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EARLY AND MIDDLE JURASSIC (PLIENSBACHIAN TO BAJOCIAN) RADIOLARIA FROM CHERTS OF KISELEVKA-MANOMA ACCRETIONARY COMPLEX (AMUR RIVER, EASTERN RUSSIA)

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ABSTRACT

The lower part of chert sequence of Kiselevka-Manoma accretionary complex, Sikhote-Alin system (Eastern Russia) is characterized by the following radiolarian assemblages (in ascending order of age):
1. Early Pliensbachian to early Toarcian with *Parahsuum izeenze*, *Bagotum maudense* and *Katroma clara*.
2. Early Toarcian with *Bistarkum rigidium* and *Citriduma hexaptera*.
3. Middle-late Toarcian to early-middle Aalenian with *Paronaella grahamensis, Praeparvicingula gigantocornis Hsuum exiguum*.
4. Early-middle Aalenian with *Parahsuum*? *grande, Parahsuum cruciferum* and *Hsuum altile*.
5. Late Aalenian with *Parahsuum*? *hiconocosta, Transhsuum hisuikyoense* and Nassellaria gen. et sp. indet. 1.
6. Early-middle Bajocian with *Sella beniderkoulensis* and *Emiluvia splendida*. New species *Olanda inflata* Bragin, n. sp. is described from this assemblage.

Studied radiolarian assemblages are Tethyan in affinity, which allows to utilize the low-latitude zonal radiolarian scales for the Jurassic (Baumgartner et al., 1995b; Carter et al., 2010). The total stratigraphic range of chert sequence of the Kiselevka-Manoma accretionary complex can be estimated as Early Jurassic (Pliensbachian-early Toarcian)-Early Cretaceous (Barremian).

INTRODUCTION

The Sikhote-Alin Ridge (Eastern Russia) includes several accretionary complexes formed during Jurassic and Early Cretaceous times (e.g. Kiselevka-Manoma complex), due to the subduction of the Pacific plates (Natal'in, 1991; Golozubov et al., 2006; Kemkin, 2006). These accretionary complexes are mainly composed of clastic rocks (clastic turbiditic successions composed of mudstone-siltstone-sandstone alterated and thick sandstone units) deposited near convergent plate boundaries and of cherty to clayey-cherty rocks sometimes associated with basic volcanics. Cherts and associated rocks are interpreted as ocean floor sediments. The youngest known paleo-oceanic deposits constituting the Kiselevka-Manoma complex are Jurassic-Early Cretaceous cherts, basic volcanics, limestones, cherty mudstones and turbidites. This complex forms a long narrow discontinuous belt along the valley of Amur River, and is located directly east from the Late Jurassic-Cenomanian turbidite sequences of the Amur Terrane (Khanchuk et al., 1994; Zyabrev, 1994; 1996; Zyabrev et al., 2005) (Figs. 1, 2).

The Kiselevka-Manoma complex has been repeatedly studied for a long time. The limestones of the complex exposed in the type locality near Kiselevka Village were dated by ammonoids and bivalvs as the Early Jurassic (probably Hettangian to Sinemurian) (Kiparisova, 1952; Geology of USSR, 1966; Zhamoida, 1972). Radiolarians from cherts and cherty mudstones of the same locality were studied in thin sections and referred to Late Triassic-Early Jurassic (Zhamoida, 1972). Later investigations based on extracted forms studied by SEM (Zyabrev, 1994; 1996) substiantally changed stratigraphy of the complex. According to Zyabrev (1996) and Zyabrev and Anoikin (2013) the Kiselevka-Manoma complex consists of several parts:

1- Assemblage of basic volcanics and Early Jurassic limestones. This assemblage is tectonically separated from other parts of the Kiselevka-Manoma complex.

2- Cherts, mostly red, sometimes interbedded with cherty mudstones, with radiolarian assemblages ranging from undifferentiated Jurassic to Early Cretaceous (Hauterivian). This unit represents paleooceanic sediments of large stratigraphic interval.

3- Olive-grey cherty mudstones and dark-grey mudstones, with radiolarians of Early Cretaceous (Barremian-middle Aptian)

4- Clastic turbidites (post-Aptian?).

The Cretaceous radiolarians were studied and illustrated by Zyabrev (Zyabrev, 1996; Zyabrev and Anoikin, 2013), but the Jurassic ones were not studied in detail or illustrated (Kuz'min and Shevelev, 1990). The aim of this work is to present the first results of the Early to Middle Jurassic (Pliensbachian-Bajocian) radiolarians and to reconstruct the stratigraphy of the studied section.

GEOLOGICAL SETTING

The Kiselevka-Manoma complex forms a long narrow band in the Lower Amur region. This band runs northeastwards along the valley of the Amur River from the southern part of Khabarovsk region to Khavanda Lake in the north. The Kiselevka-Manoma accretionary complex is separated by faults from the Amur accretionary complex northwestwards and from the Zhuravlevka turbidite basin southeastwards (Figs. 1, 2). The type locality of Kiselevka-Manoma complex is in the valley of Amur River approximately 540 km downstream from Khabarovsk Town, near Kiselevka Village (Fig. 2). Notable exposures can be seen upstream from Kiselevka, on the left bank of Amur River and along the western side of the mouth of its left tributary, the Izvestkovyi Bay (Fig. 3).

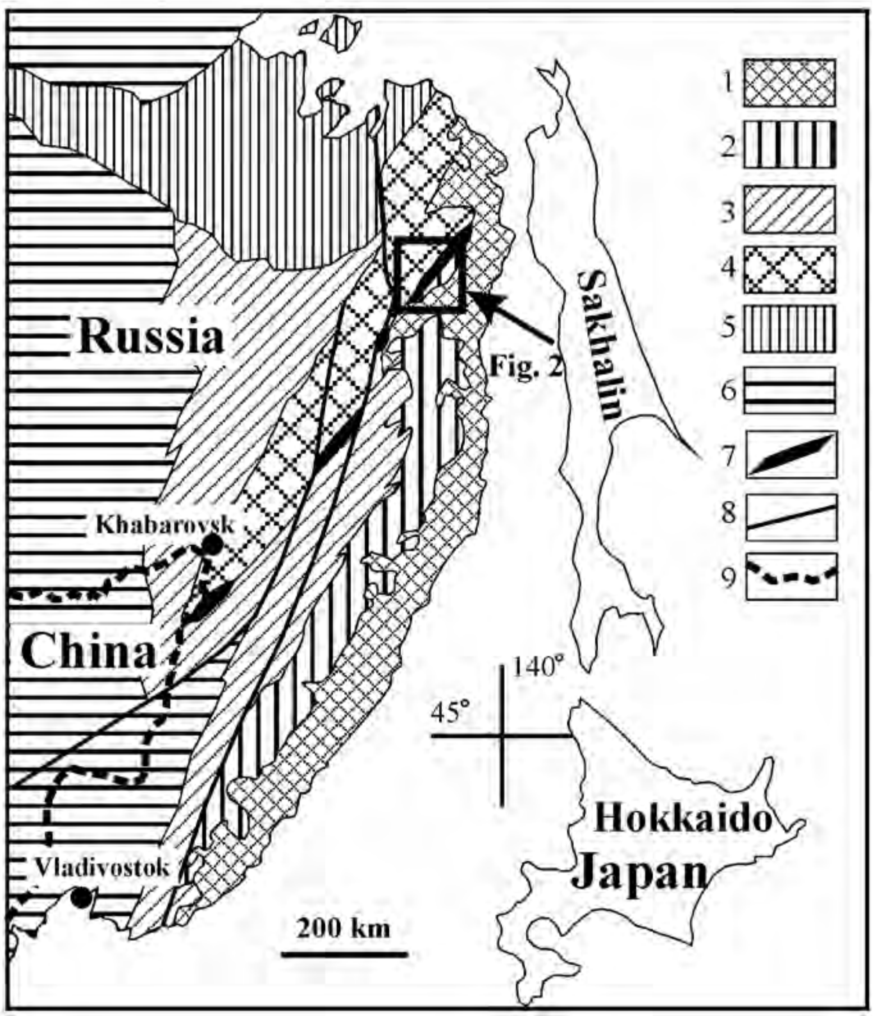


Fig. 1 - Tectonic scheme of the Russian Far East (after Zyabrev and Anoikin, 2013). 1- Late Cretaceous-Paleogene East Sikhote-Alin volcanic belt; 2- Early Cretaceous Zhuravlevka turbidite basin; 3- Jurassic Badzhal, Bikin and Samarka terranes; 4- Late Jurassic-Cretaceous Amur terrane; 5- Mongol-Okhotsk suture zone; 6- cratonic domains; 7- Jurassic-Early Cretaceous Kiselevka-Manoma accretionary complex; 8- major faults; 9- state boundary.

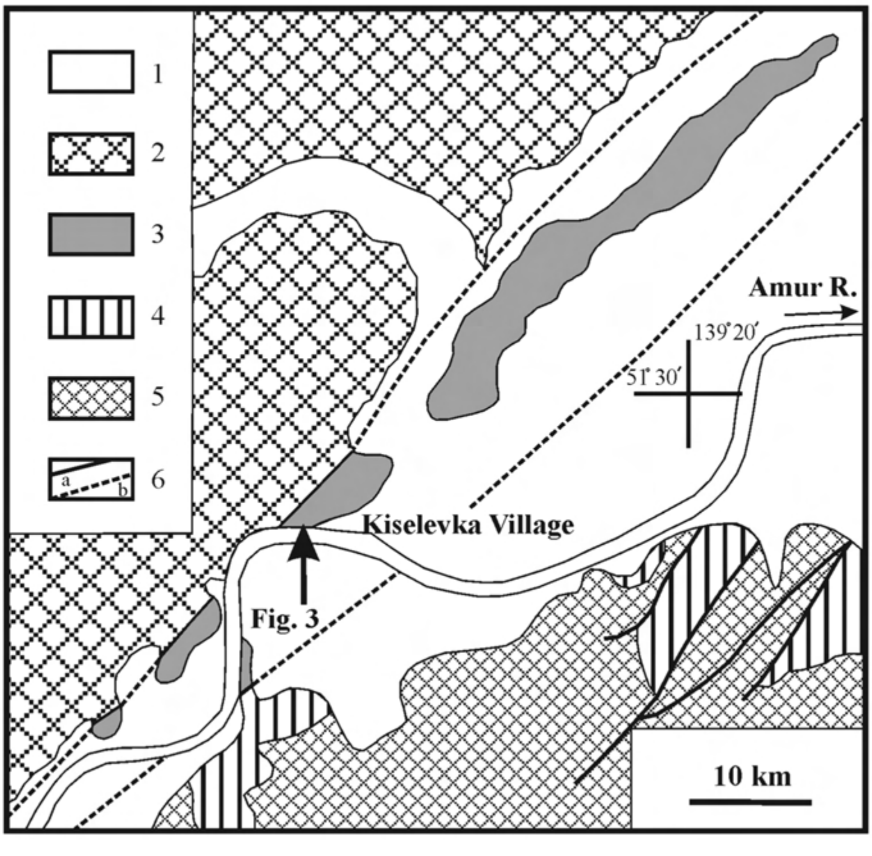


Fig. 2 - Geological map of the studied area (after Zyabrev and Anoikin, 2013). 1- Quaternary alluvial deposits; 2- Late Jurassic-Cretaceous deposits of the Amur terrane; 3- Early Jurassic-Early Cretaceous deposits of the Kiselevka-Manoma accretionary complex; 4- Early Cretaceous deposits of the Zhuravlevka turbidite basin; 5- Late Cretaceous and Paleogene volcanic rocks of the East Sikhote-Alin volcanic belt; 6- faults: a- observed; b- hidden beneath the Quaternary cover.

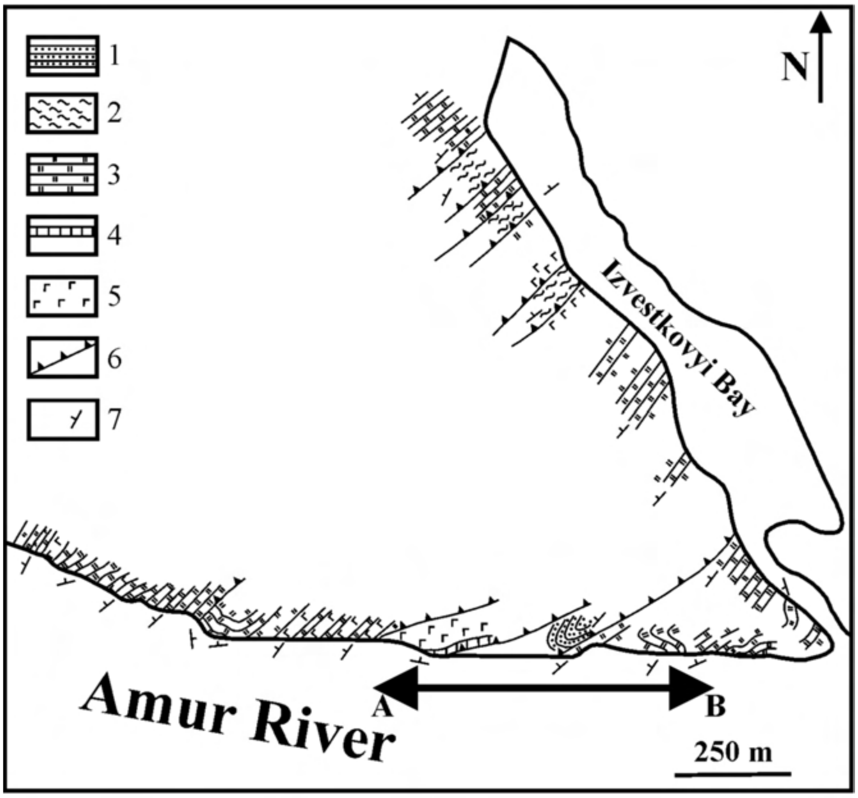


Fig. 3 - Structure of the Kiselevka-Manoma accretionary complex in the vicinity of Kiselevka Village (after Zyabrev and Anoikin, 2013). 1- siliciclastic turbidites; 2- olive-grey cherty mudstones; 3- cherts; 4- limestones; 5- basic volcanics; 6- steep thrusts; 7- dip. A-B - line of profile studied by the authors.

The main lithologies of the Kiselevka-Manoma complex are represented in its type locality by ribbon cherts, more or less clayey, commonly red and brownish-red. Large slices of basic volcanics are tectonically associated with cherts. According to the geochemical composition these basic volcanics were interpreted as oceanic within-plate basalts (Voinova et al., 1994). Large limestone lenses and blocks are present among the volcanics. The limestones are characterized by Early Jurassic (probably Hettangian to Sinemurian) macrofaunas: ammonoids (*Juraphyllites amurensis* Kiparisova), bivalves (*Chlamys textoria* Schlotheim), various *Cardinia* and *Plagiostoma*, corals (*Anabacia* and *Montlivaultia*) (Kiparisova, 1952; Geology of USSR, 1966; Westermann, 2005). Cherty mudstones and clastic turbidites are less common.

The structure of the Kiselevka-Manoma complex near the Kiselevka Village is interpreted as a stack of tectonic slices with SW vergence. These slices are several meters thick and have various internal structure: from monoclinal to strongly folded (Zyabrev and Anoikin, 2013). We studied a large slice (Zyabrev and Anoikin, 2013) located on the left bank of Amur River directly west of Izvestkovyi Bay (Fig. 3). The cherts are deformed into a large inverted synform, complicated by thrusts and shear zones. This synform is bounded westwards by a steep thrust that separates a slice of cherts from an inverted synform of siliciclastic turbidites (Figs. 3, 4). The cherts contain abundant moderately to well preserved radiolarians. Biostratigraphic data allows us to reconstruct a portion of the stratigraphic section.

Below, follows a detailed description of the outcrops on the left bank of Amur River, west of the Izvestkovyi Bay (Fig. 4). The coordinates of beginning of the measured section are 51° 23’ 58,17’’ N and 138° 57’ 17,75’’ E. The section is characterized by the following lithologies from the west to east (see Fig. 4):

1. Greenish-brown basic almond-shaped volcanics, massive and brecciated. Thickness 10 m.
2. Grey massive limestones, oolitic and detrital, sometimes recrystallized, with calcite veins. Observed thickness 20 m.
3. Dark-grey to greenish-grey conglomerate with well-rounded pebbles of basic volcanics cemented by weak marly sandstone with bivalve detritus. This layer covers the eroded surface of the limestones. Thickness from 0 to 1.5 m.
4. Greenish-brown, sometimes reddish-brown basic volcanics, massive and brecciated, almond-shaped. Thickness is 30 m.
   These units form a monocline deeping NW 310. 20° and are bounded to the east by a steep thrust.
5. Siliciclastic turbidites represented by rhythmic alternation of reddish-grey rudites with non-rounded to well-rounded fragments of red and grey cherts, grey medium to fine grained sandstones, dark-grey siltstones and mudstones. These sediments are folded to an inverted synform and bounded to the east by a steep thrust. Estimated thickness 15-20 m.
6. Red to brownish-red clayey thin-bedded cherts intercalated with brownish-red cherty mudstones. They are intensively folded and form an anticline complicated by a steep thrust to the West. Thickness 20-25 m.
7. Red thin-bedded ribbon cherts with rare intercalations of grey cherts and red cherty mudstones. Observed thickness 40-50 m.
8. Greenish basic volcanics forming small tectonic. Block up to 4 m thick.
9. Red clayey cherts. Thickness 6 m.
10. Steep shear zone with blocks (1-2 m) of grey massive cherts. Observed thickness 5-10 m.
11. Red and brownish-red clayey cherts. Observed thickness 20 m.

Coordinates of the end of section are 51° 23’ 55.50’’ N and 138° 58’ 02.26’’ E.

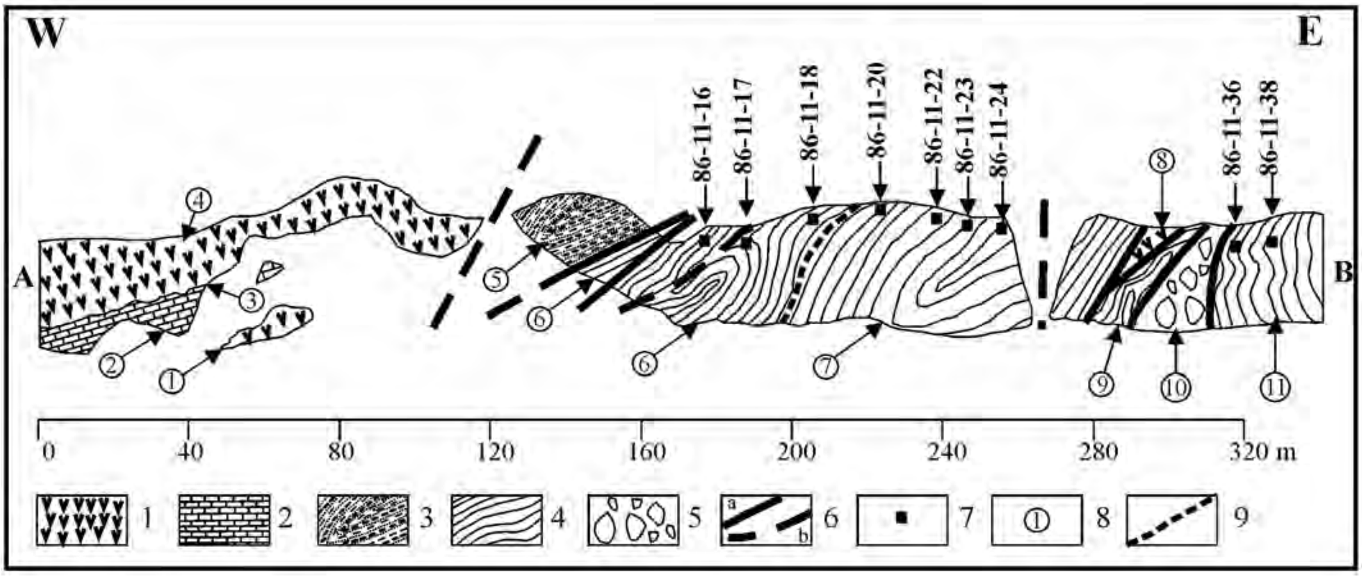


Fig. 4 - Profile of outcrops on the left bank of Amur River upstream from the Izvestkovyi Bay (line A-B). 1- basic volcanics; 2- limestones; 3- siliciclastic turbidites; 4- cherts; 5- tectonic breccia; 6- thrusts: a- documented, b- supposed; 7- samples with radiolarians; 8- numbers of members and units according to the description of section given in the text; 9- stratigraphic boundary between units 6 and 7.

The studied chert units have a tectonic contact with clastic turbidites to the west and are limited by a shear zone to the east.

The obtained data in the present paper allow to reconstruct part of stratigraphic log of the lower part of the chert sequence of the Kiselevka-Manoma accretionary complex.

RADIOLARIAN DATING

Radiolarian-bearing samples (cherts and cherty mudstones) were processed by diluted hydrofluoric acid (HF 5-10%) during 24 hours, then washed and dried. Radiolarians were picked from residue and then mounted to SEM stubs and studied by SEM Tescan 2300 using BSE detector. Taxonomic concept applied during this study follows those of Baumgartner et al. (1995a), Goričan et al. (2006) and O'Dogherty et al. (2009).

The preservation of radiolarians is moderate to good and allows determination of a major part of extracted forms. Studied Early and Middle Jurassic assemblages display clear Tethyan affinity and therefore we can determine many taxa with good stratigraphic potential (Table 1). It allows us to trace Tethyan biostratones proposed for this stratigraphic interval (Baumgartner et al., 1995b; Carter et al., 2010) (Table 2).

It is worth of note that the Aalenian Stage is subdivided only into two parts in the zonation of Carter et al. (2010) despite common subdivision of the Aalenian into three substages (Gradstein et al., 2012). In the present paper we follow the subdivision of Aalenian after Gradstein et al. (2012).

The following analyses are based on the taxa determined on species level. Forms determined in open nomenclature were not used for age determinations and have only supplementary value.

Sample 86-11-16. *Hsuum exiguum* Yeh and Cheng (Plate 1, fig. 1) has stratigraphic range from unitary associations (UA) 29 to 36 (Carter et al., 2010) which is equal to the interval from the middle-late Toarcian (*Elodium pessagnoi - Hexasaturnalis hexagonus* Zone) to the early-middle Aalenian (*Higumastra transversa - Napora nipponica* Zone) (Carter et al., 2010).

Sample 86-11-17. *Parahsuum izeense* (Pessagno and Whalen) has very wide stratigraphic range (UA 6 - UA 41; early Pliensbachian, *Zartus mostleri - Pseudoristola megaglobosa* Zone to Bajocian). *Katroma clara* Yeh (Plate 2, figs. 2, 3) is present from UA 3 to UA 26 (early Pliensbachian, *Canutus tipperi - Katroma clara* Zone to early Toarcian, *Napora relica - Eucyrtidiellum disparile* Zone). *Bagotum maudense* Pessagno and Whalen (Plate 2, fig. 4) has almost same stratigraphic range (UA 2 - UA 26) and support given age determination - early Pliensbachian to early Toarcian (Carter et al., 2010).

Sample 86-11-18. *Bistarkum rigidium* Yeh (Plate 2, fig. 9) is known from UA 22 to UA 26 (late Pliensbachian, *Eucyrtidiellum nagaiae - Praeparvicingula tlellensis* Zone to early Toarcian, *Napora relica - Eucyrtidiellum disparile* Zone). *Citriduma hexaptera* (Conti and Marcucci) (Plate 2, fig. 10) is found in UA 25 - UA 27 (early Toarcian, *Napora relica - Eucyrtidiellum disparile* Zone), and in UAZone 7 (late Bathonian-early Callovian) (Baumgartner et al., 1995b). Therefore, the age of this sample can be referred to early Toarcian (Carter et al., 2010).

Sample 86-11-20. Three species were determined. *Paronaella grahamensis* Carter (Plate 3, figs. 3, 4) has stratigraphic range from UA 3 to UA 34 (early Pliensbachian, *Canutus tipperi - Katroma clara* Zone to early-middle Aalenian, *Higumastra transversa - Napora nipponica* Zone). *Hsuum exiguum* Yeh and Cheng ranges from unitary associations (UA) 29 to 36 (middle-late Toarcian *Elodium pessagnoi - Hexasaturnalis hexagonus* Zone to early-middle Aalenian *Higumastra transversa - Napora nipponica* Zone). *Praeparvicingula gigantocornis* (Kishida and Hisada) (Plate 3, fig. 7) is known from UA 28 to UA 41 (middle-late Toarcian *Elodium pessagnoi - Hexasaturnalis hexagonus* Zone to Bajocian) (Carter et al., 2010). The interval from middle-late Toarcian to early-middle Aalenian can be determined summarizing these data.

Table 1 - Occurrence list of radiolarian species from Early to Middle Jurassic deposits of the Kiselevka section.

Samples / Radiolarian taxa	86-11-16	86-11-17	86-11-18	86-11-20	86-11-22	86-11-23	86-11-24	86-11-36	86-11-38
Acaeniotylopsis sp.							R		
Angulobracchia sp.						R			
Bagotum maudense Pessagno and Whalen		R							
Bistarkum rigidium Yeh			R						
Canoptum sp. cf. *C. anulatum* Pessagno and Poisson		C	C						
Citriduma hexaptera (Conti and Marcucci)			R						
Crucella sp. cf. *C. angulosa angulosa* Carter	R			R					
Crucella sp.	R								
Dictyomitrella? sp. aff. *D. kamoensis* Mizutani and Kido							C		
Elodium? sp. cf. *E.*? *mackenziei* Carter				R					
Elodium sp.						R			
Emiluvia splendida Carter							C		
Gongylothorax sp.							R		
Hexasaturnalis hexagonus (Yao)						C			
Higumastra transversa Blome						R			
Hsuum altile Hori and Otsuka					C			C	R
Hsuum exiguum Yeh and Cheng	R			A					
Hsuum sp. aff. *H. lucidum* Yeh	C			C	C				
Japonisaturnalis diplocyclis (Yao)				R	C			R	R
Katroma clara Yeh		C	R						
Katroma sp. cf. *K. ninstintsi* Carter	R								
Lantus sp. cf. *L. obesus* (Yeh)	C	C	C						
Mirifusus proavus Tonielli							R		
Napora sp.							R		
Nassellaria gen. et sp. indet. 1						R			
Olanda inflata n. sp.							C		
Palinandromeda sp. cf. *P. sognoensis* Baumgartner							R		
Parahsuum cruciferum Takemura					C			R	R
Parahsuum? *grande* Hori and Yao					C			C	C
Parahsuum? *hiconocosta* Baumgartner and De Wever						R			
Parahsuum? sp. cf. *P. hiconocosta* Baumgartner and De Wever					R				R
Parahsuum izeense (Pessagno and Whalen)		R	C				C		
Parahsuum? sp. cf. *P. magnum* Takemura						R			
Parahsuum sp. cf. *P. mostleri* (Yeh)		R	C						
Parahsuum? sp. cf. *P. natorense* (El Kadiri)						R			
Parahsuum sp.				R	R	R			R
Parahsuum? sp.			C						
Paronaella sp. cf. *P. corpulenta* De Wever		C	R						
Paronaella sp. cf. *P. curticrassa* Carter and Dumitrica		C							

A- abundant, C- common, R- rare.

Table 1 (*continues*)

Radiolarian taxa \ Samples	86-11-16	86-11-17	86-11-18	86-11-20	86-11-22	86-11-23	86-11-24	86-11-36	86-11-38
Paronaella grahamensis Carter				A					
Pleesus sp. cf. *P. aptus* Yeh	C	R							
Praeconocaryomma sp. cf. *P. bajahensis* Whalen	C	R	C						
Praeconocaryomma sp. cf. *P. decora* Yeh							A		
Praeconocaryomma sp.					R			R	R
Praeparvicingula gigantocornis (Kishida and Hisada)	R			C					
Praeparvicingula sp. A					R				R
Praeparvicingula sp.						R			
Protunuma? sp.			R						
Pseudoheliodiscus sp.				R					
Ristola sp.					R				R
Sella beniderkoulensis (El Kadiri)							C		
Sella chrafatensis (El Kadiri)							R		
Tetraditryma sp. cf. *T. praeplena* Baumgartner						R			
Transhsuum hisuikyoense (Isozaki and Matsuda)						C	C		
Triactoma sp.					C				R
Tritrabs sp. cf. *T. simplex* Kito and De Wever					R		C		R
Zhamoidellum spp.							A		

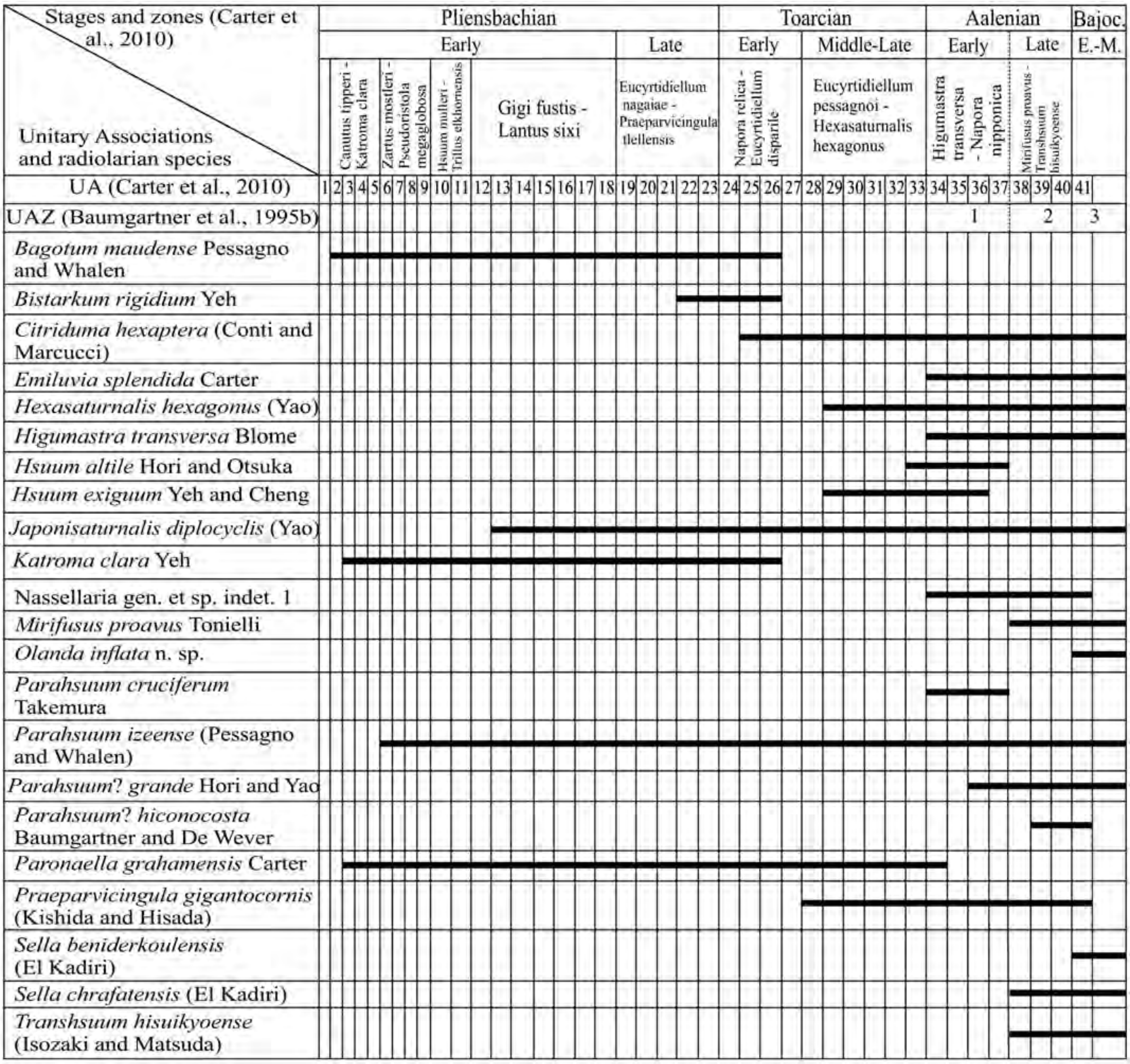
A- abundant, C- common, R- rare.

Sample 86-11-22. *Parahsuum*? *grande* Hori and Yao (Plate 4, figs. 1, 2) is represented in UA 36-37 (early-middle Aalenian, *Higumastra transversa - Napora nipponica* Zone) and in UAZones 1-3 (early-middle Aalenian - early-middle Bajocian). *Hsuum altile* Hori and Otsuka (Plate 4, figs. 4, 5) is known from UA 33 to UA 37, middle-late Toarcian (*Elodium pessagnoi - Hexasaturnalis hexagonus* Zone to early-middle Aalenian *Higumastra transversa - Napora nipponica* Zone) (Carter et al., 2010). *Japonisaturnalis diplocyclis* (Yao) (Plate 4, fig. 6) is known from UA 13 (early Pliensbachian *Gigi fustis - Lantus sixi* Zone) (Carter et al., 2010) to UAZone 3 of Middle Jurassic-Early Cretaceous zonation (Baumgartner et al., 1995b), that is equivalent to the early-middle Bajocian. Finally, *Parahsuum cruciferum* Takemura (Plate 4, fig. 11) is known only from UAZone 1 (early-middle Aalenian) (Baumgartner et al., 1995b). Therefore, sample can be dated as early-middle Aalenian.

Sample 86-11-23. *Parahsuum*? *hiconocosta* Baumgartner and De Wever (Plate 5, fig. 8) has range from UA 39 to UA 41 (middle-late Aalenian, *Mirifusus proavus - Transhsuum hisuikyoense* Zone - Bajocian) (Carter et al., 2010), or from UAZone 2 to UAZone 4 (late Aalenian to late Bajocian) (Baumgartner et al., 1995b). *Transhsuum hisuikyoense* (Isozaki and Matsuda) (Plate 5, fig. 7) is known from UAZones 2-7 (late Aalenian to late Bathonian - early Callovian) (Baumgartner et al., 1995b), and appears in UA 38 (middle-late Aalenian, *Mirifusus proavus - Transhsuum hisuikyoense* Zone) (Carter et al., 2010). *Hexasaturnalis hexagonus* (Yao) (Plate 5, figs. 10, 11) has wide range - from UA 29 (middle-late Toarcian *Elodium pessagnoi - Hexasaturnalis hexagonus* Zone) to UA 41 (Bajocian) (Carter et al., 2010) and in UAZones 1-4 (early-middle Aalenian - late Bajocian) (Baumgartner et al., 1995b). Nassellaria gen. et sp. 1 (Plate 5, fig. 9) was illustrated by Hori (1990) from *Parahsuum*? *grande* Assemblage Zone, which is correlated with early-middle Aalenian *Higumastra transversa - Napora nipponica* Zone (Carter et al., 2010) and UAZones 1-2 (early-middle Aalenian to late Aalenian) after Baumgartner et al. (1995b). *Higumastra transversa* Blome (Plate 5, fig. 1) is known from UA-34, early-middle Aalenian, *Higumastra transversa - Napora nipponica* (Carter et al., 2010) to Callovian (Blome, 1984). This sample could be dated as late Aalenian.

Sample 86-11-24. *Mirifusus proavus* Tonielli (Plate 6, fig. 1) is known from UA 38 to UA 41 (middle-late Aalenian, *Mirifusus proavus - Transhsuum hisuikyoense* Zone - Bajocian) (Carter et al., 2010), or from UAZone 2 to UAZone 4 (late Aalenian to late Bajocian) (Baumgartner et al., 1995b). *Olanda inflata* Bragin, n. sp. (Plate 6, figs. 2-4) was previously reported from UAZone 3 to UAZone 13 (early-middle Bajocian to latest Tithonian) (Baumgartner et al., 1995b). *Sella beniderkoulensis* (El Kadiri) (Plate 7, figs. 1, 2) ranges from UAZone 3 to UAZone 7 (early-middle Bajocian to late Bathonian-early Callovian). *Sella chrafatensis* (El Kadiri) (Plate 7, fig. 3) is known from UAZone 2 to UAZone 7 (late Aalenian to late Bathonian-early Callovian). *Emiluvia splendida* Carter (Plate 7, fig. 5) ranges from UAZone 1 to UAZone 3 (early-middle Aalenian to early-middle Bajocian)

Table 2 - Radiolarian zonation of Early-Middle Jurassic (Pliensbachian-Bajocian) interval and stratigraphic ranges of radiolarian taxa used for age datings.



(Baumgartner et al., 1995b). *Parahsuum izeense* (Pessagno and Whalen) (Plate 7, figs. 7, 8) has very wide stratigraphic range from early Pliensbachian *Zartus mostleri - Pseudoristola megaglobosa* to Bajocian (Carter et al., 2010), and from UAZone 1 to UAZone 3 (early-middle Aalenian to early-middle Bajocian, Baumgartner et al., 1995b). This is the youngest sample of this sequence. It can be dated as early-middle Bajocian.

Samples 86-11-36 and 86-11-38 can be dated as early-middle Aalenian (UAZone 1) (Baumgartner et al., 1995b), due to the presence of *Parahsuum*? *grande* Hori and Yao, *Hsuum altile* Hori and Osuka, *Japonisaturnalis diplocyclis* (Yao) and *Parahsuum cruciferum* Takemura the same radiolarian markers of the sample 86-11-22.

DISCUSSION AND CONCLUSIONS

The radiolarian assemblages derived from cherts of Kiselevka-Manoma accretionary complex exposed in the type locality near Kiselevka Village suggest that continuous siliceous sedimentation took place during the late Early Jurassic and early Middle Jurassic (Pliensbachian-Bajocian). Therefore, basic volcanics associated with Hettangian-Sinemurian limestones represent the lowermost part of the hypotethical stratigraphic succession of deposits incorporated in the accretionary complex and can be interpreted as seamount deposits. Volcanics and limestones were followed by red cherts with intercalations of cherty mudstones. The age of the cherts range from Pliensbachian to Early Cretaceous (Hauterivian). The lower part of this succession (Pliensbachian-Toarcian) is represented by clayey cherts with common intercalations of cherty mudstones. The cherts of the Middle Jurassic (Aalenian-Bajocian) are more siliceous and less clayey. The sedimentation of Jurassic cherts was relatively slow according to small total thickness (probably 60-75 m for Pliensbachian-Bajocian interval). There are no considerable differences between chert sedimentation in the Kiselevka-Manoma accretionary complex and in any other Mesozoic accreted terranes of Eastern Russia and Japan. It should be noted that we can observe here only a part of the Jurassic section and we do not know yet the composition of Late Jurassic radiolarian assemblages.

The following radiolarian assemblages were recovered from chert succession of Kiselevka-Manoma Complex:

- sample 86-11-17, early Pliensbachian, *Canutus tipperi - Katroma clara* Zone to early Toarcian, *Napora relica - Eucyrtidiellum disparile* Zone with *Parahsuum izeenze*, *Bagotum maudense and Katroma clara*;
- sample 86-11-18, early Toarcian, *Napora relica - Eucyrtidiellum disparile* Zone with *Bistarkum rigidium* and *Citriduma hexaptera*;
- sample 86-11-16, middle-late Toarcian, *Elodium pessagnoi - Hexasaturnalis hexagonus* Zone to early-middle Aalenian, *Higumastra transversa - Napora nipponica* Zone for the presence of *Hsuum exiguum;*
- sample 86-11-20, middle-late Toarcian, *Elodium pessagnoi - Hexasaturnalis hexagonus* Zone to early-middle Aalenian, *Higumastra transversa - Napora nipponica* Zone with *Paronaella grahamensis, Praeparvicingula gigantocornis* and *Hsuum exiguum*;
- samples 86-11-22, 86-11-36 and 86-11-38, early-middle Aalenian, *Higumastra transversa - Napora nipponica* Zone and UAZone 1 Zone with *Parahsuum*? *grande, Parahsuum cruciferum* and *Hsuum altile*;
- sample 86-11-23, late Aalenian, *Mirifusus proavus - Transhsuum hisuikyoense* Zone with *Parahsuum*? *hiconocosta, Transhsuum hisuikyoense* and Nassellaria gen. et sp. indet. 1;
- sample 86-11-24, early-middle Bajocian, UAZone 3 with *Sella beniderkoulensis* and *Emiluvia splendida*.

Studied radiolarian assemblages of Early and Middle Jurassic are represented mostly by well-known taxa with Tethyan affinity. It allows to apply, in the present paper, the global radiolarian zonation for the Pliensbachian, Toarcian and Aalenian (Carter et al., 2010) and the Middle Jurassic-Early Cretaceous zonation of Baumgartner et al. (1995b).

The taxonomic composition of the assemblages has much in common with adjacent regions, especially Japan (Hori, 1990), but substantially differs from eastern Pacific coasts like British Columbia (Carter et al., 1988; Carter et al., 2010). Some elements typical for British Columbia like representatives of genera *Broctus*, *Bagotum*, *Praeparvicingula* are absent or rare in Kiselevka-Manoma assemblages. These differences can be explained by paleogeographic position of regions being compared. The terranes of Eastern Russia and Japan were formed in low-latitude areas while British Columbia has intermediate or Southern Boreal position.

SYSTEMATIC PALAEONTOLOGY

The authors follow the taxonomic concept of De Wever et al. (2001), and their order description of taxa (families and genera). We include only descriptions of new taxon and taxa determined in open nomenclature, and do not include descriptions of well-known taxa. Poorly preserved and incomplete specimens are determined as “cf.” or as sp. A. Well-preserved specimens with clear morphological differences from basic species are determined as “aff.” The disposition of taxa in the plates is from the oldest to the youngest samples; The occurrence of taxa in samples is shown in the Table 1.

Order Spumellaria Ehrenberg, 1875
Family Conocaryommidae Lipman, 1969
Genus *Praeconocaryomma* Pessagno, 1976
Type species: *Praeconocaryomma universa* Pessagno, 1976
Praeconocaryomma sp. cf. *P. decora* Yeh, 1987
Plate 6, figs. 9, 10
Material: more then 20 specimens.
Dimensions: diameter of test 200-220 μm.
Remarks: the specimens have massive, closely spaced rounded mammae like *Praeconocaryomma decora* and *Praeconocaryomma immodica* Pessagno and Poisson. Spines were not preserved.
Range and occurrence: Middle Jurassic, early-middle Bajocian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Praeconocaryomma sp. cf. *P. bajaensis* Whalen, 2006 in Goričan et al., 2006
Plate 1, fig. 6
Material: 7 specimens.
Dimensions: diameter of test 210-230 μm.
Remarks: the specimen has large mammae with spinules similar to those of *P. bajaensis*. Test wall is poorly preserved, character of porosity cannot be observed.
Range and occurrence: Early Jurassic, Pliensbachian-Toarcian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Praeconocaryomma sp.
Plate 4, fig. 9
Material: 6 specimens
Dimensions: diameter of test 180-190 μm.
Remarks: the specimen has small subconical mammae without spines.
Range and occurrence: Middle Jurassic, early-middle Aalenian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Family Hagiastridae Riedel, 1971
Genus *Crucella* Pessagno, 1971
Type species: *Crucella messinae* Pessagno, 1971
Crucella sp. cf. *C. angulosa angulosa* Carter, 1988 in Carter et al., 1988
Plate 3, fig. 9
Material: 3 incomplete specimens.
Dimensions: length of ray 110-120 μm, width of ray 50-60 μm.
Remarks: the non-complete specimens closely resemble *C. angulosa angulosa*.
Range and occurrence: Early-Middle Jurassic, middle-late Toarcian to early-middle Aalenian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Genus *Tetraditryma* Baumgartner, 1980
Type species: *Tetraditryma pseudoplena* Baumgartner, 1980
Tetraditryma sp. cf. *T. praeplena* Baumgartner, 1984
Plate 5, fig. 12
Material: 1 specimen.
Dimensions: length of ray 200-220 μm, width of ray 65-80 μm.
Remarks: lateral spines extending from ray tips absent or not preserved. Other morphological features are similar to those of *T. praeplena*.
Range and occurrence: Middle Jurassic, late Aalenian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Family Angulobracchiidae Baumgartner, 1980
Genus *Paronaella* Pessagno, 1971
Type species: *Paronaella solanoensis* Pessagno, 1971
Paronaella sp. cf. *P. corpulenta* De Wever, 1981
Plate 1, figs. 9, 10
Material: more then 20 specimens.
Dimensions: length of ray 150-170 μm, width of ray 90-110 μm.
Remarks: characteristic shape with very massive rays similar to *P. corpulenta*.
Range and occurrence: Early Jurassic, early Pliensbachian to early Toarcian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Paronaella sp. cf. *P. curticrassa* Carter and Dumitrica, 2006 in Goričan et al., 2006
Plate 1, fig. 11
Material: 11 specimens.
Dimensions: length of ray 180-190 μm, maximal width of ray 160-170 μm.
Remarks: studied specimens have massive rays with shape similar to *P. curticrassa*.
Range and occurrence: Early Jurassic, early Pliensbachian to early Toarcian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Order Nassellaria Ehrenberg, 1875
Family Hsuidae Pessagno and Whalen, 1982
Genus *Hsuum* Pessagno, 1977
Type species: *Hsuum cuestaensis* Pessagno, 1977
Hsuum sp. aff. *H. lucidum* Yeh, 1987
Plate 3, fig. 1, 2; Plate 4, fig. 3
Material: more then 20 specimens.
Description. test conical, slender, pointed apically, with 12-13 postabdominal chambers. Cephalis small, conical, poreless, without apical horn. Thorax truncate-conical with few small pores. Abdomen and postabdominal segments gradually increasing in width and length. Postabdominal chambers with small tetragonal pore frames; pores form three transversal rows in each segment. Short thin costae are present on joints of chambers. Up to 12 costae are visible in the segments of middle part of test.
Dimensions: length of test 320-340 μm, width of test 150-160 μm.
Remarks: difference from *Hsuum lucidum* Yeh by longer and relatively thinner test with larger quantity of postabdominal chambers and with smaller costae.
Range and occurrence: Early-Middle Jurassic, middle-late Toarcian to early-middle Aalenian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Genus *Parahsuum* Yao, 1982
Type species: *Parahsuum simplum* Yao, 1982
Parahsuum? sp. cf. *P. magnum* Takemura, 1986
Plate 5, fig. 3
Material: one specimen.
Dimensions: length of incomplete specimen 330 μm, width 170 μm.
Remarks: the specimen is similar to *Parahsuum*? *magnum* Takemura but its apical part is poorly preserved and characteristic apical horn is almost absent.
Range and occurrence: Middle Jurassic, late Aalenian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Parahsuum sp. cf. *P. mostleri* (Yeh, 1987)
Plate 2, fig. 6
Material: 5 specimens
Dimensions: length of test 270-280 μm, width 150 μm.
Remarks: this specimen is similar to *Parahsuum mostleri* (Yeh), but the apical part is poorly preserved and deformed.
Range and occurrence: Early Jurassic, early Pliesbachian to early Toarcian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Parahsuum? sp. cf. *P. hiconocosta* Baumgartner and De Wever, 1995 in Baumgartner et al., 1995a
Plate 4, fig. 7
Material: 6 non-complete specimens
Dimensions: length of test without apical part 400 μm, width of test 300-310 μm.
Remarks: the specimens are partly preserved, apical part is absent. Differs from *Parahsuum*? *hiconocosta* Baumgartner and De Wever by smooth, rounded circumferential ridges and may represent its ancestral form.
Range and occurrence: Middle Jurassic, early-middle Aalenian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Parahsuum? sp. cf. *P. natorense* (El Kadiri, 1992)
Plate 5, fig. 2
Material: 3 incomplete specimens
Dimensions: length of inflated part of test 270-280 μm, width of inflated part 230-240 μm.
Remarks: only inflated part of test is preserved in all three specimens.
Range and occurrence: Middle Jurassic, late Aalenian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Family Canoptidae Pessagno in Pessagno et al., 1979
Genus *Canoptum* Pessagno in Pessagno et al., 1979
Type species: *Canoptum poissoni* Pessagno in Pessagno et al., 1979
Canoptum sp. cf. *C. anulatum* Pessagno and Poisson, 1981
Plate 1, fig. 2, 3
Material: more then 20 specimens
Dimensions: length of test 310-320 μm, width 85-90 μm.
Remarks: similar shape and size to *Canoptum anulatum* Pessagno and Poisson. One row of "pores" is present on each circumferential ridges between chambers. The "pores" have tendency to join together forming a fractured line. This is probably the result of poor preservation with partial damage (dissolution?) of test wall, especially on circumferential ridges.
Range and occurrence: Early Jurassic, early Pliensbachian to early Toarcian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Family Parvicingulidae Pessagno, 1977
Genus *Elodium* Carter in Carter et al., 1988
Type species: *Elodium cameroni* Carter in Carter et al., 1988
Elodium? sp. cf. *E.*? *mackenziei* Carter 2006 in Goričan et al., 2006
Plate 3, fig. 8
Material: 3 specimens
Dimensions: length of test 290-300 μm, width of test 110-120 μm.
Remarks: the specimens differ from *Elodium*? *mackenziei* Carter by poorly developed circumferential ridges. Apical horn not present.
Range and occurrence: Early-Middle Jurassic, middle-late Toarcian to early-middle Aalenian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Genus *Dictyomitrella* Haeckel, 1887
Type species: *Eucyrtidium articulatum* Ehrenberg, 1875
Dictyomitrella? sp. aff. *D. kamoensis* Mizutani and Kido, 1983
Plate 7, fig. 6
Material: 12 specimens.
Dimensions: length of test 250-260 μm, width of test 160-165 μm.
Remarks: the specimen differs from *Dictyomitrella*? *kamoensis* Mizutani and Kido by more large and wide test. Postabdominal segments are shorter then of *Dictyomitrella*? *kamoensis*, circumferential ridges between chambers are ornamented by prominent smooth nodes.
Range and occurrence: Middle Jurassic, early-middle Bajocian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Family Syringocapsidae Foreman, 1973
Genus *Katroma* Pessagno and Poisson, 1981
Type species: *Katroma neagui* Pessagno and Poisson, 1981
Katroma sp. cf. *K. ninstintsi* Carter 1988 in Carter et al., 1988
Plate 2, fig. 1
Material: 2 specimens.
Dimensions: maximum width 140-150 μm, length 330-340 μm, length of terminal tube 125-130 μm.
Remarks: studied specimen devoid of apical horn (or horns), thorax and abdomen wall structure is strongly damaged.
Range and occurrence: Middle Jurassic, middle-late Toarcian to early-middle Aalenian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Family Obeliscoitidae O'Dogherty, 1994
Genus *Olanda* Hull, 1997
Type species: *Olanda olorina* Hull, 1997
Olanda inflata Bragin, n. sp.
Plate 6, fig. 2-4
1977 *Sethocapsa globosa* Parona - Muzavor, p. 117, Plate 5, fig. 8.
1995a *Sethocapsa* sp. A - Baumgartner et al., p. 506, Plate 3167, figs. 1, 2.
1997 *Olanda* sp. B - Hull, p. 152, Plate 44, figs. 16, 17.
2002 *Obeliscoites* sp. A - Beccaro et al., 2002, Plate 2, fig. 11.
Holotype: Plate 6, fig. 2. Coll. GIN 7438-86-1.
Description: apical part of test conical, slender, without apical horn. Cephalis and thorax poreless, thorax with thin longitudinal ridges. Abdomen and two postabdominal segments with longitudinal rows of small circular pores. Small strictures present between abdomen and postabdominal segments. Third postabdominal segment large, strongly inflated, subsphaerical, with large circular pores in hexagonal pore frames. Aperture small, constricted.
Material: 14 specimens from sample 86-11-24.
Dimensions: length of apical part of test 120-140 μm, maximal width of apical part of test 60 μm, diameter of last postabdominal segment 230-250 μm
Remarks: the specimens differ from *O. olorina* Hull, 1997 by absence of apical horn, by short apical part of test and by large and subcircular last postabdominal segment. Specimens described by Hull (1997) as *Olanda* sp. B have smaller pores, but this minor difference can be interpreted as the result of intraspecific variability. *Olanda inflata* differs from *Stichocapsa globosa* Parona (Parona, 1890, p. 42, Plate 6, fig. 12) by large pores in distinct hexagonal pore frames and by the absence of transversal rows of pores and thin transversal ridges.
Etymology: from inflata (Latin, fem.) - inflated.
Range and occurrence: early-middle Bajocian to latest Tithonian (UAZones 3-13), worldwide in low latitudes.

Nassellaria family indet.
Genus *Lantus* Yeh, 1987
Type species: *Lantus sixi* Yeh, 1987
Lantus sp. cf. *L. obesus* (Yeh, 1987)
Plate 1, fig. 4, 8
Material: more then 20 specimens
Dimensions: length of proximal conical part 95-105 μm, length of last segment 110-120 μm, width of last segment 95-100 μm.
Remarks: the specimens are similar to *L. obesus* (Yeh) but the preservation is very low.
Range and occurrence: Early-Middle Jurassic, Pliensbachian to early-middle Aalenian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Genus *Pleesus* Yeh, 1987
Type species: *Pleesus aptus* Yeh, 1987
Pleesus sp. cf. *P. aptus* Yeh, 1987
Plate 1, fig. 7
Material: 14 specimens
Dimensions: Length of proximal conical part of test 190-200 μm, length of inflated part 80-90 μm, maximal width of test 110-120 μm.
Remarks: Studied forms have very similar shape and size to *Pleesus aptus* Yeh.
Range and occurrence: Early-Middle Jurassic, early Pliensbachian to early-middle Aalenian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Genus *Palinandromeda* Pessagno, Blome and Hull, 1993 in Pessagno et al. (1993)
Type species: *Andromeda crassa* Baumgartner in Baumgartner et al., 1980
Palinandromeda sp. cf. *P. sognoensis* Baumgartner, 1995 in Baumgartner et al. (1995a)
Plate 6, fig. 5
Material: 5 non-complete specimens.
Dimensions: length of non-complete specimen 310 μm, maximum width 300 μm.
Remarks: all observed specimens lack long high conical proximal part of test due to poor preservation. Morphology of inflated part of test is very similar to *Palinandromeda sognoensis* Baumgartner.

Range and occurrence: Middle Jurassic, early-middle Bajocian, Eastern Russia, valley of Amur River, Kiselevka-Manoma accretionary complex.

Nassellaria gen. et sp. indet. 1
Plate 5, fig. 9
1990 Nassellaria gen. et sp. indet. 1 - Hori, fig. 9.46.
1995a *Hsuum*? sp. 1 - Baumgartner et al., p. 286, Plate 2018, figs. 1, 2.
Material: 4 specimens.
Dimensions: length without apical horn 170-180 μm, maximum width 75-80 μm, length of apical horn 40 μm.
Remarks: This non-described species was illustrated from Jurassic of Japan and Tethyan Realm. It has close similarity with *Hsuum feliformis* Jud that possesses two horns in apical part (Jud, 1994), one of them represents prolongation of element A, second (more inclined) - probably of element V. Similar two horns have representatives of Echinocampidae family, like *Arctocapsula incompta* (Bragin, 2009). This specimen cannot be assigned to *Hsuum*, and new genus should be erected. Studied specimens are rare and their preservation is too poor for description of new taxon.
Range and occurrence: UAZones 1-2, Aalenian, worldwide in low paleolatitudes.

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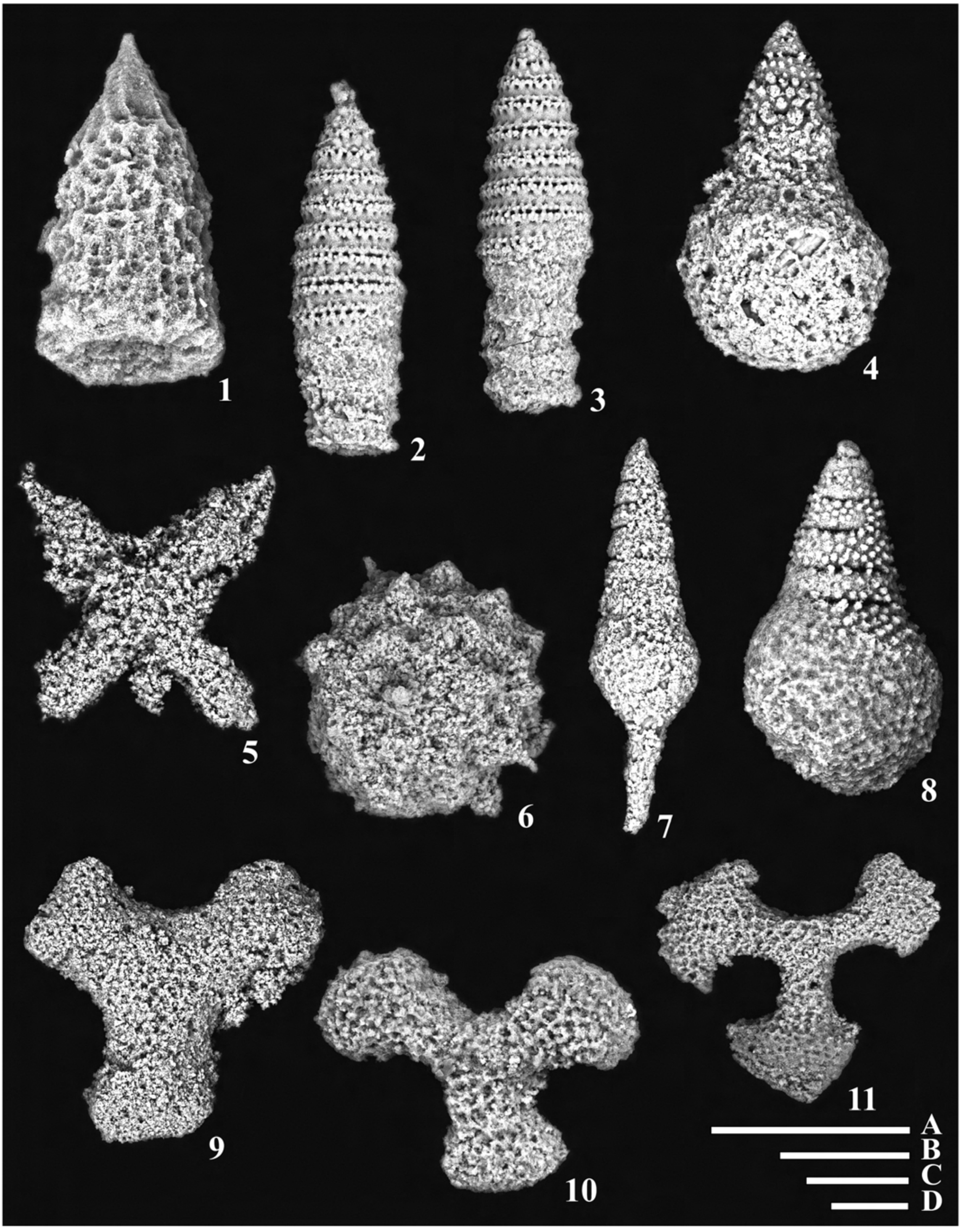

Plate 1 - 1 - *Hsuum exiguum* Yeh and Cheng. 2, 3 - *Canoptum* sp. cf. *C. anulatum* Pessagno and Poisson. 4, 8 - *Lantus* sp. cf. *L. obesus* (Yeh). 5 - *Crucella* sp.. 6 - *Praeconocaryomma* sp. cf. *P. bajaensis* Whalen. 7 - *Pleesus* sp. cf. *P. aptus* Yeh. 9, 10 - *Paronaella* sp. cf. *P. corpulenta* De Wever. 11 - *Paronaella* sp. cf. *P. curticrassa* Carter and Dumitrica.
Fig. 1, 4-8 - sample 86-11-16; fig. 2, 3, 9-11 - sample 86-11-17.
Scale bar 100 µm. A - figs. 1, 4, 8; B - figs 2, 3; C - figs. 5-7, 10; D - figs. 9, 11.

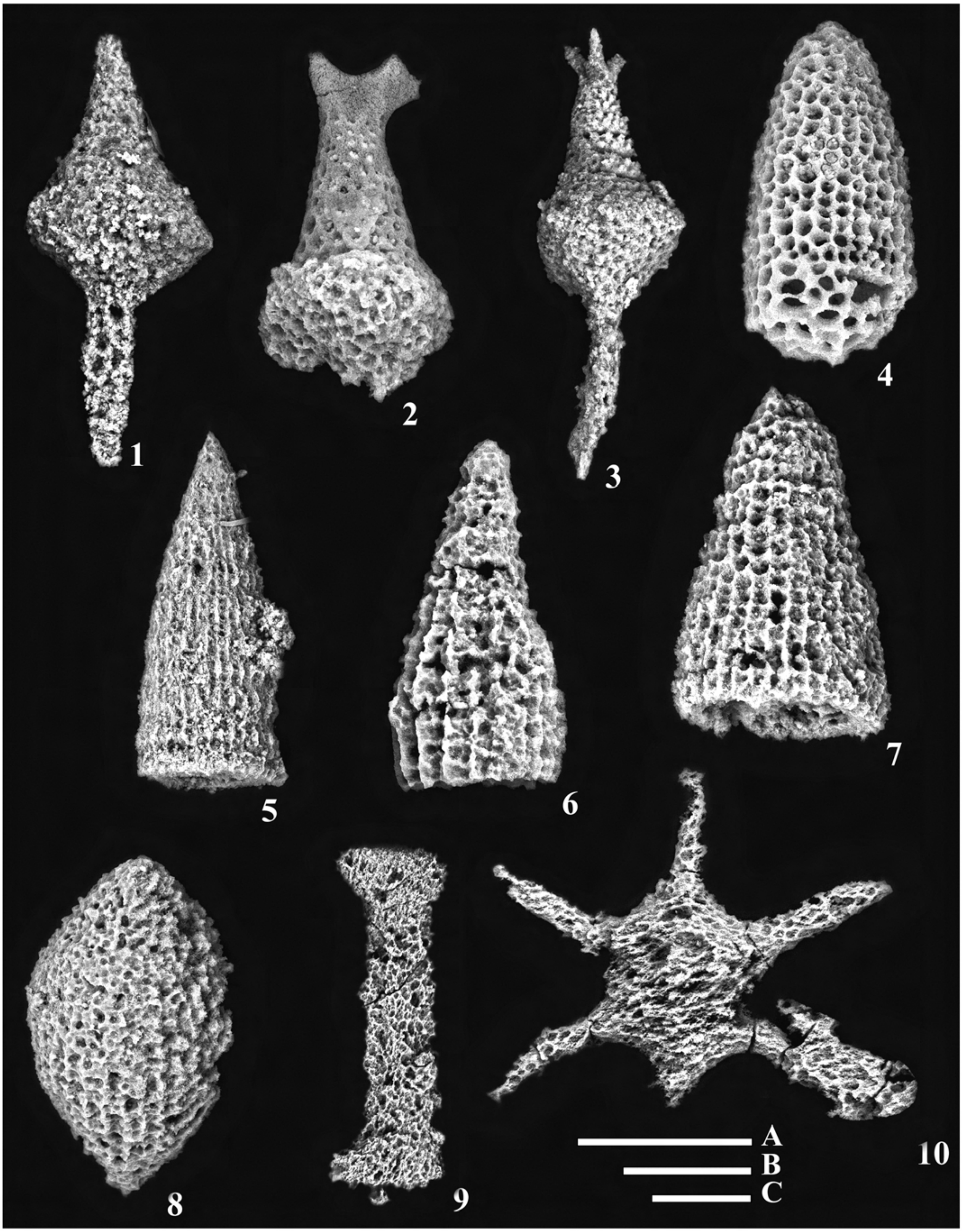

Plate 2 - 1 - *Katroma* sp. cf. *K. ninstintsi* Carter. 2, 3 - *Katroma clara* Yeh. 4 - *Bagotum maudense* Pessagno and Whalen. 5 - *Parahsuum* ? sp. 6 - *Parahsuum* sp. cf. *P. mostleri* (Yeh). 7 - *Parahsuum izeense* (Pessagno and Whalen). 8 - *Protunuma* ? sp. 9 - *Bistarkum rigidium* Yeh. 10 - *Citriduma hexaptera* (Conti and Marcucci).

Fig. 1 - sample 86-11-16; figs. 2-4 - sample 86-11-17; figs. 5-10 - sample 86-11-18.

Scale bar 100 µm. A - figs. 2, 4; B - figs. 1, 3, 5-7, 9; C - figs. 8, 10.

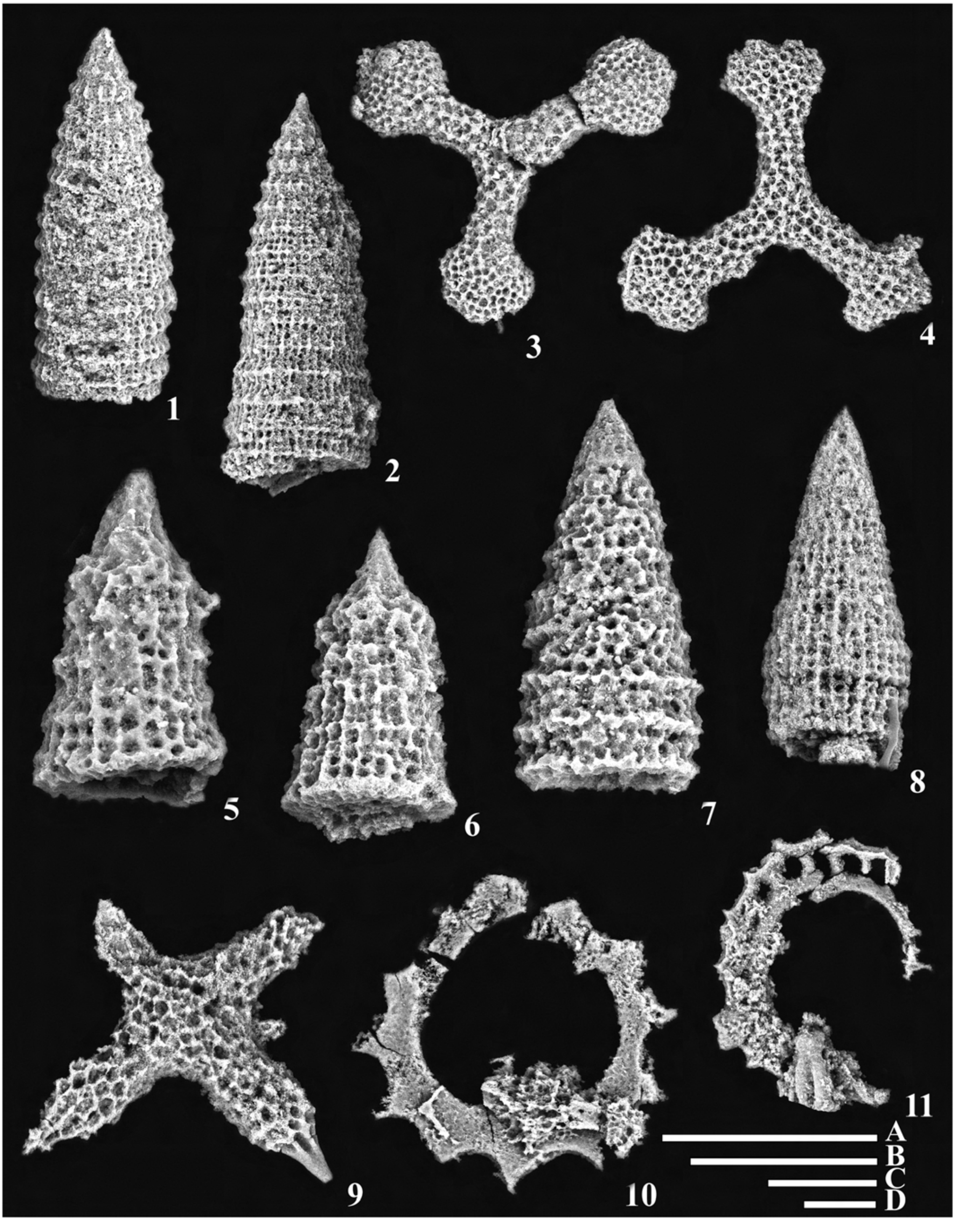

Plate 3 - 1, 2 - *Hsuum* sp. aff. *H. lucidum* Yeh. 3, 4 - *Paronaella grahamensis* Carter. 5, 6 - *Hsuum exiguum* Yeh and Cheng. 7 - *Praeparvicingula gigantocornis* (Kishida and Hisada). 8 - *Elodium*? sp. cf. *E.*? *mackenziei* Carter. 9 - *Crucella* sp. cf. *C. angulosa angulosa* Carter. 10 - *Pseudoheliodiscus* sp. 11 - *Japonisaturnalis diplocyclis* (Yao).
All specimens are from sample 86-11-20.
Scale bar 100 µm. A - fig. 5; B - figs 6, 7; C - figs 2, 8-11; D - figs. 1, 3, 4.

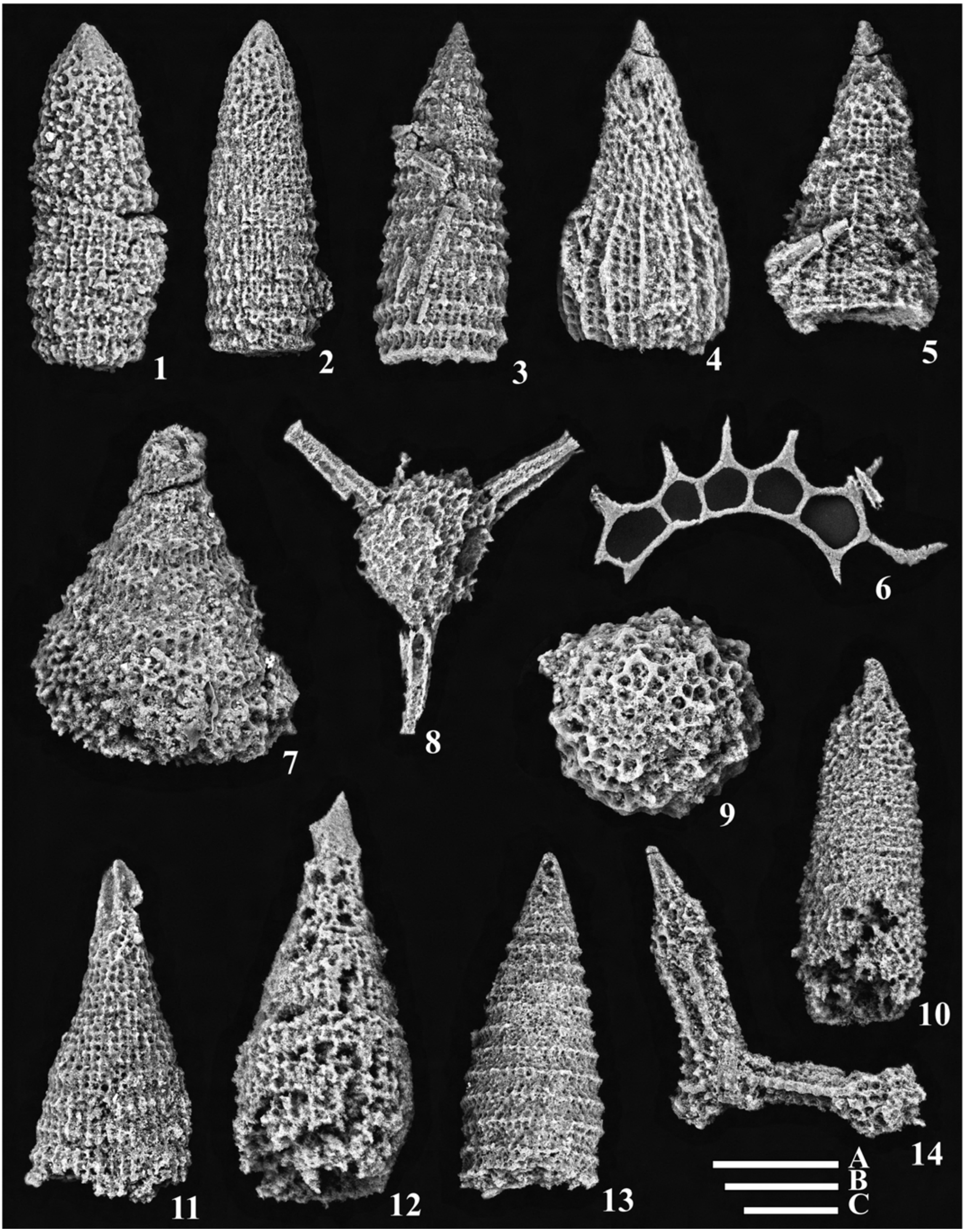

Plate 4 - 1, 2 - *Parahsuum*? *grande* Hori and Yao. 3 - *Hsuum* sp. aff. *H. lucidum* Yeh. 4, 5 - *Hsuum altile* Hori and Otsuka. 6 - *Japonisaturnalis diplocyclis* (Yao). 7 - *Parahsuum*? sp. cf. *P. hiconocosta* Baumgartner and De Wever. 8 - *Triactoma* sp. 9 - *Praeconocaryomma* sp. 10 - *Ristola* sp. 11 - *Parahsuum cruciferum* Takemura. 12 - *Parahsuum* sp. 13 - *Praeparvicingula* sp. A. 14 - *Tritrabs* sp. cf . *T. simplex* Kito and De Wever.
Figs. 1, 3-6, 8 - sample 86-11-22; figs 2, 7, 9-14 - sample 86-11-38
Scale bar 100 μm. A - figs. 5, 12; B - figs. 4, 9, 11; C - figs. 1-3, 6-8, 10, 13, 14.

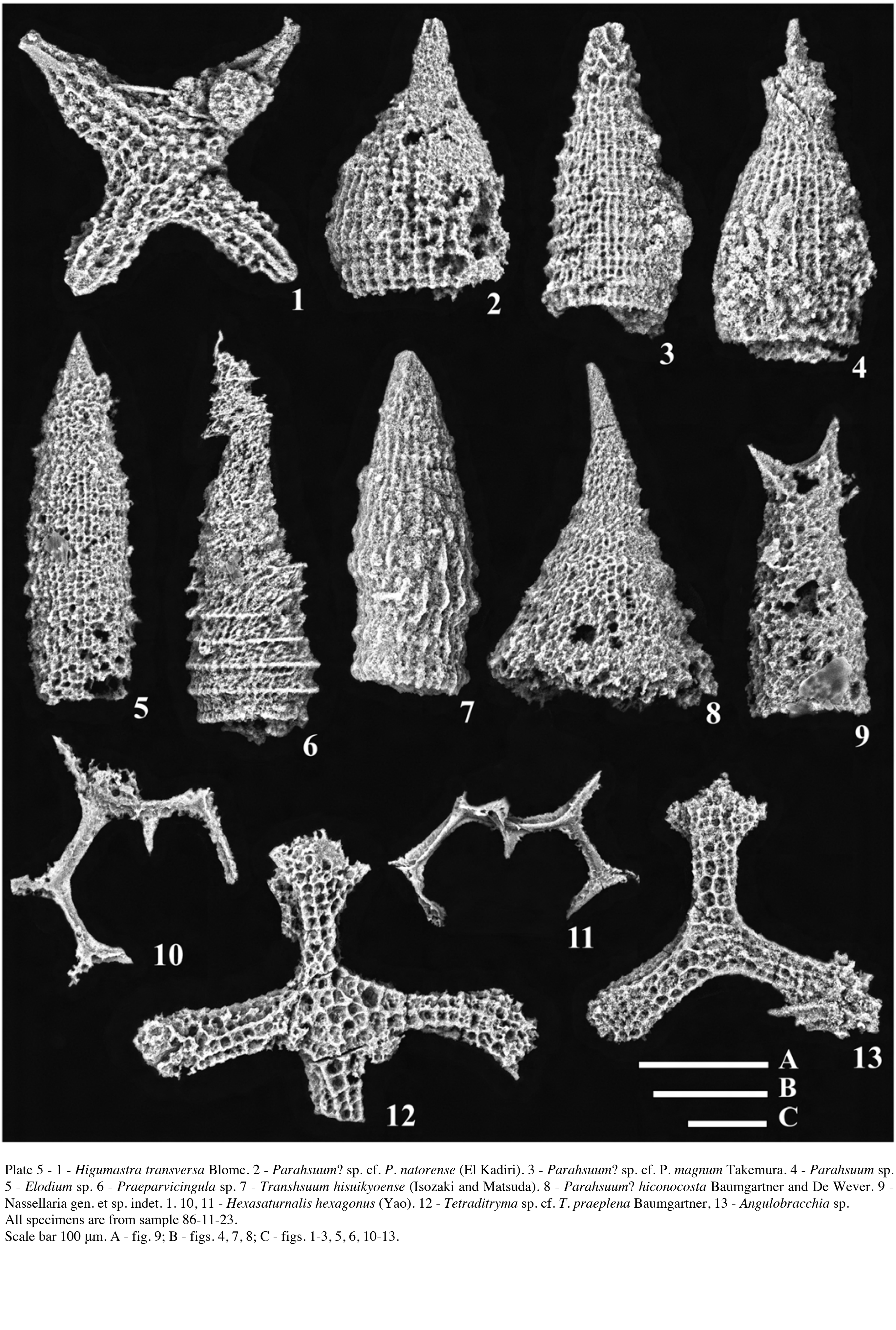

Plate 5 - 1 - *Higumastra transversa* Blome. 2 - *Parahsuum*? sp. cf. *P. natorense* (El Kadiri). 3 - *Parahsuum*? sp. cf. P. *magnum* Takemura. 4 - *Parahsuum* sp. 5 - *Elodium* sp. 6 - *Praeparvicingula* sp. 7 - *Transhsuum hisuikyoense* (Isozaki and Matsuda). 8 - *Parahsuum*? *hiconocosta* Baumgartner and De Wever. 9 - Nassellaria gen. et sp. indet. 1. 10, 11 - *Hexasaturnalis hexagonus* (Yao). 12 - *Tetraditryma* sp. cf. *T. praeplena* Baumgartner, 13 - *Angulobracchia* sp.
All specimens are from sample 86-11-23.
Scale bar 100 µm. A - fig. 9; B - figs. 4, 7, 8; C - figs. 1-3, 5, 6, 10-13.

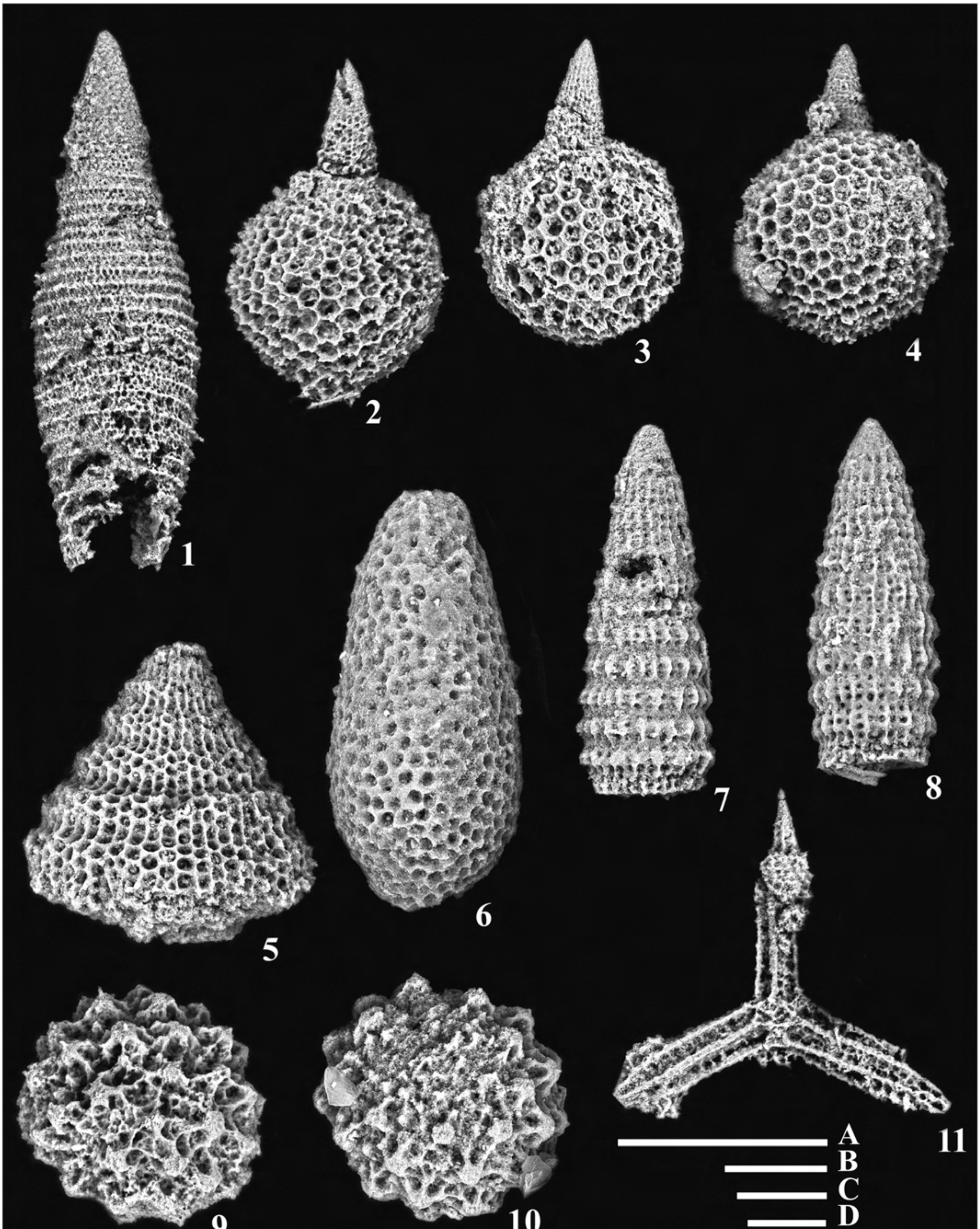

Plate 6 - 1 - *Mirifusus proavus* Tonielli. 2-4 - *Olanda inflata* Bragin, n. sp.; 2- holotype. 2-5 - *Palinandromeda* sp. cf. *P. sognoensis* Baumgartner. 6 - *Gongylothorax* sp. 7, 8 - *Transhsuum hisuikyoense* (Isozaki and Matsuda). 9, 10 - *Praeconocaryomma* sp. cf. *P. decora* Yeh. 11 - *Tritrabs* sp. cf. *T. simplex* Kito and De Wever.
All specimens are from sample 86-11-24.
Scale bar 100 μm. A - fig. 6; B - figs. 2, 5, 7, 8; C - figs. 1, 9-11; D - figs. 3, 4.

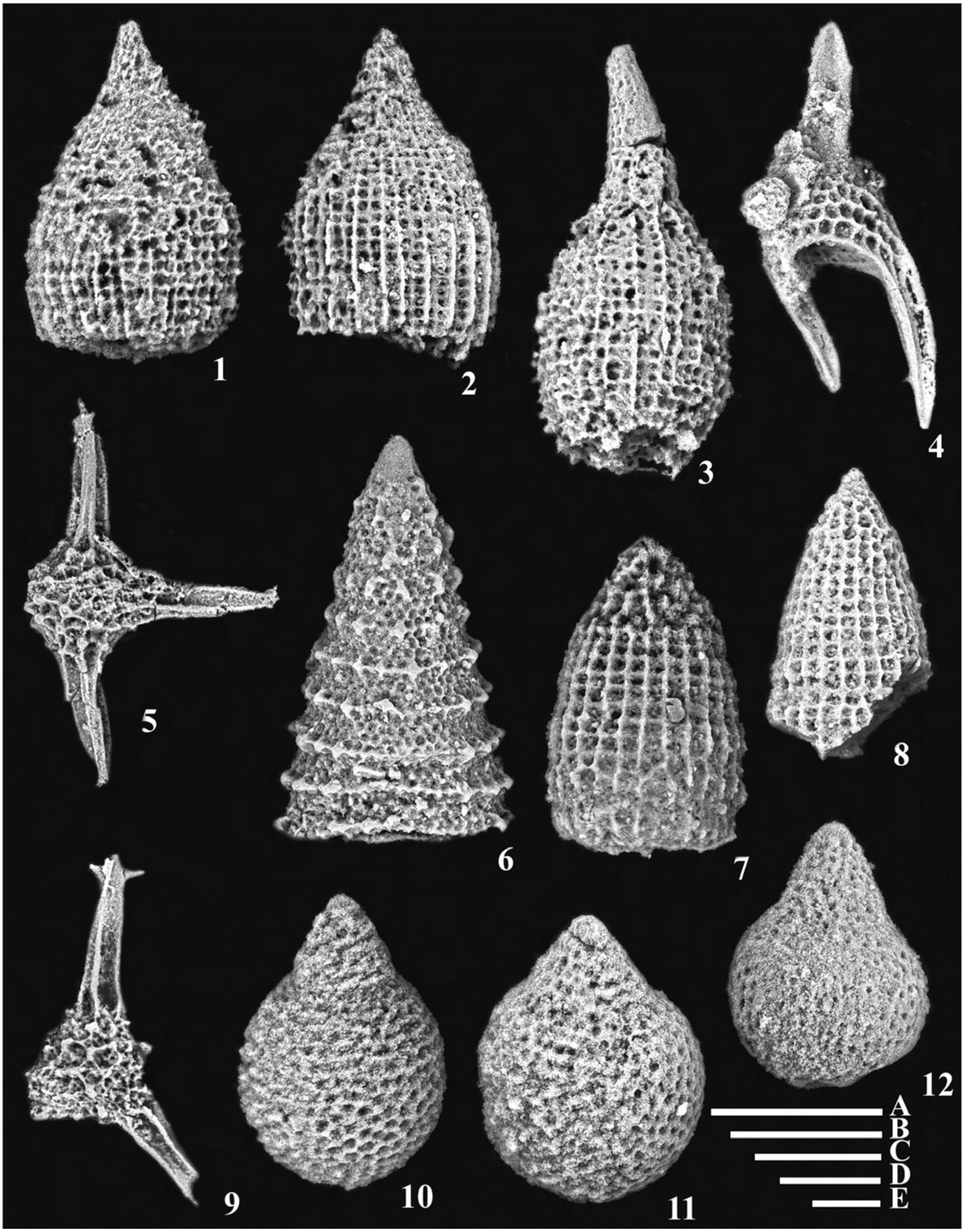

Plate 7 - 1, 2 - *Sella beniderkoulensis* (El Kadiri). 3 - *Sella chrafatensis* (El Kadiri). 4 - *Napora* sp. 5 - *Emiluvia splendida* Carter. 6 - *Dictyomitrella*? sp. aff. *D. kamoensis* Mizutani and Kido. 7, 8 - *Parahsuum izeense* (Pessagno and Whalen). 9 - *Acaeniotylopsis* sp. 10-12 - *Zhamoidellum* spp.
All specimens are from sample 86-11-24.
Scale bar 100 µm. A - figs. 10-12; B - figs. 6, 7; C - figs. 3, 8; D - figs 1, 2, 4; E - figs 5, 9.