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NEW FINDINGS OF PERMIAN MARINE AND TERRESTRIAL FOSSILS IN CENTRAL IRAN (THE KALMARD BLOCK) AND THEIR SIGNIFICANCE FOR CORRELATION OF THE TETHYAN, URALIAN, AND WEST EUROPEAN SCALES

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Abstract. The Permian litho- and biostratigraphy of the Darin and Gachal sections of the southern part of the Kalmard block, Central Iran, are described. Like the Permian in the Halvan Mountain sections of the northern part of the block, the southern sections include four formations, namely the Chili, Chah-Kular, Hermez, and Rizi. The Chah-Kular Formation, which is first established in the present paper, corresponds to the Sartakht Formation of the northern sections. Its lowest beds contain plant fossils characteristic of the Lower Permian of Europe and partly, China. The Chili Formation includes fusulinids of the Kalaktashian assemblage, which has been dated as Sakmarian based on conodonts. Fusulinids in the Halvan Mt. section, which appear at the top of the formation, were previously found in conglomerate pebbles at the base of the overlying Sartakht Formation. As the beds with the Halvan Mt. fusulinid assemblage occur above beds with late Sakmarian conodonts, the assemblage may be of Artinskian age. However, that assemblage includes taxa usually not present either in the Artinskian fusulinid assemblage of the Urals or in the fusulinids of the Yakhtashian Stage that succeeds the Sakmarian in the Tethyan scale. A new fusulinid species (*Nonpseudofusulina darinensis* Leven, sp. nov.) and plants *Annularia carinata* Gutbier, *Pecopteris monyi* Zeiller, *P. cyathea* (Schlotheim) Brongniart, *Fascipteris* cf. *robusta* (Kawasaki) Broutin, *Discinites* sp., *Taeniopteris* cf. *crassicaulis* Jongmans et Gothan are described. Palaeogeography of Central Iran region and adjacent areas is discussed.

Riassunto. Vengono descritte litostratigrafia e biostratigrafia delle sezioni nel Permiano di Darin e di Gachal nella parte meridionale del Blocco di Kalmard, in Iran Centrale. Similmente al Permiano delle sezioni nei monti di Halvan, situate nella parte settentrionale del Blocco, le sezioni meridionali comprendono quattro formazioni. Dal basso verso l'alto esse sono: Chili, Chah-Kular, Hermez e Rizi. La Formazione di Chah-Kular, definita in questo articolo, corrisponde alla Formazione Sartakht delle sezioni settentrionali. I suoi livelli più bassi contengono fossili di piante che sono caratteristici del Permiano inferiore dell' Europa e in parte della Cina. La Formazione Chili contiene fusulinidi dell'associazione Kalaktash, che viene datata al Sakmariano sulla base dei conodonti. Nelle sezioni dei monti Halvan, nella parte superiore della Formazione Chili sono state rinvenute fusulinidi, che in precedenza erano state rinvenute solo entro ciottoli nei conglomerati alla base della soprastante Formazione Sartakht. Poiché gli strati con le associazioni a fusulinid dei monti Halvan si trovano sopra livelli con conodonti del Sakmariano superiore, quella associazione potrebbe essere di età artinskiana. Tuttavia, questa associazione comprende taxa che non sono comuni né nell'Artiskiano degli Urali, né hanno affinità con le fusulinidi del piano Yakhtashiano, che succede al Sakmariano nella scala Tetidiana. Sono descritte una nuova specie di fusulinide (*Nonpseudofusulina darinensis)* e le piante *Annularia carinata* Gutbier, *Pecopteris monyi* Zeiller, *P. cyathea* (Schlotheim) Brongniart, *Fascipteris* cf. *robusta* (Kawasaki) Broutin, *Discinites* sp., *Taeniopteris* cf. *crassicaulis* Jongmans et Gothan.- Viene infine brevemente discussa la paleogeografia dell'Iran Centrale e zone limitrofe.

Introduction

The international Permian conodont-based scale is difficult to use in the Tethyan region because of the scarcity of conodonts there (Leven 2001), and so there is an independent regional scale based mainly on fusulinids. It is even more difficult to correlate the global and Tethyan scales based on marine fossils to the West Europe continental scale based on floral assemblages. Therefore, the co-occurrence of conodonts, fusulinids, and fossil plants in the Permian of Central Iran is of extreme biostratigraphic importance.

The sections studied are located within the tectonically isolated small Kalmard block between the larger Tabas and Posht-Badam blocks (Fig. 1A). The Permian

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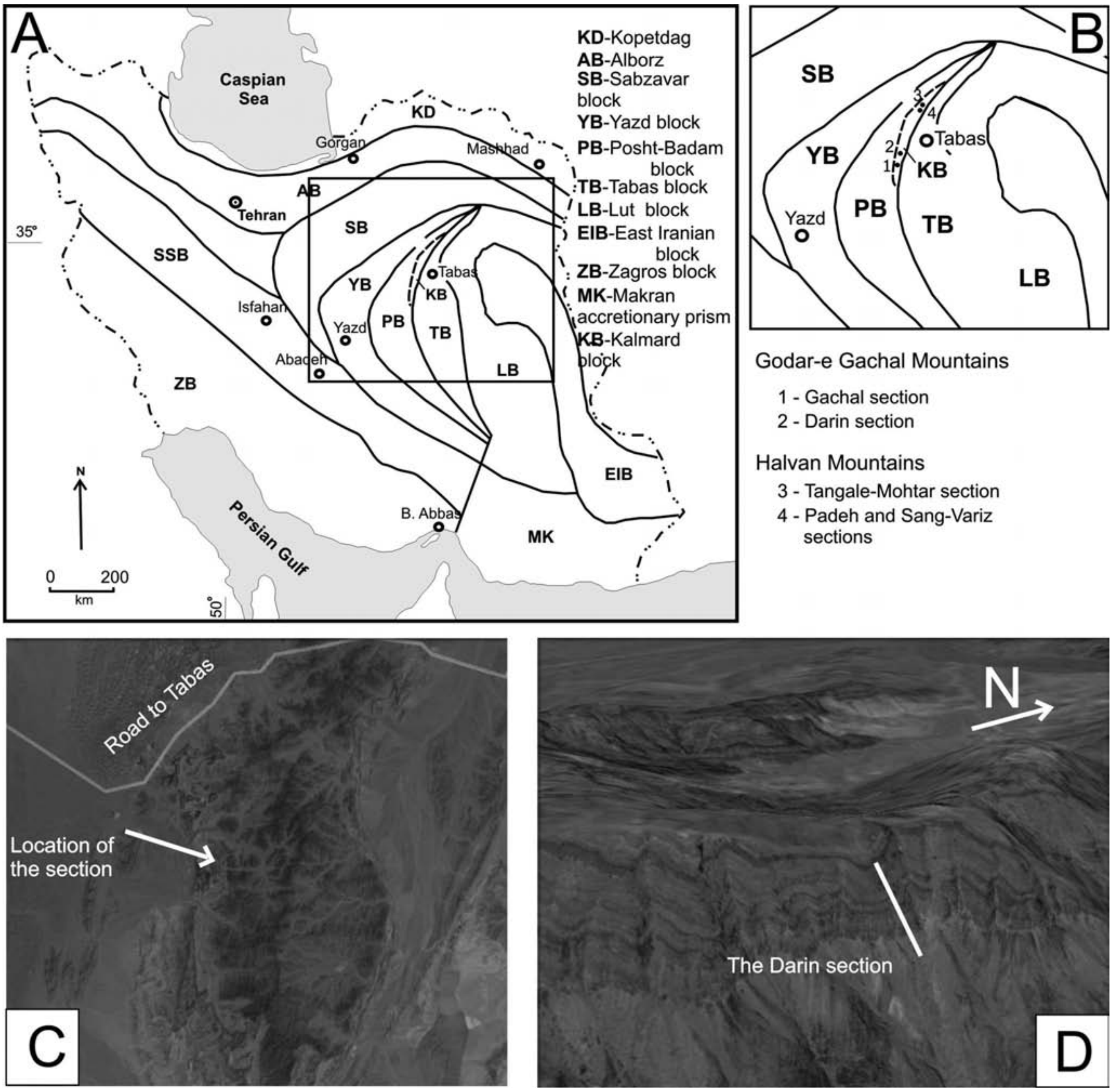
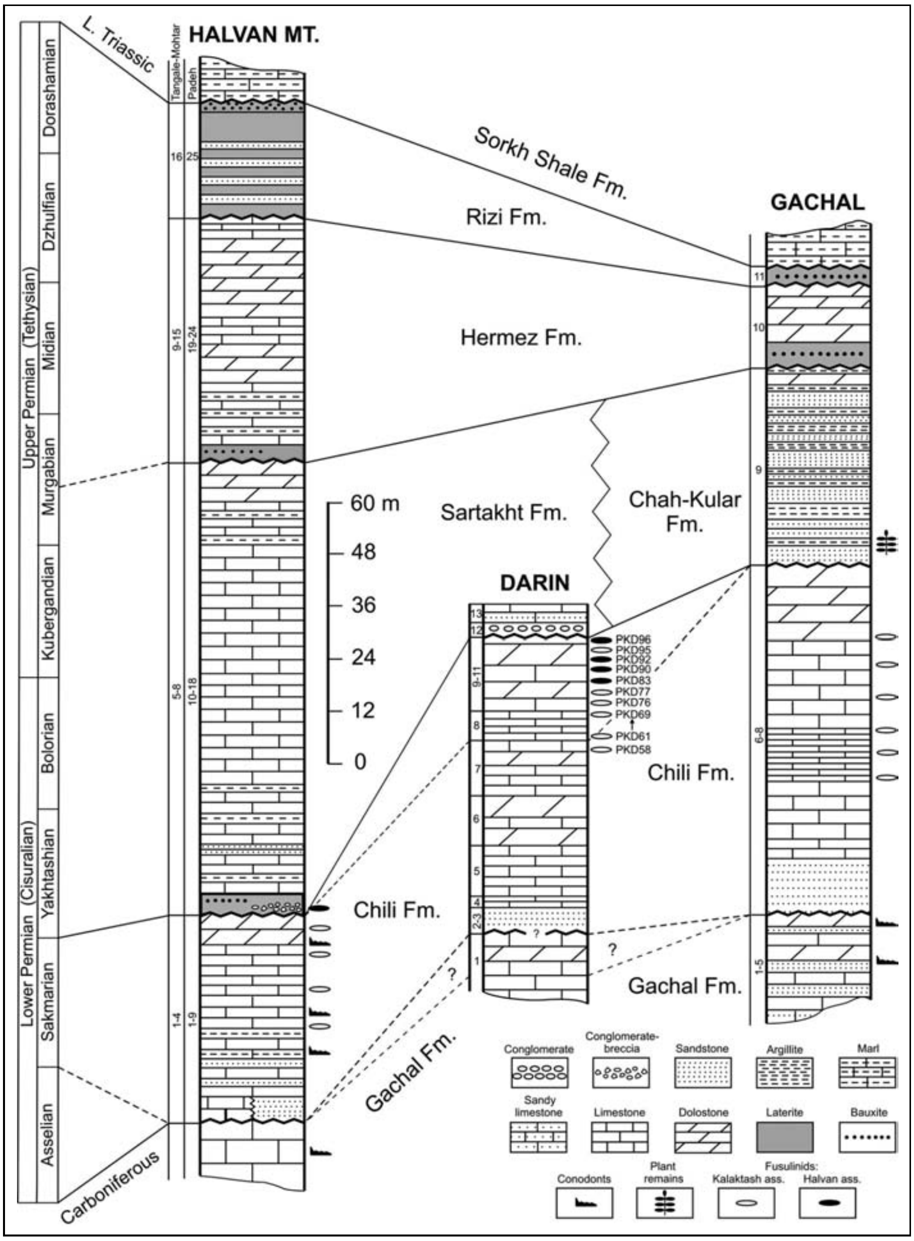


Fig. 1 - Index map. A – The tectonostratigraphic blocks identified in Iran. B – The position of the Kalmard Block near Tabas, with position of the sections discussed in the text: Godar-e Gachal Mountains: 1 - Gachal, 2 - Darin. 3, 4 - Halvan Mountains: 3 - Tangale-Mohtar; 4 - Padeh and Sang-Variz. C and D - location of the Darin section on Google map.

deposits of the Kalmard block were first identified by Aghanabati (1977), who included them all into the Khan Formation. General information about the sections of the Khan Formation was published by Wendt et al. (2005). More recently the Khan Formation of the Kalmard block was studied by Davydov & Arefifard (2007), and more comprehensively by two authors of this paper (Leven & Gorgij 2007, 2009, 2011). As a result of these studies, the Khan Formation in the northern Kalmard block was interpreted to be a group of four formations, namely (from the base upwards) the Chili, Sartakht, Hermez, and Rizi formations, which all are bounded by disconformities marked by red laterites with lenses of pisolitic bauxites. These formations were not differentiated in the southernmost section of the block (Gachal section in the Godar-e Gachal Mountains, Fig. 1B) and so the Khan Group was described as an undivided unit. The Khan Group is overlain by undated red sandstones and shales.

All the Kalmard sections yielded abundant fusulinid assemblages, in which some genera and many species are common with those of so-called Kalaktash assemblage from Central Pamir (Leven 1993). In the Halvan Mountain sections fusulinids were found in the

Fig. 2 - Permian stratigraphic sections of the Kalmard block.



uppermost Chili Formation in association with conodonts and bryozoans. An archaic fusulinid assemblage different from the Kalaktash one and called Halvan assemblage was found in conglomerate clasts in the lower part of the laterites at the base of the overlying Sartakht Formation. The origin of the clasts was unclear because of the absence of the Halvan assemblage in the underlying Chili Formation. The relationship between the northern and southern sections of the Kalmard block and the stratigraphic position of the beds with the Kalaktash fusulinid assemblage were also unclear (Leven & Gorgij 2007). In the northern area these beds occur at the top of the Chili Formation, the lowest Permian unit. Whereas to the south in the Godar-e Gachal Mountains, the beds with fusulinids occur at the top of the limestones directly under red sandstones and shales. Because the sandstones were not reliably assigned to the Permian, their Triassic age was not excluded (Leven & Gorgij 2007). Indirect evidence was provided by occurrence in these sandstones of fossil plants, that are frequent in the Triassic formations, but are unknown in the Permian deposits of Central Iran.

In order to address these uncertainties, the present authors restudied the Gachal section in the Godar-e Gachal Mountains and the Darin section between the Gachal section and the Tangal-e Mohtar, Padeh, Sang-Variz sections in the north of the Halvan Mountains previously described by Leven & Gorgij (2009, 2011). The lithostratigraphic and biostratigraphic results obtained are presented below.

Collections of fusulinids and plant fossils described herein are stored in the Geological Institute of

Russian Academy of Sciences (Nos. 4782 and 4856 respectively).

Description of the sections

The Darin section is located 70 km to the west-southwest of the Town of Tabas, on the western slopes of the mountain massif to the north of the Kalmard Pass (latitude N 33°31'01" longitude E 56°9'14", Fig. 1C,D). The Chili Formation is well represented in the section, whilst the base of the Gachal Fm. is cut by fault. The following deposits are exposed there and are described from the base up-section (Fig. 2):

1	GACHAL Fm. Dolostone and dolomitized limestone with small foraminifers, probably Carboniferous	17 m
2	CHILI Fm. Quartzitic sandstone	6.5 m
3	Sandy limestone	1 m
4	Dark grey thin-bedded nodular limestone	2.5 m
5	Dolomitized limestone with small interbeds of marls and mudstones	12 m
6	Massive dolostone and dolomitized limestone	9.5 m
7	Coarsely bedded dolomitized limestone	12 m
8	Thin- and medium-bedded dark grey clotted limestone (biomicrite and biosparite). Abundant fusulinids include prevalent *Eoparafusulina pamirensis* Leven, *E. stevensi* Davydov et Arefifard, *E.* ex gr. *tschernyschewi* (Schellwien), *E.* aff. *oblonga* (Grozdilova et Lebedeva) and less frequent Nonpseudofusulina *psharti* (Leven), *N.* aff. *insignis* (Leven), *N. karapetovi* (Leven), *N. tezakensis* (Leven), *N. macilenta* (Leven), *N. inobservabilis* (Leven), *N. pamirensis* (Leven), *N.* aff. *kalaktashensis* (Leven), *N. devexa* (Rauser-Chernousova), *N.* aff. *acallosa* (Kireeva), *N. darinensis* sp. nov. There are also single small foraminifers (*Deckerella*), echinoid spines, fragments of brachiopods, gastropods, and bryozoans (samples PKD58, PKD61, PKD66- PKD69).	6 m
9	Medium-bedded dolomitized limestone (biomicrite, biosparite) with abundant fusulinids *Nonpseudofusulina pamirensis* (Leven), *N.* aff. *kalaktashensis* (Leven), *N. karapetovi* (Leven), *N. psharti* (Leven), *N.* aff. *kalmardensis* Leven, *Nonpseudofusulina* spp., *Anderssonites* ex gr. *anderssoni* (Schellwien) (samples PKD75, PKD76, PKD77), small foraminifers *Palaeotextularia* sp., *Deckerella* sp., *Globivalvulina* sp., and fragments of bryozoans, crinoids, brachiopod spines.	9.7 m
10	Massive dolomitized limestone locally overcrowded with fusulinids *Eoparafusulina pamirensis* (Leven), *Rugosochusenella* cf. *rugosa* Leven, *Nonpseudofusulina* sp., *Parazellia elongata* (Saurin) (samples PKD83, PKD85). Small foraminifers are represented by rare *Globivalvulina* sp. and *Climacammina* sp.	4.3 m
11	Medium-bedded dolomitized limestone with fusulinids *Eoparafusulina* ex gr. *tschernyschewi* (Schellwien), *E. pamirensis* Leven, *Nonpseudofusulina* aff. *pamirensis* (Leven), *N. curteum* (Leven), *N.* aff. *muzkolensis* (Leven), *N.* aff. *fecunda* (Shamov et Scherbovich), *N.* aff. *indigaensis* (Grozdilova et Lebedeva), *N.* aff. *exuberata* (Shamov), *Parazellia falx* (Rauser-Chernousova), *P. elongata* (Saurin), *Robustoschwagerina* (?) sp. (samples PKD90-PKD96).	1.5 m
12	SARTAKHT Fm. Conglomerate with limestone pebbles.	5 m
13	Medium-bedded sandy limestone.	10 m

Layers 2-11 are assigned to the Chili Formation. The thickness of the Chili Formation in this section is 65 m. The top of layer 11 shows an erosional surface.

Layers 12 and 13 belong to the Sartakht Formation, which is mostly unexposed in the studied section.

The Gachal section is located 25 km to the south of the Darin section, latitude N 33°15'00" longitude E 56°10'12". It was described by Leven & Gorgij (2007) (Fig. 2). The reexamination of the section showed that the lower Beds 1-5 of the Gachal Formation, where no identifiable fossils have been previously found, is Early and Late Carboniferous, but not Permian, as evidenced by the occurrence of the conodonts *Gnathodus girtyi* and *Gondolella* sp. in Beds 2 and 5, respectively. Thus, only the upper half of the section (Beds 6-8), which are characterized at the top by the Kalaktash fusulinid assemblage can be assigned to the Permian. This part of the section corresponds to the Chili Formation of the Halvan Mountain and Darin sections (Fig. 2).

Bed 9 is of uncertain age and lies on the erosional surface at the top of Bed 8. It is composed of alternating reddish mudstones and light-colored quartzitic sandstone with sandy dolostone at the top. This part of the section is suggested to constitute an independent unit, here named Chah-Kular Formation with a total thickness of 37 m. At the base of the formation we found plant fossils including *Annularia carinata* Gutbier, *Pecopteris monyi* Zeiller, *P. cyathea* (Schlotheim) Brongniart, *Fascipteris* cf. *robusta* (Kawasaki) Broutin, *Taeniopteris* cf. *crassicaulis* Jongmans et Gothan, *Discinites* sp. The plant fossils are of Early Permian age (see below).

The top of the Chah-Kular Formation shows an erosional surface capped by bauxitic laterites (5.3 m) succeeded by dolostones (12 m), referred to the Hermez Formation, in turn overlain by red bauxites (3-7 m) which are covered by marls and limestones of the Lower Triassic Sorkh Shale Formation.

Correlation

The most complete stratigraphic sections of the Permian are, however, located in the northern part of the studied region, in the Halvan Mountains. The Permian deposits there are divided into four formations, namely the Chili, Sartakht, Hermez, and Rizi formations, grouped into the Khan Group (Leven & Gorgij 2009, 2011) (Fig. 2). They are underlain by the Lower Carboniferous limestones of the Gachal Formation and overlain by the Lower Triassic Sorkh Shale Formation. In the Tangal-e-Mohtar section, the Chili Formation begins with sandstones which are succeeded by dolostone and dolomitized limestone. Its thickness is 52 m. Its upper part contains abundant fusulinids of the Kalaktash assemblage. In the Padeh section, the lithological composition of the 48-m-thick formation is almost the same. The basal sandstones are absent here, and the limestones with Permian bryozoans lie on similar limestone facies with Lower Carboniferous foraminifers and conodonts. Like in the Tangal-e-Mohtar section, the upper part of the formation is overcrowded with Kalaktash fusulinids.

In the southern part of the Kalmard block the Gachal and Chili formations show similar lithological composition. The Beds 1-5 of the Gachal section and, probably, Bed 1 of the Darin section are of Carboniferous age. At the base of the Chili Formation there are sandstones that are overlain, as in the Tangal-e-Mohtar section, by mostly carbonate rocks with abundant Kalaktash fusulinids in the upper part. The thickness of the Chili Formation in the Gachal section (68 m) is comparable with that in the Darin section (65 m).

In the Halvan Mountains the Sartakht Formation unconformably overlies the Chili Formation with basal red laterites containing lenses of pisolitic bauxites, which are overlain by limestones alternating with sandstones and shales in the lower part. The uppermost beds of the Sartakht Formation consist of dolostone (Fig. 2). The thickness of the formation varies from 80 to 100 m. The basal laterites contain local lenses of conglomerates with limestone pebbles enclosing fusulinids of the Halvan assemblage, which is distinctly different from the Kalaktash assemblage. The clasts include fragments of corals, bryozoans, brachiopods, echinoids, algae, and fusulinids. The clasts are thought to derive from the erosion of the uppermost beds of Chili Formation (Leven & Gorgij 2011). This inference is confirmed by discovery of some Halvan species (*Parazellia falx, P. elongata*) at the top of the Chili Formation in the Darin section (Fig. 2). The carbonate sandstone and conglomerate, lying in the Darin section above the Chili Formation, can be correlated with the lower part of the Sartakht Formation of the Halvan Mountains. The larger part of the Sartakht Formation is missing in the Darin section. Its lowest part can be correlated only to the conglomerate with limestone clasts covering the Chili Formation.

In the Gachal section, the newly established Chakh-Kular Formation is thought to be a stratigraphic equivalent of the Sartakht Formation. It is represented by continental red sandstones and siltstones and is distinguished by almost absolute absence of carbonates. The bauxitic laterites and dolostones above the Chakh-Kular Formation are well correlated with the carbonatic Hermez Formation of the northern sections, but thickness is much thinner in the Gachal section (17 m versus 60-80 m in the Halvan Mountain sections). Both in the northern Halvan Mountain sections and the southern Gachal section the Permian deposits are overlain by continental red sandstones of the Rizi Formation, which have bauxite interbeds (24 m) in the north (Leven & Gorgij, 2009) and bauxites (3-7 m) in the south (Gachal section in this paper). Higher up there are marls of the Lower Triassic Sorkh Shale Formation.

To sum up, there is a close similarity between the Permian sections of the northern and southern parts of the Kalmard Block. In both areas there are four formations separated by unconformities marked by red laterites. The Chili Formation is well represented everywhere. The northern carbonate facies of the Sartakht Formation is substituted in the south by the mostly continental Chakh-Kular Formation. The Hermez and Rizi formations are composed of similar facies both in the north and in the south, but are different in thickness.

While the Permian sections within the Kalmard Block are similar, there are considerable differences between them and the sections of the neighboring Tabas and Yazd blocks. The Kalmard sections lack widely developed Upper Carboniferous and Asselian deposits (Leven & Taheri 2003; Leven et al. 2006). The limestones of the Chili Formation have abundant fossils (including fusulinids) and correlate to the dolostones of the Tighe-Maadanou Formation. Everywhere they are capped by an erosional surface. While the overlying Bage-Vang Formation of the Tabas Block is characterized by fusulinids and other marine fossils (Leven & Vaziri 2004), the age-corresponding rocks of the Kalmard block are the bauxitic laterites (in the Halvan Mountains) and red shales with plant fossils (in the Godar-e Gachal Mountains). The laterites occur also in the higher deposits of the Kalmard Block but are absent in the neighboring blocks. In general, laterites are not characteristic of the Permian deposits of Iran. Previously, they were recorded only in the Upper Permian beds of Alborz (Lys et al. 1981; Vaziri et al. 2005; Gaetani et al. 2009; Muttoni et al. 2009).

Thus, the Permian sections of the Kalmard Block and the contiguous Iranian blocks are quite different. It is interesting that the Kalmard sections are surprisingly similar to the Central Pamir sections, that are located about 2000 km to the east. The Chili Formation of the Kalmard Block and the coeval Dangikalon Formation of Central Pamir are almost identical both in facies composition and in composition and succession of fossil assemblages (Leven 1993; Leven & Gorgij 2011). The sections of both regions bear some levels of laterites with bauxites and generally similar plant assemblages including *Pecopteris cyathea* (Schlotheim) Brongniart, *Sphenopteris* sp., *Taeniopteris multinervis* Weiss, *T. nystroemii* Halle, *T. tingii* Halle, etc. (Central Pamir: Dronov 1964), *Annularia carinata* Gutbier, *Pecopteris monyi*

Zeiller, *P. cyathea* (Schlotheim) Brongniart, *Fascipteris* cf. *robusta* (Kawasaki) Broutin, *Discinites* sp., *Taeniopteris* cf. *crassicaulis* Jongmans et Gothan (the Kalmard block, data of the authors), but with the single common species *P. cyathea*.

Biostratigraphic analysis of fossils

The Carboniferous conodonts found in Beds 2 and 5 of the Gachal Formation in the Gachal section are the oldest fossils from the studied sections. Also, poorly preserved single Endothyrida and Ammodiscida from the base of Bed 1 in the Gachal Formation of the Darin section may have a Carboniferous age. Slightly higher in that bed there occur numerous *Globivalvulina,* which have not been found in deposits older than the Bashkirian. Therefore, the age of Bed 1 is still questionable. The Chili Formation is well characterized by fusulinids. Its basal part in both the Gachal and Halvan Mountain sections contains primitive forms of staffellids (Staffellida), but they do not provide reliable dating of this part of the Chili Formation because of their long stratigraphic range. Bryozoans found higher are assigned to the Asselian-Sakmarian (Leven & Gorgij 2007). Fusulinids appear in the middle part of the formation. In the Gachal, Darin and Halvan Mountain sections they are components of the Kalaktash assemblage formed by numerous species of *Nonpseudofusulina* and *Eoparafusulina* (Pl. 1). Many species of the first genus are endemic but some are similar to forms from the Sakmarian and lower Artinskian deposits of the Urals. Less diverse forms of the second genus include species known from the lower Sakmarian (Tastubian) beds of Timan, such as *E. tschernyschewi* and *E. oblonga* (Grozdilova & Lebedeva 1961).

The age of the Kalaktash fusulinid assemblage and, accordingly, the upper part of the Chili Formation has been long debated. Initially described from Central Pamir, this assemblage was conventionally dated as Sakmarian (Leven 1993), but bryozoan data have caused doubts. Goryunova (1975) suggested that the bryozoans were Artinskian in age. Bryozoans from the fusulinid-bearing beds of the Chili Formation were also referred by her to the Artinskian (Leven & Gorgij 2007, 2011). The problem has been settled by discovery of the conodonts *Mesogondolella pseudostriata* and *M. parafoliosa* in the lower third of the Chili Formation of the Padeh section, Halvan Mountains. *M. pseudostriata* is known to range from the upper Asselian into the lower Sakmarian, and *M. parafoliosa* is a characteristic species of the Tastubian Horizon of the lower Sakmarian. Furthemore, *Sweetognathus merrilli*, which is the zonal species of the lower zone of the Tastubian Horizon, was found in beds with the oldest Kalaktash fusulinids (Leven & Gorgij 2011). And the Upper Sakmarian conodonts *S. inornatus* and *S. anceps* were also recorded from the top of the Chili Formation of another Halvan (the Tangale-Mokhtar) section (Leven & Gorgij 2009). All these data convincingly indicate a Sakmarian age, at least, for the larger part of the Chili Formation. The basal beds of the formation may belong to the Asselian.

The age of the uppermost beds of the Chili Formation is still uncertain. As suggested above, the occurrence of limestone pebbles in conglomerates containing the Halvan fusulinids at the base of the Sartakht Formation may represent eroded remnants of the upper beds of the Chili Formation. The suggestion was confirmed by finding some Halvan species (*Parazellia falx, P. elongata,* etc) at the top of the formation in the Darin section (Fig. 2, Pl. 2). Accordingly, the Halvanian fusulinid assemblage, which was initially interpreted as Asselian (Leven & Gorgij 2009), is now considered as late Sakmarian or even Artinskian, because deposits bearing Kalaktash fusulinids (which lie below the Halvan fusulinid assemblage) contain the Sakmarian conodonts *Streptognathodus inornatus* and *S. anceps*, ancestral of the early Artinskian *S. whitei* (Leven & Gorgij 2011).

This inference allows to make some important suggestions. First, the Halvan fusulinids are quite different from the known Artinskian fusulinids, but include many archaic forms (*Sphaeroschwagerina, Parazellia, Benshiella, Eoparafusulina*). If we recognize their Artinskian age, we should admit that many genera and species, which are confined to the Asselian deposits in the Urals, passed into the Artinskian beds in the Tethyan region. Second, by recognizing the Artinskian age of the Halvan assemblage, we can state that the Yakhtashian stage succeeding the Sakmarian stage of the Tethyan scale is an equivalent of the Artinskian Stage. But the Yakhtashian fusulinids are essentially different from the Halvan fusulinids and may be even younger. This means that the Sakmarian stage has a larger scope in the Tethyan region than in the Uralian stratotypical sections and perhaps includes a part of the Artinskian stage. At present there is no solution of these problems, and additional study of the sections listed above is needed. It is particularly important, first of all, a search to document conodonts in the beds with Halvan and Yakhtashian fusulinids.

Whereas the Chili Formation can be dated with confidence, it is not possible to date the Sartakht Formation and its non-marine facies equivalent Chakh-Kular Formation properly. The position of the Sartakht Formation above the beds with the Halvan fusulinid assemblage suggests that its lower boundary may lie inside the Artinskian or Yakhtashian stages if these stages are somewhat equivalent. This suggestion is in agreement with data on plant remains from the basal part of the Chakh-Kular Formation. They are united into two distinct groups according to their age (in the type localities) and phytogeographic statute.

The first group consists of *Annularia carinata* leaves and ferns *Pecopteris monyi* and *P. cyathea*. These species are mainly characteristic of the Lower Permian (Asselian-Sakmarian) deposits of the Lower Rotliegendes (Autunian), although they also are widely present in the uppermost Carboniferous (Westphalian and Stephanian) deposits of Europe.

The second group includes *Fascipteris* cf. *robusta* and *Taeniopteris* cf. *crassicaulis*, which are common in the lower Upper Permian (using two-fold division of the Permian System) of China (in the equivalents of the Ufimian and Kazanian stages). It should be noted that *Fascipteris* cf. *robusta* was found in the Saxonian (supposedly Artinskian-Kungurian) deposits of the Guadalcanal locality of southern Spain (Broutin 1974, 1977, 1985, 1986). This species shows great morphological similarity with marattialean ferns of the group *Pecopteris unita – Diplazites longifolia*, associated frequently in the European localities with *Annularia carinata* and *Pecopteris cyathea.* As noted above, specimens of *Taeniopteris* cf. *crassicaulis* from the Gachal section are similar to the European-Asiatic Early Permian *Taeniopteris multinervis.* The genus *Discinites* mostly occurs in the Lower Permian of Euramerica and Cathaysia. Thus, in the taxonomic composition, the general character with dominating Euramerian pecopterids, and even taphonomical features (confinement to the red molasses) suggest that the Gachal flora is close to the Asselian-Sakmarian floras of the European Rotliegendes in spite of younger Katasiatic components. A conventional age of the flora is Early Permian, probably Sakmarian, but the younger, Artinskian age is more creditable owing to the mentioned conodont and fusulinid evidence.

The larger part of the Chakh-Kular and the overlying Hermez and Rizi formations can be dated through their correlation to the Halvan sections. The Sartakht Formation correlative of the Chakh-Kular Formation is dated by small foraminifers as Yakhtashian-Bolorian (the lower part) and Kubergandian-lower Murgabian (the upper part). Accordingly, this age can be supposed for the Chakh-Kular Formation. As for the Hermez and Rizi formations, they can be confidently assigned to the Upper Permian only (Leven & Gorgij 2011; Shen et al. 2009).

Some biogeographic inferences

The biogeography of fusulinids constituting the Kalaktash assemblage was considered in a number of publications (Leven 1993, 1997, 2009; Leven & Gorgij 2007, 2011; Davydov & Arefifard 2007). After its first description from the Central Pamir sections (Leven 1993) it was regarded as characteristic assemblage of the southern Peri-Gondwanian part of the Tethys, as confirmed by occurrences of the Kalaktash species in Central Afghanistan (Leven 1997), Eastern Hindu Kush (Gaetani & Leven 1993), and Southern Tibet (Nie & Song 1983). Later the assemblage was found in Oman (Angiolini et al. 2006), Karakorum (Gaetani et al. 1995; Leven 2010), the Sibumasu and Baoshan blocks of Southern China (Yunnan Province) (Ueno 2003), and Central Iran (Leven 2007; Davydov & Arefifard 2007). A characteristic feature of the assemblage is a dominance of endemic *Nonpseudofusulina*, which are associated with locally abundant *Eoparafusulina*. The Eastern Hindu Kush and Southern China sections also contain *Monodiexodina* (Ueno 2006; Leven 2010), which most probably are younger than typical Kalaktash fusulinids.

In taxonomic uniformity and species composition the Kalaktash assemblage is considerably different from a coeval association of fusulinids from the northern margins of the Paleo-Tethys (Darvaz, Tyan-Shan, Kun-Lun). *Nonpseudofusulina*, which dominates the Kalaktash assemblage are less abundant and diverse and represented by different species in the northern sections. *Eoparafusulina* is not present there. Genera are essentially more diverse in the northern area. Beside *Nonpseudofusulina*, the genera *Biwaella, Darvasites, Rugosofusulina, Quasifusulina,* as well as representatives of the family Schwagerinidae, such as *Sphaeroschwagerina, Pseudoschwagerina, Paraschwagerina, Likharevites, Robustoschwagerina, Zellia* are common in the northern assemblage. The noted differences are due to their palaeogeographic location on the opposite Paleo-tethyan margins separated by large oceanic areas and in different climatic belts, i.e., the temperate belt for the Kalaktash assemblage and the tropical belt for the northern assemblage (Leven & Scherbovich 1978; Leven 1993). However, some northern warm-water forms (*Sphaeroschwagerina, Robustoschwagerina, Zellia*) were rarely found in the upper part of the beds with the Kalaktash fusulinid assemblage in Central Pamir. Similar fusulinids were also reported from the Kalmard sections. There are some genera and species of the Halvan assemblage, such as *Sphaeroschwagerina, Parazellia, Robustoschwagerina* and others, which do not occur in Afghanistan, Pakistan, and Oman. All the above points suggest that Central Pamir and the Kalmard Block occupied a position during the Early Permian between the temperate-climate zone with the Kalaktash fusulinids, and the tropical zone with a more diverse fusulinid assemblage. This seems to be confirmed by the presence of oolites and bauxitic laterites in Central Pamir and the Kalmard Block, and their absence to the south. Additional evidence is provided by plant fossils from the

Chakh-Kular Formation and Central Pamir (Dronov 1964), which include low-latitude termophilic elements (calamites, ferns, cycadophytes, noeggerathiophytes).

If these suppositions are true, we should recognize that Central Pamir and the Kalmard Block probably settled more close to equator, than they are in modern palinspastic reconstructions (Stampfli & Borel 2002). The similarities between the Permian sections of the Kalmard Block and Central Pamir, as well as between the Permian and Triassic sections of Central Pamir and the Khaftkala Block of Middle Afghanistan (Leven 1997), allow us to suppose that all these blocks represent parts of a former single extensive geological terrain. Subsequent tectonic collisions destroyed that terrain almost completely, with only small fragments surviving (Leven 2009). The terrain may represent the northern margins of original Cimmeria, but in this case that microcontinent would stretch from the temperate to near tropical latitudes. In other words, it would be much larger than it is presently considered. However it cannot be excluded that the hypothetical terrain was far from Cimmeria and, probably, it was separated from it by an oceanic basin (the Rushan-Shuankhu Ocean of Burtman 2006).

Conclusions

The data from this study both elucidate some problems of the Iran regional geology and provide a new insight into Permian biostratigraphy and bio- and paleogeography.

In the regional aspect it is interesting to demonstrate the persistence of Permian deposits over the entire Kalmard Block and their specific character in comparison with the sections of the neighboring blocks. A question arises as to how the Kalmard Block came to be situated between the large adjacent blocks with sections of different types.

An important result of the study is to reconfirm the Sakmarian age of the beds with the Kalaktash fusulinid assemblage. Of interest also is the fact that they are overlain by beds with the Halvan fusulinid assemblage. Many genera and species of the Halvan assemblage represent archaic forms, that are characteristic components of the Sakmarian Stage of the Tethyan scale. Their position above the beds with the Sakmarian conodonts allows to revise the upper boundary of this stage in the Tethyan scale. And that applies to the correlation between the Yakhtashian and Artinskian stages of the Tethyan and global scales.

The Permian plant remains described here have been found in Iran for the first time. The occurrence of both typical Euramerian and Cathaysian species indicates free migration pathways, which were provided by a significant post-Sakmarian regression causing appearance of large subaerial territories to the north of Gondwana.

Finally, the surprising similarity of the Permian sections and fusulinids of the Kalmard Block, Central Pamir and Middle Afghanistan rose the interest. Very similar to each other, they also differ in many aspects from the sections of the regions to the north of Gondwana.

Description of the new species of fusulinids

Order **Schwagerinida** Solovieva, 1985

Family Pseudofusulinidae Dutkevich, 1934

Genus *Nonpseudofusulina* Leven, 2008

Nonpseudofusulina darinensis n. sp.

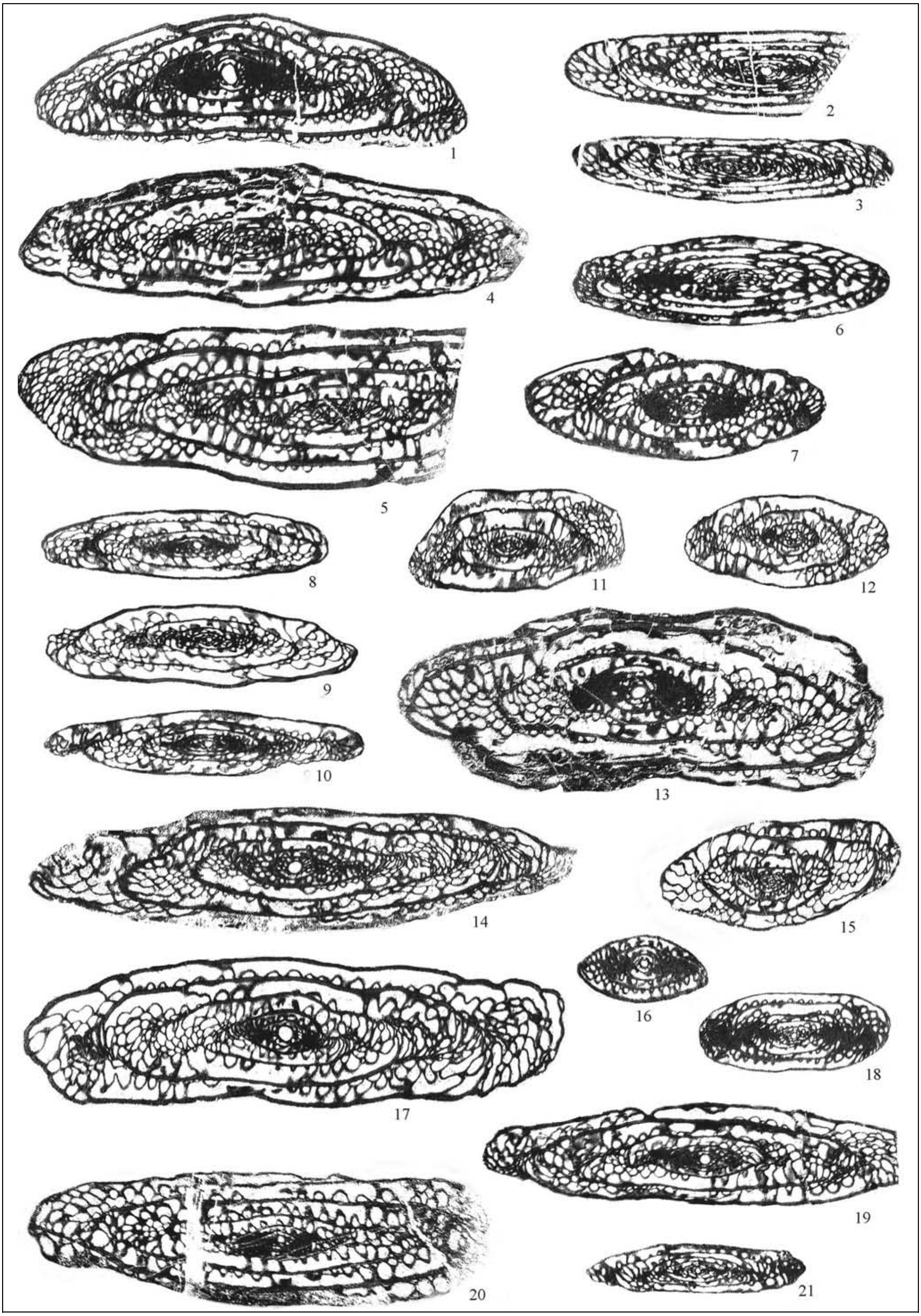
Pl. 1, fig. 11, 12, 15

Etymology: Named after the Darin fusulinid locality.

PLATE 1

Fusulinids from the Chili Fm. (Darin section, Kalaktash assemblage). Magnification x9.3 for all pictures.

1 - *Nonpseudofusulina psharti* (Leven). Axial section. Sample PDK-67; GIN4792/14.
2, 3 - *Eoparafusulina pamirensis* Leven. Axial sections. Sample PKD-66; GIN4792/2 and GIN4792/3.
4, 5 - *Nonpseudofusulina* aff. *acallosa* (Kireeva). Axial sections. Sample PKD-58; GIN4792/4 and GIN4792/5.
6 - *Eoparafusulina stevensi* Davydov et Arefifard. Subaxial section. Sample PKD-69; GIN4792/6.
7 - *Nonpseudofusulina tezakensis* (Leven). Axial section. Sample PKD-69; GIN4792/7.
8-10 - *Nonpseudofusulina inobservabilis* (Leven). Axial sections. Sample PKD-69; GIN4792/8, GIN4792/9, and GIN4792/10.
11, 12, 15 - *Nonpseudofusulina darinensis* nov. sp. Axial sections. Sample PKD-69; GIN4792/1 (holotype), GIN4792/11, and GIN4792/12.
13 - *Nonpseudofusulina insignis* (Leven).Axial section. Sample PKD-58; GIN4792/13.
14 - *Nonpseudofusulina pamirensis* (Leven). Subaxial section. Sample PKD-76; GIN4792/15.
16 - *Anderssonites* ex gr. *anderssoni* (Schellwien). Axial section. Sample PKD-76; GIN4792/16.
17 - *Nonpseudofusulina* aff. *kalaktashensis* (Leven). Axial section. Sample PKD-76; GIN4792/17.
18 - *Eoparafusulina* sp. Axial section. Sumple PKD-69; GIN4792/18.
19 - *Nonpseudofusulina karapetovi* (Leven). Axial section. Sample PKD-77; GIN4792/19.
20 - *Nonpseudofusulina devexa* (Rauser-Chernousova). Axial section. Sample PKD-69; GIN4792/20.
21 - *Nonpseudofusulina macilenta* (Leven). Axial section. Sample PKD-66; GIN4792/21.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Holotype: GIN4792/1; axial section; Iran, Darin, sample PKD-69; latest Sakmarian.

Material: Four axial and 6 tangential and oblique sections.

Description. Shell small, shortly fusiform, with cylindrical central portion and bluntly pointed poles. Mature specimens have 4 to 5 volutions and measure 3.9 to 5.5 mm in length and 1.8 to 2.2 mm in diameter. Form ratio 2.1 to 2.9. Spirotheca composed of tectum and moderately coarse keriotheca; thickness in outer volutions 0.075 mm. Septa thin, strongly but irregularly folded throughout shell. Septal folds high reaching to tops of septa. Proloculus small, its outside diameter 0.1 to 0.5 mm. Tunnel low and not wide; it has an unstable position in the volution. Chomata weak, present on the proloculus and in the first whorl.

Discussion. *Nonpseudofusulina darinensis* is similar to *N. curteum* (Leven), but differs in its smaller size, smaller proloculus, cylindrical central portion of shell, and lacking axial filling in the juvenarium.

Occurrence and age. Iran, Darin; latest Sakmarian.

Paleobotanical description

Phylum **Equisetophyta** Scott, 1900

Class **Equisetopsida** C.Agardh, 1825

Order **Calamitales** (=**Calamostachyales**) Eichwald, 1852

Family Calamitaceae Unger, 1840

Genus *Annularia* Brongniart, 1828

Annularia carinata Gutbier, 1849

Fig. 3 A, B; Pl. 3, figs 2-4

Selected synonymy:

Annularia carinata Gutbier – Barthel, 1976, p. 74-75, Pl. 26, fig. 5-8;

Annularia carinata Gutbier – Kerp, 1984, Pl. VI, 3, 4;

Annularia carinata Gutbier – Kerp, Fichter, 1985, Taf. 6, Fig. 3-6;

Annularia carinata Gutbier – Broutin, 1986, p. 47, Pl. VI, fig. 13.

Material: Three specimens. Kalmard block, Chah-Kular Formation, bed 9.

Description. There are two leafy shoots and one fragment of a leaf whorl belonging to this species in the collection studied. The most complete and best preserved leafy shoot (Fig. 3, A) is represented by an axis with one almost completely preserved leaf whorl. Second specimen attributed to the same species is a fragment of an axis with two partly preserved leaf whorls (Fig. 3, B). Third specimen is a part of bilaterally symmetrical leaf whorl (Pl. 3, fig. 3).

Maximal width of the axes is 3.5 mm, minimal width is 2 mm. Stem surface bears unclear prolonged folds. Each node bears the leaf whorl consisting of twenty long radially arranged lanceolate leaves. Leaves are free, without any leaf sheaths. Maximal width of the leaf is 3.5 mm, width of the basal leaf part is 1.5 mm. Leaf apex is acute. Leaf whorls are radially symmetrical (Fig. 3A) or bilaterally symmetrical (Fig. 3B). Bilaterally symmetrical leaf whorls are superficially similar to leaves belonging to the *Lobatannularia* genus. Such bilaterally symmetrical leaf whorls are typical of *Annularia carinata* Gutbier leaves found in the Lower Permian deposits of Western and Central Europe (Kerp & Fichter 1985; pl. 6, figs 3-6). Isolated leaf whorls of the same type and even large fragments of leafy shoots of *Annularia carinata* Gutbier were found in the Lower Permian deposits of the Cis-Urals (Naugolnykh 2005) and the Kazanian deposits of Arkhangelsk region (Soyana River, Iva-Gora locality: Naugolnykh & Kuleshov 2005). Each leaf has one weakly developed midvein coming from the leaf base to leaf apex. Midvein width doesn't exceed 0.1 mm.

Most probably, the leafy shoot of *Annularia carinata* with bilaterally symmetrical leaf whorls were lateral, plagiotropic, horizontally orientated for most

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PLATE 2

Fusulinids from the uppermost part of Chili Fm. (Darin section, Kalaktash assemblage with elements of the Halvan assemblage). Magnification x9.3 for all pictures.

1 - *Parazellia falx* (Rauser-Chernousova). Axial section. Sample PKD-90; GIN4792/22.

2, 3, 5 - *Parazellia elongata* (Saurin). Axial (2, 5) and subaxial (3) sections. Sample PKD-83; GIN4792/23 and GIN4782/24.

4 - *Robustoschwagerina*? sp. Sagittal section. Sample PKD-90; GIN4792/25.

6 - *Nonpseudofusulina* ex gr. *exuberata* (Shamov). Axial Section Sample PKD-92.

7, 15 - *Nonpseudofusulina* aff. *fecunda* (Shamov et Scherbovich). Axial sections. Sample PKD-96; GIN479227 and GIN4792/28.

8, 14 - *Nonpseudofusulina* aff. *indigaensis* (Grozdilova et Lebedeva). Subaxial sections. Sample PKD-95; GIN4792/29 and GIN4792/30.

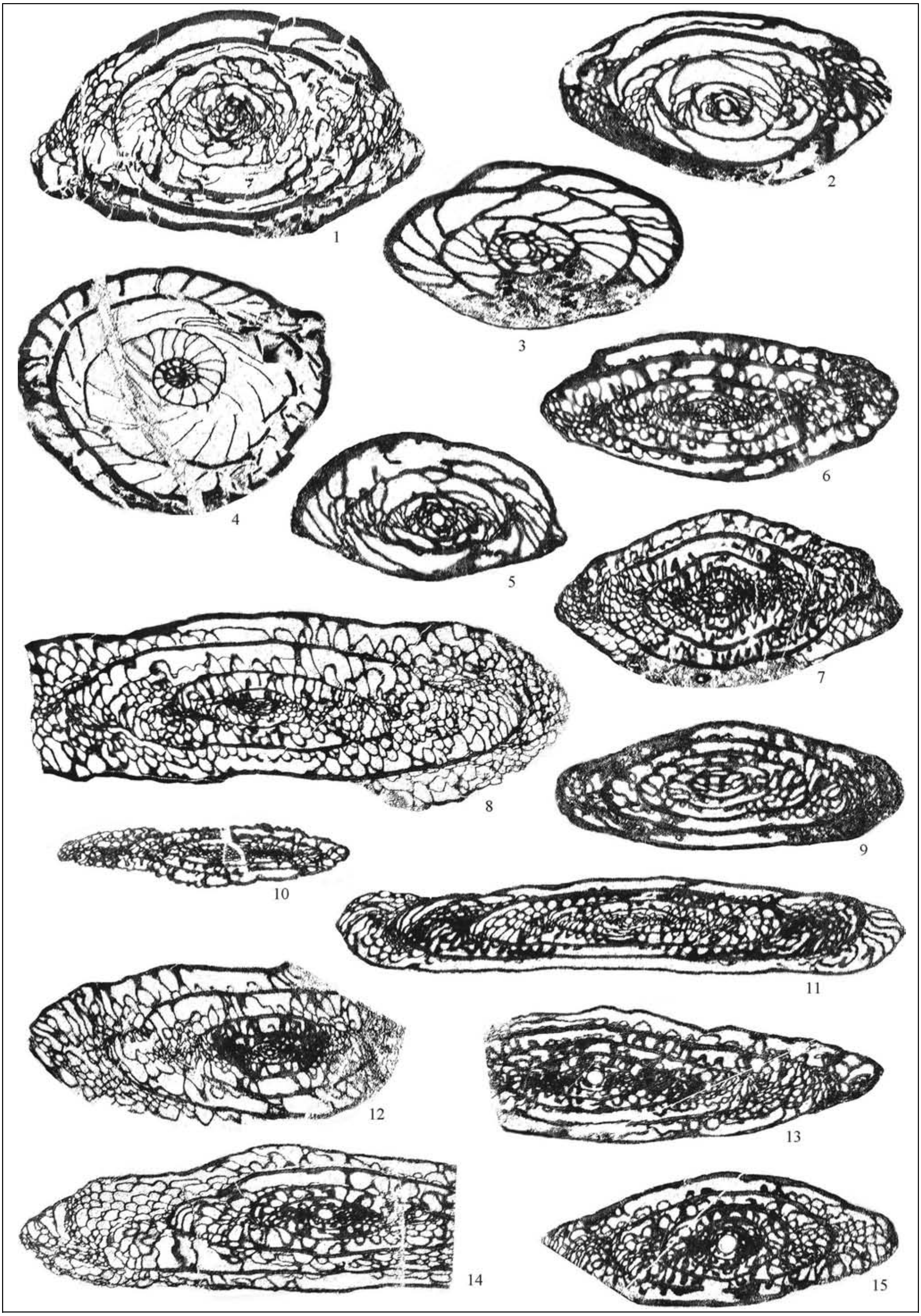
9 - *Eoparafusulina* ex gr. *tschernyschewi* (Schellwien). Tangential section. Sample PKD-93; GIN4792/31.

10 - *Rugosochusenella* cf. *rugosa* Leven. Subaxial section. Sample PKD-85; GIN4792/32.

11 - *Eoparafusulina pamitensis* Leven. Axial section. Sample PKD-83; GIN4792/33.

12 - *Nonpseudofusulina curteum* (Leven). Axial section. Sample PKD-95; GIN4792/30.

13 - *Nonpseudofusulina* aff. *muzkolensis* (Leven). Axial section. Sample PKD-95; GIN4792/34.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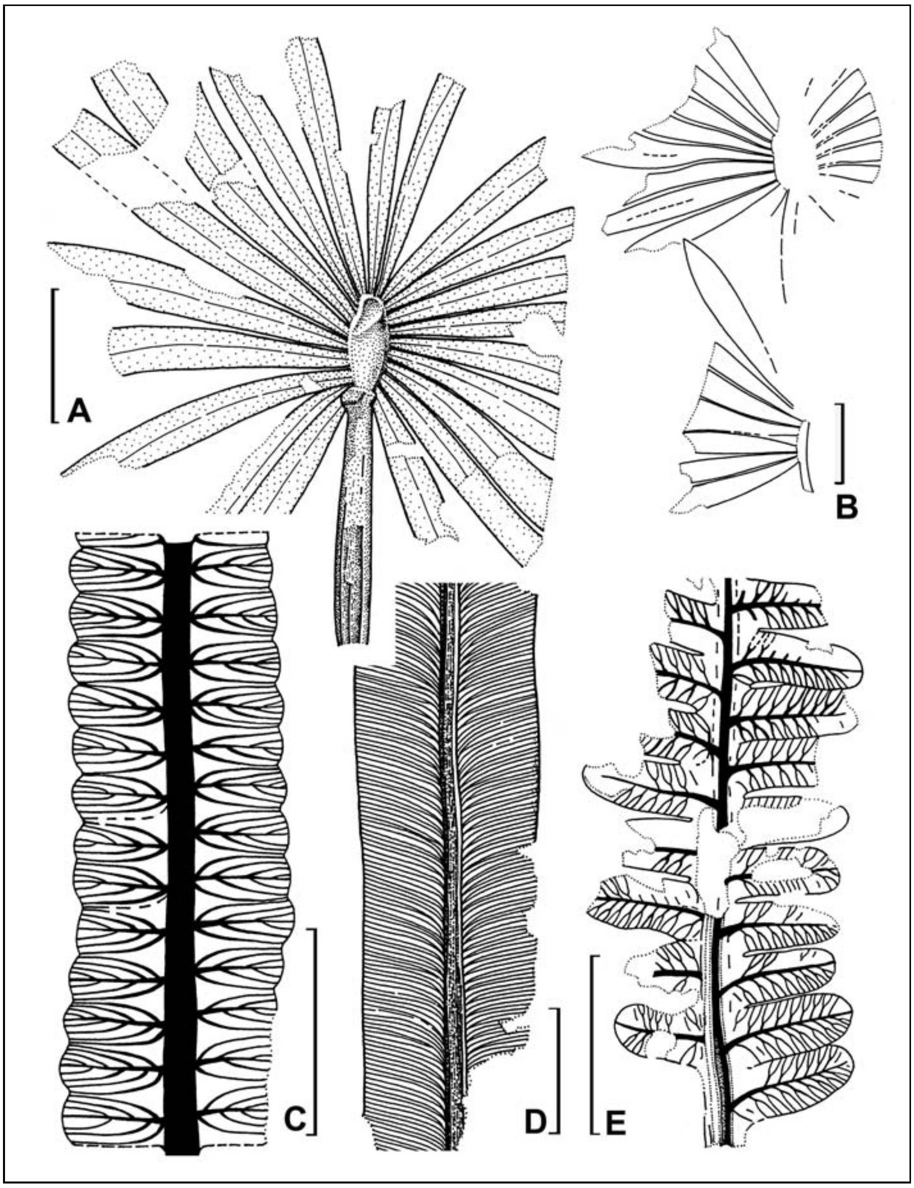

Fig. 3 - Gachal flora: morphology of higher plants. A, B - *Annularia carinata* Gutbier; C - *Fascipteris* cf. *robusta* (Kawasaki) Broutin; D - *Taeniopteris* cf. *crassicaulis* Jongmans et Gothan; E - *Pecopteris monyi* Zeiller. Kalmard block, Chah-Kular Formation, bed 9. Scale = 1 cm.

effective using of sun light, when the parent plant was alive.

Remarks. It is known now that the leaves *Annularia carinata* Gutbier belonging to *Calamites gigas* Brongniart grew in Permian times practically everywhere around the periphery of Tethys (Kerp 1984; Naugolnykh 2005).

It should be noted that the similar leafy shoots and separated leaf whorls determined as *Lobatannularia* sp. were found in Saxonian (possibly, Artinskian-Kungurian) deposits of south part of Spain (Guadalcanal flora: Broutin 1986, text -fig. 16, pl. 7, figs 1-3, 5, 6, 8-12). Practically identical leaf whorls were collected from the Kungurian deposits of the Cis-Urals [(Naugolnykh 2009) whose photo on p. 23; compare with the leaf whorl figured in Broutin, 1986, pl. 7, figs. 3, 6]. We believe that in both cases these remains should be assigned to *Annularia carinata* Gutbier and are conspecific with the specimens of *Annularia carinata* from Western Europe and Iran (this paper), but differ from them in slightly smaller size. Together with the *Lobatannularia* sp., the leaves of the typical specimens of *Annularia carinata* were found in the Guadalcanal (Urbana locality: Broutin 1986, pl. 6, fig. 13). Leaf whorls of the latter specimens also have distinct bilateral symmetry.

Leafy shoots very similar to *Annularia carinata* were figured and described from the Permian flora of Unayzah, which is known from the Saudi Arabia (El-Khayal et al. 1980; Lemoigne 1981, amongst others). Unayzah flora is a typical mixed flora and includes Euramerian, Gondwanan and Cathaysian taxonomical elements in its composition. Calamite leaves from the Unayzah flora were determined as *Annularia stellata* (Schlotheim) Brongniart (El-Khayal et al. 1980, fig. 2, b), and as *Annularia mucronata* Schenk (Lemoigne 1981, pl. 2, figs. 1-3; specimen on fig. 3 was determined

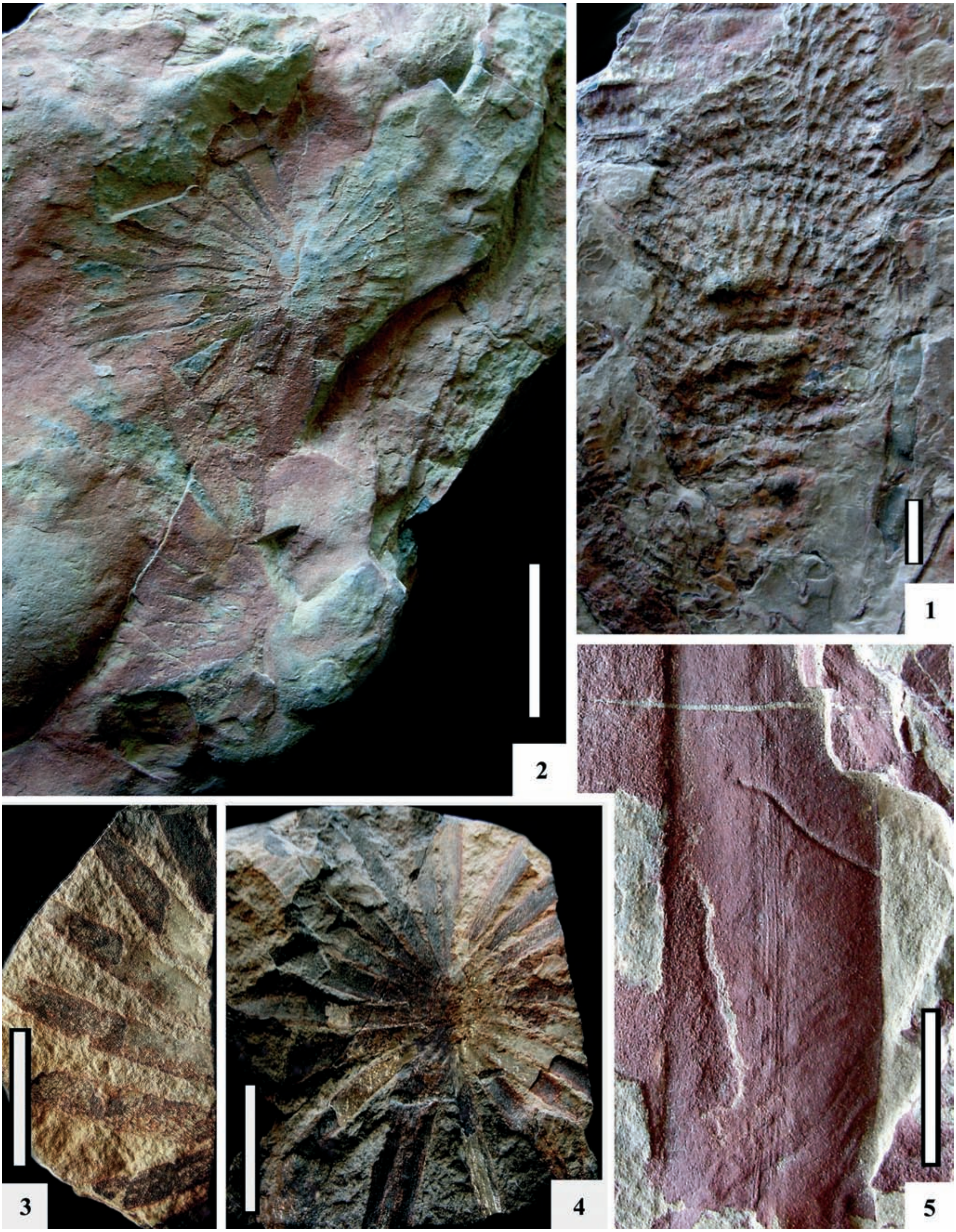

PLATE 3

Gachal flora: morphology of plants.

1 - *Discinites* sp.; 2, 3, 4 - *Annularia carinata* Gutbier; 5 - *Taeniopteris* cf. *crassicaulis* Jongmans et Gothan. Kalmard block, Chah-Kular Formation, bed 9. Scale=1 cm.

with a question mark). According to the authors, these leaves also could be assigned to *Annularia carinata*, especially taking into account the fact that the plants *Calamites multiramis* Weiss (having the *Annularia stellata* leaves: Novik 1952: 133-134) and *Calamites suckowi* Brongniart (having *Annularia mucronata* leaves, and leaves of closely related formal species) are not known from the Permian deposits of Arabia, but the *Calamites gigas* (having *Annularia carinata* leaves) is known from the Permian (Ufimian or Kubergandinian) Gharif flora in Oman (Broutin et al. 1995; Berthelin et al. 2003).

Phylum **Pteridophyta** Schimper, 1879

Class **Marattiopsida** (in part.) Doweld, 2001

Order **Marattiales** (in part.) Prantl, 1874

Family Incertae sedis

Genus *Pecopteris* Brongniart, 1828

Pecopteris monyi Zeiller, 1888

Fig. 3 E; Pl. 4, fig. 1

Selected synonymy:

Pecopteris monyi Zeiller, 1888, p. 169-171, Pl. 17, figs. 3-4;

Pecopteris monyi Zeiller - Doubinger & Alvarez-Ramis, 1984, p. 515-521, Pl. 2, fig. 5;

Pecopteris monyi Zeiller - Doubinger et al., 1995, p. 148, fig. 174-176.

Material: Three frond fragments with partly preserved last order pinnae. Kalmard block, Chah-Kular Formation, bed 9.

Description. This species is represented by large fragments of bipinnate fronds. Regular subparallel orientation of some bipinnate fragments in a matrix allows us to suggest that the fronds initially were at least tripinnate.

The size of complete fronds still remains unknown. Judging from the available specimens we can believe that length of the well developed tripinnate fronds could reach several dozens cm. Length of the best preserved frond fragments is more that 30-40 cm; width is 20 cm. Maximal observed length of the last order pinna (last-but-one order segment) is 6 cm. Last order pinna rachis is thin, straight, rarely slightly curved, with a narrow wing. Maximal observed rachis width is 0.5 mm. Width of the rachis together with a wing is 2 mm. Pinnules (last order segment) are attached to the rachis in alternate order under an angle 75-90°. Pinnules are pecopterid, connected by their bases and forming narrow wing along the last order pinna rachis. Pinnule margins are smooth, subparallel. Pinnule apex is round. Pinnule length is 7-8 mm average, width is 3 mm. Venation is pinnate. Midvein is well developed, relatively thick. Midvein maximal width is 0.3 mm. Each common pinnule bears 8-10 vein pairs. Apical pinnules bear 2-3 vein pairs. Lateral veins are alternating, rarely opposite. Most of the lateral veins are once dichotomizing in their lower (basal) part. Maximal width of the lateral veins is 0.1 mm.

Remarks. This species is a common element of near-water paleophytocoenoses of Stephanian (uppermost Upper Carboniferous) and Lower Rotliegend (Lower Permian) of the Western and Central Europe (Zeiller 1888; Doubinger & Alvarez-Ramis 1984; Doubinger et al. 1995; Wagner 2004).

Pecopteris cyathea (Schlotheim) Brongniart, 1833

Pl. 4, figs 2-4

Selected synonymy:

Pecopteris cyathea (Schlotheim) Brongniart - Brongniart, 1833, p. 307, Pl. 51, figs. 1-4.

Pecopteris cyathea (Schlotheim) Brongniart - Zeiller, 1879, Pl. 169.

Pecopteris cyathea (Schlotheim) Brongniart - Doubinger et al., 1995, p. 137, fig. 146, 149, 150.

Material: Five large fragments of well preserved last-but-one order pinnae and seven isolated last order pinnae. Kalmard block, Chah-Kular Formation, bed 9.

Description. This fern species is very well represented in Gachal flora. There are numerous isolated last order pinnae, as well as large fragments of last-but-one order pinnae in the collection studied. The *Pecopteris cyathea* specimens from Gachal flora virtually identical to classic specimens of that species from Lower Permian (Asselian-Sakmarian) deposits of Western and Central Europe (compare, for instance, the specimen figured here on Plate 4, fig. 4, and the specimen from Manebach locality (Thuringia, Germany) in Remy & Remy 1959: pl. 127).

Very small pinnules disposed closely to each other and connected to last order pinna rachis under almost 90° are characteristic of this species. One last order pinna can possess more than 30 pinnule pairs. Last order pinna attached to the last-but-one pinna rachis under an angle 55°. Pinnule length is 6-7 mm in average, pinnule width is 1.5 mm. Pinnules are entire margined, with subparallel margins. Pinnule margins are abaxially curved downwards. Pinnule apex is round. Midvein is straight, thin. Once dichotomizing alternating lateral veins connect midvein under an angle 75-80°.

Remarks. *Pecopteris cyathea* is very similar to *P. permica* Nemejc (Remy & Remy 1959: 233, fig. 186), which is also very widely distributed in Lower Permian deposits of Western and Central Europe, but *P. cyathea* is different from *P. permica* in more complex venation.

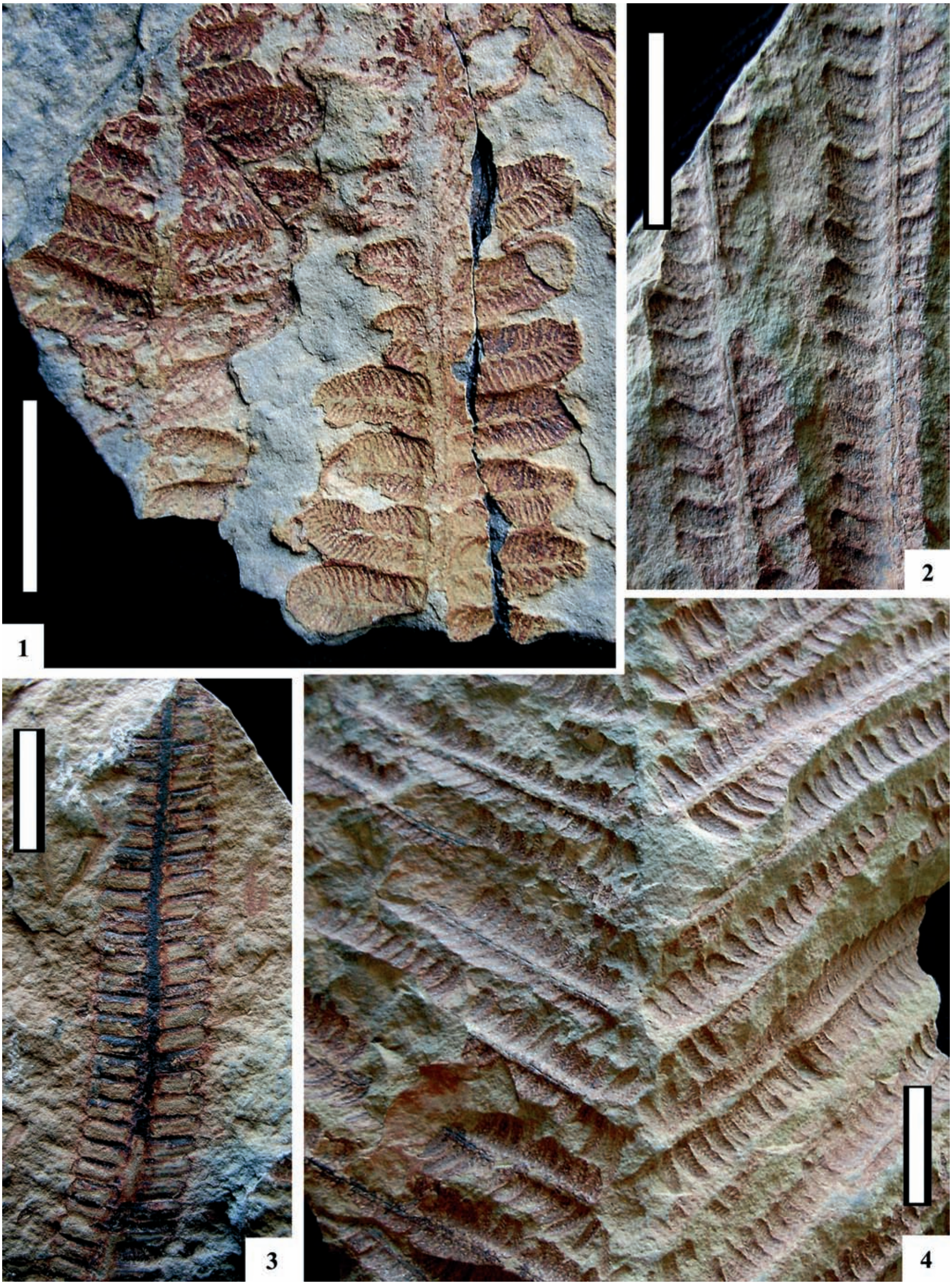

PLATE 4

Gachal flora: morphology of plants.

1 - *Pecopteris monyi* Zeiller; 2-4 - *Pecopteris cyathea* (Schlotheim) Brongniart. Kalmard block, Chah-Kular Formation, bed 9. Scale =1 cm.

Fascipteris cf. **robusta** (Kawasaki) Broutin, 1986

Fig. 3 C; Pl. 5, fig. 1-3

Selected synonymy:

Desmopteris robusta Kawasaki, 1934, p. 152, Pl. CVII, fig. 10.

Validopteris robusta (Kawasaki) – Stockmans & Mathieu:

Validopteris robusta (Kawasaki) – Stockmans & Mathieu, 1957, p. 32, Pl. XIII, fig. 4, 4a.

Fascipteris robusta (Kawasaki) Broutin – Broutin, 1986, p. 36, Pl. II, fig. 8, 8a.

Material: A single specimen with a frond fragment represented by three last order pinnae. Kalmard block, Chah-Kular Formation, bed 9.

Description. This Kathaysian fern is represented by a single but morphologically distinctive specimen with three long unicoherent pinnae of last order. Pinnules are entirely connected by their margins. Maximal observed width of the pinnae is 10 mm. Exact length of the pinnae is unknown, but it was considerably longer than 100 mm. Since this specimen is not completely preserved, it was determined in open nomenclature with "cf." mark.

Rachis of the last order pinna is thick, well developed, straight or slightly curved, smooth or bearing a shallow adaxial medial furrow. Maximal observed width of the rachis is 2 mm. Unicoherent pinnules are attached to the last order pinna under an angle 85-90°. Each last order pinna (perhaps with the exception of apical ones) bears more than 50 pairs of pinnules. Pinnule length is more or less stable per pinna. The length is very slowly decreasing towards pinna apex. Average pinnule length is 5 mm, width is 2.5 mm. Pinnule apex is round. Venation is pinnate. Midvein is distinct, coming to pinnule apex. Alternating lateral veins connected to midvein under an angle 25-30°. Lateral veins are always simple. Their width is slowly decreasing from the vein base to pinnule margin.

Remarks. Typically Cathaysian fern (Kawasaki 1934; Stockmans & Mathieu 1957) *Fascipteris robusta* is very similar to Euramerian ferns of *Pecopteris unita* group, which are common components (together with *P. cyathea*) of the paleophytocoenoses also inhabited by *Taeniopteris jejunata, Autunia* (*Callipteris*) *conferta, Subsigillaria brardii,* and *Walchia piniformis*, typical elements of Lower Permian deposits of European Rotliegens, for example, Brieve and Autun basins of France and Germany (Bubnoff 1930).

Phylum **Archaeopteridophyta** (=**Progymnosperophyta**) Snigirevskaya, 2000

Class **Noeggerathiopsida** Kryshtofovich, 1934

Order **Noeggerathiales** Darrah, 1939

Family Incertae sedis

Genus *Discinites* Feistmantel, 1880

Discinites sp.

Pl. 3, fig. 1

Material: One strobilus. Kalmard block, Chah-Kular Formation, bed 9.

Description. The strobilus is almost complete, with preserved base, but without an apex. Observed length of the strobilus is 115 mm, width is 43 mm. Inner structure of the strobilus cannot be studied in detail, because mode of preservation of this plant remain is an impression (=imprint). Nonetheless, we can state that the strobilus consists of whorls of round sporophylls with dentate margins. The sporophylls were attached to one common fertile axis. Peripheral parts of the sporophylls bear round or ovoid sporangia. Average size of the sporangia is 2x3 mm. The strobilus possesses more than 20 whorls of sporophylls.

Remarks. Despite the mode of preservation of this specimen, which doesn't allow to make a more exact determination of this strobilus, its belonging to the *Discinites* genus is obvious. This specimen is especially similar to *Discinites raconicensis* Nemejc from the Upper Carboniferous deposits of Czech Republic (for instance, Bek & Simunek 2005, fig. 7, F) and *D. sinensis* Wang from Lower Permian deposits of northern part of China (Wang 2000, fig. 1, a-c).

Phylum **Pinophyta** (**Gymnospermae**) Reveal, 1996

Class **Cycadopsida** Brongniart, 1843

Order **Cycadales** Dumortier, 1829

Family Incertae Sedis

Genus *Taeniopteris* Brongniart, 1828

Taeniopteris cf. **crassicaulis** Jongmans et Gothan, 1935

Fig. 3 D; Pl. 3, fig. 5.

Selected synonymy:

Taeniopteris crassicaulis Jongmans & Gothan, 1935, p. 148-154, Pl. 51, figs. 2, 3; Pl. 52, fig. 1.

Taeniopteris crassicaulis Jongmans & Gothan - Kon'no, 1968, p. 191-192, Pl. 22, figs. 1-3.

Taeniopteris crassicaulis Jongmans & Gothan - Kon'no et al., 1971, p. 59, Pl. 15, figs. 3, 4.

Material. Four fragmentary preserved leaves. Kalmard block, Chah-Kular Formation, bed 9.

Description. There are four fragments of simple taeniate leaves in the collection studied. All of them were attributed to the species *Taeniopteris* cf. *crassicaulis* Jongmans et Gothan in open nomenclature with "cf." mark. Unfortunately, complete leaves of this species are absent from our collection. Maximal observed width of the leaves is 20 mm, length is 70 mm, but length of complete leaves should be much longer. Leaves are en-

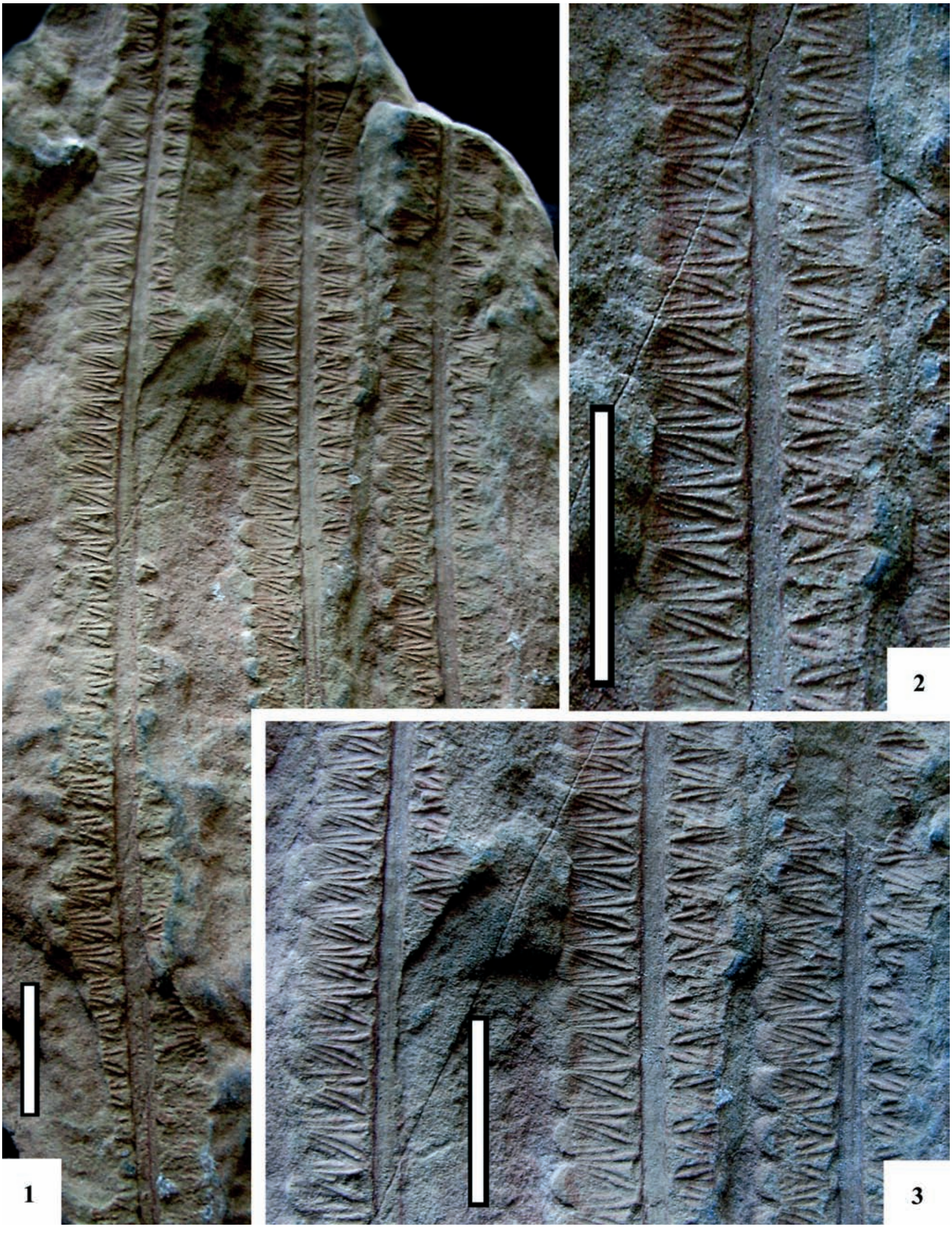

PLATE 5

Gachal flora: morphology of plants.

1-3 - *Fascipteris* cf. *robusta* (Kawasaki) Broutin. Kalmard block, Chah-Kular Formation, bed 9. Scale =1 cm.

tire margined, with subparallel margins. Sometimes slow increasing of the leaf width towards a leaf apex can be observed. There is a medial conducting strand consisted of five-six parallel veins. Width of the conducting strand is 2 mm. Width of the separate veins is 0.2 mm. The lateral veins are very thin and unclear, attached to the medial strand under an angle 65°, then gradually curved to leaf margins. The lateral veins are once dichotomizing at their bases. Sometimes simple veins also occur. Width of the lateral veins is 0.1 mm.

Remarks. The *Taeniopteris* genus now is considered as formal or morphological taxon ("morpho-taxon"), which includes simple band-like leaves with pinnate venation and lateral veins connected to midvein or medial conducting strand under an angle 70-90°. Evidences about reproductive organs are known only for several species of that genus. Presumably male fructifications *Manebachia polysporangiata* Remy et Remy were described from Manebach locality, Lower Permian of Germany (Remy & Remy 1958). Female foliar seed-bearing organs *Taeniopteris* (*Ilfeldia*) *jejunata* Grand'Eury also are known from the same locality (Barthel et al. 1975). As it is known now, taeniate leaves of *Taeniopteris jejunata* formed pinnate frond, attaching to the frond rachis by short, but distinct stalks (Barthel 2006, fig. 150). Binomen *Manebachia polysporangiata* and genus *Ilfeldia* were put in synonymy list of *Taeniopteris jejunata* (Barthel 2006: 64). Judging from this plant morphology, at least some species of *Taeniopteris* could be regarded as representatives of cycadalean gymnosperms and because of it the description of *Taenioperis* cf. *crassicaulis* is given under "Gymnospermae" caption.

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