ISSN 0869-5938, Stratigraphy and Geological Correlation, 2011, Vol. 19, No. 2, pp. 141–159. © Pleiades Publishing, Ltd., 2011.
Original Russian Text © E.Ja. Leven, M.N. Gorgij, 2011, published in Stratigrafiya. Geologicheskaya Korrelyatsiya, 2011, Vol. 19, No. 2, pp. 20–39.

The Kalaktash and Halvan Assemblages of Permian Fusulinids from the Padeh and Sang-Variz Sections (Halvan Mountains, Yazd Province, Central Iran)

E. Ja. Leven[a] and M. N. Gorgij[b]

[a] *Geological Institute, Russian Academy of Sciences, Moscow, Russia*
e-mail: erleven@yandex.ru

[b] *Department of Geology, Faculty of Sciences, University of Sistan and Baluchestan, Zahedan, Iran*
e-mail: mngorgij@yahoo.com

Received March 4, 2010; in final form, April 12, 2010

Abstract—New Permian sections have been studied in the Halvan Mountains of Iran, northwestward of Tabas. In addition to the Chili, Sartakht, and Hermez formations established here earlier, the new Rizi Formation is distinguished, underlying deposits of the Triassic Sorkh Shale Formation. Conodonts, fusulinids, and smaller foraminifers found in the rocks date the formations. In particular, it is demonstrated that the Chili Formation bearing the Kalaktash fusulinid assemblage is of Sakmarian age. The age of the Halvan fusulinid assemblage from clasts in the breccia-conglomerate at the Sartakht Formation base is reevaluated, and it is shown to be late Sakmarian but not Asselian in age. The Bolorian–Kubergandian age is established for the greater part of the Sartakht Formation. Correlation of the sections studied with the other Permian sections in different regions of Iran showed their lithological and paleontological specifics as compared to the latter. On the other hand, the sections in question are surprisingly similar in both respects to sections in the Central Pamirs. Fusulinids of the Kalaktash and Halvan assemblages are figured in four plates, and five new species belonging to the genera *Rugosochusenella, Benshiella, Parazellia*, and *Nonpseudofusulina* are described.

Keywords: stratigraphy, fusulinids, Permian, Iran.

DOI: 10.1134/S0869593811020079

INTRODUCTION

The Halvan Mountains are situated on the north of the Kalmard tectonic block, which is narrow and clamped between the greater Tabas and Posht-Badam blocks. In the Kalmard block, Permian deposits of the Khan Group are peculiar, differing from their age equivalents of neighboring blocks in terms of the section structure and composition of fusulinid assemblages occurring in the rocks. The most complete sections are recognizable in the Halvan Mountains. One of them, described earlier (Leven and Gorgij, 2009), was discovered in the Tangale-Mokhtar Valley and. The Permian part of this section is subdivided into the Chili, Sartakht, and Hermez formations, separated from each other by thin horizons of red laterites. In upper part of the first formation, there are beds with extremely abundant fusulinids of the so-called Kalaktash assemblage originally described from sections of the Central Pamirs and afterward from the Karakorum, eastern Hindu Kush, southern Afghanistan, and Oman. Kahler (1977) was the first to describe comparable fusulinids from the Kalmard block of Iran. Characterization of a fusulinid community corresponding to the Kalaktash assemblage of the Central Pamir can be found in two earlier publications (Leven and Gorgij, 2007; Davydov and Arefifard, 2007) and in our recent work dedicated to the Tangale-Mokhtar section (Leven and Gorgij, 2009). In addition to the Kalaktash fusulinids, clasts and pebbles in breccia-conglomerates locally confined to the lower part of the laterite horizon separating the Chili and Sartakht formations in the latter section yield an absolutely different fusulinid assemblage. With some reservations, we concluded that this assemblage is of the Asselian age, since some of its fusulinid species are close or even identical to those typical of the Asselian Stage of the Urals. Our doubts were associated with absence of data on the pertinent provenance of clasts containing the Asselian? fusulinids, which are lacking traces of long transportation. We failed to find the same fusulinids in the beds underlying the horizon of breccia-conglomerate, but it was difficult to completely exclude their possible occurrence, because the Permian section base is unexposed at the Tangale-Mokhtar locality.

Comparing the Tangale-Mokhtar section with the other sections that yield the Kalaktash fusulinid assemblage, we established its similarity to sections in the Central Pamir (Kalaktash, West Pshart) and Middle Afghanistan (Khaftkala). The same similarity is also characteristic of the Triassic deposits. Taking everything into consideration, we put forward two postulates: first, Permian deposits of the above sections accumulated in one basin, small relicts of which are observable at present, and second, that basin of the Early Permian was within comparatively low paleolatitudes, when the climate was warm (Leven and Gorgij, 2009; Leven, 2009). To verify the postulates, we undertook an additional study of new sections in the Halvan Mountains. The results obtained are considered below.

BRIEF CHARACTERIZATION OF THE ROCK SUCCESSION

A complete succession of Permian deposits has been described in the Padeh Valley 5 km south of the Tangale-Mokhtar section (Figs. 1, 2). Permian deposits rest here on limestones that are oolitic below and grade upward into detrital sandy varieties. Between the limestone varieties, there are visible scouring marks. The oolitic limestones contain rare Visean–Serpukhovian foraminifers *Viseidicus monstratus* (Grozdilova et Lebedeva), *Planoarchaediscus* sp., *Glomodiscus oblongus* (Conil et Lys), *Earlandia* sp., *Eogloboendothyra ?* sp., *Pseudoplanoendothyra ?* sp., and *Endothyranopsis* sp. Conodonts *Rhachistognathus primus* (Dunn) from oolitic limestone and *Gnathodus girtyi* Hass from the base of sandy limestones (determinations of A.N. Reimers and L.I. Kononova) are also the Visean–Serpukhovian in age. In addition, sandy limestones bear algal remains (*Shartymophicus*, *Komia*, *Pseudodonetzella*) probably of Serpukhovian Age. The upper boundary of these rocks, which is distinct and sharp, is overlain without unconformity and scouring marks by succession of the following rock units (from the base upward):

Chili Formation

1. Limestones, predominantly compact, gray, thick-bedded; prevailing among the rocks are detrital varieties (biomicrite and biosparite). Oolitic limestones (oomicrite, oosparite, oopelmicrite) also occurring are especially characteristic of the bed's lower part. Some interlayers contain an admixture or rounded quartz grains. In the detrital fraction, there are clasts of bryozoans, echinoids, crinoids, rare corals, codiacean algae, gastropod shells, brachiopods, bivalves, and ostracodes. Among the bryozoans (Sample PCP12), R.V. Gorjunova identified *Nikiforopora boulangei* (Termier et Termier). Particularly remarkable among the rare smaller foraminifers are *Globivalvulina* forms. In the bed's lower part, there are many sedentary foraminifers (*Ammovertella, Tolypammina*). Fusulinids frequently occurring here are represented almost exclusively by staffellids, namely by *Reitlingerina* sp. and *Parastaffelloides* sp. Single specimens of *Schubertella* sp. are of lesser significance. Thickness 14.3 m.

2. Marls with interlayers of detrital limestone (biosparite) in the upper part; rocks contain abundant bryozoans, *Nikiforopora boulangei* (Termier et Termier), *Mackinneyella supraornamentata* (Sch.-Nest.), *Shulgapora kolvae* (Stuckenberg), *Streblascopora* sp., *Raiporidra asiatica* Gorjunova, *Hexagonella* sp., and *Fistulipora* sp. inclusive (samples PCP32, PCP37). Smaller foraminifers are represented by rare *Globivalvulina* sp. and *Langella ?* sp. Rocks also bear clasts of crinoids, gastropods, brachiopods, bivalves, green algae, and *Tubyphytes*. Thickness 2 m.

3. Thick-bedded limestones (biomicrite, pelmicrite) with rare *Globivalvulina* sp., crinoid columnals, and sponge spicules. Thickness 2.1 m.

4. Frequently interlayering marls and limestones (biosparite and biomicrite). Limestones contain conodonts *Diplogbathodus* sp., *Mesogondolella pseudostriata* Chernykh, and *M. parafoliosa* Chernykh (samples PCP50 and PCP51), bryozoan fragments, crinoid columnals, and smaller foraminifers (*Globivalvulina* sp.). Scouring marks are recorded at the boundary with the underlying limestones of Bed 3. Thickness 3.3 m.

5. Limestones, bedded, detrital (biosparite, biomicrite). Crinoid columnals and fragments of bryozoans, brachiopods, and gastropods have been identified from the detrital fraction. Smaller foraminifers are represented by rare *Tetrataxis* sp. and undeterminable textulariids. Single specimens of *Nonpseudofusulina* aff. *aghanabatei* (Davydov et Arefifard) have been found in the upper part of the bed (Sample PCP63). Thickness 15 m.

6. Interlayering argillites and detrital limestones (biosparite) containing conodonts *Sweetognathus merrilli* (Kozur) (Sample PCP65). Identified species of abundant fusulinids are *Nonpseudofusulina aghanabatei* (Davydov et Arefifard), *N. callosa* (Rauser-Chernousova), *N.* ex gr. *pamirensis* (Leven), and others (Sample PCP66). In the detrital fraction, crinoids, bryozoans (*Hexagonella* sp., *Streblascopora* sp.), bivalves, gastropods, *Tubyphytes*, and smaller foraminifers (textulariids) are recognizable. Thickness 3 m.

7. Limestones (biosparite, biomicrite), thin-bedded, bearing fusulinids. The latter are represented by abundant and diverse *Nonpseudofusulina* along with relatively rare *Anderssonites* and *Eoparafusulina* forms (Sample PCP67–PCP70) The other fossils found in the rocks are rare smaller foraminifers *Palaeotextularia* sp., *Globivalvulina* sp., bryozoan species *Fistulipora nuraeformis* Gorjunova, *Hexagonella recta* Gorjunova, *Streblascopora* sp., *Rectifenestella absoluta* (Gorjunova), *Minilya* n. sp. (samples PCP68, PCP69, PCP73), gastropods, crinoid columnals, and green algae. Thickness 2.7 m.

8. Dolomites, thick-bedded, with an interlayer of red foliated argillites at the boundary with Bed 7. Thickness 5 m.

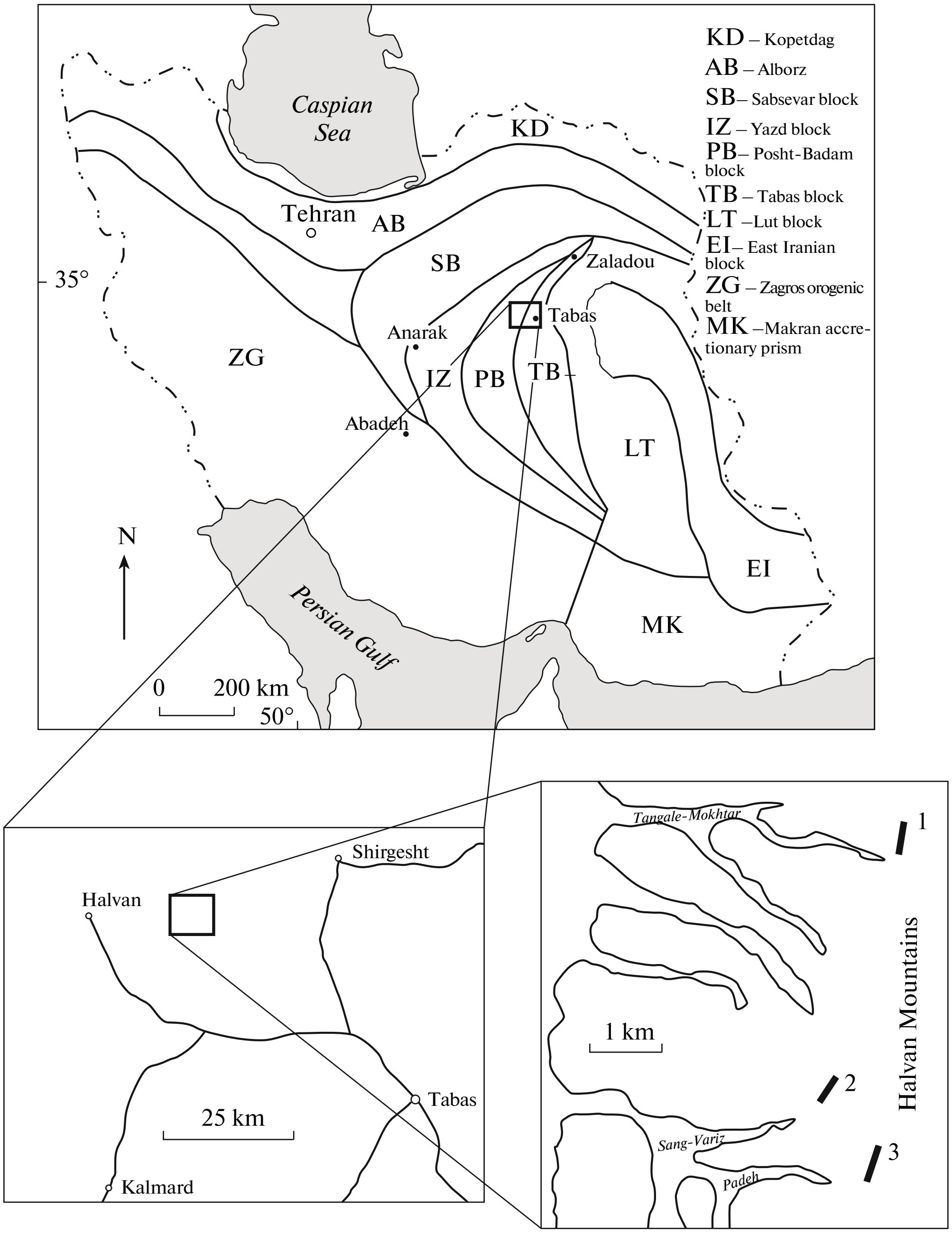


Fig. 1. Geographic localities of the Tangale-Mokhtar (1), Sang-Variz (2), and Padeh (3) sections.

9. Limestones, detrital, bedded, with abundant fusulinids of the genus *Nonpseudofusulina* exclusively (Sample PCP79, PCP80). Thickness 1.3 m. Total thickness of the Chili Formation is 48.7 m.

Sartakht Formation

10. Laterite, reddish brown, earthy, with pisolitic fabrics in places, resting on uneven surface of limestones belonging to Bed 9. In the Sang-Variz section, there is breccia-conglomerate at the laterite base, which seems to have been formed as a consequence of weathering and disintegration of limestones overlying Bed 9, because limestone clasts in breccia doubtlessly differ from limestones of Beds 7 and 9. Breccia clasts are lighter in coloration, less compact, predominantly biomicritic, mixed with less frequent oncolitic varieties. Many clasts contain fusulinids whose assemblage is obviously different from that of the underlying beds, because it includes abundant large tests of globular shape belonging to the genera *Robustoschwagerina, Parazellia*, and *Sphaeroschwagerina* (Sample PSS). These fusulinids occur in association with *Benshiella* and *Nonpseudofusulina* forms. Moreover, specific

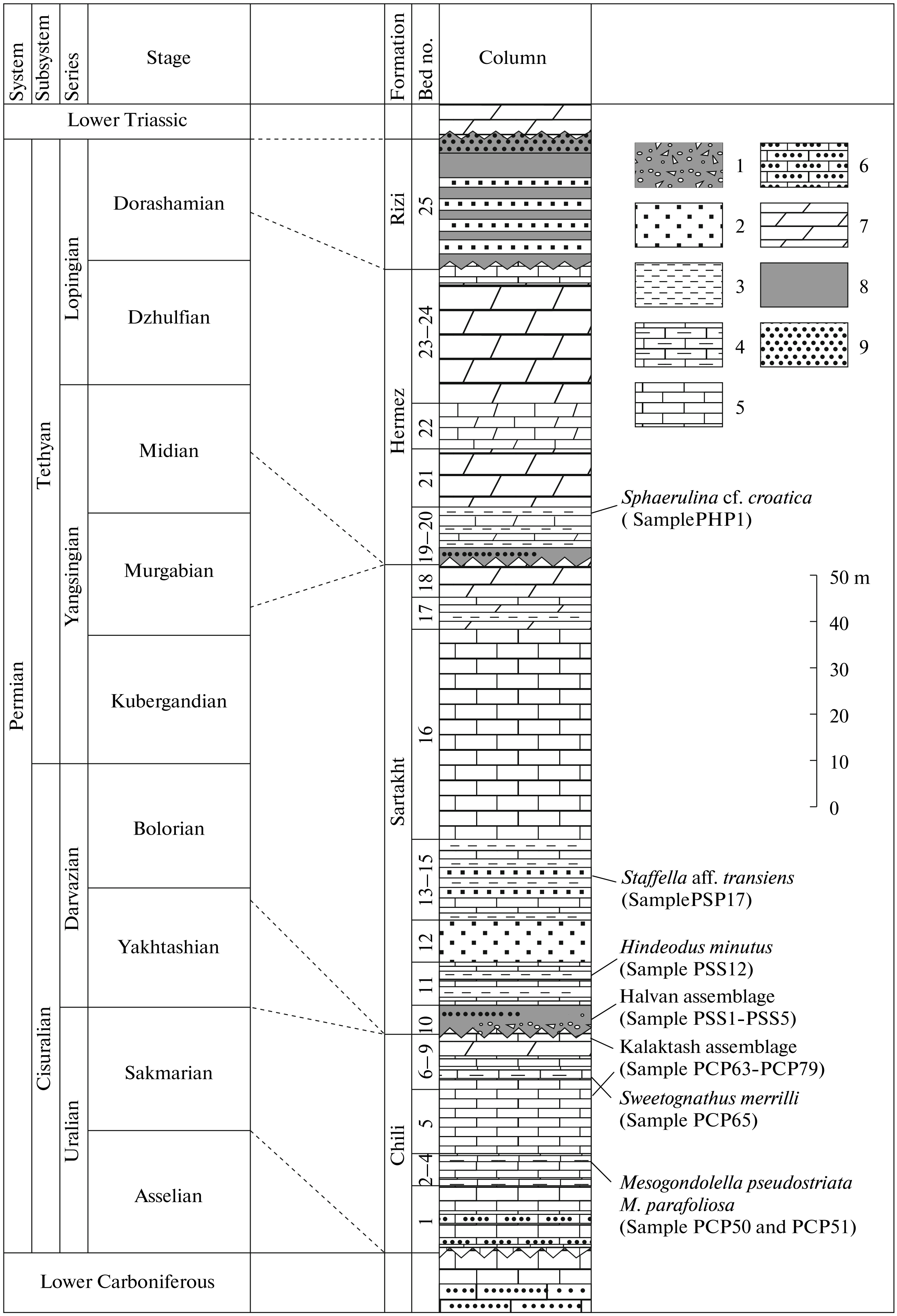

System
Subsystem
Series
Stage
Formation
Bed no.
Column
Lower Triassic
Permian
Tethyan
Cisuralian
Lopingian
Yangsingian
Darvazian
Uralian
Dorashamian
Dzhulfian
Midian
Murgabian
Kubergandian
Bolorian
Yakhtashian
Sakmarian
Asselian
Lower Carboniferous
Rizi
Hermez
Sartakht
Chili
25
23–24
22
21
19–20
18
17
16
13–15
12
11
10
6–9
5
2–4
1
1
2
3
4
5
6
7
8
9
50 m
40
30
20
10
0
Sphaerulina cf. *croatica*
(SamplePHP1)
Staffella aff. *transiens*
(SamplePSP17)
Hindeodus minutus
(Sample PSS12)
Halvan assemblage
(Sample PSS1-PSS5)
Kalaktash assemblage
(Sample PCP63-PCP79)
Sweetognathus merrilli
(Sample PCP65)
Mesogondolella pseudostriata
M. parafoliosa
(Sample PCP50 and PCP51)

Fig. 2. Composite stratigraphic column for the Padeh and Sang-Variz sections: (1) breccia-conglomerate; (2) quartz sandstone; (3) argillite; (4) marl; (5) limestone; (6) oolitic limestone; (7) dolomite; (8) laterite; (9) bauxite.

composition of the last genus is absolutely different from that established in underlying beds of the Chili Formation. Thickness of breccia-conglomerate ranges from 0 to 1.5–2 m; total thickness of Bed 10 is up to 5–6 m.

11. Thin-bedded detrital limestones (micrite, biomicrite, biosparite, biopelmicrite), intercalated with foliated, usually red argillites. Fossils of the bed include smaller foraminifers, algal fragments, gastropod shells, bivalves, crinoid columnals, and echinoid spines. The conodont *Hindeodus minutus* (Ellisson) and fusulinid *Staffella* sp. have been identified in the upper part of the bed (Sample PSS12). Thickness 9.5 m.

12. Light-colored massive quartz sandstone. Thickness 9.7 m.

13. Interlayering quartz sandstones, argillaceous shales, and sandy limestones. Shales are of reddish coloration at the base and top of the bed. Fusulinids (*Staffella* aff. *transiens* K.-Devidé, Sample PSP17), smaller foraminifers, and algal remains have been found in limestone interlayers. Thickness 8 m.

14. Quartz sandstone. Thickness 2.4 m.

15. Red argillaceous shales with limestone interlayer in the middle part. Sample PSP25 from limestone interlayer yielded smaller foraminifers and rare fusulinids (*Staffella* aff. *transiens* K.-Devidé). Thickness 4.7 m.

16. Limestones (biosparite, biomicrite) thin- to medium-bedded, dark gray, containing rare smaller foraminifers. Thickness 52 m.

17. Interlayering dolomites, detrital and crinoidal limestones, and argillites. Rare fusulinid species *Nankinella* sp. (Sample PSP38) and bryozoans are identified in limestones. Thickness 5.6 m.

18. Dolomites, thick-bedded, light gray to yellowish; thickness 7.2 m. Total thickness of the Sartakht Formation is 104.1 m.

Hermez Formation

19. Bauxite, red to yellowish brown, pisolitic. Thickness 2.2 m.

20. Interlayering red shales and dolomitized limestones containing recrystallized *Sphaerulina* aff. *croatica* K.-Devidé and *Nankinella* sp. (Sample PHP-1). Thickness 9.7 m.

21. Massive dolomite. Thickness 12 m.

22. Limestones, dolomitized, medium- to thin-bedded. Thickness 10 m,

23. Massive dolomite of light pinkish coloration. Thickness 24 m.

24. Limestones (micrite and biomicrite), light gray, nodular, dolomitized, with interlayers of white gypsinate marl. Algal limestone varieties (packstone) prevailing in the lower part are replete with fragmented *Gimnocodium* and *Permocalcus* skeletons. Higher in the bed, smaller foraminifers (largely *Hemigordius* and rare *Nodosaria* forms), ostracodes, and a small test fragment belonging presumably to the genus *Sumatrina* have been found. Thickness 3.1 m; total thickness of the Hermez Formation is 61 m.

Rizi Formation

25. Quartz sandstones interlayering with red-brown ferruginate laterite and enclosing bauxite interlayer (2 m) in the upper part; the sandstones contain poorly preserved plant remains, which, according to the preliminary conclusion of J. Sheng (personal communication) are of Permian aspect. The total thickness of the formation is 24.5 m. Rocks of the unit are overlain without visible discordance by thin-bedded dolomitized limestones of the Lower Triassic (Sorkh Shale Formation).

BIOSTRATIGRAPHIC ANALYSIS

The above description of rock succession shows that Permian deposits of the Padeh Valley consist, like in the Sang-Variz Valley nearby, predominantly of carbonate rocks, mostly biodetrital limestones. In the lower half of the Chili Formation, there are frequent interlayers of oolitic limestone, while dolomites prevail in the topmost part of the Sartakht Formation and upward in the succession. Judging from the diversity of organic remains that are principal components of the detrital fraction, limestones have been deposited in a shallow sea basin with normal salinity and relatively intense hydrodynamics. Accumulation of oolitic varieties suggests a hot subtropical or tropical climate. The same is evident from the occurrence of laterite interlayers at the boundaries between formations. Prevalence of dolomites in the upper part of the succession is most likely a consequence of changed salinity in the basin in response to a general increase in aridity.

Accumulation of Permian deposits was preceded by a long break in sedimentation that lasted throughout the Bashkirian–Asselian time span. Episodes of basin exsiccation and formation of weathering crusts also predated the accumulation epochs of sediments belonging to the Sartakht and Hermez formations, and to the Sorkh Shale Formation of the Triassic. Scouring marks and thin interlayers of red-colored rocks are indicative of other short-term events in the sedimentation history of the Permian formations.

It is difficult to estimate the length of the hiatuses that separate the Permian formations, because paleontological characterization of their rocks is inadequate for precise dating. This is also the principal obstacle for confident biostratigraphic subdivision of the whole succession. According to available data, there are three stratigraphic levels recognizable within the Chili Formation based on their fossil assemblages:

(1) Beds composed predominantly of oolitic limestones bearing abundant small staffellids (genera *Reitlingerina, Parastaffelloides*) and ammodiscids (*Ammovertella, Tolipammina*, and others) (interval of lower 8 m in Bed 1).

(2) Upper part of Bed 1 and beds 2–5, where most remarkable organic remains belong to bryozoans. The other fossils are rare smaller foraminifers (*Globivalvulina, Langella?, Tetrataxis*, and Endothyridae gen. indet) and fusulinids represented by single primitive *Schubertella* forms that are poorly preserved.

(3) The topmost part of Bed 5 and beds 6–9, characterized by abundant fusulinids of the Kalaktash assemblage occurring in association with bryozoans.

Clasts of fusulinid limestones in breccia-conglomerate at the base of the Sartakht Formation can be regarded as corresponding to a separate biostratigraphic level. As is already mentioned above, these clasts probably originated from physical weathering of the relevant limestone bed at the Chili Formation top after the basin exsiccation.

Biostratigraphic subdivision of the Sartakht and Hermez formations is complicated by the paucity of identifiable fossils in their rocks. In the first of them, three levels are recognizable with different assemblages of smaller foraminifers. In the opinion of T.V. Filimonova, who studied these fossils, the first level corresponds to beds 11, 12, and 13 of the succession. Foraminiferal taxa most characteristic of this level are *Hemigordius asimmetricus* Zolotova, *Protonodosaria* sp., *Nodosinelloides bella kamaensis* Baryshnikov, *Pachyphloia angulata irregularis* Baryshnikov, *Langella paraperforata* Lin, and *Geinitzina postcarbonica* Spandel. The second level spans Bed 15 and lower half of Bed 16. Species and subspecies identified here are *Hemigordius saranensis darvasicus* Filimonova, *Neohemigordius tenuitecus* (Kireeva), *Nodosinelloides pugioidea* Zolotova et Igonin, *Pachyphloia darvasica* Filimonova, *Globivalvulina unciata* Zolotova, *G. kungurensis* Igonin, *Langella* ex gr. *perforata perforata* (S. de C. et D.), *L.* ex gr. *perforata armenica* Rauser, and *Pseudoglandulina* ex gr. *conica* K. M.-Maclay. Dominant in the assemblage are representatives of genera *Pachyphloia* and *Langella*. In the third level corresponding to upper half of Bed 16 coupled with Bed 17, there is established occurrence of *Pachyphloia* ex gr. *paraovata* K. M.-Maclay, *P. schwageri* S. de C. et D., *Langella* ex gr. *perforata* (S. de C. et D.), *L.* ex gr. *pulchra* (Lange), and *L. wufengensis* Lin, Li et Sun.

Abundant algal remains are characteristic of the Hermez Formation lower half. Upward in the section, these fossils disappear, giving place to smaller foraminifers mostly belonging to the genus *Hemigordius*.

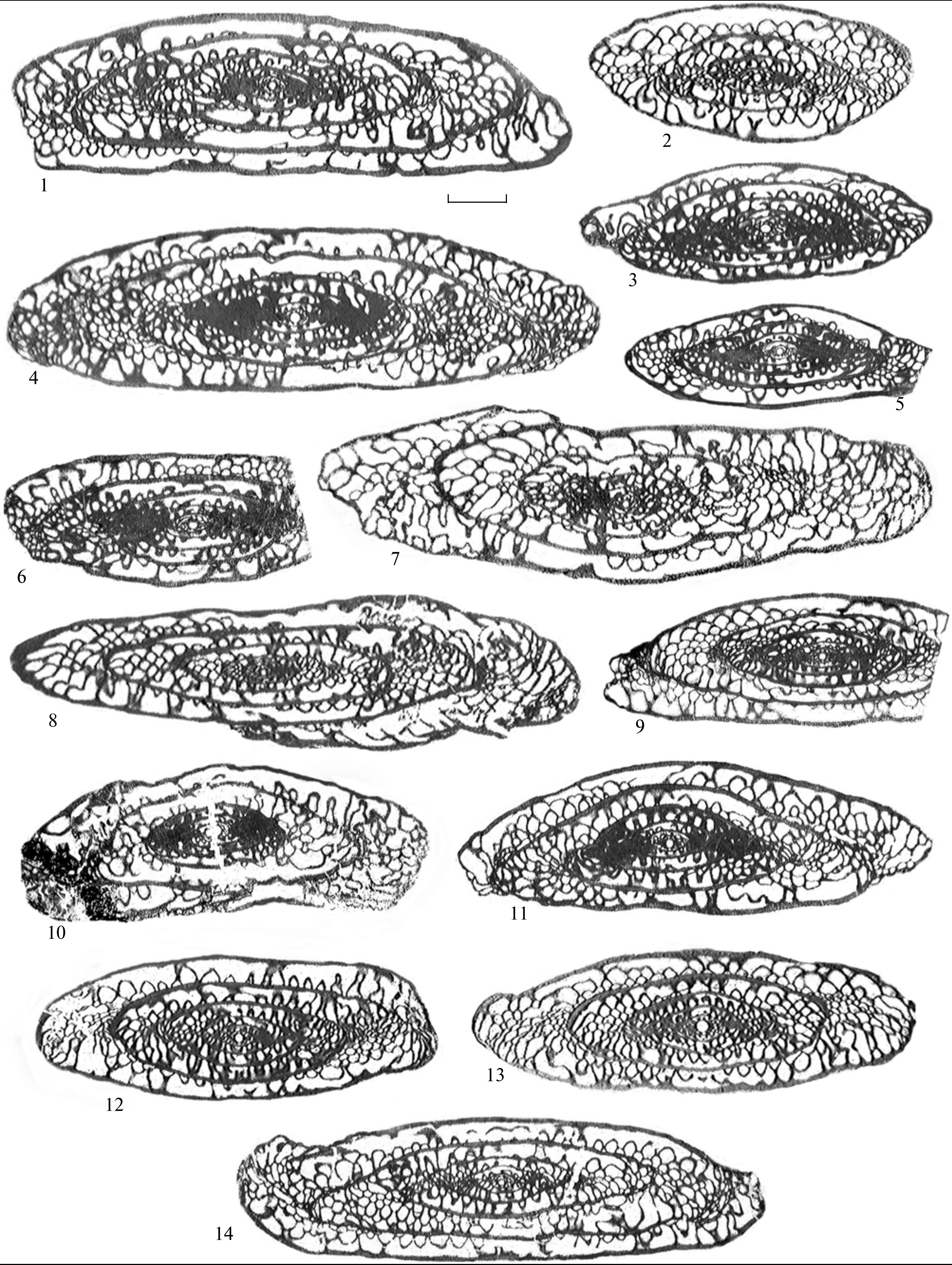
The following relatively rare fossils whose state of preservation is more or less appropriate for their identification can be considered for age evaluations of four formations distinguished in the Permian succession.

Small staffellids from the base of the Chili Formation comprise genera of wide stratigraphic ranges (from Moscovian Stage to the top of the Permian, inclusive). They change inconsequentially with age, and classification of their species is inadequate. Accordingly, this group of fossils is of low value for precise dating. Single primitive *Schubertella* forms and smaller foraminifers are also almost useless in this respect. Bryozoans occurring in association with foraminifers are undoubtedly of Early Permian age. In the Tezak section of southern Afghanistan, the species *Nikiforopora boulangei* has first been identified in the upper part of the terrigenous sequence underlying limestones with fusulinids of the Kalaktash type (Termier and Termier, 1971). According to Vachard (1980), beds with bryozoans (Zone P1 in his biostratigraphic scale) can be regarded as Asselian–Sakmarian in age. Gorjunova (1975), who determined bryozoans in our collection, found the aforementioned species in the upper part of the Bazardara Formation in the southeastern Pamirs. In her opinion, the relevant beds belong to the Artinskian Stage. On the other hand, brachiopods and ammonoids found at the same level are of Sakmarian Age (Grunt and Dmitriev, 1973).

Many bryozoan species have been identified in beds 2–5 of the Chili Formation. These are *Mackinneyella supraornamentata, Nikiforopora boulangei, Raiporidra asiatica, Rectifenestella absoluta, Fistulipora nuraeformis, Hexagonella recta*, and *Shulgapora kolvae*, but only the last taxon is known from the Artinskian deposits of the Urals. Data on *N. boulangei*

Plate I. Fusulinids of the Kalaktash assemblage (tenfold magnification of all the figures; scale bar is equal to 1 mm):
(1) *Nonpseudofusulina* aff. *paraconcessa* (Rauser-Chernousova), axial section, GIN 4791/1 (Sample PCP-67); (2) *Nonpseudofusulina licis* (Leven), axial section, GIN 4791/2 (Sample PCP-68); (3) *Anderssonites callosus* (Rauser-Chernousova), axial section, GIN 4791/3 (Sample PCP-67); (4) *Nonpseudofusulina muzkolensis* (Leven), axial section, GIN 4791/4 (Sample PCP-67); (5) *Anderssonites* aff. *seleukensis* (Rauser-Chernousova), axial section, GIN 4791/5 (Sample PCP-67); (6) *Anderssonites* aff. *escherensis* (Sjomina), axial section, GIN 4791/6 (Sample PCP-68); (7) *Nonpseudofusulina gachalensis* (Leven), subaxial section, GIN 4791/7 (Sample PCP-68); (8) *Nonpseudofusulina pamirensis* (Leven), subaxial section, GIN 4791/8 (Sample PCP-79); (9) *Nonpseudofusulina* aff. *kutkanensis* (Rauser-Chernousova), axial section, GIN 4791/9 (Sample PCP-68); (10) *Nonpseudofusulina curteum* (Leven), axial section, GIN 4791/10 (Sample PCP-67); (11) *Cuniculinella spinosai* (Davydov et Arefifard), axial section, GIN 4791/11 (Sample PCP-67); (12,13) *Nonpseudofusulina* aff. *neglectens* (Leven), axial sections, GIN 4791/12 and 4791/13(Sample PCP-68); (14) *Nonpseudofusulina* aff. *pedissequa attenuata* (Shirinkina), axial section, GIN 4791/14 (Sample PCP-67).

Plate I



are observed higher. The other species along with *Sh. kolvae* were described by Gorjunova from beds underlying limestones with the Kalaktash fusulinid assemblage in the Central Pamirs and from the topmost part of the Bazardara Formation of the southeastern Pamirs. In any case, it appears that the relevant beds are most likely of Sakmarian Age. Our conclusion that the Chili Formation part under consideration corresponds to the Sakmarian but not the Artinskian Stage is consistent with the identification of conodonts from Bed 4. As reported by Chernykh (2005) who studied type sections of the Urals, *Mesogondolella pseudostriata* appears here near the top of the Asselian Stage and transits into the lower part of the Sakmarian Stage, while *M. parafoliosa* is a characteristic species of the Tastubian Horizon in the Sakmarian Stage

Sweetognathus merrilli from the base of Bed 6 (Sample PCP65) is also Tastubian in age, as it is the index species of the lower zone in the Tastubian Horizon of the Sakmarian Stage in the type sections of the Urals (Chernykh, 2005). Abundant fusulinids from beds 6–9 of the Chili Formation belong to the Kalaktash assemblage first described from sections of the Central Pamir (Leven, 1993). The list of fusulinids identified in the assemblage includes *Nonpseudofusulina pamirensis* (Leven), *N. neglectens* (Leven), *N. licis* (Leven), *N. curteum* (Leven), *N.* ex gr. *insignis* (Leven), *N. muzkolensis* (Leven), *N. gachalensis* (Leven), *N. rahdarensis* (Davydov et Arefifard), *N. aghanabatei* (Davydov et Arefifard), *N.* aff. *longa* (Kireeva), *N.* aff. *pedissequa attenuata* (Shirinkina), *N. padehensis* n. sp., *Anderssonites ascherensis* (Sjomina), *A.* ex gr. *pseudoanderssoni* (Sjomina), *A. callosus* (Rauser-Chernousova), *A.* aff. *seleukensis* (Rauser-Chernousova), *A.* aff. *mirabilis* (Rauser-Chernousova), *Cuniculinella spinosai* (Davydov et Arefifard), and *Eoparafusulina* cf. *stevensi* (Davydov et Arefifard).

First seven species of 20 fusulinids listed above are known from the Kalaktash assemblage proper. Species *Nonpseudofusulina gachalensis, N. rahdarensis, N. aghanabatei, Cuniculinella spinosai*, and *Eoparafusulina stevensi* occur in several sections of the Kalmard block, where they are associated with typical Kalaktash fusulinids (Leven and Gorgij, 2007; Davydov and Arefifard, 2007). In the Urals, the species *Anderssonites callosus* and *N. longa* are characteristic of the Sakmarian Stage, and *N. pedissequa* is known from the base of the Artinskian Stage (Rauser-Chernousova, 1940; Kireeva, 1949; Shirinkina et al.,1980).

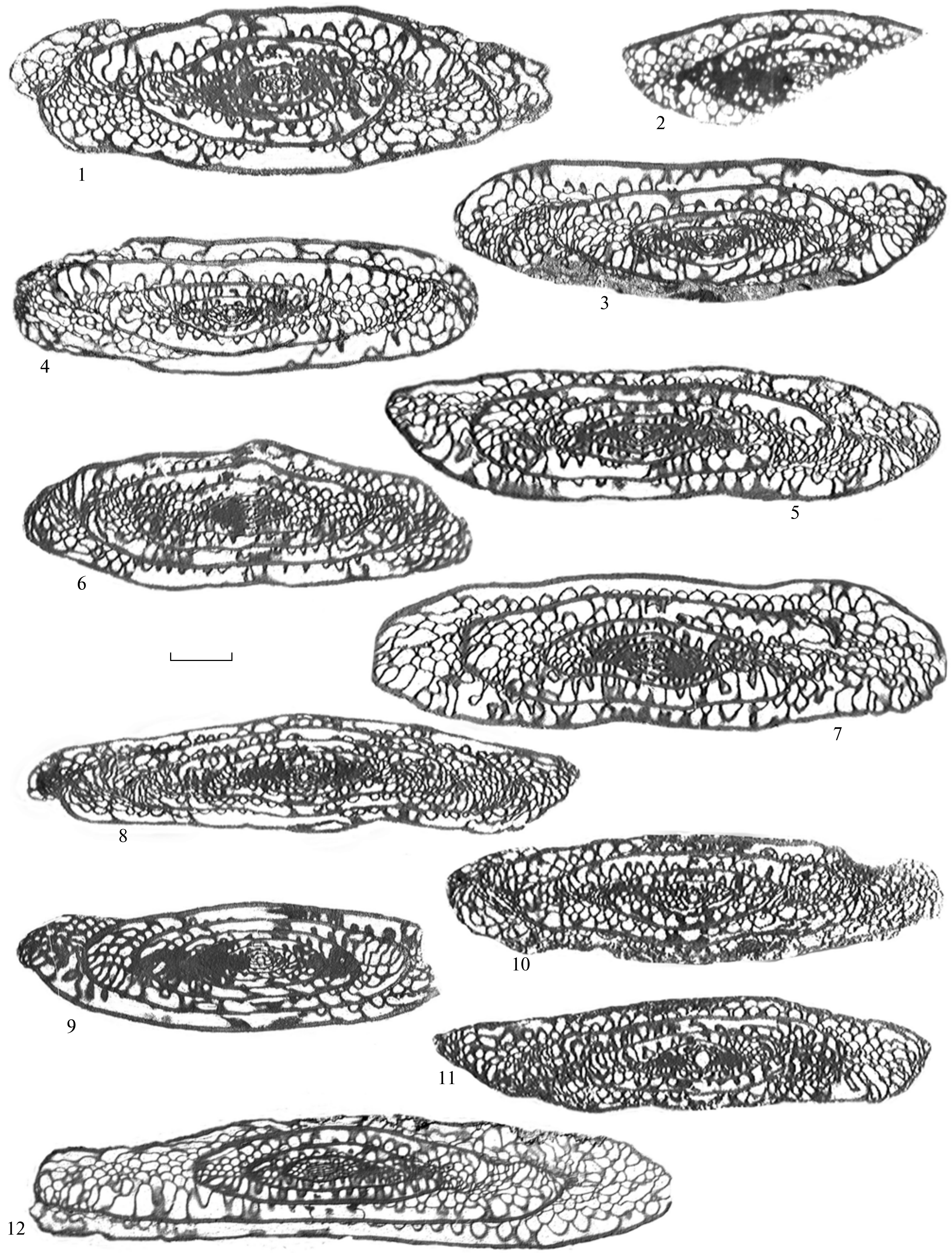
The age of the Kalaktash assemblage has remained disputable until now. In the Central Pamir, the assemblage was attributed to the Sakmarian Stage with minor reservations in favor of probable addition of the lower Artinskian based on the Artinskian age of bryozoans determined by Gorjunova, and on similarity between some species of the assemblage and Artinskian fusulinids from the Urals (Leven, 1993). Subsequent discovery of the Kalaktash fusulinids in sections of Pakistan, Afghanistan, and Oman did not resolve the problem. At the same time, it became clear that they are confined to the level above the beds with brachiopods, bivalves, and conulariids of the Gondwanan cold-water type characteristic, according to general opinion, of the Asselian Stage, but below beds with fusulinids of the Yakhtashian Stage (Gaetani and Leven, 1993; Gaetani et al., 1995; Leven, 1997; Angiolini et al., 2006; Leven, 2010).

S. merrilli found in the succession studied suggests that the lower part of beds with the Kalaktash fusulinids corresponds to the Tastubian, i.e., the lower Sakmarian level. It should be also taken into account that in the Tangale-Mokhtar section (Leven and Gorgij, 2009), in the upper part of the beds with the Kalaktash fusulinids, upper Sakmarian conodonts were found (*Sweetognathus inornatus* Ritter and *Sweetognathus anceps* Chernykh), the ancestral ones for the early Artinskian *S. whitei* (Chernykh, 2005). Consequently, we can now unambiguously refer the Kalaktash assemblage to the Sakmarian age.

The origin of the peculiar fusulinid assemblage from limestone clasts in breccia-conglomerate at the Sartakht Formation base is a particular problem. For convenience, these fusulinids are below termed the Halvan assemblage. In our description of the Tangale-Mokhtar section, this assemblage is regarded, with reservations, as Asselian in age despite the unsolved problem of the origin of clastic material. Fusulinids of the Kalaktash assemblage from beds underlying that breccia-conglomerate are represented by absolutely different genera and species as compared to fusulinids from breccia clasts. As the Permian succession base is unexposed at the Tangale-Mokhtar locality, it was reasonable to think that source rocks of the breccia clasts are concealed somewhere there. In contrast, the basal part of the Permian sequence is well observable in sec-

Plate II. Fusulinids of the Kalaktash assemblage (tenfold magnification of all the figures; scale bar is equal to 1 mm):
(1) *Nonpseudofusulina* ex gr. *insignis* (Leven), axial section, GIN 4791/15 (Sample PCP-67); (2) *Nonpseudofusulina* aff. *mirabilis* (Rauser-Chernousova), axial section, GIN 4791/16 (Sample PCP-66); (3, 4) *Nonpseudofusulina aghanabatei* (Davydov et Arefifard), axial sections, GIN 4791/17 и 4791/18 (Sample PCP-66 and PCP-67 respectively); (5, 7) *Nonpseudofusulina* ex gr. *pamirensis* (Leven), axial sections, GIN 4791/19 and 4791/21 (Sample PCP-68); (6) *Nonpseudofusulina* aff. *longa* (Kireeva), axial section, GIN 4791/20 (Sample PCP-79); (8) *Nonpseudofusulina rahdarensis* (Davydov et Arefifard), axial section, GIN 4791/22 (Sample PCP-79); (9) *Eoparafusulina* cf. *stevensi* (Davydov et Arefifard), subaxial section oblique to some extent, GIN 4791/11 (Sample PCP-67); (10, 11) *Nonpseudofusulina padehensis* Leven, n. sp., axial sections of holotype (fig. 10) and topotype, GIN 4791/23 and 4791/24 (Sample PCP-79); (12) *Nonpseudofusulina plena* (Leven), subaxial section, GIN 4791/25 (Sample PCP-69).

Plate II



tions described in this work, but we failed to find here fusulinids of the Asselian affinity. On the other hand, the Asselian fusulinids are known from sections of the Tabas (Leven and Taheri, 2003) and Yazd (Leven and Gorgij, 2006) blocks, although there they are of the other type, different from fusulinids from the breccia-conglomerate.

Considering all the data mentioned above, we now suggest that the breccia-conglomerate is clastic material that originated by disintegration of a limestone bed formerly situated at the very top of the Chili Formation immediately above the beds bearing the Kalaktash fusulinid assemblage. Consequently, rocks with fusulinids of Asselian aspect are either late Sakmarian or early Artinskian in age. Fusulinids found in breccia-conglomerate of the Sang-Variz section confirm our assumption. The list of species identified in this case is as follows: *Schubertella* sp., *Sphaeroschwagerina* cf. *gigas* (Scherbovich), *Parazellia* aff. *falx* (Rauser-Chernousova), *P. elongata* (Saurin), *P. halvanensis* n. sp., *Robustoschwagerina yunnanensis* Sheng, Wang et Zhong, *R. xiaodushanica* Sheng, Wang et Zhong, *Robustoschwagerina* sp., *Benshiella khorasanensis* Leven, *B. minuscula* n. sp., *Rugosochusenella rugosa* n. sp., *Eoparafusulina regina* Nie et Song, *E. grozdilovae* Davydov et Arefifard, *E. oblonga* (Grozgilova et Lebedeva), *E. madbeiki* Davydov et Arefifard, *Nonpseudofusulina ruttneri* n. sp., and *N.* ex gr. *exuberata* (Shamov).

Species listed above have been identified in several clasts, and composition of their assemblage is nearly uniform in all rock samples, suggesting a common origin of sediments. It is remarkable that fusulinid limestones underlying the breccia-conglomerate do not occur as clasts in the latter. Characteristic fusulinids occurring in most clasts are represented by large thick-walled swollen-fusiform and spheroidal forms attributed to the genus *Parazellia*. Some of them resemble the species *"Pseudoschwagerina" muongthensis*, "*P.*" *ischimbajica*, and *"P." falx* described by Rauser-Chernousova and Scherbovich (1949) from the Asselian beds of the Urals, and this was a reason that we initially argued for the Asselian age of fusulinids from the breccia clasts. Such a conclusion appeared to be consistent with data on the other regions (Timan, China, Vietnam), where similar forms were found, although some researchers did not completely exclude the possibility that their host beds are of Sakmarian age. In the eastern Yunnan, for instance, fusulinids in question occur in association with diverse *Robustoschwagerina* forms characteristic of the Robustoschwagerina–Paraschwagerina Zone of the Tethyan scale (Zhou et al, 1987). As in Yunnan, the genus *Robustoschwagerina* from the Sang-Variz section we studied includes the same species *Robustoschwagerina yunnanensis* and *R. xiaodushanica*. In evolutionary level, the first of them is close to *R. pamirica* Leven et Scherbovich from the base of Robustoschwagerina–Paraschwagerina Zone in sections of Darvaz (Leven and Scherbovich, 1978). *Eoparafusulina* accompanying *Parazellia* and *Robustoschwagerina* probably suggests a Sakmarian rather than Asselian age of the host rocks. The first genus is characteristic of beds correlated with the Sakmarian Stage in many sections of the Tethys.

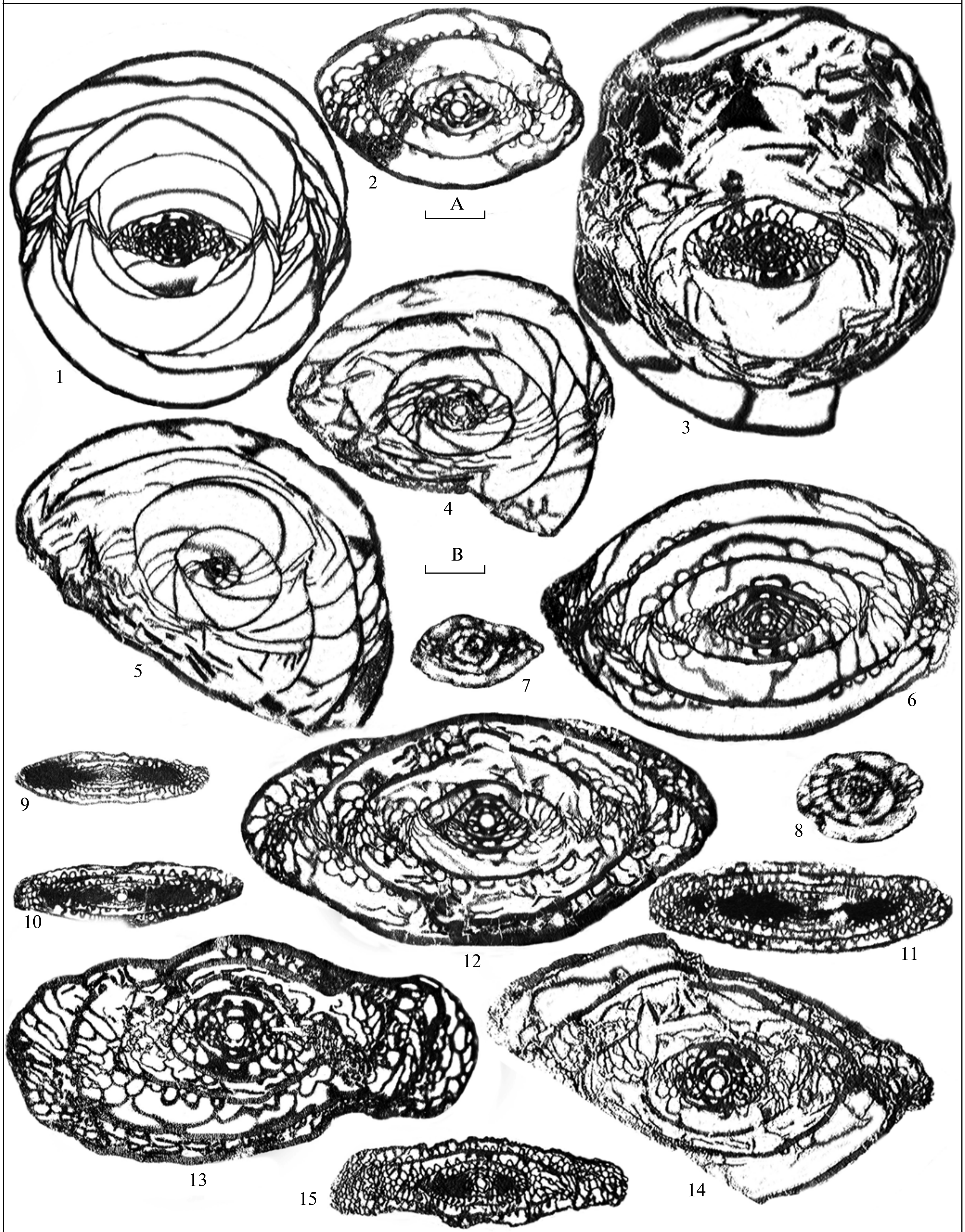
Thus, new fusulinids that have been found suggest a Sakmarian rather than Asselian age for the Halvan assemblage, despite the archaic aspect of many species it includes. Apparently, this is additional confirmation of the well-known fact that many Asselian genera and species of fusulinids survived much longer in the Tethys than in the East European seas, where many of these fossils do not cross the Asselian–Sakmarian boundary. In view of the Sakmarian age of clastic material from the breccia-conglomerate, our inference that it was formed by disintegration of beds which rested on limestones with the Kalaktash fusulinid assemblage at the top of the Chili Formation, appears to be plausible.

It is necessary to note here that in our considerations we regard the Sakmarian Stage in its range authorized in the Tethyan scale, where it is concurrent with the Robustoschwagerina–Paraschwagerina Zone. However, the equivalency of the subdivisions termed the Sakmarian Stage in the Urals and Tethys has never been properly substantiated. Considering fusulinids of the Robustoschwagerina–Paraschwagerina Zone, it is impossible to correlate precisely the subdivision ranges because of biogeographic distinctions of the Uralian and Tethyan basins. The designated zone is attributed to the Sakmarian stage based on its position above the beds correlating well with the Asselian strata and below the Yakhtashian Stage, in the upper part of which there have been found the Artinskian (upper Artinskian) ammonoids.

Plate III. Fusulinids of the Halvan assemblage (magnification tenfold in figs. 1–6, 9–15 and forty-fold in figs 7, 8; (scale bars A and B are equal to 1 and 0.25 mm respectively):

(1) *Robustoschwagerina yunnanensis* Sheng, Wang et Zhong, axial section, GIN 4791/26 (Sample PSS); (2) *Parazellia elongata* (Saurin), axial section, GIN 4791/27 (Sample PSS-2); (3) *Robustoschwagerina* sp., axial section, GIN 4791/28 (Sample PSS); (4) *Robustoschwagerina xiaodushanica* Sheng, Wang et Zhong, subaxial section, GIN 4791/29 (Sample PSS-2); (5) *Sphaeroschwagerina* cf. *sphaerica gigas* (Scherbovich), tangential section, GIN 4791/29 (Sample PSS-2); (6, 12–14) *Parazellia muongthensis halvanensis* n. subsp., axial sections, GIN 4791/27 (holotype), 4791/35, 4791/36 and 4791/37 (samples PSS-2, PSS-4, PSS-1 and PSS respectively); (7, 8) *Schubertella* ex gr. *paramelonica* Suleimanov, subaxial sections, GIN 4791/30 and 4791/31 (Sample PSS-1); (9–11) *Benshiella minuscula* Leven et Gorgij, n. sp., axial sections, GIN 4791/32, 4791/33 and 4791/34 (holotype) (Sample PSS, PSS-4, and PSS-2 respectively); (15) *Benshiella khorasanensis* Leven, axial section, GIN 4791/38 (Sample P-71).

Plate III



In addition, the Sakmarian ammonoids are known from the lower part of that zone (Leven et al., 1992). The boundary separating the Robustoschwagerina–Paraschwagerina Zone, i.e., the Sakmarian Stage of the Tethyan scale, from the Yakhtashian Stage is defined at the first occurrence level of genera *Pamirina* and *Chalaroschwagerina*, which do not occur in the Uralian sections. Consequently, there no sense in speculating about the identity of this level and the Sakmarian–Artinskian boundary in the Uralian scale. It is admissible to think that the uppermost part of the Sakmarian Stage in the Tethys may correspond to the lower part of the Artinskian Stage in the Urals. If this is correct, and if the Halvan fusulinid assemblage is certainly younger than the Kalaktash assemblage, then the former would be early Artinskian in age. The problem can be clarified based on conodonts enabling correlation between the Tethyan and Uralian sections. Data on conodonts from the Carnic Alps (Forke, 2002) are most interesting in this aspect. Based on the distribution of fusulinids, the Robustoschwagerina–Paraschwagerina Zone, i.e., the Sakmarian Stage of the Tethyan scale, corresponds here in range to the upper part of the Grenzland Formation coupled with the Upper Pseudoschwagerina Limestone. Conodonts (*Sweetognathus* aff. *whitei, Mesogondolella* cf. *bisseli*) occurring in the upper part of the latter subdivision are characteristic of the base of the Artinskian Stage in the Urals. Upward in the section, in the Trogkofel Formation, the upper Artinskian species *Neostreptognathodus pequopensis* has been found. According to Kahler (1989), typical Yakhtashian fusulinids (*Pamirina darvasica*) are known from the Goggau Limestone, which probably grades in places into the Trogkofel Limestone (Forke, 2002). Hence, data quoted above lead to the conclusion that the Yakhtashian lower boundary is inside the Artinskian Stage, and that the Sakmarian Stage of the Tethys is correlative with the synonymous stage of the Urals coupled with lower part of the Artinskian Stage. This preliminary conclusion must be verified, and further sampling of fusulinids and conodonts in particular should be carried out not only in the Carnic Alps, where the Yakhtashian Stage is practically missing, but also in the other regions, where this stage is represented more completely.

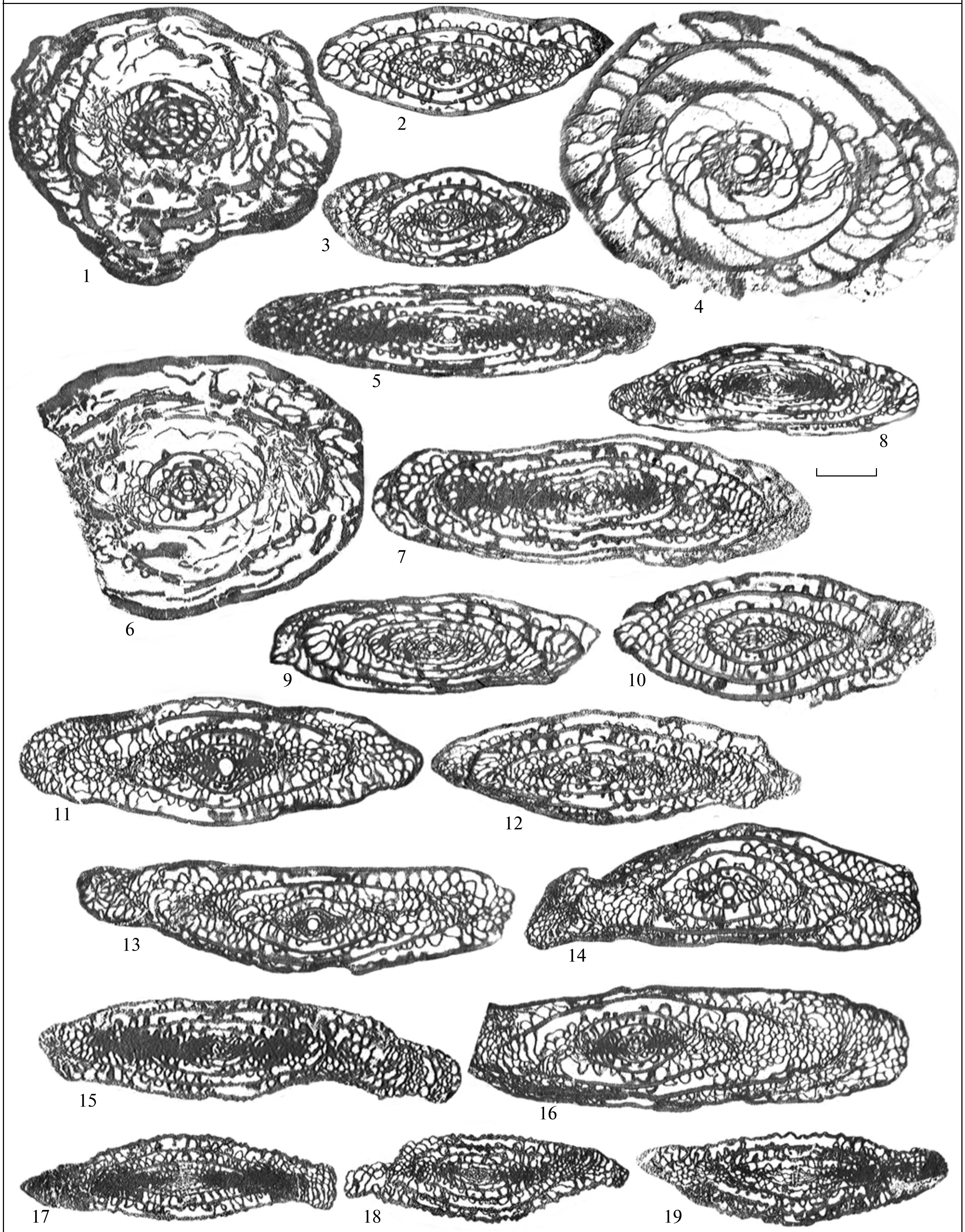
Thus, age of the Chili Formation can be determined more or less reliably based on available paleontological data, but the same cannot be said about the overlying formations of the Permian succession. Fusulinids found approximately 20 m above the Sartakht Formation base are represented by several specimens of *Staffella transiens* Kochansky-Devidé, the species first identified in the Murgabian deposits of Croatia (Kochansky-Devidé, 1965). In Transcaucasia, this taxon has been described from lower zone of the Kubergandian Stage (Leven, 1998). Staffellids of the same evolutionary level known in China, Indochina, and Japan, are confined to beds of the Bolorian, Kubergandian, and Murgabian. Taking into account these data, we can suggest only that the Sartakht Formation corresponds approximately in age to the Bolorian–Murgabian. Data on smaller foraminifers lead to a somewhat more definite conclusion. In the opinion of Filimonova, *Hemigordius asimmetricus* and *Pachyphloia angulata irregularis* found at the base of the Sartakht Formation are characteristic of the Yakhtashian–Bolorian transition in Darvaz. *Nodosinelloides bella kamaensis* and *Pachyphloia angulata irregularis* accompanying the above forms are typical of the Saranian Horizon, i.e., of the lower Kungurian in the Perm oblast of the Cis-Urals. *Langella* ex gr. *perforata*, *Pachyphloia darvasica*, and *Hemigordius saranensis darvasicus* occurring higher in the section (up to the middle of Bed 16) characterize upper zone of the Bolorian stage in Darvaz. *Nodosinelloides pugioidea* found in association with these taxa is the index species of the Filippovian Horizon in the Kungurian Stage of the Urals. The upper third of the formation under consideration belongs, as one can judge from smaller foraminifers, to the Kubergandian Stage, as rocks at this level contain advanced *Pachyphloia schwageri* and large *Langella* forms, such as *Langella* ex gr. *pulchra* and *L. wufengensis*. We therefore do not exclude the possibility that the uppermost part of the formation already belongs to the Murgabian Stage.

The Hermez Formation is without doubt of Late Permian age. The genera *Sphaerulina* and *Nankinella*, found at the very base of this formation, resemble fusulinids from the upper Murgabian–Midian deposits of Croatia (Kochansky-Devidé, 1965). Algal limestones occurring higher bear abundant *Gymnocodium,*

Plate IV. Fusulinids of the Halvan assemblage (tenfold magnification of all the figures; (scale bar is equal to 1 mm):

(1, 6) *Parazellia* aff. *falx* (Rauser-Chernousova), axial sections, GIN 4791/39 and 4791/43 (Sample PSS); (2, 3, 12) *Nonpseudofusulina* ex gr. *exuberata* (Shamov), axial sections, GIN 4791/40, 4791/41 and 4791/48 (Sample PSS-1, PSS-4 and PHP-P respectively); (4) *Robustoschwagerina ?* aff. *psharti* Leven, subaxial section oblique to some extent, GIN 4791/34 (Sample PSS-2); (5) *Eoparafusulina oblonga* (Grozdilova et Lebedeva), axial section, GIN 4791/42 (Sample PHS-P); (7) *Eoparafusulina grozdilovae* Davydov et Arefifard, axial section, GIN 4791/44 (Sample PCP-71); (8) *Eoparafusulina madbeiki* Davydov et Arefifard, axial section, GIN 4791/31 (Sample PSS-1); (9) *Eoparafusulina regina* Nie et Song, subaxial section, GIN 4791/45 (Sample PCP-71); (10) *Cuniculinella* cf. *partoazari* (Davydov et Arefifard), tangential section, GIN 4791/46 (Sample PCP-71); (11, 13, 14, 16) *Nonpseudofusulina ruttneri* Leven n. sp., axial sections, GIN 4791/47 (holotype), 4791/49, 4791/50 and 4791/52 (Sample PSS-1); (15) *Benshiella halvanensis* Leven, axial section, GIN 4781/51 (Sample PSS); (17–19) *Rugosochusenella rugosa* Leven et Gorgij n. sp., axial and subaxial sections, GIN 4791/53 (holotype), 4791/54 and 4791/55 (Sample PSS-4, PSS, PSS-1 respectively).

Plate IV



Permocalcus, and *Mizzia*, characteristic of the Upper Permian in many sections of the Tethys. In Iran, the same fossils have recently been described from the upper part of the Ruteh Formation of the Alborz (Gaetani et al., 2009).

As for the Rizi Formation, it has been regarded until recently as part of the Lower Triassic Sorkh Shale Formation. Nevertheless, plant remains of the Paleozoic (Permian?) habit occurring in this subdivision suggest that it is still of Permian (Dzhulfian–Dorashamian) age (Shen et al., 2009).

CORRELATION

Permian succession of the Kalmard block is peculiar, different from concurrent sequences of nearby blocks Tabas (Ozbak-Kuh and Shirgesht section) and Yazd (Anarak section), which are very close to each other. Carboniferous up to the Gzhelian and Lower Permian Asselian deposits (Gachal, Galeh, Absheni, and Zaladou formations) are well represented in these blocks.

(Leven and Taheri, 2003; Leven et al., 2006; Leven and Gorgij, 2006a, 2006b). The late Asselian–Sakmarian age of the overlying Tighe-Maadanou Formation, composed of barren dolomites, is determined based on its position in the sections. In the Shirgesht area, dolomites are overlain with scouring by the Bage-Vang Formation of terrigenous-carbonate rocks containing the late Yakhtashian, Bolorian, and early Kubergandian fusulinids. The Jamal Formation of carbonates resting on these rocks is suggested to be of Kubergandian–Dorashamian age according to single specimens of fusulinids and smaller foraminifers which have been found.

Comparing the above succession with that of the Halvan Mountains, one can hardly find anything in common. In the Padeh section considered in this work, deposits corresponding to the Galeh, Absheni, and Zaladou formations are missing, and the Chili Formation rests immediately on the Lower Carboniferous rocks. In age, it corresponds approximately to the Tighe-Maadanou Formation of dolomites, being of different lithological composition and comparatively rich in fossils, whereas dolomites are absolutely barren of the latter.

According to the smaller foraminifers, the Sartakht Formation corresponds approximately in age to the Bage-Vang Formation of the Shirgesht area, presumably coupled with the Jamal Formation base exposed in its stratotype area (Shotori Mountains). As in the succession of the Halvan Mountains, the correlative formations are separated from underlying deposits by a hiatus. In the Halvan Mountains, the hiatus is marked by a horizon of red laterites missing from two sections under consideration. In addition, both yield abundant organic remains, the diverse fusulinids inclusive, whereas rocks of the Sartakht Formation are almost barren of fossils.

Based exclusively on their position in upper part of the Halvan succession of Permian beds, the Hermez and Rizi formations can be correlated with the Jamal Formation, if we exclude from the latter the interval corresponding to the Bage-Vang Formation of the Shirgesht area and concurrent beds of section in the Shotori Mountains. However, the comparable intervals of two successions are again composed of different facies. First of all, this concerns red laterites observable at the Hermez Formation base and inside the Rizi Formation, but missing from sections of the Shirgesht and Shotori areas.

Similarly there is little in common between Permian successions of the Halvan and Alborz mountains. According to recent data (Gaetani et al., 2009), the Dorud Group corresponding to the basal part of the Permian succession in the Alborz is of Late Carboniferous–Asselian or Late Carboniferous–early Sakmarian age. The succession of the Halvan Mountains lacks deposits of this age. In contrast, synchronous beds of the Chili Formation, the basal in the Permian succession of the Halvan Mountains are missing from the Alborz succession. The Ruteh and Nesen formations of Alborz probably correspond in age to the Sartakht, Hermez, and Rizi formations, although such a statement is insufficiently substantiated so far in view of their dissimilar lithological composition. In addition, paleontological characterization of the Nesen Formation is representative, but the same cannot be said for the Hermez Formation. In the Permian succession of Alborz, laterites can only be observed near the boundary with Triassic strata in the Qeshlaq Formation replacing the Nesen Formation along the strike.

All lower subdivisions here lacking corresponding rocks. There are even more distinctions between the Permian successions of the Halvan Mountains and Sanandaj-Sirjan zone located southward, where the succession begins with the Vazhnan Formation of terrigenous-carbonate rocks that contain poorly preserved fusulinids, presumably of Asselian age. In the Halvan Mountains, there are no analogs of this formation. The Vazhnan Formation is separated by a hiatus partially or completely spanning the Sakmarian and Yakhtashian stages from the overlying Surmaq Formation. The Abadeh Formation of carbonate-argillaceous rocks resting on the latter is crowned in the succession by the Hambast Formation of the same lithological composition. According to the position in succession, these formations would be correlative with the interval of the Chili, Sartakht, and Rizi formations, if it were not for the difference in lithology of two sequences. Moreover, all the formations of the Sanandaj-Sirjan zone are rich in fossils and reliably dated, which cannot be said about the formations of the Halvan Mountains (Baghbani, 1993; Kobayashi and Ishii, 2003).

Hence, the only characteristic that all the Permian successions in Iran have in common is a hiatus

Plate V

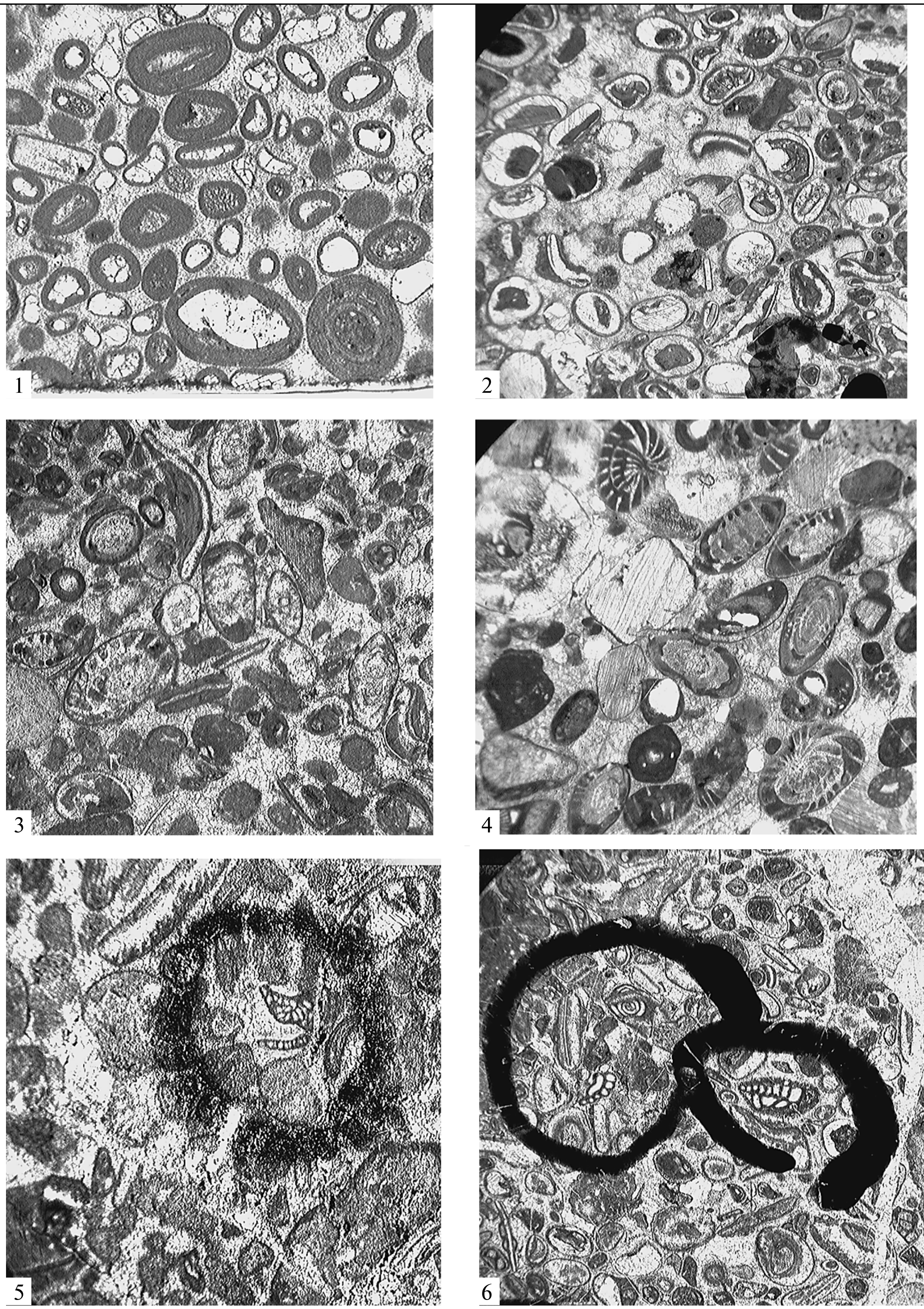


Plate V. Limestone microfacies from the Chili Formation of Iran and Dangikalon Formation of Central Pamirs:
(1, 2) oolitic peloid grainstone: (1) Chili Formation, (2) Dangikalon Formation; (3, 4) bioclastic peloid grainstone with small staffellids: (3) Chili Formation, (4) Dangikalon Formation; (5, 6) bioclastic grainstone with diverse sedentary ammodiscids: (5) Chili Formation, (6) Dangikalon Formation.

between their Asselian–Sakmarian part and the overlying transgressive beds of the upper Yakhtashian–Bolorian. In most sections (except for those of the Sanandaj-Sirjan zone), another hiatus is observable at the Permian–Triassic boundary. Because of the distinctions considered above, it is very surprising to see similarity between Permian successions of the Halvan Mountains and the Central Pamirs, separated from each other by two thousand kilometers. The similarity between their lower Chili and Dangikalon formations is particularly striking. At the base of the Dangikalon Formation in the Central Pamirs, there are, as in the basal part of the Chili Formation of the Padeh section, oolitic limestones contaminated by rounded quartz grains in their lower beds (Leven, 1993). Somewhat higher, beds of both successions bear abundant *Ammovertella, Tolypammina*, and other ammodiscids associated with small primitive staffellids. In both regions, abundant bryozoans are confined to the next interval, and bryozoan beds are overlain by strata that yield the fusulinid assemblage of the Kalaktash affinity. In the Pamirs, the hiatus at the base of these strata is marked in places by laterites. In the Padeh section, a comparable hiatus is observable at the base of thin Bed 4 underlying limestones with the Kalaktash-type *Nonpseudofusulina* forms. In the Pamirs, the Dangikalon Formation section is crowned by dolomites. The same rocks are confined to the top of the Chili Formation, although here they are of lesser thickness.

Microphotographs of thin sections in Plate V of this work illustrate the similarity between microfacies of the most characteristic rock varieties from the basal levels of the Chili and Dangikalon formations. Comparable facies frequently occur in the Carboniferous successions of the East European platform, Kazakhstan, and some other regions. The Visean–Serpukhovian limestones underlying the Chili Formation are also oolitic in part, but rocks of this kind are not typical of the Permian period. In any case, we do not know of them from any sequence of the Lower Permian in the Western Tethys, except for the sections under comparison.

The striking lithological and paleontological similarity of the Lower Permian sections in the Halvan Mountains and the Central Pamir supports our former hypothesis that the Permian deposits of the Central Pamirs, Middle Afghanistan, and Kalmard block accumulated in one basin (Leven and Gorgij, 2009; Leven, 2009). At present, we can only observe relics of that basin, the length of which was not less than 2000 km. At any rate, there is no doubt with respect to the similar accumulation settings of the Lower Permian deposits in the Halvan Mountains and the Central Pamirs.

In conclusion, we would like to attract attention to one more appreciable circumstance that can be inferred from the comparative analysis of Lower Permian deposits in the Halvan Mountains and the Central Pamirs. Oolitic limestones and laterites occurring in both regions imply deposition of the relevant sediments under similar conditions of hot tropical or subtropical climate. Earlier, when comparing fusulinids of the Kalaktash assemblage from the Central Pamirs, South Afghanistan, and Karakorum, we considered that all these regions resided within the comparatively high and cold latitudes during the Early Permian. That opinion was rooted in the endemism of the Kalaktash assemblage, which differed from concurrent assemblages of fusulinids that previously inhabited the warm-water basins of the Northern Tethys (Leven, 1993). Moreover, in sections of Afghanistan and Karakorum, beds with the Kalaktash fusulinids rest immediately on beds with brachiopods, bivalves, and conulariids, which were typical of the northerly and colder Peri-Gondwanan parts of the Tethys, e.g., of Australia, South Tibet, Himalayas, and Oman (Termier et al, 1974; Gaetani et al., 1995; Angiolini et al., 2006). In the light of new data, we should correct our former viewpoint and postulate now that the Central Pamirs were considerably further north than the Karakorum, i.e., within the low latitudes. At present, both regions are separated by only 150 km, demonstrating a considerable post-Permian convergence of two regions, which has been underestimated in contemporary paleoreconstructions.

ACKNOWLEDGMENTS

We are sincerely grateful to R.I. Gorjunova (PIN RAS), N.B. Rasskazova and N.A. Reimers (MSU), and T.V. Filimonova (GIN RAS) L.I. Kononova for identification of conodonts and foraminifers, and for useful comments.

DESCRIPTION OF FUSULINIDS (PLATES I–V)

Genus *Rugosochusenella* Skinner et Wilde, 1965

***Rugosochusenella rugosa* Leven et Gorgij n. sp.**

Plate IV, figs. 17–19

Species name from Latin “rugosa,” wrinkled.

Holotype. GIN, no. 4791/53; axial section; Iran, Sang-Variz, Sartakht Formation, Sample PSS-4 (clast from breccia-conglomerate); Sakmarian (?) Stage.

Material. Two axial and nine subaxial or oblique sections.

Description. Test not large, fusiform, with slightly tapered rounded-acuminate axial poles. In adult specimens with 5 to 6 tightly coiled volutions L = 5.1–6.0 mm, D = 1.5–1.7 mm, L : D = 3.2–3.5. Minute globular proloculus is 0.06 mm in diameter. Coiling of spirotheca regular or with a little jump after fourth volution. Spirotheca with keriotheca is rugged and strongly wrinkled, with characteristic deep septal grooves. In external volutions, spirotheca is not thicker than 0.08 mm. Septa thin and sinuous in two-three initial volutions are intensely folded all through in subsequent ones. Septal folds high, irregular in shape.

Position of narrow tunnel is unstable in volutions. Barely perceptible chomata are characteristic of innermost volutions only. Irregular axial filling is observable along the test axis.

Comparison. A high degree of spirotheca wrinkling and deep axial grooves differ *Rugosofusulina rugosa* n. sp. from all other known species of the genus.

Locality. Iran, Sang-Variz, breccia-conglomerate at the Sartakht Formation base, samples PSS-1, PSS-4, and PSS-10.

Occurrence. Unknown outside Iran.

Genus *Benshiella* Leven, 2009

***Benshiella minuscula* Leven et Gorgij n. sp.**

Plate III, figs. 9–11

Species name from Latin "minuscula," extremely small.

Holotype. GIN, no. 4791/34; axial section; Iran, Sang-Variz, Sartakht Formation, Sample PSS-2 (clast from breccia-conglomerate); Sakmarian (?) Stage.

Material. Three axial and seven subaxial or oblique sections.

Description. Test small, elongated-fusiform to subcylindrical, with rounded-acuminate poles. In adult specimens, there are up to 6 volutions with L = 5.7 mm, D = 1.7 mm, and L : D = 3.3. Globular proloculus is from 0.1 to 0.2 mm in diameter. Test coiling tight and regular. Spirotheca with keriotheca and small local wrinkles is 0.05 to 0.07 mm thick in external volutions. Septa thin, intensely folded. High septal folds of round to rounded-triangular shape decreasing in height toward moderately wide tunnel. Diminutive chomata visible in proloculus and first volution. Axial filling is well developed in all volutions except for the last one.

Comparison. The described species is most close to *Benshiella halvanensis* Leven, but its test is shorter, more tightly coiled, and respectively lesser in size.

Locality. Iran, Sang-Variz, breccia-conglomerate at the Sartakht Formation base, samples PSS, PSS-2, and PSS-4.

Occurrence. Unknown outside Iran.

Genus *Parazellia* Rauser-Chernousova, 1960

Remarks. Genus *Parazellia* with type species *Fusulina muongthensis* Deprat, 1915, was described in 1960 by D.M. Rauser-Chernousova who suggested its genetic proximity to the genus *Zellia* despite such a distinctive feature as "development of septal folding at all the evolutionary stages" (Rauser-Chernousova, 1960). The absence in America of this group of genetically interrelated fusulinids substantiated the viewpoint that *Parazellia* cannot be included in the American genus *Pseudoschwagerina*, although the basic characters of *P. muongthensis* correspond well to the diagnosis of that genus. In addition to the type species, Rauser-Chernousova attributed to the *Parazellia* group a series of Uralian species, such as *P. primigena, P. ischimbajica*, and *P. rossica*. Rozovskaya (1975) who erected the genus *Eozellia* included into this taxon all the species listed above except for *P. muongthensis*, considering the latter as belonging to *Pseudoschwagerina* and *"P." primigena* as the type species of new genus, diagnostic characters of which remained unchanged and identical to those used by Rauser-Chernousova in description of the genus *Parazellia*. It appears from the above data and practically unchanged specific composition that the separation of the genus *Eozellia* was hardly reasonable. Accordingly, we suggest to revive the former concept of the genus *Parazellia*,. As for *P. muongthensis*, this species can be certainly regarded as belonging to *Pseudoschwagerina*, but on the other hand, its affinity with *Zellia* is also evident, as one can see from materials described in this work, and following Rauser-Chernousova, we include it into composition of the genus *Parazellia*.

Hence, taking into consideration the new materials, we regard the massive swollen-fusiform to subspherical fusulinids with thick spirotheca becoming thicker in ontogeny and with a weak or clearer increment in spiral coiling as belonging to *Parazellia*. Due to the spiral coiling, test has individualized juvenarium with two–three spiral volutions. Septa are predominantly wave-folded to some extent in the juvenarium and subsequent volutions. Proloculus is usually large, and distinct chomata are characteristic of the juvenarium. Principal features differing the forms in question from *Zellia* are the looser, less regular coiling of spiral, fusiform shape of test (*Zellia* tests are usually ovoid or globular), and septal folding. *Parazellia* differ from typical *Pseudoschwagerina* forms in thicker spirotheca and less distinctly individualized juvenarium. In systematics of schwagerinids, *Parazellia* forms are transitional in structure between the genera *Zellia* and *Pseudoschwagerina*, being more or less comparable with the former and the latter.

***Parazellia halvanensis* Leven n. sp.**

Plate III, figs. 6, 12–14

Species name for the Halvan Mountains in central Iran.

Holotype. GIN, no. 4791/17; axial section; Iran, Padeh, Sartakht Formation, Sample PSS-2-4 (clast from breccia-conglomerate); Sakmarian (?) Stage.

Material. Ten axial and eight subaxial sections.

Description. Test of medium to large size, swollen-fusiform, with rounded poles occasionally tapered a little. In adult specimens with 5.5 to 6 volutions L = 7.0–9.5 mm, D = 4.8–5.5 mm, L : D = 1.6–1.8. Proloculus is sufficiently large, globular, 0.3 to 0.4 mm in diameter. Irregular spiral coiling is tight in two or three initial volutions but stepwise looser in subsequent ones; the last volution is commonly less high than the previous one. Spirotheca with keriotheca is thick, up to 0.2 mm across in external volution. Septa thin and folded in the lower septal margin as a rule. Low rounded septal folds are observable in axial sections somewhat apart from tunnel. The rest of septal folding is chaotic; folding area near axis insignificant. Tunnel narrow and high in the juvenarium is broad, having unstable position in subsequent volutions. Chomata massive and high in the juvenarium disappear in subsequent volutions.

Comparison. The described species is closest to *Parazellia muongthensis* (Deprat), differing in more elongated and less regular shape of test with somewhat tapered poles. The other close form *"Eozellia" elongata* (Saurin) from the Tangale-Mokhtar section is included at present in the genus *Parazellia*. Distinctly individualized juvenarium and looser, less regular coiling of subsequent volutions separate the new species from *P. elongata*.

Locality. Iran, Sang-Variz, Sartakht Formation, samples PSS, PSS-1, PSS-2, and PSS-4 (all from clasts of breccia-conglomerate).

Occurrence and age. Iran, presumably China and Indochina; Sakmarian (?).

Genus *Nonpseudofusulina* Leven, 2009

Nonpseudofusulina ruttneri n. sp.

Plate IV, figs. 11, 13, 14, 16

Species name after A. Ruttner who contributed much to the geological research in central Iran.

Holotype. GIN, no. 4791/47; axial section; Iran, Sang-Variz, Sartakht Formation, Sample PSS-1 (clast from breccia-conglomerate); Sakmarian (?) Stage.

Material. Four axial and three subaxial sections.

Description. Test of medium size, swollen-fusiform in inner volutions and turning then into elongated-fusiform in subsequent volutions with slightly swollen median part and rounded acuminate poles. In adult specimens with 4.5 to 5.5 volutions L = 7.0–8.5 mm, D = 2.3–2.5 mm, L : D = 3–3.6. Proloculus fairly large, globular to oval in shape is 0.2–0.4 mm in diameter. Coiling is usually tighter in two or two and a half initial volutions than in subsequent ones, although some specimens are lacking this character and free coiling is inherent of all volutions. Thickness of spirotheca with keriotheca increases gradually up to 0.08–0.1 mm in external volutions. Thin septa are intensely corrugated into high irregular septal folds arranged sometimes in two rows, filling entirely the space between volutions, and grading into complex axial reticulation. Chomata are visible on proloculus only. Insignificant axial filling is characteristic of two initial volutions. Tunnel narrow and high in internal volutions, broad in external ones. Its positioning through volutions is unstable.

Comparison. The new species is most similar to *"Pseudofusulina" ishimbajevi* Shamov from the Sakmarian Stage of the Cis-Urals, but differs from it in less tight and less regular coiling of spirotheca and in less regular septal folding.

Locality. Iran, Sang-Variz, breccia-conglomerate at the Sartakht Formation base, Sample PSS-1.

Occurrence. Unknown outside Iran.

Nonpseudofusulina padehensis n. sp.

Plate II, figs. 10, 11

Species name for the Padeh Valley in the Halvan Mountains.

Holotype. GIN, no. 4791/23; axial section; Iran, Padeh, Chili Formation, Sample PCP-79; Sakmarian (?) Stage.

Material. Five axial and seven subaxial or oblique sections.

Description. Test of medium size, fusiform to subcylindrical with pointed poles in internal volutions, which are of more rounded outlines in external ones. In adult specimens with 4.5 to 5 volutions L = 8.0–8.5 mm, D = 2.0–2.3 mm, L : D = 3.7–4. Proloculus globular, with outer diameter of 0.2–0.22 mm. Spirotheca coiling is regular, with insignificant gradual increase in height of subsequent volutions. Spirotheca with keriotheca is 0.08–0.09 mm thick in outer volution. Intense irregular septal folding is observable throughout the test length. Septal folds are high, round or irregular in outlines. Tunnel not broad, as high as the half-height of the relevant volution; chomata are invisible. Axial filling is sometimes observable in one or two initial volutions.

Comparison. *Nonpseudofusulina padehensis* n. sp. is most similar to *Nonpseudofusulina karapetovi* (Leven), being different from the latter in larger size and high intense septal folding. New species is also comparable with *Nonpseudofusulina pamirensis* (Leven), although its test is less elongated, especially in internal volutions.

Locality. Iran, Padeh, uppermost part of the Chili Formation, Sample PCP-79.

Occurrence. Unknown outside Iran.

Reviewers T.N. Isakova, V.G. Ganelin, and A.S. Alekseev

REFERENCES

Angiolini L., Stephenson M.H., and Leven E.Ja., Correlation of the Lower Permian Surface Saiwan Formation and Subsurface Haushi Limestone, Central Oman, *GeoArabia*, 2006, vol. 11, no. 3, pp. 17–38.

Baghbani D., The Permian Sequence in the Abadeh Region, Central Iran, in *Contribution to Eurasian Gejlogy*, Karoteev A.V., Ed., *Occasional Publ. Earth. Sci. Res. Inst.,* Univ. South Carolina. 1993, vol. 9B, pp. 7–22.

Chernykh, V.V., *Zonal'nyi metod v biostratigrafii. Zonal'naya shkala nizhnei permi Urala po konodontam* (Method of Zonal Biostratigraphy. Lower Permian Conodont Zonation in the Urals), Yekaterinburg: Ural. Otd. Ross. Akad. Nauk, 2005.

Davydov V.I. and Arefifard S., Permian Fusulinid Fauna of Peri-Gondwanan Affinity from the Kalmard Region, East-Central Iran and its Significance for Tectonics and Paleogeography, *Palaeontologia Electronica*, 2007. 10.2.10A. http://palaeo-electronica.org/2007_2/00124/index.html

Forke H. Biostratigraphic Subdivision and Correlation of Upper Carboniferous/Lower Permian Sediments in the Southern Alps: Fusulinidean and Conodont Faunas from the Carnic Alps (Austria/Italy), Karavanke Mountains

(Slovenia), and Southern Urals (Russia), *Facies*, 2002, vol. 47, pp. 201–276.

Gaetani M. and Leven E.Ja., Permian Stratigraphy and Fusulinids from Rosh Gol (Chitral, E. Hindu Kush), *Riv. Ital. Paleontol. Stratigr.*, 1993, vol. 101, no. 3, pp. 307–326.

Gaetani M., Angiolini L., Garzanti E., et al., Permian Stratigraphy in the Northern Karakorum, Pakistan, *Riv. Ital. Paleontol. Stratigr.*, 1995, vol. 101, no. 2, pp. 107–152.

Gaetani M., Angiolini L., Ueno K., et al., Pennsylvanian-Early Triassic Stratigraphy in the Alborz Mountains (Iran), *Geol. Soc. Spec. Publ.* (London), 2009, vol. 312, pp. 79–128.

Gorjunova, R.V., *Permskie mshanki Pamira* (Permian Bryozoans from the Pamirs), Moscow: Nauka, 1975.

Grunt, T.A. and Dmitriev, V.Yu., *Permskie brakhiopody Pamira* (Permian Brachiopods from the Pamirs), Moscow: Nauka, 1973.

Kahler F., Bemerkenswerte Fusuliniden-Funde im ostmediterranen und iranischen Raum, *N. Jahrb. Geol. Palaönt. Mh.* (Stuttgart), 1977, no. 4, pp. 199–216.

Kahler F., Die Fusuliniden, in *Catalogus Fossilium Austriae. V. II. B. 1: Foraminifera Palaeozoica,* Ebner F. and Kahler F., Eds., Wien: Sterr. Akad. Wiss., 1989, pp. 87–272.

Kireeva, G.D., *Pseudofusulina* of the Tastubian and Sterlitamakian Horizons from the Buried Massifs of Bashkortostan, *Tr. Inst. Geol. Nauk, Ser. Geol.*, 1949, vol. 105, no. 35, pp. 171–191.

Kobayashi F. and Ishii K.I., Permian Fusulinaceans of the Surmaq Formation in the Abadeh Region, Central Iran, *Riv. Ital. Paleontol. Stratigr.*, 2003, vol. 109, no. 2, pp. 307–337.

Kochansky-Devidé V., Die Fusuliniden Foraminiferen aus dem Karbon und Perm im Velebit und in der Lika (Kroatien), Mittleres und Oberes Perm, *Acta Geologica*, 1965, vol. 5, pp. 101–150.

Leven E.Ja., Early Permian Fusulinids from the Central Pamir, *Riv. Ital. Paleontol. Stratigr.*, 1993, vol. 99, no. 2, pp. 151–198.

Leven E.Ja., Permian Stratigraphy and Fusulinids of Afghanistan with Their Paleogeographic and Paleotectonic Implication, *Geol. Soc. Am.*, *Spec. Pap.,* 1997, no. 316, pp. 1–138.

Leven E.Ja., Permian Fusulinid Assemblages and Stratigraphy of the Transcaucasia, *Riv. Ital. Paleontol. Stratigr.*, 1998, vol. 104, no. 3, pp. 299–328.

Leven, E.Ja., *Verkhnii karbon i perm' Zapadnogo Tetisa: fuzulinidy, stratigrafiya, biogeografiya* (The Upper Carboniferous and Permian of Western Tethys: Fusulinids, Stratigraphy, Biogeography), Moscow: GEOS, 2009.

Leven, E.Ya., Permian Fusulinids of the East Hindu Kush and West Karakorum (Pakistan), *Stratigr. Geol. Korrelyatsiya*, 2010, vol. 18, no. 2, pp. 3–15 [*Stratigr. Geol. Correlation* (Engl. Transl.), vol. 18, no. 2, pp. 105–117].

Leven E.Ja. and Gorgij M.N., Upper Carboniferous–Permian Stratigraphy and Fusulinids from the Anarak Region, Central Iran, *Russ. J. Earth Sci.*, 2006, vol. 8, ES2002, doi:10.2205/2006ES000200.

Leven, E.Ja. and Gorgij, M.N., Gzhelian Fusulinids First Discovered in Central Iran, *Stratigr. Geol. Korrelyatsiya*, 2006, vol. 14, no. 1, pp. 19–29 [*Stratigr. Geol. Correlation* (Engl. Transl.), vol. 14, no. 1, pp. 19–29].

Leven E.Ja. and Gorgij M.N., Fusulinids of the Khan Formation (Kalmard Region, Eastern Iran) and Some Problems of Their Paleobiogeography, *Russ. J. Earth Sci.*, 2007, vol. 9, ES1004, doi:10.2205/2007 ES000219.2007.

Leven, E.Ja. and Gorgij, M.N., Section of Permian Deposits and Fusulinids in the Halvan Mountains, Yazd Province, Central Iran, *Stratigr. Geol. Korrelyatsiya*, 2009, vol. 17, no. 2, pp. 49–67 [*Stratigr. Geol. Correlation* (Engl. Transl.), vol. 17, no. 2, pp. 155–172].

Leven E.Ja. and Taheri A., Carboniferous–Permian Stratigraphy and Fusulinids of East Iran. Gzhelian and Asselian Deposits of the Ozbak-Kuh Region, *Riv. Ital. Paleontol. Stratigr.*, 2003, vol. 109, no. 3, pp. 399–415.

Leven, E.Ja. and Scherbovich, S.F., *Fuzulinidy i stratigrafiya assel'skogo yarusa Darvaza* (Fusulinids and Stratigraphy of the Asselian Stage in Darvaz), Moscow: Nauka, 1978.

Leven E.Ja., Davydov V.I., Gorgij M.N., Pennsylvanian Stratigraphy and Fusulinids of Central and Eastern Iran, *Palaeontol. Electronica,* 2006, 9.1.1A. http://palaeo-electronica.org

Leven, E.Ja., Leonova, T.B., and Dmitriev, V.Yu., *Perm' Darvaz-Zaalaiskoi zony Pamira: fuzulinidy, ammonoidei, stratigrafiya* (The Permian of the Darvaz-Transalai Zone in Pamirs: Fusulinids, Ammonoids, Stratigraphy), Moscow: Nauka, 1992.

Rauser-Chernousova, D.M., Stratigraphy of the Upper Carboniferous and Artinskian Stage in Western Flank of the Urals with Data on Fusulinid Fauna, *Tr. Inst. Geol. Nauk AN SSSR*, *Ser. Geol.*, 1940, vol. 7, no. 2, pp. 37–101.

Rauser-Chernousova, D.M., Revision of *Schwagerina* and Close Genera: Implication for the Carboniferous-Permian Boundary, *Vopr. Mikropaleontol.*, 1960, no. 4, pp. 3–32.

Rauser-Chernousova, D.M. and Scherbovich, S.F., Schwagerinids from European Part of the USSR, *Tr. In-ta Geol. Nauk AN SSSR*, *Ser. Geol.*, 1949, vol. 105, no. 35, pp. 61–114.

Rozovskaya, S.E., *Sostav, sistema i filogeniya otryada fuzulinid* (Composition, Systematics, and Phylogeny of the Order Schwagerinida), Moscow: Nauka, 1975.

Shen Sh., Gorgij M.N., Wang W., et al., Report of the Field Trip of the Permian Stratigraphy in Central and Eastern Iran, *Parmophiles*, 2009, no. 2, pp. 2–5.

Shirinkina, A.P., Morozova, A.P., Solov'eva, O.A., and Ogneva, I.I., Fusulinids of the *Pseudofusulina pedissequa* and *Pseudofusulina concavutas* Groups from Artinskian Deposits from the Perm Area of the Cis-Urals, in *Biostratigrafiya artinskogo i kungurskogo yarusov Urala* (Biostratigraphy of Artinskian and Kungurian Stages in the Urals), Sverdlovsk: Ural. Nauchn. Tsentr AN SSSR, 1980, pp. 39– 51.

Termier H. and Termier G., Bryozoaries du Paléozoique supérieur de l'Afghanistan, *Docum. Lab. Géol. Fac. Sci.* (Lyon), 1971, no. 47, pp. 1–52.

Termier G., Termier H., Lapparent A.F., Marin Ph., Monographie du Permo-Carbonifére de Wardak (Afghanistan Central), *Docum. Lab. Géol. Fac. Sci.* (Lyon), 1974, H.S. 2, pp. 1–167.

Vachard D., Tethys and Gondvana au Paléozoique supérieur les donnés Afghanes (Ph. D. Thesis), *Inst. Géologique Albert Lapparan, Documents et Travaux*, Paris, 1980, no. 2..

Zhou T., Sheng J., and Wang Y., Carboniferous-Permian Boundary Beds and Fusulinid Zones at Xiaodushan, Guangnan, Eastern Yunnan, *Acta Micropaleontol. Sinica*, 1987, vol. 4, no. 6, pp. 123–160.