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PALEOZOIC CALCAREOUS ALGAE FROM SOUTHERN TIEN SHAN, UZBEKISTAN, CENTRAL ASIA

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(4 figures, 5 plates)

ABSTRACT. This paper is the first illustration of Late Ordovician- Early Silurian, Early Devonian and Middle Carboniferous- Early Permian calcareous marine algae from Uzbekistan. Chlorophyta are very prolific and diverse. They are associated with some cyanophytes and rhodophytes. Taxa have been previously recorded. The flora is typically Central Tethyan and compares easily with that of Central and Southern Urals. Most algae have a wide stratigraphic range, are facies sensitive, and thus have only local age significance.

KEYWORDS: Paleozoic, calcareous algae, Central Asia.

RÉSUMÉ. Cet article constitue la première illustration d'Algues calcaires marines paléozoïques de l'Ouzbekistan (Ordovicien Supérieur/Silurien Inférieur, Dévonien Inférieur, Carbonifère Moyen/ Permien Inférieur). Les Chlorophytes sont abondantes et diversifiées. Elles sont associées à quelques Cyanophytes et Rhodophytes. Tous les taxa ont été antérieurement décrits. La flore est typique de la Téthys Centrale et se compare facilement à celle de l'Oural Central et Méridional. La plupart des Algues ont une répartition étendue en âge, sont sensibles à l'environnement, et n'ont donc qu'une valeur stratigraphique locale.

MOTS-CLEFS: Paléozoïque, Algues calcaires, Asie Centrale.

1. Introduction

Marine paleozoic deposits are widely distributed in Southern Tien Shan (Uzbekistan, Kirgizstan). Well-exposed (Balakin and Bensh, 1975) sections and abundant fossils permit a detailed stratigraphic zonation (fusulines, brachiopods, corals, conodonts) (Fig.1). In Paleozoic history, succeeded several periods when the Tien Shan region was covered by shallow warm water seas with widespread carbonate sedimentation. Calcareous algae were an important component and sometimes led to the construction of build-ups. Surprisingly these microfossils have remained one of the least studied groups in Central Asia. To fill this gap we present here a short review of the microflora observed at different intervals of the Paleozoic.

2. Late Ordovician - Early Silurian

In many mountain ranges, Ordovician deposits are exposed as separate isolated tectonic blocks. The Lower and Middle Ordovician is chiefly terrigenous and represented by claystones, siltstones and sandstones (Saltovskaya, 1981). The microflora is poorly represented. More favourable conditions were found in the Late Ordovician, which consists in part of carbonate rocks deposited in shallow marine environment. The Upper Ordovician crops out in the Zeravshan Range as a continuous 30 km sublatitudinally directed belt. They form the Shachriomon Formation, the name of the pass where these deposits are well-exposed with a continuous transition into the Lower Silurian. The rich assemblages of brachiopods, tabulates, trilobites, graptolites allowed recognition of the Caradocian and the Ashgilian (Fig.2A). The Caradocian is composed of claystones, siltstones with intercalations of sandstones. The Ashgilian deposits are characterized by the appearence of volcanic-clastic rocks, tuffs, tuff sandstones, tuff gritstones with numerous chert fragments. Upwards, volcanic clastic deposits give way to sandstones, sandy limestones and organic sandy and clayey limestones. The stage ends in diagenic dolomites. These carbonates rocks (about 50 m) have been given the local name of Archalig Beds. The total thickness of the Ordovician at the Shachriomon Pass is 420 m.

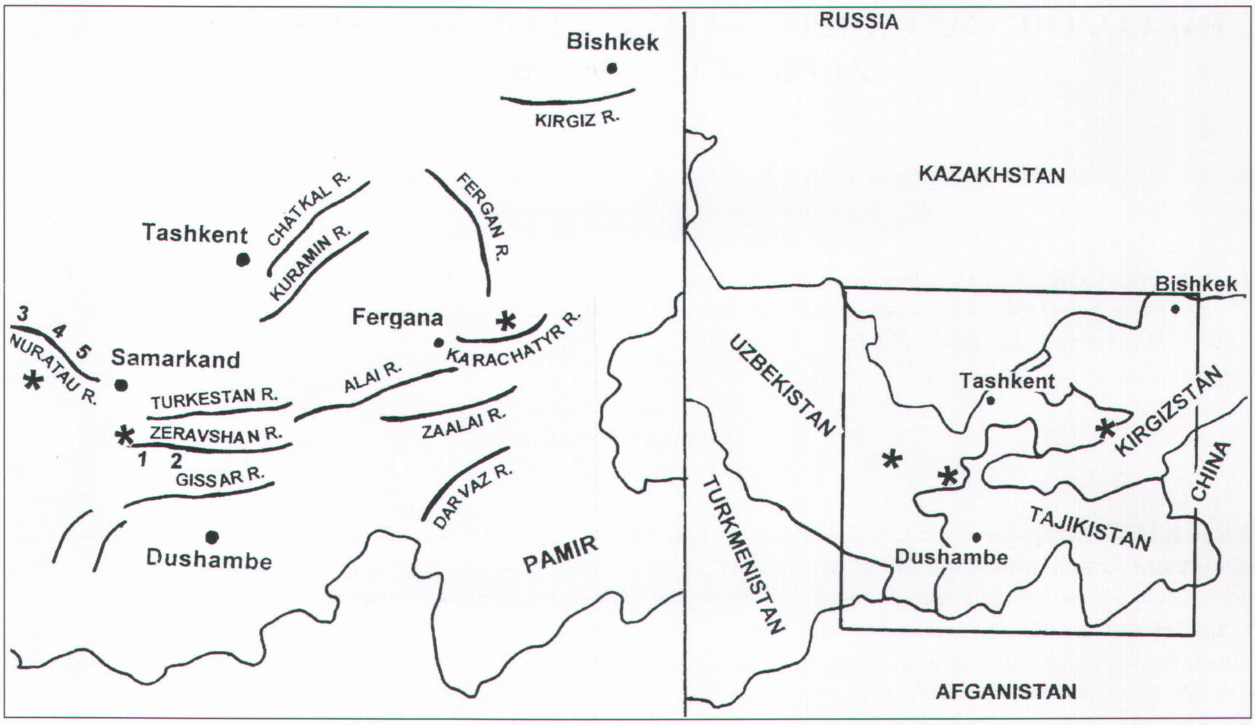

Figure 1. Location of the Karachatyr, Zeravshan and Nuratau Ridges (1- Shachriomon Mts Pass, 2- Kitab, 3- Shakhtau, 4-Michin Syncline, 5- Kysklysay)

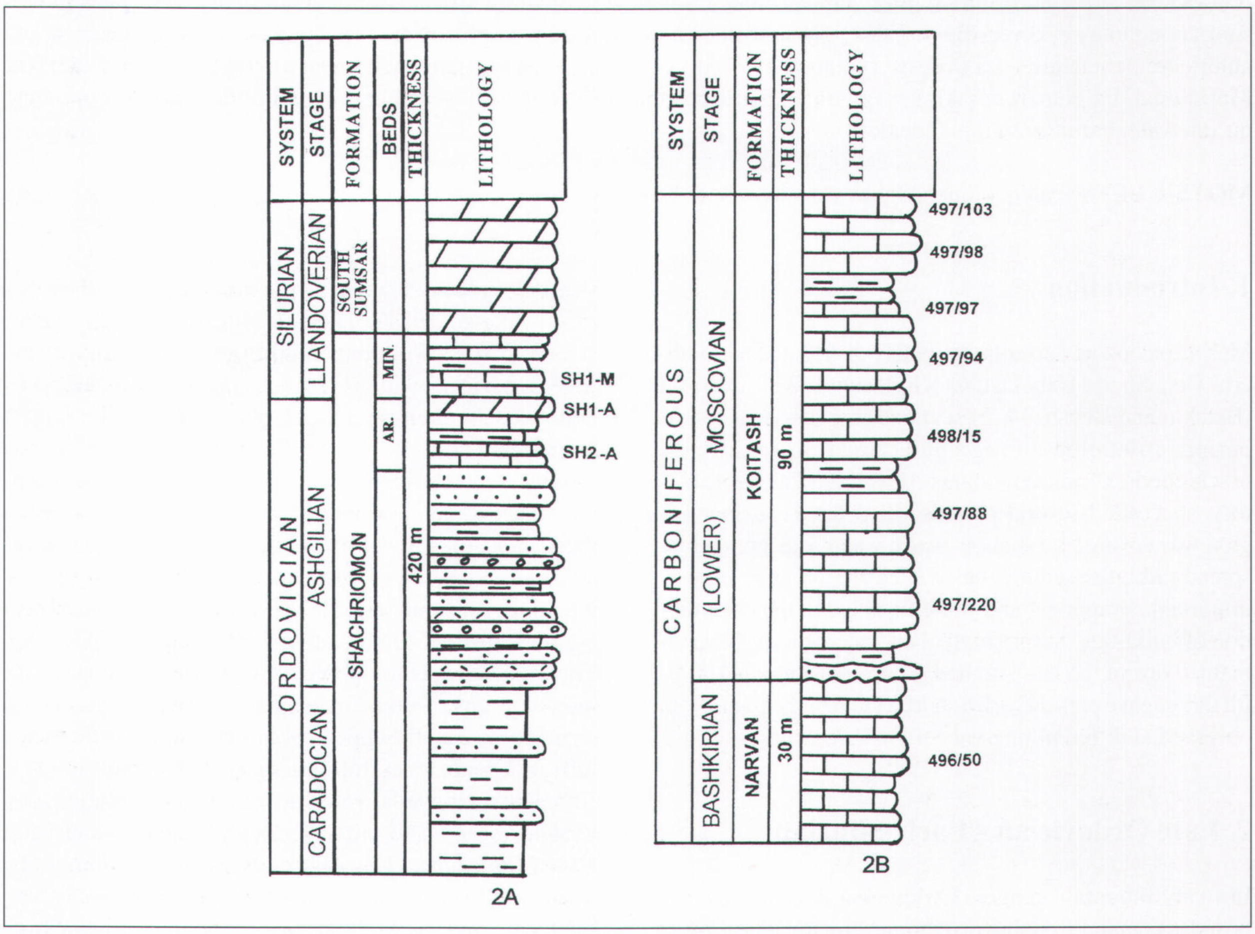

Figure 2. Stratigraphic sections: A. Zeravshan Ridge, Ordovician/Silurian (AR.- Archalig, MIN.- Minkuchar beds); B. Nuratau Ridge, Bashkirian/Moscovan.

The Archalig Beds contain abundant and very diverse fauna and an algal microflora, that has rock-building importance. Among them *Dimorphosiphon* is the most abundant (*D. rectangulare* Hoeg, *D. magnum* Gnilovskaya, *D. diadromum* Gnilovskaya). Diverse vermiporellid occur (*Vermiporella* cf. *V. inconstance* Hoeg, *V.* cf. *V. borealis* Hoeg, *V. acerosa* Gnilovskaya, *V.*aff .*wesenbergensis* Moskalenko) mixed with *Rhabdoporella pachyderma* Rothpletz. Small Cyanobacteria nodules are formed by *Girvanella problematica* Nicholson et Etheridge. Red algae are scarce with the exception of *Furcatoporella coalita* Gnilovskaya.

Tremendous fossil abundance is found in the Lower Llandovery deposits, named the Minkuchar Beds. This unit consists of organic limestones (about 20 m). The extent of the Minkuchar Beds is about 17 km; along the strike they are replaced by dolomites. Upwards they are overlain by a thick member of dolomites, the South Sumsar Formation (Middle and Upper Llandovery).

The Minkuchar and Archalig microflora are quite similar. *Dimorphosiphons* (*D. magnum* Gnilovskaya, *D. rectangulare* Hoeg) occur rather frequently, but they do not form mass accumulations as observed in the underlying beds. Numerous nodules with *Girvanella problematica* Nicholson et Etheridge are present in the limestone mixed with frequent *Vermiporella* cf. *V. fragilis* Stolley, *V. acerosa* Gnilovskaya, *Anticostiporella vaurealensis* Mamet et Roux and minute *Hoeegonites* sp.

Although the Upper Silurian in Central Asia contains shallow marine carbonate facies, any identifiable material has not been recognized up to now.

3. Early Devonian

The Devonian is widely distributed in Central Asia. Two different types of succession are distinguished. The first is composed of volcanic-carbonates and it is typical of the Middle Tien Shan. The second, mainly of carbonate facies, is typical of the Southern Tien Shan. Material for Devonian calcareous algae was collected in the Kitab National Geological Park situated in the western part of the Zeravshan Range (Fig.3A). Continuous sections of the Lower and Middle Devonian with abundant and diverse fauna crop out (Kim *et al.* 1978). Later this section was investigated in detail and chosen as a Lower Devonian local stratotype for the Tien Shan. In 1989 the International Geological Congress in Washington established it as a boundary-standard between Pragian and Emsian. In the Kitab National Park, the Lower Devonian is subdivided into two formations. The lower reef bearing Madmon Formation is of Lochkovian and Pragian age. The Emsian Khodzhakurgan Formation consists of bedded carbonates and carbonate siliceous rocks accumulated on shelf and continental slope.

The Madmon Formation (about 800 m) is largely made up of massive and partly of layered, light and dark coloured, aphanitic, crystalline limestones. Fossils show irregular distribution and occur usually in a form of scattered clusters or small layers. The massive facies contain branching, cabbage -shaped colonies of tabulate corals, colonies of stromatoporoids and compounds of rugose corals. This indicates a reef genesis for that part of the formation. Layers of limestone breccia are observed in the lower part while in the upper part there are many stromatactoid structures.

In the lower part of this unit, a few detrital limestone layers yield rare algae among numerous stromatoporoids, tabulate and rugose corals. Cyanobacteria are represented by rare *Girvanella problematica* Nicholson et Etheridge. Nodular Codiaceans include *Hedstroemia halimedoidea* Rothpletz and *Bevocastria conglobata* Garwood. Dasycladaceans are restricted to *Issinella devonica* Reitlinger, *I. grandis* Chuvashov in assosiation with stromatoporoids.

The Khodzhakurgan Formation (about 800 m) conformably overlies the Madmon limestones and consists of layered, dark-coloured, silicified turbidites with shales and black chert partings. Abundant and diverse fauna represented both pelagic and reworked benthic organisms. On the basis of paleontological data and changes in lithology it is subdivided into Zinzilban, Norbonak, Dzhaus, and Obisafit Beds. Reworked microflora is present in Zinzilban, Norbonak and Obisafit Beds of medium layered grey-coloured limestones. These limestones with rough bedding planes are non persistent along the strike grading into small bioaccumulations (1-3 m). Fossils are irregulary distributed in the form of clusters of brachiopods, corals, and crinoids.

Microflora of the Zinzilban Beds are not very diverse. *Issinella devonica* Reitlinger, *I. grandis* Chuvashov, *Issinellina*(?) sp. are numerous, while fragments of Udoteaceans are less common. A few axial sections permit recognition of *Pseudopaleoporella lummatonensis* (Elliott) and *Wagonella*(?) sp.

The Norbonak Beds are notable for abundant and diverse algae. The most prolific microflora is observed in the lower part in grey-coloured thick-bedded limestones. Cyanobacteria are represented by *Girvanella problematica* Nicholson et Etheridge, the Codiaceae by frequent *Sphaerocodium gotlandicum* Rothpletz, and dasyclads by *Issinella devonica* Reitlinger, *I. grandis* Chuvashov, and *Issinellina* (?) cf. *calva* Shuysky. This assemblage also includes numerous and various

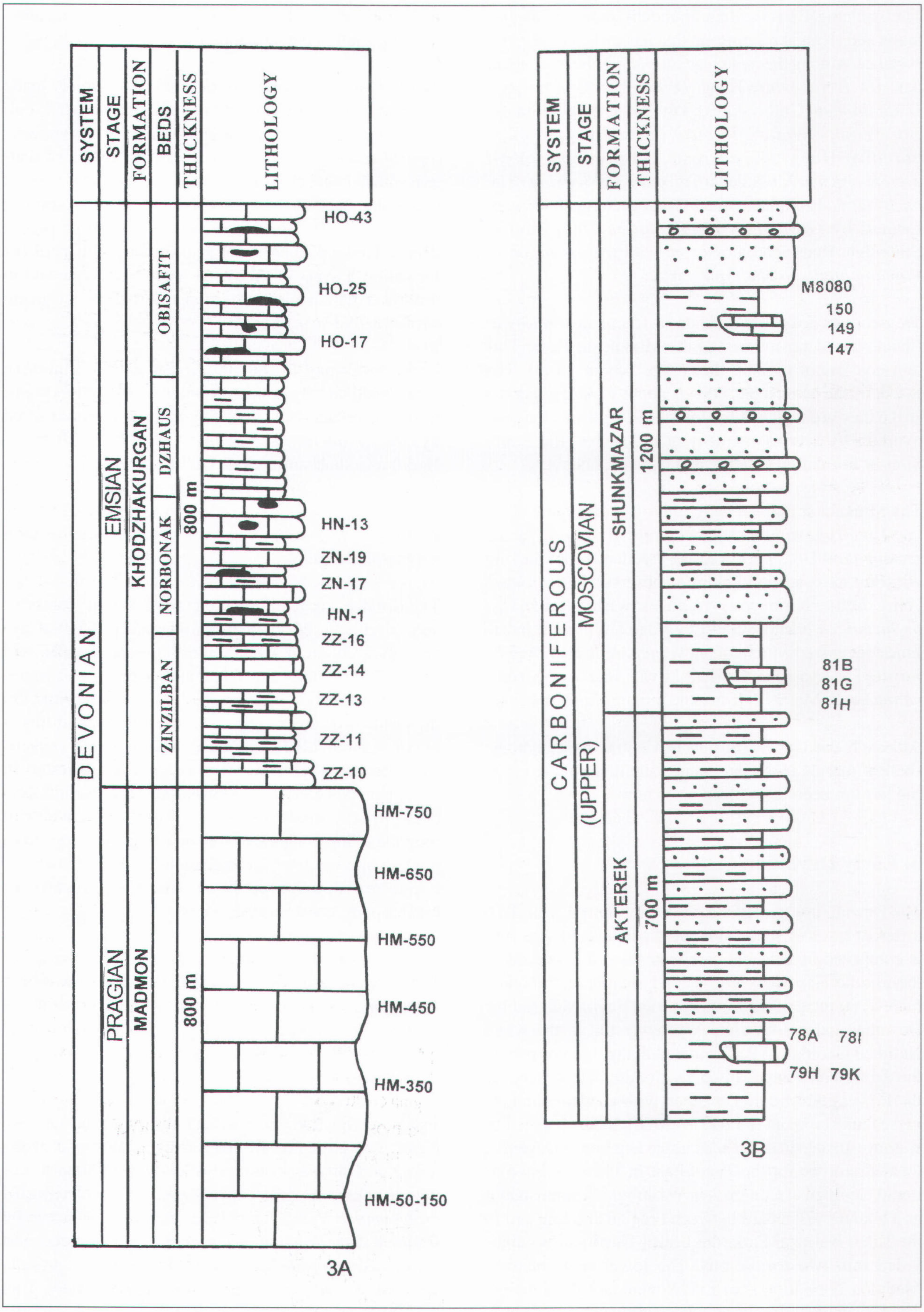

Figure 3. Stratigraphic sections: A. Zeravshan Ridge, Devonian; B. Karachatyr Ridge, Moscovian.

Udoteaceae (Shuysky and Schirschova, 1985 ; 1988): *Litanaia* sp., *L. polysticta* Vachard, *L. mira* Maslov, *Pseudopalaeoporella(?) filosa* Mamet and Préat, *Litanaella metulae*(?) Mamet and Préat, *Litanaella* sp., *Parabacella* (?) sp., *Lancicula* sp., *L. alta* Maslov, *Lepidolancicula kakvensis* Shuysky, *L. valeriae* (Pantic), *Perrierella* sp., *P. walliseri* (Langenstrasse), *P. eifelensis* Mamet and Préat, *Semilancicula*(?) sp.

The fauna (brachiopods, corals, trilobites) of the Obisafit Beds is stunted. Algae occur rarely and are poorly preserved: *Issinella devonica* Reitlinger, silicified fragments of *Hedstroemia* sp., *Ortonella*(?) sp., *Pseudopalaeoporella* sp.

4. Middle Carboniferous - Early Permian

Carboniferous and Permian deposits are widely distributed and represented by heterofacial sections. Their biostratigraphy is based upon brachiopods, goniatites, foraminifers and conodonts. The continental sequences yield plant megafossils and miosporas. The Middle Carboniferous successions of Northern Nuratau Ridge (Fig.2B) and Middle-Upper Carboniferous (Fig.3B, 4A) and Lower Permian (Fig.4B) series of the Karachatyr Ridge are considered in this paper. The Nuratau Ridge is a complex dislocated region and the Middle Carboniferous sections crop out in widely separated blocks. Studies are complicated by abrupt facies lateral variations, by repeated deposition interruptions, crusts of weathering and accumulations of bauxite. A long hiatus persisted in the Early Bashkirian.

The Upper Bashkirian (about 30 m) disconformably overlies more ancient rocks. It is represented by various carbonate rocks, alternations of thick-layered, detrital, oolitic, fossiliferous, light-grey or dark-grey limestones. In the lower part are partings of sandstones, gritstones, conglomerates and bauxite lenses. The limestones contain a rich fauna (corals, gastropods, foraminifers, bryozoans and crinoids) and prolific algal microflora. The algal assemblage comprises *Donezella lutugini* Maslov, *Beresella machaevi* (?) Kulik, *B. translucea* Kulik, *B.* cf. *herminae* Racz, *Dvinella secunda* Kulik, *D.* cf. *comata* Khvorova. Rhodophytes are very frequent: *Petschoria elegans* Kordé, and *Ungdarella uralica* Maslov. Dasyclads are very rare, only *Paraepimastopora* sp. has been found.

The Lower Moscovian (90 m) is composed of limestones that lies unconformably on bauxite-like rocks. Calcareous algae are plentiful. Beresellids and Ungdarellaceae (*Komia* and *Ungdarella*) have a rock-building role. They form buildups (biostromes) that attain 3 m in thickness. Beresellids are abundant and diverse: *B. polyramosa* Kulik, *B. translucea* Kulik, *B. erecta* Maslov and Kulik, *B. ishimica* Kulik, *Dvinella secunda* Kulik, *D.comata* Khvorova, *D.(Trinodella?) bifurcata* Maslov and Kulik, *Amarellina* n.sp., and *Uraloporella variabilis* Kordé. Red algae are also plentiful: *Ungdarella uralica* Maslov, *Komia abundans* Kordé, *Pseudokomia tenuicrustata* (Shuysky). The encrusting incertae sedis *Claracrusta catenoides* (Homann) is abundant. Dasyclads are rare (single *Paraepimastopora* sp., *Atractyliopsis* n.sp.) associated with *Bevocastria conglobata* Garwood.

Extensive deposits of Upper Moscovian to Lower Permian age are exposed in the Karachatyr Mountains located in the eastern part of Southern Fergan, in the low foothills of the Alai Ridge. Mainly terrigenous rocks compose the deposits of the Akterek and the Shunkmazar Formations. The Akterek Formation (Zone of *Fusulina kamensis*, *Putrella brazhnikovae*) is characterized by rocks of extremely diverse composition. This formation begins with basal conglomerates that are overlied by sandstones and siltstones (about 700 m thick), containing lenses of fossiliferous limestones. The algal assemblage differs from Early Moscovian microflora. The first appearance of phylloid algae (*Ivanovia tenuissima* Khvorova, *Eugonophyllum johnsoni* Konishi and Wray) is notable. At the same time, the reduction of the beresellids should be mentioned. They are replaced by dasyclads: *Macroporella ginkeli* Racz, *Herakella paradoxa* Kochansky-Devidé, *Anthracoporella spectabilis* Pia. Rare *Epimastoporella* sp., and *Antracoporellopsis* sp. have been found. In contrast to the Lower Moscovian, red algae rarely occur. These are *Ungdarella uralica* Maslov, *Komia abundans* Kordé, *Fourstonella* (?) *johnsoni* (Flügel), *Ungdarellina peratrovichensis* (Mamet and Rudloff). The incertae sedis *Claracrusta catenoides* (Homann) and *Richella incrustata* Mamet and Roux usually grow attached to various fragments or debris.

The Shunkmazar Formation (upper part of the Upper Moscovian, *Fusulinella schwagerinoides, Hemifusulina bocki* zones) is also composed of terrigenous rocks. Two fossiliferous intervals are known, one in the basal part and the other near the top. These are siltstones with nodules, lenses and intercalations of various limestones containing foraminifers, crinoids, gastropods and algae.The thickness of this unit is around 1200 m. This interval is noted for abundant phylloid algae (*Eugonophyllum johnsoni* Konishi and Wray, *E. magnum* (Endo), *E. mulderi* Racz, *Anchicodium* sp., *Ivanovia* aff. *tenuissima* Khvorova). Also common are *Clavaporella reinae* Racz and *´Epimastoporella'(?) crassitheca* Chuvashov and Anfimov, and rare *Atractyliopsis weyanti* Mamet and Roux. Beresellids occur rather frequently but are not rock-building as was the case in Lower Moscovian. They include *Beresella erecta* Maslov and Kulik, *B. polyramosa* Kulik, *B. translucea* Kulik, *Uraloporella variabilis* Kordé, *Dvinella comata* Khvorova, *D. secunda* Kulik,

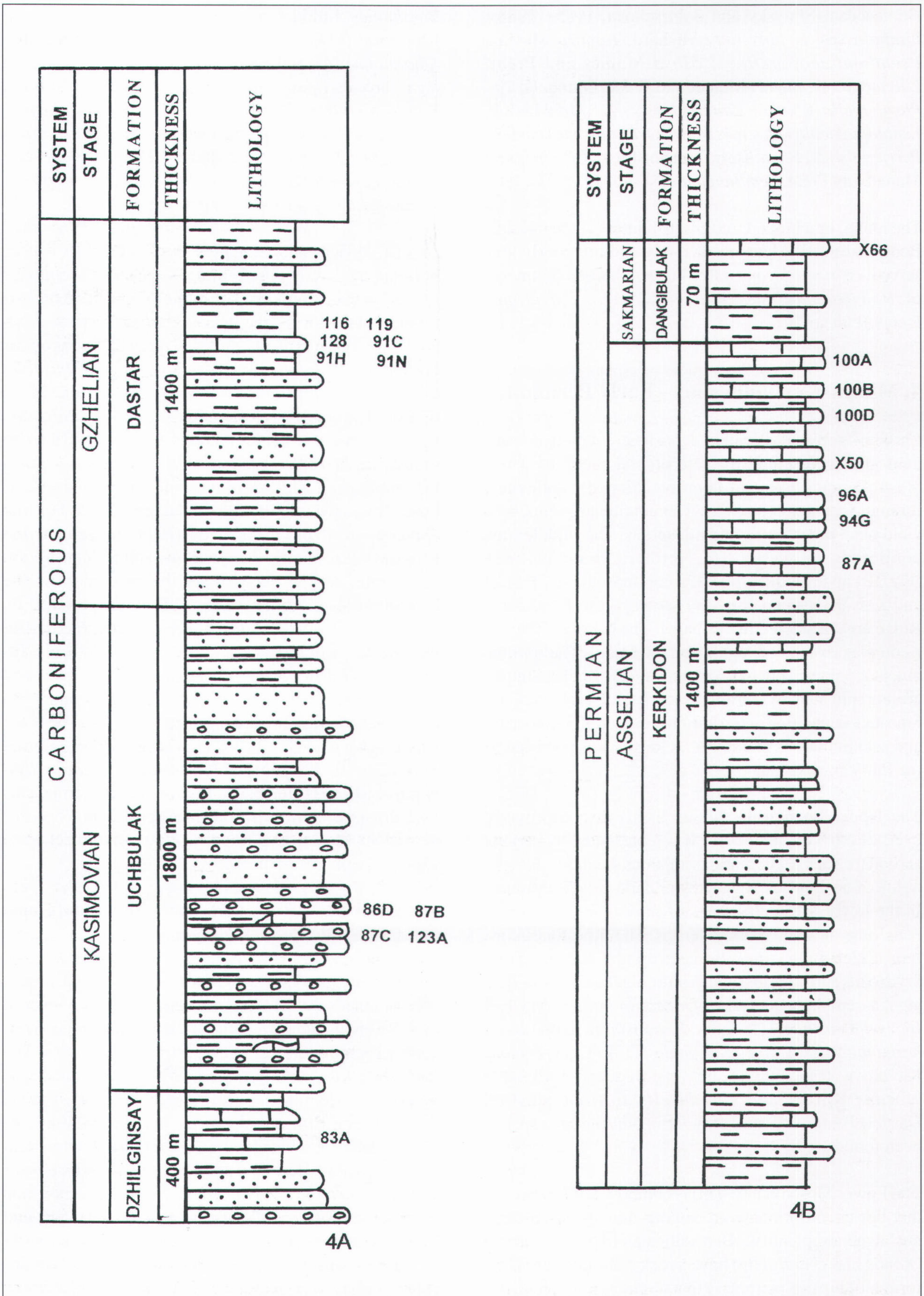

Figure 4. Stratigraphic sections: A. Karachatyr Ridge, Upper Carboniferous; B. Karachatyr Ridge, Lower Permian.

D. distorta Kulik, *D. (Trinodella?) bifurcata* Maslov and Kulik. Red algae occur rarely (*Komia abundans* Kordé, *Fourstonella ?johnsoni* (Flügel). *Claracrusta catenoides* (Homann) forms small oncoids associated with crusts of *Richella incrustata* Mamet and Roux. Large branched forms of *Anthracoporella spectabilis* Pia and thick encrustations of *Tubiphytes obscurus* Maslov often occur together and form small bioherms up to 3-5 m in length and up to 1,0-1,5 m in thickness. They are clearly identified in the sequence as restricted lenses of dark-grey clayey limestones among siltstones or thin-layered limestones.

Two formations are distinguished in the Kasimovian. The Dzhiginsay Formation (*Protriticites pseudomontiparus - Obsoletes obsoletus* zone, about 400 m) is composed in the lower part of terrigenous rocks, conglomerates and sandstones. In the upper part it consists chiefly of siltstones with lenses and intercalations of sandstones and clayey fossiliferous limestones. Recrystallized phylloid algae predominate. They form mass accumulations of large unbroken and unsorted plates that occur in dark-grey pelletoidal clayey limestones.

The Uchbulak Formation (*Montiparus montiparus*, *Rauserites quasiarcticus -R. acutus zones*, 1800 m thick) is represented by coarse terrigenous rocks. Fossils are confined to the limestone beds that occur amidst siltstones, sandstones and conglomerates as interlayers, nodules and lenses. The limestones contain algae, which are often rock building, fusulinids, brachiopods, gastropods, and less frequently corals and bryozoans. The algofloristic assemblage chiefly includes dasycladaceans. The most numerous are representatives of the Gyroporelleae, a tribe that achieved its maximum development during the Permian and Triassic (Granier and Deloffre, 1995). Abundant *Gyroporella likana* Kochansky-Devidé, *G. intraseptata* Kochansky-Devidé, *G. prisca* Kochansky-Devidé, *'Pseudoepimastopora' pertunda* Endo are restricted to the formation. Algae with wider stratigraphic ranges include *Gyroporella constricta* Kochansky-Devidé, *G. clavata* TChuvashov, *G. dissecta* Chuvashov, numerous *Anthracoporella spectabilis* Pia, *'Epimastoporella'(?) crassitheca* (Chuvashov and Anfimov), *Connexia fragilis* Kochansky-Devidé, *Herakella paradoxa* Kochansky-Devidé, rare *Anthracoporellopsis* sp., common *Anchicodium funile*(?) Johnson, *Anchicodium japonicum*(?) Endo, *Eugonophyllum johnsoni* Konishi and Wray, *E. mulderi* Racz, *Ivanovia tenuissima* Khvorova, and less common *Neoanchicodium catenoides* Endo. Beresellids are represented by rare *Dvinella (Trinodella?) bifurcata* Maslov and Kulik and *Beresella polyramosa* Kulik. The abundance of *Richella incrustata* Mamet and Roux should be noted. Together with *Claracrusta catenoides* (Homann), they form massive crustose accumulations.

The Gzhelian stage corresponds to the Dastar Formation where three fusulinid zones have been established (*Triticites rossicus - Rauserites stuckenbergi*; *Jigulites turanicus - Daixina asiatica, Pseudofusulina ferganensis*). This formation is composed of terrigenous deposits: siltstones and sandstones (1300-1400 m) with lenses and beds of fossiliferous limestones. In the Dastar mountain, at the base of the *Pseudofusulina ferganensis* Zone, these limestones thicken up and form the Dastar bioherm (with a maximum thickness of 70 m). Its base consists of dark-grey clayey fossiliferous limestones grading into light-grey and pink-grey algal detrital limestones. Algae are very abundant and diverse. Dasycladales are represented by numerous *'Atractyliopsis'*(?) *carnica* Flügel, less frequent *Pseudogyroporella mizziaformis* Endo, *P. tobensis* (Mu), *Gyroporella intusannulata* Kochansky-Devidé, *'Velebitella' simplex* Kochansky-Devidé, *Epimastoporella alpina* (Kochansky and Herak), *E. piae* (Bilgütay), *E. likana* (Kochansky and Herak), *E. seleukensis* (Kulik), *E. japonica* (Endo), *Epimastopora rolloensis* (Racz), and *Paraepimastopora kansasensis* (Johnson). Derived from the Uchbulak Formation *Connexia fragilis* Kochansky-Devidé, *'Epimastoporella' crassitheca(?)* (Chuvashov and Anfimov) together with other dasyclads have rock-building significance. The characteristic *Mizzia minuta* Johnson and Dorr, *M. cornuta* Kochansky and Herak and *M. bramkampi* Rezak first appear. Common phylloids have been found: *Ivanovia tenuissima* Khvorova, *Anchicodium plumosum* (?) Johnson, *Eugonophyllum johnsonii* Konishi and Wray and *E. mulderi* Racz. Rhodophytes are represented by a single *Fourstonella ? johnsoni* (Flügel). *Incertae sedis* occur sporadically growing on broken debris: *Tubiphytes obscurus* Maslov, *Claracrusta catenoides* (Homann). Rare *Nostocites vesiculosa* Maslov have been found.

Upwards lie deposits of the Asselian stage recognized as the Kerkidon Formation, where three fusulinid zones have been established (*Occidentoschwagerina alpina - Licharevites paranitidus* Zone, *Schwagerina moelleri - Pseudofusulina fecunda* Zone, *Schwagerina glomerosa* Zone). The lower part of the formation consists of terrigenous rocks with intercalations of limestones. The upper part of the unit is composed of carbonate rocks. These limestones are thick- or medium-bedded, detrital and contain diverse fauna, represented by fusulinids, brachiopods, gastropods, corals, crinoids, algae. Asselian algae are very abundant. Recrystallized phylloid algae (*Eugonophyllum* sp., *Ivanovia* sp., *Anchicodium* sp.) were significant components of the biostromes. They have better preservation in detrital limestones: *Eugonophyllum johnsoni* Konishi and Wray, *E. mulderi* Racz, *Neoanchicodium catenoides* Endo. Among the dasyclads are diverse epimastoporids: *Epimastoporella japonica* (Endo), *E.alpina* Kochansky and Herak, *E. flugeli* (Kulik), *E. piae* (Bilgütay), *E.*(?) *rolloensis* Racz, *'Epimasto-*

porella' (?) *crassitheca* Chuvashov and Anfimov, *Paraepimastopora kansasensis* (Johnson). *Mizzia* and *Gyroporella* : *Mizzia yabei* (?) Karpinsky, *M. pseudocornuta* (?) Kulik, *M. cornuta* Kochansky and Herak, *Pseudogyroporella mizziaformis* Endo, *Gyroporella nipponica* Endo, *'Atractyliopsis'* (?) *carnica* Flügel. *Pseudovermiporella nipponica* (Endo), *Vermiporella* (?) *hispanica* Racz, *Anthracoporella vicina* Kochansky-Devidé, and *'Eokoninckopora' einori* Saltovskaya make a first appearence. The traditional problematica *Claracrusta catenoides* (Homann) and *Tubiphytes obscurus* Maslov together with *Anthracoporella spectabilis* Pia form small bioherms (thickness 0,5-1,0 m, length up to 3-5 m). Numerous *Ramovsia limes* Kochansky-Devidé and *Ellesmerella permica* (Pia) are also notable.

5. Stratigraphy and paleogeography

It would be tempting to use Paleozoic algae for stratigraphic zonation. However this approach is quite deceiving (Roux, 1985) as most are difficult to classify, and are long ranging and facies sensitive (consult for instance Calcareous Algae and Stromatolites edited by Robert Riding, 1991, or Studies of Fossil Benthic Algae, edited by Filippo Barattolo *et al.*, 1993).

Some dasycladales from the Permian are somewhat more restricted in time (Granier and Deloffre, 1995, Granier and Grgasovic, 2000) but older taxa (Devonian to Carboniferous, in particular the beresellids) are deceiving. As for udoteaceans and rhodophyta, they can characterize systems, but not stages. In the Paleozoic, it is this very long life-span and very slow evolutionary rate that permits establishment of valid comparisons between ecologies separated by long intervals of geological time.

As Roux noted (1991b), the Ordovician is characterized by 'the appearance and diversification of filamentous codiaceans and erect udoteaceans'. The Uzbek flora contains the *Vermiporella-Palaeoporella-Dimorphosiphon* trilogy that Roux (1991a, fig.4) correlated with the Ordovician equatorial belt.

The Devonian udoteaceans of Uzbekistan are dominated by the Litanaiae-Lanciculae. The flora is identical to that of similar age from central Urals (Ivanova and Bogush, 1992 ; Chuvashov *et al.*, 1993).

In the Carboniferous and basal Permian, the microflora is typically Tethyan (Mamet, 1991, 1992) with a mixture of abundant cosmopolitan and Tethyan endemic species. The *Uraloporella* flora which is one of the rare and privileged links between the Tethyan and Arctic flora is well represented.

One of the main interest of the Uzbek flora is an excellent representation of the Kasimovian-Gzhelian interval. This flora is known only from a few localities and in particular from the rather ancient but significant contribution of Kochansky-Devidé in Slovenia-Croatia (see for instance Kochansky-Devidé, 1970) and the more recent contribution of Vachard and Krainer (2001).

6. Conclusions

Although uncomplete in time, the Uzbek flora is quite representative of different warm water Paleozoic assemblages. As elsewhere in the Paleotethys, it indicates a slow decline of the poorly calcified udoteaceans, progressively replaced by calcified dasycladales, that will dominate the chlorophytes in Permian time.

7. Acknowledgements

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For each figure we give the location number (Uzbek Institute of Geology, or Mamet collections), magnification, geographic location, number of ULB. collection, and age.

PLATE 1

Late Ordovician - Early Silurian algal microflora

1-2. *Dimorphosiphon rectangulare* Hoeg, 1927
1) Uzbek I.G. SH1-A3/1, x 20, Zeravshan Ridge, Shachriomon Mt. Pass, ULB 968/8, Upper Ordovician, Shachriomon Formation. Axial oblique section, showing terminations of laterals.
2) Uzbek I.G. SH1-A3/1, x 20, same as fig.1, ULB 968/7.

3-4. *Dimorphosiphon magnum* Gnilovskaya, 1972
3) Uzbek I.G. SH2-A2, x 20, same as fig.1, ULB 968/13-14, oblique longitudinal section.
4) Uzbek I.G. SH2-A2, x 20, same as fig.1, ULB 968/15-16, axial section.

5. *Vermiporella* cf. *V.borealis* Hoeg, 1932
Uzbek I.G. SH1-A3/1, x 20, same as fig.1, ULB 968/1.

6-9. *Rhabdoporella pachyderma* Rothpletz, 1913
6) Uzbek I.G. SH1-A2, x 80, same as fig.1, ULB 969/9, axial section.
7) Uzbek I.G. SH1-A2, x 80, same as fig.1, ULB 969/10, oblique section
8) Uzbek I.G. SH1-A2/1, x 65, same as fig.1, ULB 969/10, longitudinal section.
9) Uzbek I.G. SH1-A2, x 80, same as fig.1,ULB 969/8, axial section.

10. *Anticostiporella vaurealensis* Mamet and Roux, 1992
Uzbek I.G. SH1-M2, x 20, Zeravshan Ridge, Shachriomon Mt. Pass, ULB 967/27, Early Silurian, Shachriomon Formation, Minkuchar Beds, axial section.

11. *Girvanella problematica* Nicholson and Etheridge, 1878
Uzbek I.G. SH1-M8, x 65, same as fig.10, ULB 967/35.

12. *Vermiporella* cf. *V. fragilis* Stolley, 1893
Uzbek I.G. SH1-M4, x 20, same as fig.10, ULB 967/32.

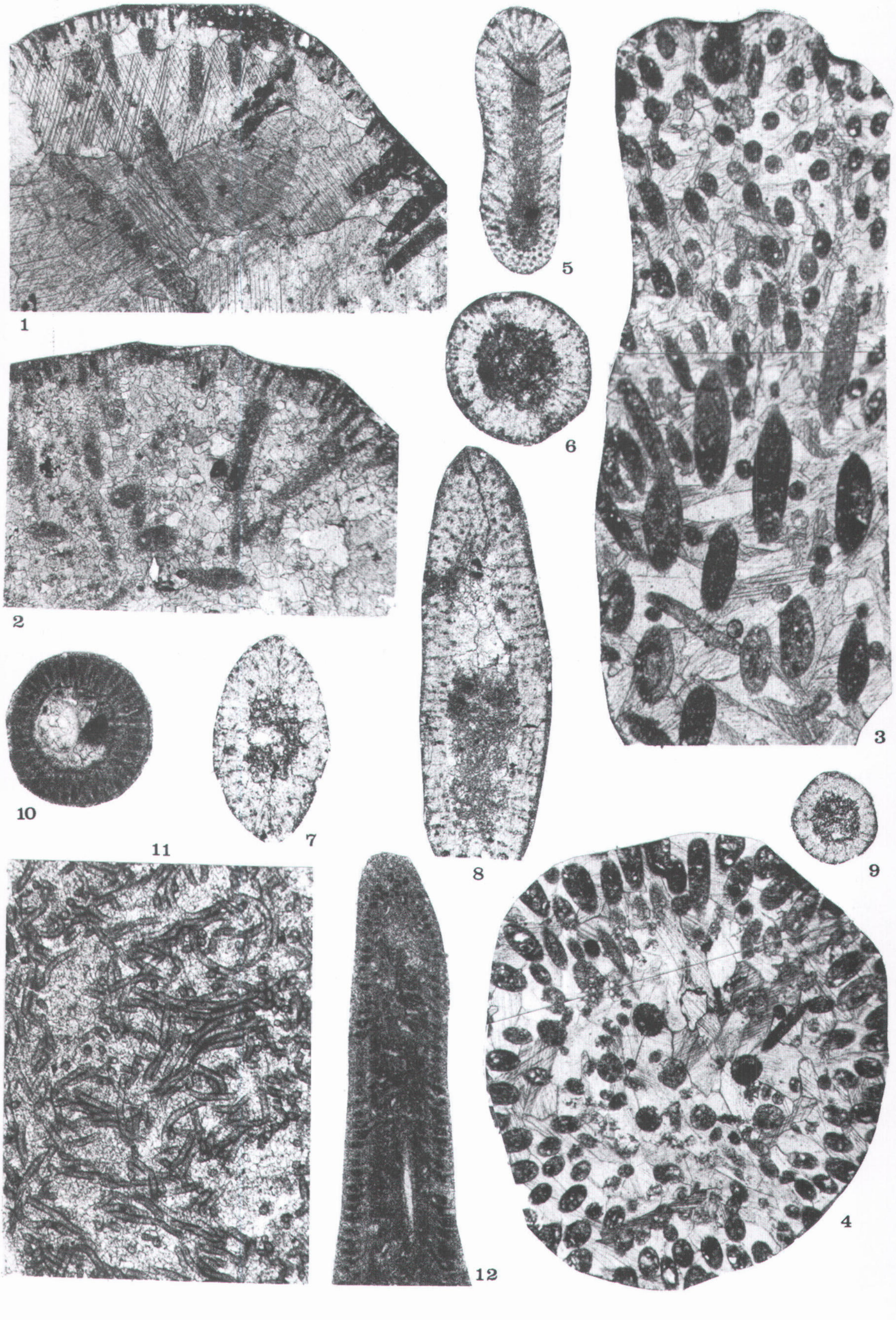
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PLATE 2

Early Devonian algal microflora

1. *Lepidolancicula kakvensis* Shuysky, 1985
   Uzbek I.G. HN 4/5, x 20, Zeravshan Ridge, Kitab, ULB 967/24, Emsian, Khodzhakurgan Formation, longitudinal section.
2. *Lepidolancicula valeriae* (Pantic, 1973)
   Uzbek I.G. ZN 17/16, x 20, ULB 967/10, same as fig. 1.

3-4. *Issinella grandis* Chuvashov, 1965
   3) Uzbek I.G. ZN 17/8, x 50, ULB 967/21, same as fig. 1, axial section, referred as *Luteotubulus.*
   4) Uzbek I.G. ZN 17/8, x 50, , ULB 967/18, same as fig. 1

5. *Litanaia mira* Maslov, 1956
   Uzbek I.G. ZN 17/14, x 20, ULB 967/12, same as fig. 1, longitudinal section.
6. *Perrierella* sp.
   Uzbek I.G. ZN 17/11, x 20, ULB 967/16, same as fig. 1, longitudinal section.
7. *Hedstroemia halimedoidea* Rothpletz, 1913
   Uzbek I.G. HM 50-150, x 20, ULB 969/1, Pragian, Madmon Formation.
8. *Sphaerocodium gotlandicum* Rothpletz, 1908 *emend* Wood, 1948
   Uzbek I.G. ZN 17/15, x 50, ULB 967/15, same as fig. 1.

Carboniferous beresellid microflora

9. *Dvinella (Trinodella?) bifurcata* Maslov, 1956
   Uzbek I.G. 497/220, x 50, Nuratau Ridge, Michin Syncline, ULB 963/5, Lower Moscovian, Koitash Formation, with triangular shape of the ´dark bands'

10-12. *Beresella ishimica* Kulik, 1964
   10) Uzbek I.G. 497/220, x 50, same as fig. 9, ULB 963/17 with characterictic tear shape of ´white bands'
   11) Uzbek I.G. 497/94, x 50, Nuratau Ridge, Shakhtau, ULB 968/32, Lower Moscovian, Koitash Formation.
   12) Uzbek I.G. 497/94, x 50, same as fig. 11, ULB 968/31

13-14. *Beresella* of the group *B.polyramosa* Kulik, 1964
   13) Mamet 81G, x 19, Karachatyr, ULB 197/20, Upper Moscovian, Shunkmazar Formation.
   14) Mamet 81H, x 19, same as fig.13, ULB 197/24.

15. *Dvinella comata* Khvorova, 1949
   Mamet 81H, x 16, same as fig.13, ULB 197/22.
16. *Donezella lutugini* Maslov, 1929
   Uzbek I.G. 496/50, x 50, Nuratau Ridge, Kyskolysay, ULB 963/21, Bashkirian, Narvan Formation. Numerous species of *Donezella* have been proposed on the thallus dimensions, but the taxon is irregularly branching and they all belong to the same species.

17-18. *Beresella translucea* Kulik, 1964
   17) Uzbek I.G. 497/97, x 20, Nuratau Ridge, Shakhtau, ULB 968/35, Lower Moscovian, Koitash Formation.
   18) Uzbek I.G. 497/97, x 20, same as fig.17, ULB 963/33, note the diaphragmes.

19. *Uraloporella variabilis* Kordé, 1950
   Uzbek I.G. 497/98, x 20, same as fig.17, ULB 963/34. The genus is also referred to *Samarella*. Compare with Saltovskaya 1984, pl. XII, fig. 1-10, and pl.XIII, fig. 1-11, with traces of probable parietal conceptacles.

20-21. *Beresella erecta* Maslov and Kulik, 1956
   20) Mamet 81B, x 39, same as fig.13, ULB 197/14.
   21) Uzbek I.G. 149, x 20, Karachatyr, ULB 967/4, Upper Moscovian, Shunkmazar Formation.

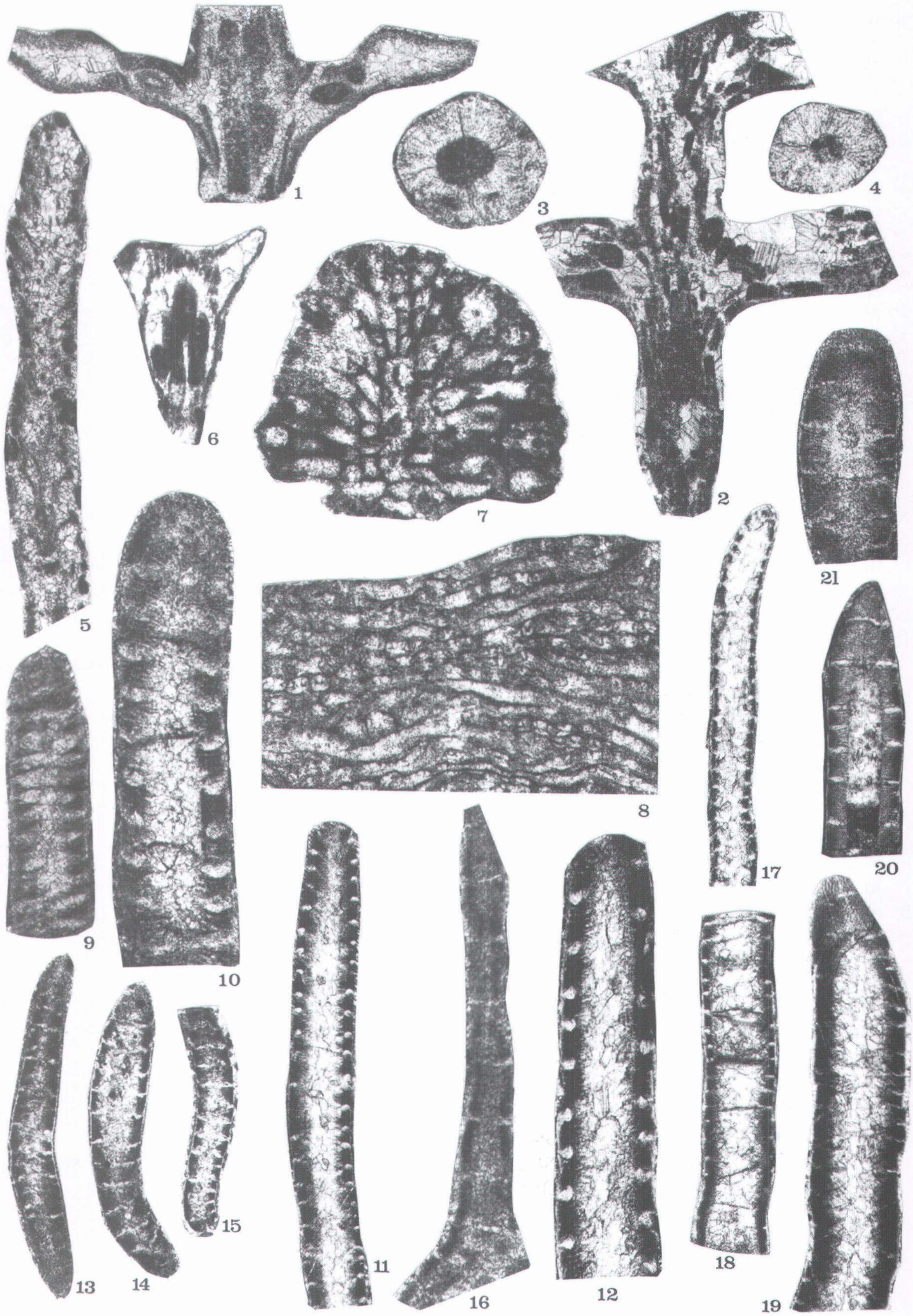
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PLATE 3

Carboniferous - Early Permian epimastoporid

1-4. *Epimastoporella alpina* (Kochansky and Herak, 1960)
1) Mamet 91N, x 39, Karachatyr, ULB 201/8, Gzhelian, Dastar Formation.
2) Uzbek I.G. 116, x 16, Karachatyr, ULB 965/9, Gzhelian, Dastar Formation.
3) Uzbek I.G. 116, x 16, Karachatyr, ULB 965/9, same as fig. 2.
4) Uzbek I.G. 119, x 16, Karachatyr, ULB 965/15, same as fig. 2.

5-7. *Epimastoporella japonica* (Endo, 1951)
5) Mamet 100B, x 19, Karachatyr, ULB 203/9, Asselian, Kerkidon Formation.
6) Mamet 100A, x 19, ULB 203/9bis same as fig. 5.
7) Mamet 100A, x 19, ULB 203/9ter same as fig. 5.

8. *Paraepimastopora kansasensis* (Johnson, 1946)
Uzbek I.G. 87A, x 20, Karachatyr, ULB 965/34, Asselian, Kerkidon Formation.

9. *Epimastoporella (?) rolloensis* (Racz, 1966)
Mamet 100D, x 16, ULB 203/17 same as fig. 5.

10. *Epimastoporella likana* (Kochansky and Herak, 1960)
Uzbek I.G. 116, x 20, Karachatyr, ULB 965/12, Gzhelian, Dastar Formation.

11. *'Epimastoporella' crassitheca* (Chuvashov and Anfimov, 1988)
Mamet 83A, x 19, Karachatyr, ULB 198/10, Kasimovian, Dzhilginsay Formation.

Diverse dasycladales

12-13. *Atractyliopsis weyanti* Mamet and Roux, 1979
12) Uzbek I.G. 150, x 20, Karachatyr, ULB 966/36, Upper Moscovian, Shunkmazar Formation, oblique section.
13) Uzbek I.G. 150, x 20, Karachatyr, ULB 966/35, same as fig. 12, axial section.

14-15. *Clavaporella reinae* Racz, 1966
14) Uzbek I.G. M8080, x 20, Karachatyr, ULB 963/35, Upper Moscovian, Shunkmazar Formation, axial section.
15) Uzbek I.G. M8080, x 20, same as fig. 14, ULB 964/0, oblique section.

16-18. *Connexia fragilis* Kochansky-Devidé, 1970
16) Mamet 87B, x 16, Karachatyr, ULB 198/24, Kasimovian, Uchbulak Formation.
17) Uzbek I.G. 156, x 50, Karachatyr, ULB 964/20, Kasimovian, Uchbulak Formation.
18) Mamet 87B, x 16, same as fig. 16, ULB 198/28.

19. *Anthracoporellopsis* sp.
Mamet 86D, x 39 Karachatyr, ULB 198/20, Kasimovian, Uchbulak Formation.

20. *Macroporella ginkeli* Racz, 1966
Mamet 79K, x 16, Karachatyr, ULB 197/11, Moscovian, Akterek Formation, longitudinal section.

21,28. *Anthracoporella vicina* Kochansky and Herak, 1960
21) Mamet 100A, x 16, Karachatyr, ULB 202/26, Asselian, Kerkidon Formation, oblique section.
28) Mamet 100A, x 16, same as fig. 21, ULB 202/28.

22-23. *'Velebitella' simplex* Kochansky-Devidé, 1964
22) Mamet 91H, x 39, Karachatyr, ULB 201/6, Gzhelian, Dastar Formation, axial section.
23) Mamet 91N, x39, same as fig. 22, ULB 201/10, longitudinal section.

24. *Anthracoporella spectabilis* Pia, 1920
Uzbek I.G. 128, x 20, Karachatyr, ULB 965/21, Upper Gzhelian, Dastar Formation.

25-27. *Herakella paradoxa* Kochansky-Devidé, 1970
25) Mamet 78A, x 19, Karachatyr, ULB 196/4, Moscovian, Akterek Formation, axial section.
26) Mamet 86D, x 19, Karachatyr, ULB 198/22, Kasimovian, Uchbulak Formation, longitudinal section.
27)) Mamet 78A, x 19, same as fig. 25, ULB 196/1, longitudinal section.

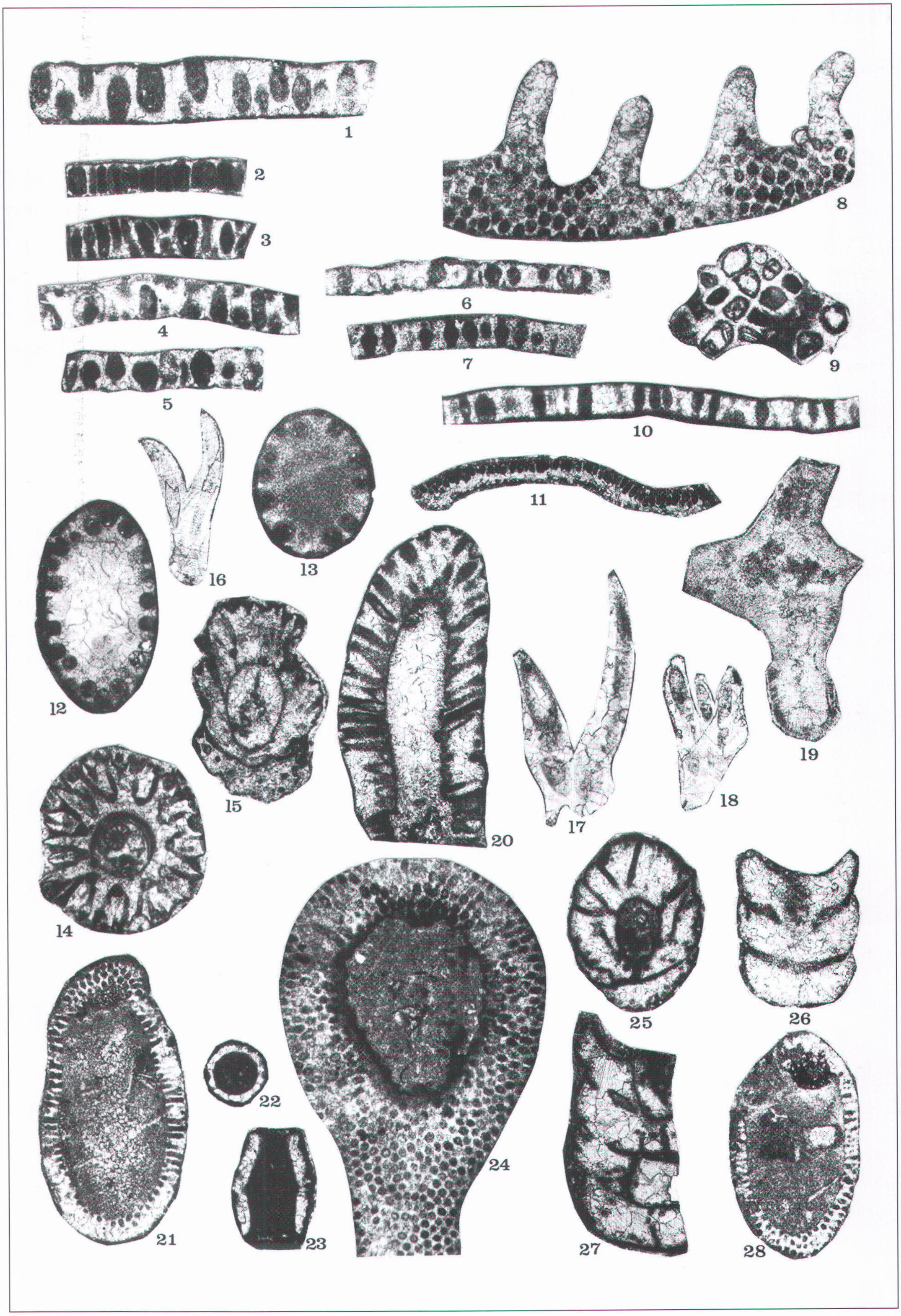
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PLATE 4

Gyroporellid dasycladales

1. *Gyroporella intraseptata* Kochansky-Devidé, 1970
Uzbek I.G. X-156, x 20, Karachatyr, ULB 964/28, Kasimovian, Uchbulak Formation, longitudinal section.

2-3. *Pseudogyroporella mizziaformis* Endo, 1951
2) Uzbek I.G. 87A, x 20, Karachatyr, ULB 966/6, Asselian, Kerkidon Formation, oblique section.
3) Uzbek I.G. 87A, x 20, same as fig.2, ULB 965/36, axial section. The taxon is often referred as *Mizzia yabei* auct non Karpinsky.

4. *'Atractyliopsis'* (?) *carnica* Flügel, 1966
Uzbek I.G. 128, x 20, Karachatyr, ULB 965/30, Upper Gzhelian, Dastar Formation, longitudinal section. The species is intermediate between an *Atractyliopsis*, a *Gyroporella* and a *Mizzia.*

5. *Gyroporella likana* Kochansky-Devidé, 1964
Uzbek I.G. X-156, x 20, Karachatyr, ULB 964/33+34, Kasimovian, Uchbulak Formation. The slender longitudinal section is reminiscent of *Gyroporella longithalla* Endo, 1961, but differs by the shape of the pores.

6. *Gyroporella pertunda* (Endo, 1960)
Uzbek I.G. X-156, x 20, same as fig.1, ULB 964/6, oblique longitudinal section.

7. *Gyroporella intusannulata* Kochansky-Devidé, 1970
Mamet 89E, x 16, Karachatyr, ULB 200/15, Gzhelian, Dastar Formation, longitudinal section.

Phylloid algae

8. *Anchicodium* sp.
Uzbek I.G. X-156, x 20, same as fig.1, ULB 964/12.

9. *Ivanovia tenuissima* Khvorova, 1946
Mamet 86D, x 39, Karachatyr, ULB 198/12, Kasimovian, Uchbulak Formation. Section along plate.

10. *Eugonophyllum johnsonii* Konishi and Wray, 1961 covered by *Ellesmerella* sp.
Uzbek I.G. X-66, x 20, Karachatyr, ULB 966/20, Sakmarian, Kerkidon Formation. Section along a plate.

11. *Eugonophyllum mulderi* Racz, 1966
Mamet 100B, x 19, Karachatyr, ULB 203/7, Asselian, Kerkidon Formation. Section along a plate.

12. *Eugonophyllum magnum* (Endo, 1951)
Uzbek I.G. X-147, x 20, Karachatyr, ULB 966/29, Upper Moscovian, Shunkmazar Formation. Curved plate.

13. *Neoanchicodium catenoides* Endo *in* Endo and Kanuma, 1954
Mamet 87C, x 39, Karachatyr, ULB 199/25, Kasimovian, Uchbulak Formation. Transverse section.

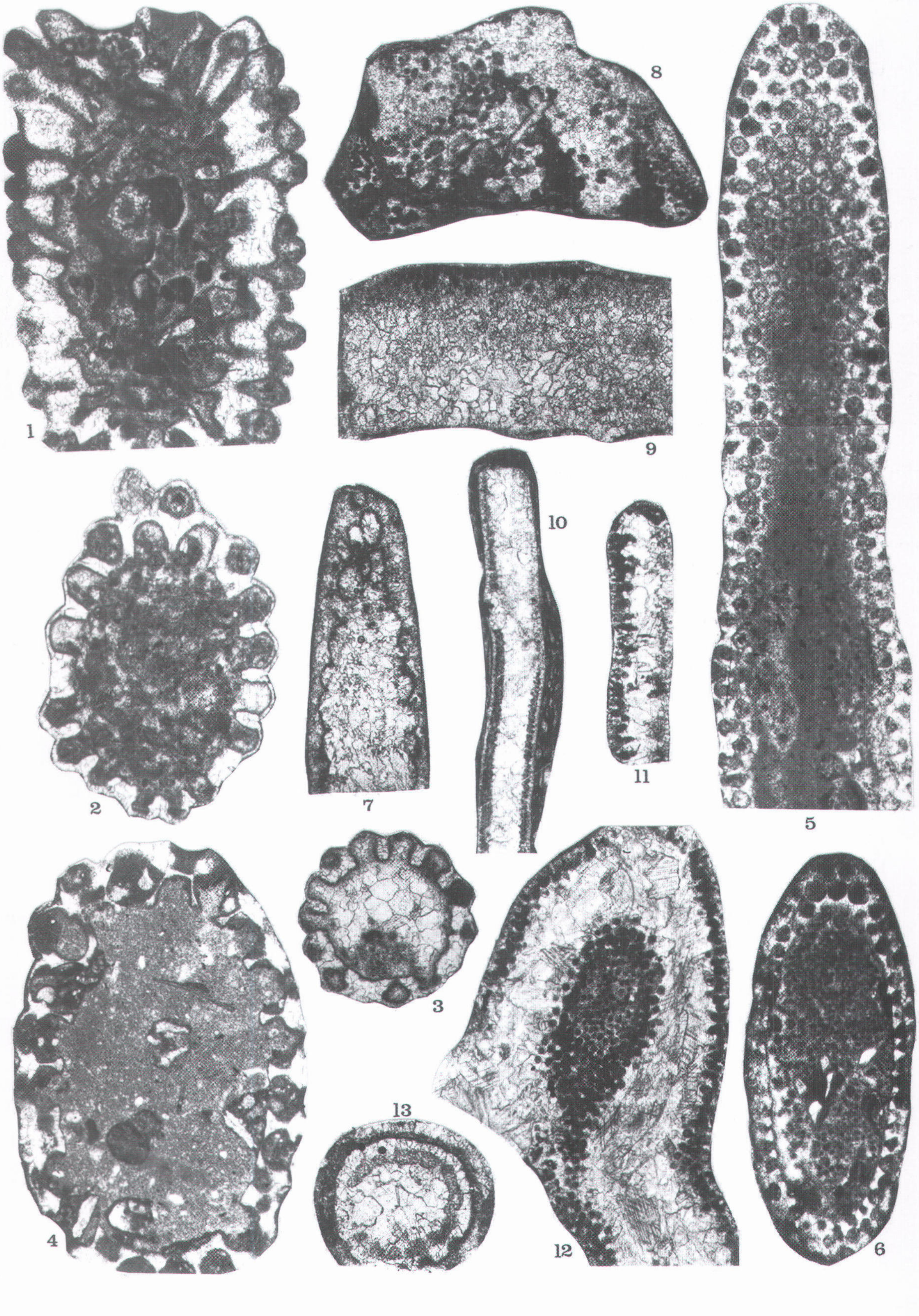
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PLATE 5

Middle Carboniferous - Early Permian red algae

1. *Komia abundans* Kordé, 1951
   Uzbek I.G. 498/15, x 20, Nuratau Ridge, ULB 963/32, Lower Moscovian, Koitash Formation. A red algal boundstone.
2. *Petschoria* sp.
   Uzbek I.G. 496/50, x 20, Nuratau Ridge, Kyskolysay, ULB 963/32, Bashkirian, Narvan Formation, longitudinal section.
3. *Pseudokomia tenuicrustata* (Shuysky, 1973).
   Uzbek I.G. 497/220, x 51, Nuratau Ridge, Michin Syncline, ULB 963/0, Lower Moscovian, Koitash Formation, longitudinal section.
4. *Fourstonella (?) johnsoni* (Flügel, 1966)
   Uzbek I.G. 123 A, x 20, Karachatyr, ULB 964/4, Kasimovian, Uchbulak Formation. There is no concensus on the relations between *Fourstonella*, *Eflugelia* and *Cuneiphycus* that have been proposed for *johnsoni.*
5. *Ungdarellina peratrovichensis* (Mamet and Rudloff, 1972).
   Mamet 79H, x 16, Karachatyr, ULB 196/27, Upper Moscovian, Akterek Formation. Shows the characteristic succession of encrustations.

6-7. *Ungdarella uralica* Maslov, 1956
6) Uzbek I.G. 497/103, x 51, Nuratau Ridge, Shakhtau, ULB 963/26, Lower Moscovian, Koitash Formation. The extraordinary preservation of the thallus, clearly shows the succession of subquadratic cells.
7) Uzbek I.G. 497/103, x 51, same as preceding 6, ULB 963/28, axial section.

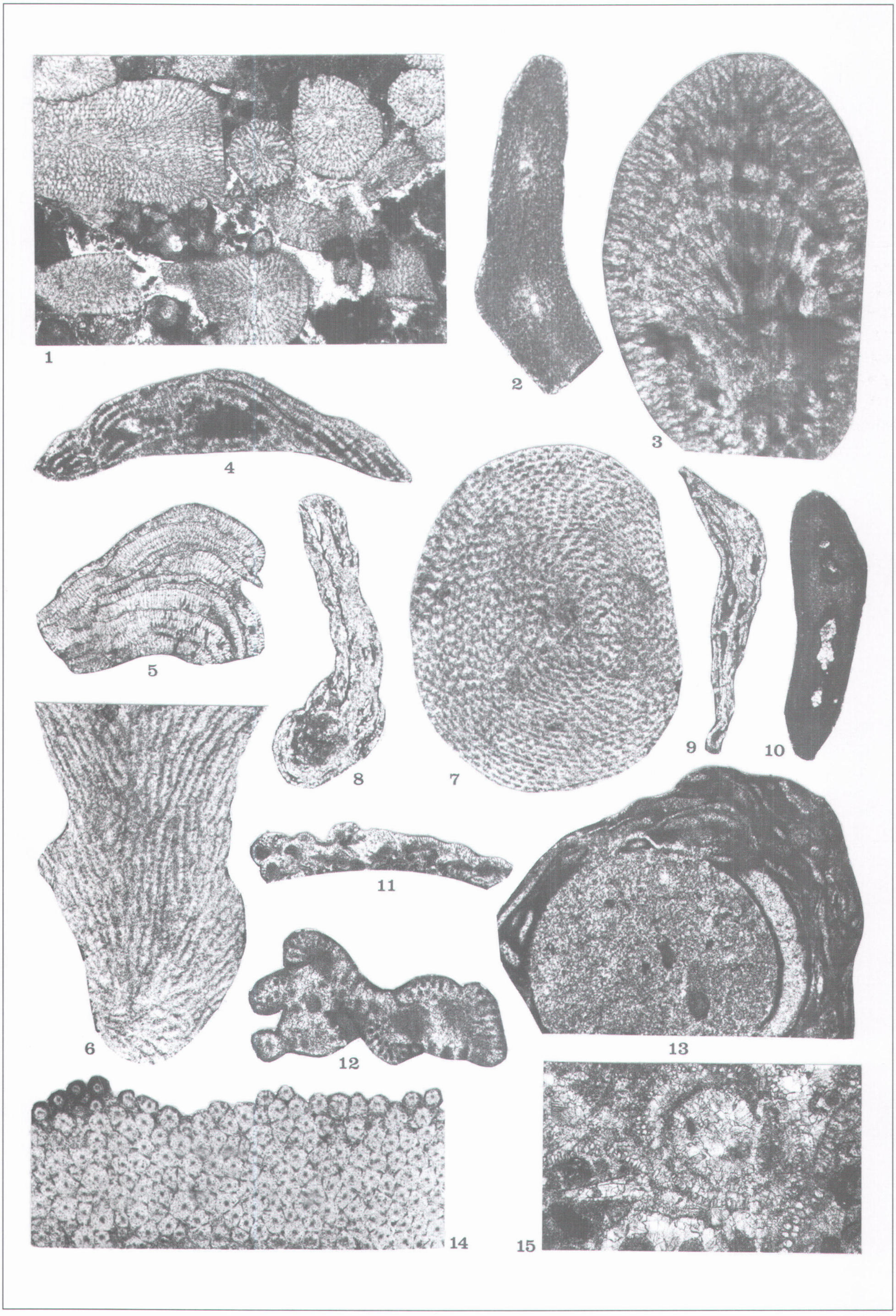
Incertae sedis and problematica

8-9 *Claracrusta catenoides* (Homann, 1972)
8) Mamet 96A, x 25, Karachatyr, ULB 201/30, Asselian, Kerkidon Formation.
9) Mamet 78I, x 20, Karachatyr, ULB 196/18, Upper Moscovian, Akterek Formation. Both figures show the characteristic rows of encrustations.

10. *Tubiphytes obscurus* Maslov, 1956
    Mamet 94G, x 25, Karachatyr, ULB 201/71, Asselian, Kerkidon Formation. The cosmopolitan and widespread genus has been attributed to various organisms, but its nature remains controversial.

11-12. *Richella incrustata* Mamet and Roux, 1987
11) Uzbek I.G.X-156, x 20, Karachatyr, ULB 964/24, Kasimovian, Uchbulak Formation
12) Mamet 79H, x 34, same as fig.5, ULB 196/28.

13. *Ellesmerella permica* (Pia, 1937) encrusting *Ramovsia limes* Kochansky-Devidé, 1973
    Uzbek I.G. X-50, x 51, Karachatyr, ULB 966/10, Asselian, Kerkidon Formation.
14. *Nostocites vesiculosa* Maslov, 1929
    Uzbek I.G. 116, x 51, Karachatyr, ULB 965/4, Upper Gzhelian, Dastar Formation. The taxon is often confused in literature with the Mesozoic *Globochaetete*.
15. *'Eokoninckopora' einori* Saltovskaya, 1984
    Mamet 91C, x 16, Karachatyr, ULB 200/28, Gzhelian, Dastar Formation. Reported by Saltovskaya from the Tournaisian of Tadzikistan, it is probably not to be attributed to the algae.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