RADIOLARIAN AGES FOR THE SEDIMENTARY COVER OF SEVAN OPHIOLITE (ARMENIA, LESSER CAUCASUS)

Gayané Asatryan*,°,✉, **Taniel Danelian****, **Marc Sosson*****, **Lilit Sahakyan***, **Alain Person**°°, **Ara Avagyan*** and **Ghazar Galoyan***

* *Institute of Geological Sciences, National Academy of Sciences of Armenia, Yerevan, Armenia.*
** *Université de Lille 1, Dept. of Earth Sciences, CNRS-FRE 3298 Géosystèmes, Lille, France.*
*** *Université de Nice Sophia Antipolis, CNRS, OCA-UMR Géosciences AZUR, Nice, France.*
° *Université P. & M. Curie (Paris VI), CNRS-UMR 7207 CR2P Centre de recherche sur la paléobiodiversité et les paléoenvironnements, Paris, France.*
°° *Université P. & M. Curie (Paris VI), CNRS-ISTeP Institut des Sciences de la Terre, Paris, France.*
✉ *Corresponding author, e-mail: asatryan@geology.am*

Keywords: *Radiolaria, radiolarite, Jurassic, Cretaceous, Sevan ophiolite. Armenia, Lesser Caucasus.*

ABSTRACT

Age data of Armenian ophiolites are of great importance for understanding the palaeogeographic and geodynamic evolution of Tethys in the Caucasus area and for lateral correlations of Tethyan ophiolitic belts in the Middle East area. Moderately well-preserved radiolarian assemblages obtained during this study from the Sarinar section of eastern Armenia allow to investigate the sedimentary and volcanic history recorded in a ca. 30 m-thick radiolarite sequence associated with spilitic lavas of the Sevan ophiolitic suture zone.

The latest Bajocian-early Bathonian assemblage yielded from a sample situated close to the base of the studied sequence suggests that radiolarian ooze accumulation took place on oceanic crust of late Middle Jurassic age (probably Bajocian). Several tuffite levels are intercalated within the lower to middle part of the radiolarite sequence; a late Bathonian-early Oxfordian assemblage from a sample taken just below the uppermost tuffitic bed, suggests that during this time the oceanic domain of Sevan ophiolites was close to subaerial volcanic activity.

INTRODUCTION

A good understanding of the various geologic aspects of ophiolites throughout the Alpine mountain chains is of key importance for reconstruction of the Neo-Tethys Ocean (Dercourt et al., 1986; Bortolotti et al., 1990). In particular, volcanic rocks of ancient oceanic crust and their sedimentary cover (i.e. radiolarites) provide important clues to decipher the geodynamic evolution of Neo-Tethys, especially by constraining the time of opening and spreading of the various parts of this complex Mesozoic oceanic realm (De Wever and Dercourt, 1985; Chiari et al., 1997; 2000; Al-Riyami et al., 2000; 2002; Bill et al., 2001; Tekin et al., 2002; Bortolotti et al., 2004; Bortolotti and Principi, 2005; Danelian et al., 2008a). In this respect radiolarian biochronology has become invaluable during the last thirty years for understanding the geodynamic and palaeoenvironmental evolution of Tethyan oceanic basins and continental margins (Baumgartner, 1984; Karakitsios et al., 1988; Tekin et al., 2002; O'Dogherty et al., 2006; Cordey and Bailly, 2007). This is especially true for ophiolites cropping out within the Dinarides-Hellenides system, as well as the Alpine mountains in Turkey (Baumgartner, 1985; Bragin and Tekin, 1996; Danelian et al., 2000; 2006; Chiari et al., 2003; 2004; Vrielynck et al., 2003; Beccaletto et al., 2005; Göncüoglu et al., 2006; Tekin and Göncüoglu, 2007; Bortolotti et al., 2008).

Dating the siliceous sedimentary cover of ancient oceanic crust preserved in Armenia is very important for our understanding of the geodynamic evolution of the greater area between Eurasia and the South-Armenian Block (SAB) (Fig. 1), a micro-continent that was detached from Gondwana during the Late Palaeozoic - Early Mesozoic time interval. Several ophiolite outcrops occur in the country. They are organised mainly in two ophiolitic zones (Fig. 2):

– The Sevan-Akera Zone (Knipper, 1975; Aslanyan and Satian, 1977; Knipper and Khain, 1980) crops out at the E and SE of Lake Sevan and represents the main Tethyan suture zone between Eurasia and the South-Armenian Block (SAB). The Amassia-Stepanavan ophiolites that crop out in the north-western part of the country are considered as the north-westward extension of the Sevan-Akera ophiolite zone (Sosson et al., 2010).

– The Vedi ophiolite, situated south-east of the capital Yerevan. It corresponds to a folded klippe sequence that was thrust during the Late Cretaceous onto the South Armenian Block (Sosson et al., 2010).

Recent French-Armenian joint studies on the Armenian ophiolitic zones collected new radiolarian data on the sedimentary cover of the Vedi and Stepanavan ophiolites, obtaining Middle and Late Jurassic ages (Danelian et al., 2007; 2008b; 2010; Asatryan, 2009). Some palaeontological ages also exist for the Sevan-Akera ophiolitic zone. Early studies pointed to a poorly constrained Late Jurassic-Neocomian time interval for radiolarites intercalated or overlying ophiolitic lavas from the Sevan zone (Zakariadze et al., 1983). More recently, Vishnevskaya (1995) reported Bajocian to early Bathonian ages on cherts overlying basaltic lavas, while Knipper et al. (1997) found Carnian and Toarcian radiolarian cherts intercalated with ophiolitic breccias.

In this paper, we describe new radiolarians from a radiolarite sequence overlying Middle Jurassic spilitic lavas of the Sevan ophiolite. The presence of several tuffite levels intercalated within the radiolarites is of particular importance because it provides, for the first time, evidence of a Middle/Late Jurassic source of subaerial volcanic activity in the vicinity of the Neo-Tethys Ocean, remnants of which are preserved in Armenia.

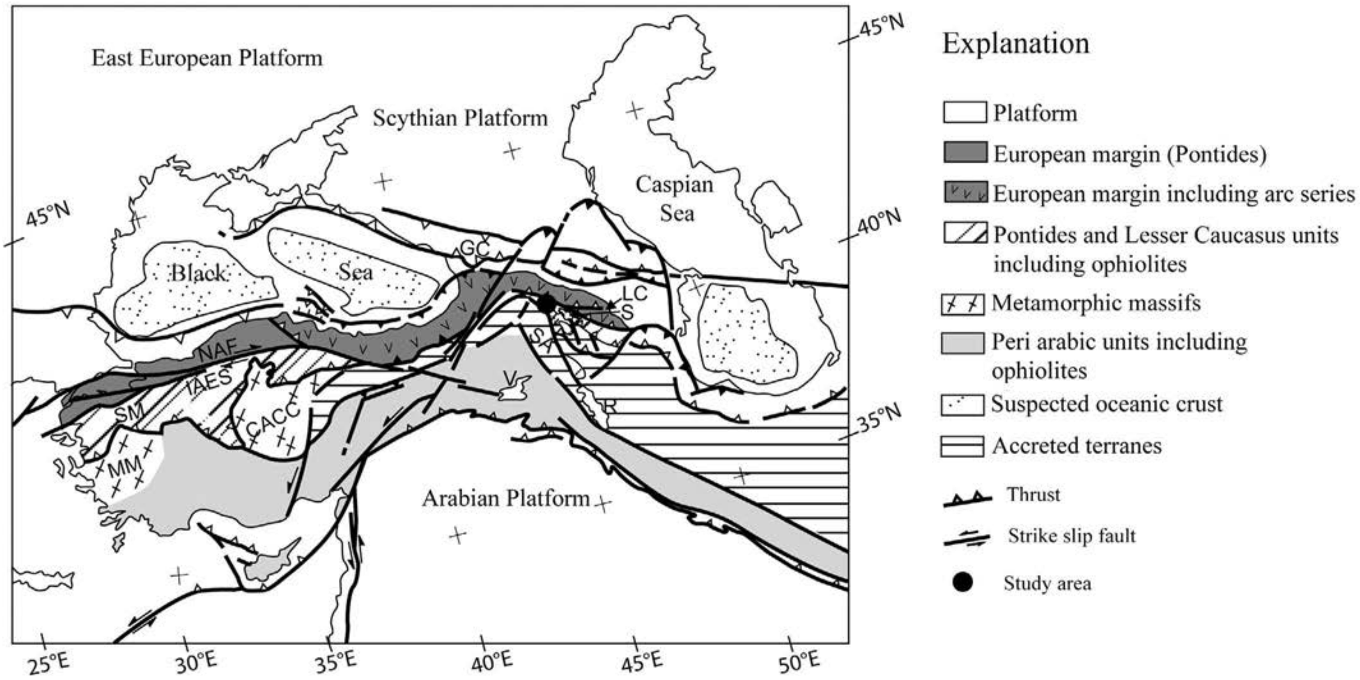

Fig. 1 - Structural map of the Arabia-Eurasia collision area, after Avagyan et al. (2005), modified. CACC: Central Anatolian Crystalline Complex, KM: Kirsehir Massif, MM: Menderes Massif, SM: Sakarya Massif, IAES: Izmir-Ankara-Erzinchan Suture, NAF: North Anatolian Fault, EAF: East Anatolian Fault, GC: Great Caucasus, LC: Lesser Caucasus, SA: South-Armenian Block, V: Van Lake, S: Sevan Lake, R: Reziyeh Lake.

GEOLOGICAL SETTING

The NW-SE oriented Sevan-Akera ophiolite zone crops out for ca. 300 km, from Amassia (NW Armenia) to the Karabagh region. It constitutes the suture zone of the Tethys ocean in the Lesser Caucasus, resulted from collision between the SAB and Eurasia, with the main collision stage ranging in age between Palaeocene and Middle Eocene (Sosson et al., 2010). The suture zone is deformed by NW-SE trending folds and thrusts related to the collision of Arabia with the SAB in the Oligo-Miocene.

The geology and geodynamic setting of the Sevan ophiolite have been recently detailed by Galoyan et al. (2009) and Rolland et al. (2009). The main characteristics are summarized below:

1- The Sevan ophiolitic sequence displays a high level of fractional crystallisation, including olivine and pyroxene gabbros intruded and overlain by amphibole-bearing gabbros and diorites to plagiogranites. It is considered to have been formed in a slow-spreading ridge setting.

2- Pillow lavas and doleritic dykes are relatively rare. The geochemical composition of lavas is tholeitic to andesitic, pointing also to slow spreading in a back-arc setting.

3- Peridotites are frequent and are in general serpentinized. They are considered to have been exhumed as a result of intraoceanic extension.

Regarding the age of the igneous parts of the Sevan ophiolite, Zakariadze et al. (1990) obtained a 160±4 Ma age following application of the U-Pb method on zircons from tonalite. More recently, Galoyan et al. (2009) obtained a 165.3±1.7 Ma age, by applying the $^{40}Ar/^{39}Ar$ method on amphiboles from gabbro. These radiometric age ranges correspond to the Callovian-Oxfordian and Bathonian-early Callovian intervals, respectively, based on the time scale of Gradstein et al. (2004). They suggest that oceanic crust production took place essentially during the late Middle Jurassic.

FIELD OBSERVATIONS OF THE STUDIED SECTION

North-eastwards of Lake Sevan the suture zone includes tectonic slices made of ophiolites, overlain unconformably by a Santonian to Maastrichtian marine sedimentary sequence. The latter is followed upwards by unconformable Middle to Late Eocene detrital and volcanic rocks. In this area of the Lesser Caucasus, the various structures that can be observed are generated by several different phases of deformation; some of them are related to the obduction of the ophiolites over the SAB, while others to collision of the SAB with Eurasia; finally, other structures are due to the post Late Eocene shortening of the belt following the Arabia/SAB collision (Sosson et al., 2010).

The Sarinar section is situated East of Lake Sevan, towards the northeastern end of the homonymous torrent (altitude 2550 m, N 40º 21.395'; E 45° 40.51'; Fig. 3). It is located at the southern flank of an anticline, where the bedding displays an inverted plunge. This structure is a SW verging fold involving the ophiolite and its sedimentary cover (Fig. 4).

The studied section is composed of about 30 metres of radiolarian cherts, intercalated in their lower/middle part with three rather thick beds of tuffites (Fig. 5). The section being overturned was measured and sampled from the top to the bottom but it will be described with its original stratigraphic polarity. The sequence starts with approximately 10 metres of bedded siliceous argillites (the beds are thicker in the first 2-2.5 metres of the sequence), which overlie conformably (with a stratigraphic contact) lavas considered as being part of the Sevan ophiolitic sequence. The siliceous argillites become increasingly finely-bedded up to a level situated ca. 2 m above the second tuffite bed, where a significant lithological change is observed. The following 4.5 m up the sequence consist of 2-10 cm thick radiolarian chert beds, which are practically devoid of any argillite interlayers. Above the third tuffite bed, the siliceous sedimentary sequence is made of ca. 6 m of finely bedded cherts and abundant argillite interlayers. A significant lithological change is observed at this level, above which the sequence is made of a 6 m-thick interval of rather thick blackish chert beds (rich in Mn). The last 5 m of the sequence are essentially made of decimetric reddish-purple bedded cherts and millimetric argillaceous interlayers. On top, the sedimentary sequence is stratigraphically overlain by dark coloured spilitic pillow lavas.

MATERIAL AND METHODS

Fifteen radiolarian chert samples were collected throughout the sequence, each sample at approximately 2 m intervals. Volcanic rocks are stratigraphically intercalated. Thin section analyses of all the 8 samples collected identify them as tuffites. Radiolarians were extracted by repetitive leaching of samples with low-concentration hydrofluoric acid (HF 4%). The material was dry picked and mounted on SEM stubs. Taxonomic concepts applied during this study follow essentially those of Baumgartner et al. (1995a), but also those of O'Dogherty (1994), O'Dogherty et al. (2006), Dumitrica and Dumitrica-Jud (2005) and Danelian (2008) for some species. Generic names are updated according to O'Dogherty et al. (2009). The inverted commas (" ") are used for genera that are not valid, where an appropriate new genus has not been described yet.

RESULTS

Three samples only yielded identifiable Radiolaria (Table 1). In general, the preservation of the faunas is moderate to poor. The main age-diagnostic species are illustrated in Plates 1-3.

Sample Sar-14 can be assigned to the U.A.Z. 5 of Baumgartner et al. (1995b) (correlated with the latest Bajocian-early Bathonian interval), based essentially on the presence of *"Tricolocapsa"* sp. M *sensu* Baumgartner et al. 1995a; additional evidence is provided by the very likely presence of *Praewilliriedellum robustum* (U.A.Z. 5-7 for *Stichocapsa robusta in* Baumgartner et al., 1995b) and *Striatojaponocapsa synconexa* O'Dogherty, Goričan and Dumitrica (= *Tricolocapsa plicarum* ssp. A *sensu* Baumgartner et al., 1995a; U.A.Z. 4-5, although according to Prela et al. 2000 the age range of this morphotype could be slightly longer - U.A.Z. 4-6).

The co-occurrence of *"Dictyomitrella" kamoensis* (U.A.Z. 3-7; Bajocian-early Callovian) and *Zhamoidellum ovum* (UAZ 9-11; Oxordian-early Tithonian) in sample Sar-10

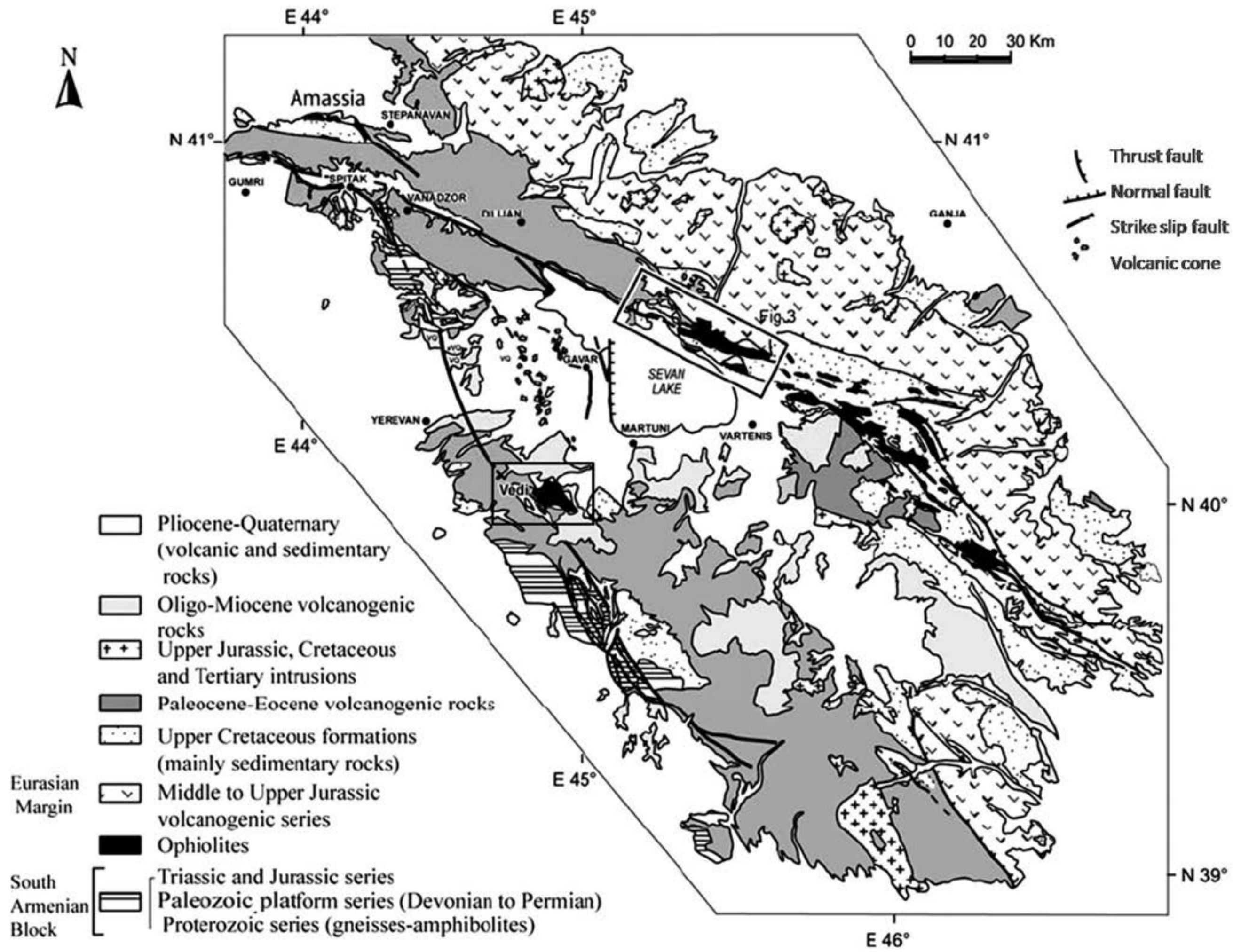

Fig. 2 - Geological map of Armenia, displaying the extent of ophiolitic outcrops and with location of the study area (detailed in Fig. 3).

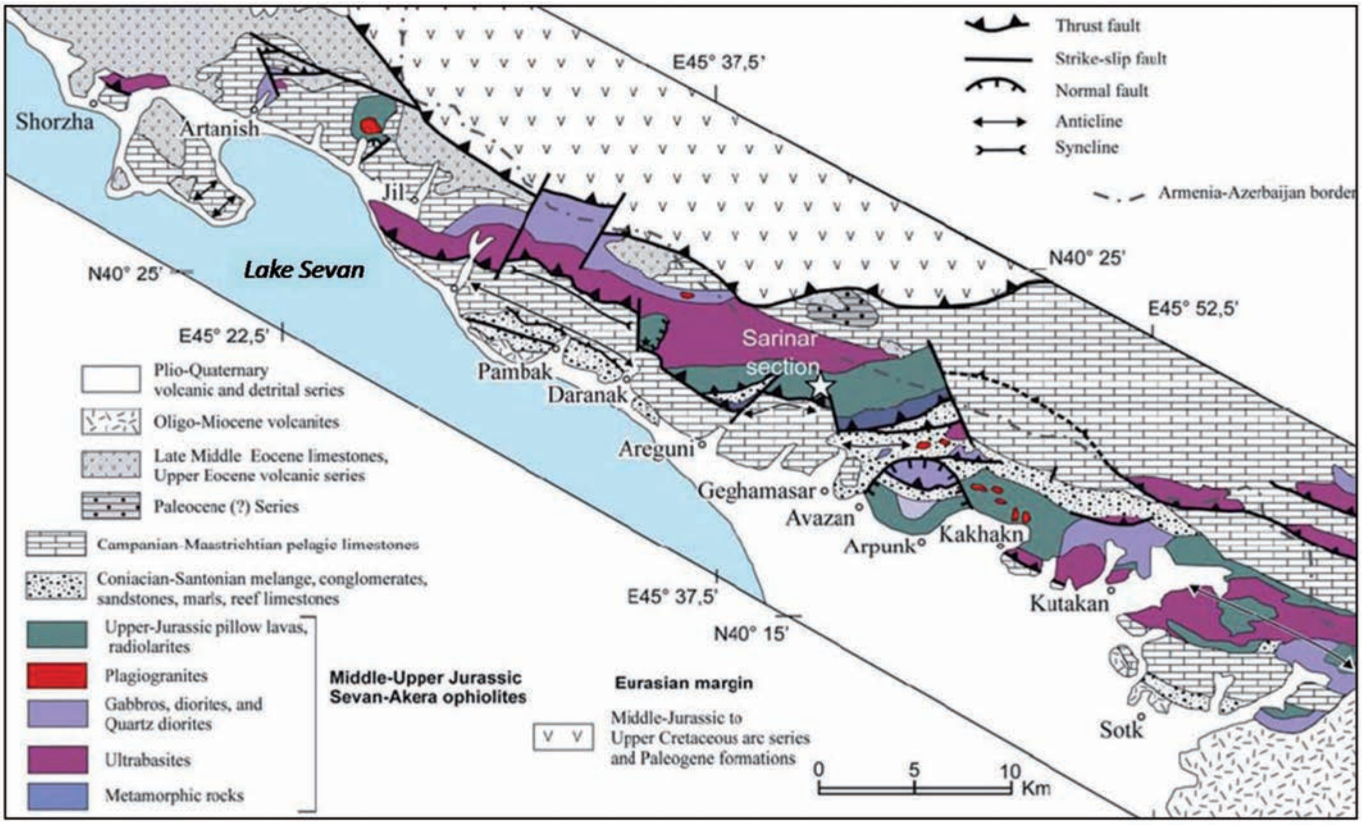

Fig. 3 - Simplified geological map of the ophiolitic outcrops in the east of lake Sevan, including the localization of the studied section.

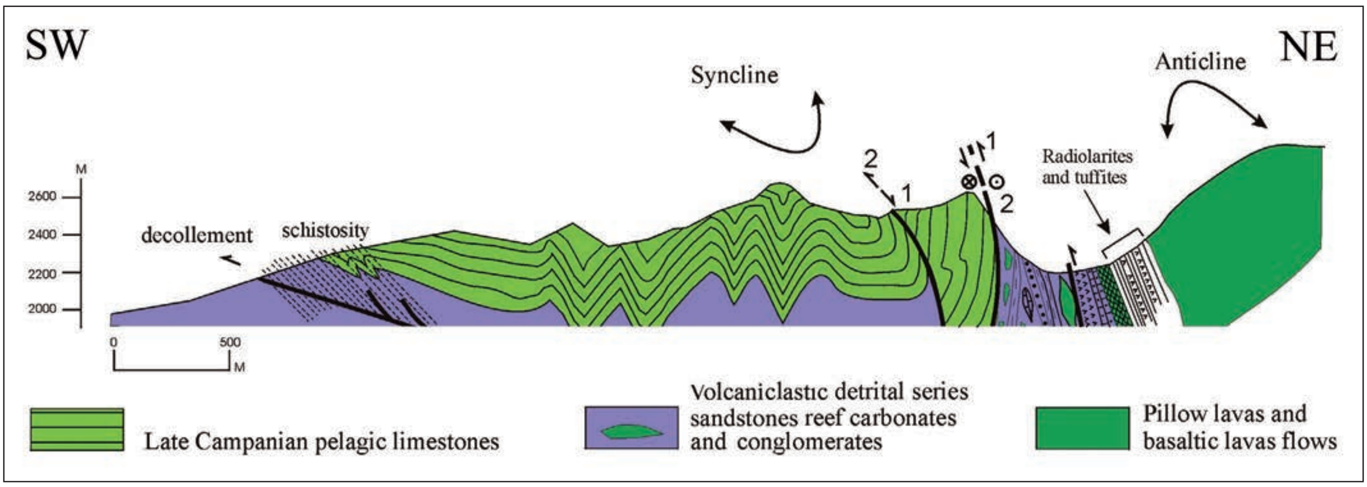

Fig. 4 - Geological section along the studied outcrop.

is at first glance problematic. However, we should bear in mind that *Z. ovum* cannot be considered any longer as a good Late Jurassic marker species, because it has been found many times in Middle Jurassic assemblages (Smuc and Gorican, 2005; Danelian et al., 2008a). Given the presence of *Zhamoidellum ventricosum* (U.A.Z. 8-11), we tentatively consider the age of this sample as late Bathonian to early Oxfordian (U.A.Z. 7-8).

Finally, sample Sar-05 can be assigned to the U.A. 3-35 of Jud (1994) or U.A.Z. 11-22 of Baumgartner et al. (1995b; late Kimmeridgian to early Aptian) because of the co-occurrence of species *Archaeodictyomitra excellens, Tethysetta boesii* and *Hiscocapsa uterculus*. The latter two species last occur in the lower Aptian Verbeeki subzone (U.A. 5) of O'Dogherty (1994).

Consequently, the Radiolarian fauna yielded from the three chert samples of the Sarinar section suggest that the studied sequence is overturned. This result is in agreement with the anticline structure which displays inverted plunge of the southwest flank (Fig. 4).

DISCUSSION AND CONCLUSION

The latest Bajocian-early Bathonian (U.A.Z. 5) radiolarian fauna identified in sample Sar-14, situated ca. 2 m above the underlying ophiolitic lavas, is in good agreement with the discovery by Vishnevskaya (1995) of Bajocian-early Bathonian (U.A.Z. 3-5) radiolarian cherts overlying basaltic lavas within the Sevan-Akera zone (Mt. Karawul). These data are also in good agreement with Bajocian (U.A.Z. 3-4) radiolarian cherts intercalated with submarine volcanic lavas of the Vedi ophiolite (Danelian et al., 2008b; Asatryan, 2009). All three localities argue for radiolarian ooze accumulation on oceanic crust of late Middle Jurassic (Bajocian ?) age. Petrological and geochemical data for the Sevan ophiolite suggest Middle Jurassic slow oceanic spreading, which would have taken place in a marginal back-arc setting of a basin situated behind an intra-oceanic subduction zone (Galoyan, 2008; Galoyan et al., 2009; Rolland et al., 2009).

The radiometric ages obtained so far from tonalites (160±4 Ma; Zakariadze et al., 1990) and gabbros (165.3±1.7 Ma; Galoyan et al., 2009) of the Sevan ophiolite suggest that oceanic crust formation continued during the Bathonian-Callovian, and possibly the Oxfordian, especially if we take into account the evidence from late Oxfordian-early Kimmeridgian radiolarian cherts which are found to be in stratigraphic contact with lavas of the Vedi ophiolite (Danelian et al., 2010).

Several tuffite levels are intercalated within the lower to middle part of the studied radiolarian chert sequence; the late Bathonian-early Oxfordian (U.A.Z. 7-8) radiolarian assemblage that was identified in sample Sar-10, comes from a level situated just below the uppermost tuffitic bed. Given the stratigraphic position of the two dated samples, the three tuffite beds are tentatively regarded as late Middle-early Late Jurassic in age (Bathonian-early Oxfordian). This is the first time that tuffites are reported within the sedimentary cover of the Armenian ophiolites. Their age, obtained here, suggests that subaerial volcanic activity was taking place at the same time as oceanic crust was being formed, as discussed earlier. Although a continental origin cannot be excluded, it is likely that these tuffites are the sedimentary output of the intra-oceanic arc volcanism that was active in the oceanic realm of Neo-Tethys preserved in Armenia (Galoyan et al., 2009; Rolland et al., 2009).

The spilitic lavas that are in stratigraphic contact at the top of the sequence point to a renewal of submarine volcanic activity in the area. Regrettably, the age range obtained for sample Sar-05 is poorly resolved to provide new insights for this event. If the presence of species *Cryptamphorella conara* is confirmed in the future it would imply an Early Cretaceous (late Valanginian-early Aptian) age for these lavas (this species is known from the U.A. 35-45 of Gorican, 1994).

The ophiolites preserved in Armenia are considered to represent an eastward extension of the Izmir-Ankara-Erzinçan ophiolitic suture zone (Fig. 1), in which the presence of Jurassic, Late Triassic and Early Cretaceous radiolarites intercalated with ophiolitic lavas are known (Bragin and Tekin, 1996; Tekin et al., 2002). Although much less evident, it is also possible that the Armenian ophiolites are related to the Khoy ophiolite, preserved in northern Iran, where there are two distinct oceanic complexes, one pre-Jurassic and the other of Late Cretaceous age (Khalatbari-Jafari et al., 2004).

In conclusion, our results from the studied section at Sarinar are consistent with the development, during the Middle and Late Jurassic, of an intra-oceanic back-arc basin in the oceanic realm of Neo-Tethys preserved in Armenia. Accumulation of radiolarian ooze was taking place during the latest Bajocian-early Bathonian on oceanic crust formed probably during the Bajocian, in a marginal basin situated behind an intra-oceanic subduction zone. Bathonian to early Oxfordian tuffites are the sedimentary output of a subaerial volcanic activity that was probably linked to the ongoing intra-oceanic arc volcanism.

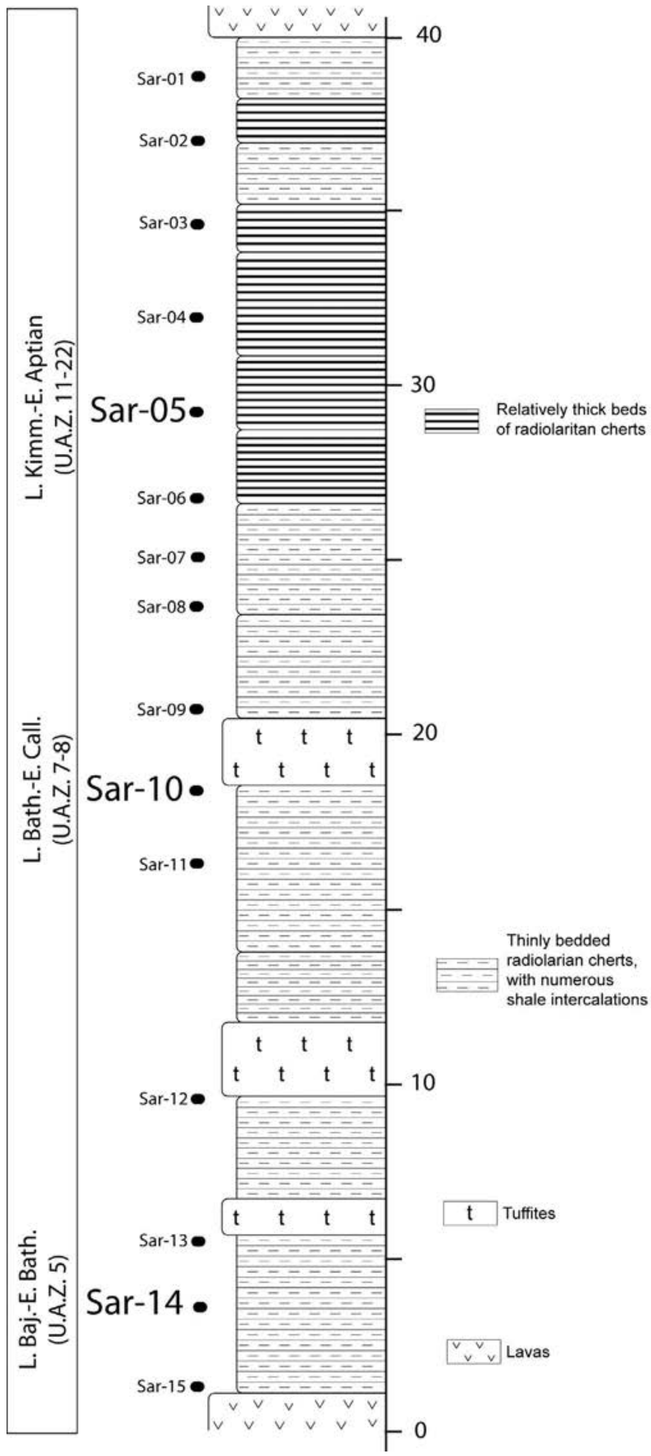

Fig. 5 - Lithological column of the Sarinar section and position of the collected samples.

Table 1 - Radiolarian occurrences in samples of the Sarinar section.

Species Samples	Sar-05	Sar-10	Sar-14	U.A.Z.
Archaeodictyomitra apiarium (Rüst)	P			8-22
Archaeodictyomitra excellens (Tan)	P			11-22
Archaeodictyomitra oleadita Hull		P		
Cinguloturris sp. cf. *C. carpatica* Dumitrica		P		
Cryptamphorela clivosa (Aliev)	?			
Cryptamphorela conara (Foreman)	?			
Dictyomitra pseudoscalaris (Tan)	?			
"*Dictyomitrella*" *kamoensis* Mizutani and Kido		P		3-7
Eucyrtidiellum sp. cf. *E. unumaense* (Yao)		P		
Hexasaturnalis minor Baumgartner (*sensu* Dumitrica and Dumitrica-Jud, 2005)		P		3-11
Loopus sp.		?		
Hiscocapsa sp. cf. *H. lugeoni* O'Dogherty, Gorican and Dumitrica		P		
Hiscocapsa uterculus (Parona)	P			11-22
Parvicingula veghae (Grill and Kozur)		P		
Praewilliriedellum sp. cf. *P. robustum* (Matsuoka)			P	
Protunuma japonicus Matsuoka and Yao		P		7-12
Pseudoxitus sp.	?			
Spongocapsula sp.cf. *S. palmerae* Pessagno			P	
"*Stichomitra*" *annibill* Kocher		P		
Striatojaponocapsa plicarum (Yao) *s.l.* (*sensu* Baumgartner et al. 1995a)			P	3-8
Tethysetta boesii (Parona)	P			9-22
Thanarla brouweri (Tan)	P			
Thanarla sp. cf. *T. pulchra* (Squinabol)	P			
Transhsuum sp. cf. *T. brevicostatum* (Ozvoldova) gr.		P		
"*Tricolocapsa*„ sp. M *in* Baumgartner et al., 1995a			P	5-5
Williriedellum yahazuense (Aita)		P		
Zhamoidellum ovum Dumitrica		P		? 9-11
Zhamoidellum ventricosum Dumitrica		P		8-11

U.A.Z. = Unitary Association Zones of Baumgartner et al., 1995b.

ACKNOWLEDGMENTS

Funding from the Middle East Basins Evolution (MEBE) program, the French Ministry for Foreign Affairs (ECONET grant to T. Danelian) and the French Embassy in Armenia (student grant to G. Asatryan) are gratefully acknowledged. Fieldwork was greatly facilitated by support from the Institute of Geological Sciences of the Armenian Academy of Science. Constructive remarks by S. Gorican, L. O'Dogherty and M. Chiari have greatly improved the initial manuscript.

REFERENCES

Al-Riyami K., Robertson A.H.F., Xenophontos C., Danelian T. and Dixon J.E., 2000. Tectonic evolution of the Mesozoic Arabian passive continental margin and related ophiolite in Baer-Bassit region (NW Syria). In: I. Panayides, C. Xenophontos and J. Malpas (Eds.), Third Intern. Conf. on the geology of the Eastern Mediterranean, Proceed., p. 61-81.

Al-Riyami K., Danelian T. and Robertson A.H.F., 2002. Radiolarian biochronology of Mesozoic deep-water successions in NW Syria and Cyprus: implications for south-Tethyan evolution. Terra Nova, 14: 271-280.

Asatryan G., 2009. New data about the age of ophiolites in the Vedi Zone on the basis of radiolarian assemblages. Proc. Nat. Acad. Sci. Armenia, Earth Sci., 62 (2): 16-28.

Aslanyan A.T. and Satian M.A., 1977. On the geological features of Transcaucasian ophiolitic zones. Izvestia Acad. Sci. Armenian SSR, Nauki o Zemle, 4-5: 13-26 (in Russian).

Avagyan A., Sosson M., Philip H., Karakhanian A., Rolland Y.A., Melkonyan R., Rebai S. and Davtyan V., 2005. Neogene to Quaternary stress field evolution in Lesser Caucasus and adjacent regions using fault kinematics analysis and volcanic cluster data. Geodyn. Acta, 18: 401-416.

Baumgartner P.O., 1984. Middle Jurassic-Early Cretaceous low-latitude radiolarian zonation based on Unitary Associations and age of Tethyan radiolarites. Ecl. Geol. Helv., 77: 729-837.

Baumgartner P.O., 1985. Jurassic sedimentary evolution and nappe emplacement in the Argolis Peninsula (Peloponnesus, Greece). Mém. Soc. Helv. Sci. Nat., 99: 1-111.

Baumgartner P.O., O'Dogherty L., Gorican S., Dumitrica-Jud R., Dumitrica P., Pillevuit, A., Urquhart E., Matsuoka A., Danelian T., Bartolini A., Carter E.S., De Wever P., Kito N., Marcucci M. and Steiger T., 1995a. Radiolarian catalogue and systematics of Middle Jurassic to Early Cretaceous Tethyan genera and species. In: P.O. Baumgartner et al. (Eds.), Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, systematics, biochronology. Mém. Géol., Lausanne, 23: 37-685.

Baumgartner P.O., Bartolini A., Carter E.S., Conti M., Cortese G., Danelian T., De Wever P., Dumitrica P., Dumitrica-Jud R., Gorican S., Guex J., Hull D.M., Kito N., Marcucci M., Matsuoka A., Murchey B., O'Dogherty L., Savary J., Vishnevskaya V., Widz D. and Yao A., 1995b. Middle Jurassic to Early Cretaceous radiolarian biochronology of Tethys based on Unitary Associations. In: P.O. Baumgartner et al. (Eds.), Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, systematics, biochronology. Mém. Géol., Lausanne, 23: 1013-1048.

Beccaletto L., Bartolini A.-C., Martini R., Hochuli P.A. and Kozur H., 2005. Biostratigraphic data from the Çetmi Mélange, northwest Turkey: palaeogeographic and tectonic implications. Palaeo. Palaeo. Palaeo., 221: 215-224.

Belov A., Bragin N., Vishnevskaya V., Satian M. and Sokolov S., 1991. New data on the age of Vedi ophiolite (Armenia). C. R. Acad. URSS, 321: 784-787 (in Russian).

Bill M., O'Dogherty L., Guex J., Baumgartner P.O. and Masson H., 2001. Radiolarite ages in Alpine-Mediterranean ophiolites: Constraints on the oceanic spreading and the Tethys-Atlantic connection. GSA Bull., 113 (1): 129-143.

Bortolotti V., Principi G. and Treves B., 1990. Mesozoic evolution of the western Tethys and the Europe/Iberia/Adria plate junction. Mem. Soc. Geol. It., 45: 393-407.

Bortolotti V., Chiari M., Marcucci M., Marroni M., Pandolfi L., Principi G. and Saccani E., 2004. Comparison among the Albanian and Greek ophiolites, in search of constraints for the evolution of the Mesozoic Tethys Ocean. Ofioliti, 29:19-35.

Bortolotti V. and Principi G. 2005. Tethyan ophiolites and Pangea break-up. Island Arc, 14: 442-470.

Bortolotti V., Chiari M., Marcucci M., Photiades A., Principi G. and Saccani E., 2008. New geochemical and age data on the ophiolites from the Othrys area (Greece): implication for the Triassic evolution of the Vardar Ocean. Ofioliti, 33: 135-151.

Bragin N.Y. and Tekin U.K., 1996. Age of radiolarian-chert blocks from the Senonian Ophiolitic Mélange (Ankara, Turkey). Isl. Arc, 5: 114-122.

Chiari M., Bortolotti V., Marcucci M., Photiades A. and Principi G., 2003. The Middle Jurassic siliceous sedimentary cover at the top of the Vourinos ophiolite (Greece). Ofioliti, 28: 95-103.

Chiari M., Cortese G., Marcucci M. and Nozzoli N., 1997. Radiolarian biostratigraphy in the sedimentary cover of ophiolites in south-western Tuscany, Central Italy. Ecl. Geol. Helv., 90 (1): 55-77.

Chiari M., Marcucci M. and Principi G., 2000. The age of radiolarian cherts associated with the ophiolites in the Apennines (Italy) and Corsica (France): a revision. Ofioliti, 25: 141-146.

Chiari M., Marcucci M. and Principi G., 2004. Radiolarian assemblages from Jurassic cherts of Albania: new data. Ofioliti, 29: 95-105.

Cordey F. and Bailly A., 2007. Alpine ocean seafloor spreading and onset of pelagic sedimentation: new radiolarian data from the Chenaillet-Montgenèvre ophiolite (French-Italian Alps). Geodyn. Acta, 20 (3): 131-138.

Danelian T., 2008. Diversity and biotic changes of Archaeodictyomitrid Radiolaria from the Aptian/Albian transition (OAE 1b) of southern Albania. Micropal., 54: 3-13.

Danelian T., Asatryan G., Sahakyan L., Galoyan G., Sosson M. and Avagyan A., 2010. New and revised radiolarian biochronology for the sedimentary cover of ophiolites in the Lesser Caucasus (Armenia). In: M. Sosson, N. Kaymakci, R. Stephenson, F. Bergerat and V. Starostenko (Eds.), Sedimentary basin tectonics from the Black Sea and Caucasus to the Arabian Platform. Geol. Soc. London, Spec. Publ., 340: 383-391.

Danelian T., Asatryan G., Sosson M., Person A., Sahakyan L. and Galoyan G., 2008b. Discovery of Middle Jurassic (Bajocian) Radiolaria from the sedimentary cover of the Vedi ophiolite (Lesser Caucasus, Armenia), C. R. Pal. Evol., 7 (6): 327-334.

Danelian T., De Wever P. and Durand-Delga M., 2008a. Revised Radiolarian ages for the sedimentary cover of the Balagne ophiolite (Corsica, France). Implications for the palaeoenvironmental evolution of the Balano-Ligurian margin. Bull. Soc. Géol. France, 179 (3): 169-177.

Danelian T., Galoyan G., Rolland Y. and Sosson M., 2007. Palaeontological (Radiolarian) Late Jurassic age constraint for the Stepanavan ophiolite (Lesser Caucasus, Armenia). Bull. Geol. Soc. Greece, 40: 31-38.

Danelian T., Lekkas S. and Alexopoulos A., 2000. Découverte de radiolarites triasiques dans un complexe ophiolitique à l'extrême sud du Péloponnèse (Agelona, Lakonie, Grèce). C. R. Acad. Sci. Paris, 330: 639-644.

Danelian T., Robertson A.H.F., Collins A. and Poisson A., 2006. Biochronology of Jurassic and Early Cretaceous radiolarites from the Lycian Mélange (SW Turkey) and implications for the evolution of the Northern Neotethyan Ocean: In: A.H.F. Robertson and D. Mountrakis (Eds.), Tectonic development of the Eastern Mediterranean Region. Geol. Soc. London Spec. Publ., 260: 229-236.

Dercourt J., Zonenshain L.P., Ricou L.E., Kazmin V.G., Le Pichon X., Knipper A.L., Grandjacquet C., Perchersky D.H., Boulin J., Sibuet J.C., Savostin L.A., Sorokhtin O., Westphal M., Bashrov M.L., Lauer J.P. and Biju-Duval B., 1986. Geological evolution of the Tethys belt from the Atlantic to the Pamirs since the Lias. Tectonophysics, 123: 241-315.

De Wever P. and Dercourt J., 1985. Les radiolaires triasico-jurassiques marqueurs stratigraphiques et paléogéographiques dans les chaînes alpines périméditerranéennes: une revue. Bull. Soc. Géol. France, 8, I, 5: 653-662.

Dumitrica P. and Dumitrica-Jud R., 2005. *Hexasaturnalis nakasekoi* nov.sp., a Jurassic saturnalid radiolarian species frequently confounded with *Hexasaturnalis suboblongus* (Yao). Rev. Micropal., 48: 159-168.

Galoyan G. 2008. Etudes pétrologiques, géochimiques et géochronologiques des ophiolites du Petit Caucase (Arménie). PhD Thesis, Univ. Nice Sophia Antipolis, 287 pp.

Galoyan G., Rolland Y., Sosson M., Corsini M., Billo S., Verati C. and Melkonyan R., 2009. Geology, geochemistry and $^{40}Ar/^{39}Ar$ dating of Sevan ophiolites (Lesser Caucasus, Armenia): Evidence for Jurassic back-arc opening and hot spot event between the South Armenian Block and Eurasia. J. Asian Earth Sci., 34: 135-153.

Göncüoglu, M.C., Yalınız, K. and Tekin, U.K., 2006. Geochemistry, tectono-magmatic discrimination and radiolarian ages of basic extrusives within the Izmir-Ankara Suture Belt (NW Turkey): Time constraints for the Neotethyan evolution. Ofioliti, 31: 25-38.

Gorican S., 1994. Jurassic and Cretaceous radiolarian biostratigraphy and sedimentary evolution of the Budva Zone (Dinarides, Montenegro). Mém. Géol., Lausanne, 118, 120 pp.

Gradstein F.M., Ogg J.G., Smith A.G., Bleeker W. and Lourens L.J., 2004. A new Geologic Time Scale, with special reference to Precambrian and Neogene. Episodes, 27: 83-100.

Jud R., 1994. Biochronology and systematics of Early Cretaceous Radiolaria of the Western Tethys. Mém. Géol. Lausanne, 19: 147 pp.

Karakitsios V., Danelian T. and De Wever P., 1988. Datations par les Radiolaires des Calcaires à Filaments, Schistes à Posidonies supérieurs et Calcaires de Vigla (Zone Ionienne, Epire, Grèce) du Callovien au Tithonique terminal. C.R. Acad. Sci. Paris, 306 (II): 367-372.

Khalatbari-Jafari M., Juteau T., Bellon H., Whitechurch H., Cotton J. and Emami H., 2004. New geological, geochronological and geochemical investigations on the Khoy ophiolites and related formations, NW Iran. J. Asian Earth Sci., 23: 507-535.

Knipper A.L., 1975. The oceanic crust in the Alpine belt. Tr. GIN NAS USSR, Edition 267, 207 pp. (in Russian).

Knipper A.L. and Khain E.V., 1980. The structural position of ophiolites of the Caucasus. Ofioliti, Spec. Issue, 2: 297-314.

Knipper A.L., Satian M.A. and Bragin N.Yu., 1997. Upper Triassic-Lower Jurassic volcanogenic and sedimentary deposits of the Old Zod Pass (Transcaucasia). Stratigraphy, geological correlation, 3: 58-65. (in Russian).

O'Dogherty L., 1994. Biochronology and paleontology of Mid-Cretaceous radiolarians from Northern Apennines (Italy) and Betic Cordillera (Spain). Mém. Géol. Lausanne, 21: 411 pp.

O'Dogherty L., Bill M., Gorican S., Dumitrica P. and Masson H., 2006. Bathonian radiolarians from an ophiolitic mélange of the Alpine Tethys (Gets Nappe, Swiss-French Alps), Micropal., 51 (6): 425-485.

O'Dogherty L., Carter E.S., Dumitrica P., Gorican S. and De Wever P., 2009. An illustrated and revised catalogue of Mesozoic radiolarian genera - objectives, concepts and guide for users. Geodiversitas, 31 (2): 191-212.

Prela M., Chiari M. and Marcucci M., 2000. Jurassic radiolarian biostratigraphy of the sedimentary cover of ophiolites in the Mirdita Area, Albania: new data. Ofioliti, 25: 55-62.

Rolland Y., Galoyan Gh., Bosch D., Sosson M., Corsini M., Fornari M. and Verati C., 2009. Jurassic back-arc and Cretaceous hot-spot series in the Armenian ophiolites - Implications for the obduction process. Lithos, 112: 163-187.

Smuc A. and Gorican S., 2005. The Jurassic evolution of carbonate platform into a deep-water basin, Mt. Mangart (Slovenian-Italian border). Riv. Ital. Paleont. Strat., 111 (1): 45-70.

Sosson M., Rolland Y., Muller C., Danelian T., Melkonyan R., Kekelia S., Adamia S., Babazadeh V., Kangarli T., Avagyan A., Galoyan G. and Mosar J., 2010. Subductions, obduction and collision in the Lesser Caucasus (Armenia, Azerbaijan, Georgia), new insights. In: M. Sosson, N. Kaymakci, R. Stephenson, F. Bergerat and V. Starostenko (Eds.), Sedimentary basin tectonics from the Black Sea and Caucasus to the Arabian Platform. Geol. Soc. London Spec. Publ., 340: 329-352.

Tekin U.K. and Göncüoglu M.C., 2007. Discovery of the oldest (Upper Ladinian to Middle Carnian) Radiolarian assemblages from the Bornova flysch zone in western Turkey: implications for the evolution of the Neotethyan Izmir-Ankara ocean. Ofioliti, 32: 131-150.

Tekin U.K., Göncüoglu M.C. and Turhan N., 2002. First evidence of Late Carnian radiolarians from the Izmir-Ankara suture complex, central Sakarya, Turkey: Implications for the opening age of the Izmir-Ankara branch of Neo-Tethys. Geobios, 35 (1): 127-135.

Vishnevskaya V., 1995. Jurassic and Cretaceous Radiolarians from the Lesser Caucasus (Zod Pass, Mount Karawul and site 22 in the Koshuni River Basin). In: P.O. Baumgartner, L. O'Dogherty, S. Gorican, E. Urquhart, A. Pillevuit and P. De Wever (Eds.), Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurences, systematics, biochronology. Mém. Géol., Lausanne, 23: 701-708.

Vrielynck B., Bonneau M., Danelian T., Cadet J.P. and Poisson A., 2003. New insights on the Antalya Nappes in the apex of the Isparta angle: The Isparta Cay unit revisited. Geol. J., 38: 283-293.

Zakariadze G.S., Knipper A.L., Sobolev A.V., Tsamerian O.P., Dmitriev L.V., Vishnevskaya V.S. and Kolesov G.M., 1983. The ophiolite volcanic series of the Lesser Caucasus. Ofioliti, 8 (3): 439-466.

Zakariadze G.S., Knipper A.L., Bibikova E.V., Silantiev S.A., Zlobin S.K., Gracheva T.V., Makarov S.A. and Kolesov G.M., 1990. The setting and age of the plutonic part of the NE Sevan ophiolite complex. Acad. Sci. USSR Geol. Series, 3: 17-30 (in Russian).

Received, March 3, 2010
Accepted, September 10, 2010

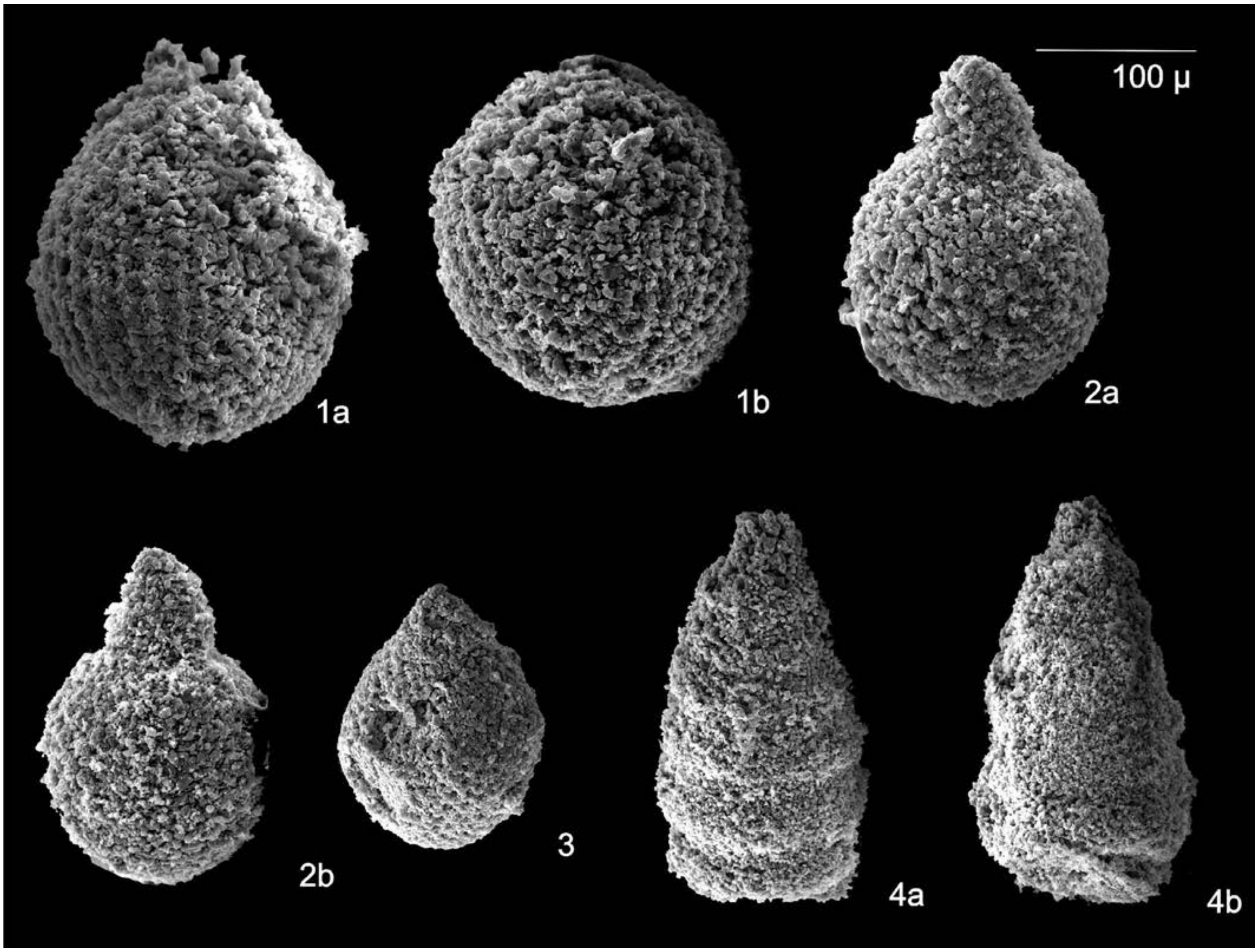

Plate 1 - Scanning electron micrographs of Radiolaria yielded from sample Sar-14. 1) *Striatojaponocapsa plicarum* (Yao) *s.l.;* although not well preserved, the illustrated specimen resembles *Striatojaponocapsa synconexa* O'Dogherty, Goričan and Dumitrica (= *Tricolocapsa plicarum* ssp. A *sensu* Baumgartner et al. 1995a); 2) "*Tricolocapsa"* sp. M *in* Baumgartner et al., 1995a; 3) *Praewilliriedellum* sp. cf. *P. robustum* (Matsuoka); 4) *Spongocapsula* sp.cf. *S. palmerae* Pessagno.

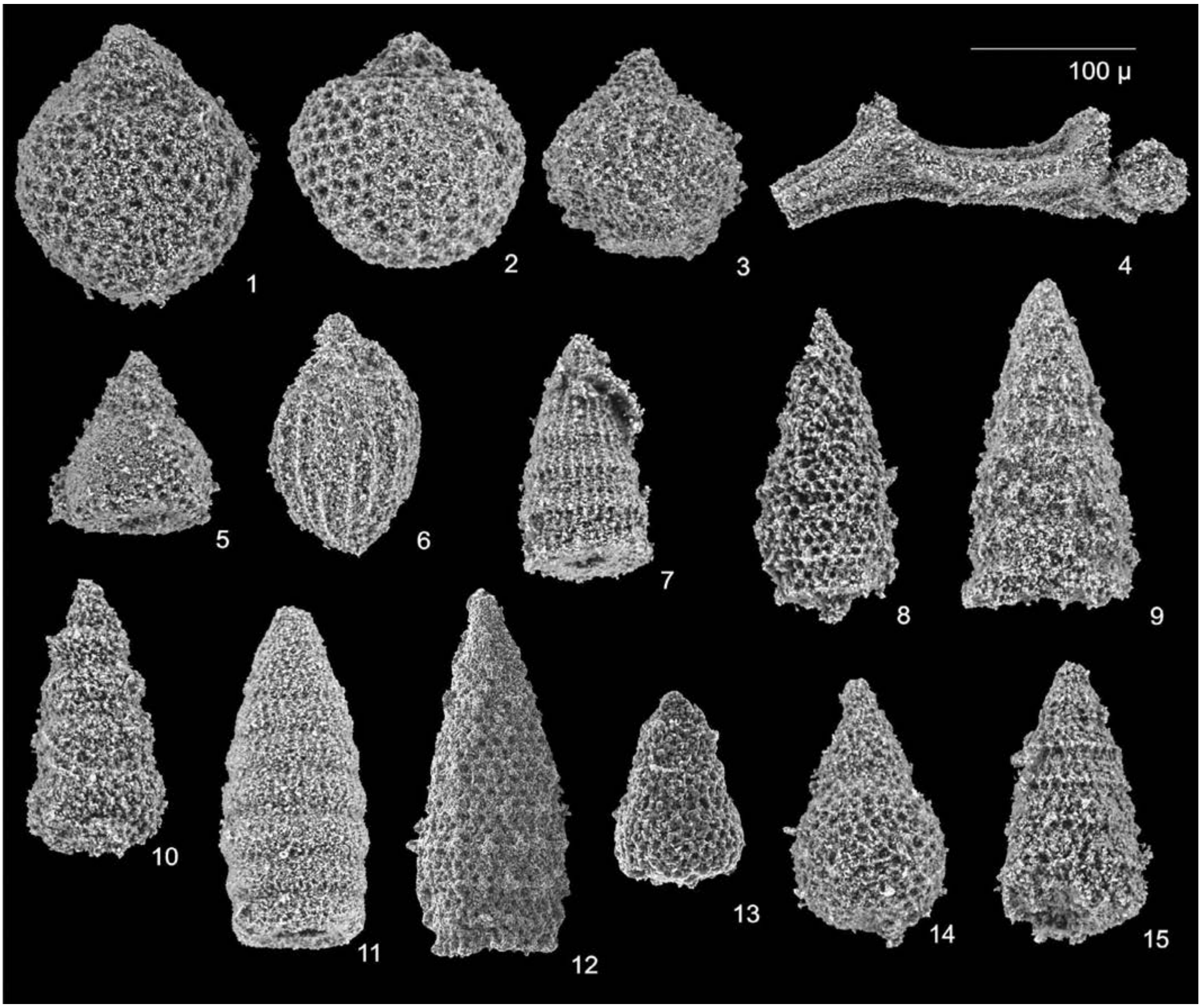

Plate 2 - Scanning electron micrographs of Radiolaria yielded from sample Sar-10. 1) *Zhamoidellum ovum* Dumitrica; 2) *Zhamoidellum ventricosum* Dumitrica; 3) *Williriedellum yahazuense* (Aita); 4) *Hexasaturnalis minor* (Baumgartner); 5) *Eucyrtidiellum* sp. cf. *E. unumaense* Yao; 6) *Protunuma japonicus* Matsuoka and Yao; 7) *Archaeodictyomitra oleadita* Hull; 8) *Parvicingula veghae* (Grill and Kozur); 9) *Transhsuum* sp.cf. *T. brevicostatum* (Ozvoldova) gr.; 10) *Cinguloturris* sp. cf. *C. carpatica* Dumitrica; 11) probably *Loopus* sp.; 12) *Parvicingula veghae* (Grill and Kozur); 13) *"Stichomitra" annibill* Kocher; 14) *Hiscocapsa* sp. cf. *H. lugeoni* O'Dogherty, Gorican and Dumitrica; 15) "*Dictyomitrella" kamoensis* Mizutani and Kido.

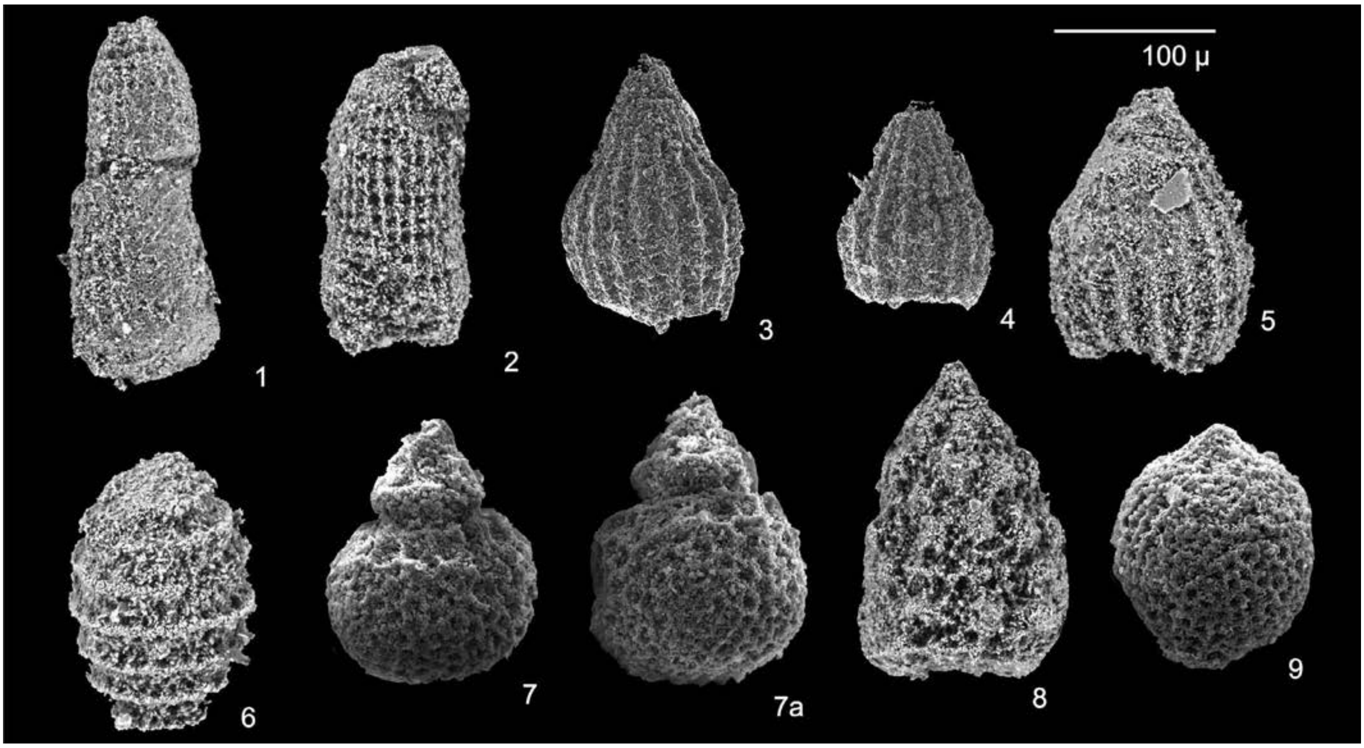

Plate 3 - Scanning electron micrographs of Radiolaria yielded from sample Sar-05. 1) *Archaeodictyomitra excellens* (Tan); 2) *Archaeodictyomitra apiarium* (Rüst); 3) *Thanarla* sp. cf. *T. pulchra* (Squinabol); 4-5) *Thanarla brouweri* (Tan); 6) *Tethysetta boesii* (Parona); 7-7a) *Hiscocapsa uterculus* (Parona); 8) *Pseudoxitus* (?) sp.; 9) *Cryptamphorella* sp. cf. *C. conara* (Foreman).