AGE AND GEOCHEMISTRY OF MIDDLE TO LATE CARNIAN BASALTS FROM THE ALAKIRÇAY NAPPE (ANTALYA NAPPES, SW TURKEY): IMPLICATIONS FOR THE EVOLUTION OF THE SOUTHERN BRANCH OF NEOTETHYS

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Keywords: *Antalya Nappes, conodonts, dating, OIB-type pillow basalts, radiolarians, southern branch of Neotethys. Turkey.*

ABSTRACT

The geochemical features of spilitic basalts and the radiolarian fauna of associated pelagic sediments have been studied from two different sections of the Alakırçay Nappe of the Antalya Nappes, SW Turkey. The first section in Cukurkoy is located in the eastern part of the Antalya Gulf and includes thick spilitic basalts, overlain by an alternation of mudstone, marl and pelagic cherty limestone. Radiolarian data from the cherty limestone in this unit reveals a middle Carnian age for this section.

The second section in Yaylakuzdere is situated in the western part of the Antalya Gulf. In this section, thick pillow basalts are overlain by a succession of limestone/cherty limestone and shale beds. The age of the limestones interlayered with the pillow basalts was assigned to the late Carnian, whereas the basal part of the overlying cherty limestones was dated as latest Carnian/earliest Norian by conodont and radiolarian faunas.

The pillow lavas in the Çukurköy and Yaylakuzdere regions consist of within-plate type alkaline basalts and display multi-element pattern similar to typical oceanic island basalts (OIB). Low La/Yb, Zr/Y and La/Nb < 1 ratios are also indicative for an OIB-like deep mantle source. These alkaline basalts have not suffered interactions with a subducted slab and/or continental crust due to presence of high HFSE abundance, the lack of depletion in Nb and Ta that are characteristics of subduction and/or crustal contamination processes.

Based on this data, it can be concluded that alkaline volcanism in these two regions of the Antalya Nappes have been probably generated by a small OIB-type mantle plume during the middle - late Carnian time interval, in the advanced stages of rifting of the Antalya Nappes successions in the southern branch of Neotethys. This data reveals the generation of a rift basin before middle Carnian for this ocean.

INTRODUCTION

The Tauride belt in southern Turkey includes a number of tectonostratigraphic units. Brunn et al. (1971; 1973) initially defined three main nappes in the SW Taurides as the Beysehir-Hoyran-Hadım, the Lycian and the Antalya Nappes based on their emplacement age. However, Ozgul (1971; 1976; 1984) has shown that the structural building of the Taurides was further modified by slicing of both allochthonous and autochthonous units with intervening parautochthonous sequences. According to Ozgul's (1971; 1976; 1984) model, the Taurides comprise six main tectono-stratigraphic units (the Geyikdagı, the Bolkardagı, the Aladag, the Bozkir, the Antalya and the Alanya). Reconstruction of these slices related to their original paleogeographic locations on the Tauride-Anatolide platform was realized by Ozgul (1984). Based on this combination, it was suggested that the Tauride-Anatolide platform (Fig. 1a) is a microcontinent surrounded by the northern and southern Neo-Tethyan branches of Sengor and Yılmaz (1981). One stack of nappes, the Antalya Nappes (Antalya Unit *sensu* Ozgul, 1976; 1984) including Paleozoic and Mesozoic pelagic and platform sediments occurs along the southern edge of the autochthonous zone in the Taurides (Brunn et al., 1971; Fig. 1b). According to Sengor and Yılmaz (1981), they originated from the "southern branch of Neotethys" and are widely exposed along the southern part of the Taurides (Fig. 1b).

There have been many hypotheses on timing of opening of the northern and southern Neo-Tethyan branches. According to Sengor and Yılmaz (1981) and Gorur et al. (1983), the Izmir-Ankara Ocean of the northern branch of Neotethys opened during Liassic times. However, some authors (Bragin and Tekin, 1996; Tekin, 1999; Göncüoglu et al., 2000; Tekin et al., 2002; Göncüoglu et al., 2003; 2006; Tuysuz and Tekin, 2007) have stated that this ocean started to open already in Late Triassic. As for the timing of opening of the Izmir-Ankara ocean of the northern branch of Neotethys, there are controversies concerning the opening time in the southern branch of Neotethys. According to Sengor and Yılmaz (1981), the Eastern Mediterranean, as a part of the southern branch of Neotethys, began to open in the Carnian-Norian time interval. In contrast to this view, Ozgul (1983; 1984) suggested that the middle Anisian-Ladinian rifting occurred on continental crust.

For better understanding the opening time of the southern branch of Neotethys, we investigated the successions of the Antalya Nappes including abundant Radiolaria-bearing Mesozoic pelagic sediments. Radiolarian faunas and dating of these pelagic sediments have been subjects of some previous studies (Tekin, 1999; 2002a; 2002b; Tekin and Yurtsever, 2003; Yurtsever et al., 2003). Within the Antalya Nappes, the basic volcanics rocks are assigned to the Late Triassic for the finding of different microfaunas (bivalves, ammonites etc.) in the associated pelagic sediments. These data are very important for the reconstruction of the sedimentary history of these nappes, as discussed in some articles (Marcoux, 1970; Dumont et al., 1972; Juteau and Marcoux, 1973; Juteau, 1974; Yılmaz, 1984; Robertson and Waldron, 1990; Dixon and Robertson, 1999). In the Eastern Mediterranean, volcanic rocks dated in the southern branch of Neotethys have also been studied by other researchers such as Lapierre (1975), Lapierre and Rocci (1976), Lapierre et al. (2007) in the Mamonia Complex (SW

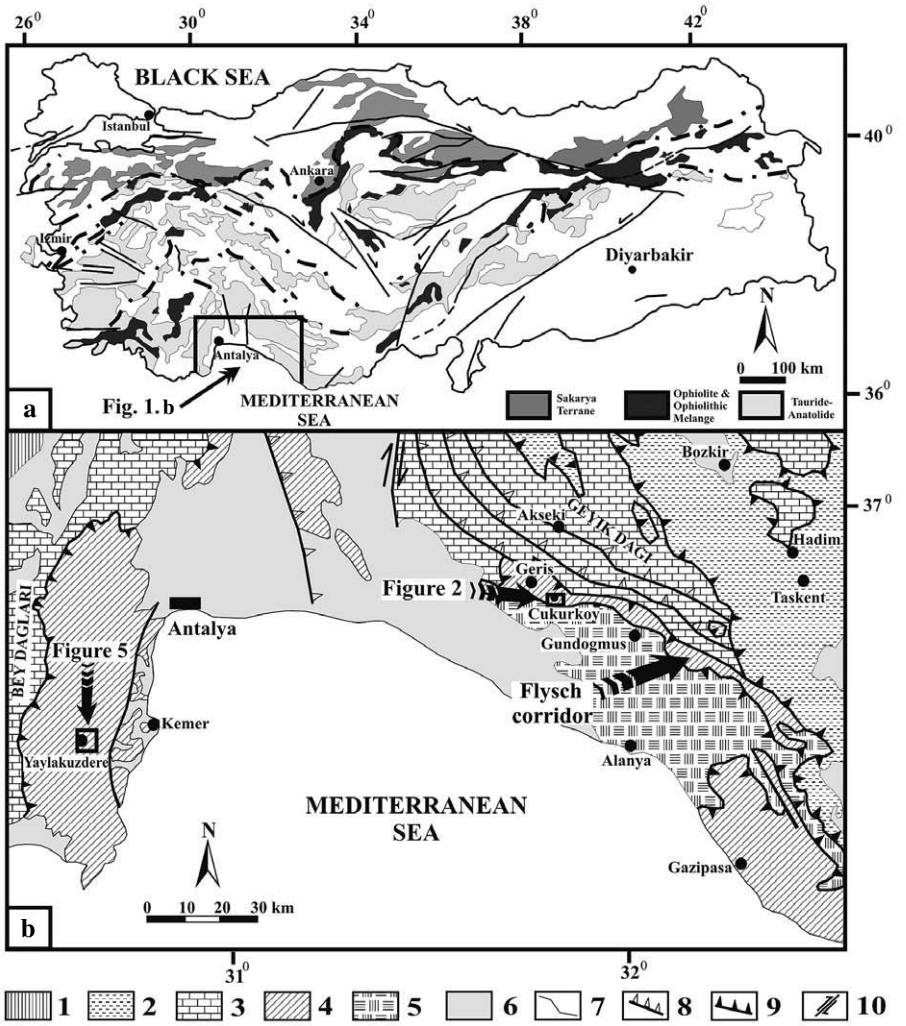


Fig. 1 - (a) Map showing the distribution of Alpine terranes (simplified after Göncüoglu et al., 1996) and the location of Fig. 1b; (b) Schematic map of the area between the western and central Taurides (revised after Ozgul, 1984) and locations of detail maps of the Cukurkoy and Yaylakuzdere regions. 1- Lycien Nappes; 2- Beysehir-Hoyran-Hadım Nappes; 3- Beydagları-Anamas-Akseki autochthon; 4- Antalya Nappes; 5- Alanya Nappe; 6- post-Eocene cover rocks; 7- Stratigraphic contact; 8- Minor thrust; 9- Main thrust; 10- Strike-slip fault.

Cyprus), and by Al-Rayami et al. (2000) in the Baer-Bassit region (NW Syria).

At the west end of the eastern Mediterranean region, Bortolotti et al. (2004a; 2004b; 2006) have analysed MOR and OI basalts covered by Middle to Upper Triassic cherts in subophiolitic complexes of the Mirdita ophiolitic nappe in Albania. Based on these data, they concluded that a Middle to Upper Triassic oceanic basin with MORB magmatism was present between the Adria and Eurasia plates.

In this study, we analysed two sections of the Alakırçay Nappe with basalts and pelagic sediments in the Antalya Nappes, in SW Turkey, for better understanding the geochemical characteristics and precise age of the basic volcanic rocks. The aim of this study was to evaluate the geochemical properties of the Carnian basic volcanics rocks and to analyse the radiolarian faunas from associated sediments in the Alakırçay Nappe and to discuss the implications for the evolution of the southern branch of Neotethys.

GEOLOGICAL SETTING

The Antalya Nappe was first named and described by Lefevre (1967) as a single nappe in the west of the Antalya Gulf (Fig. 1b). Afterwards, Brunn et al. (1971) subdivided it into three nappes: the "Cataltepe Unit (lower nappe)", the "Alakırçay Unit (middle nappe)" and the "Tahtalıdag Unit (upper nappe)" according to their internal relations. Subsequently, the Antalya Nappes have been named as the "Antalya Unit" by Ozgul (1976) and the "Antalya Complex" by Woodcock and Robertson (1977). Recently, the Antalya Nappes were subdived into four units by Senel et al. (1992): the "Cataltepe Nappe", the "Alakırçay Nappe", the "Tahtalıdag Nappe" and the "Tekirova ophiolitic Nappe".

The Alakırçay Nappe (middle nappe) includes Middle to Upper Triassic pelagic sediments (radiolarian cherts, pelagic limestones etc.) associated with basic volcanics at its base. They are overlain by Jurassic-Cretaceous pelagic sediments (mainly radiolarian cherts) (Senel et al., 1992; 1996; Tekin, 1999). The Middle to Upper Triassic pelagic rock units of the Alakırçay Nappe were named as the Alakırçay group by Senel et al. (1981). The group includes Karadere-type spilitic pillow basalts and Gokdere-type pelagic sediments which were studied in detail.

The Karadere basalts were named by Juteau and Marcoux (1973) and generally comprise brown, green, greenish black, red colored, pillow basalts, spilits and spilitic basalts (Juteau, 1974). They include cherts, pelagic limestones, shales, agglomerates and tuffaceous materials. The thickness of this formation is up to 700 meters (Senel, 1997). The age of these volcanics is Late Triassic (Marcoux, 1970; Dumont et al., 1972; Robertson and Waldron, 1990), on the basis of bivalvia, ammonites, corals and microfaunas. According to Senel (1997), these volcanic rocks can be actually dated as Ladinian to Norian according to their relationships with the sedimentary formations.

Thin to medium-bedded, beige to red limestones and cherty limestones of Triassic age in Alakırçay group are called "Gokdere Formation" and were named by Kalafatcioglu (1973) in the western side of the Antalya Gulf. This formation also contains calciturbidite, shale and tuffite interlayers showing a thickness ranging from 10 to 350 meters (Senel, 1997). This formation includes next to abundant *Halobia* and radiolarians that may help for accurate dating. In two sections, the Cukurkoy section from the central Taurides and the Yaylakuzdere section from the western Taurides, radiolaria bearing limestones (the Gokdere-type) for dating and pillow basalts (the Karadere-type) for geochemical evaluation have been sampled.

GEOLOGY OF THE STUDIED SECTIONS

The Cukurkoy section

The Cukurkoy section is located in the central Taurides. In this region, the Antalya Nappes extending SE to NW were regionally called as the "Flysch Corridor (Zone Separatrice)" by Blumenthal (1951) (Fig. 1b). Occurrence of pelagic limestones, basalts and radiolarite in this zone was first reported by Blumenthal (1951) and subsequently by Nebert (1964) and they regarded the age of these turbidite sediments as Cretaceous-Tertiary. The presence of Antalya Nappes was first reported by Brunn et al. (1971) in this zone. Based on detail mapping of the western part of this corridor by Monod (1977; 1978), this zone is mainly composed of Mesozoic sediments belonging to the Antalya Nappes. A geological outline of the Flysch Corridor around the Geris - Akseki region was clarified by Dırık (1978), and a detail stratigraphy of the different units has been provided by Senel et al. (1992; 1996). Upper Triassic and Lower Jurassic radiolarian faunas from this region have been studied by Tekin (2002a; 2002b).

The Cukurkoy section is located 1 km east of the-Cukurkoy village (O27-b1 quadrangle) in the Flysch corridor (see Table 1 for coordinates; Fig. 2). Around the Cukurkoy village, the Antalya Nappes are mainly exposed in the north, whereas in the south these nappes are overthrust by the Alanya Nappe (Fig. 2; Monod, 1977). Above the Alakırçay Nappe where the Cukurkoy section is measured, the Tahtalıdag Nappe appears as huge slices especially in the northern part of the area (Fig. 2). Twenty meters thick, mainly thin-bedded, beige, clayey limestones occur at the bottom of the section (Fig. 3). This part is followed by five meters thick, medium to thick-bedded, beige to yellow dolomites. Here, we called this unit the Gokdere-type pelagic sediments, as it resembles the one originally defined by Kalafatcioglu (1973).

Towards the upper part of the section, spilitic pillow basalts, fifty-four meters thick show primary contact with the underlying carbonates (Fig. 3). These basalts are called the "Karadere Basalts" according to the original definition of Juteau and Marcoux (1973). Sample 04-CK-4 was taken from the basal part of this unit. In addition, samples 04-CK-5 (see Table 1 for coordinates; Figs. 2, 3 and 4.1) were taken from the eastern continuation of the same unit. We also collected two more basalt samples (see Table 1 for coordinates; Fig. 2) very close to the Cukurkoy village at the eastern continuation of the Cukurkoy section where fresh samples can be collected. These samples are probably representative of the central part of the Karadere-type spilitic pillow basalts.

Table 1 - Basal and top coordinates (given in UTM, Universal Transverse Mercator) of the Cukurkoy and Yaylakuzdere sections, in addition to coordinates of basalt samples collected for geochemical analyses and some limestone samples collected for radiolaria analyses.

Cukurkoy section		Yaylakuzdere section	
	Coordinates		Coordinates
Section base	3.97.260 E, 40.81.985 N	Section base	2.69.720 E, 40.51.000 N
Section top	3.97.245 E, 40.82.185 N	Section top	2.69.990 E, 40.51.200 N
04-CK-1	3.97.230 E, 40.82.125 N	04-YK-1	2.69.875 E, 40.51.150 N
04-CK-2	3.97.240 E, 40.82.125 N	04-YK-2	2.69.850 E, 40.51.100 N
04-CK-3	3.97.320 E, 40.82.140 N	04-YK-3	2.69.850 E, 40.51.100 N
04-CK-4	3.97.225 E, 40.82.015 N	04-YK-4	2.69.825 E, 40.51.100 N
04-CK-5	3.97.290 E, 40.82.025 N	04-YK-5	2.69.875 E, 40.51.100 N
04-CK-6	3.97.350 E, 40.82.010 N	04-YK-6	2.69.925 E, 40.51.150 N
04-CK-7	3.97.420 E, 40.82.090 N		
04-CK-8	3.95.890 E, 40.82.090 N		
04-CK-9	3.95.800 E, 40.82.060 N		

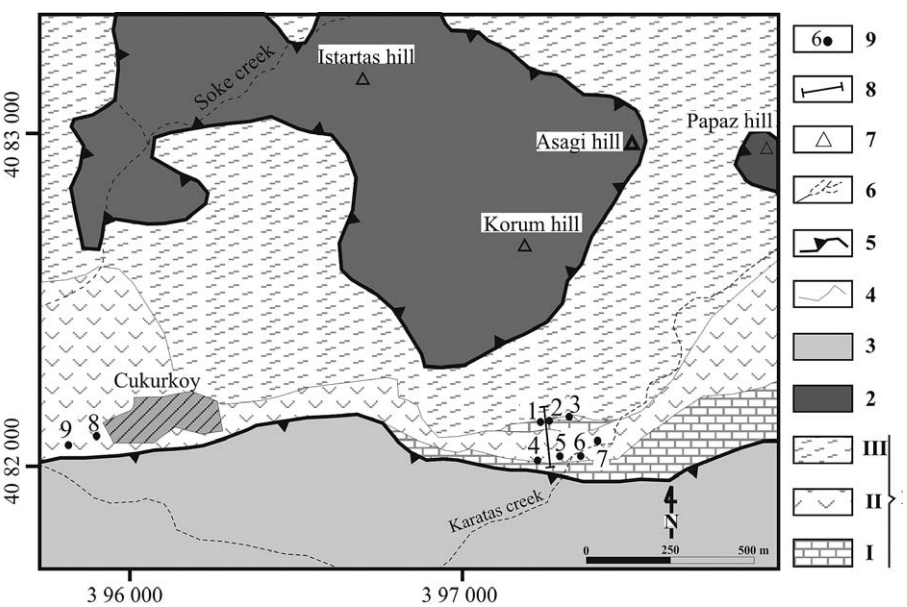


Fig. 2 - Geological map showing the locality of the Cukurkoy section (revised after Monod, 1977) and sampling points. 1- Alakırçay Nappe of the Antalya Nappes (I- Gokdere-type pelagic sediments, mainly Triassic carbonates; II- Karadere-type spilitic pillow basalts, mainly Triassic volcanics; III- Candır-type clastics, mainly Triassic plant remains bearing clastics); 2- Tahtalıdağ Nappe of Antalya Nappes; 3- Alanya Nappe; 4- Stratigraphic contact; 5- Thrust; 6- Drainage system; 7- Main peaks; 8- Location of the Cukurkoy section; 9- Sampling points.

In the section, the Karadere-type spilitic pillow basalts are overlain by six meters thick Gokdere-type pelagic sediments (Figs. 2 and 3). This formation includes an alternation of thin-bedded, green-red-brown mudstone, marl and pelagic cherty limestone. Moderately preserved middle Carnian radiolarians were obtained from a cherty limestone (sample 04-CK-1) sampled from the Gokdere-type pelagic sediments at the top of the section. Within this formation, spilitic pillow basalts, present in minor amount, have been sampled (04-CK-2) for chemical analysis (Figs. 2, 3, and 4.2)

Two meters thick Karadere-type spilitic pillow basalts overlie the Gokdere-type pelagic sediments. From this unit, sample 04-CK-3 (see Table 1 for coordinates) was obtained for chemical analysis (Figs. 2 and 3). The uppermost part of the section is comprises the Candır-type clastics, named and described as "Candır Formation" by Akbulut (1980) in the central Taurides. Here, this formation is mainly characterized by sandstones and mudstones with plant remains (Figs. 2, 3 and 4.1). The uppermost part of the section is covered by debris.

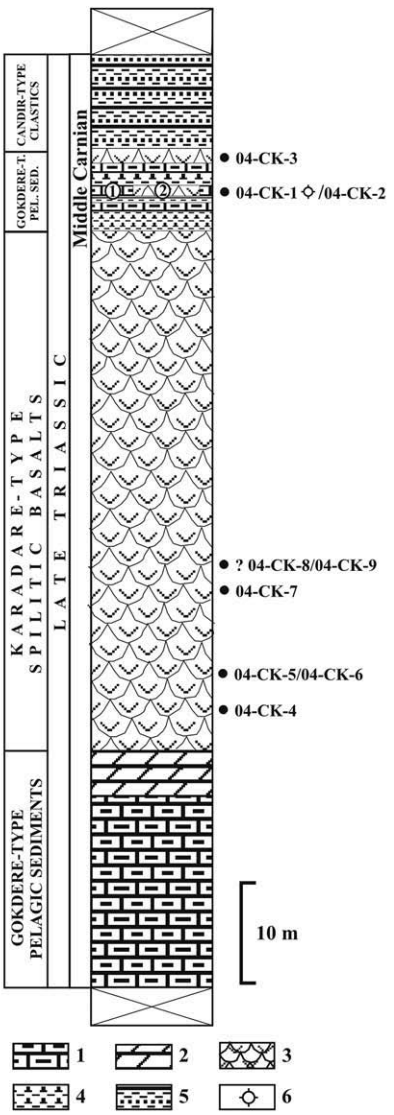


Fig. 3 - Log of the Cukurkoy section and sampling points. 1- Clayey limestone; 2- Dolomites; 3- Pillow basalts; 4- Alternation of mudstone and marl; 5- Alternation of mudstone and sandstone with plant remains; 6- Radiolaria occurrence.

The Yaylakuzdere section

Second studied locality is the Yaylakuzdere section situated in the western Taurides, west of the Antalya Gulf (Fig. 1b). In this region, the Antalya Nappes are exposed as imbricated tectonic slices between the Mediterranean Sea and Beydagları. This part of the Antalya Nappes has been studied by several authors (see Tekin, 1999 and references therein).

This section was measured at the SE bank of the Gurleyikdere Creek (Antalya O24-c3 quadrangle, see Table 1 for coordinates; Fig. 5), located is very close to the Yaylakuzdere village. General characteristics of this section and details of the radiolarian fauna were given in Tekin (1999).

Eighty samples for radiolaria and conodonts determinations and six samples for chemical analyses have been taken from the section (Fig. 6). The basal part of the section is represented by thick, dark, spilitic pillow basalts (the Karadere-type; Figs. 5, 6 and 7.1-2). Along the section, the total thickness of the Karadere-type spilitic pillow basalts was estimated as 310 meters (Figs. 5 and 6). Red limestone interlayers are common within the well-developed pillow lavas along this formation (Figs. 6 and 7.1). Five samples were collected from the pillow basalts for chemical analysis (samples 04-YK-1, 04-YK-2, 04-YK-3, 04-YK-4 and 04-YK-5, see Table 1 for coordinates).

The Gokdere-type pelagic sediments topped by the Karadere-type spilitic pillow basalts include an alternation of thin to medium-bedded limestones and shales (Figs. 6 and 7.2; Tekin, 1999). Although it is highly fractured, its total thickness can be estimated as 32 meters. Very well-preserved and diverse, mainly pyritized radiolaria were extracted from the limestone layers of this formation. An 80 cm thick volcanic sill occurs very close to the base of the Gokdere-type pelagic sediments where sample 04-YK-6 has been collected for chemical analysis (Figs. 5 and 6, see Table 1 for coordinates). Limestone layers at the upper part of the Gokdere-type pelagic sediments contain black chert nodules (Fig. 6). The Gokdere-type pelagic sediments in this section were dated as latest Carnian/earliest Norian to early Norian based on the radiolarian and conodont faunas (Tekin, 1999).

AGES OF SEDIMENTARY ROCKS

The Cukurkoy section

In the Cukurkoy section, moderately-preserved Radiolarian fauna was obtained from sample 04-CK-1 (Figs. 3 and 4.2) and includes the following taxa: *Spongostylus carnicus* Kozur and Mostler (Plate 1, Fig. 1), *S. tortilis* Kozur and Mostler (Plate 1, Fig. 2), *Vinassaspongus subsphaericus* Kozur and Mostler (Plate 1, Figs. 3 and 4), *Orbiculiforma* sp. (Plate 1, Fig. 5), *Capnuchosphaera triassica* De Wever (Plate 1, Figs. 6 and 7), *Weverella* sp. cf. *W. tetrabrachiata* Kozur and Mostler (Plate 1, Figs. 8 and 9), *Paronaella* sp. cf. *P. glaber* (Kozur and Mostler) (Plate 1, Fig. 10), *P.* sp. cf. *P. simoni* (Kozur and Mostler) (Plate 1, Fig. 11), *Crucella* sp. cf. *C. carnica* (Kozur and Mostler) (Plate 1, Fig. 12), *Crucella* sp. (Plate 1, Fig. 13), *Hindeosphaera austriaca* Kozur and Mostler (Plate 1, Fig. 14), *Hindeosphaera* sp. cf. *H. austriaca* Kozur and Mostler (Plate 1, Fig. 15), *Hindeosphaera bispinosa* Kozur and Mostler (Plate 1, Fig. 16), *Tetraporobrachia* sp. (Plate 1,

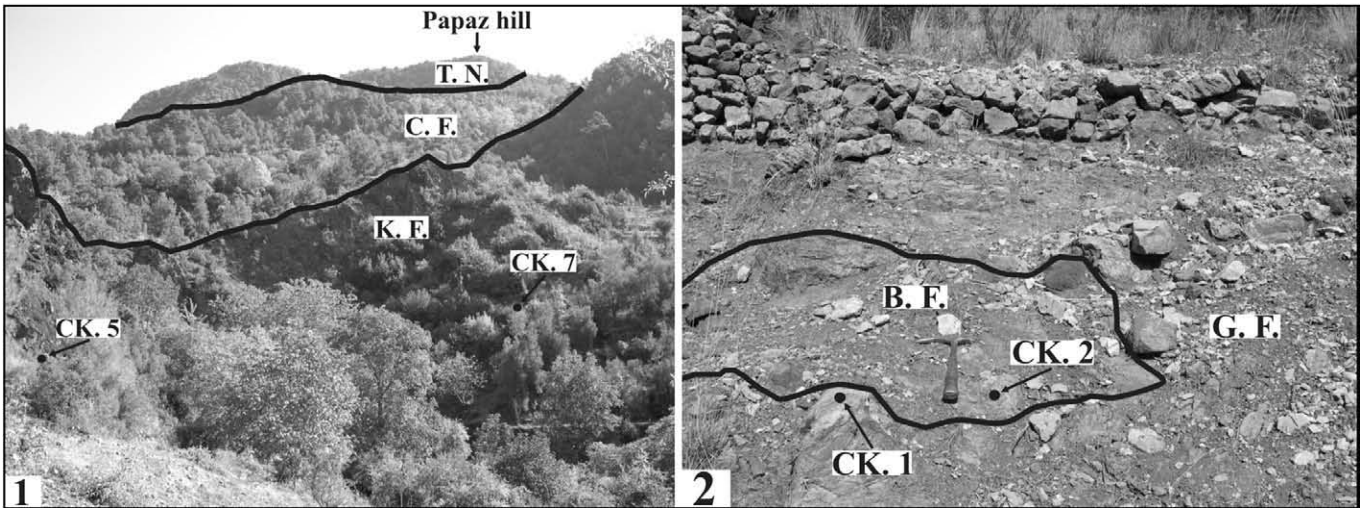


Fig. 4 - Photographs showing lithologies and some sample locations around the Cukorkoy section. 1. Photograph showing the general view of the Karadere-type spilitic pillow basalts and overlying Candır-type clastics (C. F.) along the Karatas Creek. CK. 5 and CK. 7 indicate positions of two basalt samples (04-CK-5 and 04-CK-7) collected from the Karadere-type spilitic pillow basalts. Massive limestone unit at the back of photograph belongs to the Tahtalıdag Nappe (T. N.) of the Antalya Nappes; 2. Detail view of the Gokdere-type pelagic sediments located at the top of the section and basalt flow (B. F.) in the upper part of the section. While CK-1 indicates the position of limestone sample (04-CK-1) with abundant middle Carnian radiolarians, CK-2 indicates the position of sample (04-CK-2) from a basalt flow.

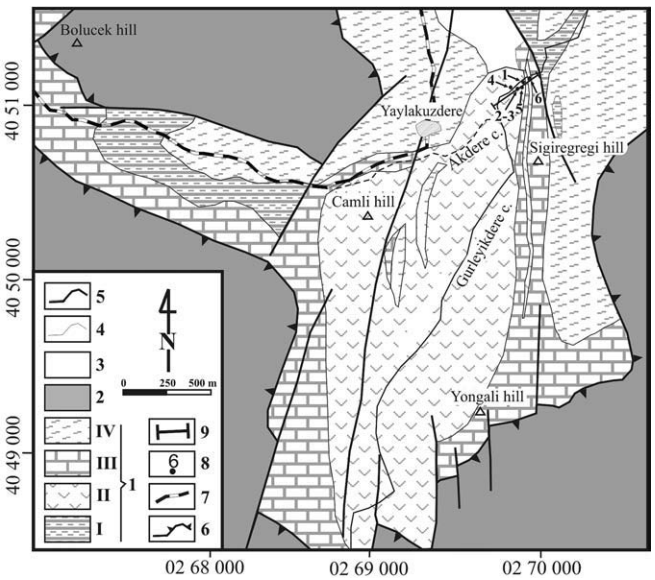


Fig. 5 - Map showing the location and geology of the Yaylakuzdere section (revised after Senel, 1978 and 1986) and separate sampling points of volcanic rocks from the Alakırçay Nappe of the Antalya Nappes. 1- Alakırçay Nappe of the Antalya Nappes (I- Tesbihli Formation, mainly Triassic bedded chert; II- Karadere-type spilitic pillow basalts, mainly Triassic volcanics; III- Gokdere-type pelagic sediments, mainly Triassic carbonates; IV- Candır-type clastics, mainly Triassic plant remains bearing clastics); 2- Tahtalıdag Nappe of the Antalya Nappes; 3- post-Eocene cover rocks; 4- Normal contact; 5- Fault; 6- Overthrust; 7- Main roads; 8- Locations of the samples from volcanic rocks; 9- Location of the Yaylakuzdere section.

Fig. 17), *Poulpus piabyx* De Wever (Plate 1, Fig. 18), *Xiphotheca karpenissionensis* De Wever (Plate 1, Figs. 19 and 20).

Within this fauna, *Hindeosphaera austriaca* is characteristic species for middle Carnian strata and it is only known from the Goestling region in Austria and indicates the middle Carnian (Kozur and Mostler, 1979). The basal part of the middle Carnian is the first appearance datum for *Spongostylus carnicus* (Kozur and Mostler, 1979; 1981; Lahm, 1984; Yeh, 1989; Carter et al., 1989; Grapes et al., 1990; Halamic and Gorican, 1995; Bragin and Krylov, 1999; Tekin, 1999) and the top of middle Carnian is last appearance datum for two taxa (*Vinassaspongus subsphaericus* and *Hindeosphaera bispinosa*) (Kozur and Mostler, 1979; Kido, 1982; Lahm, 1984; Gorican and Buser, 1990; Tekin, 1999) within this fauna. Co-occurrence of these taxa also reveals a middle Carnian age for sample 04-CK-1 from the Cukurkoy section (Fig. 8).

One of the specimens in the fauna (*Tetraporobrachia* sp.; Plate 1, Fig. 17) has resemblance to *Tetraporobrachia haeckeli,* but preservation is not goud enough for proper determination. This species has been suggested as index form for the middle Carnian by Kozur and Mostler (1994; 1996), therefore, the presence of this badly-preserved specimen probably also indicates a middle Carnian age. In addition, taking into consideration also the presence of badly preserved taxa (*Weverella* sp. cf. *W. tetrabrachiata*, *Crucella* sp. cf. *C. carnica, Paronaella* sp. cf. *P. glaber*, *P.* sp. cf. *P. simoni),* it can be concluded that this fauna has great similarity to the faunas previously obtained from middle Carnian strata of Austria (Kozur and Mostler, 1978; 1979; 1981; Lahm, 1984) and Turkey (Tekin, 1999; Tekin and Göncüoglu, 2002; Tekin and Bedi, 2007a; 2007b). Based on these facts, middle a Carnian age is assigned to sample 04-CK-1 from the Cukurkoy section (Fig. 9).

The Yaylakuzdere section

The Yaylakuzdere section from the Alakırçay Nappe of the Antalya Nappes includes highly diverse and well-preserved, mainly pyritized radiolarian faunas associated with conodonts in the Gokdere-type pelagic sediments (Fig. 6). Three conodont zones were determined as the "*Epigondolella primitia*" (latest Carnian/earliest Norian), "*Epigondolella abneptis*" (early Norian), and "*Epigondolella triangularis*" (upper part of early Norian) in the Gokdere-type pelagic sediments of the Yaylakuzdere section. Detail determinations of the radiolarian and conodont faunas and their distributions were given in Tekin (1999). Some synopsis of radiolarian faunas associated to the conodonts can be summarized as follows.

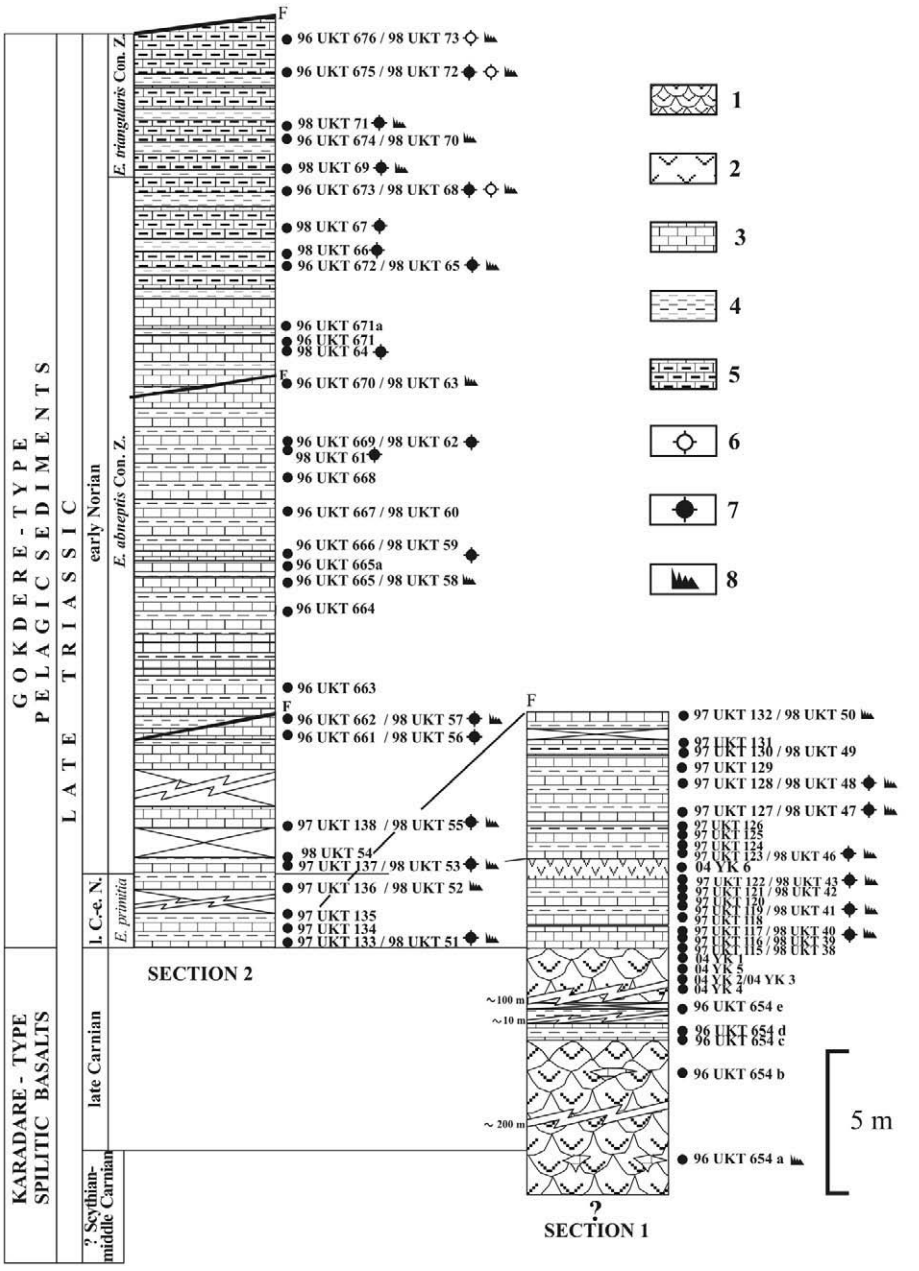


Fig. 6 - Log of the Yaylakuzdere section from the Alakırçay Nappe of the Antalya Nappes with locations of radiolaria and/or conodont bearing samples. Explanations: 1- Limestone layer in pillow lava; 2- Volcanic sill; 3- Limestone; 4- Shale; 5- Cherty limestone; 6- Occurrence of normal Radiolaria; 7- Occurrence of pyritized Radiolaria; 8- Occurrence of conodonts; Abbreviation: l. C.-e. N.: latest Carnian - earliest Norian (revised after Tekin, 1999).

1. Conodont (*Gladigondolella* sp.) remains obtained from limestone interlayer within pillow lava (sample 96-UKT-654a) in the Karadere-type spilitic pillow basalts from the basal part of the Yaylakuzdere section indicate a Scythian-middle Carnian age for this part. The age of the Karadere-type spilitic pillow basalts close to the top where the volcanic samples were taken (04-YK-1 to O4-YK-5) can be assigned as late Carnian, as the bottom of the overlying Gokdere-type pelagic sediments is latest Carnian - earliest Norian (Tekin, 1999; Fig. 9).

2. The basal part of the Gokdere-type pelagic sediments corresponds to the *Epigondolella primitia* Conodont Zone, for the presence of an index conodont taxon dated as latest Carnian-earliest Norian. Regarding radiolarians, species of the genus *Capnodoce* especially *C. media* Blome and *C. extenta* Blome are common within this zone. Some of the radiolaria taxa as *Catoma* sp. A, *Capnodoce* sp. cf. *C. minuta* Yeh, *Syringocapsa* sp. B and *Annulotriassocampe* ? sp. A were only found within the strata corresponding to this zone in the section (Tekin, 1999; Fig. 9).

3. The radiolarian fauna of the *Epigondolella abneptis* Conodont zone (early Norian) in the Yaylakuzdere section is very abundant and diverse. Some of the radiolarian taxa determined only in the strata corresponding to the *Epigondolella abneptis* Conodont zone are: *Kahlerosphaera kemerensis adentatus* Tekin, *K. kemerensis kemerensis* Tekin, *Capnuchosphaera constricta* (Kozur and Mock), *Monocapnuchosphaera subtornata dextra* Tekin, *Dicapnuchosphaera elegans* Tekin, *D. sengori* Tekin, *Paricrioma deweveri* Tekin, *Sarla robusta* Tekin, *Palaeosaturnalis mocki* Kozur and Mostler, *P. raridenticulatus* Kozur and Mock, *Triarcella sulovensis* Kozur and Mock, *Bulbocyritium globosus* Tekin, *Deflandrecyrtium tegumentiformis* Tekin, *Podobursa galeata* Tekin, *Veghia sulovensis* Kozur and Mock, *Senelella triassica* Tekin, *Xiphotheca pseudolonga* Tekin, *X.* ? *transitus* Tekin, *Tauridastrum longitubus* Tekin (Tekin, 1999; Fig. 9).

4. The radiolarian fauna corresponding to the *Epigondolella triangularis* Conodont Zone (upper part of early Norian) in the Yaylakuzdere section does not resemble the one

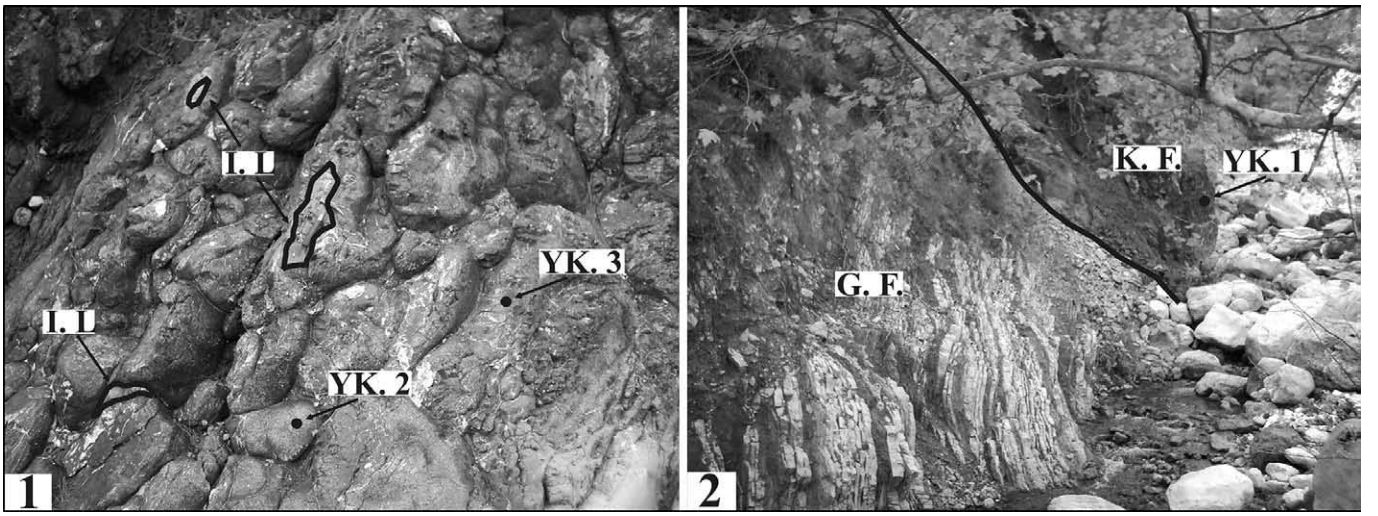


Fig. 7 - Photographs showing the lithologies and some sample locations around the Yaylakuzdere section. 1. Detail view of pillow basalts and intra-pillow limestones and positions of samples 04-YK-2 (YK-2) and 04-YK-3 (YK-3); 2. General view showing the relation of the Karadere-type spilitic pillow basalts and overlying Gokdere-type pelagic sediments including mainly limestones. Sample 04-YK-1 (YK-1) was taken from the uppermost part of the Karadere-type spilitic pillow basalts.

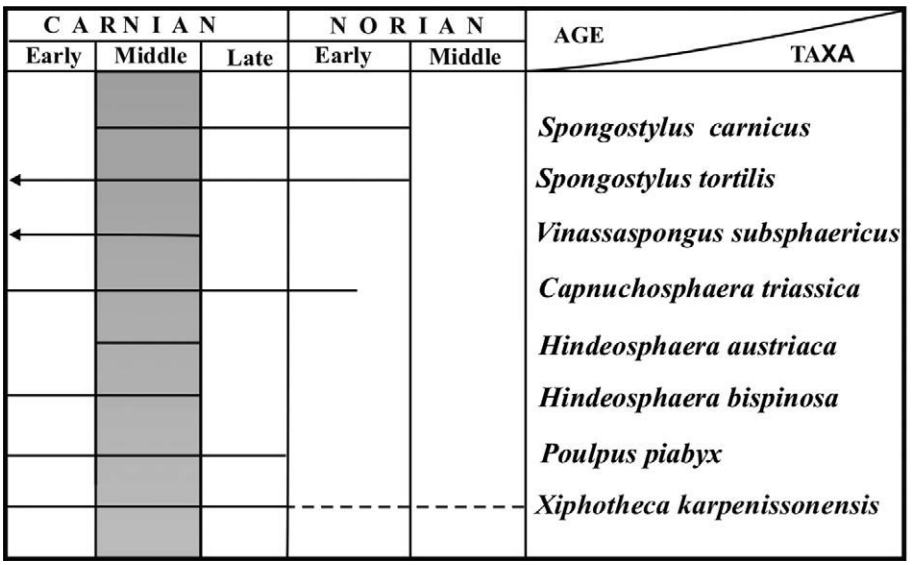


Fig. 8 - Stratigraphic ranges of selected taxa from sample 04-CK-1 in the Cukurkoy section from the Alakırçay Nappe, Antalya Nappes. The dotted area shows the supposed age of the studied assemblage. The broken lines show the supposed part of stratigraphic intervals of the taxa.

corresponding to the *Epigondolella abneptis* Conodont Zone. The saturnalid fauna (e.g. *Stauroacanthocircus* ? *poetschensis* Kozur and Mostler, *Praehexasaturnalis burnensis* (Blome), *Pr. tenuispinosus* (Donofrio and Mostler), *Pseudoheliodiscus elongates*, *Ps. validus* (Donofrio and Mostler) and *Palaeosaturnalis dotti* (Blome) Group is very rich and abundant especially at the top of strata belonging to the *Epigondolella triangularis* Conodont Zone. Some of the important taxa as *Xiphosphaera fistulata* Carter and *Kahlerosphaera norica* Kozur and Mock were also encountered from strata corresponding to the top of this zone (Tekin, 1999; Fig. 9). Species of genus *Harsa* Carter were not determined in strata corresponding to the top of the *Epigondolella triangularis* Conodont Zone; this is the only differences the radiolarian fauna reported from Queen Charlotte Islands (Carter, 1991). Recently, the association of "*Capnodoce serisa* (senior synonym of *C. fragilis)- Harsa siscwaiensis- Xiphosphaera fistulata"* suggested by Carter (1991) from the Queen Charlotte Islands was found in upper lower to lower middle Norian strata in the Antalya Nappes (Tekin and Yurtsever, 2003).

PETROGRAPHIC AND GEOCHEMICAL FEATURES OF THE BASALTS

Fourteen volcanic samples from the Cukurkoy and Yaylakuzdere sections have been collected for petrographical studies, of which only ten (samples 04-CK- 2, 3, 4, 8, 9 from the Cukurkoy region and samples 04-YK-1, 2, 3, 4, 5 from the Yaylakuzdere region) have been selected for geochemical analysis. Major elements were analyzed on pressed powder pellets by using a "Spectro X-Lab 2000 X-ray fluorescence spectrometer (XRF)" at the Ankara University (Turkey). Trace and rare earth element concentrations were analyzed at ACME laboratories (Vancouver, CANADA) by ICP-MS using a fusion method.

All samples exhibit medium to coarse-grain amygdaloidal texture filled with secondary minerals such as carbonate, chlorite, zeolite and quartz. They display typical porphyritic and intersertal textures with dominantly plagioclase, pyroxene and rarely olivine phenocrysts set in a matrix of the same minerals.

Major and trace element analyses are reported in Table 2.

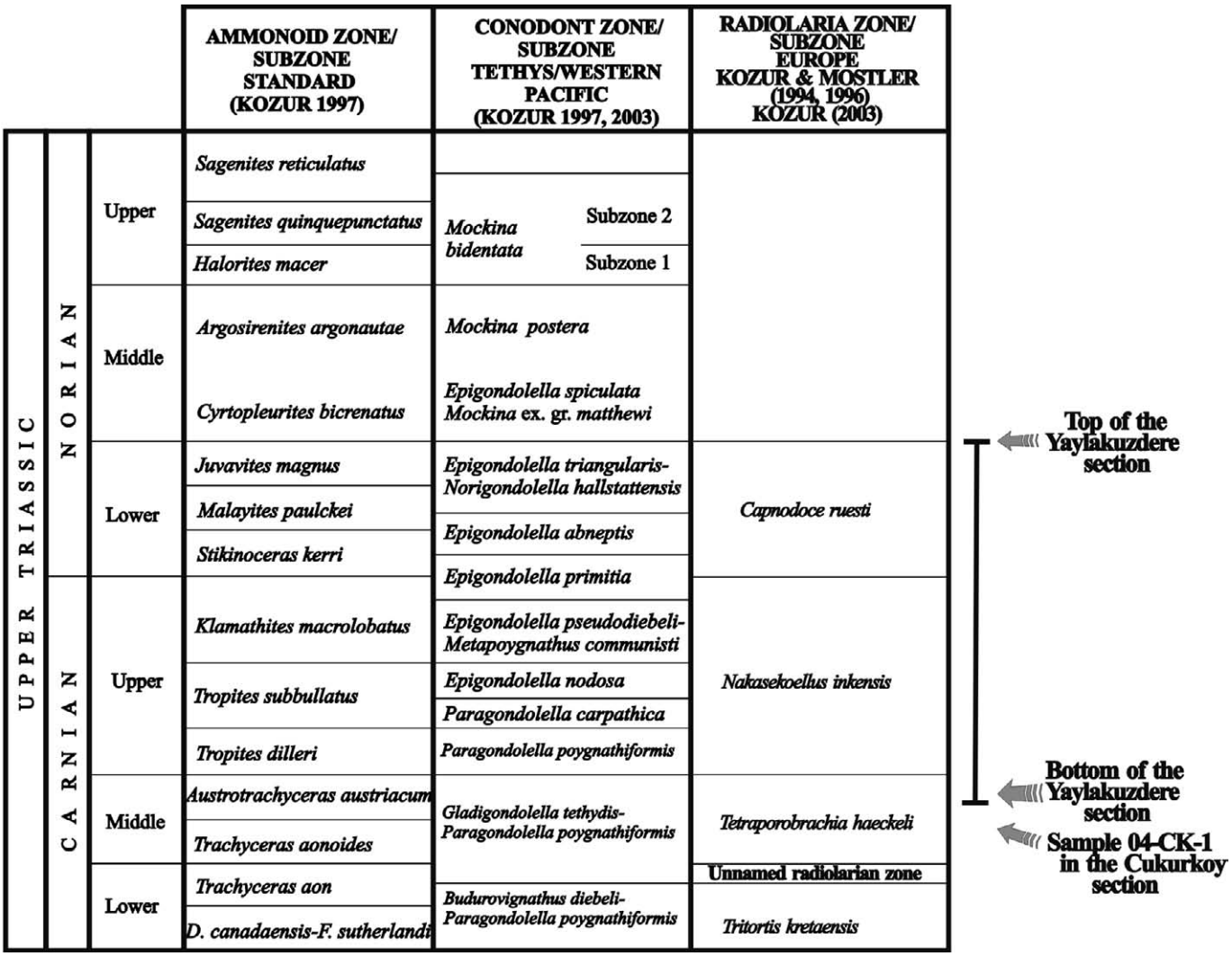


Fig. 9 - Integrated ammonoid, conodont and radiolaria zonations of Carnian to Norian periods after Kozur (1997; 2003) and Kozur and Mostler (1994; 1996). Arrows indicate position of sample O4-CK-1 in the Çukurkoy section and bottom and top of the Yaylakuzdere section.

Their loss on ignition values are high, because of vesicles filled with secondary carbonate and/or silica, and alteration. For geochemical evaluation of these volcanic rocks, we used the geochemical discrimination diagrams of mostly immobile trace elements such as Ti, Zr, Y and Nb that are stable under conditions of alteration and up to medium metamorphic grades (Rollinson, 1993).

The SiO_2 contents of samples range from 43.6 to 48.6. This indicates that all the analysed samples are basaltic in composition with high TiO_2 contents. The Cukurkoy and Yaylakuzdere volcanic rocks plot in the field of alkali basalt in the Zr/Ti vs Nb/Y diagram of Winchester and Floyd (1977) (Fig. 10a). For the discrimination of the tectonic environment in which these alkali basalts originated, they were plotted in the Hf-Th-Ta diagram of Wood (1980) (Fig. 10b) which indicates that they all belong to within plate-type.

The primitive mantle and chondrite normalized multi-element diagrams of volcanic rocks taken from Cukurkoy and the Yaylakuzdere regions exhibit similar trace element abundance patterns to oceanic island basalts (OIB) (Figs. 11a and 11b). They have also rare earth elements characteristics similar to OIB. They have low Y/Nb, Ba/Nb, La/Nb and high La/Yb, Zr/Ba ratios and display no Nb and Ta negative anomalies. All these characteristics indicate that these volcanic rocks derived from an OIB-like mantle source with no or negligible crustal contamination. The Rb, Ba, K, Sr, Ti negative anomalies in some samples may be consistent with remains of phlogopite, amphibole, Fe-Ti oxides (such as ilmenite, rutile, magnetite) and plagioclase in the residual melts during partial melting. The negative K anomalies, low La/Yb and Zr/Y ratios may be attributed to partial melting of a garnet-bearing mantle source. Such source requires that partial melting occurred at considerable depths and high pressure. The La/Nb < 1 ratio also supports a deep mantle source (De Paolo and Daley, 2000). The low Zr/Nb and high LILE/HFSE, LREE/HREE ratios of the Yaylakuzdere volcanic rocks relative to the Cukurkoy volcanic rocks indicate variations in the degree of partial melting.

The Nb/Y vs Th/Y diagram of Pearce (1983) is used in Fig. 12 for the discrimination of the mantle source and of other components possibly involved in the volcanic rock petrogenesis. The high Th/Y ratios with respect to Nb/Y ratios indicate crustal components that enriched the mantle source. Th tends to be concentrated and Nb and Ta generally depleted in continental crust. Therefore, the higher Th/Y ratios with respect to Nb/Y ratios indicate crustal components that enriched the mantle source. From the diagram of (Fig. 12) the Cukurkoy and Yaylakuzdere lavas appear to have low Th/Y and high Nb/Y ratios and plot in the mantle

Table 2 - Major, trace and rare earth elements content of selected volcanic rocks from the Alakırçay Nappe in the Cukurkoy and Yaylakuzdere regions.

Sample no.	04-CK-02	04-CK-03	04-CK-04	04-CK-08	04-CK-09	04-YK-01	04-YK-02	04-YK-03	04-YK-04	04-YK-05
SiO_2	43,60	44,74	46,08	46,93	45,79	48,10	47,39	46,29	45,71	47,93
TiO_2	2,15	2,89	2,58	3,32	3,31	3,14	1,87	1,95	2,37	2,15
Al_2O_3	6,60	7,94	8,92	9,91	10,43	12,16	11,81	11,85	11,77	12,47
Fe_2O_3	9,71	9,32	10,19	12,68	11,82	10,68	8,26	9,28	10,68	11,61
MnO	0,30	0,12	0,18	0,14	0,15	0,19	0,22	0,22	0,18	0,14
MgO	5,36	4,73	5,78	5,15	4,96	9,35	5,61	7,19	4,99	11,99
CaO	19,28	17,90	14,00	11,30	12,61	5,30	13,22	10,36	11,12	4,82
Na_2O	0,78	0,50	2,65	1,86	1,22	2,48	1,57	2,96	2,35	1,52
K_2O	0,34	2,71	0,07	1,25	2,10	0,84	1,75	1,14	0,90	0,28
P_2O_5	0,40	0,41	0,52	0,53	0,59	0,58	0,27	0,31	0,37	0,34
LOI(1050°C)	10,30	8,15	8,49	5,93	6,22	6,25	8,65	8,82	8,67	5,82
Total	**88,52**	**91,27**	**90,97**	**93,07**	**92,98**	**92,82**	**91,96**	**91,54**	**90,44**	**93,25**
Co	44,80	39,40	32,70	37,20	35,90	31,80	34,70	43,00	30,60	42,50
Rb	9,00	37,70	0,00	23,40	41,20	21,50	33,70	29,00	19,90	4,80
Sr	342,3	335,5	246,5	476,3	504,9	328,9	474,7	244,6	300,6	382,0
Y	21,60	22,30	25,30	28,50	28,60	44,40	21,70	22,50	29,50	30,10
Zr	166,6	200,0	249,0	281,6	285,6	246,7	128,1	129,9	192,2	204,0
Hf	4,00	4,80	6,10	7,10	7,40	6,90	3,30	3,40	4,70	5,40
Ta	2,50	3,00	3,40	4,00	4,10	5,30	2,70	2,60	2,50	2,80
Nb	35,80	43,60	49,30	58,20	61,20	82,90	39,10	42,40	36,90	39,20
Ba	157,30	612,70	75,20	131,90	313,00	110,90	184,40	168,90	113,50	70,70
La	36,30	39,10	46,10	55,50	54,10	66,10	31,60	36,80	32,40	31,20
Ce	71,30	80,00	89,20	114,40	118,90	129,00	61,50	70,50	66,20	66,30
Pr	8,26	9,45	10,76	13,91	13,67	13,84	7,13	7,42	7,89	7,96
Nd	34,70	39,20	44,50	55,90	59,00	53,90	26,90	31,40	33,10	34,30
Sm	6,70	7,90	8,60	11,50	10,40	10,90	5,70	6,20	6,70	7,30
Eu	2,06	2,24	2,50	3,27	3,18	3,07	1,53	1,72	2,09	2,26
Gd	5,61	6,35	6,75	8,25	8,19	8,92	4,88	4,76	6,47	6,00
Tb	0,81	0,88	0,90	1,17	1,23	1,33	0,73	0,75	1,01	1,06
Dy	4,18	5,10	4,79	6,00	6,18	8,16	3,97	4,28	5,40	5,37
Ho	0,76	0,85	0,86	1,05	1,14	1,69	0,76	0,84	1,08	1,11
Er	2,00	2,11	2,41	2,63	2,61	4,64	2,18	2,35	2,88	3,18
Tm	0,30	0,31	0,34	0,36	0,37	0,63	0,31	0,36	0,39	0,46
Yb	1,68	1,45	1,74	2,04	2,06	3,97	1,61	1,89	2,28	2,62
Lu	0,22	0,25	0,27	0,32	0,33	0,53	0,29	0,26	0,32	0,37
Th	3,00	3,10	5,00	4,90	5,20	7,70	3,20	3,60	3,10	3,10
U	1,00	1,90	1,70	1,40	2,00	1,40	1,20	0,90	0,80	1,10

array. They display a within plate enrichment trend and reflect the characteristics of an OIB-type mantle source with no or negligible crustal contamination.

DISCUSSION AND CONCLUSION

In this study, we have studied Upper Triassic spilitic basalts (the Karadere-type) and radiolarian and conodont bearing pelagic limestones (the Gokdere-type) from the Alakırçay Nappe of Antalya Nappes in two sections (Cukurkoy in central Taurides and Yaylakuzdere in western Taurides). The age of the spilitic basalts in the Cukurkoy section is middle Carnian due to radiolarian dating from the overlying pelagic limestones. Similar to the dating in the Cukurkoy section, age of the spilitic basalts in the Yaylakuzdere section is assigned as late Carnian as overlying pelagic limestones dated as latest Carnian/earliest Norian based on the conodont and radiolarian faunas.

The geochemical investigations on the pillow lavas from the Alakırcay Nappe in two localities revealed that they are alkaline basalts and of within-plate type. The geochemical features are indicative for an OIB-like deep mantle source according to low La/Yb, Zr/Y and La/Nb < 1 ratios. The high HFSE abundance, the lack of depletion of Nb and Ta that are characteristics of subduction and/or crustal contamination processes, indicate that these alkaline basalts have not suffered interactions with subducted slab and/or continental crust.

Similar to our findings, in previous studies as Robertson and Waldron (1990), they defined the formation of MORB and OIB-type basalts in Antalya Nappes as an oceanic basin with deposition of marginal to deep basinal Triassic sedimentary units (radiolarian bearing limestone levels, ammonite bearing Hallstatt facies) intercalated with these volcanic rocks. Dixon and Robertson (1999) also determined two distinct sources such as mantle plume and MORB-type mantle source for the Triassic basalts along the Gondwanan margin in the Mediterranean region. In addition to these data, the geochemical results of Lapierre et al. (2007) indicate four type volcanic rocks such as depleted olivine tholeiites, ocean island tholeiites, alkali basalts and trachytes exhibiting features of ocean island basalts from the Mamonia complex (Cyprus) of Late Triassic age. All these types of volcanic rocks were derived from the partial melting of an enriched OIB-type mantle source without crustal contamina-

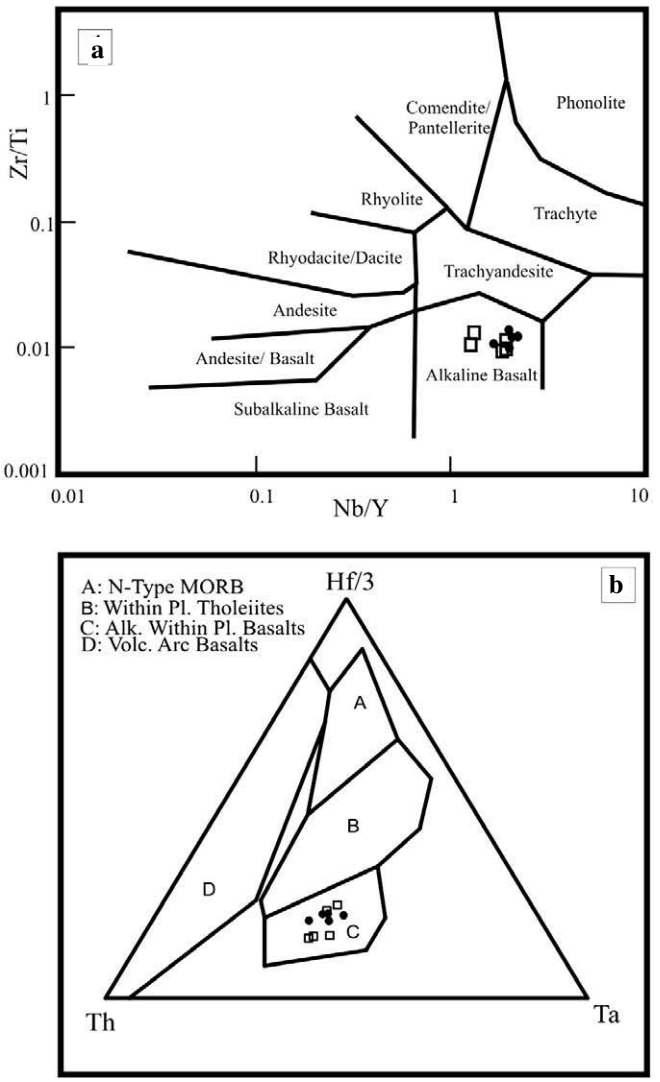


Fig. 10 - a - Zr/Ti vs Nb/Y classification diagram of Winchester and Floyd (1977) showing alkaline features of the Cukurkoy (CK) and Yaylakuzdere (YK) basaltic rocks (solid circles, CK; open squares, YK) and discrimination diagrams of tectonic environments, b - Hf-Th-Ta (after Wood, 1980).

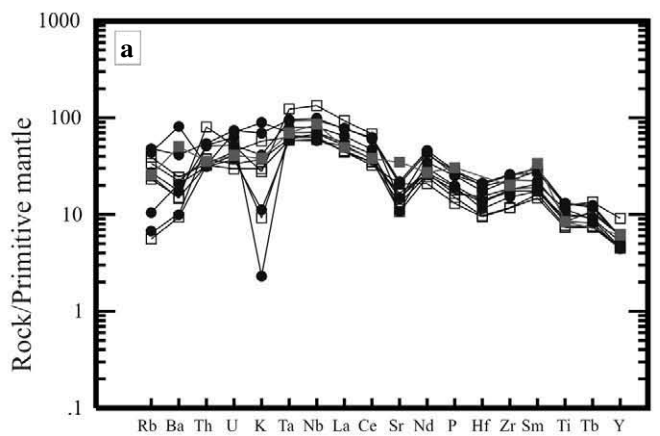
tion. This feature is consistent with emplacement of these rocks within an oceanic domain with the activity of a hot spot according to the authors.

According to Campbell and Griffiths (1992) and Hill (1993), the interaction of a deep mantle plume may be one of the possible mechanisms of the evolution of alkaline basalts. The widespread occurrence of alkali basalts of Late Triassic age from Greece, Turkey to Cyprus reported from previous studies could be explained by the rising of a small mantle plume. If true, subsequent partial melting caused by ascending of mantle plume to progressively shallower levels may be expected to lead to uplifting, thinning, weakening and rifting of lithosphere. The determined lack of crustal interaction of Yaylakuzdere and Cukurkoy volcanic rocks from the geochemical data should be explained as this relative thinning of the crust. Based on these facts, it can be concluded that alkaline volcanism of studied regions in Alakırçay Nappe have been likely generated by a small OIB-type mantle plume at the middle - late Carnian time interval during the advanced stages of the rifting of Antalya Nappes in the southern branch of Neotethys sensu Sengor and Yılmaz (1981) between the Gondwana and Cimmerian continents.

Eastern Mediterranean as a part of southern branch of Neotethys, began to open in Carnian-Norian time interval according to Sengor and Yılmaz (1981). However, Ozgul (1983; 1984) have reported sequence includes olistoliths and debris flows of Anisian age over the Scythian rocks followed by Ladinian radiolarites, shales and volcanic rocks in Alakırçay Nappe at the SE of Alanya town. Based on these observations, he has suggested the middle Anisian-Ladinian rifting on continental crust. Our result is well-consistent with the generation of rift basin before middle Carnian during middle Anisian-Ladinian time interval suggested by Ozgul (1983; 1984) in Antalya Nappes as a part of southern branch of Neotethys.

ACKNOWLEDGMENTS

Authors wish to express their thanks to Mustafa Senel (General Directorate of Mineral Research and Exploration, Ankara, Turkey) for his kind contributions during the field trip to the Yaylakuzdere section and to Heinz W. Kozur (Budapest, Hungary) for his conodont determinations. M. Cemal Göncüoglu (Middle East Technical University,



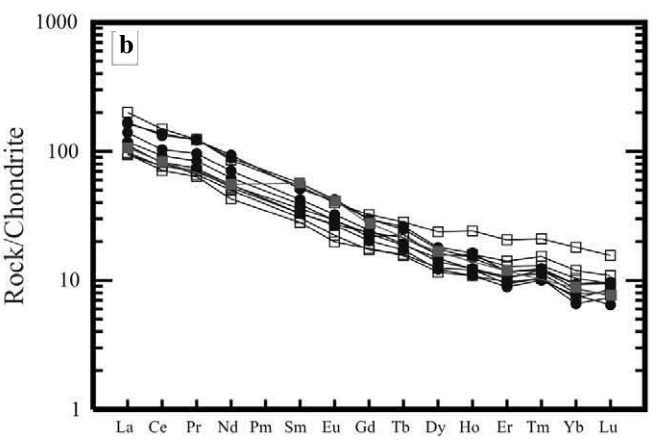


Fig. 11 - a - Primitive mantle normalized multi-element diagram (Sun and McDonough, 1989) for the Cukurkoy (CK) and Yaylakuzdere (YK) basaltic rocks, b - Chondrite-normalized multi-element diagram (Nakamura, 1974) for the Cukurkoy (CK) and Yaylakuzdere (YK) basaltic rocks (values for oceanic island basalts (OIB) are from Sun and McDonough, 1989) (solid circles- CK; open squares- YK; solid squares- OIB).

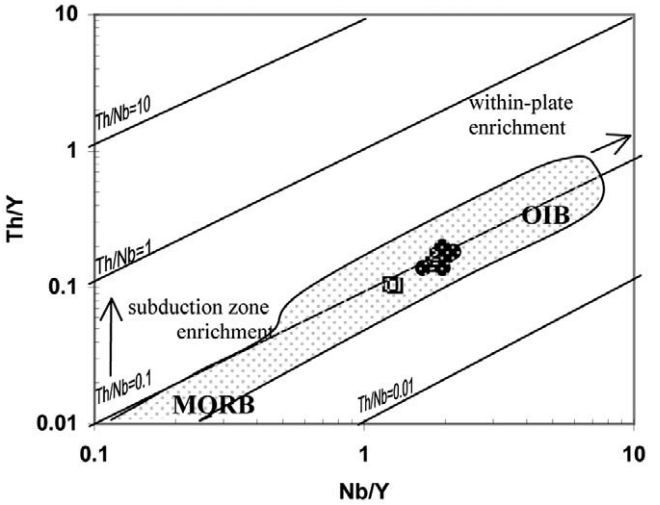


Fig. 12 - Th/Y vs Nb/Y diagram for the Cukurkoy (CK) and Yaylakuzdere (YK) basaltic rocks (solid circles, CK; open squares, YK).

Ankara, Turkey), Tekin Yurur (Hacettepe University, Ankara, Turkey), Marco Chiari and Marta Marcucci (Dipartimento di Scienze della Terra, Università di Firenze, Italy) are acknowledged for reviewing the manuscript. Evren Cubukcu (Hacettepe University, Ankara, Turkey) is gratefully acknowledged for his technical helps during SEM studies and Yusuf Kagan Kadioglu (Ankara University, Ankara, Turkey) for major elements analysis on XRF.

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Received, May 29, 2007
Accepted, November 25, 2007

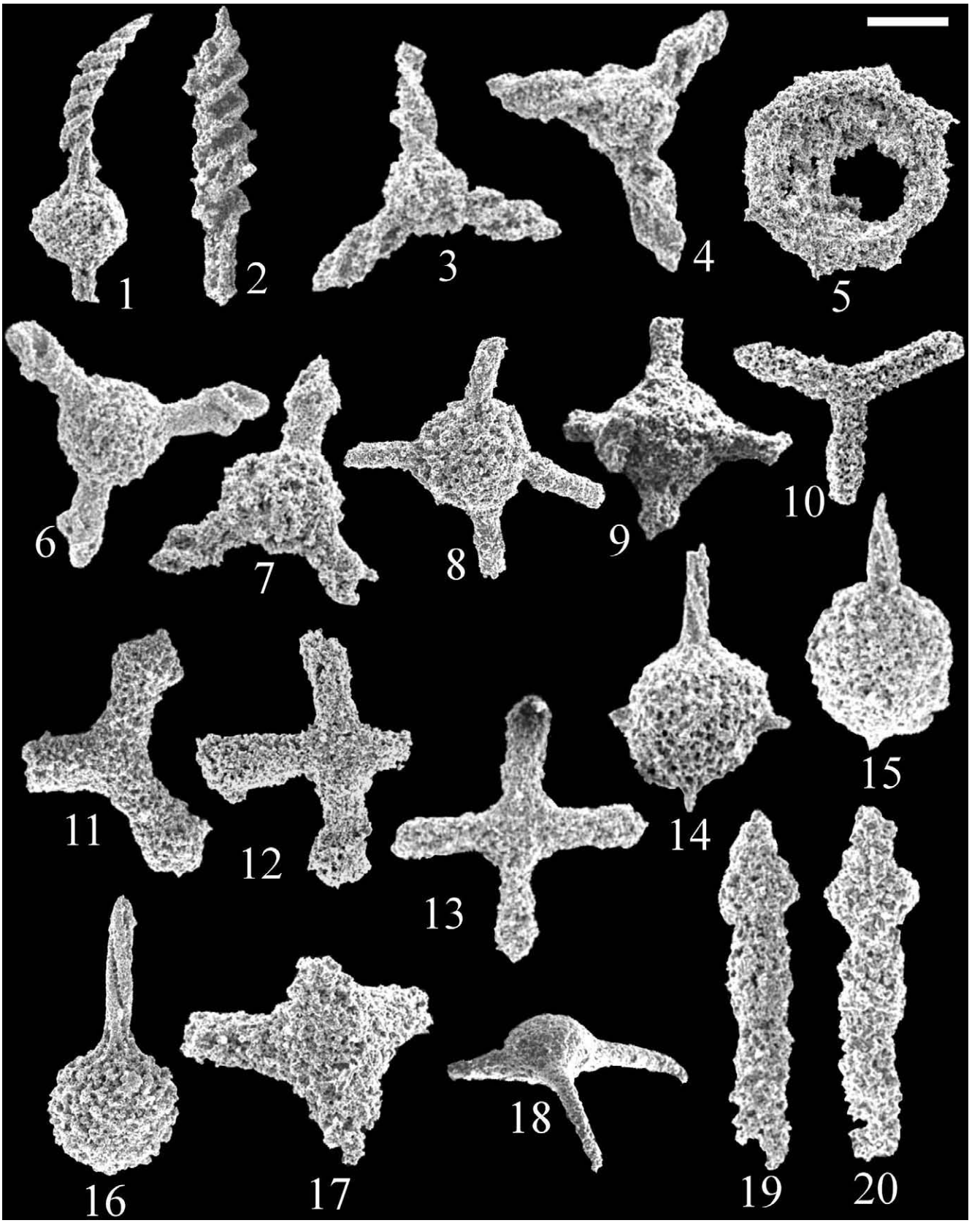

Plate 1 - Scanning electron photomicrographs of middle Carnian radiolarians from the Cukurkoy section, the Alakırçay Nappe of the Antalya Nappes. All materials are from sample 04-CK-1. Scale- number of microns for each figure: 1) *Spongostylus carnicus* Kozur and Mostler, scale bar- 125 μm; 2) *Spongostylus tortilis* Kozur and Mostler, scale bar- 90 μm; 3-4) *Vinassaspongus subsphaericus* Kozur and Mostler, scale bar- 95 and 90 μm, respectively; 5) *Orbiculiforma* sp., scale bar- 110 μm; 6-7) *Capnuchosphaera triassica* De Wever, scale bar for both specimens- 110 μm; 8-9) *Weverella* sp. cf. *W. tetrabrachiata* Kozur and Mostler, scale bar- 100 and 90 μm, respectively; 10) *Paronaella* sp. cf. *P. glaber* (Kozur and Mostler), scale bar- 130 μm; 11) *Paronaella* sp. cf. *P. simoni* (Kozur and Mostler), scale bar- 150μm; 12) *Crucella* sp. cf. *C. carnica* (Kozur and Mostler), scale bar- 115 μm; 13) *Crucella* sp., scale bar- 110 μm, 14) *Hindeosphaera austriaca* Kozur and Mostler, scale bar- 150 μm; 15) *Hindeosphaera* sp. cf. *H. austriaca* Kozur and Mostler, scale bar- 110 μm; 16) *Hindeosphaera bispinosa* Kozur and Mostler, scale bar- 160 μm; 17) *Tetraporobrachia* sp., scale bar- 90 μm; 18) *Poulpus piabyx* De Wever scale bar- 65 μm; 19-20) *Xiphotheca karpenissionensis* De Wever, scale bar- 80 and 65 μm, respectively.