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Stratigraphy of Mesozoic (Upper Triassic–Lower Cretaceous) Volcanogenic-Sedimentary Deposits of the Dhiarizos Group, the Allochthonous Mamonia Complex of Cyprus

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Abstract—Data on the studied radiolarians from cherty rocks are used to distinguish stratigraphic subdivisions of diverse volcanogenic rocks in the Dhiarizos Group of the allochthonous Mamonia Complex, in Southwest Cyprus. The results obtained confirm the Triassic–Early Cretaceous age of a basalt-chert-carbonate succession corresponding to the Phasoula Formation and first define the Early Jurassic age of basalt–diabase breccias in the Loutra tis Aphroditis Formation. The results represent new basis for deciphering the Mesozoic geological history of Cyprus and East Mediterranean.

Key words: Cyprus, ophiolites, allochthon, stratigraphy, volcanics, Mesozoic, Triassic, Jurassic, Cretaceous, radiolarians, melange, olistostrome.

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INTRODUCTION

The allochthonous Mamonia Complex of Southwest Cyprus is a valuable source of information about the geological history and evolution of the Tethyan basin in the Mesozoic. That complex includes a diverse sedimentary (Agios Photios Group) and volcanogenic-sedimentary (Dhiarizos Group) rocks of the Triassic, Jurassic, and Cretaceous. The rocks have been formed on the southern passive margin of the Tethys in different settings varying from the continental slope to the basin floor, including the volcanic rises on the latter (Lapierre, 1975; Robertson and Woodcock, 1979; Swarbrick, 1980; Kaz'min et al., 1987; Robertson, 1990; Sharaskin et al., 1995). The elaboration of the detailed stratigraphy of the allochthonous Mamonia Complex is an important prerequisite for deciphering geological events and sedimentation settings in the respective oceanic paleobasin and for understanding its evolution. Unfortunately, sedimentary rocks of the Mamonia Complex are either lacking or extremely poor in macrofossils or micropaleontological remains (foraminifers), traditionally used in stratigraphy. Radiolarians represent the only group of microfossils widespread in rocks of the complex.

Until the present time, the study of radiolarians has been used to elaborate in detail the stratigraphic chart of the Agios Photios Group, which is entirely composed of the Upper Triassic, Middle–Upper Jurassic, Lower Cretaceous, and Cenomanian–Turonian sediments, classed with deposits of the continental slope and its rise (Bragin and Krylov, 1996, 1999; Bragin et al., 2000). This work is dedicated to the results of stratigraphic research, concerning the Dhiarizos Group, composed predominantly of basic volcanic, enclosing interlayers and other bodies of different sedimentary rocks. The work is based on materials collected during my field observations in Cyprus in 1990, 1998, 2003, and 2007.

COMPOSITION, DISTRIBUTION, AND STRUCTURAL POSITION OF THE DHIARIZOS GROUP

The diverse basic volcanics of the Dhiarizos Group are represented by phyric to aphyric pillow lavas and lava breccias, pierced by subvolcanic diabase bodies. The volcanic rocks are intercalated with sedimentary deposits, occurring as inclusions and lenses of limestones, limestone and radiolarian chert interlayers, or members of sedimentary breccias composed of clasts of basic volcanics, amphibolites, and gabbroids. According to peculiarities of lithologic composition, the Dhiarizos Group is divided into the Phasoula, Loutra tis Aphroditis, and Petra tou Romiou formations.

The Phasoula Formation corresponds to a thick (up to 200 m) sequence of paleotypal pillow lavas with thin interlayers of micritic limestones and radiolarian cherts, concentrated predominantly in the upper part of the sequence (Robertson and Woodcock, 1979; Swarbrick and Robertson, 1980). Rocks of the formation are widespread, and their outcrops are dispersed

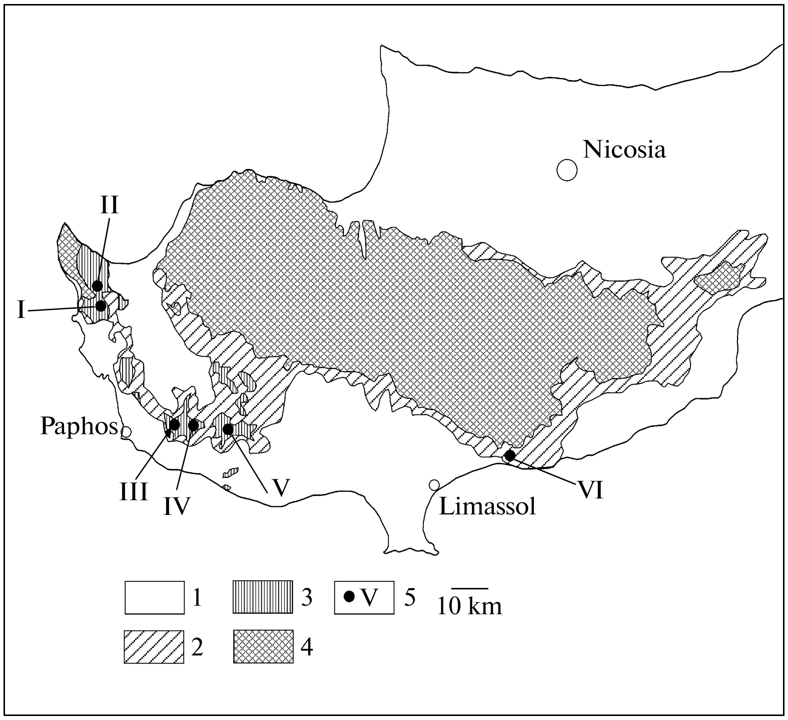


Fig. 1. Schematic geological structure of southern Cyprus: (1) Quaternary and Neogene deposits; (2) Upper Cretaceous and Paleogene deposits; (3) Triassic–Cretaceous rocks of the Mamonia Complex; (4) Troodos Complex of ophiolites; (5) localities of the studied sections numbered in the figure: (I) Lara Bay, (II) Akamas peninsula, (III) Ezousa River, (IV) Nea Kholetria, (V) Phasoula, (VI) Parekklisia.

throughout the distribution area of the Mamonia Complex. They are exposed on the Akamas Peninsula and in the Mavrokolymbos, Ezousa, and Dhiarizos river basins (Fig. 1). Beyond the Mamonia Complex, blocks of volcanics belonging to the Phasoula Formation are known within the distribution area of the Moni Olistostrome in southern Cyprus (Robertson and Woodcock, 1979; Urquhart and Robertson, 2000; Fig. 1).

A thick (not less than 100 m) sequence of the Loutra tis Aphroditis Formation is composed of sedimentary breccias with clasts of basic volcanics, amphibolites, and gabbro. The breccia bodies are intercalated with underformed members of basic volcanics and thin interlayers of micritic limestones and radiolarian cherts. Rocks of the formation are exposed in the stratotype area along the northern coast of the Akamas Peninsula (Robertson and Woodcock, 1979), being traceable from here toward the peninsula central part (Fig. 1).

The Petra tou Romiou Formation is represented by basic lavas, enclosing bodies of shallow-water reefal limestones with colonial corals (Robertson and Woodcock, 1979). It is difficult to estimate the thickness of the formation, since its rocks occur only as blocks in the polymictic melange with a volcano-terrigenous matrix (Krylov et al., 2005a). Outside the stratotype area, limestones of the formation occur also as separate blocks at the Loutra tis Aphroditis locality (Fig. 1).

All three formations are separated by tectonic boundaries, and facies transitions between their rocks are not preserved. It is possible therefore to consider only general structural position of the Dhiarizos Group in the allochthonous Mamonia Complex, which represents a system of tectonic sheets thrust over the Troodos ophiolites (Fig. 1), formed in the initial Late Cretaceous (Robertson and Woodcock, 1979; Blome and Irwin, 1985; Bragina and Bragin, 1996). Bragin and Krylov (1999) studied in detail the internal structure of the Mamonia Complex in the Ezousa River basin (Fig. 2), where a packet of thrust sheets is dislocated by a system of faults striking in the sublatitudinal and northwestern directions. At the lower structural level, there is a melange with a terrigenous matrix, cementing blocks of different rocks derived from the Mamonia and Troodos complexes. This melange is overridden by a series of allochthonous tectonic sheets. From the base upward, the imbricated sheets are of the following composition (Fig. 2):

(1) A serpentinite melange with blocks of lavas derived from the Troodos Complex;

(2) Metamorphic rocks of the Agia Varvara Group: amphibolites and quartz-mica schists;

(3) A serpentinite melange with blocks of rocks derived from the Mamonia and Troodos complexes;

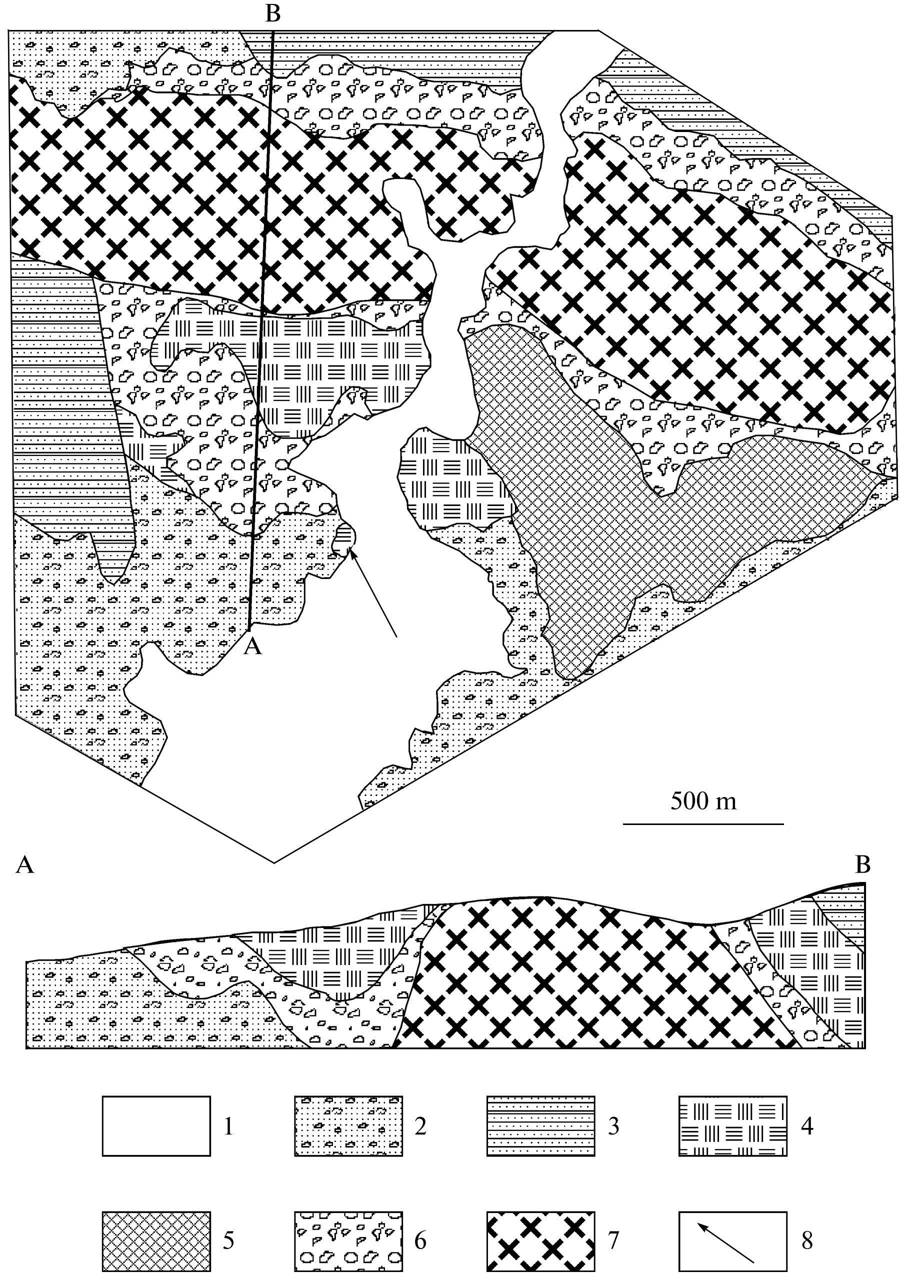


Fig. 2. Geological structure of the Mamonia Complex in the Ezousa River basin (Bragin and Krylov, 1999): (1) Quaternary deposits; (2) terrigenous melange of the Late Cretaceous age; (3) the Agios Photios Group of the Triassic–Cretaceous; (4) the Dhiarizos Group of the Triassic–Cretaceous; (5) metamorphic rocks of the Agia Varvara Group; (6) serpentinite melange; (7) basalts of the Troodos Complex; (8) locality of limestone block with Triassic radiolarians.

(4) Volcanogenic-sedimentary rocks of the Dhiarizos Group: basalts, diabases, subordinate limestones, and jaspers;

(5) Sedimentary rocks of the Agios Photios Group: cherts, jaspers, argillites, aleurolites, sandstones, marls, and limestones.

SUBDIVISION AND CORRELATION OF ROCKS FROM THE DHIARIZOS GROUP

Phasoula Formation

The most complete stratigraphic succession of the Phasoula Formation is observable on the Akamas Pen-

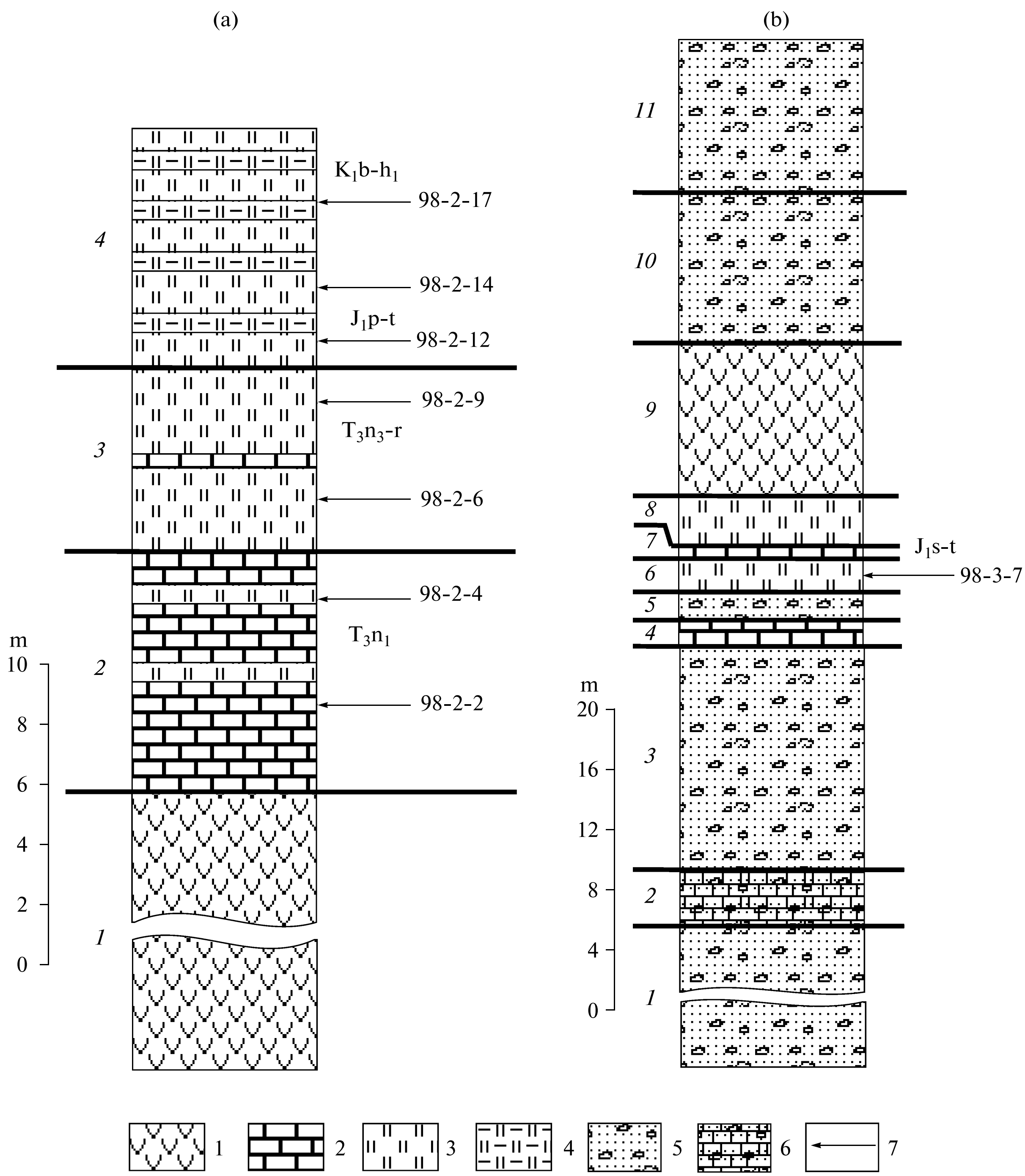


Fig. 3. Principal sections of the Dhiarizos Group: (a) the Phasoula Formation section illustrating structure of volcanogenic-cherty sequence in the Akamas Peninsula and (b) section of volcanogenic-sedimentary deposits of the Loutra tis Aphroditis Formation in the Akamas Peninsula: (*1*) basic volcanics; (*2*) limestone; (*3*) chert and jasper; (*4*) cherty shale; (*5*) breccia composed of ophiolitic clasts; (*6*) ophicalcite; (*7*) occurrence levels of radiolarians. Bed numbers are designated to the left of columns; geologic indices and sample numbers to the right.

insula, 3 km to the east-northeast of Lara Bay (Bragin et al., 2005; Bragin, 2007); coordinates 34°57′59.5″ N, 32°20′16.5″ E.

The following rock units are exposed here from the base upward (Figs. 1, 3):

(1) Basalts, brown to greenish brown, sometimes preserving a pillow structure and subjected to intense cataclasis. Apparent thickness 50–100 m.

(2) Limestones, white, flaggy, intensively marmorized, enclosing interlayers of pink micritic limestone

and red jasper with radiolarians of the lower Norian (samples 98-2-2, 98-2-4). The identified radiolarian species are *Betraccium irregulare* Bragin, *Braginastrum curvatus* Tekin, *Capnodoce anapetes* De Wever, *C. crystallina* Pessagno, *Capnuchosphaera deweveri* Kozur et Mostler, *C. theloides* De Wever, *C. triassica* De Wever, *C. tricornis* De Wever, *Carinaheliosoma carinata* (Kozur et Mostler), *Deflandrecyrtium curvatum* Kozur et Mostler, *Dicapnuchosphaera carterae* Tekin, *Haeckelicyrtium carterae* Bragin, *Icrioma cruciformis* Tekin, *Kahlerosphaera norica* Kozur et Mock, *K. aspinosa* Kozur et Mock, *K. kemerensis adentata* Tekin, *Kinyrosphaera trispinosa* Bragin, *K. helicata* Bragin, *Liassosaturnalis parvus* Kozur et Mostler, *Monocapnuchosphaera inflata* Tekin, *Mostlericyrtium sitepesiformis* Tekin, *Palaeosaturnalis latiannulatus* Kozur et Mostler, *P. triassicus* Kozur et Mostler, *Palaeosaturnalis karnicus* (Kozur et Mostler), *P. raridenticulatus* Kozur et Mock, *Poulpus transitus* Kozur et Mostler, *Sanfilippoella lengeranlii* Tekin, *Sarla vizcainoensis* Pessagno, *Spongotortilispinus tortilis* (Kozur et Mostler), *S. carnicus* (Kozur et Mostler), *Trialatus robustus levantinensis* Bragin, *Veghicyclia haeckeli* Kozur et Mostler, *Xiphothecaella rugosa* (Bragin), *Zhamojdasphaera proceruspinosa* Lahm, and others. Thickness 8 m.

(3) Jasper, red, thin-flaggy, insignificantly clayey, almost lacking argillite interlayers but enclosing rare interlayers of pink and gray micritic limestones; the rocks (samples 98-2-6, 98-2-9) yield radiolarians of the upper Norian–Rhaetian: *Livarella densiporata* Kozur et Mostler, *L. longa* Yoshida, *L. inflata* Yeh, *Pentactinocarpus sevaticus* Kozur et Mostler, and others. Thickness 5–7 m.

(4) Jasper, red, thin-flaggy, clayey, with frequent interlayers of red-brown cherty shale and rare interlayers of greenish gray chert. Radiolarians found in lower part of the member (samples 98-2-12, 98-2-14) are represented by the Early Jurassic (presumably Pliensbachian–Toarcian) species *Bipedis* sp. cf. , *B. yaoi* Hori, *Canoptum* sp. cf. *C. anulatum* Pessagno et Poisson, *Elodium* sp., *Hsuum* sp. cf. *H. matsuokai* Isozaki et Matsuda, *Katroma clara* Yeh, *Lantus* sp. cf. *L. obesus* (Yeh), *Parahsuum simplum* Yao, *P.* sp. cf. *P. longiconicum* Sashida, *P. izeense* (Pessagno et Whalen), and *Praeconocaryomma bajahensis* Whalen. The upper part of the member (sample 98-2-17) yielded radiolarians of the Lower Cretaceous: *Archaeodictyomitra tumandae* Dumitrica, *A. vulgaris* Pessagno, *Cryptamphorella conara* (Foreman), *Podocapsa amphitreptera* Foreman, *Wrangellium puga* (Schaaf), and *Zhamoidellum* sp. cf. *Z. testatum* Jud. The joint occurrence of *Wrangellium puga, Archaeodictyomitra tumandae* and *Cryptamphorella conara* suggests the Berriasian–early Hauterivian age of the assemblage. Apparent thickness 7–10 m.

Hence, a thick sequence of volcanic rocks is overlain in the section under consideration by comparatively thin carbonate-siliceous deposits, which form a very condensed succession, lacking a meaningful stratigraphic interval of the Middle–Upper Jurassic. The hiatus is confined to the upper siliceous part of the succession. In the other areas, the Phasoula Formation is dislocated to a greater extent, and the stratigraphic succession of its rocks can hardly be reconstructed in such cases. Nevertheless, representative assemblages of microfossils found in many outcrops add some details to the general stratigraphic trend.

In the Dhiarizos River basin 1 to 1.5 km eastward of the Kholetria village (Fig. 1), there are remarkable outcrops of basic pillow lavas with numerous small inclusions of sedimentary material between the pillows. These inclusions of pink, sometimes greenish gray limestones are enriched in volcaniclastic material and contain separate valves and clasts of bivalve shells with very thin walls (presumably immature *Halobia*) in addition to abundant recrystallized radiolarians. The conodont species *Epigondolella spatulata* (Hayashi) and *E. abneptis* (Huckriede) found in the same rocks are of the Norian age. The thickness of the exposed lavas can be greater than 100 m.

Directly northward of the Mamonia village (Fig. 1), a thick (100–200 m) sequence of pillow lava is exposed, the stratotype of the Phasoula Formation (Swarbrick and Robertson, 1980). The sequence includes thin interlayers of red clayey jasper bearing conodonts *Epigondolella abneptis* (Huckriede) and *Pseudozarkodina tortilis* (Tatge), which suggest the upper Carnian–Norian interval of the host deposits.

In an excavation adjacent to the Nea Kholetria–Staurokono road (Fig. 1), highly altered volcanics with intercalations of deformed thin-flaggy jasper colored red are observable (Sharaskin et al., 1995; Bragin et al., 2005). The jasper intercalations bear the Bajocian–early Oxfordian radiolarian species *Acanthocircus suboblongus* (Yao), *Archaeodictyomitra* sp. cf. *A. rigida* Pessagno, *Guexella nudata* (Kocher), *Hsuum brevicostatum* Ozvoldova, *H. maxwelli* Pessagno, *Mirifusus* sp. cf. *M. guadalupensis* Pessagno, *Protunuma ochiensis* Matsuoka, and *Tricolocapsa* sp. cf. *T. parvipora* Tan. The assemblage age is defined, based on the distribution range of *Guexella nudata*, because the other species are of wider stratigraphic ranges.

Finally, 1.5 km to the north-northeast of the village of Agia Varvara, in the Ezousa River basin (Figs. 1, 2), there are outcrops of highly altered volcanic rocks with numerous interlayers and lentils of white massive marmorized limestones and pink to red thick-flaggy jaspers (Sharaskin et al., 1995; Bragin et al., 2005). The jasper interlayers contain the following radiolarian species of the Lower Cretaceous: *Alievium helenae* Schaaf, *Archaeodictyomitra apiara* (Rüst), *A. excellens*

(Tan), *Cecrops septemporatus* (Parona), *Pantanellium squinaboli* (Tan), *Podocapsa amphitreptera* Foreman, *Xitus alievi* (Foreman), *Tethysetta boesii* (Parona), and *Wrangellium puga* (Schaaf). The coexistence of *Cecrops septemporatus* and *Podocapsa amphitreptera* suggests that the assemblage age can be defined as corresponding to the late Valanginian–early Hauterivian (Baumgartner et al., 1995).

In addition to bedrock outcrops, the rocks of the Phasoula Formation occur as rootless blocks in the melange and olistostrome bodies. In the Ezousa River basin, for instance, a large block of micritic limestones set into terrigenous melange, which occupies the lower structural position in the system of allochthonous sheets of the Mamonia Complex, was studied (Fig. 2). The micritic limestones of that block bear an assemblage of very diverse radiolarians and conodonts of the lower Norian (Bragin and Krylov, 1999; Bragin, 2007). These limestones are very pure, deprived of a terrigenous admixture and differ in composition and older age from the upper Norian micrites, occurring in the middle part of the Vlamburos Formation and enriched in terrigenous material (Bragin and Krylov, 1996). The fragment of sedimentary succession observable in the block is composed of the following rocks:

(1) Limestone, white, thick-flaggy to massive, with interlayers of gray chert. Apparent thickness 1.5 m.

(2) Limestone, pink, thick-flaggy. Thickness 1.5 m.

(3) Limestone, greenish gray, flaggy, cherty. Thickness 1 m.

(4) Limestone, pink, massive. Radiolarian species discovered from the bed top are *Annulotriassocampe* sp. cf. *A. sulovensis* (Kozur et Mock), *Archaeocenosphaera* sp., *Bulbocyrtium latum* Bragin, *Caphtorocyrtium tenerum* Bragin, *Capnodoce ruesti* Kozur et Mock, *Capnuchosphaera deweveri* Kozur et Mostler, *C.* sp. cf. *C. deweveri* Kozur et Mostler, *C. theloides minor* Bragin, *C.* sp. cf. *C. theloides* De Wever, *C.* sp. aff. *C. carpathica* Kozur et Mock, Capnuchosphaeridae gen. et sp. indet., *Carinaheliosoma carinata* (Kozur et Mostler), *Bientactinosphaera* sp. aff. *B. simoni* (Kozur et Mostler), *B.* (?) sp. 1, *B. (?)* sp. 2, *Ferresium* sp. aff. *F. conclusum* Carter, *Foremanellina (?)* sp., *Haeckelicyrtium carterae* Bragin, *Heliosoma (?) riedeli* Kozur et Mostler, *H. (?)* sp., *Icrioma tetrancistrum* De Wever, *I.* sp. aff. *I. tetrancistrum* De Wever, *Kahlerosphaera aspinosa* Kozur et Mock, *K. norica* Kozur et Mostler, *Karnospongella bispinosa* Kozur et Mostler, *Kinyrosphaera trispinosa* Bragin, *K. helicata* Bragin, *K. (?)* sp., *Laxtorum (?)* sp., *Liassosaturnalis parvus* Kozur et Mostler, *Loffa (?)* sp., *Mostlericyrtium striata* Tekin, *Multimonilis pulcher* Yeh, *Nabolella trispinosa* Bragin, *Napora (?)* sp. 1, *N.* sp. 2, *Neopylentonema* sp. aff. *N. procera* Sugiyama, *Palaeosaturnalis triassicus* (Kozur et Mostler), *P. latiannulatus* Kozur et Mostler, *P. mocki* Kozur et Mostler, *Papiliocampe tokerae* Tekin, *Paronaella norica* Kozur et Mock, *P.* sp., *Pentactinocarpus* sp. aff. *P. tetracanthus* Dumitrica, *P.* sp., *Praemesosaturnalis* sp. cf. *P. multidentatus* (Kozur et Mostler), *Pentaspongodiscus* sp. 1, *P.* sp. 2, *Poulpus piabyx* De Wever, *Pseudosaturniforma carnica* Kozur et Mostler, *Praenanina veghae* Kozur, *Praeorbiculiformella goestlingensis* Kozur et Mostler, *Pseudostylosphaera (?)* sp., *Sarla transita* (Kozur et Mock), *S. (?)* sp., *Senelella spinellifera* (Bragin), *Sepsagon* sp., *Sethocapsa* sp., *Spongotortilispinus carnicus* (Kozur et Mostler), *S. tortilis* (Kozur et Mostler), *Sulovella constricta* Kozur et Mock, *Syringocapsa batodes* De Wever, *S.* sp., *Trialatus robustus* (Nakaseko et Nishimura), *Triassobipedis* (?) sp., *Triassocrucella triassica* (Kozur et Mostler), *Veghicyclia* sp. cf. *V. robusta* Kozur et Mostler, *Whalenella* sp. aff. *W. perfecta* (Blome), *W. robusta* Bragin, *Xiphothecaella rugosa* (Bragin), *X. longa* (Kozur et Mock), *X.* sp., and *Zhamojdasphaera proceruspinosa* Lahm. Radiolarians occur in association with the early Norian conodonts *Epigondolella spatulata* (Hayashi). Thickness 2 m.

(5) Chert, pink, flaggy. Thickness 0.5 m.

(6) Limestone, white to pink, massive. Apparent thickness 4 m.

On the extreme south of Cyprus, northward and northeastward of Limassol, large blocks of the Phasoula Formation rocks are components of the Moni Olistostrome attributed to the Campanian–Maastrichtian (Robertson and Woodcock, 1979). One of the blocks exposed southward of the Parekklisia village (Fig. 1) and confined to the lower part of the olistostrome body (Bragin, 2007) is 1.5 km long. The reddish brown and greenish, highly altered volcanics of the block are not less than 100 m thick and contain thin (1–2 m) lenses of white, light gray, and pink micritic limestones with thin interlayers of gray and pink chert. Species *Capnodoce sarisa* De Wever, *Capnuchosphaera concava* De Wever, *C. silviesensis* Blome, *C. triassica* De Wever, *Loffa mulleri* Pessagno, *Nabolella trispinosa* Bragin, *Podobursa yazgani* Tekin, *Praexehasaturnalis tenuispinosus* (Donofrio et Mostler), *Spongotortilispinus carnicus* (Kozur et Mostler), and *Xiphothecaella longa* (Kozur et Mostler) represent radiolarians of the middle Norian, found in the chert interlayers.

According to the obtained results, the Phasoula Formation spans the stratigraphic interval from the Upper Triassic (upper Carnian–lower Norian) to the Lower Cretaceous inclusively, which is consistent with earlier inferences (Robertson and Woodcock, 1979; Swarbrick and Robertson, 1980). The Phasoula Formation almost corresponds in range to the Agios Photios Group, although its section includes the Lower Jurassic deposits, missing from the section of the Agios Photios Group, due to the regional break in sedimentation (Bragin and Krylov, 1996, 1999). Sedimentary rocks do not occur everywhere in the upper part of the formation section, as it was suggested earlier (Swarbrick and Robertson, 1980). They are confined to different levels of the volcanogenic sequence, which includes the Triassic and younger (Jurassic and Cretaceous) volcanic rocks. Only two lithologic types represent the sedimentary rocks of the formation. These are the micritic limestones, deprived of terrigenous admixture and radiolarian cherts, which accumulated very slowly in periods of the cessation of volcanic activity. The most representative stratigraphic succession of micrites and cherts preserved in the Lara Bay section is most likely incomplete and includes cryptic hiatuses hardly detectable in such a condensed section.

Loutra tis Aphroditis Formation

Along the northern coast of the Akamas Peninsula, which is the stratotype area of the Loutra tis Aphroditis Formation (Fig. 1), a west-to-east succession of tectonic sheets composed of the following rocks is observable:

(1) Metamorphic rocks of the Agia Varvara Complex: black-green amphibolites, gray calcite-mica schists after carbonate-clay sediments, and red and pink quartzites after radiolarian cherts.

(2) Volcanic rocks and breccias of the Loutra tis Aphroditis Formation: pillow lavas intercalated with breccia members that are composed of diabase, basalt, and amphibolite clasts. Volcanic rocks enclose rare interlayers and thin members of bright red clayey chert. Outcrops of these intensively dislocated rocks extend over a distance of over a 100 m.

(3) Terrigenous melange with blocks of red jasper and gray calcarenite of the Jurassic–Cretaceous age. The blocks are comparable in lithology with the Jurassic–Cretaceous sedimentary members of the Episkopi Formation from the Agios Photios Group (Mamonia Complex).

Fossils appropriate for dating the above rocks have not been discovered yet in the stratotype area. Significant dynamometamorphism of the formation rocks in that area dismiss the chance to discover radiolarians here in a satisfactory preservation state. Researchers suggested earlier the comparatively young Cretaceous age of the Loutra tis Aphroditis Formation (Swarbrick and Robertson, 1980). This is inconsistent however with data obtained by tracing the lateral continuation of the formation outcrops.

On the Akamas Peninsula, there is a large tectonic window, where the exposed rocks of the Troodos ophiolite association are overridden by a system of thrust sheets of the allochthonous Mamonia Complex. In the central part of the peninsula, 4 km to the northeast of Lara Bay (Fig. 1), right in the area of the window periclinal closure (coordinates 35°00′11.2″ N, 32°20′40.5″ E), two tectonic slices are thrust over the terrigenous lange, occupying the lower structural position in the system of thrust sheets. The lower slice is composed of volcanogenic rocks of the Dhiarizos Group; the upper one of sedimentary deposits of the Agios Photios Group. Among rocks of the Dhiarizos Group, there are recognizable breccias and volcanics of the Loutra tis Aphroditis Formation. In the submeridional chain of outcrops, characterizing the basal interval of the allochthonous Mamonia Complex (Bragin et al., 2005), the following succession of rock units is established there (Fig. 3):

(1) Green, greenish brown and red breccias composed of prevailing coarse clasts (5 to 20 cm across) of basalts and diabase and also of subordinate gabbroid clasts. Apparent thickness 100 m.

(2) Pink to gray and greenish gray ophicalcite with clasts of basic volcanics and serpentinized gabbroids. Thickness 4 m.

(3) Breccias similar to those of Bed 1 but composed of clasts smaller in size (3 to 10 cm across), among which there are hyaloclastites. Thickness 15 m.

(4) Pink thin-bedded micritic limestone. Thickness 2 m.

(5) Breccias identical to those of Bed 1. Thickness 1–3 m.

(6) Dark red to brown thin-flaggy jasper with radiolarians of the Lower Jurassic (most likely of the Sinemurian–Toarcian; sample 98-3-7): *Bipedis japonicus* Hori, *Broctus* sp., *Canoptum* sp., *Crucella* sp. cf. *C. jadeae* Carter et Dumitrica, *Gorgansium* sp. aff. *G. gongyloideum* Kishida et Hisada, *Katroma elongata* Carter, *K. ninstintsi* Carter, *K. hocakoeyensis* Tekin, *Parahsuum simplum* Yao, *P.* sp. cf. *P. viscainoense* Whalen et Carter, *Paronaella* sp. cf. *P. notabilis* Whalen et Carter, *P.* sp. cf. *P. snowshoensis* (Yeh), *Praeconocaryomma bajahensis* Whalen, *Trexus* sp., and *Triactoma* sp. Thickness 2–4 m.

(7) Pink micritic limestone. Thickness 1 m.

(8) Jasper comparable with that of Bed 6. Thickness 4 m.

(9) Green pillow lavas of basaltic composition. Thickness 10 m.

(10) Breccias with interlayers of white to pink micrites and red jasper. Thickness 10 m.

(11) Breccias with solitary blocks (up to 1 m across) of gray fine-grained polymictic sandstone. Apparent thickness 10 m.

Most widespread in the succession are dark-colored unsorted breccias, composed predominantly (over 90%) of angular basaltic and diabase clasts (from 0.5 to 30–40 cm across), variable in composition and of subordinate gabbroid, serpentinite, hyaloclastite, and sandstone clasts. Rock clasts are cemented by a matrix of low volume, which contains decomposed volcanic glass and small clasts of mineral crystals, chert, and carbonates.

Ophicalcite with a light gray to pink matrix of microcrystalline calcite cementing diabase and basaltic clasts occur in small lenses, having sedimentary relations with breccias hosting them. The other sedimentary rocks are thin-bedded micritic limestones with stylolites and dark-colored laminated radiolarian cherts. At the top and base of these sedimentary interlayers and lenses, there are thin laminae of cherty argillites, containing small (up to 0.5 cm across) clasts of volcanics.

In contrast to the Phasoula Formation, the rock succession described above is of narrow (Lower Jurassic) stratigraphic range. Breccias of the Loutra tis Aphroditis Formation accumulated quickly on steep submarine slopes. Micritic limestones and radiolarian cherts accumulated in periods, when avalanche sedimentation on slopes ceased. Clasts of gabbroids and sandstones are most remarkable components of the described breccias. The gabbroid clasts certainly prove that in Cyprus there are preCretaceous ophiolites, representing part of the allochthonous Mamonia Complex and relics of the respectively old oceanic crust (Krylov et al., 2005b). The sandstone clasts are close in composition to the terrigenous rocks of the Triassic Vlamburos Formation, a subdivision of the Agios Photios Group. If this is the case, then the appearance of sandstone clasts in breccias could be associated with the large hiatus recorded at the boundary, separating the Upper Triassic Vlamburos Formation from the overlying Episkopi Formation of the Middle Jurassic–Cretaceous rocks, when the Triassic terrigenous sediments were subjected to partial scouring (Bragin and Krylov, 1996, 1999).

Petra tou Romiou Formation

In the stratotype area extending along southwestern coast of Cyprus (Fig. 1), this formation is composed of basic volcanic, intercalated with size-variable bodies of shallow-water reefal limestones. In coastal outcrops of that area, a polymictic melange of intricate structure is exposed (Krylov et al., 2005a). The melange matrix, consisting of crushed volcanics and ground aleuritic clay, fills in the interstices between clasts of solid rocks of variable size (from a few centimeters to dozens of meters across) and composition. Clasts of basic volcanics (basalts and diabases) occur most frequently, and some of them contain inclusions of shallow-water coralline limestones or small lenses and thin interlayers of micritic limestones and cherts bearing the Early Triassic conodonts. White to light gray massive marmorized limestones of the shallow-water type, with relict organogenic structures, also occur in the form of large isolated blocks. In addition, abundant small inclusions in the melange correspond in composition to the Jurassic and Cretaceous radiolarian cherts, calcarenites, and sandstones, comparable with the same rocks of the Middle Jurassic–Cretaceous Episkopi Formation. Consequently, the melange body under consideration originated in response to the disintegration of different rocks, characteristic of the allochthonous Mamonia Complex.

Rocks that can be attributed to the Petra tou Romiou Formation proper are only the Upper Triassic limestones of shallow-water origin and associated basic volcanics. The other volcanics intercalated with micritic limestones and cherts belong most likely to the Phasoula Formation. As there is no section that retains primary relations between the rocks, it is possible to characterize the Petra tou Romiou Formation in a tentative manner only. The original sequence that yielded blocks of the formation occurring in the melange was likely composed of basic volcanics with thick (dozens of meters) limestone members. The total sequence of thickness could make up the first hundreds of meters. The position of limestones in the sequence could be variable, and they could crown the volcanic rocks or occur inside the latter as interlayers or intercalations. It is clear nevertheless that the sequence was of the Late Triassic age.

STRATIGRAPHIC SUBDIVISIONS OF THE DHIARIZOS GROUP AND CHARACTERISTIC RADIOLARIAN ASSEMBLAGES

Hence, the Dhiarizos Group includes the Phasoula, Loutra tis Aphroditis, and Petra tou Romiou formations that are considerably different in composition and stratigraphic ranges. The great stratigraphic interval of the Phasoula Formation extends from the Upper Triassic to the Lower Cretaceous inclusively, whereas the ranges of the Loutra tis Aphroditis and Petra tou Romiou formations are constrained by the Lower Jurassic and Upper Triassic respectively. Based on radiolarians, it is possible to subdivide in detail only the Phasoula and Loutra tis Aphroditis formations that frequently contain these microfossils represented by diverse assemblages.

Conodonts *Epigondolella abneptis* (Huckriede) and *Pseudozarkodina tortilis* (Tatge) have been found at the lowermost stratigraphic position: in interlayers and interstices between basaltic pillow lavas of the Phasoula Formation below the appearance level of members, composed of limestones and radiolarian cherts. These conodont species suggest the upper Carnian–Norian interval for their host deposits. The oldest *Capnodoce crystallina–Trialatus robustus* radiolarian assemblage (Bragin, 2007) is identified at the base of the pelitomorphic limestone member sampled in the Phasoula Formation section of the Akamas Peninsula. The

Plate I. Triassic radiolarians from the Dhiarizos Group (Cyprus):

(1) *Carinaheliosoma carinata* (Kozur et Mostler); (2) *Kahlerosphaera aspinosa* Kozur et Mock; (3) *Kahlerosphaera norica* Kozur et Mock; (4) *Kahlerosphaera kemerensis adentata* Tekin; (5) *Kinyrosphaera helicata* Bragin; (6) *Capnuchosphaera theloides theloides* De Wever; (7) *Capnuchosphaera tricornis* De Wever; (8) *Kinyrosphaera trispinosa* Bragin; (9) *Capnuchosphaera triassica* De Wever; (10) *Capnuchosphaera deweveri* Kozur et Mostler; (11) *Dicapnuchosphaera carterae* Tekin; (12) *Monocapnuchosphaera inflata* Tekin; (13) *Betraccium irregulare* Bragin; (14) *Icrioma cruciformis* Tekin; (15) *Braginastrum curvatus* Tekin; (16) *Capnodoce anapetes* De Wever; (17) *Capnodoce crystallina* Pessagno; (18) *Spongotortilispinus carnicus* (Kozur et Mostler); (19) *Spongotortilispinus tortilis* (Kozur et Mostler); (20) *Palaeosaturnalis triassicus* Kozur et Mostler; (21) *Liassosaturnalis parvus* Kozur et Mostler; (22) *Zhamojdasphaera proceruspinosa* Lahm; (23) *Palaeosaturnalis karnicus* (Kozur et Mostler); (24) *Palaeosaturnalis raridenticulatus* Kozur et Mock; (25) *Veghicyclia haeckeli* Kozur et Mostler.

All specimens from the Akamas Peninsula, Lara section, Phasoula Formation, Upper Triassic, lower Norian. Figs. 1, 2, 5–9, 12–17, 20, 22, 23, 25 – ×130; figs. 3, 4, 10, 11, 18, 19, 24 – ×100; fig. 21 – ×150.

assemblage includes characteristic species *Capnodoce anapetes, C. crystallina, Capnuchosphaera deweveri, C. theloides, C. triassica, C. tricornis, Carinaheliosoma carinata, Kahlerosphaera norica, Palaeosaturnalis latiannulatus, P. raridenticulatus, Xiphothecaella rugosa*, and others (Plates I and II) suggesting the early Norian age of the member. The block of pelitomorphic limestones sampled in the Ezousa River valley represents the other site of the occurrence of the same assemblage. Based on many species in common, the assemblage is concurrent to the typical lower Norian assemblages from Turkey (De Wever et al., 1979; Tekin, 1999). In addition, the other species of wider geographic range are known from the Upper Triassic of Japan (Sugiyama, 1997), Oregon (Blome, 1983, 1984; Yeh, 1989), and Sikhote Alin (Bragin, 1991, 2000). The assemblages distribution range is ranked in this work as the *Capnodoce crystallina–Trialatus robustus* Beds of the lower Norian (Fig. 4).

System	Series	Stage	Biostratigraphic subdivisions
Cretaceous	Lower	Hauterivian	*Podocapsa amphitreptera–Wrangellium puga*
		Valanginian	
		Berriasian	
Jurassic	Upper	Tithonian	
		Kimmeridgian	
		Oxfordian	
	Middle	Callovian	*Guexella nudata*
		Bathonian	
		Bajocian	
		Aalenian	
	Lower	Toarcian	*Parahsuum simplum*
		Pliensbachian	
		Sinemurian	
		Hettangian	
Triassic	Upper	Rhaetian	
		Norian	*Livarella densiporata–Lysemelas olbia*
			Capnodoce sarisa
			Capnodoce crystallina–Trialatus robustus

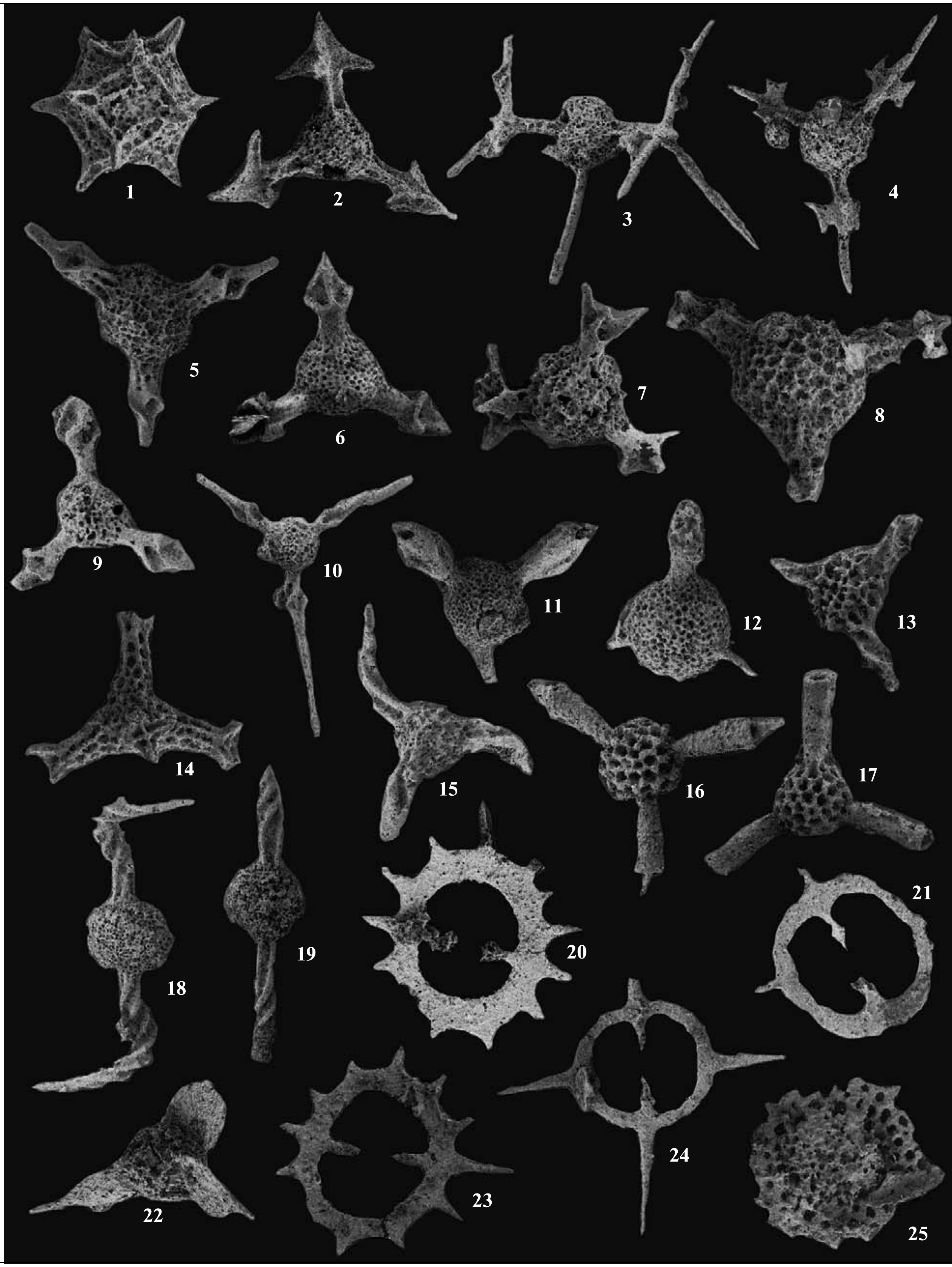
Fig. 4. Scheme of the Dhiarizos Group subdivision based on radiolarians (hatched intervals separating biostratigraphic units may correspond to stratigraphic hiatuses).

The aforementioned pelitomorphic limestones span also the middle Norian interval. The *Capnodoce sarisa* radiolarian assemblage (Bragin, 2007) is known so far only from a large block of the Phasoula Formation rocks exposed near the Parekklisia village. This assemblage is less diverse in taxonomic composition than the assemblage of the early Norian is, but it includes species *Capnodoce sarisa*, described from the middle Norian of Turkey (De Wever et al., 1979). Naturally, it is impossible to regard the early and middle Norian assemblages as conjoint, and host deposits of the latter are attributed to the *Capnodoce sarisa* Beds (Fig. 4).

The *Livarella densiporata–Lysemelas olbia* radiolarian assemblage of the late Norian (Bragin, 2007) is confined to a higher stratigraphic level, which corresponds to the base of the red radiolarian chert, overlying the limestones of the lower–middle Norian. In addition to index species, the assemblage includes *Pentactinocarpus sevaticus* and species of the genus *Livarella* characteristic of the upper Norian in Turkey (Tekin, 1999), Japan (Sugiyama, 1997), and eastern Russia (Bragin, 1991, 2000). Radiolarians of the Rhaetian Stage have not been found in the sections of Cyprus, where nothing is known about the other fossils that can evidence the occurrence of this stage. In this work, the upper Norian interval is attributed to the *Livarella densiporata–Lysemelas olbia* Beds (Fig. 4).

In sections of the Agios Photios Group, entirely composed of sedimentary rocks and representing the age analog of the Dhiarizos Group in the Mamonia Complex, a regional stratigraphic hiatus, spanning the interval from the Rhaetian Stage to the lower part of the Middle Jurassic, has been established (Bragin and

Plate I



→

Plate II. Triassic and Early Jurassic radiolarians from the Dhiarizos Group (Cyprus):

(1) *Palaeosaturnalis latiannulatus* Kozur et Mostler; (2) *Praemesosaturnalis* sp.; (3) *Praemesosaturnalis* sp. cf. *P. multidentatus* (Kozur et Mostler); (4) *Sarla vizcainoensis* Pessagno; (5) *Poulpus transitus* Kozur et Mostler; (6) *Sanfilippoella lengeranlii* Tekin; (7) *Trialatus robustus levantinensis* Bragin; (8) *Haeckelicyrtium carterae* Bragin; (9) *Xiphothecaella longa* (Kozur et Mostler); (10) *Xiphothecaella rugosa* (Bragin); (11) *Mostlericyrtium sitepesiformis* Tekin; (12) *Deflandrecyrtium curvatum* Kozur et Mostler; (13) *Livarella longa* Yoshida; (14, 15) *Gorgansium* sp. aff. *G. gongyloideum* Kishida et Hisada; (16, 17) *Crucella* sp. cf. *C. jadeae* Carter et Dumitrica; (18, 19) *Paronaella* sp. cf. *P. snowshoensis* (Yeh); (20) *Paronaella* sp. cf. *P. notabilis* Whalen et Carter; (21) *Crucella* sp.; (22) *Praeconocaryomma bajaensis* Whalen; (23) *Bipedis* sp.; (24, 25) *Parahsuum simplum* Yao.

Specimens 1, 5–12 from the Akamas Peninsula, Lara section, Phasoula Formation, Upper Triassic, lower Norian; specimens 2–4, 13 from the Akamas Peninsula, Lara section, Phasoula Formation, upper Norian; specimens 14–21 from the Akamas Peninsula, Loutra tis Aphroditis Formation, Lower Jurassic; specimens 22–25 from the Akamas Peninsula, Lara section, Phasoula Formation, Lower Jurassic.

Figs. 1–4, 7–10, 12 – ×130; figs. 11, 13, 16–22 – ×100; figs. 5, 6, 14, 15, 23–25 – ×150.

Krylov, 1996, 1999). In Cyprus, radiolarian assemblages of the lower Jurassic for sure have been discovered in two formations (Phasoula and Loutra tis Aphroditis) of the Dhiarizos Group. According to the composition of the radiolarians (Plates II and III), sections of both subdivisions include the Sinemurian–Toarcian deposits, but reliable data on the Hettangian sediments have not been obtained yet. I do not exclude, however, that in sections of the Dhiarizos Formation there could be a hiatus of a lesser range spanning the Rhaetian and Hettangian stages, but this is only an unproved presumption. The expected incompleteness of the Jurassic interval in the sections can be a consequence of the weakly developed sedimentary interlayers in the sequence largely composed of volcanic rocks.

The assemblage of Early Jurassic radiolarians from the Phasoula Formation is comparatively diverse in composition, although its species are identified in open nomenclature only because of the unsatisfactory preservation state. Nevertheless, the assemblage includes some identifiable forms of wide geographic ranges. For instance, *Katroma clara* is known from the Pliensbachian of Oregon and Mexico and from the Pliensbachian–Aalenian of Oman (Gorican et al., 2006), *Parahsuum simplum* occurs worldwide in the Lower Jurassic deposits (Gorican et al., 2006), and *P. izeense* is a characteristic species of the Pliensbachian in Oregon and of the Pliensbachian–Toarcian in British Columbia (Gorican et al., 2006). Due to the occurrence of these species, it is possible to assume the Pliensbachian–Toarcian age of the assemblage.

The Early Jurassic radiolarian assemblage found in the Loutra tis Aphroditis Formation is of considerably different taxonomic composition and includes some species missing from the above assemblage. These are *Bipedis japonicus*, known from the Lower Jurassic of Japan (Gorican et al., 2006) and *Katroma elongata* and *K. ninstintsi*, occurring in the Pliensbachian–Toarcian of British Columbia. *Parahsuum simplum* is a species in common for both assemblages. The age of the assemblage from the Loutra tis Aphroditis Formation can be defined broadly as corresponding to the Early Jurassic, most likely to the Sinemurian–Toarcian. Both radiolarian assemblages of the Lower Jurassic are comparable with concurrent assemblages of Turkey (Pessagno and Poisson, 1981; De Wever, 1982; Tekin, 2002), Mexico and Japan (Gorican et al., 2006). Radiolarians from the Lower Jurassic interval of the studied sections characterize the *Parahsuum simplum* Beds of the Sinemurian–Toarcian age presumably (Fig. 4).

The Middle Jurassic radiolarians have not been found in the described sections, but the assemblage from jaspers intercalated with strongly dislocated volcanics, which are exposed along the Nea Kholetria–Staurokono road, is comparable with well-known assemblages in the Mediterranean region (Baumgartner et al., 1995) and ranging in age from the late Bajocian to the early Oxfordian, as one can judge from the occurrence interval of *Guexella nudata*. Accordingly, the Middle–basal Upper Jurassic interval of the sections considered in this work is ranked as the *Guexella nudata* Beds (Fig. 4). Younger Jurassic radiolarians are unknown so far from the Dhiarizos Group. The Upper Jurassic radiolarian assemblages are widespread however in the Agios Photios Group, representing the age analog of the Dhiarizos Group.

The Early Cretaceous radiolarians occur in the upper part of the Lara Bay section, being also known from an isolated outcrop among the volcanic rocks of the Ezousa River basin. Species suggesting the Early Cretaceous age of the host deposits in both localities are typical of the Mediterranean region. In particular, the association of *Podocapsa amphitreptera* and *Wrangellium puga* (Plate III), established in sediments of the Lara Bay section suggests the late Tithonian–early Hauterivian age of the respective radiolarian assemblage (Baumgartner et al., 1995). However, the same assemblage also includes *Archaeodictyomitra tumandae*, the species known from the Berriasian–lower Hauterivian of Oman, Romania, and Italy (Dumitrica et al., 1997), and the lower distribution limit of the assemblage should be constrained therefore by the Berriasian. The other assemblage from the Ezousa River basin can be regarded as corresponding

Plate II

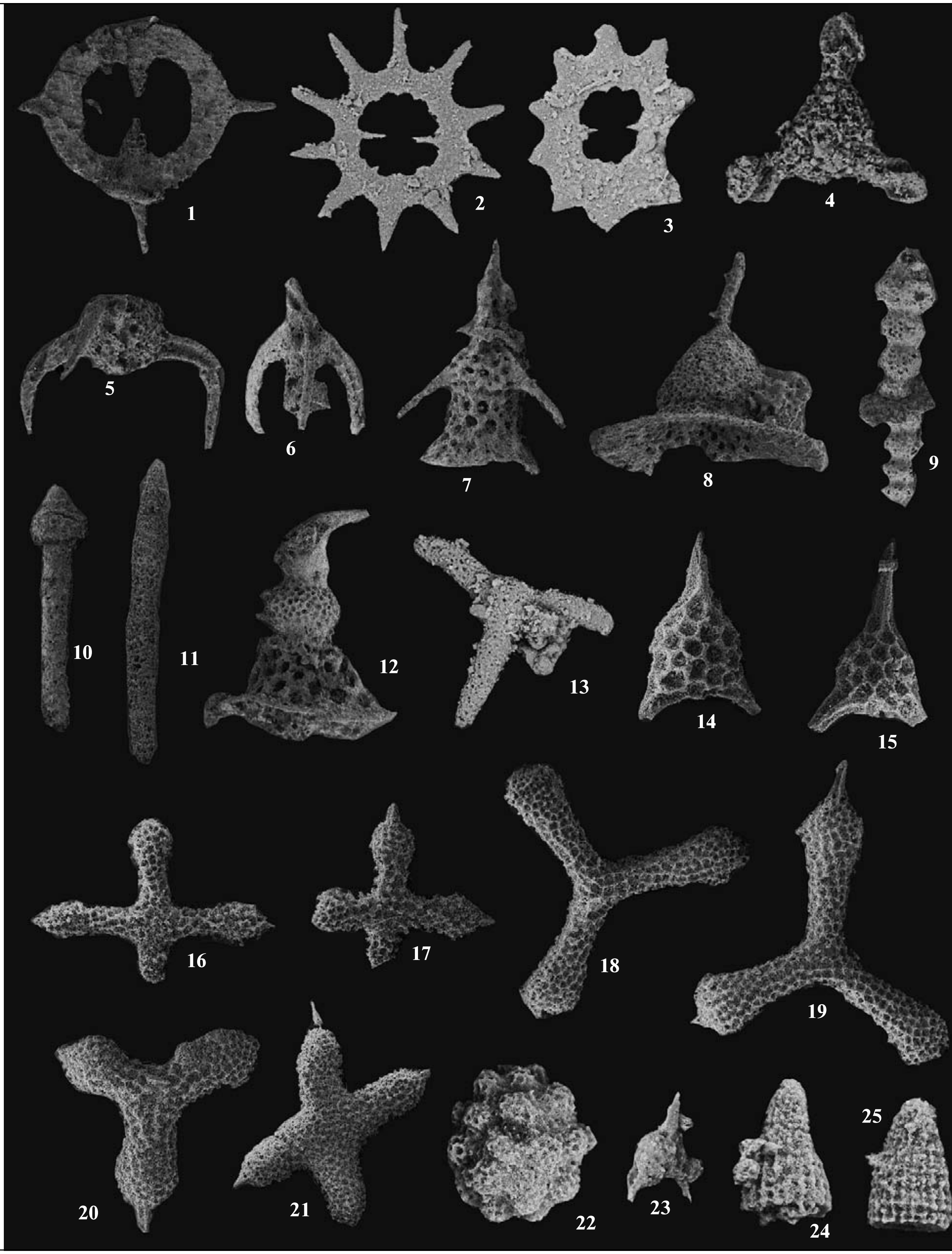


Plate III

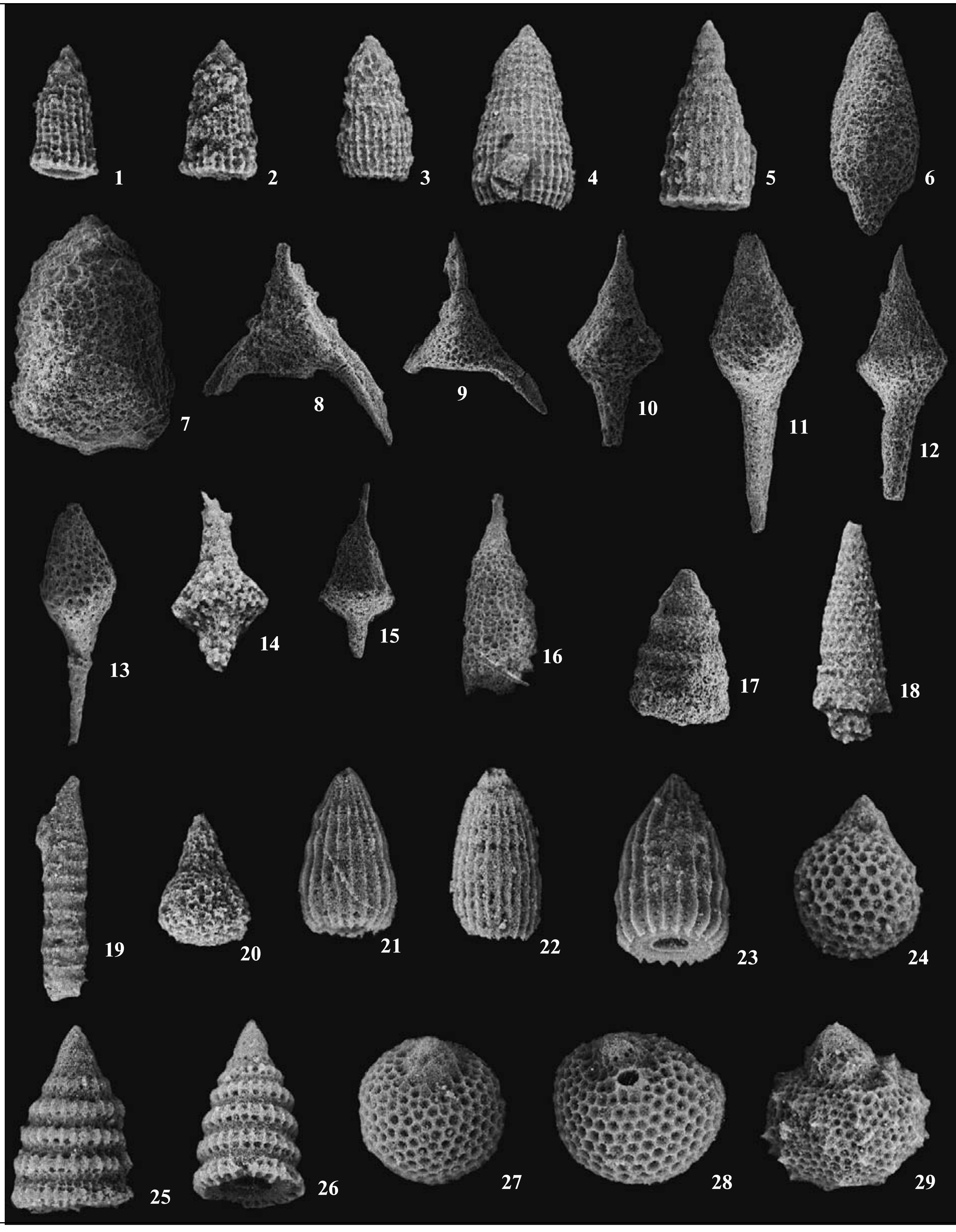


Plate III. Early Jurassic and Early Cretaceous radiolarians from the Dhiarizos Group (Cyprus):

(1–3) *Parahsuum* sp. cf. *P. longiconicum* Sashida; (4) *Parahsuum izeense* (Pessagno et Whalen); (5) *Hsuum* sp. cf. *H. matsuokai* Isozaki et Matsuda; (6) *Broctus* sp.; (7) *Trexus* sp.; (8, 9) *Bipedis japonicus* Hori; (10) *Katroma ninstintsi* Carter; (11) *Katroma elongata* Carter; (12) *Katroma* sp.; (13) *Katroma?* sp.; (14) *Katroma clara* Yeh; (15) *Katroma hocakoeyensis* Tekin; (16) *Elodium?* sp.; (17) *Canoptum* sp.; (18) *Hsuum* sp.; (19) *Canoptum* sp. cf. *C. annulatum* Pessagno et Poisson; (20) *Lantus* sp. cf. *L. obesus* (Yeh); (21, 23) *Archaeodictyomitra tumandae* Dumitrica; (22) *Archaeodictyomitra vulgaris* Pessagno; (24) *Cryptamphorella* sp.; (25, 26) *Wrangellium puga* (Schaaf); (27, 28) *Cryptamphorella conara* (Foreman); (29) *Zhamoidellum* sp. cf. *Z. testatum* Jud.

Specimens 1–5, 14, 16–20 from the Akamas Peninsula, Lara section, Phasoula Formation, Lower Jurassic; specimens 6–13, 15 from the Akamas Peninsula, Loutra tis Aphroditis Formation, Lower Jurassic; specimens 21–29 from the Akamas Peninsula, Lara section, Phasoula Formation, Lower Cretaceous.

Figs. 1–6, 8–20, – ×130; figs. 7, 21–29, – ×150.

in age to the late Valanginian–early Hauterivian. In terms of radiolarian biostratigraphy, the Berriasian–lower Hauterivian interval of the Lower Cretaceous corresponds in the study area to the *Podocapsa amphitreptera–Wrangellium puga* Beds (Fig. 4).

Since the youngest deposits of the Agios Photios Group have been attributed to the Albian–Turonian (Bragin et al., 2000), there is a chance that the Dhiarizos Group sections also include sediments that are younger than the sediments of the group dated at present. It should be admitted therefore that currently we are still far from gaining a deep insight into the biostratigraphy of the Dhiarizos Group: the distinguished beds with radiolarian assemblages are separated by intervals barren of fossils and consequently represent the disjointed biostratigraphic units (Fig. 4).

CONCLUSIONS

(1) In southwestern Cyprus, volcanogenic-sedimentary deposits of the Mamonia Complex are attributed to the Dhiarizos Group, subdivided into the Phasoula, Loutra tis Aphroditis, and Petra tou Romiou formations, which are considerably different in their stratigraphic ranges. The Phasoula Formation is of the greatest stratigraphic range, spanning the interval from the Upper Triassic (upper Carnian) to Lower Cretaceous (Berriasian–lower Hauterivian). The Loutra tis Aphroditis and Petra tou Romiou formations are of the Early Jurassic and Late Triassic ages respectively.

(2) Radiolarian assemblages discovered in sections of the Phasoula and Loutra tis Aphroditis formations are used for the subdivision of the respective sediments into a series of biostratigraphic units ranked as beds with fauna. These are the *Capnodoce crystallina –Trialatus robustus* (lower Norian), *Capnodoce sarisa* (middle Norian), *Livarella densiporata–Lysemelas olbia* (upper Norian), *Parahsuum simplum* (Lower Jurassic, presumably Sinemurian–Toarcian), *Guexella nudata* (Middle–Upper Jurassic, Bajocian–lower Oxfordian), and *Podocapsa amphitreptera–Wrangellium puga* (Lower Cretaceous, Berriasian–lower Hauterivian) beds.

(3) All three formations of the Dhiarizos Group originated in different settings. The Phasoula Formation origin was associated with eruptions of basic lavas in a paleobasin and the slow, probably condensed, accumulation of pelagic sediments, i.e., of micritic limestones and radiolarites. The Loutra tis Aphroditis Formation of rudaceous sediments, composed of ophiolitic clastic material, were deposited, according to ordinary logic, at the time of a rifting event. Sediments of the Petra tou Romiou Formation are undoubtedly of shallow-water origin, deposited in areas of volcanogenic rises.

Reviewers A.Ya. Sharaskin
and V.S. Vishnevskaya

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