RADIOLARIAN EVIDENCE FOR EARLY CRETACEOUS (LATE BARREMIAN - EARLY APTIAN) SUBMARINE VOLCANIC ACTIVITY IN THE TETHYAN OCEANIC REALM PRESERVED IN KARABAGH (LESSER CAUCASUS)

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ABSTRACT

Dating radiolarites in the ophiolitic sequences of Alpine mountain belts is important for the geodynamic reconstruction of Neo-Tethys in the Lesser Caucasus. However, radiolarian data from Karabagh are very rare. A moderately well-preserved radiolarian assemblage was obtained from radiolarites that overlie pillow lavas cropping out west of the village of Vank in the mountainous region of Karabagh. The presence of the easily recognisable subspecies *Aurisaturnalis carinatus perforatus* is of particular significance because it is the end member of a well studied lineage that went extinct in the early Aptian. Indeed, the middle late Barremian - early early Aptian age range of this subspecies allows to suggest that submarine volcanic activity took place during this interval in the Tethyan oceanic realm preserved in Karabagh. Given that this submarine volcanic event is more or less contemporaneous to the Aptian alkaline OIB-type lavas from the Vedi ophiolite, it is likely that the Karabagh lavas are also the expression of a volcanic activity associated to the emplacement of the same oceanic volcanic plateau.

INTRODUCTION

The sedimentary cover of ophiolites, preserved along the Alpine mountain belts such as the Lesser Caucasus, provides important time constraints to decipher the geodynamic evolution of the Tethys Ocean (De Wever and Dercourt, 1985; Chiari et al., 1997; 2000; Al-Riyami et al., 2000; 2002; Bill et al., 2001; Bortolotti et al., 2004; Bortolotti and Principi, 2005; Danelian et al., 2008a). The use of the unitary association method (Guex, 1977; 1991) for the elaboration of radiolarian biostratigraphic schemes (Baumgartner et al., 1980; 1995b; Baumgartner, 1984) provided the scientific community with a well-adapted tool to date siliceous sedimentary sequences, with as a consequence the improved understanding of the palaeoenvironmental evolution of Tethyan oceanic basins and continental margins (i.e., Baumgartner, 1984; Karakitsios et al., 1988; Danelian and Baudin, 1990; Caridroit et al., 1992; Goriçan, 1994; Bragin and Tekin 1996; 2000; Danelian et al., 2000; 2006; Tekin et al., 2002; Chiari et al., 2003; 2004; Vrielynck et al., 2003; O'Dogherty et al., 2006; Cordey and Bailly, 2007; Tekin and Göncüoglu, 2007; Bortolotti et al., 2008).

The ophiolitic units preserved in the Lesser Caucasus bear a special significance for the reconstruction of the geodynamic history of the greater area between Eurasia and the South-Armenian Block (SAB). Recent French-Armenian joint studies on the ophiolitic units of the Lesser Caucasus generated new radiolarian data for the sedimentary cover of the Vedi and Stepanavan-Sevan ophiolites in Armenia (Danelian et al., 2007; 2008b; 2010; Asatryan, 2009; Asatryan et al., 2010). However, very little is known about the age of the sedimentary cover of the Sevan-Hagari (Akera) ophiolite zone in the mountainous region of Karabagh. A number of previous works (Zhamoida et al., 1976; Kazintsova and Abbasov, 1981; Gazanov, 1985) mention the presence of Jurassic and Cretaceous Radiolaria in the region (i.e., along the Tartar and Tuthun river valleys); however, most of these studies were conducted at a very early stage development of modern Mesozoic radiolarian taxonomy and biostratigraphy. In addition, they are relatively difficult to be integrated into the geological/geodynamic analyses because little information is provided about the outcrops and stratigraphic position of studied samples. One remarkable exception is the study of Vishnevskaya (1995) who, in addition to a number of clearly indicated radiolarian assemblages from the Mt. Karawul section, found also Bajocian-early Bathonian radiolarian in cherts overlying stratigraphically basaltic lavas (sample 146).

In this paper, we describe a new Early Cretaceous radiolarian assemblage from a volcano-sedimentary sequence situated in the south-eastern part of Sevan-Hagari (Akera) suture zone, in Karabagh (Figs. 1 and 2). Since the dated radiolarites overly stratigraphically pillow lavas, our dating provides important time constraint to one of the youngest submarine volcanic events that occurred in the Tethyan realm of the Lesser Caucasus.

REGIONAL GEOLOGICAL FRAMEWORK

The ophiolites that occur in the Lesser Caucasus are part of a Tethyan suture zone (Knipper, 1975; Adamia et al., 1981; Zakariadze et al., 1983; Knipper et al., 1986; Dercourt et al., 1986; Galoyan, 2008; Sosson et al., 2010; Danelian et al., 2011). They represent the relics of an oceanic realm that was situated between Eurasia and the South Armenian Block (SAB), a micro-continent that was detached from Gondwana during the Late Palaeozoic - Early Mesozoic time interval and it is mainly known by its characteristic Middle to Late Palaeozoic sedimentary sequences. The

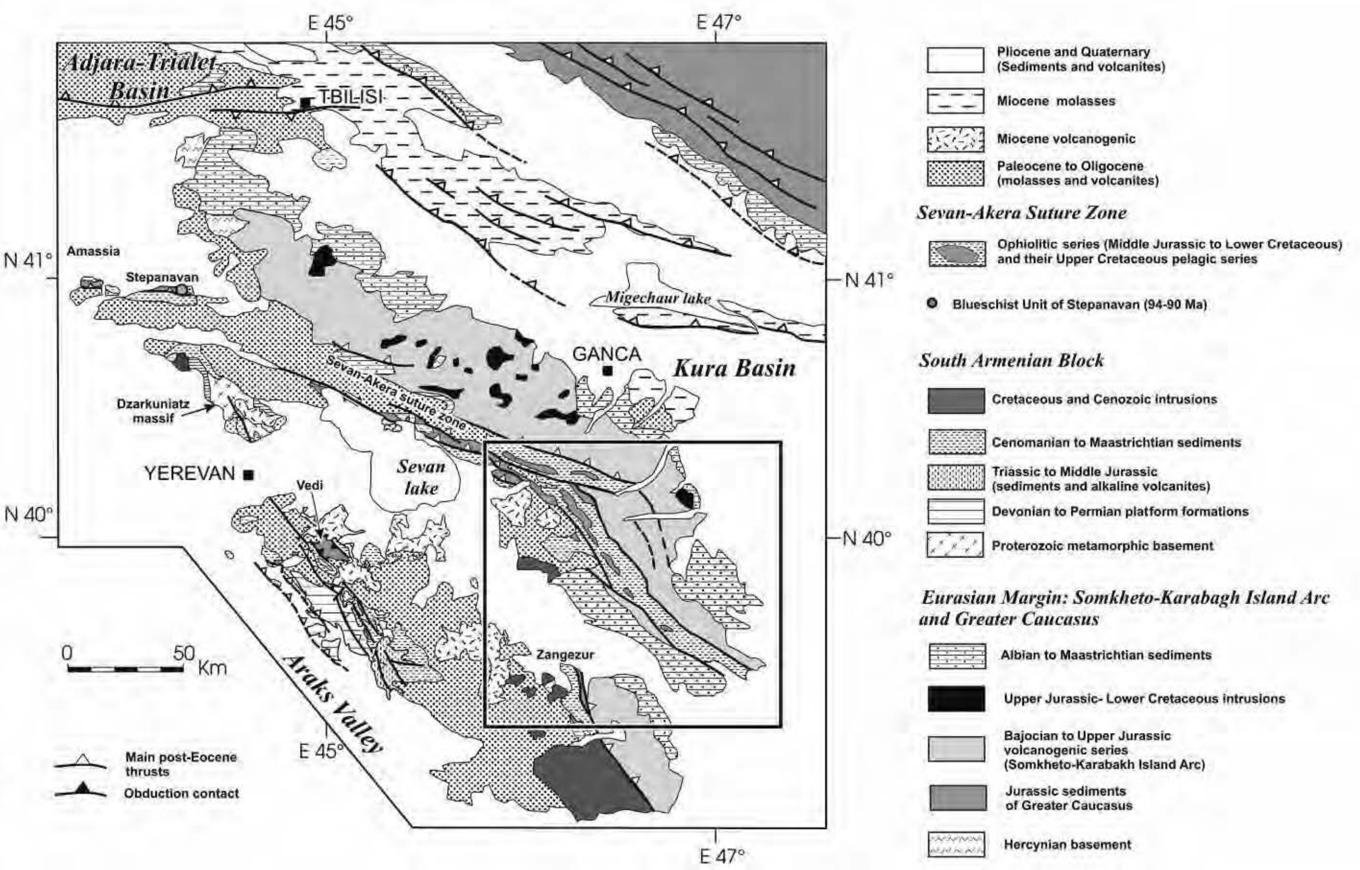

Fig. 1 - Geological map of the Lesser Caucasus (after Sosson et al., 2010, modified), including the extent of ophiolitic outcrops and location of the studied area (detailed in Fig. 2).

Eurasian margin was an active margin during most of the Mesozoic and it is known mainly from its Middle Jurassic - Late Cretaceous volcano-sedimentary sequences.

The outcrops of ophiolitic rocks that occur in the area can be grouped in mainly two zones (Fig. 1):

– The Sevan-Hagari (Akera) zone, known mainly after the work of Knipper (1975), Knipper and Khain (1980), Aslanyan and Satian (1977), Galoyan (2008) and Galoyan et al. (2009), regroups outcrops situated E and SE of Lake Sevan. Smaller but distinct ophiolitic outcrops, situated in northern Armenia (i.e. the Amassia and Stepanavan ophiolites) can be considered as the north-westward extension of the Sevan-Akera ophiolite zone (Rolland et al., 2009; 2010; Sosson et al., 2010), forming thus a ca. 400 km-long and NW-SE oriented ophiolite zone running from Amassia (NW Armenia) to Karabagh. There is a general agreement that it represents the main suture zone of Tethys Ocean in the Lesser Caucasus, as a result of collision between Eurasia and the South-Armenian Block (SAB) during the latest Cretaceous- Early Eocene (Sosson et al., 2010).

– The Vedi ophiolite, situated further to the west, is mainly known from outcrops situated around the Khosrov natural reserve of Vedi, in the south-east of the capital Yerevan. It is also known to exist from a number of boreholes situated in the Araks Valley. According to Sokolov (1977) and Sosson et al. (2010) it corresponds to a folded klippe sequence that was thrust during the Coniacian-Santonian obduction of oceanic crust onto the South Armenian Block.

LOCAL GEOLOGICAL SETTING

The Karabagh region allows better investigate the relationship between the Sevan-Akera suture zone and the Eurasian margin (Fig. 1). Following recent fieldwork in 2010 we obtained new insights on the structural framework of the region. Its large scale structure corresponds to a long and wide NW-SE trending nappe anticline (Fig. 2). The core of this structure is characterized by huge lenses of ophiolitic series covered by Late Cretaceous pelagic deposits. The main thrust contact between the Eurasian margin and the ophiolites was reactivated as a normal fault (probably before the Oligocene, although the age of the molassic formation is not well constrained) and more recently as right lateral strike slip fault.

The studied outcrop is located in the valley of River Khachenaget, 12 km to the East of the River Tuthun, West of the village of Vank (Fig. 2, altitude 1,625 m, N 40° 3,655’; E46° 23,010’), where rocks of an ophiolitic sequence can be observed (Fig. 3). From West to East and from bottom to top, a wide top to the west sheared serpentinite unit is intruded by dolerites and plagiogranites. There is no well-developed dike complex and thick pillowed lavas flow. These ultramafic and mafic rocks are covered, with a clear stratigraphic contact, by a volcanogenic sequence. Near this contact, some listvenite dikes occur (Fig. 3). The series overlying the serpentinites is characterized by interbedded breccias reworking ophiolites, by pillow lavas of basalts overlain by red coloured radiolarites, conglomerates, lenses of pelagic limestones, basaltic lava flows and graywackes.

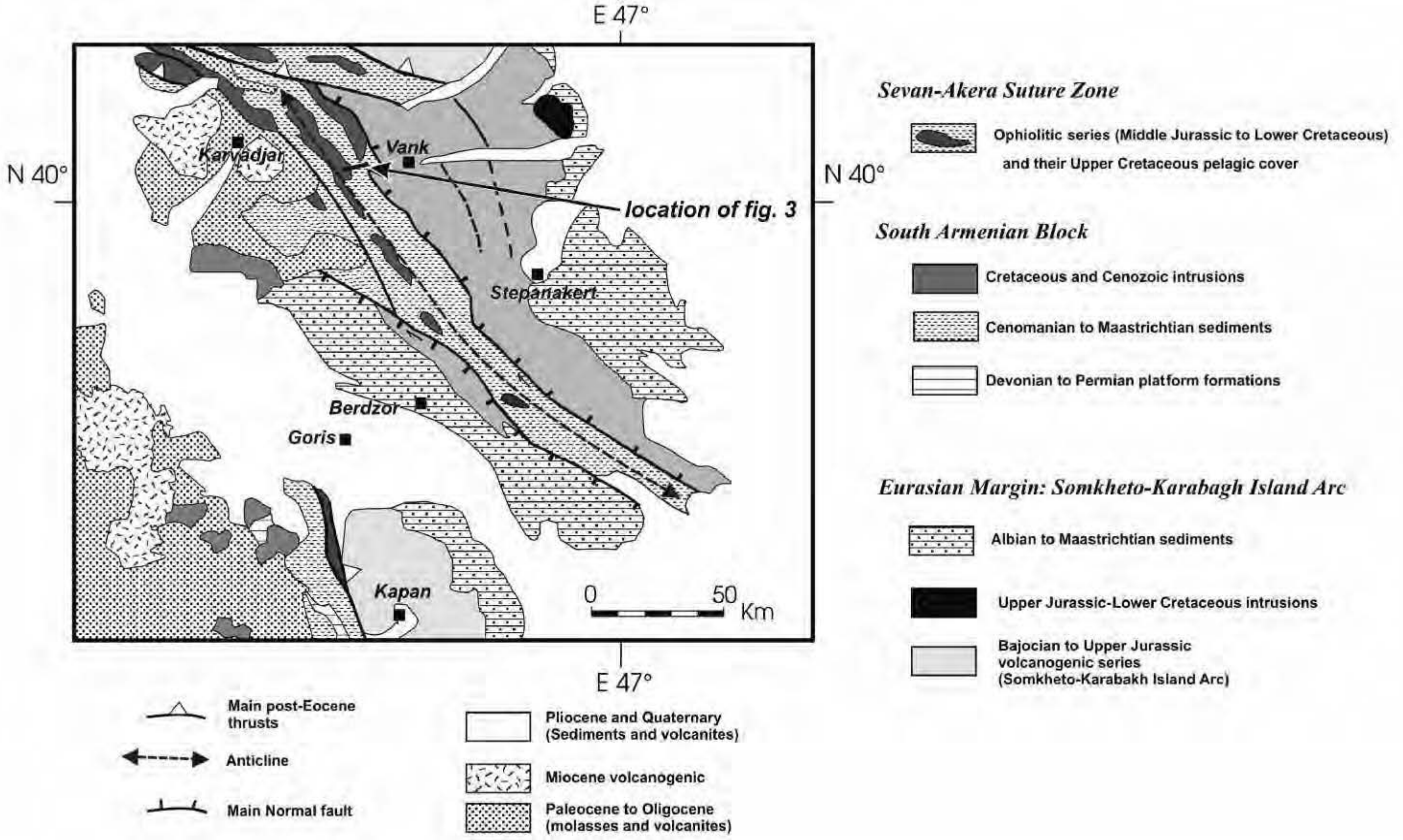

Fig. 2 - Simplified geological map of Karabagh, including the localization of the studied section (after Sosson et al., in prep.).

This ophiolitic section is stratigraphically covered by Cretaceous conglomerates reworking the ophiolites, sandstones, turbidites and pelagic limestones (Fig. 2). Middle Jurassic to Lower Cretaceous formations, composed essentially of calc-alkaline magmatic rocks and shallow marine sediments, crop out to the East of the studied section. This is a typical middle to Upper Cretaceous sequence of the Eurasian active margin (Somkheto-Karabagh island arc; Adamia et al., 1981; Sosson et al., 2010) and it seems overthrusting the ophiolitic unit and its cover; however, as mentioned above, this contact was subsequently reactivated as normal and strike-slip fault (Fig. 2).

RESULTS

Sample Ar-10-16, collected from the eastern part of the Vank section (Fig. 3), was processed with diluted hydrofluoric acid (HF 5%). Radiolarians were extracted by repetitive leaching of the sample for ca. 24 hours. They were then dry picked from the residue and mounted on SEM stubs. Taxonomic concepts applied during this study follow those of Baumgartner et al. (1995a), Dumitrica et al. (1997), Dumitrica and Dumitrica-Jud (1995; 2005), Danelian (2008), O'Dogherty (1994) and O'Dogherty et al. (2009).

The preservation of the fauna extracted is moderate. The following taxa were identified, most of them being illustrated in Plates 1-3:

Aurisaturnalis carinatus perforatus Dumitrica and Dumitrica-Jud; *Acaeniotyle diaphorogona* Foreman *sensu* Baumgartner et al. (1995a); *Acaeniotyle umbilicata* (Rüst); *Acaeniotyle* sp. cf. *A. umbilicata* (Rüst); *Angulobracchia* (?) *portmanni portmanni* Baumgartner; *Archaeodictyomitra lacrimula* (Foreman); *Archaeodictyomitra vulgaris* Pessagno; *Archaeodictyomitra* sp. cf. *A. ioniana* Danelian; *Archaeodictyomitra* sp. cf. *A. tumandae* Dumitrica; *Crucella* sp. cf. *C. bossoensis* Jud; *Dicerosaturnalis trizonalis* (Rüst) *sensu* Dumitrica and Zügel (2008); *Hiscocapsa* sp. cf. *H. uterculus* (Parona); *Holocryptocanium* sp. cf. *H. barbui* Dumitrica; *Loopus blabla* (Schaaf) *sensu* Dumitrica et al. (1997); *Mictyoditra* sp. cf. *M. pseudodecora* (Tan); *Pantanellium masirahense* Dumitrica; *Pantanellium squinaboli* (Tan); *Pantanellium* sp. cf. *P. masirahense* Dumitrica; *Pantanellium* sp.; *Podobursa* sp. cf. *P. typica* (Rüst) *sensu* O'Dogherty (1994); *Podobursa* (?) sp.; *Pseudodictyomitra* sp. cf. *P. lanceloti* Schaaf; *Pseudodictyomitra* sp. cf. *P. lilyae* (Tan); *Pseudoeucyrtis corpulentus* Dumitrica; *Pseudoeucyrtis zhamoidai* (Foreman) gr. *sensu* Dumitrica *et al.* (1997); *Pseudoeucyrtis* sp.; *Sethocapsa* sp. A; *Sethocapsa* sp. B; *Suna hybum* (Foreman); *Svinitzium* sp. cf. *S. pseudopuga* Dumitrica; *Tethysetta* sp. cf. *T. pygmaea* Dumitrica; *Thanarla broweri* (Tan) *sensu* O'Dogherty (1994); *Thanarla pacifica* Nakaseko and Nishimura; *Thanarla* sp. cf. *T. broweri* (Tan) *sensu* O'Dogherty (1994); *Thanarla* sp. cf. *T. pacifica* Nakaseko and Nishimura; *Xitus* sp.

Following the biozonation of Baumgartner et al. (1995b) the co-occurrence of species *Aurisaturnalis carinatus*, *Acaeniotyle diaphorogona* gr., *Acaeniotyle umbilicata*, *Angulobracchia* (?) *portmanni*, *Archaedictyomitra lacrimula*,

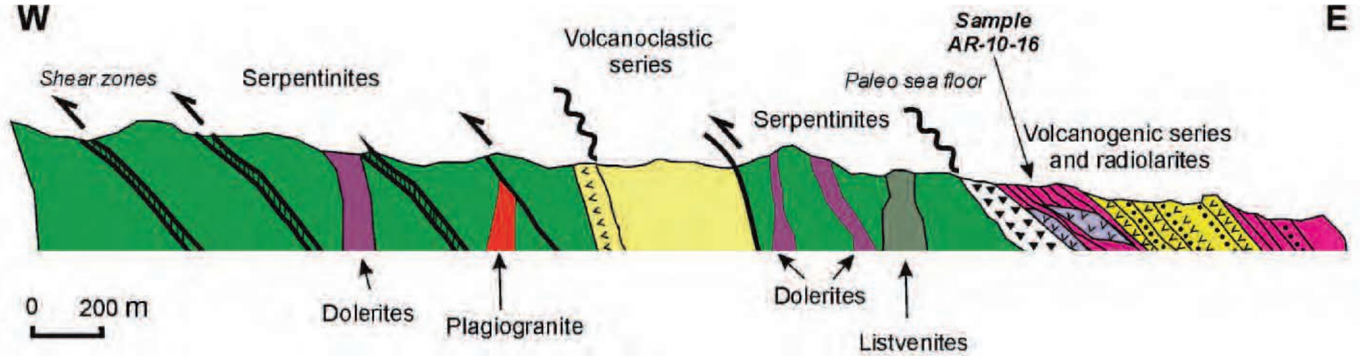

Fig. 3 - Geological section of the studied outcrop along the valley located west of Vank (see location on Fig. 2; after Sosson et al., in prep.).

Dicerosaturnalis trizonalis, *Pantanellium squinaboli* and *Suna hybum* allows to assign sample Ar-10-16 to the Unitary Association Zones 18-22 and to be thus correlated with the late Valanginian/early Hauterivian to late Barremian/early Aptian time interval. However, since no strata younger than the lower Aptian U.A.Z. 22 are considered in this biozonation, the possibility for the age of this sample to be younger than the early Aptian cannot be excluded based only on the biozonation of Baumgartner et al (1995b). Nevertheless, species *Aurisaturnalis carinatus* and *Angulobracchia* (?) *portmanni* last occur in the lower Aptian Verbeeki subzone of O'Dogherty's (1994) biozonation. In addition, the age range of species *Dicerosaturnalis trizonalis*, is known to be limited in the late Kimmeridgian - Aptian interval (Dumitrica and Zügel, 2008) and the last occurrence of genera *Loopus* and *Tethysetta* is known to occur in the early Aptian (O'Dogherty et al., 2009). Finally, the single presence of species *Aurisaturnalis carinatus perforatus* (Plate 1, Fig. 1-4) can date our sample more accurately, since this easily recognisable subspecies represents the last morphospecies of the *Aurisaturnalis carinatus* lineage, which went extinct in the early Aptian, as this is established in the microevolutionary study of Dumitrica and Dumitrica-Jud (1995). More particularly, based on material from well-dated sections of Central Italy (Jud, 1994), these authors found that the age range of *Aurisaturnalis carinatus perforatus* coincides with the magnetozone M1 and the middle late Barremian - early early Aptian (anterior of the OAE 1a event) part of the sedimentary sequence. In conclusion, sample Ar-10-16 can be correlated with the middle late Barremian to early early Aptian interval.

DISCUSSION

The observed relationship between the volcano-sedimentary cover and the serpentinites is suggestive of a paleo-sea floor (Fig. 3), alike the ones observed along modern slow rate spreading ridges (Lagabrielle and Cannat, 1990). The few listvenite dykes that were observed near the contact with the volcano-sedimentary sequence may correspond to the hydrothermalized level situated near the paleo-sea floor. This relationship is typical of the Ligurian type ophiolites in the Alps *s.l.* and comparable to other ophiolitic complexes of the Sevan-Hagari (Akera) suture zone (Galoyan et al., 2009; Rolland et al., 2010). The late Barremian to early Aptian radiolarites of the Vank section, by their genetic relationship with pillow lavas, allow dating a submarine volcanic activity that took place most likely during this interval. Are they related to ocean floor spreading in the Tethyan realm of the Lesser Caucasus?

The early phases of oceanic spreading of Neotethys in the Lesser Caucasus took place sometime during the Middle to Late Triassic transition. This can be argued essentially on the basis of the Late Triassic radiometric ages (224±8 Ma and 226±13 Ma) obtained with the Sm-Nd method by Bogdanovski et al. (1992) from norites and gabbro-norites that crop out in Karabagh, but also by the Carnian-Toarcian sequence of siliceous pelites and ophiolitic breccia described by Knipper et al. (1997).

The bulk of ophiolites in the Lesser Caucausus are probably the relics of a marginal back-arc basin, which opened with a slow spreading rate during the Middle Jurassic and which was situated behind an intra-oceanic subduction zone (Galoyan et al., 2009).

Most of the absolute ages obtained so far on the ophiolitic sequences of the Lesser Caucasus point to Middle and Late Jurassic intervals. More specifically, the radiometric ages obtained by the application of both the U-Pb method on zircons from tonalites (160±4 Ma; Zakariadze et al., 1990) and of the ^{40}Ar/^{39}Ar method on amphiboles from gabbros (165.3±1.7 Ma; Galoyan et al., 2009) of the Sevan ophiolite suggest that oceanic crust was being formed during the Bathonian-Callovian, as well as probably during the Oxfordian. Palaeontological (Radiolarian) ages on the sedimentary cover of ophiolitic lavas from three different localities, situated quite far apart, suggest that submarine volcanism was active since at least the Bajocian (i.e., Vedi, Danelian et al., 2008b; Asatryan, 2009; Sarinar, Asatryan et al., 2010 and Karawul, Vishnevskaya 1995). Other radiometric ages on the intrusive part of the Sevan ophiolite are in good agreement with middle/upper Oxfordian to upper Kimmeridgian/lower Tithonian radiolarites that accumulated above ophiolitic lavas of the Vedi and Stepanavan ophiolites (Danelian et al., 2007; 2010; 2011).

The Aptian age obtained radiometrically (117.3±0.9 Ma; Rolland et al., 2009) for alkaline lavas from Vedi is of particular importance for our study because it is considered as the expression of an extensive oceanic island/plateau, generated by a mantle plume event, that was emplaced during the late Early Cretaceous above the Middle-Upper Jurassic oceanic crust, formed previously behind an intra-oceanic subduction setting. It is therefore likely that the late Barremian-early Aptian submarine volcanism dated at the Vank section is part of the same geodynamic event. However, this still need to be confirmed by geochemical analyses applied on the lavas of our studied section.

CONCLUSION

The radiolarian assemblage (and more particularly subspecies *Aurisaturnalis carinatus perforatus*) yielded from radiolarian cherts overlying pillow lavas west of the village Vank of Karabagh suggests that submarine volcanic activity took place during the middle late Barremian to early early Aptian interval. The stratigraphic relationships at the outcrop allow suggest that pillow lavas and radiolarian ooze covered hydrothermalized peridotites that were exposed at the paleo-sea floor possibly adjacent to a slow spreading ridge. The age of this submarine volcanic event preserved in Karabagh is more or less contemporaneous to the Aptian alkaline OIB-type lavas dated by Rolland et al. (2009) in the Vedi ophiolite. It is therefore likely that both of them are associated to the same oceanic volcanic plateau that was being emplaced during the Aptian in the oceanic realm of the Lesser Caucasus.

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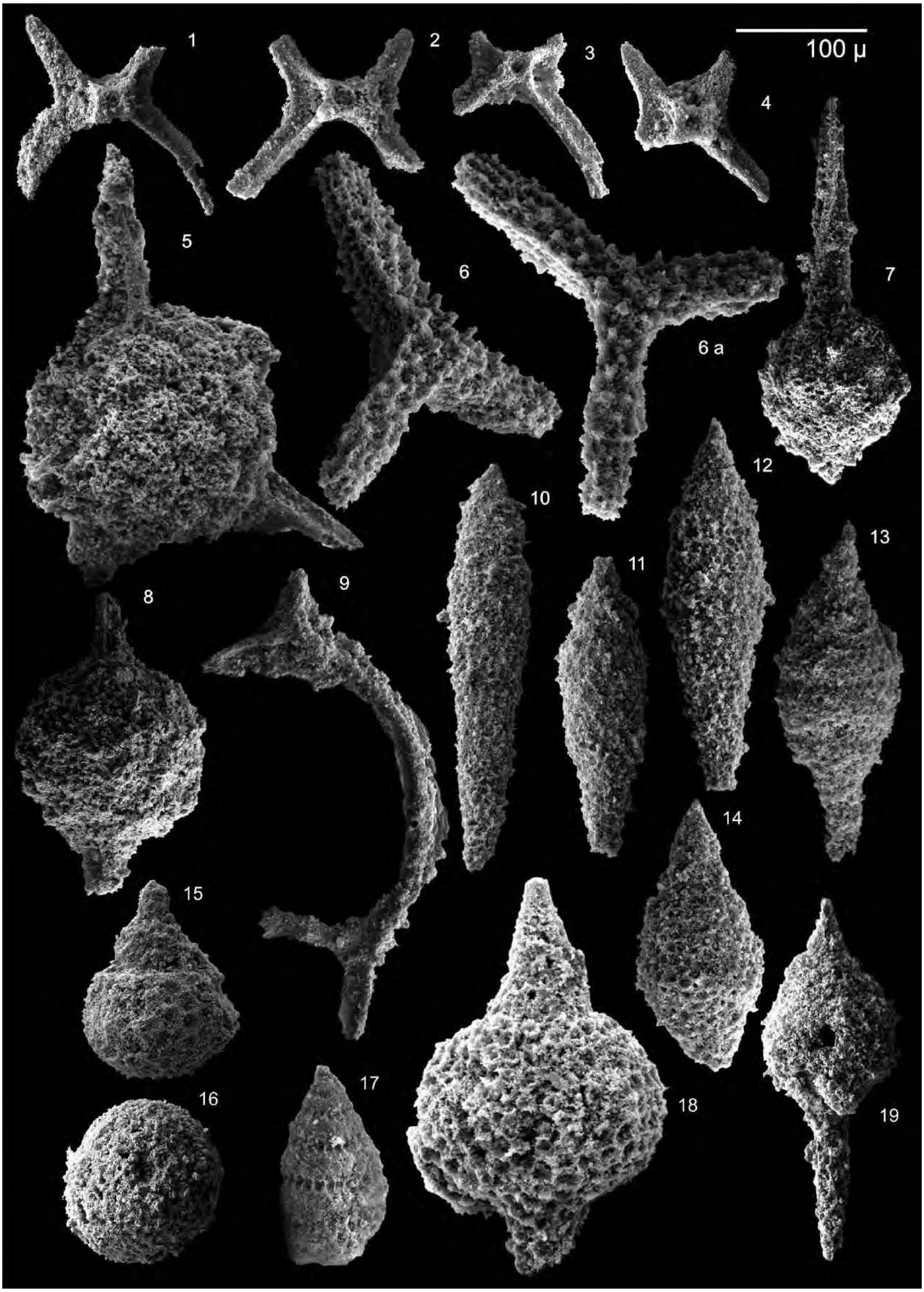

Plate 1 - Scanning electron micrographs of Radiolaria yielded from sample Ar-10-16. 1-4) *Aurisaturnalis carinatus perforatus* Dumitrica and Dumitrica-Jud; 5) *Acaeniotyle diaphorogona* Foreman *sensu* Baumgartner et al. (1995a); 6-6a) *Angulobracchia* (?) *portmanni portmanni* Baumgartner; 7) *Acaeniotyle* sp. cf. *A. umbilicata* (Rüst); 8) *Acaeniotyle umbilicata* (Rüst); 9) *Dicerosaturnalis trizonalis* (Rüst) *sensu* Dumitrica and Zügel (2008); 10-11) *Pseudoeucyrtis* sp.; 12) *Pseudoeucyrtis zhamoidai* (Foreman) gr. *sensu* Dumitrica et al. (1997); 13-14) *Pseudoeucyrtis corpulentus* Dumitrica; 15) *Hiscocapsa* sp. cf. *H. uterculus* (Parona); 16) *Holocryptocanium* sp. cf. *H. barbui* Dumitrica; 17) *Loopus blabla* (Schaaf) *sensu* Dumitrica et al. (1997); 18) *Podobursa* sp. cf. *P. typica* (Rüst) *sensu* O'Dogherty (1994); 19) *Podobursa* (?) sp.

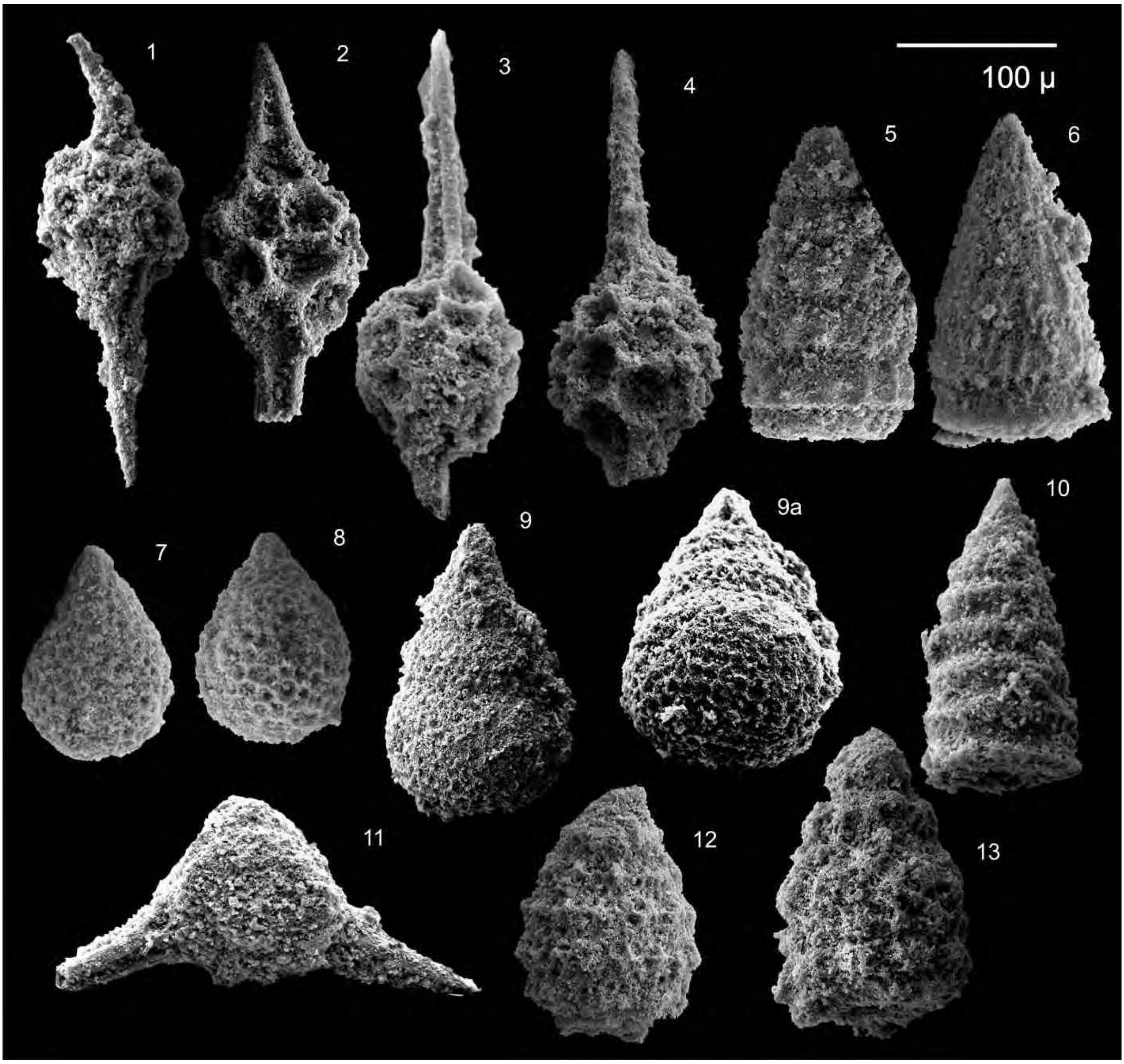

Plate 2 - Scanning electron micrographs of Radiolaria yielded from sample Ar-10-16. 1) *Pantanellium* sp.; 2) *Pantanellium squinaboli* (Tan); 3) *Pantanellium masirahense* Dumitrica; 4) *Pantanellium* sp. cf. *P. masirahense* Dumitrica; 5) *Pseudodictyomitra* sp. cf. *P. lanceloti* Schaaf; 6) *Pseudodictyomitra* sp. cf. *P. lilyae* (Tan); 7-8) *Sethocapsa* sp. A; 9-9a) *Sethocapsa* sp. B; 10) *Svinitzium* sp. cf. *S. pseudopuga* Dumitrica; 11) *Suna hybum* (Foreman); 12) *Tethysetta* sp. cf. *T. pygmaea* Dumitrica; 13) *Xitus* sp.

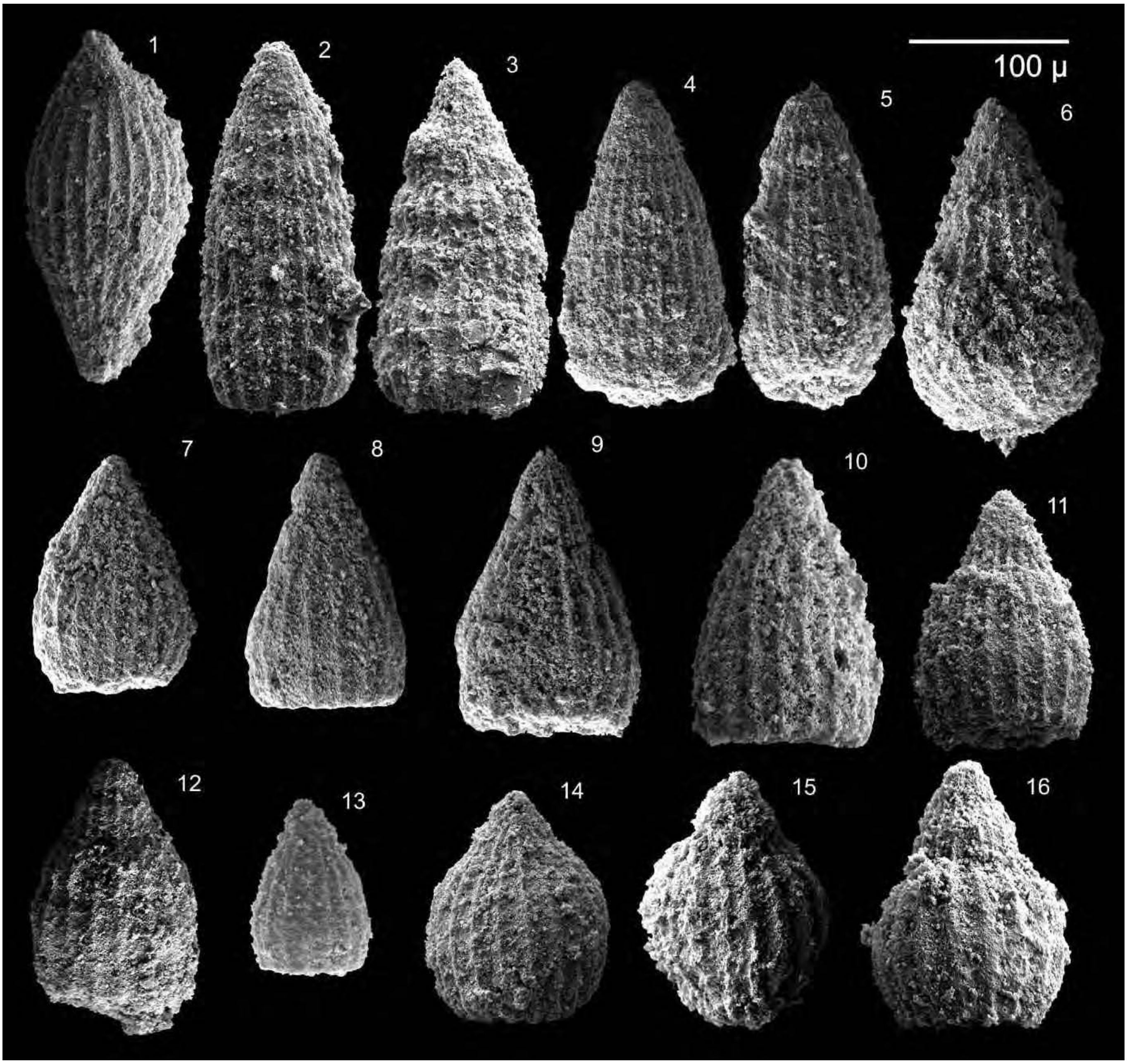

Plate 3 - Scanning electron micrographs of Archaeodictyomitrid Radiolaria yielded from sample Ar-10-16. 1) *Archaeodictyomitra lacrimula* (Foreman); 2) *Archaeodictyomitra vulgaris* Pessagno; 3) *Archaeodictyomitra* sp. cf. A. *tumandae* Dumitrica; 4-5) *Archaeodictyomitra* sp. cf. *A. ioniana* Danelian; 6) *Mictyoditra* sp. cf. *M. pseudodecora* (Tan); 7-12) *Thanarla broweri* (Tan) *sensu* O'Dogherty (1994); 13) *Thanarla* sp. cf. *T. broweri* (Tan) *sensu* O'Dogherty (1994); 14-15) *Thanarla* sp. cf. *T. pacifica* Nakaseko and Nishimura; 16) *Thanarla pacifica* Nakaseko and Nishimura.