

UPPER JURASSIC RADIOLARIANS FROM INICI MT. AREA (NORTH-WESTERN SICILY, ITALY): BIOCHRONOLOGY AND CALIBRATION BY AMMONITES

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Abstract. This research is devoted to the biostratigraphic analysis of radiolarian assemblages of the Upper Jurassic intermediate siliceous member of the Rosso Ammonitico Formation in the Inici Mountain area (North-western Sicily, Italy). The aims of this paper are to give the first description of the radiolarian associations, to establish a direct biostratigraphy by means of radiolarians, and to calibrate radiolarian zones by ammonite zones.

During Late Jurassic time, Inici Mt. area was part of a submerged pelagic plateau characterized by the deposition of Rosso Ammonitico condensed facies (Rosso Ammonitico Inferiore -RAI- and Rosso Ammonitico Superiore -RAS-) and basinal facies (Rosso Ammonitico Medio -RAM-). Four stratigraphical sections of RAM have been studied: Fornazzo Strada, Fornazzo Cava, Castello Inici and Balada di Baida. In all sections RAM consists of siliceous nodular limestone alternating with marly limestone, and contains moderately preserved radiolarians.

Biostratigraphic correlation has been made using the Unitary Associations (UAs) method: 11 UAs have been identified and grouped in 5 biozones (Unitary Associations Zones: UAZs) whose age is calibrated by ammonites found in the same successions and/or in the under- and overlying formations. Ammonite assemblages assign the top of RAI to mid Oxfordian and the top of RAM to upper Kimmeridgian.

The ranges of *Eucyrtidiellum unumaense* (Yao) s.l. and *Williriedellum* (?) *marucciae* Cortese have been extended with respect to those stated in Baumgartner et al. 1995a. Syringocapsidae family is extraordinarily abundant and new morphogroups are presented here: *Podobursa* sp. A, *Podobursa* sp. B, *Syringocapsa* sp. A, *Syringocapsa* sp. B. Other new morphogroups are: *Fultacapsa sphaerica* (Ozoldova) ssp. A, *Loopus* sp. A, transitional forms between *Emiluvia orea* Baumgartner and *Emiluvia ultima* Baumgartner & Dumitrica, transitional forms between *Tetratrans bulbosa* Baumgartner and *Tetratrans zealis* (Ozoldova).

Riassunto. La ricerca svolta riguarda l'analisi biostratigrafica delle associazioni a radiolari del RAM (Rosso Ammonitico Medio: membro pelagico e siliceo del Rosso Ammonitico) nell'area del M. Inici (Sicilia

nord-occidentale, Italia). Gli scopi di tale lavoro sono di presentare la prima descrizione delle associazioni a radiolari nelle sezioni del RAM del M. Inici, di stabilire una biocronostratigrafia diretta tramite i radiolari e di calibrare le zone a radiolari con le zone ad ammoniti.

Alla fine del Giurassico il M. Inici costituiva parte di un alto strutturale caratterizzato dalla deposizione di facies condensate (Rosso Ammonitico Inferiore -RAI- e Rosso Ammonitico Superiore -RAS-) e di facies bacinali (Rosso Ammonitico Medio -RAM-). Sono state studiate quattro sezioni stratigrafiche del RAM, costituito essenzialmente da calcari silicei nodulari alternati a calcari marnosi. La preservazione dei radiolari è moderata e simile in tutte le sezioni.

La correlazione biostratigrafica è stata effettuata con il metodo delle Associazioni Unitarie (UAs): 11 UAs sono state identificate e raggruppate in 5 biozone (Zone ad Associazioni Unitarie: UAZs). L'età delle 5 UAZs è fornita dalla calibrazione con le ammoniti rinvenute nelle successioni studiate e/o nelle formazioni sovra- e sottostanti. Le associazioni ad Ammoniti assegnano il tetto del RAI all'Oxfordiano medio ed il tetto del RAM al Kimmeridgiano superiore.

Le età di *Eucyrtidiellum unumaense* (Yao) s.l. e *Williriedellum* (?) *marucciae* Cortese sono state estese rispetto a quelle proposte da Baumgartner et al. 1995a. La famiglia Syringocapsidae è abbondantemente rappresentata e vengono presentati nuovi morfogruppi: *Podobursa* sp. A, *Podobursa* sp. B, *Syringocapsa* sp. A, *Syringocapsa* sp. B. Altri nuovi morfogruppi sono: *Fultacapsa sphaerica* (Ozoldova) ssp. A, *Loopus* sp. A, forme transizionali tra *Emiluvia orea* Baumgartner ed *Emiluvia ultima* Baumgartner & Dumitrica, forme transizionali tra *Tetratrans bulbosa* Baumgartner e *Tetratrans zealis* (Ozoldova).

Introduction

Radiolarian assemblages have been identified in the intermediate pelagic siliceous member (RAM) of the Rosso Ammonitico Fm. in the Inici Mt. area (North-western Sicily, Italy). No previous biostratigraphic data are available for the RAM in this area. The ages for upper and lower boundaries are currently based on the ages of under- and overlying members (Rosso Ammonitico In-

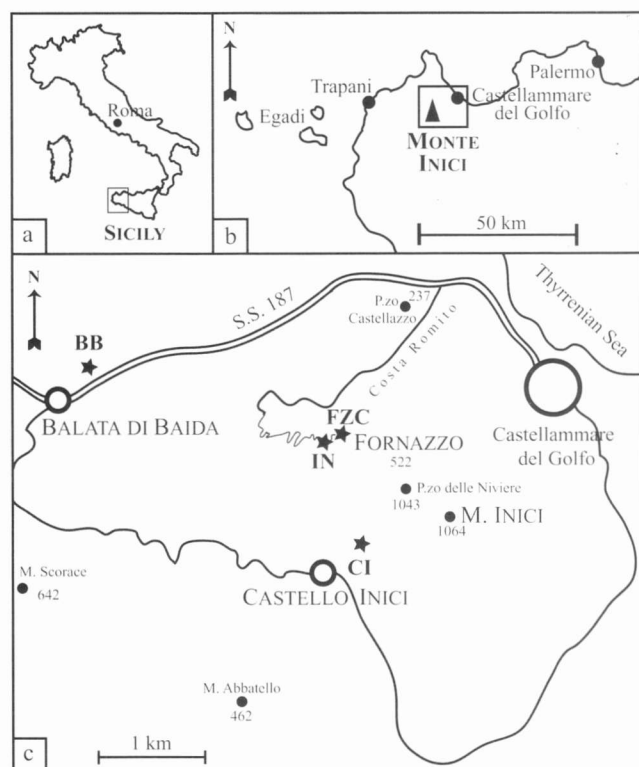


Fig. 1 - Sketch map of studied area in the North-western Sicily, Italy (a), in the Inici Mt. area (b), and geographical location of studied sections (c). BB: Balata di Baida, CI: Castello Inici, FZC: Fornazzo Cava, IN: Fornazzo Strada.

feriore -RAI- and Rosso Ammonitico Superiore -RAS-). Radiolarians occur throughout the entire RAM, and their study is useful for establishing the chronostratigraphic range of the succession.

The studied sections are important because of the co-occurrence of radiolarians and ammonites in the same successions, as well as the presence of ammonites in both the under- and overlying sediments. This co-occurrence improves the radiolarian biostratigraphy through the better defined age provided by ammonites.

Radiolarian assemblages of Inici Mt. are very similar to the assemblages of other Tethyan sections. The total ranges of most taxa are still poorly known, mainly because the preservation of Mesozoic radiolarians strongly depends on suitable lithologies and dissolution. This fact hinders the application of interval zones defined by first and last appearances of a single species. Unitary Associations method (Guex 1987, 1991) best copes with the incompleteness of the radiolarian record. Unitary Associations (UAs) represent maximal assemblages of co-occurring species, and are based on the totality of mutual relationships (superposition, co-occurrence and mutual exclusion) of all taxa from a given dataset (Guex 1987, 1991). A Unitary Association Zone (UAZ) is a biochronozone that results from the union of two or more UAs. A UAZ is therefore characterized by groups of spe-

cies and groups of pairs of species resulting exclusively from the union of given UAs in the UAZ. In a UAZ all the elements of the joined UAs are considered as virtually coexistent.

In addition, high resolution sampling of the sections permits a more detailed distribution of radiolarian taxa along the studied succession and, consequently, identifies a larger number of UAs. This fact results in a better zonation by UAZ.

Geological setting

The Sicilian chain represents a segment of the Alpine collisional belt formed during the Mesozoic time along the boundary between the European and African plates (Di Stefano & Gullo 1997).

At the Triassic-Jurassic boundary, tectonic movements (associated with the opening of the North Atlantic Ocean and the shifting between the African and European plates) progressively dissected the Triassic Siculo-Tunisian carbonate platform. In the mid Early Jurassic the tectonic activity became stronger, dissecting definitively the Siculo-Tunisian platform, and generating several blocks with different subsidence rates and drowning times. Around the end of the Early Jurassic, the wide Siculo-Tunisian platform became a complex mosaic of basins, pelagic plateaux and limited platform sectors (Di Stefano 2002). During the Mid-Late Jurassic extensional tectonic movements continued to modify the paleogeographical arrangement of paleoenvironments. The Late Jurassic was the time of the deposition for the condensed nodular ammonite-bearing Rosso Ammonitico Formation on the pelagic plateaux (Inici Mt. area was part of the Trapanese submerged plateau), and of Tethyan acme of siliceous sediments (Baumgartner 1987). By the end of the Late Jurassic the environment became more uniform: both in the basins and on the plateaux, and pelagic sediments turned gradually into fine grained white calpionellids limestone (Lattimusa Fm.).

Lithological description

The intermediate pelagic siliceous member (RAM) of the Rosso Ammonitico Fm. has been studied in four stratigraphical sections near Castellammare del Golfo (North-western Sicily, Italy; Fig. 1). Two sections crop out near the Fornazzo locality (northern side of Inici Mt.): the Fornazzo Strada section is situated along the road toward the old Fornazzo quarry, and the Fornazzo Cava section is exposed in the old quarry (attainable by a small footpath). The Castello Inici section is located along a small road on the south-western side of Inici Mt. The last studied section, Balata di Baida, crops out on the left side of the Sarcona river, close to Balata di Baida village.

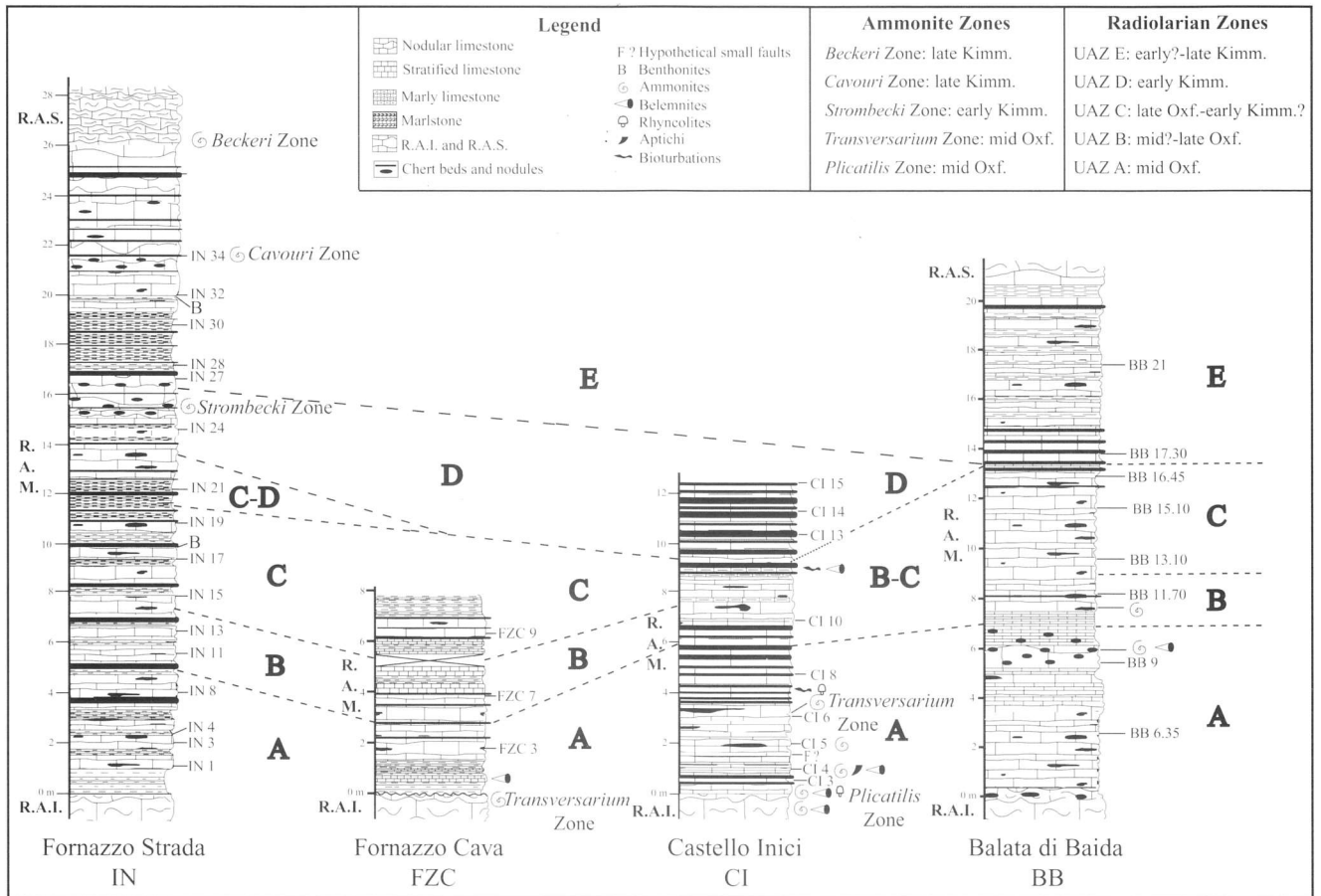


Fig. 2 - a) Stratigraphical sections of the Upper Jurassic intermediate siliceous member (RAM) of the Rosso Ammonitico Fm. in the Inici Mt. area, and their correlation by means of radiolarian biozones (Unitary Associations Zones: UAZs A-E). RAI: Rosso Ammonitico Inferiore, RAM: Rosso Ammonitico Medio, RAS: Rosso Ammonitico Superiore.

Fornazzo Strada (Fig. 2)

In this section, the RAM is 26 m thick, showing a sharp basal contact with RAI and a gradual top transition toward RAS. The base of RAM is marked by about 1 m of whitish-green clayey marlstone and pink marly limestone, followed by an alternance of siliceous limestone and calcareous marlstone. Red siliceous limestone (wackestone) is well stratified: individual layers are 5-15 cm thick with a planar base and undulating top. The grey calcareous marlstone has very thin (3-5 cm) layers often grouped in thicker packages (20-40 cm). Chert is present throughout the entire succession, either stratiform or nodular, with a highly variable colour (red, brown, black and yellow). When stratiform, chert beds are 10-15 cm thick and normally reddish-brown. The nodules range from 3-6 cm to 10-12 cm in size, and are variable in colour. Scattered silicification is present where chert beds and nodules are absent. Towards the top of RAM, the siliceous limestone shows greater clay content, the abundance of chert nodules increases, chert layers prevail, and a strongly nodular structure begins to develop.

Fornazzo Cava

Here RAM crops out for 8 m only, the upper part and the contact with RAS are covered. A hardground surface marks the contact between RAI and RAM. The base of the RAM is represented by about 1 m of whitish-green clayey marlstone and a few layers of pink marly limestone. Stratification is very thin with *Chondrites* on the bedding planes and scattered small chert nodules. While the lithotypes and their organisation are the same as in the Fornazzo Strada section, the only difference is the presence of ammonites moulds and belemnites. This section is important because of the close co-occurrence of radiolarians and ammonites.

Castello Inici (Fig. 2)

Castello Inici section exposes the sharp contact between RAI and RAM and about 12 m of RAM, the rest is covered. The section starts with 1.5 m of thin alternating siliceous limestone and marly limestone; the remaining strata are very similar to Fornazzo sections. Chert layers and nodules are more widespread, and a diffuse silicification is present where chert beds and nodules are absent. Macrofossils such as ammonites, belemnites, aptychi, and rhyncholites occur frequently.

Balata di Baida (Fig. 2)

This section includes the entire RAM which is about 21 m thick; the contact is gradual between RAI and RAM and sharp between RAM and RAS. The base of RAM was established in correspondence of a layer of red siliceous limestone with red and black chert nodules. These red siliceous limestone are locally interbedded with stratified or nodular limestone and marlstone. Chert is present as scattered silicification, the abundance and dimensions of chert nodules is much reduced. The main concentration of the chert beds is between 16 to 18 m above the base of the section. Ammonites and belemnites also occur in this section.

Ammonite data

Fornazzo Strada (Fig. 2) - The first ammonite is a specimen of *Lessinicerus* sp. at 15.5 m. It belongs to *Strombecki* Zone and suggests an early Kimmeridgian age for the middle-upper part of the section (Bovero 2000). At 22 m above the base of RAM, a specimen of

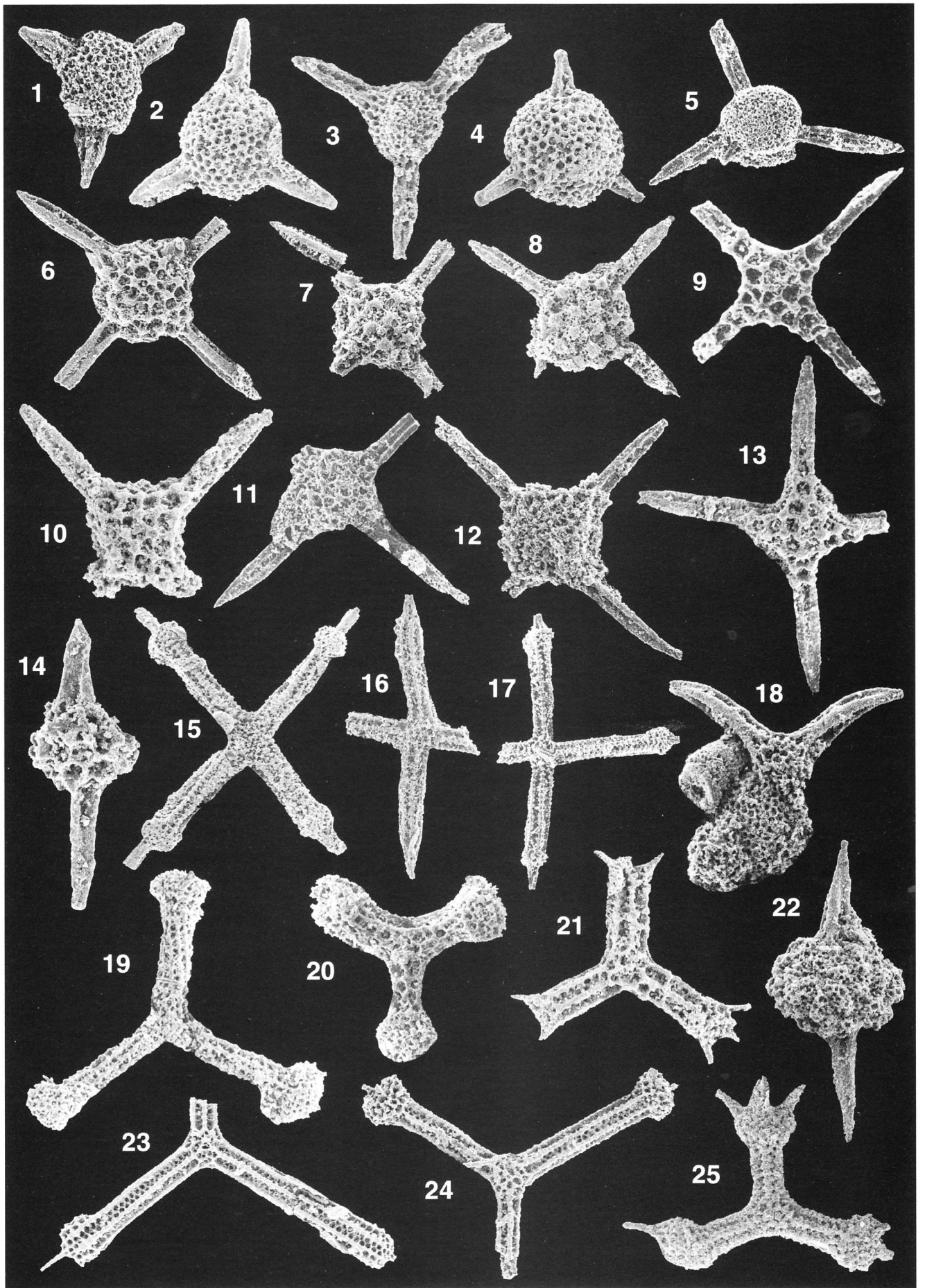


PLATE 1

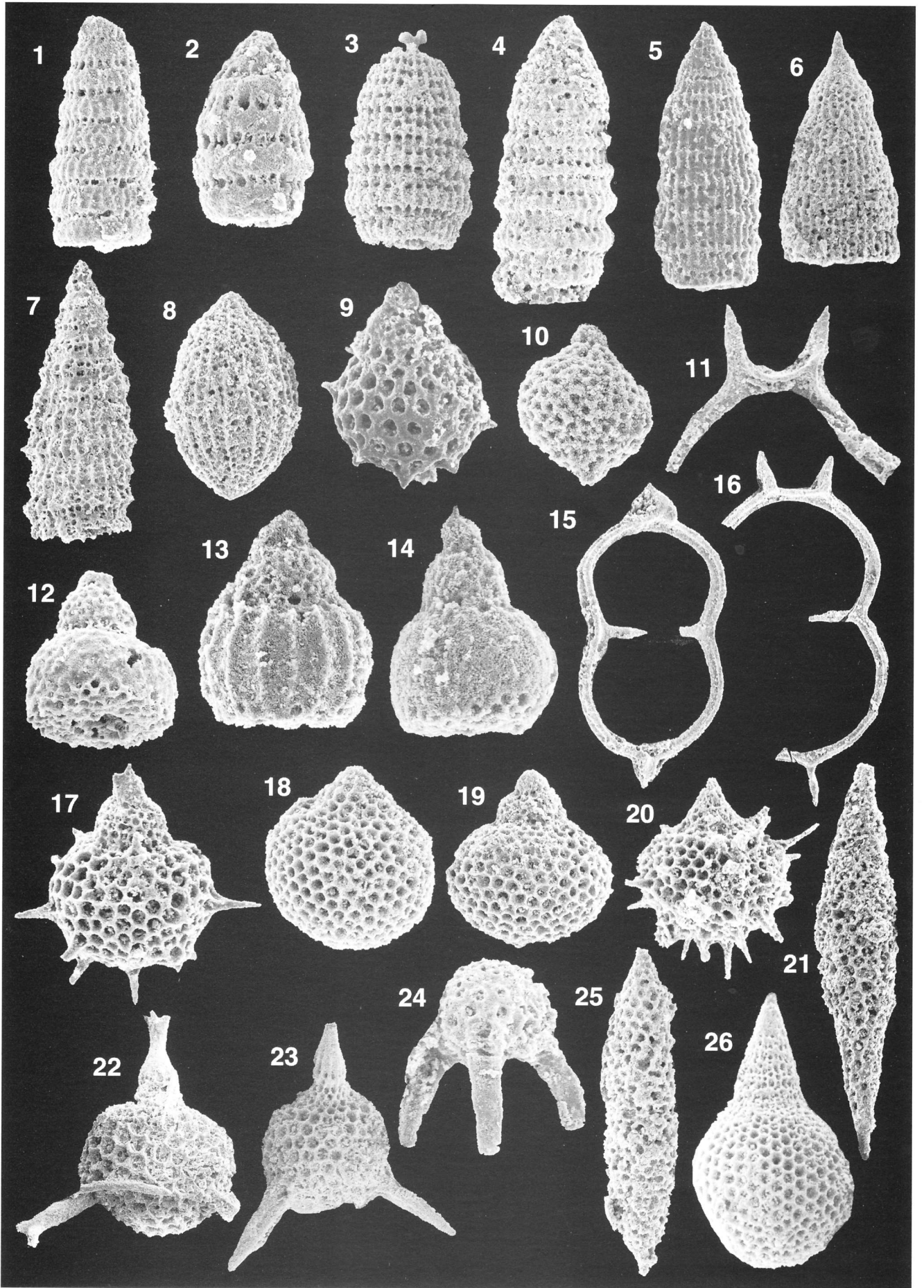


PLATE 2

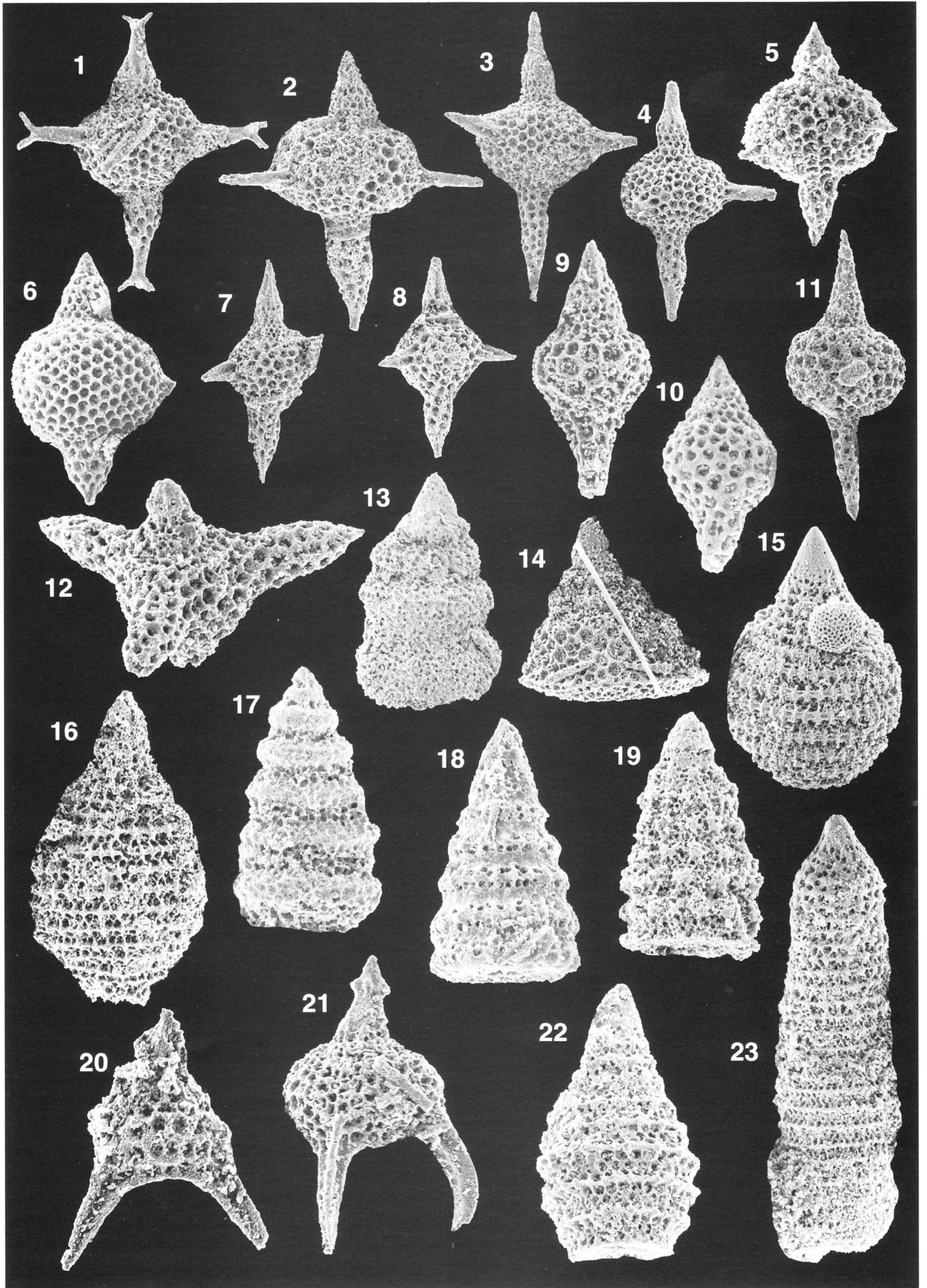


PLATE 3

Radiolarian systematics

The systematics will be discussed only for a few species due to the biostratigraphic nature of this paper. The complete list of species is shown in Fig. 3, where distribution in the samples, MRD (Mesozoic Radiolarian Database) codes and the illustrations are indicated. Species marked with an asterisk have not been used for biochronologic purposes because of their discontinuous record. All species carrying a MRD number-code are illustrated in Baumgartner et al. (1995b), where the synonymy is available. In some cases, the taxonomy of Baumgartner et al. (1995b) has been revised without changing the morphological concept and maintaining the MRD code. The species bearing codes composed of letters and numbers are not illustrated in Baumgartner et al. (1995b) and the main references are reported here. Radiolarian preservation is moderate and about the same for all sections.

Genus *Archaeodictyomitra* Pessagno, 1976

Archaeodictyomitra wangi * Yang, 1993

Pl. 2, fig. 5

1993 *Archaeodictyomitra wangi* Yang, p. 113, pl. 20, figs 2-3, 16; pl. 22, fig. 9.

Genus *Emiluvia* Foreman, 1973

This genus is represented by several species in the studied sections. Many transitional forms between *Emiluvia orea* Baumgartner (Pl. 1, fig. 6) and its descendant *Emiluvia ultima* Baumgartner & Dumitrica (Pl. 1, fig. 8) have been found in the lower half of the RAM succession. Transitional forms (Pl. 1, fig. 7) between *E. orea* and *E. ultima* have more prominent and less numerous nodes than in *E. orea* but the structure of the spines is closer to *E. orea*.

Genus *Fultacapsa* Ozvoldova & Frantova, 1997

Fultacapsa sphaerica (Ozvoldova, 1988)

Pl. 2, figs 22-23

1987 *Lythocanoma* sp. cf. *L. xiphophora* (Rüst) - Aita, p. 65, pl. 13, fig. 2.

1987 *Lythocanoma* sp. cf. *L. longicorne* (Rüst) - Aita, p. 65, pl. 13, fig. 3.

1988 *Acotripus sphaericus* Ozvoldova, p. 376, pl. 5, figs 1-5, 7; pl. 8, fig. 7.

1995 *Sethocapsa sphaerica* (Ozvoldova) - Baumgartner et al. (1995b), p. 500, pl. 3168, fig. 1-4.

1997 *Fultacapsa sphaerica* (Ozvoldova) - Ozvoldova & Frantova, p. 59, pl. 5, figs 1-2.

Clear morphological differences exist among the specimens. Two subspecies have been distinguished: *Fultacapsa sphaerica sphaerica** and *Fultacapsa sphaerica* n. ssp. A*. *F. sphaerica sphaerica** is identical to the holotype (Ozvoldova 1988, pl. 5, fig. 1). *F. sphaerica* ssp. A* (Pl. 2, fig. 22) differs from *F. sphaerica sphaerica** (Pl. 2, fig. 23) by the presence of 3-4 very short spines at the end

of the apical horn and of the spines. The record of these two subspecies in the sections is discontinuous and for the biostratigraphical analysis it is more useful to consider them as *Fultacapsa sphaerica* s.l.

Genus *Loopus* Yang, 1993

***Loopus* sp. A**

Pl. 2, fig. 2

This species is characterized by a bell-shaped test with 4-7 segments, each separated by a row of quite elongated large pores, and by the absence of longitudinal costae. It differs from *Loopus primitivus* (Matsuoka and Yao) (Pl. 2, fig. 1) by the number of segments, the shape and size of pores, and the absence of longitudinal costae.

Genus *Olanda* Hull, 1997

Olanda* sp. B sensu Hull, 1997

Pl. 2, fig. 26

1997 *Olanda* sp. B Hull, p. 152, pl. 44, figs 16-17.

Genus *Podobursa* Wisniowski, 1889, emend. Foreman, 1973

This genus is extraordinarily abundant in all the sections. Its morphological variability is very high and new morphogroups have been identified.

Podobursa triacantha (Fischli, 1916) gr.

Pl. 3, figs 2-4

1916 *Theosyringium acanthophorum* Rüst var. *triacanthus* Fischli - Fischli, p. 47, fig. 38.

1973 *Podobursa triacantha* (Fischli) - Foreman, p. 266, pl. 13, fig. 1.

This group includes specimens with a long apical part, enlarged final chamber, long terminal tube and three spines. Apical parts, pore patterns and structure of the spine can differ greatly from one specimen to another.

***Podobursa* sp. A**

Pl. 3, figs 5-6

This morphogroup is characterized by a short apical part, a very globose final chamber, a short distal tube and three or more short spines. The distal tube is normally shorter than the final chamber; sometimes the dis-

Fig. 3 - Distribution of radiolarian taxa in the studied samples of Fornazzo Strada (IN), Fornazzo Cava (FZC), Castello Inici (CI) and Balata di Baida (BB) sections. Species marked with an asterisk have not been used for biostratigraphical purposes. The column "MRD" refers to the species codes necessary to mathematically treat the data by the software BioGraph. The column "Illustration" refers to the photos in the plates.

tal tube can be as long as the final chamber. Pores are mainly hexagonal. The inflated segment is larger and the distal tube is shorter than in *Podobursa triacantha* (Fischli, 1916) gr.

Podobursa sp. B

Pl. 3, figs 7-8

This morphogroup is similar to *Podobursa triacantha* (Fischli) gr. (Pl. 3, figs 2-4) but differs by shorter terminal tube, by the presence of very large pores on the enlarged final chamber, by the shorter spines, and by the smaller size.

Genus *Pseudoeucyrtis* Pessagno, 1977a

Pseudoeucyrtis sp. B sensu Widz, 1991

Pl. 2, fig. 21

1991 *Pseudoeucyrtis* sp. B Widz, p. 253, pl. 3, fig. 22.

Genus *Saitoum* Pessagno, 1977b

Saitoum dercourti Widz & De Wever, 1993

Pl. 2, fig. 24

1993 *Saitoum dercourti* Widz and De Wever, p. 85, pl. 1, fig. 17.

Genus *Syringocapsa* Neviani, 1900

Syringocapsa sp. A

Pl. 3, figs 9-10

This morphogroup includes specimens with a short and very stout apical part, slightly enlarged final chamber and stout terminal tube. Small rounded pores randomly ordered on the apical part; large pentagonal to hexagonal pores on the final chamber and terminal tube. This species differs from *Syringocapsa* sp. B (Pl. 3, fig. 11) by the stout apical part and a stout terminal tube.

Syringocapsa sp. B*

Pl. 3, fig. 11

This morphogroup is characterized by a long apical part, an enlarged final chamber and long thin distal tube. The pores are quite large and hexagonal to pentagonal in shape. This species differs from *Syringocapsa* sp. A (Pl. 3, figs 9-10) by the slender apical part and the longer distal tube.

Genus *Tetracapsa* Haeckel, 1881

Tetracapsa molengraaffi * (Tan, 1927)

Pl. 2, fig. 9

1927 *Cyrtocapsa Molengraaffi* Tan, p. 66, pl. 14, figs 114-116.

1999 *Tetracapsa molengraaffi* (Tan) - Kiessling, p. 60, pl. 13, fig. 5.

Genus *Tetratrabs* Baumgartner, 1980

This genus is represented in the studied sections by two species: *Tetratrabs bulbosa* Baumgartner and *Tetratrabs zealis* (Ozvodova). Transitional forms (Pl. 1, fig. 16) between *T. bulbosa* and *T. zealis* have a slightly enlarged terminal part of the rays and prominent nodes at the base of the spines. The structure of the spines is the same as in *T. zealis*.

Genus *Zhamoidellum* Dumitrica, 1970

Zhamoidellum (?) exquisita * Hull, 1997

Pl. 2, fig. 17

1997 *Zhamoidellum (?) exquisita* Hull, p. 132, pl. 38, figs 5-16-17-21.

Radiolarian taxa	MRD codes	UAZ																			
		A			B	C				D	E										
		1	2	3	4	5	6	7	8	9	10	11									
<i>Willriedellum (?) marcucciae</i>	4060	...	■																		
<i>Homoeoparonaella argolidensis</i>	3103	...	■	■	■	■															
<i>Zhamoidellum ventricosum</i>	3308	...	■	■	■	■	■	■	■												
<i>Transsuum brevicostatum</i> gr.	3181	...	■	■	■	■	■	■	■	■	■	■	■								
<i>Ristola altissima altissima</i>	3241	...	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Hexasaturnalis minor</i>	3085	...	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Eucyrtidiellum unumaense</i> s.l.	3052	.....	■																	
<i>Bernoullius dicera</i>	3223	.....	■	■																
<i>Emiluvia orea</i>	3224	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Tetratrabs zealis</i>	3121	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Xitus magnus</i>	3259	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Dicerosaturnalis angustus</i>	3082	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Loopus</i> sp. A	LPA0	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Tritrabs exotica</i>	3119	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Parahsuum carpathicum</i>	3240	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Podobursa</i> sp. A	PDA0	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Podobursa</i> sp. B	PDB0	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Podobursa triacantha</i> gr.	PDT0	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Tritrabs ewingi worzeli</i>	3115	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Emiluvia hopsoni</i>	3225	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Tritrabs ewingi</i> s.l.	3113	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Tritrabs casmaliaensis</i>	3117	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Triactoma blakei</i>	3095	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Tetratrabs bulbosa</i>	3122	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Eucyrtidiellum ptyctum</i>	3017	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Napora lospensis</i>	3036	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Cinguloturris carpatica</i>	3193	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Spongocapsula perampla</i>	3267	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Hexasaturnalis suboblongus</i>	3088	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Mirifusus dianae</i> s.l.	3161	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Podobursa spinosa</i>	3230	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Archaeodictyomitra apiarium</i>	3263	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Protunuma japonicus</i>	3292	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Loopus</i> sp. B	LPB0	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Angulobracchia biordinalis</i>	3145	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Fultacapsa sphaerica</i> s.l.	3168	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Emiluvia ordinaria</i>	4015	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Zhamoidellum ovum</i>	4079	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Syringocapsa</i> sp. B	SYCB	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Sina echiodes</i>	3094	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Wrangellium okamurai</i>	3179	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Triactoma foremanae</i>	4068	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Tritrabs rhododactylus</i>	3118	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Emiluvia ultima</i>	4070	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Loopus primitivus</i>	3189	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Saitoum dercourti</i>	SAD0	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Pseudoeucyrtis</i> sp. B	PEB0	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Podocapsa amphitrioptera</i>	3171	.....	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Fig. 4 - Range chart of radiolarian taxa (TGJ file of BioGraph): 11 Unitary Associations (UAs) are grouped in 5 Unitary Associations Zones (UAZs A-E).

Biostratigraphical discussion

The biostratigraphical analysis has been made using the Unitary Associations method (Guex 1987, 1991). Unitary Associations (UAs) are assemblages of taxa that are unique and mutually exclusive. UAs are constructed by treating mathematically the faunal data of each section, and afterwards manually grouped in biostratigraphic units (Unitary Associations Zones: UAZs) by evaluating the lateral traceability of each UAs. The Unitary Associations method uses the software BioGraph (Savary & Guex 1990, 1999) for data analyses.

In this study 11 UAs have been identified by BioGraph (Figs 4, 5) and manually grouped in 5 UAZs A-E (Figs 4, 6). Grouping is made by evaluating the radiolarian assemblages (Fig. 4) and lateral traceability (Fig. 6) of each UA. Calibration of UAZs was provided by ammonite biozones (Fig. 2). The assignment of each sample to UAs is shown in Fig. 5, while the assignment to UAZs and correlation among studied sections is shown in Fig. 2.

UAZ A: mid Oxfordian age due to the presence of *Plicatilis* and *Transversarium* ammonite Zones at the top of RAI in the Fornazzo Cava and Castello Inici sections.

UAZ B (mid?-late Oxfordian) and **UAZ C** (late Oxfordian-early Kimmeridgian?): their age assignment is based on their stratigraphical position between the well dated UAZ A and UAZ D. The UAZ B and UAZ C are in superposition in three sections (Fornazzo Strada, Fornazzo Cava, Balata di Baida). In Castello Inici section, UAZ B and UAZ C are not well distinguished because of the poorly preserved radiolarians in the sample CI 10.

UAZ D: early Kimmeridgian age by the presence of *Strombecki* Zone in the Fornazzo Strada section. UAZ D is missing in the Balata di Baida section though no hardground surfaces have been seen. One hypothesis to justify the lack of UAZ D could be the more condensed nature of RAM in this section, probably related to topographic variations in respect to other sections. Another hypothesis could be that UAZ D has no chronological significance: UAZ D could be partially included either in UAZ C or in UAZ E.

UAZ E: early?-late Kimmeridgian age due to the presence of ammonites from the *Strombecki* Zone (early Kimmeridgian) of UAZ D which occurs less than 1 m below the lower boundary of UAZ E, from *Cavouri* Zone (late Kimmeridgian) which occurs in same level of IN 34 sample in the Fornazzo Strada section, and from *Beckeri* Zone (late Kimmeridgian) which is present at the very base of RAS in the Fornazzo Strada section.

New age information is now available for certain species by comparing the age assignments by UAZs A-E with the ages shown in Baumgartner et al. (1995a). The age of *Eucyrtidiellum unumaense* s.l. (Yao) is stated as UAZ 3-8 (early-mid Baj. to mid Call.-early Oxf.) (Baumgartner et al. 1995a), but it ranges at least to mid Oxfordian. In fact *Eucyrtidiellum unumaense* s.l. has been

Section 1 FORNAZZO STRADA	Section 3 CASTELLO INICI
16 (IN 34): 11 - 11	9 (CI 15): 10 - 10
15 (IN 32): 11 - 11	8 (CI 14): 8 - 10
14 (IN 30): 11 - 11	7 (CI 13): 9 - 9
13 (IN 28): 11 - 11	6 (CI 10): 4 - 7
12 (IN 27): 11 - 11	5 (CI 8): 3 - 3
11 (IN 24): 10 - 10	4 (CI 6): 3 - 7
10 (IN 21): 8 - 10	3 (CI 5): 3 - 7
9 (IN 19): 8 - 8	2 (CI 4): 3 - 4
8 (IN 17): 6 - 7	1 (CI 3): 3 - 7
7 (IN 15): 7 - 7	
6 (IN 13): 4 - 4	Section 4 BALATA DI BAIDA
5 (IN 11): 4 - 4	8 (BB 21): 11 - 11
4 (IN 8): 3 - 3	7 (BB 17.3): 11 - 11
3 (IN 4): 3 - 4	6 (BB 16.45): 8 - 8
2 (IN 3): 3 - 4	5 (BB 15.1): 8 - 8
1 (IN 1): 1 - 1	4 (BB 13.1): 5 - 5
Section 2 FORNAZZO CAVA	3 (BB 11.7): 4 - 4
3 (FZC 9): 6 - 6	2 (BB 9): 3 - 4
2 (FZC 7): 4 - 4	1 (BB 6.35): 3 - 4
1 (FZC 3): 2 - 2	

Fig. 5 - Correlation table (TGK file of BioGraph): For each sample of each section (sample codes: IN, FZC, CI, BB) are indicated the assignments to one or more Unitary Associations (UAs 1 to 20).

found in the sample FZC 3 (UAZ A; Fig. 2), 2 m above the *Transversarium* Zone (mid Oxf.). The range of *Williriedellum (?) marucciae* Cortese dates UAZ 4-8 (late Baj. to mid Call.-early Oxf.) (Baumgartner et al. 1995a) but it ranges at least to mid Oxfordian. *Williriedellum (?) marucciae* has been found in the sample IN 1 belonging to UAZ A (mid Oxf.) (Fig. 2).

Finally, another biostratigraphical consideration should be mentioned. Although saturnalids are common in all sections, *Dicerosaturnalis diacranacanthos* (Squinabol, emend. Foreman (= *Acanthocircus trizonalis diacranacanthos* in Baumgartner et al. 1995b) has not been found but its ancestor *Dicerosaturnalis angustus* is common. Probably the FAD of *D. diacranacanthos* (UAZ 10: late Oxf.-early Kim.; Baumgartner et al. 1995b) is too old.

Conclusions

Biostratigraphical analysis of radiolarian assemblages presented in this paper provides the first radiolarian data for the Upper Jurassic intermediate pelagic siliceous member (RAM) of Rosso Ammonitico Fm. in the Inici Mt. area (North-western Sicily, Italy).

The radiolarian data have been treated by Unitary Associations method: 11 Unitary Associations (UAs 1-11) have been obtained and 5 Unitary Associations Zones (UAZs A-E) have been recognized. Specific co-occurrence of radiolarians and ammonites in the same sections has made possible the age calibration of UAZs A-E. The time interval covered by the UAZs A-E spans from mid Oxfordian to late Kimmeridgian.

UAs	n	IN	FZC	CI	BB	UAZs
11	2	■	■	■	■	E
10	2	■		■		D
9	1			■		
8	2	■			■	
7	1	■		■		C
6	1		■			
5	1			■	■	
4	3	■	■	■	■	B
3	2	■		■		
2	1		■			A
1	1	■				

Fig. 6 - The reproducibility of the 11 Unitary Associations (UAs) (TGL file of BioGraph) and of the 5 Unitary Associations Zones (UAZs A-E) is shown. "n" indicates the number of sections in which each UA occurs. Black squares refer to UAs identified by BioGraph; grey column refers to unions of UAs. BB: Balata di Baida, CI: Castello Inici, FZC: Fornazzo Cava, IN: Fornazzo Strada.

Comparing the radiolarian assemblages and age results from this study to those of Baumgartner et al. (1995a), new age information has been discussed for three taxa. The ranges of *Eucyrtidiellum unumaense* s.l. (Yao) and *Williriedellum (?) marcucciae* Cortese are longer than those previously thought. Conversely, the range of *Dicerosaturnalis diacranacanthos* is shorter.

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