The middle Jurassic siliceous sedimentary cover at the top of Vourinos ophiolites (Greece)

THE MIDDLE JURASSIC SILICEOUS SEDIMENTARY COVER AT THE TOP OF THE VOURINOS OPHIOLITE (GREECE)

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ABSTRACT

The age of the Vourinos ophiolitic massif, pertaining to the Jurassic Tethys Ocean, is not yet exactly known. Four sections in the cherts at the top of the basalts yielded well preserved radiolarian assemblages according to which the age of the end of the "ophiolitic activity" (= the end of ocean spreading) was immediately before or within the latest Bajocian interval. A radiometric (Ar/Ar) age of the metamorphic sole at the base of the ophiolite gave 171±4 Ma (late Bajocian), this is, an age slightly older than that of the cherts: this can mean that the metamorphic soles pertain to an intraoceanic hot thrust, doubling the oceanic crust/lithosphere.

INTRODUCTION AND GEOLOGICAL SETTING

In this study, we describe some radiolarian assemblages that have been extracted from the cherts of the sedimentary cover of the Vourinos ophiolite.

The Vourinos Massif is one of the better known ophiolites of the Mediterranean area. Till the end of the sixties it was considered an autochthonous magmatic body, emplaced, as an enormous lava flow (Brunn, 1956) or "as a crystal mush or a deforming solid mass rather than as a magma" (Moores, 1969), on the continental crust. Its allochthonous position on the metamorphic Pelagonian Zone, now almost unanimously accepted, was firstly put forward by Bortolotti et al. (1969), Zimmerman (1969), Dercourt (1970). Its origin as a portion of an ocean floor was proposed by Dercourt (1970), Zimmerman (1972), Bernoulli and Laubscher, (1972), etc.

If its original position was to the west or to the east, or if it belongs to a "Pindos Ocean" or to the "Vardar Ocean" are till now matter of debate. These problems are beyond the scope of this article. In any case, we incline to a provenance from the Vardar Ocean, situated to the east (see Bernoulli and Laubscher, 1972), which, according our paleogeographic and geodynamic reconstructions, was the only ocean in the Hellenic area (Bortolotti et al. 2003, with bibl.).

The Vourinos Massif consists of a tectonically disrupted but complete ophiolite sequence, which is interpreted as the product of a supra-subduction zone (Beccaluva et al., 1984). It consists of two main bodies (Western and Eastern Vourinos) and three minor satellite bodies (Krapa Hills, Zyghosti Creek and Mikrokastro). The main outcrops expose a serpentinite carapace, which coats the main mass of harzburgites (with minor lherzolites), dunites and gabbros *lato sensu* (Moores, 1969; Jackson et al., 1975; Beccaluva et al., 1984). The satellite bodies are made of harzburgites, often serpentinised, cumulates (present only in the Krapa Hills), an extrusive sequence of IAT type (Beccaluva et al., 1984) which includes pillow basalts, basalts andesites, minor dacites and, at the top, scattered thin levels of cherts and cherty limestones. Basalts and cherts are uncomformably covered by Lower or Upper Cretaceous limestones.

In spite of the very profound knowledge of the ophiolitic body, no data were available so far on the age of this ophiolite; only a sample from the amphibolite sole gave a radiometric age (Ar/Ar) of 171±4 Ma (Spray et al., 1984), which, according to the Pálfi et al. (2000) time scale corresponds to the ?late Bajocian. The Jurassic age of the ophiolite was established only on calpionellids "of Tithonian (?) or Neocomian (?) age" in "brecciated limestones" covering the cherts at Langadhakia (Moores, 1969) and on the Latest Jurassic - Early Cretaceous age of the transgressive limestones on top of the massif (Brunn, 1956; Pichon and Lys, 1976).

The radiolarian assemblages here described provide more exact datings for the Vourinos ophiolite.

BIOSTRATIGRAPHY AND SECTION DESCRIPTION

The radiolarians assemblages described, come from four sections of cherts (Fig. 1 and 2), cropping out at the top of the basalts in the satellite bodies of Krapa Hills (Section A), Mikrokastro (Section B) and Zygosti Creek (Sections C and D).

Fourteen samples have been collected for radiolarian analyses. The radiolarians have been extracted from the cherts with hydrofluoric acid at different concentrations, utilising the method proposed by Dumitrica (1970), Pessagno and Newport (1972), Baumgartner et al. (1981) and De Wever (1982).

The radiolarian zonation based on Unitary Association Zones (UAZ.) proposed by Baumgartner et al. (1995) is adopted herein. The complete faunal assemblages from the examined samples are reported in Fig. 3, the ranges in Fig. 4, and the most important taxa are shown in Plates 1 and 2.

Section A - Krapa Hills

In the Krapa Hills area, near Langadhakia, (NE of Grevena, behind the Aliakmon River) on the eastern side of the road, pillow basalts that lie at the top of the intrusives, are

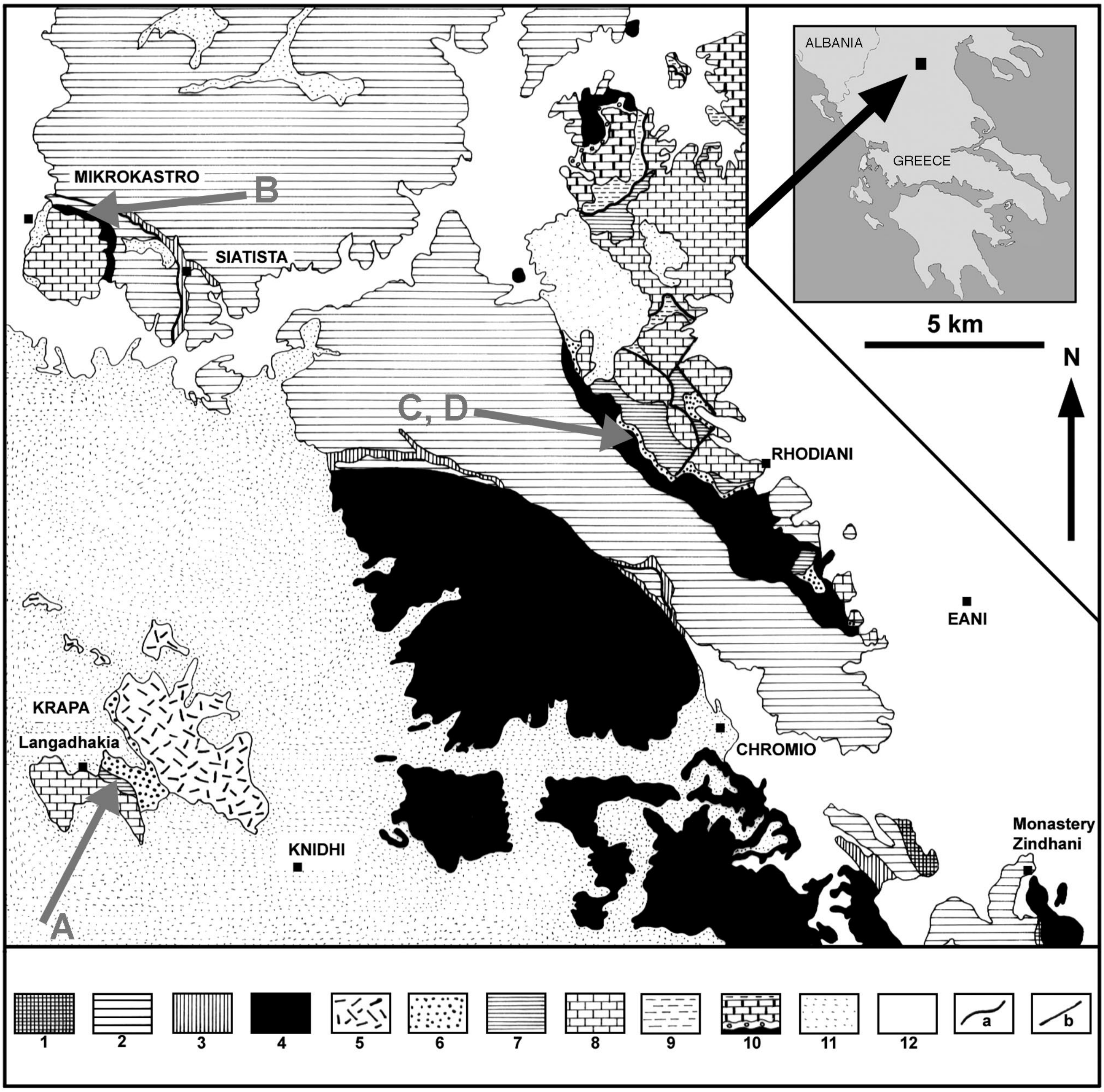

Fig. 1 - Geological map of Vourinos area (Moores 1969; Mavrides et al. 1982; 1991) modified.
1- Pelagonian basement with gneiss and schists; 2- Triassic-Jurassic Pelagonian marbles; 3- Jurassic "sub-ophiolite" mélange rich in schists and amphibolite soles; 4- More or less serpentinised harzburgites including dunites rich in chromite and pyroxenite bodies; 5- Ultramafic (dunite, wherlite, pyroxenite, troctolite, gabbronorite) and mafic (pyroxenite, gabbro) cumulates; 6- Dolerite sheeted dyke complex with pillow lavas intruded by boninitic dykes and overlain by radiolarian red chert sequence; 7- Upper Jurassic limestones; 8- Cretaceous limestones; 9- Upper Maastrichtian flysch; 10- Post-flysch tectonic unit including serpentinites, ophiolitic conglomerates, Upper Cretaceous rudistic limestones and flysch; 11- Upper Aquitanian-Burdigalian (Miocene) molassic sediments; 12- Plio-Quaternary deposits; a- thrust; b- normal fault.
A- Krapa section; B- Mikrokastro Section; C, D- Zyghosti sections.

overlain by about 3 m of red radiolarian cherts grading upwards to ?Tithonian thin-bedded cherty limestones which yielded not determinable ammonites and belemnites. Further up, the succession continues with redeposited Jurassic limestones and is uncomformably covered by Upper Cretaceous limestones (Fig. 2A).

In this section four samples were collected:

- GR 19 (uncertain stratigraphic position) yielded a well preserved radiolarian assemblage. The coexistence of *Mirifusus fragilis praeguadalupensis* Baumgartner and Bartolini with *Guexella nudata* (Kocher), *Mirifusus guadalupensis* Pessagno, *Protunuma* (?) *ochiensis* Matsuoka, *Protunuma quadriperforatus* O'Dogherty and Gorican, , *Ristola altissima major* Baumgartner and De Wever and *Stylocapsa* (?) *hemicostata* Matsuoka indicates a latest Bajocian-early Bathonian age (UAZ. 5). The presence of *Hexasaturnalis nakasekoi* Dumitrica and Dumitrica-Jud could indicate a more restricted time interval: early Bathonian age.

- GR 20 (about 1.30 m above the basalts). Age not determinable due to the poorly preserved fauna.

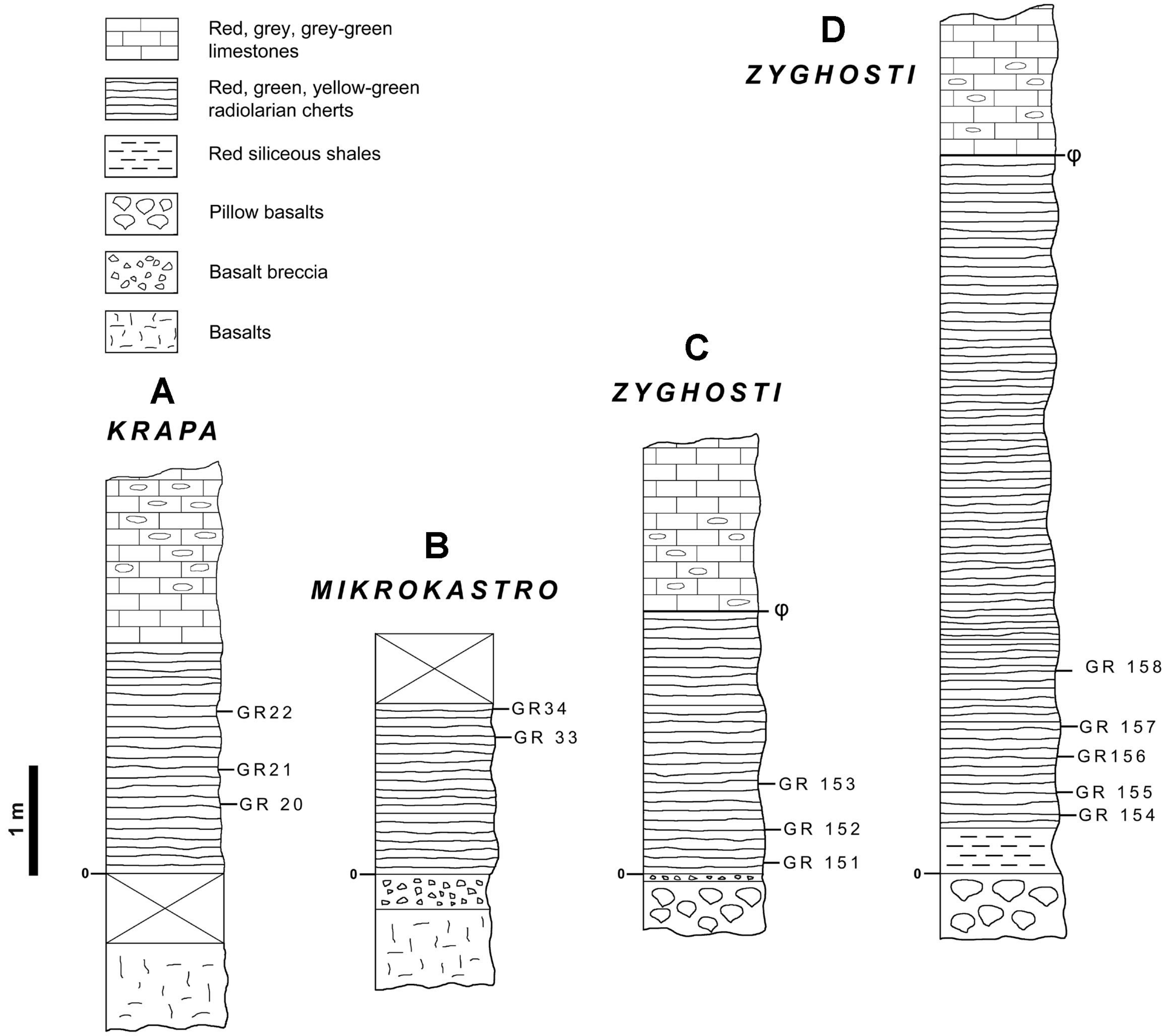

Fig. 2 - Logs of the examined sections.

- GR 21 (about 1.60 m above the basalts). Age not determinable due to the poorly preserved fauna.

- GR 22 (about 2.10 m above the basalts). The presence of *Ristola altissima major* Baumgartner and De Wever indicates a latest Bajocian - early Bathonian to late Bathonian-early Callovian age (UAZ. 5-7).

Section B - Mikrokastro

In the Siatista area, about two km from Mikrokastro, on the right of the road towards Siatista, the ophiolite outcrop consists of schistose serpentinites, at the base, and pillow lavas covered by a thin level of red and green radiolarian cherts, at the top. The contact between serpentinites and cherts is covered and probably tectonic. A tectonic contact (fault?) separates also the ophiolitic rocks from a Lower Cretaceous cherty limestone succession (Fig. 2B).

In this section two samples were collected for radiolarian analyses:

- GR 33 (about 1.5 metres above the basalts), yielded a well preserved radiolarian assemblage. The coexistence of *Bernoullius cristatus* Baumgartner, *Protunuma quadriperforatus* O'Dogherty and Gorican and *Stichocapsa robusta* Matsuoka with *Unuma latusicostata* (Aita) indicates a latest Bajocian-early Bathonian age (UAZ. 5). The presence of *Hexasaturnalis suboblongus* (Yao) could indicate a more restricted time interval: latest Bajocian age.

- GR 34 (about 1.8 metres above the basalts). The coexistence of *Guexella nudata* (Kocher), *Protunuma quadriperforatus* O'Dogherty and Gorican, *Ristola altissima major* Baumgartner and De Wever and *Stichocapsa robusta* Matsuoka with *Theocapsomma medvednicensis* Gorican indicates a latest Bajocian-early Bathonian age (UAZ. 5).

Sections C and D - Zyghosti Creek

In the Zyghosti Creek area, about 10 km S-SW of Kozani, some tens of metres of pillow basalts tectonically cover the harzburgite-dunite complex. Scattered thin outcrops of radiolarian cherts are present at the top of the basalts. A thrust surface separates this succession from the Middle and Upper Jurassic carbonate platform deposits that

Sections	KRAPA				MIKRO-KASTRO		ZYGHOSTI A		ZYGHOSTI B	
Taxa / ***Samples***	GR 19	GR 20	GR 21	GR 22	GR 33	GR 34	GR151	GR 153	GR 154	GR 157
Angulobracchia sp.					■					
Archaeodictyomitra (?) *amabilis* Aita					■	■				
Archaeodictyomitra (?) sp. cf. *A. amabilis* Aita									■	
Archaeodictyomitra sp. cf. *A. apiarium* (Rüst)					■					
Archaeodictyomitra sp. cf. *A. etrusca* Chiari, Cortese and Marcucci						■				
Archaeodictyomitra sp. cf. *A. spelae* Chiari, Cortese and Marcucci					■					
Archaeodictyomitra sp.					■	■			■	
Bernoullius cristatus Baumgartner					■					
Dictyomitrella (?) *kamoensis* Mizutani and Kido					■					
Dictyomitrella (?) sp. cf. *D.* (?) *kamoensis* Mizutani and Kido									■	
Emiluvia premyogii Baumgartner	■									
Emiluvia sp. cf. *E. premyogii* Baumgartner	■									
Emiluvia sp.		■								
Eucyrtidiellum sp. cf. *E. unumaense dentatum* Baumgartner									■	
Eucyrtidiellum sp. cf. *E. unumaense pustulatum* Baumgartner					■					
Eucyrtidiellum unumaense s.l. (Yao)					■	■				
Eucyrtidiellum sp.					■				■	
Guexella nudata (Kocher)	■					■				
Hexasaturnalis nakasekoi Dumitrica and Dumitrica-Jud	■									
Hexasaturnalis suboblongus (Yao)					■					
Homoeoparonaella (?) sp. cf. *H.* (?) *pseudoewingi* Baumgartner						■				
Homoeoparonaella sp.		■								
Levileugeo ordinarius Yang & Wang	■									
Linaresia sp.	■									
Mirifusus fragilis praeguadalupensis Baumgartner and Bartolini	■									
Mirifusus guadalupensis Pessagno	■									
Mirifusus sp. cf. *M. fragilis praeguadalupensis* Baumgartner and Bartolini						■				
Napora sp. cf. *N. saginata* Takemura					■					
Pantanellium sp.	■				■	■				
Paronaella sp. cf. *P. broennimanni* Pessagno	■				■					
Paronaella bandyi Pessagno	■									
Podobursa helvetica (Rüst)	■									
Protunuma (?) *ochiensis* Matsuoka	■									
Protunuma quadriperforatus O'Dogherty and Gorican	■				■	■				
Protunuma turbo Matsuoka					■					
Protunuma sp.						■				
Protunuma (?) sp.					■					
Pseudoeucyrtis sp. cf. *P.* sp. J Baumgartner et al.	■									
Ristola altissima major Baumgartner and De Wever	■			■		■			■	
Saitoum levium De Wever					■					
Saitoum sp. cf. *S. pagei Pessagno*					■					
Saitoum sp.					■	■				
Sethocapsa funatoensis Aita						■				
Sethocapsa sp.						■	■			
Sethocapsa (?) sp.			■							
Stichocapsa convexa Yao	■				■				■	
Stichocapsa robusta Matsuoka					■	■		■	■	
Stichocapsa sp.	■									
Striatojaponicapsa conexa (Matsuoka)					■					
Striatojaponicapsa plicarum s.l. (Yao)						■				
Striatojaponicapsa sp. cf. *S. conexa* (Matsuoka)						■				
Striatojaponicapsa sp. cf. *S. plicarum* ssp. A (Baumgartner et al.)	■									
Striatojaponicapsa sp.							■		■	
Stylocapsa (?) *hemicostata* Matsuoka	■									
Stylocapsa oblongula Kocher									■	
Stylocapsa sp. cf. *S. oblongula* Kocher									■	
Stylocapsa tecta Matsuoka									■	
Stylocapsa sp.					■				■	
Tethysetta dhimenaensis s.l. (Baumgartner)	■				■	■				
Tethysetta dhimenaensis ssp. A (Baumgartner et al.)					■	■				
Tethysetta sp. cf. *T. dhimenaensis* ssp. A (Baumgartner et al.)						■				
Tetraditryma sp.	■									
Theocapsomma medvednicensis Gorican						■				

Fig. 3 - Occurence chart of the radiolarian taxa.

Sections	KRAPA				MIKRO-KASTRO		ZYGHOSTI A		ZYGHOSTI B	
Taxa / Samples	GR 19	GR 20	GR 21	GR 22	GR 33	GR 34	GR151	GR 153	GR 154	GR 157
Theocapsomma sp.					■				■	
Transhsuum maxwelli gr. (Pessagno)	■									
Transhsuum sp. cf. *T. maxwelli* gr. (Pessagno)					■					
Transhsuum sp.	■			■	■	■			■	
Tritrabs sp. cf. *T. casmaliaensis* (Pessagno)	■									
Unuma gorda Hull						■			■	
Unuma sp. cf. *U. gorda* Hull				■	■					
Unuma latusicostatus (Aita)					■					
Unuma sp.					■	■			■	■
Williriedellum sp. cf. *W.* sp. A Matsuoka	■									
Williriedellum sp. cf. *W. carpathicum* Dumitrica				■						
Wrangellium brevicostatum gr. (Ozvoldova)	■					■				
Wrangellium sp. cf. *W. brevicostatum* gr. (Ozvoldova)						■				
Zhamoidellum triangulosa (Tan)				■						

Fig. 3, continued.

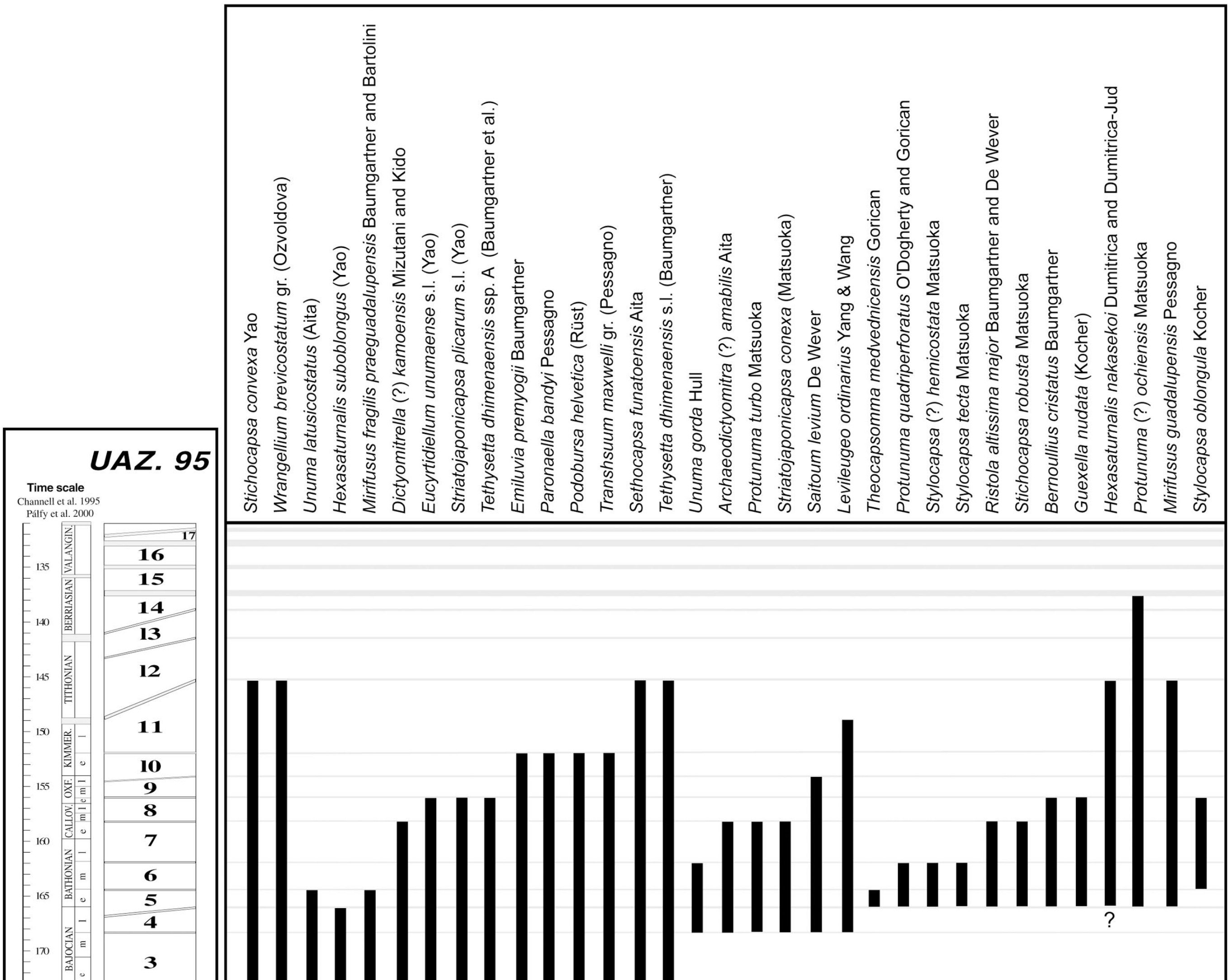

Fig. 4 - Range chart of the radiolarian taxa. Radiolarian zonation after Baumgartner et al. (1995), time scale after Channel et al. (1995) and Pálfy et al. (2000). Range of *Theocapsomma medvednicensis* Gorican after Halamic et al. (1999); *Protunuma quadriperforatus* O'Dogherty and Gorican after O'Dogherty and Gorican (2002); *Hexasaturnalis nakasekoi* Dumitrica and Dumitrica-Jud after Dumitrica and Dumitrica-Jud (2003), *Hexasaturnalis suboblongus* (Yao), Dumitrica (pers. com.).

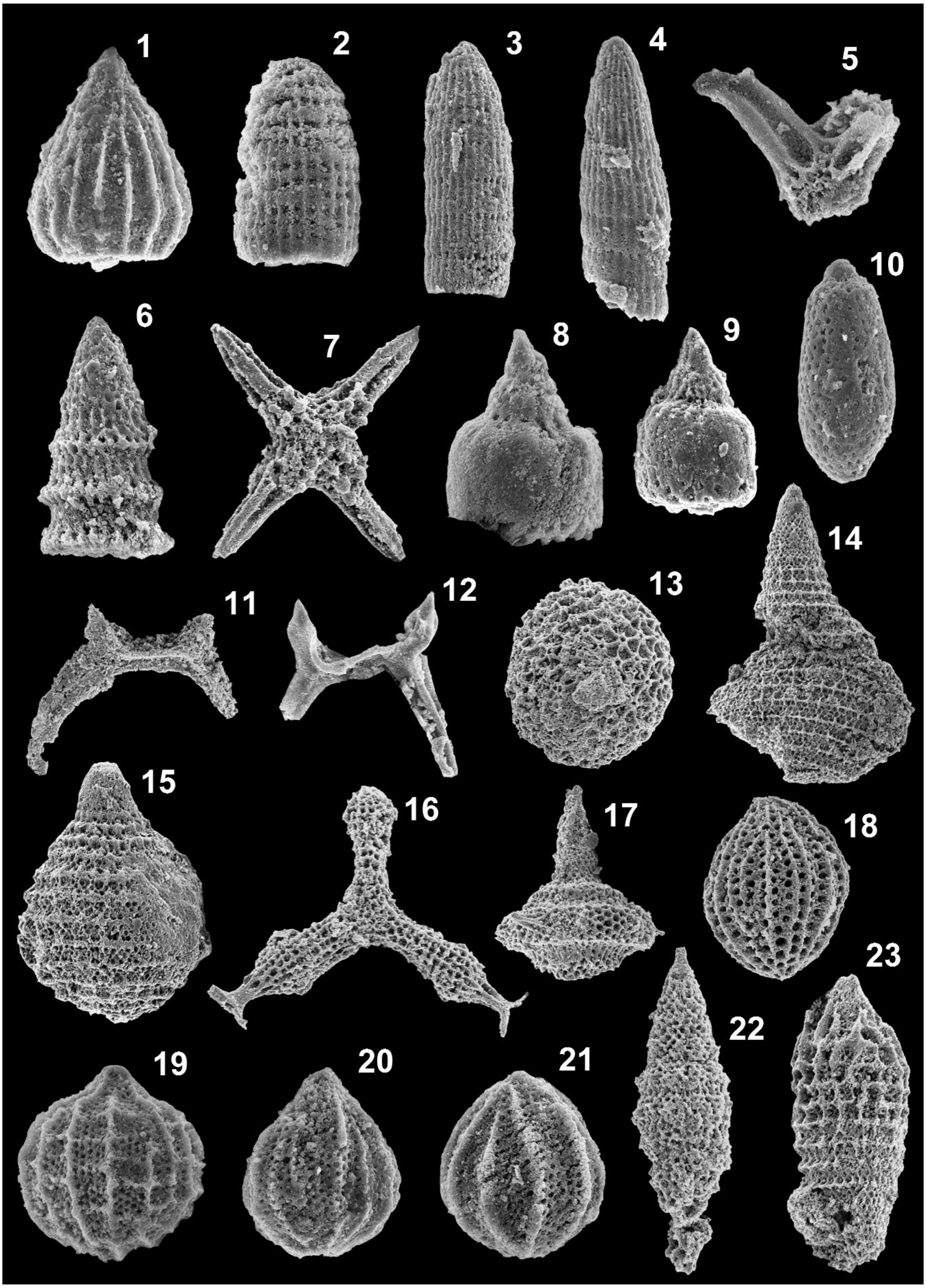

Plate 1 - 1) *Archaeodictyomitra* (?) *amabilis* Aita, GR 33, x290; 2) *Archaeodictyomitra* sp. cf. *A. apiarium* (Rüst), GR 33, x290; 3) *Archaeodictyomitra* sp. cf. *A. etrusca* Chiari, Cortese and Marcucci, GR 34, x290; 4) *Archaeodictyomitra* sp. cf. *A. spelae* Chiari, Cortese and Marcucci, GR 33, x290; 5) *Bernoullius cristatus* Baumgartner, GR 33, x240; 6) *Dictyomitrella* (?) *kamoensis* Mizutani and Kido, GR 33, x390; 7) *Emiluvia premyogii* Baumgartner, GR 19, x186; 8) *Eucyrtidiellum unumaense* s.l. (Yao), GR 33, x345; 9) *Eucyrtidiellum* sp. cf. *E. unumaense pustulatum* Baumgartner, GR 33, x345; 10) *Guexella nudata* (Kocher), GR 34, x400; 11) *Hexasaturnalis nakasekoi* Dumitrica and Dumitrica-Jud, GR 19, x137; 12) *Hexasaturnalis suboblongus* (Yao), GR 33, x137; 13) *Levileugeo ordinarius* Yang and Wang, GR 19, x115; 14) *Mirifusus fragilis praeguadalupensis* Baumgartner and Bartolini, GR 19, x70; 15) *Mirifusus guadalupensis* Pessagno, GR 19, x140; 16) *Paronaella bandyi* Pessagno, GR 19, x160; 17) *Podobursa helvetica* (Rüst), GR 19, x122; 18) *Protunuma* (?) *ochiensis* Matsuoka, GR 19, x258; 19) *Protunuma quadriperforatus* O'Dogherty and Gorican, GR 19, x228; 20) *Protunuma turbo* Matsuoka, GR 33, x228; 21) *Protunuma* (?) sp., GR 33, x258; 22) *Pseudoeucyrtis* sp. cf. *P.* sp. J Baumgartner et al., GR 19, 150; 23) *Ristola altissima major* Baumgartner and De Wever, GR 19, x150.

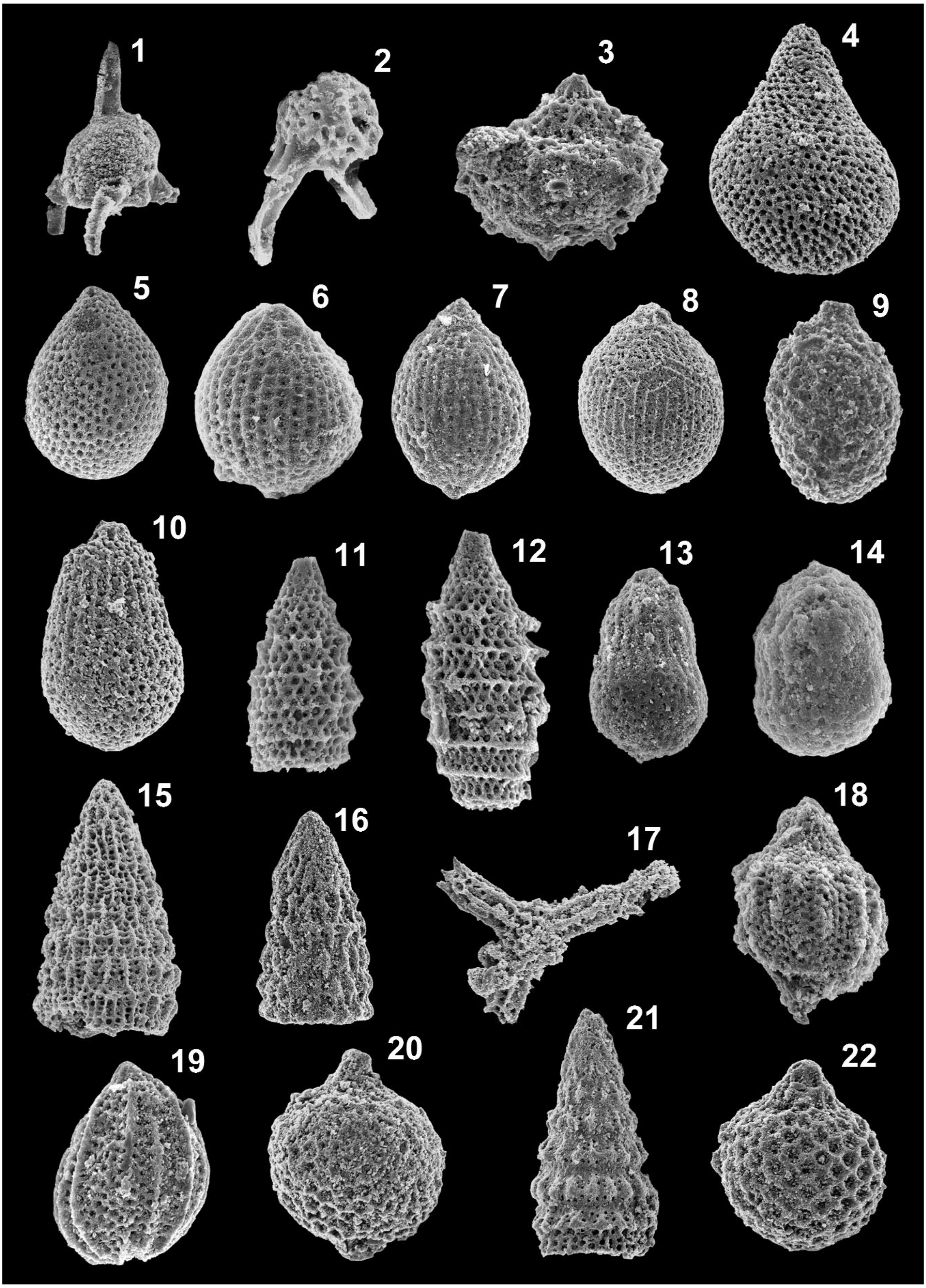

Plate 2 - 1) *Saitoum levium* De Wever, GR 33, x298; 2) *Saitoum* sp. cf. *S. pagei* Pessagno, GR 33, x242; 3) *Sethocapsa funatoensis* Aita, GR 34, x288; 4) *Stichocapsa convexa* Yao, GR 19, x214; 5) *Stichocapsa robusta* Matsuoka, GR 33, x238; 6) *Striatojaponicapsa conexa* (Matsuoka), GR 33, x244; 7) *Striatojaponicapsa plicarum* s.l. (Yao), GR 34, x292; 8) *Stylocapsa* (?) *hemicostata* Matsuoka, GR 19, x216; 9) *Stylocapsa oblongula* Kocher, GR 154, x365; 10) *Stylocapsa tecta* Matsuoka, GR 154, x276; 11) *Tethysetta dhimenaensis* s.l. (Baumgartner), GR 34, x270; 12) *Tethysetta dhimenaensis* ssp. A (Baumgartner et al.), GR 33, x270; 13) *Theocapsomma medvednicensis* Gorican, GR 34, x360; 14) *Theocapsomma* sp., GR 33, x360; 15) *Transhsuum maxwelli* gr. (Pessagno), GR 19, x180; 16) *Transhsuum* sp., GR 22, x180; 17) *Tritrabs* sp. cf. *T. casmaliaensis* (Pessagno), GR 19, X158; 18) *Unuma latusicostatus* (Aita), GR 33, x310; 19) *Unuma gorda* Hull, GR 34, x308; 20) *Williriedellum* sp. cf. *W. carpathicum*, Dumitrica, GR 22, x136; 21) *Wrangellium brevicostatum* gr. (Ozvoldova), GR 19, x188; 22) *Zhamoidellum triangulosa* (Tan), GR 22, x272.

according to Brunn (1956) constituted the uncomformable cover of the ophiolites. These two tectonic units were piled up before the Cenomanian, which is the age of a marine transgression that sealed the Jurassic platform and the ophiolites (Carras et al., 2004, in press).

In the main outcrop of the cherts, on the left side of the creek, about 750 m NE of Aghios Nicolas Chapel, two sections (C and D) about 20 m from one another were sampled (Fig. 2C, 2D).

In the section C three samples were collected:

- GR 151 (about 0.13 metres above the basalts). Age not determinable due to the poorly preserved fauna.
- GR 152 (about 0.45 metres above the basalts). Age not determinable due to the poorly preserved fauna.
- GR 153 (collected about 0.85 cm above the basalts). The presence of *Stichocapsa robusta* Matsuoka indicates a latest Bajocian-early Bathonian to late Bathonian-early Callovian age (UAZ. 5-7

In the section D five samples were collected:

- GR 154 (about 0.50 cm above the basalts). The presence of *Stylocapsa tecta* Matsuoka, *Unuma gorda* Hull and *Stylocapsa oblongula* Kocher indicates a middle Bathonian age (UAZ. 6).
- GR 155 (about 0.75 metres above the basalts). Age not determinable due to the poorly preserved fauna.
- GR 156 (about 1.05 metres above the basalts). Age not determinable due to the poorly preserved fauna.
- GR 157 (about 1.30 metres above the basalts). Age not determinable due to the poorly preserved fauna.
- GR 158 (about 1.75 metres above the basalts). Age not determinable due to the poorly preserved fauna.

FINAL REMARKS

The ages given by the radiolarian cherts at the top of the Vourinos basalts are as follows:

1- Krapa Hills: early Bathonian;
2- Mikrokastro: latest Bajocian;
3- Zyghosti: latest Bajocian-early Bathonian to late Bathonian-early Callovian age, section C; middle Bathonian, section D.

We can conclude that in the Vourinos ophiolite the basalt extrusion (and the seafloor spreading?) ended immediately before or within the latest Bajocian - early Callovian age interval. This age is slightly younger than the age of the metamorphism of the amphibolite sole at the base of the massif. We argue that here, as in other cases (Mirdita ophiolites of Albania) the amphibolite soles pertain to an intraoceanic “high-temperature shear zone formed at the base of an overridden section of oceanic lithosphere” (Bortolotti et al., 1996; Carosi et al., 1996).

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