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Radiolarian correlation of Jurassic siliceous successions of the Rosso Ammonitico Formation in the Southern Alps and Western Sicily (Italy)

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Key words: Radiolarians, Ammonites, Biostratigraphy, Unitary Associations Zones, Rosso Ammonitico Medio, Middle-Late Jurassic, Italy
Parole chiave: Radiolari, Ammoniti, Biostratigrafia, Zone ad Associazioni Unitarie, Rosso Ammonitico Medio, Giurassico medio-superiore, Italia

ABSTRACT

This paper deals with the radiolarian biostratigraphy of Middle-Upper Jurassic pelagic siliceous successions of the Southern Alps and Western Sicily (Italy). The crucial complement to this research is the occurrence of ammonites in the studied successions (Rosso Ammonitico Medio: the intermediate siliceous member of the Rosso Ammonitico Formation), as well as in the under- and overlying sediments (Rosso Ammonitico Inferiore and Rosso Ammonitico Superiore, respectively). The abundance of radiolarians in all successions allow to analyse them for a twofold purpose: to date directly most of the successions, and to improve the calibration of radiolarian biozones thanks to the occurrence of ammonites. The biostratigraphic analysis has been carried out using the Unitary Associations method, and six new radiolarian biozones have been defined: the combined occurrence of radiolarians and ammonites provided a new Bathonian to late Kimmeridgian radiolarian zonation for the Southern Alps and Western Sicily (Italy). The new Unitary Association Zones show a good reproducibility throughout the investigated successions, and make possible a first direct dating and correlation by radiolarians of the Rosso Ammonitico Medio. Furthermore, the radiolarian biozones reveal a significant diachronism for both the lower and the upper limit of the Jurassic pelagic siliceous facies in the Alpine and Sicilian sections. In the light of new radiolarian biozones, the age assignments of the Ceniga (Southern Alps) and the Sant'Anna (Sicily) sections, and the ranges of some taxa are discussed.

RIASSUNTO

La ricerca riguarda la biostratigrafia a radiolari di successioni pelagiche silicee riferibili al Giurassico Medio-Superiore delle Alpi Meridionali e della Sicilia occidentale (Italia). L'aspetto più importante è la presenza di ammoniti sia nelle successioni studiate (Rosso Ammonitico Medio: porzione intermedia silicea della Formazione del Rosso Ammonitico) sia in quelle sotto- e sovrastanti (rispettivamente Rosso Ammonitico Inferiore e Rosso Ammonitico Superiore). L'abbondanza di radiolari in tutte le sezioni studiate ha permesso di analizzarli sia per datare direttamente la maggior parte delle successioni sia per migliorare la calibrazione delle biozone a radiolari grazie alla presenza delle ammoniti. L'analisi biostratigrafica è stata effettuata con il metodo delle Associazioni Unitarie e sono state definite sei nuove biozone a radiolari: la copresenza di radiolari ed ammoniti ha così fornito una nuova zonazione a radiolari per l'intervallo di tempo Batoniano-Kimmeridgiano delle Alpi Meridionali e della Sicilia occidentale (Italia). Le Zone ad Associazioni Unitarie identificate mostrano una buona riproducibilità tra le sezioni stratigrafiche analizzate ed hanno permesso una prima datazione e correlazione diretta a radiolari del Rosso Ammonitico Medio. Le biozone a radiolari hanno inoltre rivelato un significativo diacronismo sia per il limite inferiore sia per il limite superiore delle facies pelagiche silicee nelle sezioni alpine e siciliane. Alla luce dei nuovi dati biostratigrafici forniti dai radiolari sono infine discusse le età della facies silicea nelle sezioni di Ceniga (Alpi Meridionali) e di Sant'Anna (Sicilia) e la distribuzione stratigrafica di alcuni taxa.

Introduction

The study of siliceous successions in the Southern Alps and in Western Sicily (Italy) benefits from the fact that such successions are approximately coeval and may be referred to analogous paleogeographic settings. These similarities enable to compare radiolarian assemblages of different geographic areas and to correlate different Tethyan paleogeographic regions. The paleogeographic domains are two pelagic plateaux (Trapanese Domain in Western Sicily and Trento Plateau in the Southern Alps) and one basin (Sicanian Domain in Western Sicily) (Figs. 1 and 2). The age of the studied successions ranges from the Bathonian to the Kimmeridgian.

The Sicilian chain and the Southern Alps represent segments of the Alpine collisional belt formed during the "Tertiary" time along the boundary between the European and African plates. The Jurassic paleogeographic settings of Sicily and the Alps result from the breakup of the Triassic carbonate platform and the subsequent extensional movements. The platform was divided in several areas with different subsidence rates, and different paleogeographic domains were formed (pelagic plateaux, basins and limited areas of platforms) (Figs. 1 and 2). During the Middle Jurassic a general deepening took place and the deposition of sediments in the Rosso Ammonitico facies occurred on the pelagic plateaux up to Late Jurassic

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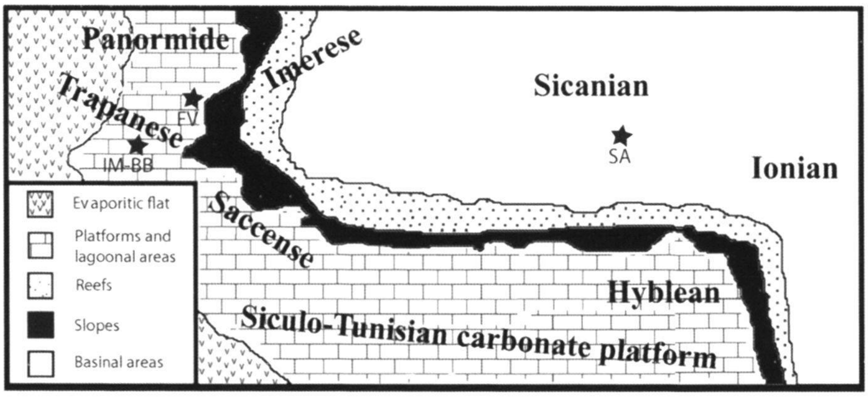

Fig. 1. An attempt of paleogeographic reconstruction of the Sicilian area at the Late Triassic time (Catalano et al. 1996). Favignana, Balata di Baida and Inici Mt. sections belong to the pelagic plateau of the Trapanese Domain; Sant'Anna section belongs to the Sicanian Basin. The paleogeographic location of the stratigraphic sections is only indicative.

(Winterer & Bosellini 1981; Catalano et al. 1996). The Rosso Ammonitico sediments consist of condensed red nodular limestone rich in ammonites, and are subdivided in three members whose ages differ between the Southern Alps and Sicily. The lower part (RAI: Rosso Ammonitico Inferiore) spans the late Bajocian-early Callovian in the Alps and the Bathonian-mid Oxfordian in Sicily. The upper part (RAS: Rosso Ammonitico Superiore) starts in the mid Oxfordian in the Alps and in the early Kimmeridgian in Sicily. RAI and RAS are separated by the intermediate siliceous member (RAM: Rosso Ammonitico Medio), assigned to upper Callovian-mid Oxfordian in the Alps and mid Oxfordian-Kimmeridgian in Sicily. The intermediate siliceous member represents the studied sediments in all the stratigraphic sections except for Sant'Anna (Sicily).

Very few authors have studied the Jurassic radiolarian assemblages of the Southern Alps and Western Sicily. Kocher (1981) was the first author who studied radiolarians from the Southern Alps but mainly in the Lombardian basin. The Ceniga section was first described by Fogelgesang (1975), and then studied for radiolarians by Baumgartner (1984) and Baumgartner et al. (1995b). The Coston delle Vette section was first described by Dal Piaz (1907), then analysed by Bosellini & Dal Cin (1968) and Della Bruna & Martire (1985), and finally studied for radiolarians by Beccaro (1998) and Beccaro et al. (2002). The Cava Vianini was only described by Papa (1994) for sedimentologic purposes. Concerning Western Sicily, several authors studied the geology for different aims (Giunta & Liguori 1972, 1973; Wendt 1964, 1971; Catalano et al. 1989; Cecca et al. 2001; Catalano et al. 2002 among others). Nevertheless, the radiolarian papers regarding the Sicanian Basin have been mainly focused on the Sant'Anna section (Riedel & Sanfilippo 1974; Mascle 1973, 1979; Baumgartner et al. 1980; Origlia-Devos 1983; Baumgartner 1984; De Wever et al. 1986; Aita 1987; De Wever 1995) because of its rich fossil content (ammonites, belemnites, brachiopods, echinoderms, nannofossils). Other Sicanian sections were studied by Kito et al. (1990) and Kito & De Wever (1992, 1994).

Generally, the close association of ammonite-bearing beds with levels containing well-preserved radiolarians is quite rare. In the investigated sections, the ammonites occur both in the under- and overlying sediments and, in some instances, also within the siliceous successions: This fact motivates the analysis of radiolarian assemblages in the selected sections. The abundance of radiolarians enables to study them for a twofold purpose: to date directly most of the siliceous facies (whose age was generally based on the ages of the bracketing formations) and to improve the calibration of radiolarian zones by ammonite zones.

This paper deals with the main results of the author's PhD research (Beccaro 2002) where radiolarian assemblages were studied for the first time in the following sections: Fornazzo Strada, Fornazzo Cava, Castello Inici, Balata di Baida, Favignana (North-western Sicily) (Beccaro 2002, 2004a) and Cava Vianini (Southern Alps) (Beccaro 2002). Concerning the Sant'Anna (South-western Sicily) and the Ceniga (Southern Alps) sections, new radiolarian data improved the former biochronologic assignments. New species of Nassellaria (*Fultacapsa ozvoldovae, Podobursa andreai, Podobursa vannae, Loopus doliolum martae*) and Spumellaria (*Emiluvia peteri, Triactoma enzoi*) from the cited sections have been described in Beccaro 2004b.

Lithologic description of the stratigraphic sections

In Western Sicily five stratigraphic sections of the Rosso Ammonitico Medio (RAM) have been studied in the Trapanese Domain (pelagic plateau) and one section in the Sicanian Basin (Fig. 1). The geographic location of these sections is shown in Figure 3.

Trapanese Domain (North-western Sicily) – Fornazzo sections are located at the Inici Mt. near Castellammare del Golfo. The **Fornazzo Strada** section crops out along the road to Fornazzo quarry. The RAM is 26 m thick and consists of well-stratified red siliceous limestone alternating with calcareous marlstone. Nodules and beds of dark red chert are abundant (Fig. 4). The **Fornazzo Cava** section crops out in the old Fornazzo quarry, and the **Castello Inici** section is located in the southwestern side of the Inici Mt. In both sections the RAM is incomplete and it is 8 m and 13 m thick, respectively. The lithology is the same as at Fornazzo Strada and the main

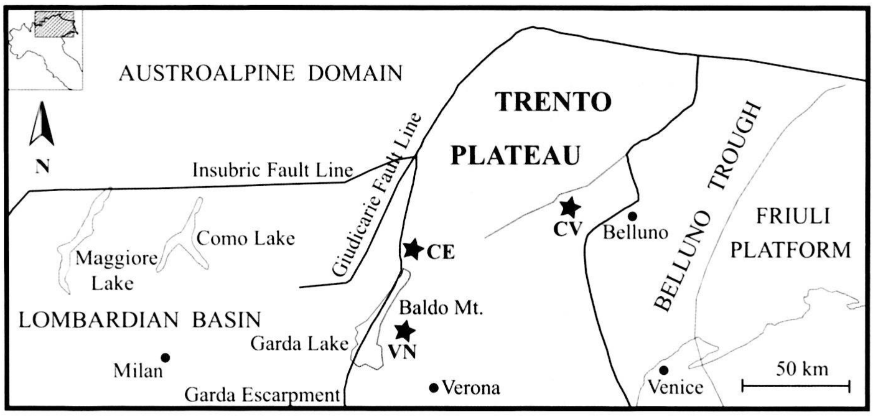

Fig. 2. Geographic location of the stratigraphic sections and present day distribution of Mesozoic paleogeographic domains in the Southern Alps (Italy) (Bosellini et al. 1981; Martire 1992). CE: Ceniga, CV: Coston delle Vette, VN: Cava Vianini.

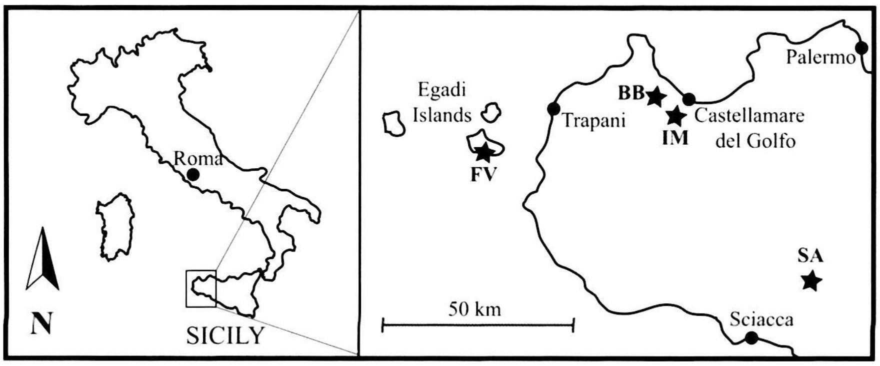

Fig. 3. Geographic location of the stratigraphic sections in Western Sicily (Italy). BB: Balata di Baida, FV: Favignana, IM refers to the three sections of the Inici Mt. (Fornazzo Strada, Fornazzo Cava and Castello Inici), SA: Sant'Anna.

difference is the occurrence of macrofossils (ammonites and belemnites; Fig. 4). The **Balata di Baida** section crops out along the orographic left of the Sarcona River at Balata di Baida village (near Inici Mt.). The RAM is 21 m thick, and it consists of an alternation of nodular red limestone and variously coloured chert beds; thin levels of marlstone are widespread along the section (Fig. 4). The radiolarian preservation in the Inici sections is moderate. The **Favignana** succession is located in the southern coast of the Favignana island (Egadi Archipelago). The section is 2 m thick, and it consists of thin limestone and marlstone alternating with thin chert beds black and red in colour (Fig. 4). Neither the base nor the top of the siliceous succession crop out. The radiolarian preservation is very good.

SICANIAN DOMAIN (South-western Sicily) – The basinal succession of **Sant'Anna** crops out at about 1 km NE of Sant'Anna village (near Sciacca). The stratigraphic section is 9 m thick, and consists of a regular alternation of whitish limestone and marlstone; the chert is rare. The base is not exposed (Fig. 4). The radiolarian preservation is good.

In the Southern Alps three stratigraphic sections have been studied in the Trento Plateau (Fig. 2). The **Cava Vianini** section crops out in an active quarry close to Madonna della Corona Sanctuary (eastern side of the Garda Lake). The RAM is 10 m thick, and it consists of an alternation of dark siliceous limestone and beds chert (light brown, red and black in colour). Some levels of bentonites occur at the top of the section (Fig. 4). The radiolarian preservation varies from moderate to very good. The **Ceniga** section crops out near the Sarca River, south of Ceniga village (North of the Garda Lake). In this section it is also possible to observe the Early Jurassic platform deposits of San Vigilio Oolite (oolitic-bioclastic grainstone). The top of San Vigilio Oolite is overlain by a very thin RAI (20 cm) formed by pink pelagic limestone and bearing a hardground at its top. The RAM is 9 m thick, and it consists of an alternation of red siliceous limestone thinly stratified and thin whitish marlstone. Six levels of bentonites occur in the middle part of the section (Fig. 4). The radiolarian preservation is poor. The **Coston delle Vette** section is located in the Feltrine Alps (Dolomiti Bellunesi). Here, the time-equivalent facies of the RAM is the Fonzaso Formation, which reaches a thickness of 100 m. The Fonzaso Fm. consists of a quite regular alternation of packstone and wackestone with subordinate oolitic grainstone and mudstone, and chert ribbons and nodules (Fig. 4) (Della Bruna & Martire 1985; Beccaro 1998; Beccaro et al. 2002). The central part of the formation is characterized by the oolitic grainstone resedimented from the Friuli Platform. The radiolarian preservation varies from moderate to very good.

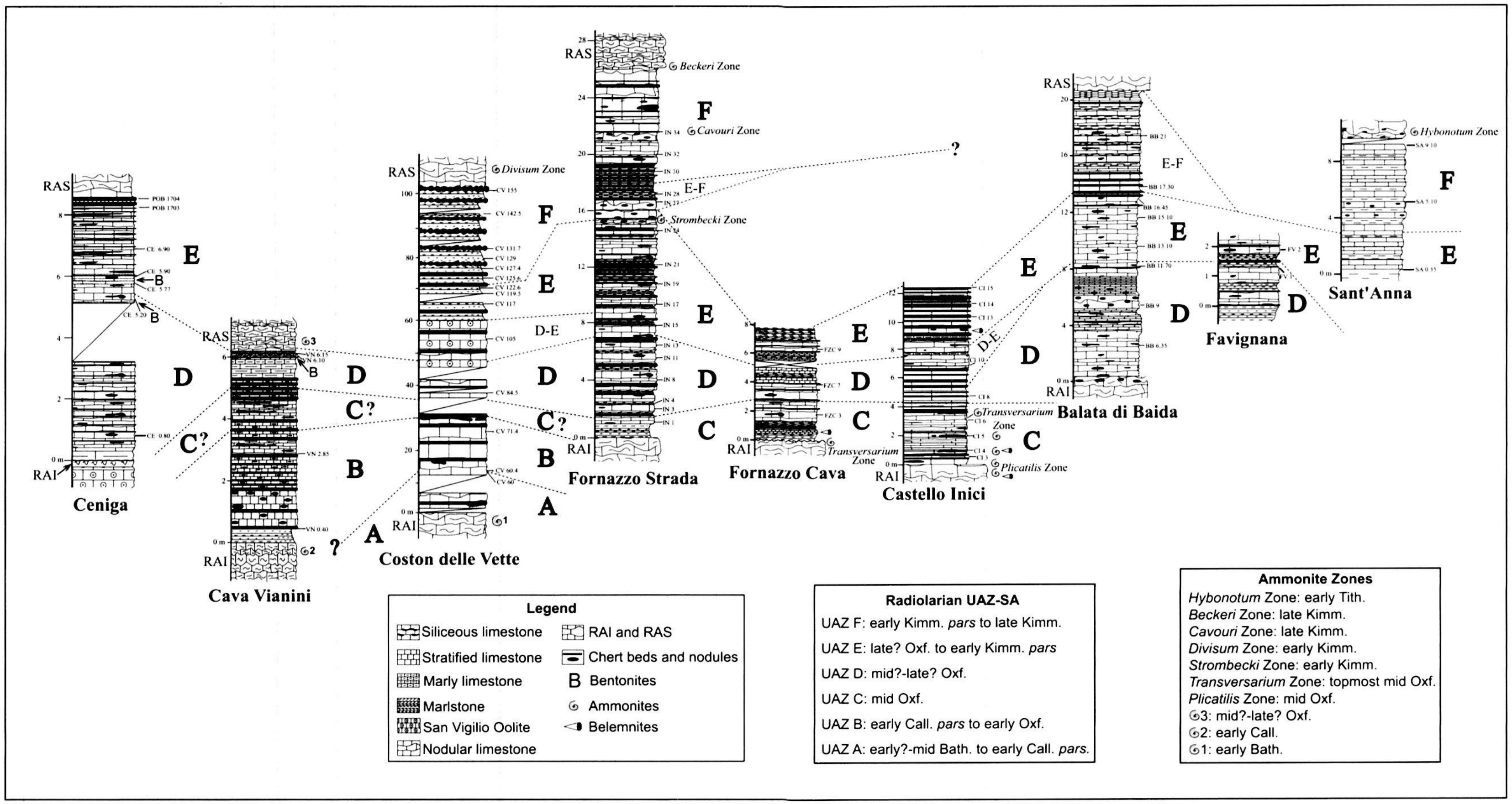

Fig. 4. Radiolarian biostratigraphic correlation of pelagic siliceous facies between Western Sicily and the Southern Alps by means of the six radiolarians biozones UAZ A–F. Three sections from the Southern Alps (Ceniga, Cava Vianini, Coston delle Vette), five sections from North-western Sicily (Fornazzo Strada, Fornazzo Cava, Castello Inici, Balata di Baida, Favignana), and one section from South-western Sicily (Sant'Anna) have been dated and correlated. The investigated successions represent the intermediate pelagic siliceous member (RAM) of the Rosso Ammonitico Fm. in all the sections, except at Coston delle Vette (where the Fonzaso Fm. is the time-equivalent siliceous facies of the RAM) and at Sant'Anna (where a basinal section crops out). The age of the biostratigraphic units UAZ A–F is provided by calibration with ammonite assemblages found both in the studied successions and in the under- and overlying sediments.

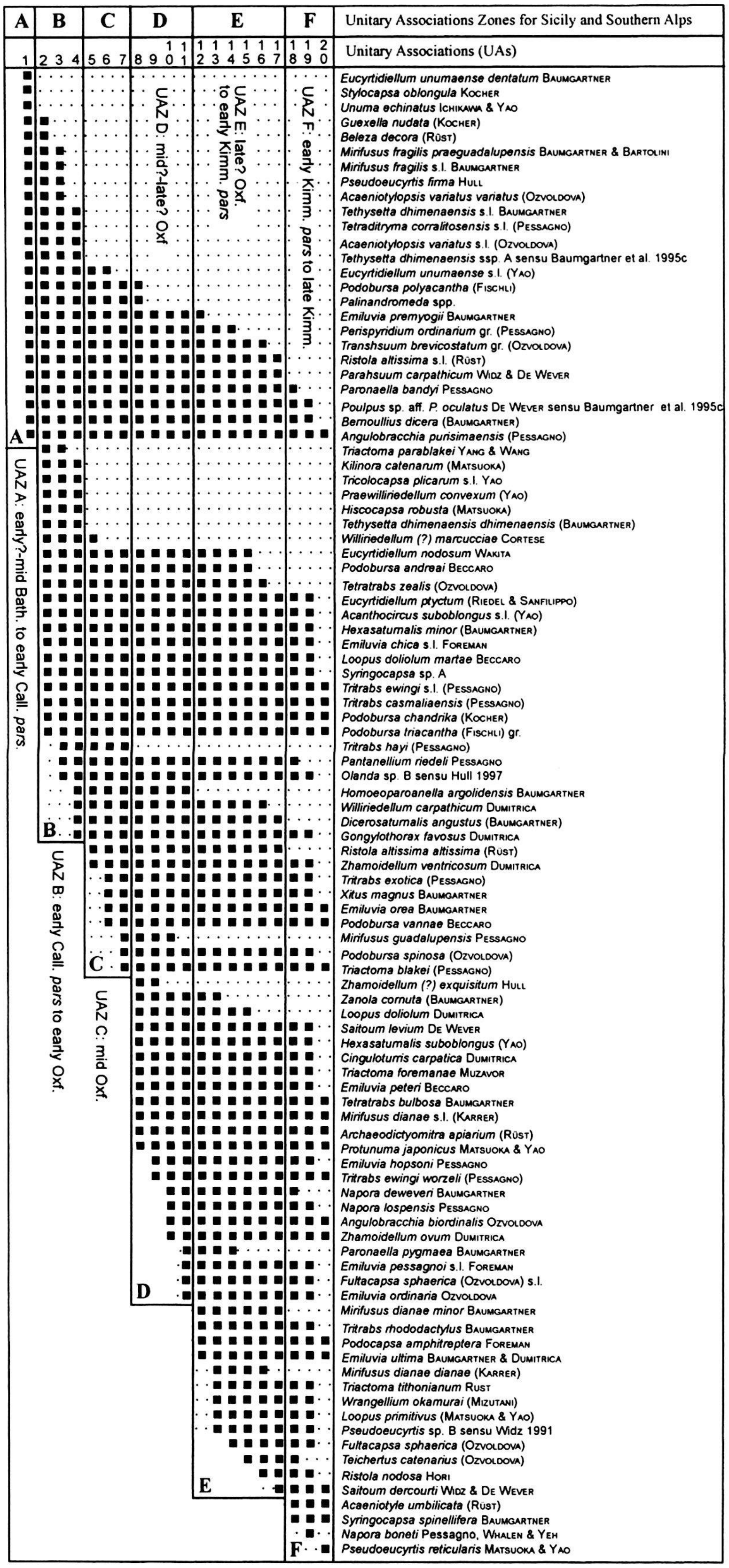

Fig. 5. Range chart: occurrences of radiolarian taxa used for the biozonation. The software BioGraph grouped 100 selected species in 20 Unitary Associations which have been manually assembled in six Unitary Associations Zones: UAZ A–F.

Radiolarian biozones UAZ A–F

The radiolarian biostratigraphy illustrated in this paper has been carried out using the Unitary Associations method (Guex 1977, 1991) and the software BioGraph (Savary & Guex 1991, 1999), and represents a new regional zonation for the Southern Alps and Western Sicily (Italy). About 130 radiolarian species have been identified from 8 stratigraphic sections, and 100 taxa have been retained to construct the zonation (Fig. 5). Also added to this database are the radiolarian occurrences of the Coston delle Vette section (Trento Plateau, Southern Alps) (Beccaro et al. 2002), and the raw data of two Baumgartner's samples (POB 1703 and POB 1704) of the Ceniga section (Trento Plateau, Southern Alps) (Baumgartner 1984; Baumgartner et al. 1995b). The adding of the Baumgartner's samples was necessary in order to get a radiolarian record also from the upper part of the Ceniga section that lacked in well preserved samples from PhD field work. Six Unitary Associations Zones (UAZ A–F) have been defined (Fig. 5), and the chronostratigraphic value of each UAZone is provided by calibration with the ammonites found in the RAM of the studied sections and in the under- and overlying sediments (RAI and RAS).

UAZ A (early?-mid Bathonian – early Callovian *pars*)

UAZ A occurs only at the Coston delle Vette section (Southern Alps; Fig. 4). Some species characteristic of UAZ A are illustrated in Plate 1, Figures 1–3. UAZ A is assigned to early?–mid Bathonian – early Callovian pars thanks to the presence of early Bathonian ammonites at the top of RAI at the Coston delle Vette section (Della Bruna & Martire 1985), and the early Callovian pars age assignment of the following UAZ B.

UAZ B (early Callovian *pars* – early Oxfordian)

UAZ B is present at the Cava Vianini and Coston delle Vette sections (Southern Alps; Fig. 4). Species belonging to UAZ B are shown in Plate 1, Figures 4–11. The base of UAZ B is dated as early Callovian *pars* due to the presence of early Callovian ammonites at the top of RAI (Papa 1994) at the Cava Vianini section. The upper part of UAZ B is constrained to early Oxfordian by the well-dated UAZ C.

UAZ C (mid Oxfordian)

UAZ C has been recognized in the Fornazzo Strada, Fornazzo Cava and Castello Inici sections (North-western Sicily; Fig. 4). Species belonging to UAZ C are illustrated in Plate 1, Figures 12–13 and 15–18. In the Alpine sections UAZ C seems missing but no evidence of stratigraphic gaps has been found. Most likely, UAZ C was not recognized at the Coston delle Vette section due to the cover, and in the Cava Vianini section due to the low frequency sampling. At the Ceniga section the time interval corresponding to UAZ C is probably included in the very condensed RAI (Fig. 4). UAZ C is assigned to mid Oxfordian by the occurrence of ammonite assemblages belonging to *Plicatilis* and *Transversarium* Zones at the Castello Inici section (Savary 2000), and *Transversarium* Zone at the Fornazzo Cava section (Bovero 2000).

UAZ D (mid?-late? Oxfordian)

UAZ D is the most widespread and best recorded biozone in all the sections except Sant'Anna (Sicanian Domain, South-western Sicily; Fig. 4). Species belonging to UAZ D are shown in Plate 1, Figures 14 and 19–24. UAZ D is questionably assigned to mid-late Oxfordian due to the age assignment of the well calibrated UAZ C (mid Oxf.) and the occurrence of ammonites referred to the boundary mid-late Oxfordian (Papa 1994) at the base of RAS in the Cava Vianini section (Southern Alps; Fig. 4).

UAZ E (late? Oxfordian – early Kimmeridgian *pars*)

UAZ E is well recorded in all sections except Cava Vianini (Southern Alps), where the time-equivalent facies is the RAS (Fig. 4). Species belonging to UAZ E are shown in Plate 1, Figures 25–31. Ammonites belonging to *Strombecki* Zone (early Kimmeridgian) occur at the very top of UAZ E at the Fornazzo Strada section (North-western Sicily) (Bovero 2000) so that it is likely that UAZ E also comprises the late Oxfordian.

Bentonite levels occur at the top of UAZ D at the Cava Vianini and Ceniga sections, and at the very base of UAZ E at the Ceniga section. The time intervals expressed by UAZ D (mid?-late? Oxfordian) and UAZ E (late? Oxfordian-early Kimmeridgian *pars*) suggest that the volcanic activity took place also in the late Oxfordian-early Kimmeridgian time, and not only in the mid Oxfordian as stated in the literature (Martire 1989; Baumgartner et al. 1995b).

UAZ F (early Kimmeridgian *pars* – late Kimmeridgian)

UAZ F has been recognized at the Coston delle Vette section (Southern Alps), and at the Fornazzo Strada and Sant'Anna sections (Western Sicily; Fig. 4). Species occurring into UAZ F are illustrated in Plate 1, Figures 32–35. UAZ F spans all the Kimmeridgian due to the presence of *Divisum* Zone (early Kimmeridgian) at the base of the RAS in the Coston delle Vette section (Southern Alps) (Dal Piaz 1907), and of *Cavouri* Zone (late Kimmeridgian) at the Fornazzo Strada section (North-western Sicily) (Bovero 2000). The extremely base of the RAS at the Fornazzo Strada section is dated as late Kimmeridgian (*Beckeri* Zone) (Bovero 2000). In the Sant'Anna section (South-western Sicily) the top of the pelagic siliceous succession is assigned to UAZ F, and is overlain by ammonite-bearing limestone belonging to the *Hybonotum* Zone (early Tithonian) (De Wever et al. 1986).

Diachronism of the Jurassic siliceous facies between the Southern Alps and Western Sicily

The stratigraphic correlation through UAZ A–F reveals a significant diachronism for the lower as well as for the upper limit of the pelagic siliceous facies in the Alpine and Sicilian sections.

In the Southern Alps (Trento Plateau) the siliceous deposition began in the early?-mid Bathonian-early Callovian *pars* (UAZ A) at the Coston delle Vette section, in the early Callovian *pars* – early Oxfordian (UAZ B) at the Cava Vianini, and in the mid?-late? Oxfordian (UAZ D) at the Ceniga section (Fig. 4). In North-western Sicily (Trapanese Domain) the siliceous deposition started in the mid-late Oxfordian: UAZ C (mid Oxf.) at the Fornazzo Strada, Fornazzo Cava and Castello Inici sections; UAZ D (mid?-late? Oxf.) at the Balata di Baida and Favignana sections. In the basinal section of Sant'Anna the onset of the siliceous facies is the youngest: UAZ E (late? Oxf.-early Kimm. *pars*) (Fig. 4). On the other hand, UAZ D (mid?-late? Oxf.) corresponds to the final phase of the siliceous deposition at the Cava Vianini section (Southern Alps), and UAZ E (late? Oxf.-early Kimm. *pars*) corresponds to the final phase of the siliceous deposition in the Ceniga section (Southern Alps). UAZ F (early Kimm. *pars*-late Kimm.) indicates the end of the siliceous facies at the Coston delle Vette (Southern Alps), Fornazzo Strada and Sant'Anna (Western Sicily). The diachronism of the ending of the siliceous facies in the Fornazzo Cava, Castello Inici and Favignana sections is only due to the incompleteness of the successions (Fig. 4).

As can be inferred by the above discussion, the diachronism of the siliceous facies occurs within the same paleogeographic domain as well (Fig. 4). The three Alpine sections were located in different sectors of the Trento Plateau, and the diachronism suggests that local topography and/or tectonic movements primarily controlled the onset of the siliceous deposition. Different bottom morphology and tectonics may have influenced different spatial and temporal distribution of the siliceous facies: the oldest onset and the youngest end took place at Coston delle Vette (located in a transitional area between Trento Plateau and Belluno Basin) while the youngest onset was at Ceniga (located near the strongly tectonic active Garda Escarpment). On the other hand, the Sicilian sections belonging to the Trapanese Domain were paleogeographically very close to each other, and the diachronism of the onset amongst them is minor (only Favignana section shows a rather younger onset but its base does not crop out).

Age assignment discussion on the siliceous facies at Ceniga (Southern Alps) and Sant'Anna (Sicily)

In the light of new radiolarian biozones UAZ A–F, the age assignments of the Ceniga (Trento Plateau, Southern Alps) and the Sant'Anna (Sicanian Domain, South-western Sicily) sections have been discussed.

Concerning the Ceniga section, the time interval stated in the previous papers (Baumgartner 1984; Baumgartner et al. 1995b) spans the mid Callovian to early Tithonian. The radiolarian assemblages of the new samples CE 0.80 and CE 5.20 belong to UAZ D (Fig. 4) and assign most of the section to mid?-late? Oxfordian. The radiolarian content of the new samples CE 5.77, CE 5.90 and CE 6.90 belong to UAZ E (Fig. 4), and refer the upper part of the section to late? Oxfordian-early Kimmeridgian *pars*. The last two samples (POB 1703 and POB 1704) are from Baumgartner's sampling and they were assigned to late Oxfordian-early Tithonian (Baumgartner 1984). The radiolarian assemblages of these samples belong now to UAZ E (late? Oxf.-early Kimm. *pars*). In account of this research, the age of the Rosso Ammonitico Medio at the Ceniga section is restricted to mid? Oxfordian-early Kimmeridgian *pars* (UAZ D–E) (Fig. 4). This age assignment highly differs from those stated for other sections in the Trento Plateau, where the RAM is referred to late Callovian – mid Oxfordian (e.g., Cava Vianini, this paper; Martire 1996).

Concerning the Sant'Anna section, several authors assigned it to a variety of ages: mid Oxfordian to mid Tithonian (Origlia-Devos 1983), mid Oxfordian to early Kimmeridgian (De Wever et al. 1986), mid-late Oxfordian to late Oxfordian-early Kimmeridgian (De Wever 1995). The radiolarian content of the new sample SA 0.35 belongs to UAZ E (Fig. 4) and constrains the first layers of the succession to late? Oxfordian-early Kimmeridgian *pars*. The radiolarian assemblages of the new samples SA 5.10 and SA 9.10 belong to UAZ F (Fig. 4) and date the middle and upper parts of the section to early Kimmeridgian *pars*-late Kimmeridgian. This age assignment is consistent with the early Tithonian age of the ammonite assemblages found at the base of the overlying nodular limestone (De Wever et al. 1986). The present study now restricts the age of the pelagic siliceous succession of the Sant'Anna section to the late? Oxfordian-late Kimmeridgian (UAZ E–F).

Age assignment discussion for some taxa

After the calibration of UAZ A–F through ammonite zones, the stratigraphic distribution of some taxa can be compared with those of Baumgartner et al. (1995a). In the following discussion the lettered UAZones (e.g., UAZ A) refer to the new biozones illustrated in the present paper; the numbered UAZones (e.g., UAZ 8–13) refer to the biozones of Baumgartner et al. (1995a). Some age considerations were illustrated also in Beccaro (2004a) concerning *Eucyrtidiellum unumaense* s.l. (Yao) and *Williriedellum (?) marcucciae* Cortese. The ranges of these species remained unchanged after the new zonation by UAZ A–F: *Eucyrtidiellum unumaense* s.l. (Yao) and *Williriedellum (?) marcucciae* Cortese extended to mid Oxfordian (and not only to early Oxfordian as the previous assignment of Baumgartner et al. 1995a).

Podobursa polyacantha (Fischli) (Pl. 1, Fig. 14)

Its range is assigned to UAZ 5–8 (latest Baj.-early Bath. to mid Call.-early Oxf.) but in the studied sections *P. polyacantha* reaches the very base of UAZ D (mid?-late? Oxf.) (Fig. 5).

Ristola altissima altissima (Rüst) and *Ristola altissima nodosa* Hori (Pl. 1, Figs. 13 and 30, respectively)

The age of *R. altissima altissima* is stated as UAZ 7–12 (late Bath.-early Call. to early-early late Tith.). In the studied sections *R. altissima altissima* first appears in UAZ C (mid Oxf.), and its ancestral form *R. altissima major* Baumgartner & De Wever occurs in samples assigned to UAZ B (early Call. *pars*-early Oxf.) at the Coston delle Vette section (Southern Alps) (Beccaro et al. 2002). Furthermore, *R. altissima altissima* disappears at the top of UAZ E (late? Oxf.-early Kimm. *pars*) when *R. altissima nodosa* first appears. *R. altissima nodosa* was comprised in the synonymy of *R. altissima altissima* in Baumgartner et al. 1995c and this fact explains the long range (UAZ 7–12: late Bath.-early Call. to early-early late Tith.) of the latter species. *R. altissima nodosa* is very probable the transitional form between *R. altissima altissima* and *R. cretacea* (Baumgartner), whose range is UAZ 12–17 (early-early late Tith. to late Val.). It is therefore reasonable that the range of *R. altissima altissima* (UAZ 7–12: late Bath.-early Call. to early-early late Tith.) is restricted to UAZ C–E (mid Oxf. – early Kimm. *pars*).

Syringocapsa spinellifera Baumgartner (Pl. 1, Fig. 34)

Its range is referred to UAZ 9–12 (mid-late Oxf. to early-early late Tith.) but in the studied sections *S. spinellifera* does not appear before UAZ F (early Kimm. *pars*-late Kimm.) (Fig. 5). The age assignment of this taxa should be reconsidered in the light of the present data.

Tetratrabs bulbosa Baumgartner and *Tetratrabs zealis* (Ozvoldova) (Pl. 1, Figs. 21 and 22, respectively).

T. zealis (UAZ 4–13: late Baj. to latest Tith.-earliest Berr.) disappears towards the top of UAZ E (late? Oxf.-early Kimm. *pars*) whereas is stated to reach the earliest Berriasian (Baumgartner et al. 1995c). *T. bulbosa* is assigned to UAZ 7–11 (late Bath.-early Call. to late Kimm.-early Tith.) but it first appears in UAZ D (mid?-late? Oxf.).

Conclusions

The main conclusions of this research concern the definition of six new radiolarian biozones for the Southern Alps and Western Sicily (Italy), the dating of the intermediate pelagic siliceous member (Rosso Ammonitico Medio) of the Rosso Ammonitico Fm. in the studied area, and the correlation of the investigated successions by means of the new radiolarian biozones.

Nine stratigraphic sections of the Rosso Ammonitico Medio or time-equivalent siliceous facies have been analysed in the Southern Alps and Western Sicily. Six new radiolarians biozones (UAZ A–F) have been defined (Figs. 4 and 5): UAZ A (early?-mid Bath.-early Call. *pars*), UAZ B (early Call. *pars*-early Oxf.), UAZ C (mid Oxf.), UAZ D (mid?-late? Oxf.), UAZ E (late? Oxf.-early Kimm. *pars*), UAZ F (early Kimm. *pars*-late Kimm.). The chronostratigraphic value of each UA Zone is provided by calibration with the ammonites found in the same stratigraphic sections. The new UAZones show a good reproducibility throughout the investigated successions, and make possible the first correlation by radiolarians of the intermediate siliceous member of the Rosso Ammonitico Fm. between the Southern Alps and Western Sicily (Fig. 4).

The newly defined radiolarian biozones also confirm the diachronism of the Middle Jurassic siliceous deposition in the studied area. On the Trento Plateau (Southern Alps) the siliceous deposition began in the early?-mid Bathonian – early Callovian *pars* (UAZ A) at the Coston delle Vette section, in the early Callovian *pars* – early Oxfordian (UAZ B) at the Cava Vianini, and in the mid?-late? Oxfordian (UAZ D) at the Ceniga section (Fig. 4). In the Trapanese Domain (Northwestern Sicily) the siliceous deposition started in the mid-late Oxfordian: UAZ C (mid Oxf.) at the Fornazzo Strada, Fornazzo Cava and Castello Inici sections, and UAZ D (mid?-late? Oxf.) at the Balata di Baida and Favignana sections. In the Sicanian Basin (South-western Sicily) the onset of the siliceous facies at the Sant'Anna section was in UAZ E (late? Oxf.-early Kimm. *pars*) (Fig. 4).

In the light of the new radiolarian biozones UAZ A–F, the age assignments of the Ceniga and Sant'Anna sections have been compared with the literature data. The age of the Ceniga section has been restricted to mid? Oxfordian – early Kimmeridgian *pars* (UAZ D–E), and the age of the Sant'Anna section is now referred to the late? Oxfordian – late Kimmeridgian (UAZ E–F) (Fig. 4).

Thanks to the calibration with ammonites, some range considerations have been stated for certain taxa. The age of *Podobursa polyacantha* (Fischli) is extended to mid-late Oxfordian. At least for the studied area, it could be possible that: *Syringocapsa spinellifera* Baumgartner does not appear before early Kimmeridgian, *Tetratrabs bulbosa* Baumgartner does not appear before the mid Oxfordian, the range of *Ristola altissima altissima* (Rüst) is restricted to mid Oxfordian – early Kimmeridgian *pars*.

The radiolarian biostratigraphy by means of new UAZ A–F is a contribution for a better-defined radiolarian zonation of the Jurassic Mediterranean Tethys. All radiolarian data provided by this research will be used both to improve the zonation of the INTERRAD Jurassic-Cretaceous Working Group (Baumgartner et al. 1995d), and to create a database for the definition of new radiolarian biozones for the Jurassic Mediterranean Tethys.

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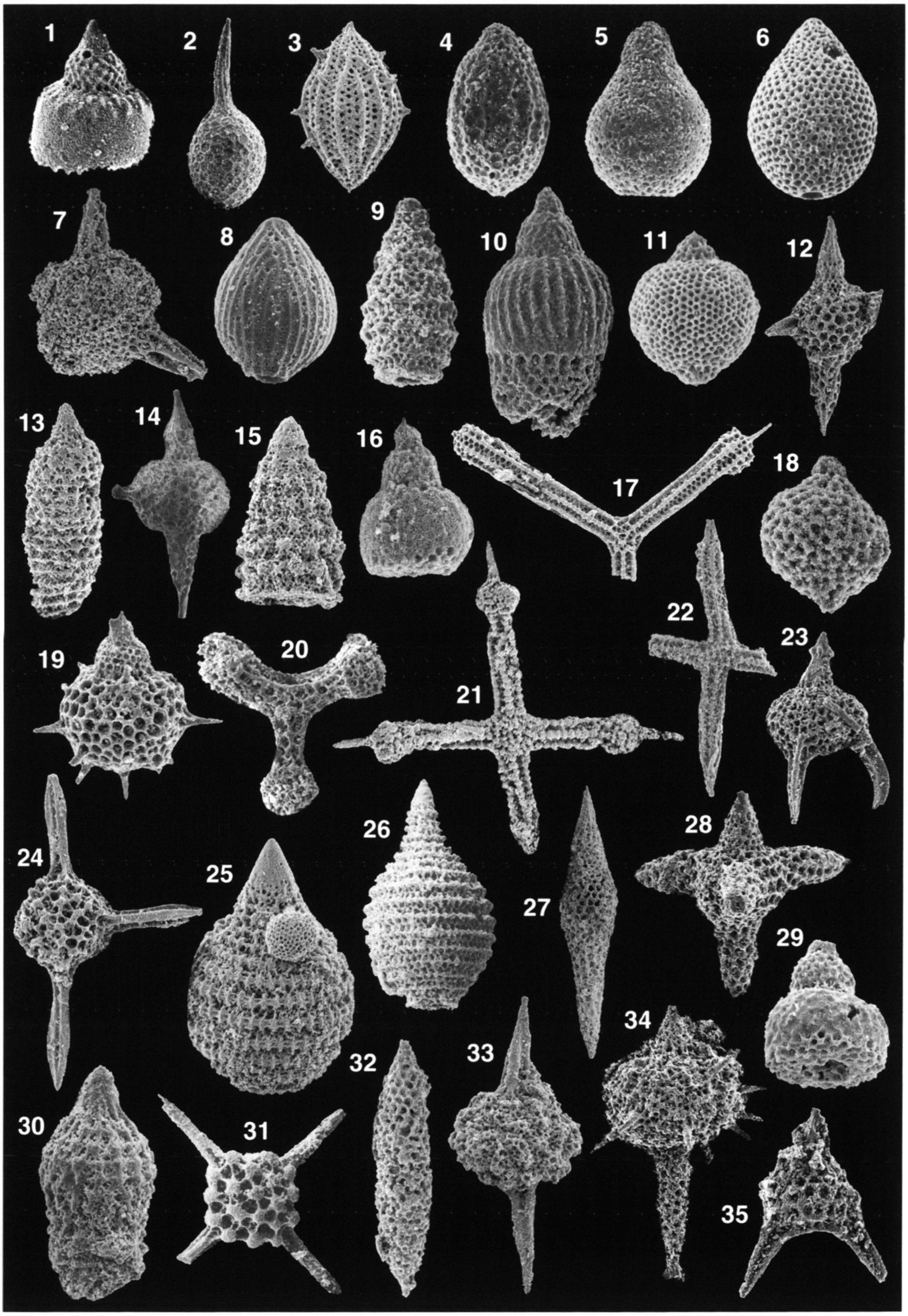
Plate 1

Scanning electron micrographs of the most important radiolarians used for the definition of the UAZ A–F are illustrated. For each photo are given the code of the section, the number of the sample, the UAZone of the sample, and the magnification. The codes of the stratigraphic sections are: BB-Balata di Baida, CI-Castello Inici, CV-Coston delle Vette, FZC-Fornazzo Cava, FV-Favignana, IN-Fornazzo Strada, SA-Sant'Anna, VN-Cava Vianini.

1 – *Eucyrtidiellum unumaense dentatum* BAUMGARTNER, CV 60, UAZ A, x250
2 – *Stylocapsa oblongula* KOCHER, CV 60, UAZ A, x200
3 – *Unuma echinatus* ICHIKAWA & YAO, CV 60, UAZ A, x150
4 – *Stylocapsa catenarum* MATSUOKA, VN 2.85, UAZ B, x350
5 – *Praewilliriedellum convexum* (YAO), VN 2.85, UAZ B, x200
6 – *Stichocapsa robusta* MATSUOKA, VN 2.85, UAZ B, x200
7 – *Triactoma parablakei* YANG & WANG, VN 0.40, UAZ B, x100
8 – *Tricolocapsa plicarum* s.l. YAO, VN 2.85, UAZ B, x250
9 – *Tethysetta dhimenaensis dhimenaensis* (BAUMGARTNER), VN 2.85, UAZ B, x250
10 – *Eucyrtidiellum ptyctum* (RIEDEL & SANFILIPPO), VN 0.40, UAZ B, x250
11 – *Williriedellum carpathicum* DUMITRICA, VN 2.85, UAZ B, x200
12 – *Podobursa vannae* BECCARO, CI 4, UAZ C, x100
13 – *Ristola altissima altissima* (RÜST), IN 3, UAZ C, x100
14 – *Podobursa polyacantha* (FISCHLI), CE 5.20, UAZ D, x100
15 – *Xitus magnus* BAUMGARTNER, CI 5, UAZ C, x120
16 – *Eucyrtidiellum unumaense* s.l. (YAO), FZC 3, UAZ C, x250
17 – *Tritrabs hayi* (PESSAGNO), CI 5, UAZ C, x75
18 – *Williriedellum (?) marcucciae* CORTESE, IN 1, UAZ C, x300
19 – *Zhamoidellum (?) exquisitum* HULL, IN 3, UAZ D, x200
20 – *Angulobracchia biordinalis* OZVOLDOVA, BB 11.70, UAZ D, x200
21 – *Tetratrabs bulbosa* BAUMGARTNER, CI 8, UAZ D, x60
22 – *Tetratrabs zealis* (OZVOLDOVA), IN 3, UAZ D, x60
23 – *Napora lospensis* PESSAGNO, IN 8, UAZ D, x100
24 – *Emiluvia orea* BAUMGARTNER, CI 8, UAZ D, x80
25 – *Mirifusus dianae minor* BAUMGARTNER, CI 15, UAZ E, x100
26 – *Mirifusus dianae dianae* (KARRER), SA 0.35, UAZ E, x100
27 – *Pseudoeucyrtis* sp. B sensu WIDZ 1991, SA 0.35, UAZ E, x100
28 – *Podocapsa amphitreptera* FOREMAN, CV 122, UAZ E, x130
29 – *Eucyrtidiellum nodosum* WAKITA, IN 19, UAZ E, x300
30 – *Ristola altissima nodosa* HORI, BB 15.10, UAZ E, x150
31 – *Emiluvia ultima* BAUMGARTNER & DUMITRICA, SA 0.35, UAZ E, x100
32 – *Pseudoeucyrtis reticularis* MATSUOKA & YAO, IN 32, UAZ F, x120
33 – *Acaeniotyle umbilicata* (RÜST), IN 32, UAZ F, x100
34 – *Syringocapsa spinellifera* BAUMGARTNER, CV 125.6, UAZ F, x100
35 – *Napora boneti* PESSAGNO, WHALEN & YEH, IN 30, UAZ F, x150



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