern Iran, which is referred to the Bolorian Stage. The Anarak section is in general very similar to those from eastern Iran, namely, from the Ozbak-Kuh Mountains, Shirgesht, and Shotori. This permits the proposition of a single scheme for subdivision of the Carboniferous and Permian in central and eastern Iran, where these sediments are subdivided into three groups and several formations [*Leven and Gorgij,* 2005] (Table 1).

[3] All the above reported age determinations of stratigraphic units were inferred from foraminifers, mainly fusulinids that occur throughout the section. Their comprehensive descriptions were made only for the Bashkirian and Moscovian stages [*Leven et al.,* 2006]. The first findings of the Gzhelian and Asselian fusulinids were also described [*Leven and Gorgij,* 2006]. This paper contains the characteristics of the Gzhelian (Kasimovian?)–Asselian part of the Anarak section referred to the Zaladou Formation, and of the encountered fusulinids twice collected by M. N. Gorgij. The samples numbered AC and P were collected initially, then followed by samples C. The relation of samples to the section is shown in Figure 2. Additionally, the samples PR,

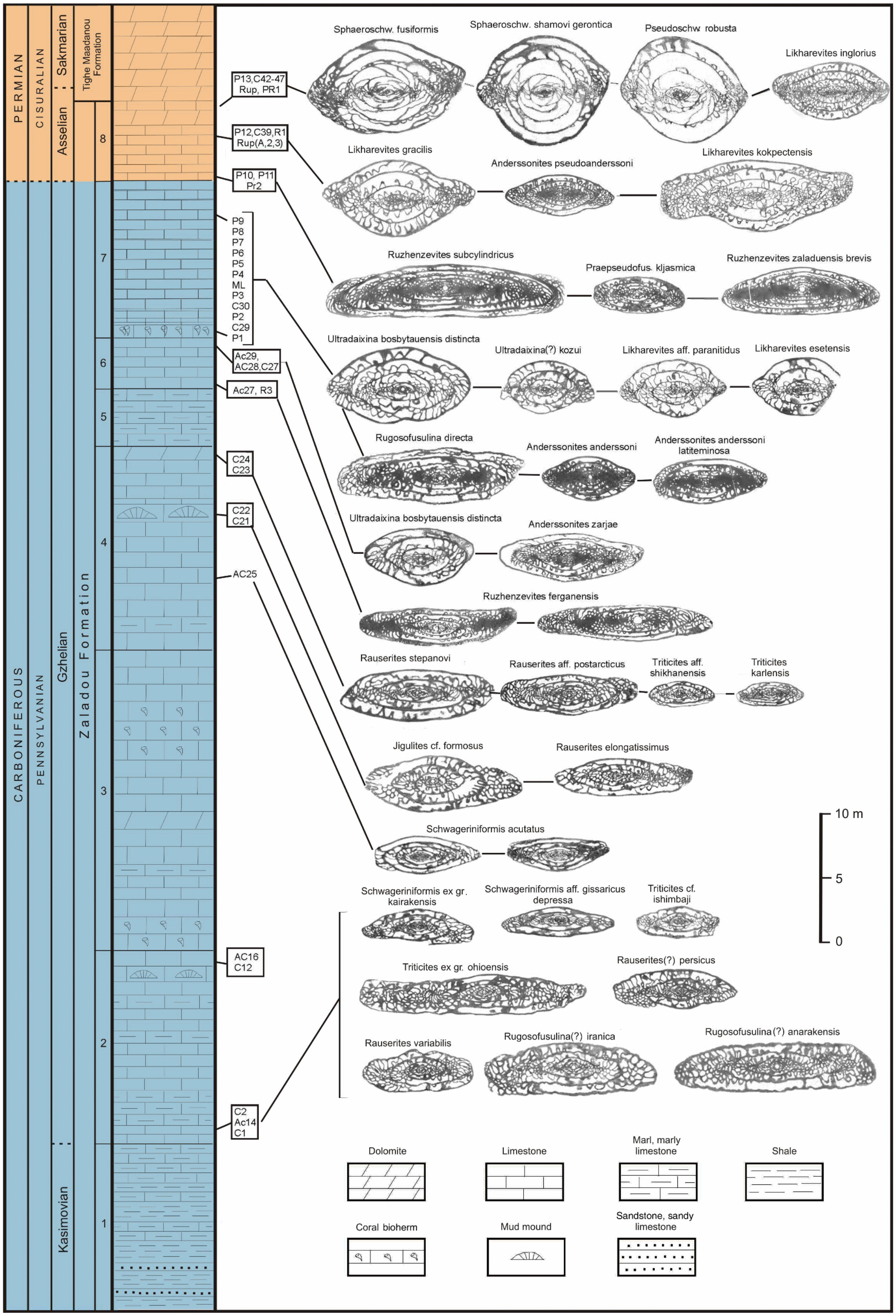


Figure 2. Stratigraphic column and fusulinid distribution.

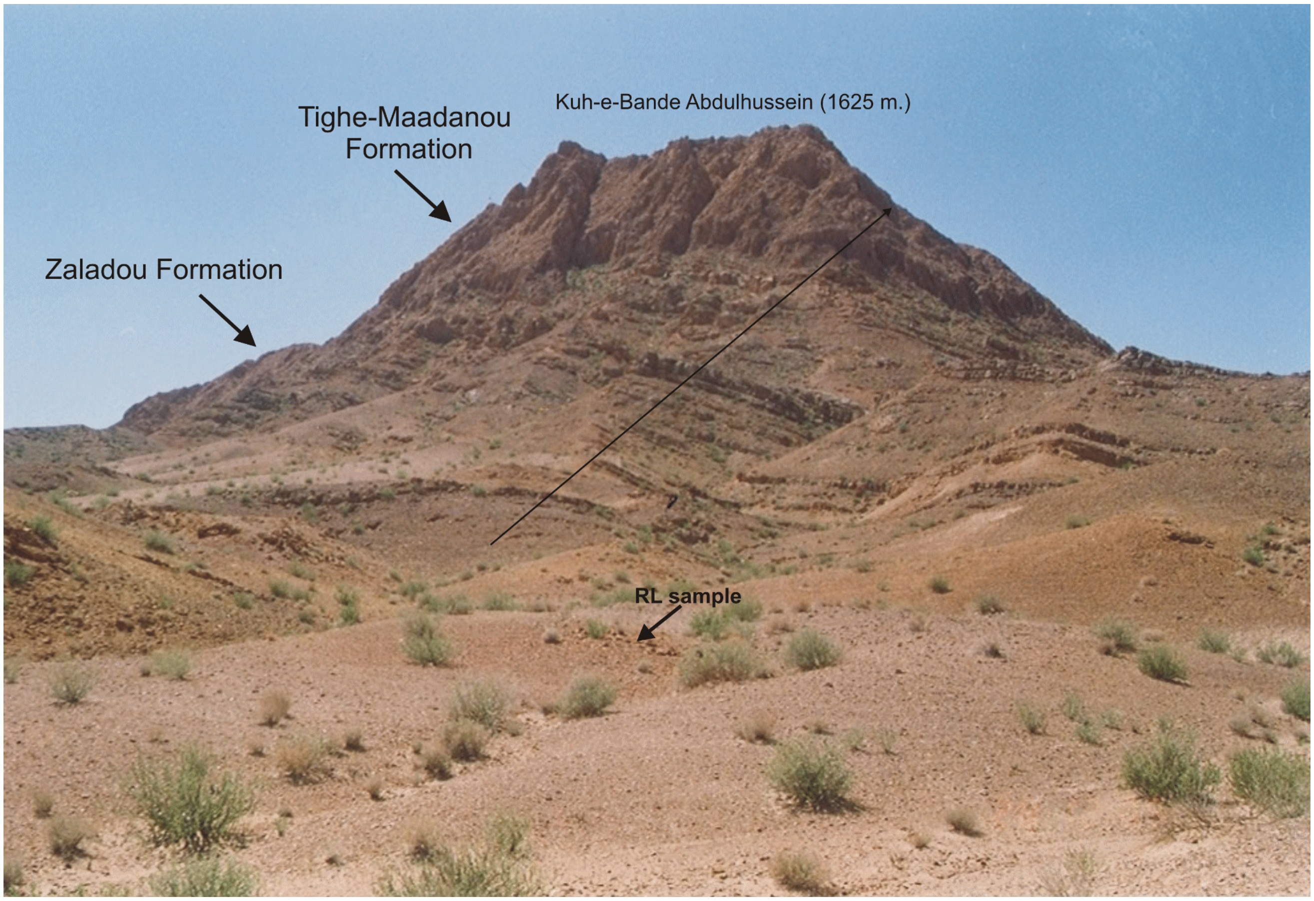


Figure 3. Anarak section.

R, RL, Rup, and ML were derived from certain outcrops. Their precise relation to the section is not assured though its degree is rather high, which is indicated by the involved fusulinids. Over 800 oriented thin sections bearing fusulinids were produced from the samples. They were described by E. Ja. Leven. The thin sections are deposited in the Laboratory of Micropaleontology in the Geological Institute, Russian Academy of Sciences under the number 4781.

Brief Characteristics of the Section

[4] The discussed section is located on the southern slope of Mount Kuh-e-Bande Abdulhussein, 1625 m high, about 25 km southeast of the Anarak town (Figures 1 and 3). At the base of the slope there is a small separate outcrop of limestone bearing the following fusulinids from the lower zone of the Gzhelian: *Schubertella* sp., *Ozawainella* sp., *Schwageriniformis* sp., *Triticites* aff. *ishimbaji, T.* ex gr. *simplex, T.* ex gr. *secalicus, T. nefandus, T.* aff. *samaricus, Rauserites rossicus, R.* ex gr. *postarcticus, R. variabilis, R. persicus, Rauserites* sp. 1, *Rugosofusulina* aff. *elliptica*, and *Rugosofusulina* sp. 1 (Sample RL). Upward the slope the limestone likely related to the Upper Permian Jamal Formation is recovered, which is evidenced by the involved small foraminifers *Geinitzina, Pachyphloia, Langella*, and others. Further upward from the base the uninterrupted sequence of limestones of the Zaladou Formation occurs (Samples AC9–P13 and C1–C47). The top of the mountain is composed by dolomites of the Tighe-Maadanou Formation.

[5] Below is a brief characteristics of the sequence of the Zaladou Formation (upward from the base).

[6] 1. Light grey clayey shale bearing beds of shaly, silty and sandy, biomicritic, biosparitic, and oobiosparitic limestone, rarer of coarse-grained sandstone. Numerous *Reitlingerina bradyi* and scarce, non-identified more precisely *Triticites* occur (Samples AC9–AC13). The total thickness is 15.5 m.

[7] The relationship of the member with the sediments located down the slope is unclear. Considering the probable relation of the latter to the Jamal Formation, the contact between them should be of tectonic origin. However, this was not recorded in describing the section.

[8] 2. Clotted, thin- or medium-bedded limestone (silty and sandy biosparite, oobiosparite, packstone, scarcely grainstone); small coral bioherms (Samples AC14–AC16, C1–C12). The limestones bear single corals, bryozoans, brachiopods, and fusulinids. Among the latter *Eostaffella* aff.

acuta, Seminovella ex gr. *carbonica, Eoschubertella obscura, Schubertella* sp., *Quasifusulina* sp., *Schwageriniformis* aff. *perstabilis, Sch.* ex gr. *kairakensis, Sch.* aff. *gissaricus depressa, Sch.* cf. *perlongus, Triticites* aff. *ishimbaji, T. globoides, T.* ex gr. *ohoiensis, Rauserites variabilis, R.* aff. *samaricus, R.* (?) *persicus, Rugosofusulina uralica, R.* (?) *iranica*, and *R.* (?) *elongata* were encountered at the base of the member (Samples AC14, C1, C2). The overlying sediments yield *Eostaffella* sp., *Eoschubertella obscura, Reitlingerina* aff. *tachtavica* (Sample AC16), and fragments of ferruginated and likely redeposited *Schubertella* ex gr. *kingi, Schwageriniformis (Tumefactus)* sp., *Montiparus* (?) sp., *Triticites* sp., and *Pulchrella* sp. (Sample C12). The thickness is 16.5 m.

[9] 3. Grey medium- and coarsely bedded limestone (biomicritic or dismicritic packstone) with two thick beds, at the base and in mid-member, of coral prereef breccia (boundstone) (Samples AC17–AC21, C13–C16). Fusulinids are missing. The total thickness is 22.3 m.

[10] 4. Grey, brownish, coarsely bedded, in places dolomitized limestone (biomicritic or sparitic, sometimes oomicritic packstone, rarer grainstone and rudstone) (Samples AC22–AC26, C17–C24). Small mud mounds of algae-fusulinid limestone occur in the upper part. The limestones of the member are mostly poor in organic remains, however, certain beds are overfilled with fusulinids. One of them is in the middle part of the member and contains numerous *Schwageriniformis acutatus* n. sp. (Sample AC25). The limestone mud mounds located slightly above yield *Rauserites elongatissimus, R.* cf. *erraticus*, and *Jigulites* cf. *formosus* (Samples C20–C24). *Reitlingerina bradyi, Triticites* aff. *shikhanensis, Rauserites* aff. *postarcticus, R. karlensis*, and *R.* (?) *stepanovi* were found nearby the top of the member (Samples AC22–AC26). The total thickness is 15.6 m.

[11] 5. Rose-colored marl, 4.3 m thick.

[12] 6. Light grey, brownish, medium bedded limestone (biomicritic and biosparitic floatstone and rudstone) bearing numerous fusulinids and fragments of bryozoans, crinoid columns, algae, corals, and echinoid spines. At the base the limestone is overfilled with *Ruzhenzevites ferganensis* (Samples AC27 and R-3). The overlying beds contain *Reitlingerina* sp., *Anderssonites* aff. *zarjae, A.* aff. *nanus, U. bosbytauensis distincta*, and *Ultradaixina* (?) aff. *kozui* (Samples AC28, AC29, and C27). The thickness is 3.7 m.

[13] 7. Grey, medium- and coarsely bedded, in places dolomitized, ferruginated and recrystallized algae-fusulinid limestone (biosparitic wackestone, packstone, occasionally floatstone); coral bioherms at the base of the member. Small foraminifers, brachiopod valves, and bryozoans occur together with fusulinids and algae. Among fusulinids *Eostaffella* sp., *Schubertella* sp., *Ozawainella* (?) sp., *Ultradaixina bosbytauensis distincta, U. kosvaensis, U.* (?) *kozui, Likharevites esetensis, L.* aff. *paranitidus, Anderssonites anderssoni, A. pseudoanderssoni latiterminosa, A. paraanderssoni,* and *A. nanus* were identified; nearby the top *Rugosofusulina directa* and *R. mutabilis* were recorded (Samples P1–P9, C29, C30, ML, and others). The thickness is 11.4 m.

[14] 8. Algae-fusulinid limestone analogous to that of Member 7. In the lower part fusulinids *Sphaeroschwagerina* sp., *Ruzhenzevites subcylindricus, R. zaladuensis zaladuensis, R. zaladuensis brevis*, and *Praepseudofusulina kljasmica* were found (Samples P10, P11). The overlying beds yield *Eoschubertella* sp., numerous *Likharevites gracilis*, and *L. kokpectensis* and *Pseudofusulina* aff. *conspiqua* (Samples C38, C39, P12, R1, R2, RupA, Rup2, Rup3). The uppermost beds contain *Schubertella* sp., *Boultonia* sp., *Ozawainella* sp., *Quasifusulina longissima, Rugosofusulina* cf. *directa, Likharevites inglorius, Pseudoschwagerina* ex gr. *extensa, Ps. robusta, Ps.* sp. n., *Sphaeroschwagerina shamovi primitiva, Sph. shamovi gerontica, Sph. pavlovi, Sph.* ex gr. *sphaerica, Sph. moelleri, Sph. notabilis, Sph. ellipsoidalis, Sph. fusiformis, Pseudofusulina* (?) *narjanmarica, Rugosochusenella paragregaria*, and *Praeskinnarella* (?) *huangchuigouensis* (Samples P13, Rup, C42–C47, PR1). The thickness is 5.85 m.

[15] The total (incomplete) thickness of the Zaladou Formation is 95 m.

[16] The Zaladou Formation grades into the dolomitic Tighe-Maadanou Formation of about 80–100 m thick. It is overlain by the 8–10-m-thick loose quartz sandstone and the 2-m-thick shaly argillite. The latter is sharply unconformably overlain by the limestone Jamal Formation that bears the Upper Permian fusulinids (*Staffella, Nankinella*, and *Chusenella*) and small foraminifers, which are going to be described later.

Analysis of Foraminiferal Assemblages and Age Determination of the Sediments

[17] The discussed section is strongly unevenly characterized by foraminifers. They mainly occur in the upper portion of the sequence.

[18] Fusulinids from Member 1 are mostly represented by *Reitlingerina bradyi*, a species of wide stratigraphic range from the Bashkirian of the Upper Carboniferous to the Permian inclusive. Additionally we encountered several poorly preserved, likely *Triticites* tests chiefly ranging from the uppermost Kasimovian to the Gzhelian (Late Carboniferous).

[19] A significantly richer fusulinid assemblage was found at the base of Member 2. It includes 9 genera and 18 species. Most of the encountered species are endemics and their identification with the known forms is difficult. The species of *Triticites* and *Rauserites* are most similar to that of the uppermost Kasimovian Triticites quasiarcticus–Tr. acutus Zone and of the lowermost Gzhelian Rauserites rossicus–R. stuckenbergi Zone. One of the three species *Rugosofusulina* (*R. uralica*) was described by *Mikhailova* [1967] from the lowermost Gzhelian in the Northern Urals. Two other, which assignment to *Rugusofusulina* is doubtful, resemble *"Triticites arcticus"* and *Rugosofusulina scaphulaeformis* described by G. P. Zolotukhina from the upper zone of the Kasimovian in the southern East European Platform. The *Schwageriniformis* species indicate the same age. For instance, *Sch. perstabilis* is characteristic of

the Kasimovian and Gzhelian of the Caspian syneclise [*Scherbovich,* 1969]. The rest forms were described by *Bensh* [1969, 1972] from the upper Kasimovian beds of the southern Gissar and southern Fergana region. However, according to V. I. Davydov (personal communication), in southern Fergana the *Schwageriniformis* forms referred by Bensh to the Kasimovian, were recorded in the lower part of the Uchbulak Horizon together with the Gzhelian ammonoids [*Popov et al.,* 1989].

[20] Based on the reported data the age of the discussed assemblage can be roughly estimated as the latest Kasimovian and earliest Gzhelian. According to the general development of *Triticites* and *Rauserites*, it is similar to the association derived from the isolated limestone outcrop located on the slope downward from the base of the above-discussed section (Sample RL). Among its forms *Rauserites rossicus*, the index species of the Gzhelian lower zone, occurs. The concurrent fusulinids more likely confirm the early Gzhelian age of the sediments than contradict it. We are not aware to what part of the described section the *R. rossicus*-bearing limestone corresponds. Most likely it is close to the base of Member 2. If so, the assemblage from its lower part is Gzhelian as well. In that case the question of the presence of the Kasimovian sediments in the section remains open. True, the upper portion of Member 2 contains the Kasimovian-like fusulinids, as *Schwageriniformis (Tumefactus), Montiparus* (?), and *Pulchrella*. However, these identifications are not quite reliable owing to a poor preservation of the forms. Additionally all of them have traces of redeposition.

[21] Member 3 lacks fusulinids. They occur in the middle of Member 4 and are represented there by *Schwageriniformis acutatus*, the new species similar to the forms encountered by V. I. Davydov in the uppermost Gzhelian of Darvaz and the Chios Island, Greece (personal communication). Although the species differs in lesser number of whorls and accordingly in smaller size, its Gzhelian age is beyond question. Fusulinids from the upper portion of Member 4 are also estimated as Gzhelian. The species *Triticites shikhanensis, Rauserites erraticus, R. elongatissimus*, and *R. postarcticus* are characteristic of the lower zone of the Gzhelian in the East European Platform and the South Urals. However, the concurrent occurrence of *Jigulites* cf. *formosus* suggests the successive, Jigulites jigulensis Zone of the Gzhelian.

[22] Marls of Member 5 are barren of fusulinids. *Ruzhenzevites ferganensis* encountered immediately above, at the base of Member 6, is known in Central Asia in the uppermost Gzhelian, beginning at the beds correlated with the Daixina sokensis Zone of the East European sections [*Bensh,* 1972; *Davydov,* 1986]. *Anderssonites* and *Ultradaixina* first occur in the upper portion of Member 6. The former is characteristic of the lower zone of the Asselian in a great deal of East European sections but first occurs in the uppermost Gzhelian Ultradaixina bosbytauensis Zone. Precisely this zone is indicated by the latter genus that is represented by the new subspecies of the index form and by the Indo-Chinese species described by *Deprat* [1914] as *Fusulina kozui*, which is transitional between the typical *Ultradaixina* and the genus *Likharevites*.

[23] The assemblage of Member 7 differs from the previous one in a greater number of diverse *Anderssonites* forms and in the *Likharevites* first occurrence. The species *L. esetensis* and *L. paranitidus* are known in the South Urals and northern Fergana region, where they are associated with the beds underlying the Asselian. This fact and the presence of *Ultradaixina bosbytauensis distincta* indicate that the discussed assemblage should be referred to the U. bosbytauensis Zone, i.e. it is still Gzhelian. It is not therewith improbable that the uppermost part of Member 7 is referred to the Asselian.

[24] Member 8 is undoubtedly of Asselian age, which is evidenced by the finding of *Sphaeroschwagerina* at its very base. Despite a small (under 6 m) thickness of the bed, three significantly distinct fusulinid assemblages can be recognized in it. The first one in addition to few *Sphaeroschwagerina* includes *Praepseudofusulina kljasmica, Ruzhenzevites subcylindricus, R. zaladuensis zaladuensis* and *R. zaladuensis brevis.* The former species is characteristic of the uppermost Gzhelian and the lower zone of the Asselian in the East European Platform and Darvaz. *R. subcylindricus* was described from the Asselian of the southern Fergana region. Both subspecies of *Ruzhenzevites* were recorded in the Asselian part of the Zaladou Formation in the Ozbak-Kuh Mountains, eastern Iran.

[25] The second assemblage mainly includes numerous *Likharevites gracilis* and scarcer *L. kokpectensis* and *Anderssonites pseudoanderssoni.* *L. gracilis* is the new species and it is hard to judge of its age. However, it is similar to the form described as *Paraschwagerina acuminata uralensis* from the lower half of the Asselian in the Nikol'skii section of the South Urals [*Rauzer-Chernousova and Scherbovich,* 1949]. *L. kokpectensis* is known from the Caspian and southern Fergana sediments correlated with the middle zone of the Asselian in the Urals [*Bensh,* 1972; *Scherbovich,* 1969].

[26] The latter assemblage recorded in Member 8 is typical just for that zone. This is evidenced by the occurrence of numerous *Sphaeroschwagerina*, namely, *Sph. shamovi, Sph. moelleri*, and *Sph. pavlovi*, and of characteristic species of *Pseudoschwagerina* and *Likharevites.*

[27] The dolomitic Tighe-Maadanou Formation lacks faunal remains. Its late Asselian–Sakmarian age is indicated by the position in the section above the beds bearing the middle Asselian fusulinids. Recall that limestones of the Zaladou Formation grade into the dolomites.

Correlation

[28] *Eastern Iran.* In eastern Iran the sediments synchronous to that discussed above were reliably recorded only in the Ozbak-Kuh Mountains of the Tabas region, where the Zaladou Formation was first recognized [*Leven and Taheri,* 2003]. The formation is subdivided there into two parts. The 50-m-thick lower unit is mainly composed of terrigenous sediments bearing few faunal remains. Its age is conventionally estimated as Kasimovian–early Gzhelian. The overlying 35-m-thick part of the formation is carbonate in composition. Fusulinids were encountered in the upper 15 m of the section. This faunal bed yields in its lower part *Ruzhenzevites*

Table 2. Correlation of the Anarak section with the most well-studied Upper Carboniferous and Permian sequences of Iran

System	Subsyst.	Series	Stage	Anarak	Shirgesht	Ozbak-Kuh	Alborz	Kalmard	Zagros
PERMIAN	TETHYSIAN	LOPINGIAN	Dorashamian						HAMBAST FORMATION *Reichelina* sp., *Codonofusiella* sp.
			Dzhulfian	Shirgesht Group: JAMAL FORMATION	JAMAL FORMATION *Paradoxiella insueta*, *Reichelina pulchra*, *Colaniella parva*	JAMAL FORMATION	NESSEN FORMATION *Reichelina* sp. *Palaeofusulina* sp.		
		YANGSINGIAN	Midian				*Pseudodoliolina ozawai*		ABADEH FORMATION *Yabeina globosa*; SURMAQ FORMATION
			Murgabian		*Neoschwagerina* sp., *Sumatrina* sp.		RUTEH FORMATION		*Neoschw. margaritae*; *Eopolydiexodina persica*
			Kubergandian		*Mesogondolella siciliensis*		*Armenina* sp., *Neofusulinella* sp.		*Cancellina cutalensis*; *Armenina salgirica*, *Misellina ovalis*
	CYSURALIAN	DARVASIAN	Bolorian	?	BAGHE-VANG FORMATION *Armenina urtzensis*; *Misellina parvicostata*, *Mis. (B.) dyhrenfurthi*; *Pamirina darvasica*	?	?		*Darvasites ordinatus*, *Chalaroschw.* cf. *mengi*
			Yakhtashian						
		URALIAN	Sakmarian	Anarak Group: TIGHE-MAADANOU FM.	UNNAMED FORMATION	TIGHE-MAADANOU FM.	DORUD FORMATION *Sphaeroschw. shamovi*, *Pseudoschw. beedei*	KHAN FORMATION *Eoparafusulina* sp., *Pseudofusulina* (?) sp.	VAZHNAN FORMATION
			Asselian	ZALADOU FORMATION *Sphaeroschw. moelleri*, *Likharevites gracilis*	*Conglomerate, sandstone, limestone interbeds*	ZALADOU FORMATION *Pseudoschw. uddeni*			*Pseudoschwagerina* sp.
CARBONIFEROUS	PENNSYLVANIAN		Gzhelian	*Ultradaixina bosbytauensis*, *Ruzhenzevites ferganensis*, *Jigulites* cf. *formosus*, *Rauserites rossicus*		*Ruzhenzevites ferganensis*, *Rauserites elongatissimus*, *R. samaricus*			
			Kasimovian						
			Moskovian	Sardar Gr.: ABSHENI FORMATION *Fusiella typica*, *Putrella persica*, *Aljutovella cafirniganica*	SARDAR GROUP	ABSHENI FORMATION *Putrella donetziana*, *Aljutovella cafirniganica*	GHESELGALEH FORMATION *Fusulinella mosquensis*, *Aljutovella tikhonovichi*		*Ozawainella mosquensis*
			Bashkirian	GHALEH FORMATION *Profusulinella parva*, *Pseudostaffella compressa*		GHALEH FORMATION *Pseudost. paracompressa*, *Plectost. bogdanovkensis*	*Profusulinella primitiva*, *Pseudostaffella antiqua*, *Plectostaff. varvariensis*		

ferganensis and numerous *Rauserites* including the characteristic Gzhelian forms. The upper 5 m of the section contain *Pseudoschwagerina*, the genus typical for the middle zone of the Asselian. Limestones of the Zaladou Formation are overlain by the dolomite sequence over 100 m thick.

[29] In the Anarak section the terrigenous portion of the Zaladou Formation is missing, probably cut by the fault. The Gzhelian–Asselian Anarak limestone is as a whole correlated with the carbonate portion of the Zaladou Formation in the Ozbak-Kuh section. In both sections the beds bearing the upper Gzhelian *Ruzhenzevites ferganensis*, and the overlying layers with the Asselian *Pseudoschwagerina* are recorded in the upper part of the limestone sequence (Table 2). Also in both sections these beds are extremely thin (15–20 m) and embrace two or three Gzhelian and two Asselian fusulinid zones. It is hardly the result of a low sedimentation rate, which is evidenced by the occurrence of coarsely detritic facies of fusulinid limestone, from a wackestone to rudstone. The most likely reason is the short-term, nonidentified hiatuses that are quite probable considering the shallow character of the limestones. This inference is indirectly confirmed by frequently occurring sharp differences between fusulinid assemblages in adjacent beds without any succession.

[30] In both the Anarak region and Ozbak-Kuh Mountains the Zaladou limestones are overlain by dolomites that we distinguish as the Tighe-Maadanou Formation. These units make up the Anarak Group. The latter unconformably overlies the Moscovian Absheni Formation and is also unconformably overlain by the Bolorian–Upper Permian Shirgesht Group [*Leven and Gorgij,* 2006; *Leven et al.,* 2006]. All these facts underline the similarity of the discussed sections and indicate that at least in the second half of the Carboniferous and in the Permian the sedimentary sequences in the studied areas were accumulated in a single basin with like conditions of sedimentation. In the current structure these regions are referred to the different, namely, Yazd (Anarak region) and Tabas (Ozbak-Kuh region), fault blocks (Figure 1).

[31] The Carboniferous–Permian sections in the Shotori Mountains are also referred to the Tabas block. The sediments in part or completely synchronous to the Zaladou and Tighe-Maadanou formations, i.e. to the Anarak Group, are likely represented there by a white quartz sandstone sequence, 60 m thick, that occurs between the shaly Sardar Group and the Jamal Formation's limestone and is separated by stratigraphic unconformities. The unconformity at the base of the quartz sandstone is underlined by the presence of coal beds.

[32] The sediments that can be referred to the Anarak Group are recorded in the Pashte-Badam block (Kalmard region) west of the Tabas block. According to *Arefifard and Davydov* [2004] and to our observations, they are represented by the 300-m-thick Khan Formation composed of interbedded conglomerates, quartz sandstones, shales, and limestones. Fusulinids derived from the middle and upper portions of the section indicate the Asselian and Sakmarian age. The lower part of the formation is probably Gzhelian or Kasimovian, which is evidenced by the findings of *Ferganites* and *Daixina*, not related to the section [*Kahler,* 1977].

[33] *Alborz.* The analogue of the Anarak Group in the central and eastern Alborz is the Dorud Formation distinguished by *Assereto* [1963]. In the type section north of Teheran he subdivided it into four parts. Subsequently *Bozorgnia* [1973] separated its lowest part as the Dozdeband Formation based on findings of the Visean–Serpukhovian conodonts and Bashkirian foraminifers [*Ahmadzadeh,* 1971; *Bozorgnia,* 1973]. According to our preliminary data, the Dozdeband Formation includes the Moscovian sediments as well. If this will be confirmed, the formation can be correlated with the Sardar Group of the central and eastern Iran, whereas the Anarak Group will correspond to Beds 2–4 of the Dorud Formation in its initial interpretation. The age of the Dorud Formation is commonly estimated as the Asselian–Sakmarian or even Asselian–Artinskian. In so doing the records by *Kahler* [1976] are cited. In the middle of the formation (Bed 3 after Assereto) he encountered the Asselian *Pseudoschwagerina* and numerous fusulinids that he referred to different species of the Lower Permian, including the Artinskian, *Triticites* and *Pseudofusulina*. These species are closely similar and certain of them actually resemble the Sakmarian and Yakhtashian Darvazites. However, they are no less related to *Praepseudofusulina* reported from a great deal of Asselian sections, including the Anarak section discussed in this paper.

[34] Unlike the central Iran sections, where the Dorud Formation includes sandstone beds, in the eastern Alborz, namely, in the Gheselghaleh section nearby Gorgan, it is mainly composed of limestone. Its age without the proper substantiation, mostly based on the geologic position and by analogy with the western sections, was determined as the middle Asselian–Sakmarian [*Lys et al.,* 1978]. The limestone is overlain by dolomites of the Kuh-e-Sariambar Formation presumably dated as the Artinskian and Kubergandian. In our opinion, considering the records on the Anarak and Ozbak-Kuh sections, both units correspond to the Zaladou and Tighe-Maadanou formations, i.e. to the Anarak Group. The additional collections of fossils in the Gheselghaleh section will permit the more valid conclusion.

[35] *Zagros.* The stripe of mainly Upper Permian sediments stretching along the Shahreza-Abadeh-Hambast Range is commonly referred to central Iran. However, they strongly differ from the deposits of the Anarak section primarily in a greater abundance and diversity of fusulinids, among which the *Eopolydiexodina* members dominate. In this regard they are similar to the sections described from certain Zagros regions. Undoubtedly the Late Permian basin located in the modern Zagros area differed in environmental conditions from the basin that occupied central and eastern Iran and Alborz. These basins were likely separated from each other, which explains the above- mentioned difference in benthic fauna. It is not, however, improbable that the basin was single though relatively deeper in the northern part, where the Late Permian benthic biota was oppressed and did not evolve.

[36] The sediments that can be correlated with the Anarak Group were studied by *Baghbani* [1993] in the vicinity of Shahreza town, in the Tang-e-Darchaleh section. They were distinguished as the Vazhnan Formation represented by the 142-m-thick variegated interbedded sandstone and limestone sequence. Bearing the basal conglom-

erates at its base the formation overlies the Moscovian sediments yielding *Ozawainella mosquensis* and with no visible unconformity but with a probable hiatus is overlain by limestones of the Surmaq Formation that bears the Kubergandian fusulinids slightly above its base. The lower portion of the Vazhnan Formation contains the Asselian *Pseudoschwagerina* and Sakmarian *Robustoschwagerina*. Based on this fact Baghbani estimated the age of the formation as the Asselian–Sakmarian. However, on the photos in his paper the forms identified as *"Robustoschwagerina"* possess distinct septal flutings, which are not characteristic of this genus as its septa are completely straight. Thus we assign these forms to *Pseudoschwagerina*; if so, the Sakmarian age of the sediments is not proved. However, considering that *Pseudoschwagerina* and *"Robustoschwagerina"* were found at the base of the formation, the assignment of its upper part to the Sakmarian cannot be excluded. In that case the Vazhnan Formation can be correlated with the Asselian–Sakmarian portion of the Anarak Group and we can state that despite the relation of the discussed sections to different biogeographic provinces, they are characterized by the same transgressive–regressive cycle of sedimentation in the time span between the Moscovian and Kubergandian (Bolorian–Kubergandian) ages.

[37] In a vast territory of southern Iran from Luristan on the west to Iranian Baluchistan on the east the *Sigillaria persica*-bearing sandstone that overlies various horizons of the Lower Paleozoic and is transgressively overlain by the Upper Permian limestones, most likely corresponds to the Vazhnan Formation.

Conclusions

[38] The major results of our investigation can be summarized as follows.

[39] 1. The Anarak section is nowadays the most complete and well-studied among the Gzhelian and Asselian sequences that are known in Iran. The Gzhelian Stage is represented there in a full range; the Asselian, by two lower fusulinid zones. The uppermost Asselian is likely characterized by dolomite facies and lacks fauna.

[40] 2. Despite certain peculiarities, the Gzhelian and Asselian fusulinid assemblages of the discussed section are quite correlative with that from classic East European sections and from sequences located in the Tethian northern margin, namely, in the Carnic Alps, Fergana, and Darvaz. This indicates the occurrence of free connections between the basin in central and eastern Iran and Alborz and the major Paleotethys basin.

[41] 3. The single Gzhelian–Sakmarian (Kasimovian?–Sakmarian) sedimentation cycle is recorded in the territory of Iran. The sediments of the Anarak Group accumulated during that time – continental on the south (Zagros) and shallow marine on the north (central and eastern Iran and Alborz) – overlie the Sardar Group and older deposits and are overlain by the Shirgesht Group with stratigraphic but not angular unconformities.

[42] 4. The attribution of the Shahreza-Abadeh-Hambast region to central Iran is controversial, as the biofacies peculiarities of the Upper Permian sediments distributed there indicate that they are more similar to the synchronous sediments of Zagros than to those from central and eastern Iran and Alborz.

Systematic Descriptions

[43] The described fusulinid collection is sufficiently numerous and diverse, which primarily results from a significantly large studied interval spanning the whole Gzhelian and most of the Asselian Stage. At the same time the small size of the available samples and poor preservation of some shells do not permit the complete enough characteristics of the fusulinid assemblages in certain beds and the reconstruction of their evolution. The Iranian fusulinids are still extremely poorly studied. Therefore, their species identification is significantly difficult, since we have to be oriented to fusulinids from other than central Iran biogeographic provinces. This results in incompletely reliable certain species identifications that we are led to give in an open nomenclature, which in turn produces the non-confident age determinations. Many specimens by convention referred to certain known forms, should be likely recognized as separates species. However, the limited amount of material generally prevents from doing it.

[44] In the discussed part of the section we identified 70 fusulinid species referred to 21 genera and 12 families. Among them six species and one subspecies are new. They are described below (Plates 1–10).

Genus *Schwageriniformis* Bensh, 1996
Subgenus *Schwageriniformis* Bensh, 1996

Schwageriniformis (*Schwageriniformis*) *acutatus* Leven, n. sp.
Plate 1, figs 23, 25, 27, 28

[45] **Etymology.** *Acutatus* – acutate (Lat.).

[46] **Holotype.** GIN 4781/20. Axial section; Iran, Anarak, Zaladou Formation, Sample AC-25; Late Carboniferous (Pennsylvanian), Gzhelian.

[47] **Material.** 9 axial and subaxial sections.

[48] **Description.** Shell moderate in size, slender fusiform, with straight to slightly convex lateral slopes and acutely pointed poles. Mature shells have 7 to 8 whorls and measure 3.5 mm to 4.8 mm in length and 1.3 mm to 1.6 mm in diameter; form ratio 2.7 to 3. First 3 to 4 whorls make up tightly coiled juvenarium, which is followed by loosely coiled adult stage. Thin in inner 4 to 5 volutions and thick in following ones spirothesa composed of tectum and thin alveolar keriotheca, its thickness in last whorl 0.06 mm to

0.07 mm. Septa essentially plane across middle of shell, becoming moderately fluted near poles. Proloculus small, its outside diameter 0.04 mm to 0.05 mm. Tunnel about half as high as chambers, narrow in the juvenarium, significantly widening outwards. Low and narrow chomata developed in early 4 to 5.5 volutions.

[49] **Discussion.** *Schwageriniformis acutatus* n. sp. is very similar to *Schwageriniformis schwageriniformis* (Rauser-Chernousova) characteristic of the upper zone of the Kasimovian and, to a lesser degree, of the lower zone of the Gzhelian in a great deal of sections of the East European Platform, Urals, and Central Asia. The Iranian species differs in a stronger isolated juvenarium and smaller chomata. The forms similar to *Schwageriniformis acutatus* were recorded by V. I. Davydov in the uppermost Gzhelian of the Darvaz region and Chios Island, Greece (personal communication). However, they possess a greater number of whorls and greater size, which indicates their relatively advanced character.

[50] **Occurrence and age.** The same as holotype.

Genus *Rauserites* Rozovskaya, 1950

Rauserites stepanovi Leven, n. sp.
Plate 4, figs 5, 7, 8

[51] **Etymology.** The species named in honor of Professor D. L. Stepanov, the outstanding investigator of the Carboniferous and Permian of Iran.

[52] **Holotype.** GIN 4781/62. Subaxial section; Iran, Anarak, Zaladou Formation, Sample C23; Carboniferous, Pennsylvanian, Gzhelian.

[53] **Material.** 5 axial and subaxial sections.

[54] **Description.** Shell small, fusiform, with bluntly rounded poles. Mature shell has 5 to 5.5 volutions and measures 4.9 mm to 6.3 mm in length and 1.7 mm to 2.2 mm in diameter; form ratio 2.7 to 2.9. First 3 to 3.5 whorls rather tightly coiled, after which coiling becomes loose. Spirotheca composed of tectum and moderately coarse keriotheca, 0.07 mm to 0.08 mm thick in last whorl. Septa rather strongly and very irregularly fluted from pole to pole. Septal folds high and wide. Proloculus moderately sized, its outside diameter 0.125 mm. Tunnel low and wide. Chomata weak, present only on proloculus and in 2 or 3 inner whorls. Axial filling is absent.

[55] **Discussion.** *Rauserites stepanovi* n. sp. is the most similar to *"Triticites" tabinicus* Alksne from the boundary Kasimovian and Gzhelian sediments of the Urals, but differs in a more elongated shell, particularly in the inner whorls, and in a more uniform coiling.

[56] **Occurrence and age.** The same as holotype.

Rauserites (?) *persicus* Leven, n. sp.
Plate 3, figs 7–9

[57] **Etymology.** The species name derived from the ancient name of Iran – Persia.

[58] **Holotype.** GIN 4781/52. Axial section; Iran, Anarak, Zaladou Formation, Sample AC14; Carboniferous, Pennsylvanian, late Kasimovian (?) or early Gzhelian.

[59] **Material.** 3 axial sections.

[60] **Description.** Shell small, fusiform, with straight to slightly convex lateral slopes and bluntly pointed poles. Adult individuals have 4.5 to 5 volutions and measure 4.5 mm to 5.3 mm in length and 1.5 mm to 1.9 mm in diameter; form ratio 2.7 to 3.3. Irregular undulated spirotheca composed of tectum and fine textured keriotheca; thickness in last whorl 0.6 mm to 0.8 mm. First 1 or 2 whorls rather tightly coiled but later ones looser. Septa rather strongly fluted from pole to pole. Septal folds irregular, high, usually reaching tops of septa. Proloculus small, its outside diameter 0.05. Tunnel narrow and poorly observed. Chomata weak, present only on proloculus and in first one or two whorls.

[61] **Discussion.** The species differs from all the *Rauserites* members in a small proloculus; irregular coiling, tight in the initial whorls and looser in the last whorl; and in weakly developed chomata. The attribution of our species to *Rauserites* is not obvious, however, it cannot be referred with enough reason to any other known genus.

[62] **Occurrence and age.** Iran, Anarak, Zaladou Formation, Samples AC14 and RL; Pennsylvanian, late Kasimovian(?)–early Gzhelian.

Genus *Rugosofusulina* Rauser-Chernousova, 1937

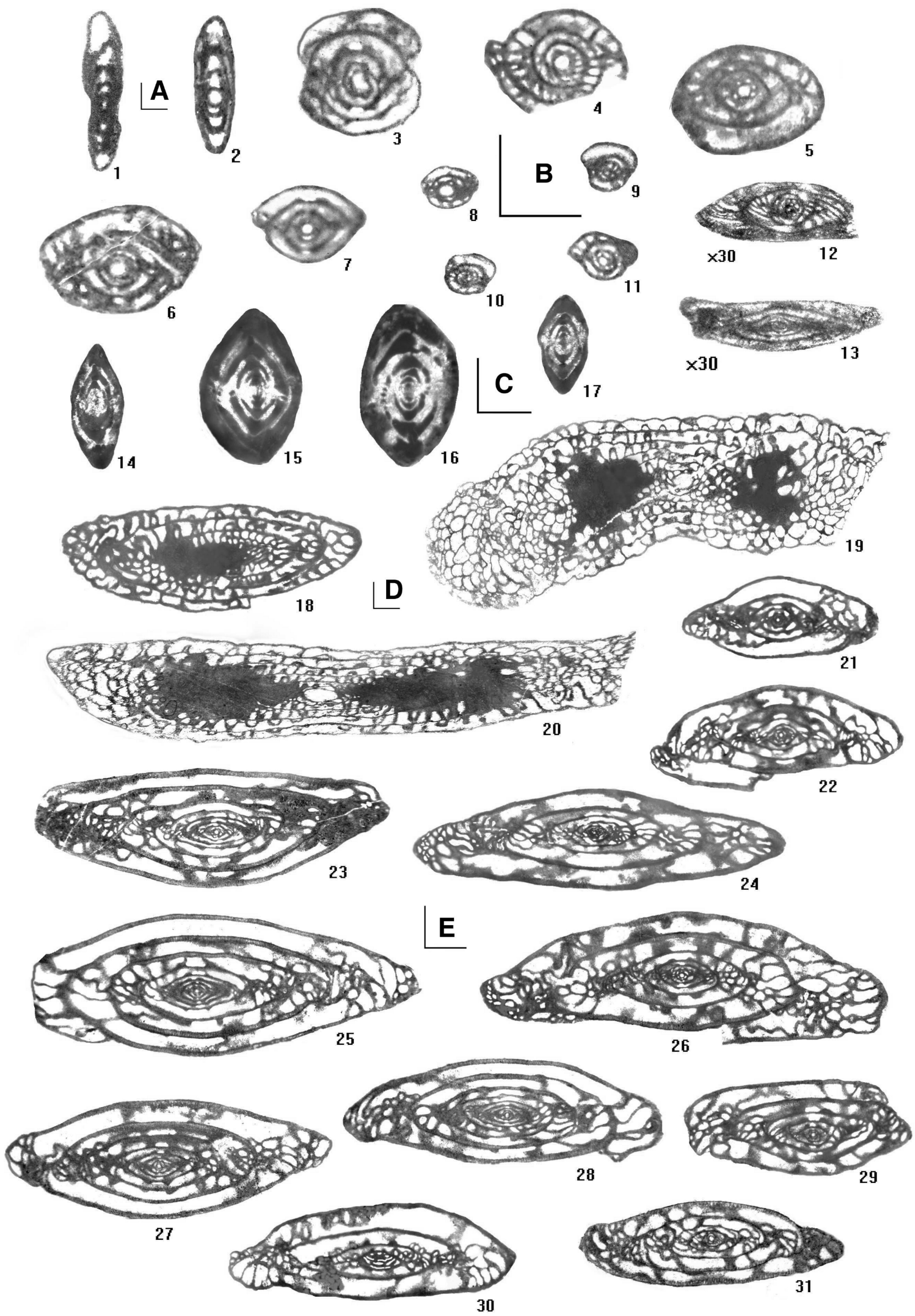
Rugosofusulina (?) *iranica* Leven, n. sp.
Plate 5, figs. 1, 2

[63] **Etymology.** The species name is derived from the word Iran.

[64] **Holotype.** GIN 4781/70. Axial section; Iran, Anarak, Zaladou Formation, Sample AC14; Carboniferous, Pennsylvanian, late Kasimovian (?)–early Gzhelian.

[65] **Material.** 2 axial sections.

[66] **Description.** Shell moderately large, short fusiform in first 3 whorls and elongate fusiform, with bluntly rounded poles in following ones. Mature individuals 4.5 to 5 volutions and measure 6.3 mm to 7.5 mm in length and 2 mm in diameter; form ratio 3.12 to 3.75. Shell loosely coiled except for first 2 to 3 whorls. Waved and here and there corrugated spirotheca composed of tectum and thin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⇐ **Plate 1.** 1. *Seminovella* ex gr. *carbonica* Grozdilova et Lebedeva. ×50. GIN 4781/1, Sample C1; 2. *Eostaffella* aff. *acuta* Grozdilova et Lebedeva. ×50. GIN 4781/157, Sample AC14; 3–6. *Schubertella* sp. 1. ×30. GIN 4781/2, GIN 4781/3, GIN 4781/4, GIN 4781/5 accordingly, Sample AC24; 7. *Schubertella* ex. gr. *giraudi* (Deprat). ×30. GIN 4781/6, Sample AC24; 8–11. *Eoschubertella obscura* (Lee et Chen). ×30. GIN 4781/1, GIN 4781/7, GIN 4781/8, Samples C1, C6, and AC24 accordingly; 12. *Schubertella* ex gr. *kingi* Dunbar et Skinner. ×30. GIN 4781/9, Sample C12; 13. *Boultonia willsi* Lee. ×30. GIN 4781/10, Sample R3; 14, 17. *Reitlingerina* aff. *tachtavica* (Rumjanzeva). ×20. GIN 4781/11, GIN 4781/14, Sample AC16; 15, 16. *Reitlingerina bradyi* (Moeller). ×20. GIN 4781/12, GIN 4781/13, Samples AC26 and AC9 accordingly; 18. *Quasifusulina* sp. ×10. GIN 4781/15, Sample AC14; 19. *Quasifusulina cayeuxi* (Deprat). ×10. GIN 4781/16, Sample P13; 20. *Quasifusulina longissima* (Moeller). ×10. GIN 4781/17, Sample Rup; 21. *Schwageriniformis* aff. *perstabilis* (Scherbovich). ×15. GIN 4781/18, Sample AC14; 22, 26, 29. *Schwageriniformis* ex gr. *kairakensis* (Bensh). ×15. GIN 4781/19, GIN 4781/23, GIN 4781/26 accordingly, Sample AC14; 24. *Schwageriniformis* aff. *gissaricus derpessa* (Bensh). ×15. GIN 4781/21, Sample AC14; 23, 25, 27, 28. *Schwageriniformis acutatus* Leven, n. sp. ×15. GIN 4781/20 (holotype), GIN 4781/22, GIN 4781/24, GIN 4781/25 accordingly, Sample AC25; 30. *Schwageriniformis* cf. *perlongus* (Bensh). ×15. GIN 4781/27, Sample AC14; 31. *Schwageriniformis* sp. ×15. GIN 4781/28, Sample C2. Figs. 1 and 2 – scale-bar A = 0.1 mm, figs. 3 to 13 – scale-bar B = 0.5 mm, figs. 14 to 17 – scale-bar C = 0.5 mm, figs. 18 to 20 – scale-bar D = 0.5 mm, figs. 21 to 31 – scale-bar E = 0.5 mm.

alveolar keriotheca 0.07 mm to 0.08 mm thick in last volution. Septa strongly but irregularly fluted throughout shell; septal folds of different height and shape. Proloculus moderately large, its outside diameter 0.17 mm. Tunnel half as high as chamber, narrow in inner 2 to 3 volutions, significantly widening outwards. Clear, narrow and high chomata developed in early 3 volutions.

[67] **Discussion.** The species is referred to *Rugosofusulina* by convention, for its spirotheca is not as waved and corrugated as described in the diagnosis of the genus. At the same time the wavy spirotheca does not permit the assignment of the species to *Triticites*, which forms are similar to it in all parameters excluding the character of spirotheca. *Rugosofusulina* (?) *iranica* closely resembles *R. scaphulaeformis* Semikhatova known from the Triticites quasiarcticus–Tr. acutus Zone of the Kasimovian in the Donetsk basin, differing from it in a tighter coiling of inner whorls, their more elongated form, and in slightly more fluted septa.

[68] **Occurrence and age.** The same as holotype.

Rugosofusulina (?) *elongata* Leven, n. sp. Plate 5, figs 3–6

[69] **Etymology.** *Elongata* – elongated.

[70] **Holotype.** GIN 4781/88. Axial section; Iran, Anarak, Zaladou Formation, Sample AC14; Carboniferous, Pennsylvanian, late Kasimovian (?) or early Gzhelian.

[71] **Material.** 5 axial sections.

[72] **Description.** Shell fairly large, elongated, subcylindrical, with bluntly rounded to bluntly pointed poles. Mature shell has 4 to 4.5 volutions and measures 5 mm to 7 mm in length and 1.4 mm to 1.7 mm in diameter; form ratio 3.5 to 4.1. Spirotheca waved in first two whorls and more or less corrugated in following ones. Spirotheca composed of tectum and thin alveolar keriotheca; its thickness 0.07 mm in outer volution. Septa strongly and irregularly fluted; septal folds of different height and shape. Proloculus moderately large, its outside diameter 0.17 mm. Tunnel half as high as chamber, narrow in inner two volutions, significantly widening outwards. Clear rounded chomata developed in proloculus and two early volutions.

[73] **Discussion.** *Rugosofusulina* (?) *elongata* n. sp. differs from *R.* (?) *iranica* n. sp. in its subcylindrical shape of shell and more pronounced corrugation of spirotheca.

[74] **Occurrence and age.** The same as holotype.

Genus *Ultradaixina* Davydov, 1982

Ultradaixina bosbytauensis distincta Leven, n. subsp. Plate 5, figs 7–9, 11, 13, 14, 18

[75] **Etymology.** *Distincta* – distinct.

[76] **Holotype.** GIN 4781/77. Axial section. Iran, Anarak, Zaladou Formation; Carboniferous, Pennsylvanian, latest Gzhelian.

[77] **Material.** 10 axial and subaxial sections.

[78] **Description.** Shell of moderate but variable size, fusiform to inflated fusiform, with convex lateral slopes and

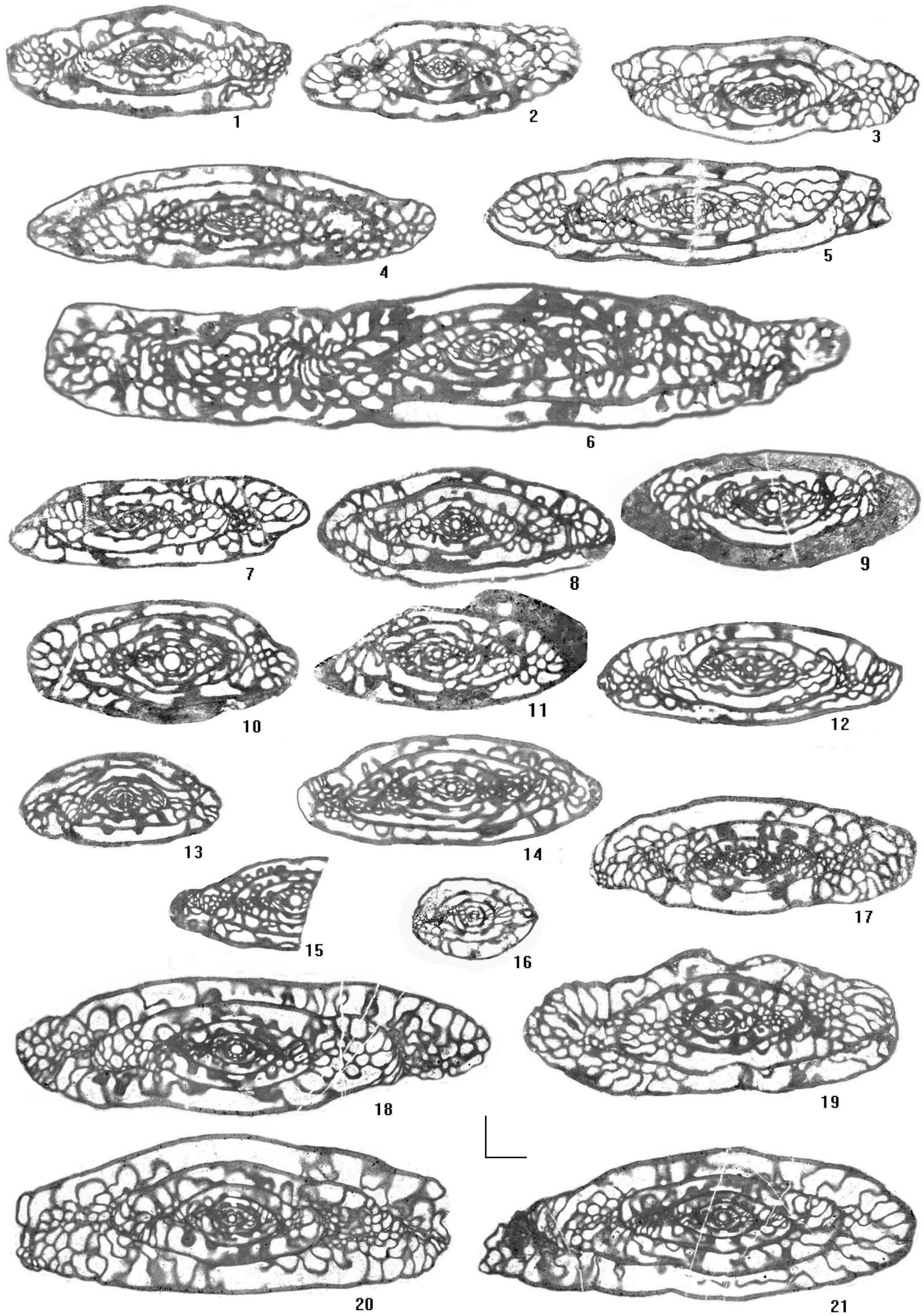

Plate 2. 1–3. *Triticies* aff. *ishimbaji* Rozovskaya. GIN 4781/ 29, GIN 4781/ 21, GIN 4781/30 accordingly, Samples AC14 and RL; 4–7. *Triticites* ex gr. *ohioensis* Thompson. GIN 4781/31, GIN 4781/1, GIN 4781/32, GIN 4781/33 accordingly, Sample C1; 8–10. *Triticites* aff. *shikhanensis* Rozovskaya. GIN 4781/34, GIN 4781/35, Sample C24; 11–15. *Triticites karlensis* Rozovskaya. GIN 4781/36, GIN 4781/37, GIN 4781/34, GIN 4781/35, GIN 4781/38 accordingly, Sample C24; 16. *Triticites globoides* Z. Mikhailova. GIN 4781/39, Sample AC14; 17, 18. *Rauserites* ex gr. *postarcticus* (Rauser-Chernousova). GIN 4781/40, GIN 4781/41, Samples RL2 and RL accordingly; 19–21. *Rauserites variabilis* Rozovskaya. GIN 4781/42, GIN 4781/43, GIN 4781/44 accordingly, Samples AC14 and RL. All figures – scale-bar = 0.5 mm.

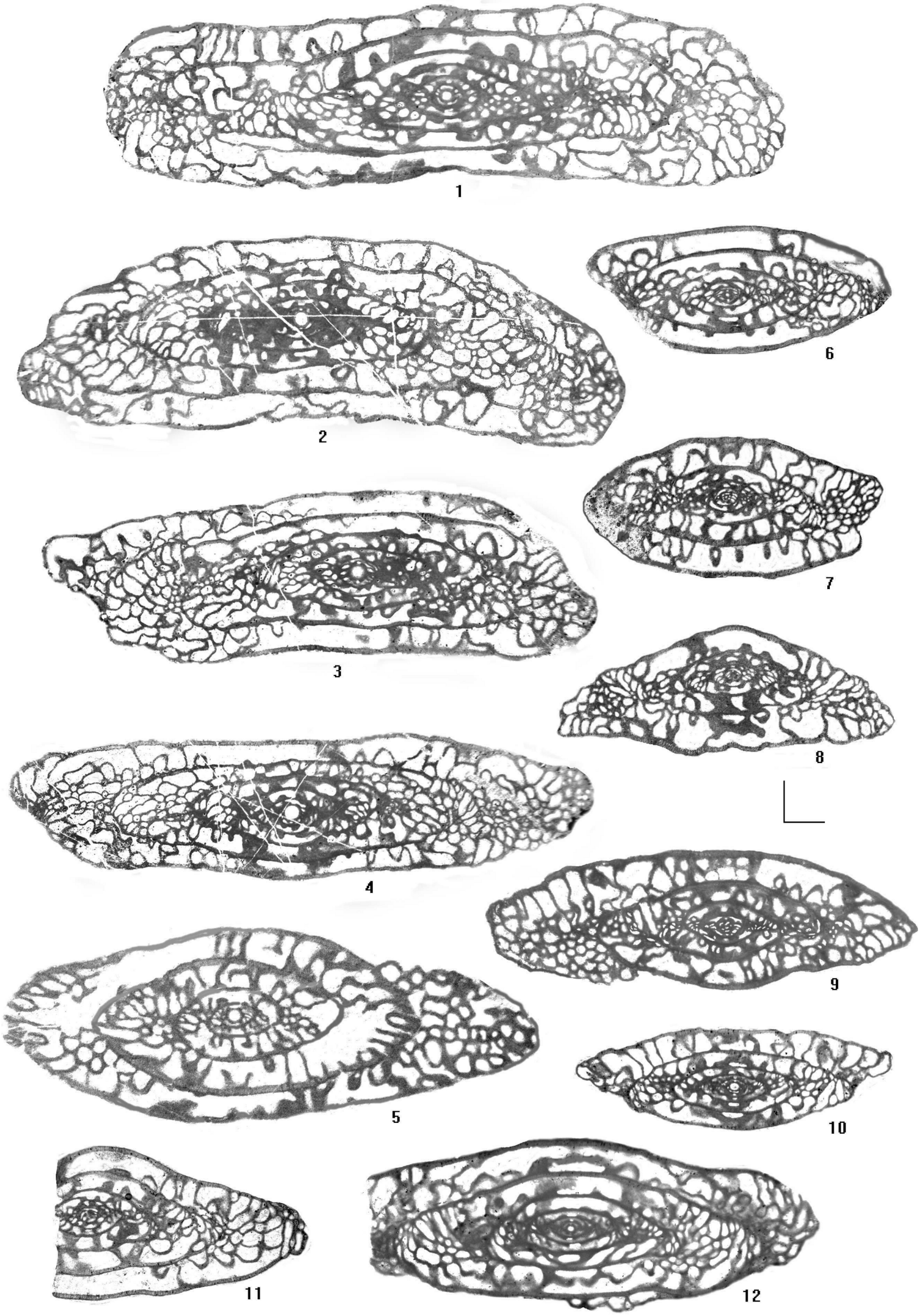

Plate 3. 1–4. *Rauserites rossicus* (Schellwien). GIN 4781/45, GIN 4781/46, GIN 4781/47, Sample RL1; 5. *Jigulites* cf. *formosus* Rozovskaya. GIN 4781/48, Sample C21; 6. *Triticites* aff. *samaricus* Rauser-Chernousova. GIN 4781/49, Sample RL2; 7–9. *Rauserites* (?) *persicus* n. sp. GIN 4781/50, GIN 4781/51, GIN 4781/52 (holotype) accordingly, Samples RL and AC14; 10. *Rauserites* sp. 1. GIN 4781/53, Sample RL; 11. *Triticites* ex gr. *simplex* (Schellwien). GIN 4781/54, Sample RL; 12. *Triticites* ex gr. *secalicus* Say. GIN 4781/55, Sample RL. All figures – scale-bar = 0.5 mm.

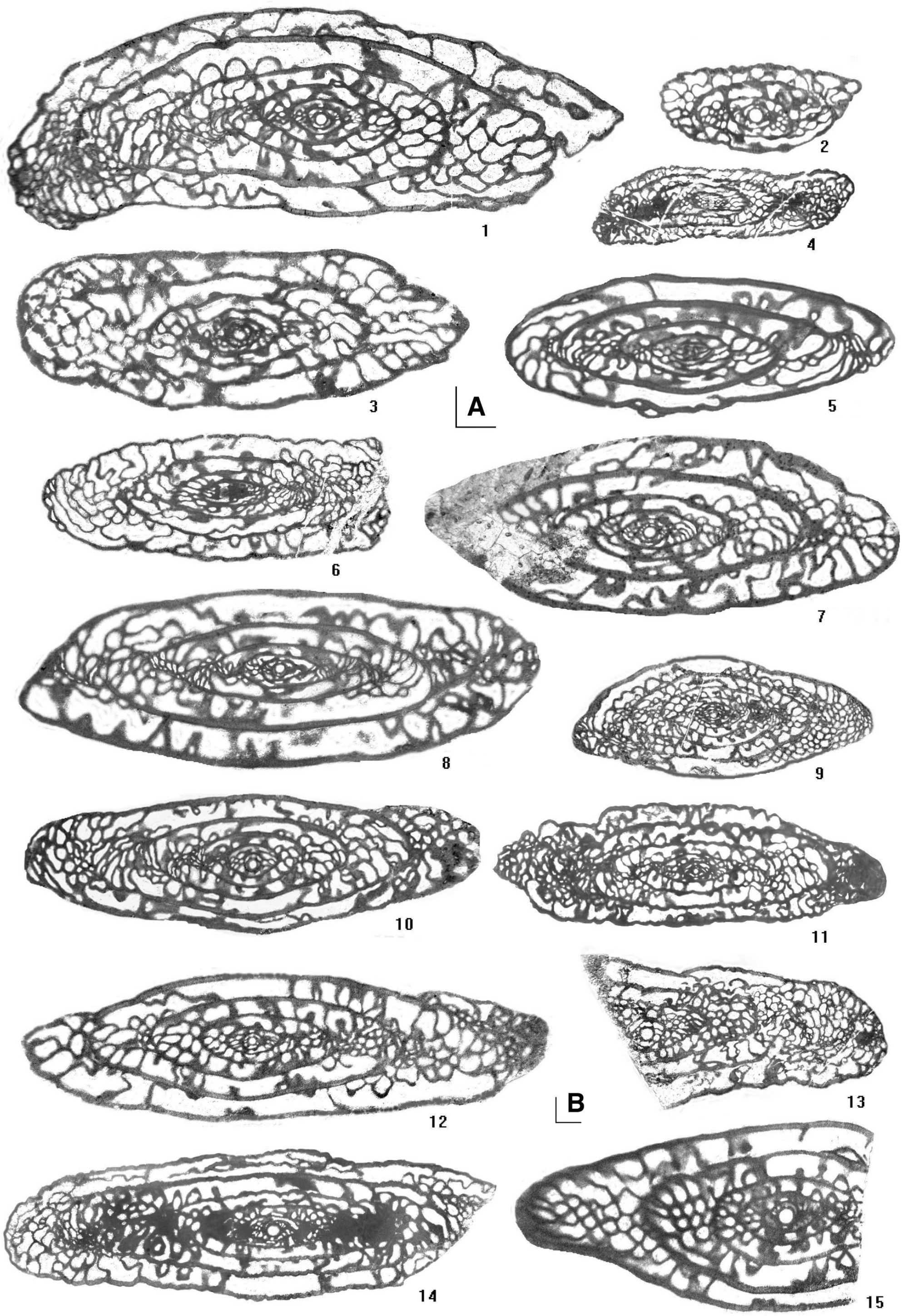

Plate 4. 1. *Triticites nefandus* Grozdilova. ×15. GIN 4781/56, Sample RL; 2. *Rugosofusulina* sp. 1. ×10. GIN 4781/41, Sample RL; 3. *Triticites* ex gr. *nefandus* Grozdilova. ×15. GIN 4781/57, Sample RL; 4. *Rugosofusulina* sp. 2. ×10. GIN 4781/58, Sample C45; 5, 7, 8. *Rauserites stepanovi* n. sp. ×15. GIN 4781/59, GIN 4781/61, GIN 4781/62 (holotype) accordingly, Sample C23; 6. *Rugosofusulina* aff. *elliptica* Rozovskaya. ×10. GIN 4781/60, Sample RL2; 9. *Daixina* aff. *osinovkensis* Scherbovich. ×10. GIN 4781/63, Sample C25; 10. *Rauserites* aff. *postarcticus* (Rauser-Chernousova). ×15. GIN 4781/23, Sample C23; 11. *Rugosofusulina uralica* Z. Mikhailova. ×10. GIN 4781/65, Sample C14; 12. *Rauserites elongatissimus* Rozovskaya. ×15. GIN 4781/66, Sample C20; 13. *Rugosofusulina mutabilis* Bensh. ×10. GIN 4781/ 67, Sample P9; 14. *Rugosofusulina directa* Bensh. ×10. GIN 4781/68, Sample P9; 15. *Rauserites* cf. *erraticus* Rozovskaya. ×15. GIN 4781/69, Sample C21. Figs. 1, 3, 5–8, 10, 12, 15 – scale-bar A = 0.5 mm, figs. 2, 4, 9, 11, 13, 14 – scale-bar B = 0.5 mm.

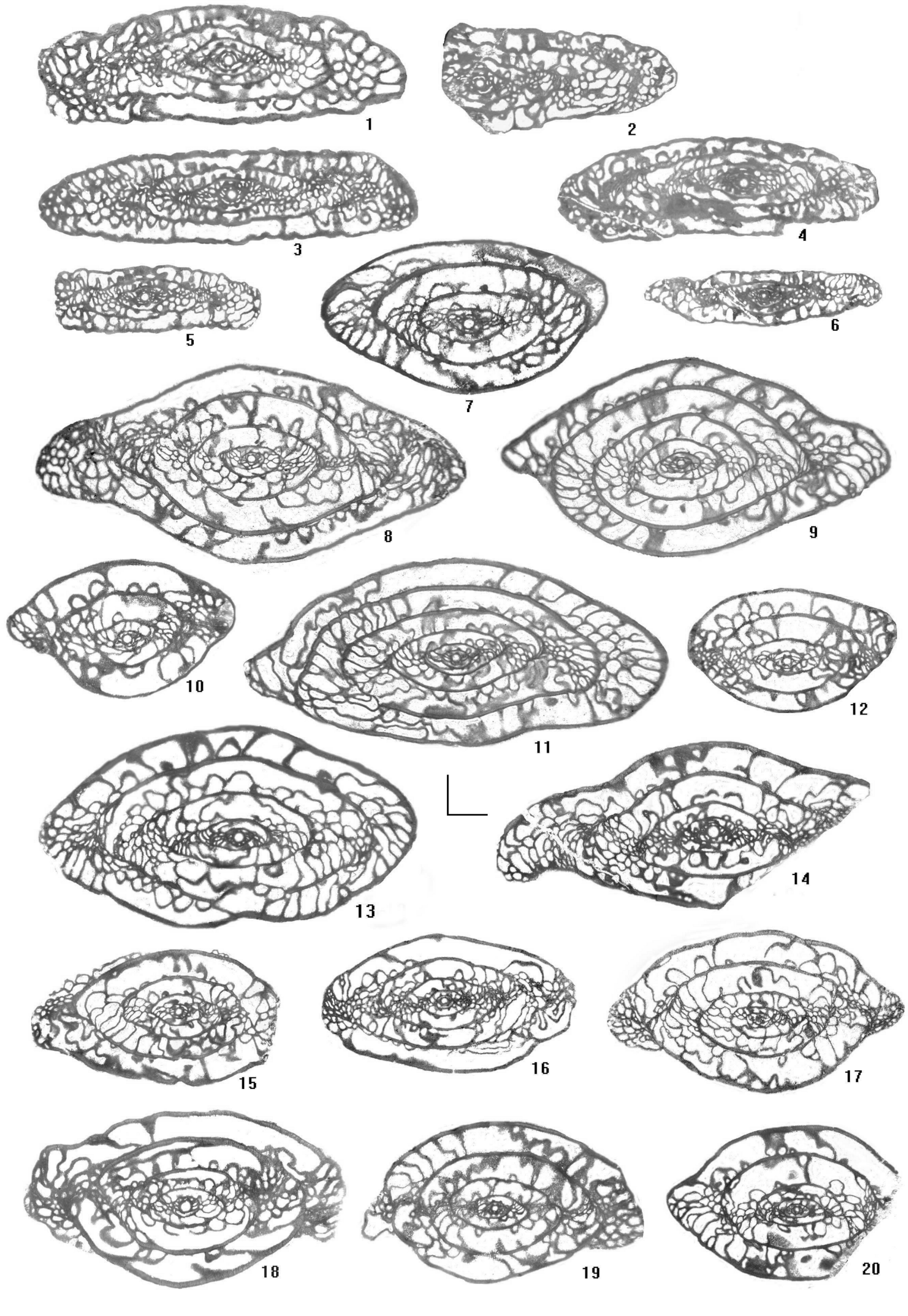

Plate 5. 1, 2. *Rugosofusulina* (?) *iranica* n. sp. GIN 4781/70 (holotype), GIN 4781/71, Sample AC14; 3–6. *Rugosofusulina* (?) *elongata* n. sp. GIN 4781/88 (holotype), GIN 4781/89, GIN 4781/90, GIN 4781/91 accordingly, Sample AC14; 7–9, 11, 13, 14, 18. *Ultradaixina bosbytauensis distincta* n. subsp. (7) GIN 4781/72, Sample AC29; (8, 9, 11) GIN 4781/77 (holotype), GIN 4781/78, GIN 4781/79 accordingly, Sample ML3; (13) GIN 4781/80, Sample P3; (14, 18) GIN 4781/81, GIN 4781/92, Sample P6; 10, 12, 19. *Ultradaixina* (?) *kozui* (Deprat). (10,12) GIN 4781/82, GIN 4781/83, Sample P4; (19) GIN 4781/84, Sample P8; 15, 16. *Ultradaixina* (?) *kosvaensis* (Echlakov). GIN 4781/85, GIN 4781/86, Samples P3 and C accordingly; 17. *Likharevites* aff. *paranitidus* (Bensh). GIN 4781/87, Sample P4; 20. *Likharevites esetensis* (Davydov). GIN 4781/93, Sample P2. All figures – scale-bar = 0.5 mm.

bluntly pointed poles. Adult shells of 4.5 to 5 volutions measure 5.0 mm to 7.2 mm in length and 2.5 mm to 3.9 mm in diameter, form ratio 1.8 to 2.4. First 1 to 2 volutions constitute tightly coiled juvenarium, followed by more or less abrupt expansion into loosely coiled adult stage. Spirotheca composed of tectum and thin alveolar keriotheca, 0.1 mm to 0.125 mm thick in outer whorls. Septa irregularly fluted from pole to pole or only slightly wavy across middle of shell. Proloculus medium-sized, its outside diameter 0.15 mm to 0.21 mm. Tunnel low or narrow. Chomata narrow and developed only in juvenarium. Axial fillings are absent.

[79] **Discussion.** *Ultradaixina bosbytauensis distincta* n. subsp. is similar to *Ultradaixina bosbytauensis bosbytayensis* (Bensh) but differs from it in a slightly isolated juvenarium, presence of chomata, and generally in lesser size.

[80] **Distribution and age.** Iran, Precaspian syneclise; Carboniferous, Pennsylvanian, latest Gzhelian.

[81] **Occurrence.** Iran, Anarak, Zaladou Formation, Samples P3, P6, C1, C27, AC29.

Genus *Likharevites* Davydov, 1987, emend. Leven

[82] **Remarks.** A great deal of Permian sections in the Tethys and South Urals regions contain fusulinids characterized by a more or less inflated fusiform shell, extremely small proloculus, tightly coiled juvenarium, widely and loosely coiled following whorls, and thin septa strongly and as a rule irregularly fluted throughout the whole width and length. Over many years these fusulinids were referred to the American genus *Paraschwagerina* Dunbar et Skinner, 1936. A lot of researchers continue doing this up to now. After the distinction of *Occidentoschwagerina* [*Miklukho-Maclay,* 1959] and *Alpinoschwagerina* [*Bensh,* 1972] some of like fusulinids were assigned to these genera. The above-mentioned genera were mainly described from the Asselian and Sakmarian, though their first members were recorded in the upper Gzhelian Ultradaixina bosbytauensis Zone and the last ones, in the Yakhtashian sediments. Fusulinids of this type were recently found in the lower Gzhelian in the Darvaz and Donetsk basin and were recognized as a new genus *Darvasoschwagerina* [*Leven and Davydov,* 2001].

[83] The above-reported major morphologic characters of the discussed fusulinids remained almost unchanged with time. Only juvenarium was progressively altered. In Gzhelian forms, for instance, (*Darvasoschwagerina donbassica* Leven et Davydov, 2001 and others), it resembles that of the Kasimovian *Montiparus* in the wall structure and massive chomata. Juvenarium of the late Gzhelian, Asselian, and, partly, Sakmarian forms, namely, of *"Alpinoschwagerina" paranitida* Besh, 1972, *"Occidentoschwagerina kokpectensis"* Bensh, 1972, *"Paraschwagerina" pseudomira* M.-Maclay, 1949, and others, is similar to that of the Gzhelian *Triticites* and *Rauserites*. Beginning with the Sakmarian time, it gained features of *Pseudofusulina* s. l. characterized by strongly and regularly fluted septa, sometimes with pronounced axial fillings, as in *"Paraschwagerina" kanmerai* [*Nogami,* 1961], *"P." akiyoshiensis* [*Toriyama,* 1958], and *"P." zhen'anensis* [*Xia et al.,* 1996]. According to the biogenetic law, at early stages of ontogeny the organisms bear ancestor characters. If so, the marked differences in the juvenarium structure of the discussed fusulinids mean that different ancestors repeatedly and at different times produced morphologically similar forms that, despite their general similarity, should be interpreted as separate taxa. At first sight the current taxonomy fits this requirement, keeping in mind that these forms are referred to different genera, namely, D*arvasoschwagerina, Occidentoschwagerina, Alpinoschwagerina*, and *Paraschwagerina*. However, on distinguishing these genera (excluding the former) no particular significance was attached to differences in the juvenarium structure. Moreover, the validity of *Occidentoschwagerina* and *Alpinoschwagerina* can be questioned following *Forke* [2002], based on their diffuse diagnosis and undoubted similarity of the genotypes with the genus *Pseudoschwagerina*. As for *Paraschwagerina*, judging from the juvenarium with strongly fluted septa and general habitus, it can be compared only with relatively young, Sakmarian–Yakhtashian members of the discussed fusulinid group. However, they are also most likely of independent origin considering the attribution of typical Paraschwagerina to the other, significantly isolated from the Tethys, Midcontinent–Andean biogeographic region.

[84] All the above suggests the necessary distinction of Paraschwagerina-like fusulinids with a simple juvenarium structure, such as *"Alpinischwagerina" paranitida* Bensh, *"Occidentoschwagerina" kokpectensis* Bensh, *"Paraschwagerina" acuminata uralensis* Rauser-Chernousova, *"P." inflata* Chang, and a lot of others, in a separate genus. This conclusion was previously made by V. I. Davydov who recognized the new genus *Likharevites*. Unfortunately its diagnosis was published in the Deponent of VINITI and was almost beyond the reach of most of researchers. Owing to this, though the author repeatedly used the name *Likharevites*, it actually remained nomen nudum. With the aim of securing this name we give below the diagnosis of the genus similar to that by the author, however, with certain refinements produced by the latest available records.

[85] **Diagnosis.** Shell small to moderately large, fusiform to nearly spherical, with bluntly pointed poles. Mature individuals usually possess 5 to 6 whorls. First three of them constitute very tightly coiled juvenarium, which is followed by abrupt expansion into loosely coiled adult stage. Spirotheca composed of tectum and thin alveolar keriotheca. Septa thin, rather strongly but irregularly fluted throughout the shell. Septal folds variable in height; some involve only lower third of septa, whereas others extend to tops of chamber. Regularity of septal flutings increases from ancient to more developed species. In juvenarium septa wavy or gently fluted in the highly developed species. Axial filling is absent. Tunnel low and feebly marked. Chomata weak but clear, present only in juvenarium.

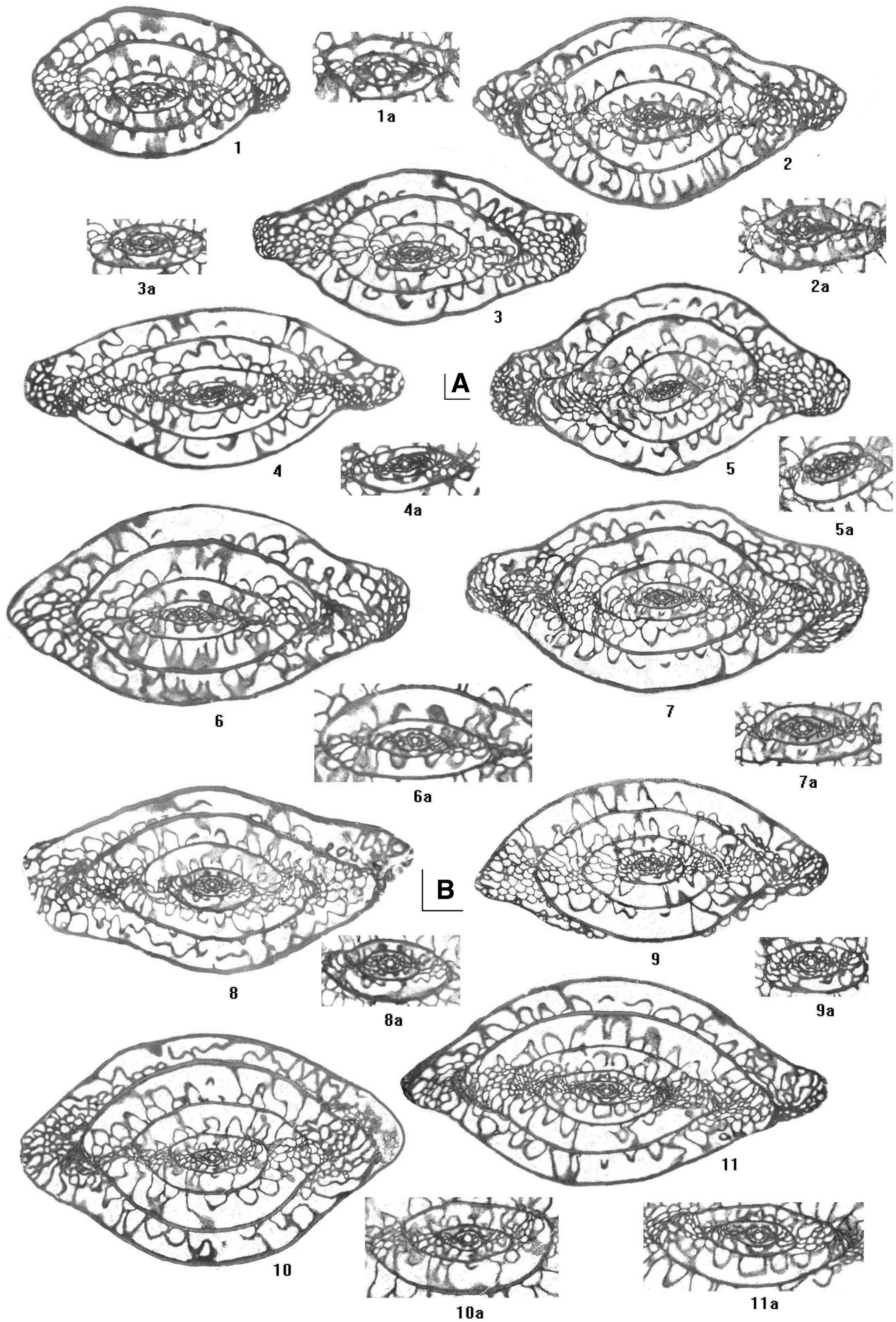

Plate 6. 1, 1a. *Ultradaixina* (?) *kozui* (Deprat). GIN 4781/94, Sample P8; 2–11, 2a–11a. *Likharevites gracilis* n. sp. (2, 2a) GIN 4781/95 (holotype), Sample C38; (3, 5, 8) GIN 4781/96, GIN 4781/98, GIN 4781/101, Sample RupA; (4, 12) GIN 4781/97, GIN 4781/102, Sample P12; (6, 7) GIN 4781/99, GIN 4781/100, Sample Rup2; (10, 11) GIN 4781/103, GIN 4781/104, Sample R2. Figs. 1 to 11 – scale-bar A = 0.5 mm, figs. 1a to 11a – scale-bar B = 0.5 mm.

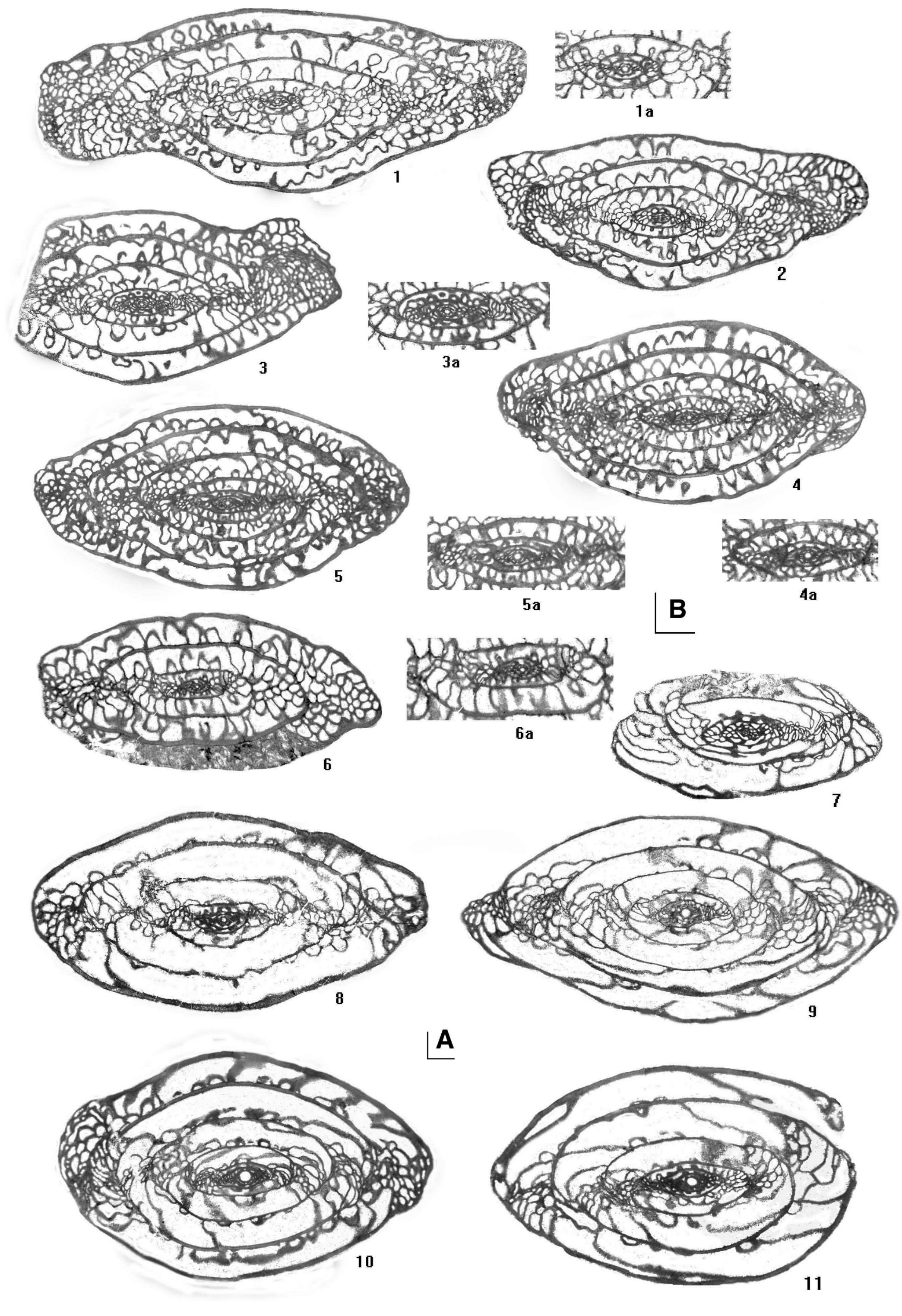

Plate 7. 1–3, 1a, 3a. *Likharevites kokpectensis* (Scherbovich). (1, 3) GIN 4781/105, GIN 4781/106, Sample R2; (2) GIN 4781/107, Sample RupA; 4, 4a, 5, 5a. *Likharevites inglorius* (Bensh). GIN 4781/108, GIN 4781/109, Sample C45; 6, 6a. *Likharevites* ex gr. *inglorius* (Bensh). GIN 4781/110, Sample C47; 7. *Pseudoschwagerina* ex gr. *extensa* F. et G. Kahler. GIN 4781/111, Sample P13; 8. *Pseudoschwagerina* sp. GIN 4781/112, Sample C45; 9–11. *Pseudoschwagerina extensa* F. et G. Kahler. GIN 4781/113, GIN 4781/114, GIN 4781/115, Samples C42, C45, and PR1 accordingly.
Figs. 1 to 11 – scale-bar A = 0.5 mm, figs. 1a, 3a to 6a – scale-bar B = 0.5 mm.

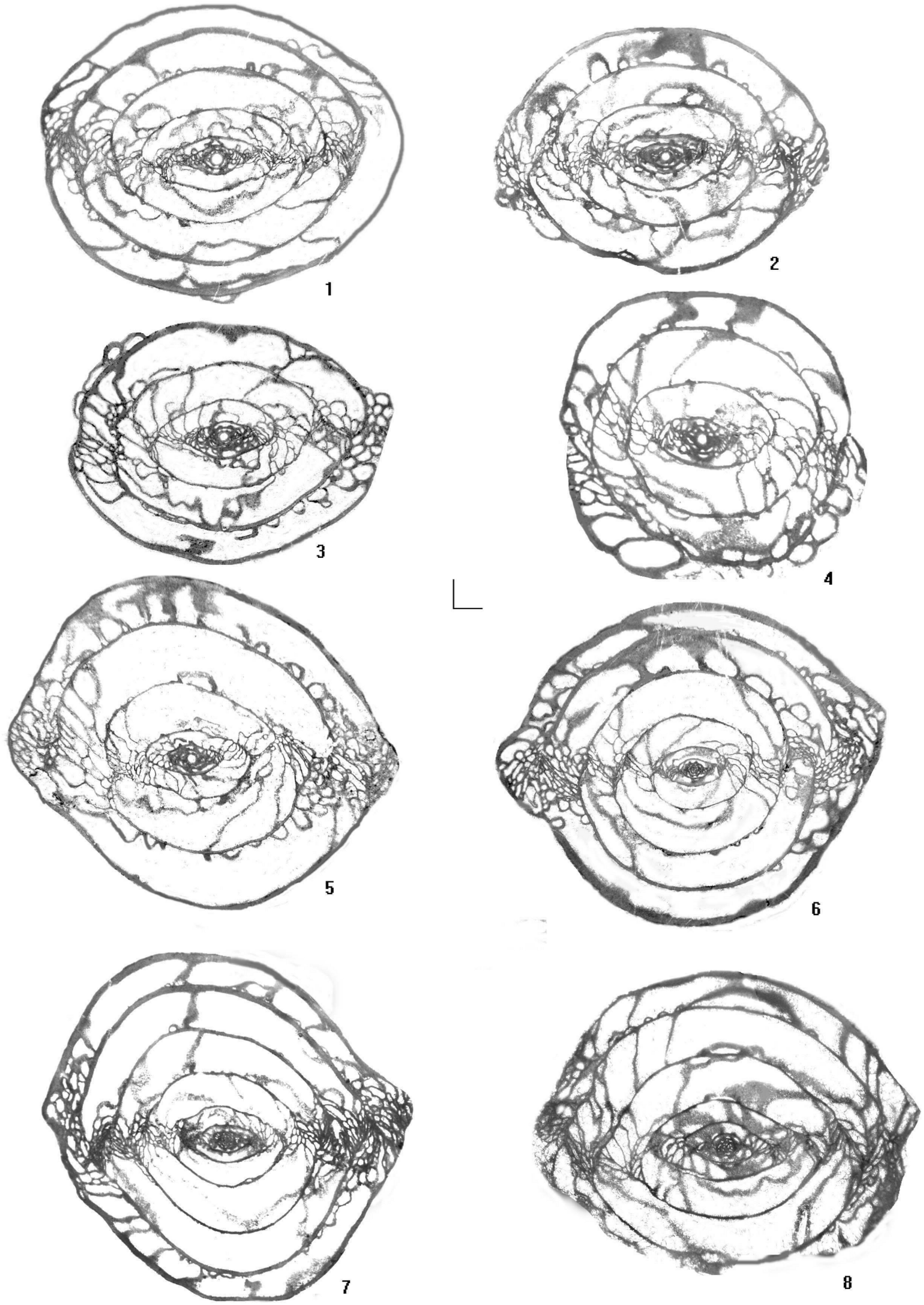

Plate 8. 1–3. *Pseudoschwagerina turbida* F. et G. Kahler. GIN 4781/116, GIN 4781/117, GIN 4781/118 accordingly, Sample C45; 4. *Pseudoschwagerina* ex gr. *turbida* F. et G. Kahler. GIN 4781/119, Sample PR1; 5. *Pseudoschwagerina robusta* (Meek). GIN 4781/120, Sample C47; 6, 7. *Sphaeroschwagerina shamovi gerontica* (Scherbovich). GIN 4781/121, GIN 4781/122, Samples C45 and PR1; 8. *Sphaeroschwagerina* sp. 1. GIN 4781/123, Sample P13. All figures – scale-bar = 0.5 mm.

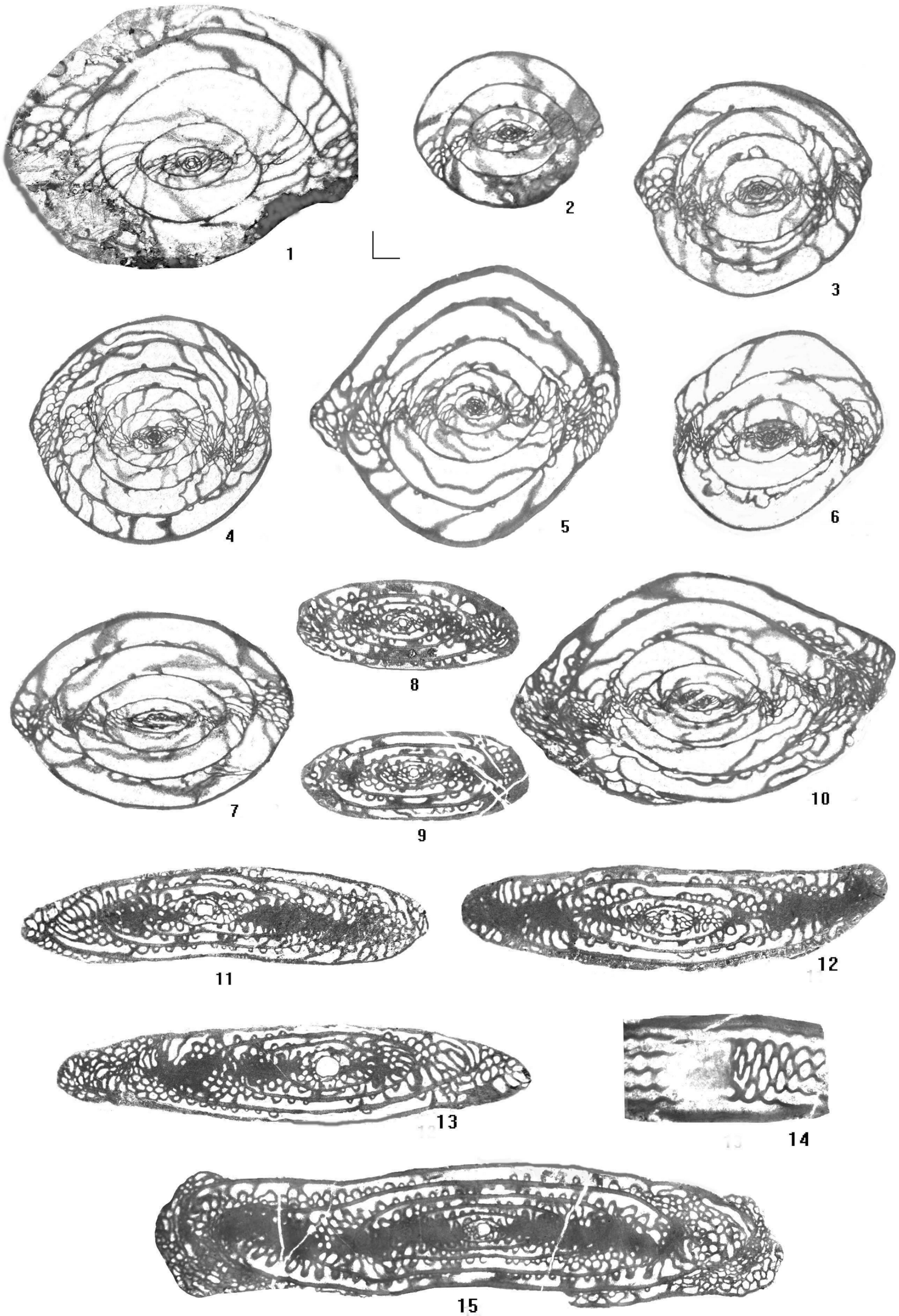

Plate 9. 1. *Sphaeroschwagerina pavlovi* (Scherbovich). GIN 4781/124, Sample C45; 2. *Sphaeroschwagerina* ex gr. *spaerica* (Scherbovich). GIN 4781/125, Sample C45; 3. *Sphaeroschwagerina shamovi primitiva* (Leven et Scherbovich). GIN 4781/126, Sample C45; 4. *Sphaeroschwagerina moelleri* (Rauser-Chernousova). GIN 4781/127, Sample P13; 5. *Sphaeroschwagerina notabilis* (Grozdilova). GIN 4781/128, Sample PR1; 6. *Sphaeroschwagerina* sp. 2. GIN 4781/129, Sample PR1; 7. *Sphaeroschwagerina ellipsoidalis* Rauser-Chernousova. GIN 4781/130, Sample PR1; 8, 9. *Praepseudofusulina kljasmica* (Sjomina). GIN 4781/131, GIN 4781/132, Sample P11; 10. *Sphaeroschwagerina fusiformis* (Krotowi). GIN 4781/133, Sample PR1; 11–13. *Ruzhenzevites ferganensis* (Dutkevitch). GIN 4781/134, GIN 4781/45, GIN 4781/10, Sample R3; 14, 15. *Ruzhenzevites subcylindricus* (Bensh). GIN 4781/136, GIN 4781/137, Sample PR2. All figures – scale-bar = 0.5 mm.

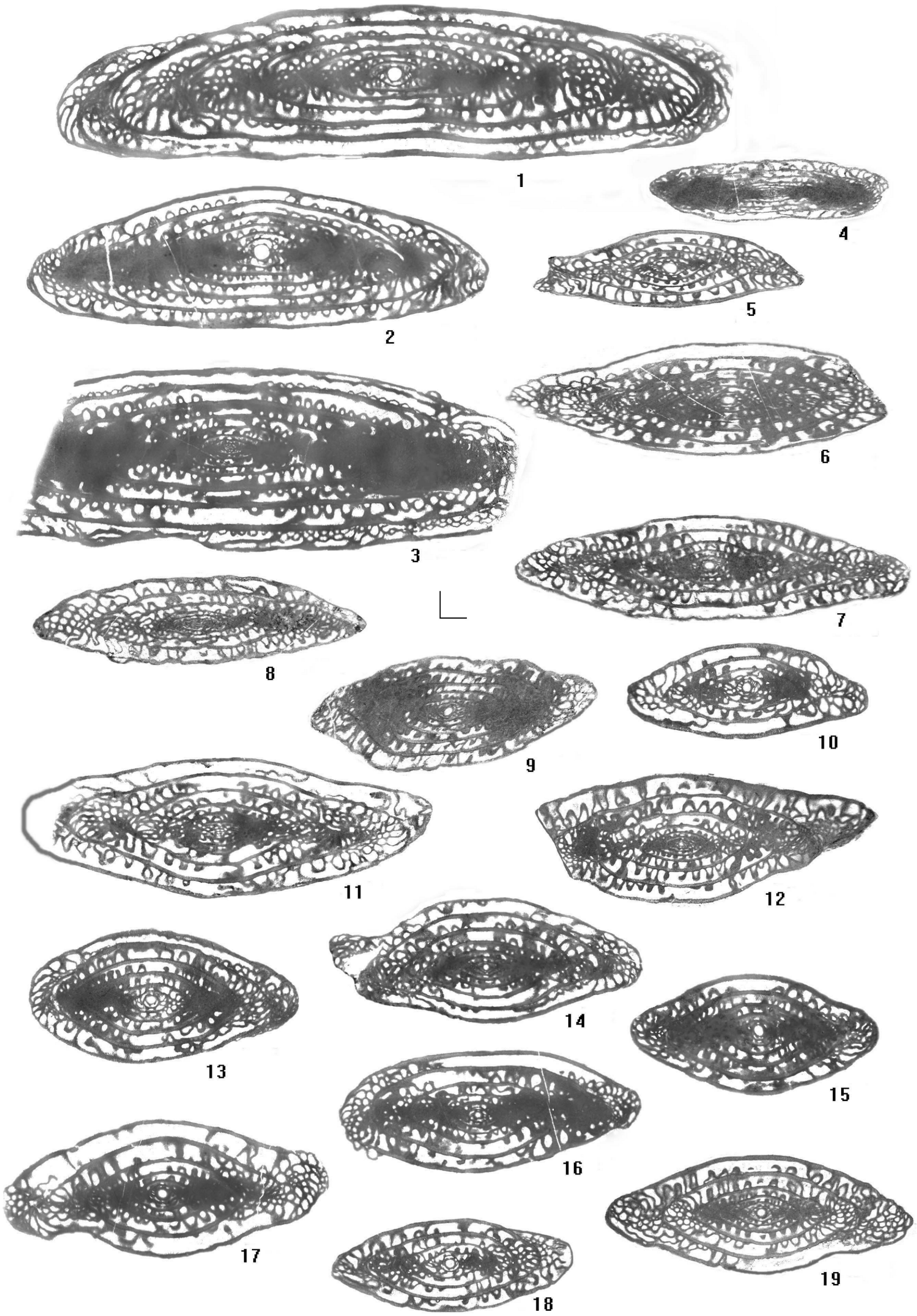

Plate 10. 1. *Ruzhenzevites subcylindricus* (Bensh). GIN 4781/138, Sample PR2; 2. *Ruzhenzevites zaladuensis brevis* Leven. GIN 4781/139, Sample PR2; 3. *Ruzhenzevites zaladuensis zaladuensis* Leven. GIN 4781/140, Sample P10; 4. *Rugosochusenella* sp. GIN 4781/141, Sample C46; 5. *Pseudofusulina* (?) sp. GIN 4781/142, Sample R2; 6, 7. *Pseudofusulina* (?) *narjanmarica* Konovalova. GIN 4781/143, GIN 4781/144, Samples Rup and C46; 8. *Rugosochusenella paragregaria* (Rauser-Chernousova). GIN 4781/145, Sample C47; 9. *Praeskinnerella* (?) *huangchuigouensis* Zhang et Xia. GIN 4781/146, Sample Rup; 10, 18. *Anderssonites nanus* (Sjomina). GIN 4781/147, GIN 4781/48, Sample P6; 11. *Anderssonites* (?) aff. *zarjae* Potievskaya. GIN 4781/149, Sample AC28; 12. *Pseudofusulina* aff. *conspiqua* Rauser-Chernousova. GIN 4781/150, Sample RupA; 13. *Anderssonites anderssoni nibelensis* Volozhanina. GIN 4781/151, Sample P3; 14, 19. *Anderssonites pseudoanderssoni pseudoanderssoni* (Sjomina). GIN 4781/152, GIN 4781/153, Samples P8 and RupA; 15. *Anderssonites anderssoni* (Schellwien). GIN 4781/154, Sample P8; 16. *Anderssonites pseudoanderssoni latiterminosa* (Sjomina). GIN 4781/155, Sample P1; 17. *Anderssonites* sp. 4781/156, Sample P1.
All figures – scale-bar = 0.5 mm.

[86] **Discussion.** The discussed genus differs from *Paraschwagerina* Dunbar et Skinner (s.s.) in a more simple juvenarium, which indicates that it originated from a relatively primitive ancestor. This is also confirmed by the older, late Gzhelian–Sakmarian age of our genus. The typical American *Paraschwagerina* members are dated as the Sakmarian–Artinskian [*Wardlaw and Davydov,* 2000]. *Likharevites* generally differs from *Alpinoschwagerina* (Bensh) (s.s.) in a fusiform shell, significantly stronger fluting of septa, and in smaller size. The author of the genus referred to it fusulinids from the *Triticites* (?) *fornicatus* Kanmera group, which was in our opinion untrue, since they correspond to the above diagnosis neither in shell size nor in coiling and septal fluting and most likely should be recognized as a separate genus.

[87] Type species – *Pseudoschwagerina* (?) *sartauensis* [*Davydov,* 1986, p. 92–93, Plate 14, fig. 11].

Likharevites gracilis, n. sp.
Plate 6, figs 2–11a

[88] *Paraschwagerina inflata* Chang. [*Kahler,* 1989, Plate 5, fig. 2, p. 224].

[89] *Alpinoschwagerina confinii* F. et G. Kahler. [*Chen Genbao et al.,* 1992, Plate 28, figs. 5, 6].

[90] *Paraschwagerina bianpingensis* Zhang et Dong. [*Chen Genbao et al.,* 1992, Plate 28, fig. 9].

[91] *Paraschwagerina* aff. *toriyamaia* (Igo). [*Forke,* 2002, Plate 38, fig. 11, p. 250].

[92] **Etymology.** *Gracilis* – slender, slim (Lat.).

[93] **Holotype.** GIN 4781/95. Axial section. Iran, Anarak section, Zaladou Formation, Unit 8; Permian, Cisuralian, Asselian.

[94] **Material.** 25 axial sections.

[95] **Description.** Shell moderately large, fusiform to nearly spherical, with bluntly pointed poles. Mature individuals usually possess 5 to 6 whorls. First three of them constitute very tightly coiled juvenarium, which is followed by abrupt expansion into loosely coiled adult stage. Spirotheca composed of tectum and thin alveolar keriotheca. Septa thin, rather strongly but irregularly fluted throughout the shell. Septal folds high and broad. In juvenarium septa wavy or gently fluted. Axial filling is absent. Tunnel low and feebly marked. Chomata weak but clear, present only in juvenarium.

[96] **Variability.** The outer shape of shell and juvenarium are primarily subject to variations. Juvenarium is particularly variable: from elongated fusiform to short oval. The degree of septal fluting slightly varies as well. Variations are sometimes so significant (for instance, between figs. 4 and 5, Plate 6) that the affiliation of certain forms to the same species casts some doubt. However, the concurrent occurrence of numerous intermediate forms permits the consideration of these variations as a result of intraspecific variability.

[97] **Discussion.** The species is similar to *Likharevites kokpectensis* (Bensh) but possess a shorter and more inflated shell. In this respect it can be compared with *Likharevites inflatus* (Chang). However, this Chinese species has a more elongated juvenarium, looser coiling, and slightly stronger and more regular septal fluting. The tighter coiling and lesser septal folds differentiate the discussed species from the Japanese *Likharevites shimodakensis* (Kanmera). *Likharevites gracilis* is very similar to the species described by Rauser-Chernousova as *Paraschwagerina acuminata* var. *uralensis* from the Asselian of the South Urals [*Rauser-Chernousova and Scherbovich,* 1949]. However it differs from the Uralian form in a somewhat looser coiling and less strong septal fluting.

[98] **Distribution and age.** Iran, Carnian Alps, China; Permian, Cisuralian, Asselian.

[99] **Occurrence.** Iran, Anarak, Zaladou Formation, Samples P4, P8, P12, C25, C38, C39, RupA, Rup2, Rup4, R1, R2.

[100] **Acknowledgments.** This work was supported by the Russian Foundation for Basic Research, project no. 06-05-65201

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