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Late Ladinian radiolarians from the Tahtalidag Nappe of the Antalya nappes, SW Turkey: remarks on the late Middle and Late Triassic evolution of the Tahtalidag Nappe

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ABSTRACT:

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The late Ladinian to Late Triassic succession of the Tahtalidag (upper) Nappe of the Antalya nappes was studied in the Egregindere section, north of the city of Antalya, SW Turkey. The chert bands in the central part of the section have yielded poorly to moderately preserved radiolarians documenting the Late Ladinian *Muelleritortis firma* and *Muelleritortis cochleata* radiolarian zones. Based on the Egregindere succession, a major deepening event, evidenced by radiolarian cherts, took place between the middle and late Late Ladinian. The Late Triassic thick-bedded neritic limestones represent a shallowing-upward sequence, which formed as a result of the horst-like rising of the Tahtalidag Nappe during the Late Triassic block faulting.

Fifty-nine radiolarian taxa have been determined from the Upper Ladinian of the Egregindere section. One species (*Muelleritortis elegans)* and two subspecies (*Muelleritortis firma equispinosa* and *Muelleritortis firma globosa)* are described as new.

Key words: The Antalya nappes; Ladinian; Late Triassic; Radiolaria; Neotethys; Tahtalidag Nappe; Taxonomy.

INTRODUCTION

The Triassic rifting south of the Taurides is known as the opening event of the southern branch of the Neotethys (Sengör and Yilmaz 1981). The basin that opened between the Beydaglari and Anamas-Akseki units was referred to as the Pamphylian (Antalya) Basin (Dumont *et al*. 1972) and the opening event was dated either as Carnian–Norian (Sengör and Yilmaz 1981) or late Anisian–Ladinian (e. g. Özgul 1983, 1984; Senel *et al*. 1992; Varol *et al*. 2007). To decide between these two interpretations we selected the Egregindere section (Tahtalidag Nappe of the Antalya nappes; see Sengör and Yilmaz 1981; Özgul 1984), north of the city of Antalya, which offers a late Ladinian–Late Triassic succession through the southern branch of the Neotethys for detailed stratigraphical studies. Our assumption was that the precise stratigraphy of this apparently continuous succession would allow detailed dating of the major tectonically-induced deepening and shallowing events in the basin and, consequently, dating of the main tectonic events in the history of the southern branch of the Neotethys.

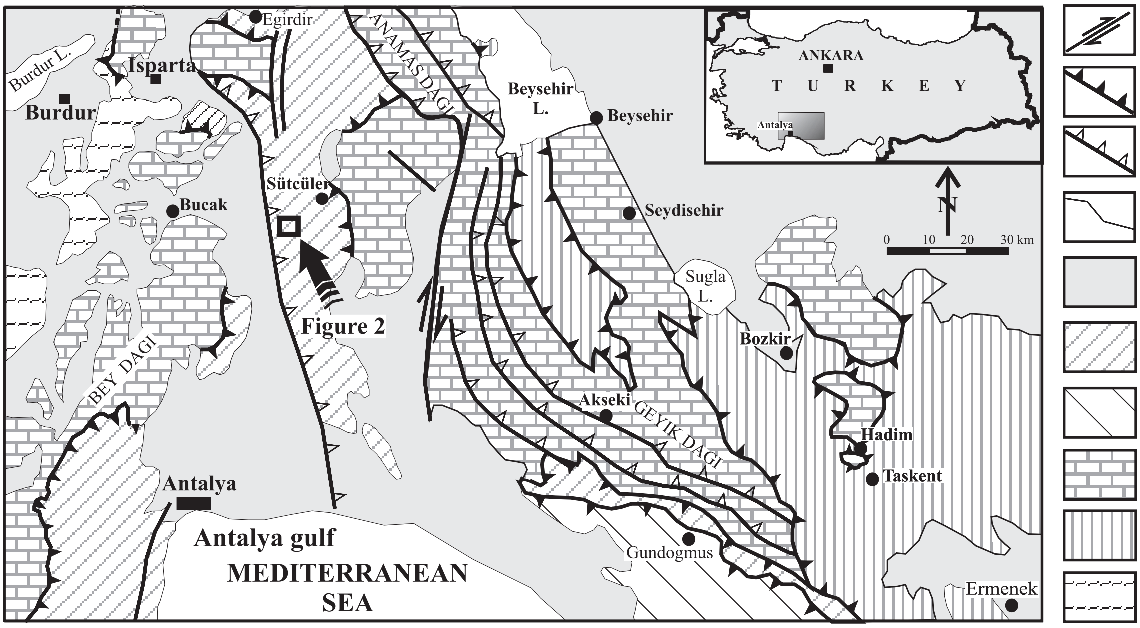
The dating is based on radiolarians which were shown to be a very useful tool in the biostratigraphy of the Middle and Late Triassic (e.g. Nakaseko and Nishimura 1979; Dumitrica 1982; Kozur and Krahl 1984; De Wever 1984; Bragin 1986, 1991; Kozur 1988a, 1988b; Dosztaly 1989, 1991, 1993; Kolar-Jurkovsek 1989, 1990; Gorican and Buser 1990; Kozur and Mostler 1994, 1996a, b, 2006; Halamic and Gorican 1995; Sugiyama 1997; Tekin 1999; Tekin and Mostler 2005a, b; Tekin and Göncüoglu 2007). The previous studies on radiolarians from the area related to parts of the late Ladinian strata and did not cover the entire Late Ladinian radiolarian succession.

REGIONAL GEOLOGY

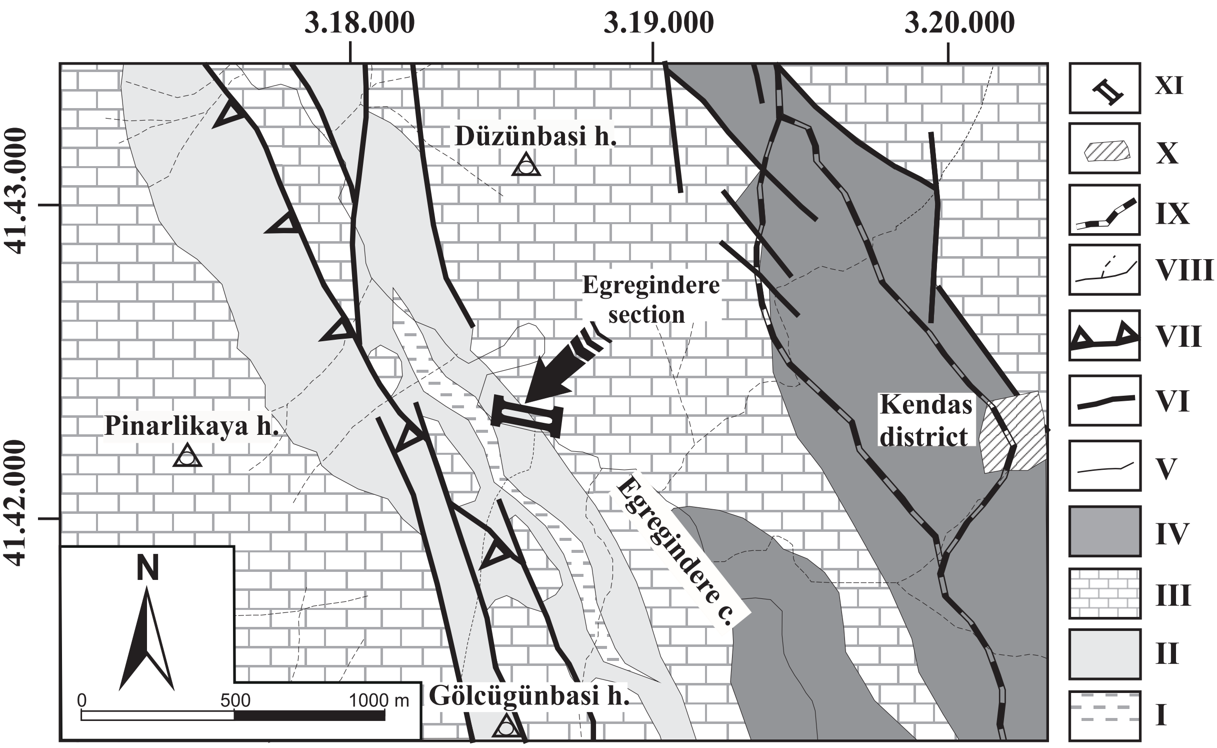
The Taurides of southern Turkey includes allochthonous and autochthonous nappe units. The southernmost part of the Taurides is built mainly of the Antalya nappes (Text-fig. 1), which are interpreted as originating either from the southern branch of the Neotethys (e.g. Sengör and Yilmaz 1981; Sengör *et al.* 1984; Özgül 1984) or as having a northerly origin (e.g. Ricou *et al.* 1974; Ricou 1980; Kozur 2000; Stampfli and Kozur 2006). The first view is supported by structural analysis (Özgül 1984) and it is accepted herein.

The Antalya nappes are composed of Mesozoic pelagic sediments dated by radiolarian faunas (e. g. Tekin 1999, 2002a, 2002b; Tekin and Yurtsever 2003; Yurtsever *et al*. 2003; Varol *et al*. 2007; Moix *et al.* 2009). These nappes were first described as a single nappe (the Antalya nappe) (Lefevre (1967) and were shown subsequently to be a multi-nappe system (Antalya nappes system) composed of the Cataltepe (lower), Alakircay (middle), and the Tahtalidag (upper) nappes (Brunn *et al*. 1971).

North of the Antalya Gulf, where the Egregindere section is located (Text-fig. 2), the slices of the Antalya nappes, trending NNW to SSE, crop out widely (Text-fig. 1). In this area, different structural units of the Tahtalidag Nappe were defined (Senel *et al*. 1992, 1996; and Senel (1997). The Egregindere section belongs to the Dutdibi unit (Senel *et al*. 1992, 1996) (Text-fig. 3A). The basal part of the Dutdibi unit is represented by the Scythian Akıncibeli Formation (Demirtasli 1987), composed of claystones, argillaceous limestones and marls. It is overlain unconformably by the Ladinian–Norian Günlük Formation (Senel *et al*. 1992), dominated by pelagic, radiolarian-bearing sediments (Text-fig. 3B). The Günlük Formation is overlain conformably by the Rhaetian–Cenomanian Katrandagi Limestone (Blumenthal 1951), composed of medium- to thick-bedded, grey to beige limestones and dolomitic limestones (Senel *et al*. 1996;



Text-fig. 1. Schematic map showing the distribution of autochthonous and allochthonous sequences in the area between western and central Taurides and location of the study area (revised after Özgul 1984). Legend: I – The Lycien nappes. II – The Beysehir-Hoyran-Hadim nappes. III – The Beydaglari and Anamas-Akseki autochthonous sequences. IV – The Alanya nappe. V – The Antalya nappes. VI – Post-Eocene cover rocks. VII – Normal contact. VIII – Thrust. IX – Overthrust. X – Strike-slip fault



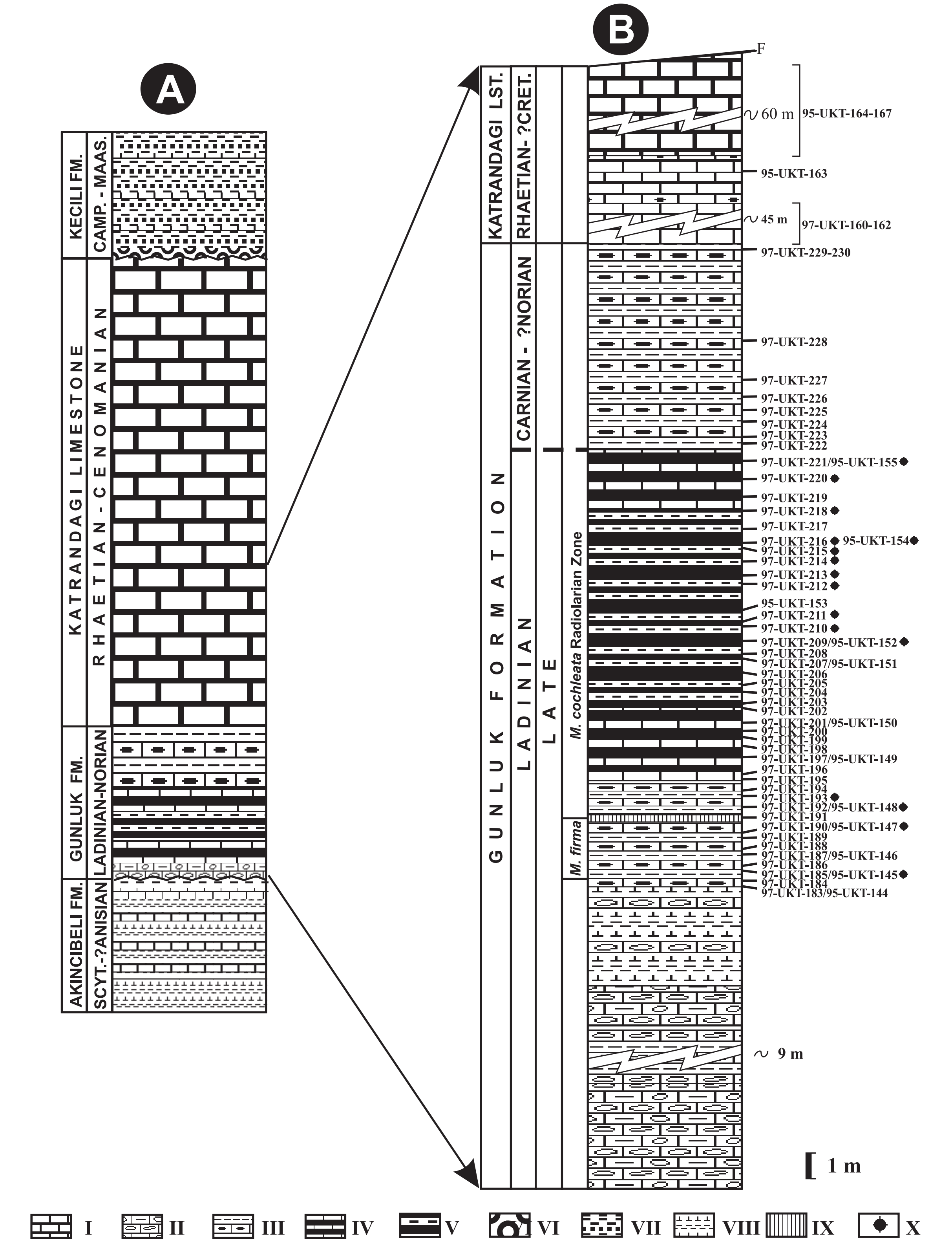
Text-fig. 2. Geological map of the Egregindere section and its surroundings (modified after Gedik 1990). Legend; I-IV – The Tahtalidag nappe of the Antalya Nappes. I – Early to Middle Triassic Akincibeleni formation. II – Middle to Late Triassic Günlük formation. III – Latest Triassic to Early Cretaceous Katrandagi limestone. IV – Late Cretaceous to Quaternary deposits. V – Normal contact. VI – Fault. VII – Thrust. VIII – Drainage systems. IX – Main roads. X – Settlement. XI – Location of the Egregindere section

Senel 1997; Text-fig. 3A). The youngest unit is the Campanian–Maastrichtian Kecili Formation (Juteau 1975), composed of carbonate and siliciclastic deposits (Senel *et al*. 1996; Senel 1997; Text-fig. 3A).

GENERAL CHARACTERISTICS OF THE EGREGINDERE SECTION

The Egregindere section, located south of the town of Egirdir and southwest of the town of Sütcüler (Text-fig. 1), spans the Günlük and the Katrandagi formations. The section is located on the northeastern bank of the Egregindere Creek (Isparta N25b2 quadrangle, between 41.42.325 N/3.18.300 E and 41.42.287 N/3.18.675 E UTM coordinates), 1.5 km west of Kendas district (Text-fig. 2).

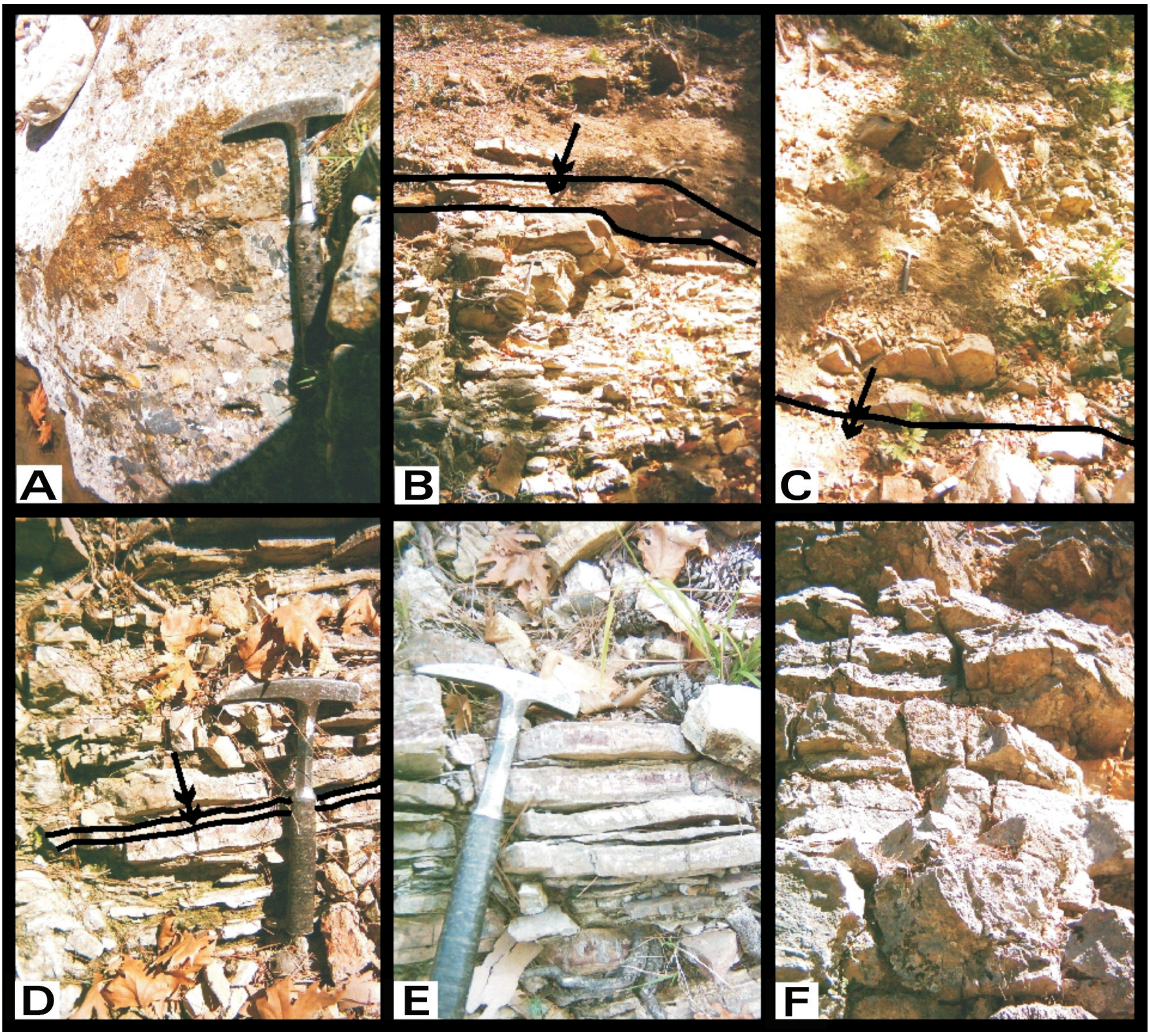
The succession starts with the basal part of the Günlük Formation, represented by alternating grey to beige conglomeratic limestones and grey to green shales (Text-figs 3B and 4A). These are followed by an alternation of thin-bedded, grey to green shales and mudstones (Text-fig. 3B). The first radiolarian-bearing unit occurs still higher, and is composed of alternating thin to very thin-bedded, green shales and grey to green limestones with rare chert bands and nodules (Text-figs 3B and 4B). This part is terminated by a 20 cm thick iron- and silica-rich zone (Text-figs 3B, 4B and 4C), interpreted as hydrothermal alteration of Late Triassic deposits (Senel *et al*. 1996). This zone is overlain by alternating thin-bedded, green shales and grey to green limestones with rare chert bands and nodules (Text-figs 3B, 4B and 4C). The chert content increases greatly in the overlying part, characterized by alternating thin-bedded, grey to pinkish limestones and red cherts (Text-figs 3B and 4D). Higher in the succession, there occurs a monotonous alternation of thin-bedded, red radiolarian cherts and mudstones, yielding very abundant radiolarians (Text-figs 3B and 4E). Higher upsection, the chert content decreases steadily and the succeeding 1 m thick part of the section is characterized by an alternation of thin-bedded, grey to pinkish limestones and red cherts. The overlying unit is composed of a seven metre thick alternation of thin-bedded, grey to green limestones with rare chert bands/nodules and green shales, of Carnian to Norian age (Senel *et al*. 1992, 1996). The topmost part of the Egregindere succession is represented by



Text-fig. 3. A – Log showing the general characteristics of the Dutdibi structural unit (modified after Senel *et al*. 1992, 1996) and B – Log of the Egregindere section and sampling levels. Legen: I – Limestone. II – Conglomeratic limestone. III – Cherty limestone and mudstone alternation. IV – Limestone and chert alternation. V – Chert and mudstone alternation. VI – Conglomerate. VII – Sandstone and mudstone alternation. VIII – Marl and mudstone alternation. IX – Zone of the hydrothermal alteration. X – Radiolaria occurrence thick-bedded, grey to beige limestone with rare shale interbeds and chert nodules of the Katrandagi Limestone (Text-figs 3B and 4F), of Rhaetian–Cretaceous age (Senel *et al*. 1992, 1996).

MATERIALS, METHODS AND REPOSITORY

Sixty-seven samples were taken from both chert nodules/bands and limestone beds of the Günlük and Katrandagi formations of the Egregindere section (see Text-fig. 3). The chert samples were etched with dilute hydrofluoric acid (5–10 %), while the carbonate samples were processed with formic acid (5–10%) following the Pessagno and Newport (1972) method. All holotypes and paratypes are housed in the collections of the Paleontology Laboratory of Geological Engineering Department, Hacettepe University, Ankara, Turkey.

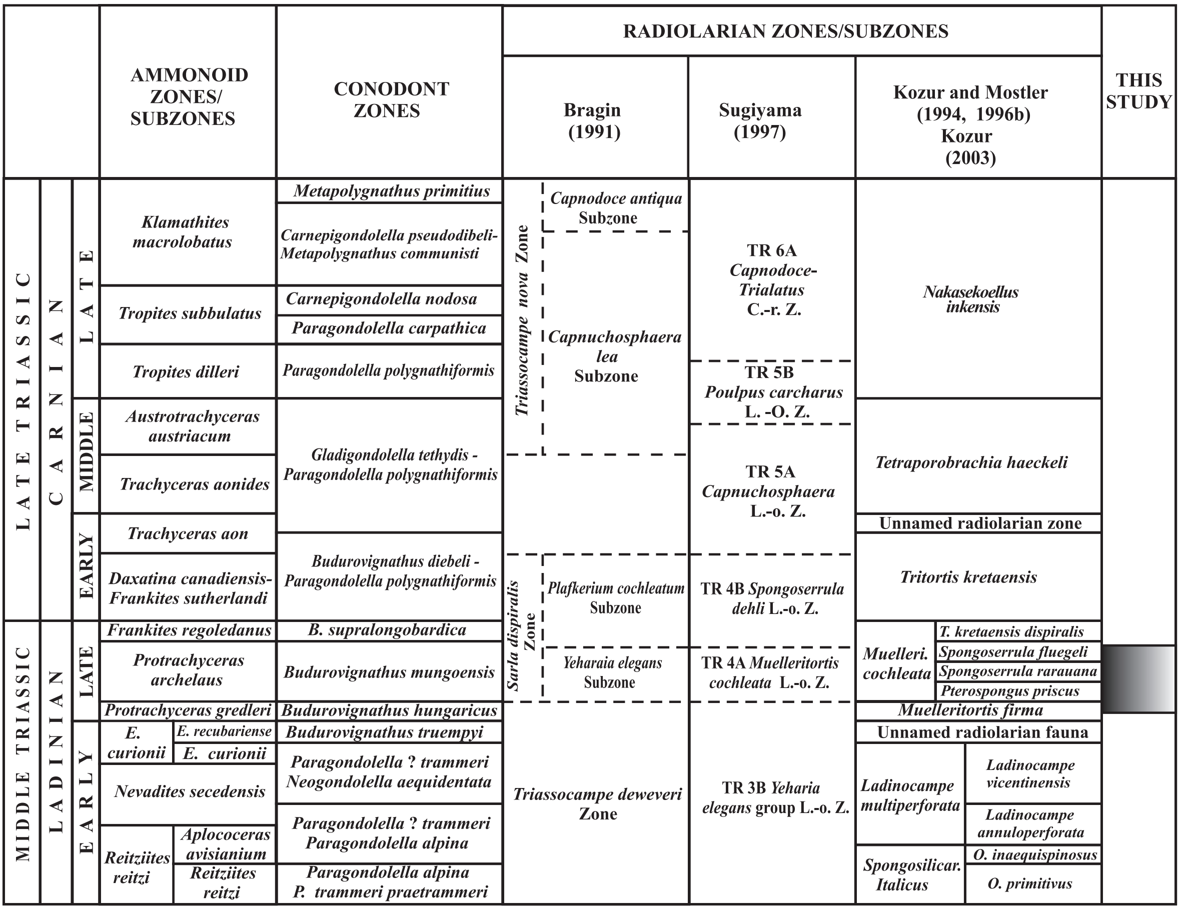


Text-fig. 4. Photographs showing the details of the different levels of the Egregindere section. **A** – Close up view of the grey to beige conglomeratic limestone with different pebbles. **B** – Photograph showing 20 cm thick hydrothermal alteration zone (indicated by arrow) and adjacent units. Underlying part of this zone is represented by a green shale and grey to green limestones with rare chert bands and nodules of early Late Ladinian age (*Muelleritortis firma* radiolarian Zone). **C** – View from unit including an alternation of thin-bedded grey to pinkish limestone and red chert of middle Late Ladinian (basal part of the *Muelleritortis cochleata* radiolaria Zone) overlying the hydrothermal alteration zone (indicated by arrow). **D** – Close up view of the pinkish limestone and red chert alternation of middle to late Late Ladinian (basal part of the *Muelleritortis cochleata* radiolaria Zone). Arrow indicates the pinkish limestone bands. **E** – Close up view of the red radiolarian chert and mudstone alternation of middle to late Late Ladinian (central and upper part of the *Muelleritortis cochleata* radiolaria Zone). **F** – Thick-bedded neritic limestone beds in the Katrandagi limestone of Rhaetian-Cretaceous age

DATING AND CORRELATION OF THE RADIOLARIANS

Samples 95UKT145 and 95UKT147, from the chert-bearing unit, yielded a diverse radiolarians (see Table 1). Some of the taxa (*Pararuesticyrtium mediofassanicum* Kozur and Mostler and *Triassocampe deweveri* (Nakaseko and Nishimura)) have their acme occurrence in the early Ladinian (Nakaseko and Nishimura 1979; Kozur and Mostler 1994), although ranging higher, into the late Ladinian. Also abundant in this part of the section are various subspecies of *Muelleritortis firma* (Gorican), including *Muelleritortis firma globosa* subsp. nov. and *M. firma equispinosa* subsp. nov. (Table 1). Based on the presence of *Muelleritortis firma* and associated taxa, the interval between samples 95UKT145 and 95UKT147 may safely be assigned to the *Muelleritortis firma* radiolarian Zone (as defined by Kozur and Mostler 1994, 1996b and Kozur 2003), of early Late Ladinian age (Text-fig. 3B, 5 and Table 1). This interval can also be correlated with the top of the "TR 3.B *Yeharia elegans* Zone" of Sugiyama (1997) and the "*Triassocampe deweveri* Zone" of Bragin (1991) (Text-fig. 5). The *M. firma* Zone also corresponds to the *Protrachyceras gredleri* ammonoid Zone and to the *Budurovignathus hungaricus* conodont Zone (Kozur and Mostler 1994; Kozur 2003; see also Text-fig. 5)

Rare representatives of *Muelleritortis cochleata* (Nakaseko and Nishimura) first appear in sample 95UKT148, and this level is taken herein as the base of the *Muelleritortis cochleata* radiolarian Zone, as defined by Kozur and Mostler (1994). It is noteworthy that the lowermost two samples (95UKT148 and 97UKT193; see Text-fig. 3 and Table 1) of this zone are still dominated by *Muelleritortis firma.* Unfortunately, the 5.2 m-thick interval which follows sample 97UKT193 is barren and the nature of the change from the *M. firma*-rich interval to the interval with abundant *M. cochleata*, which starts in sample 95UKT152, is unknown. The latter sample, besides the dominant *M. cochleata*, contains rare to very rare *Muelleritortis firma* and common Oertlispongidae, such as *Spongoserrula rarauana trinodosa* Kozur and Mostler and *S. rarauana rarauana* Du-



Text-fig. 5. Integrated ammonoid, conodont (after Kozur 2003) and radiolarian zonations (after Bragin 1991; Sugiyama 1997; Kozur and Mostler 1994; 1996b; Kozur 2003) for the Ladinian and Carnian. Bar in the figure indicate the stratigraphic position of radiolarian-bearing samples in the Egregindere section mitrica. The latter species is an index taxon of the *Spongoserrula rarauana* Subzone of the *Muelleritortis cochleata* Zone (Kozur and Mostler 1996b). Consequently, the interval between samples 95UKT148 and 95UKT152 most probably corresponds to the *Pterospongus priscus* Subzone of the *M. cochleata* Zone.

SERIE			MIDDLE TRIASSIC												
STAGE			LATE LADINIAN												
RADIOLARIAN ZONES	M. f.		*Muelleritortis cochleata* R. Z.												
	95-UKT-145	95-UKT-147	95-UKT-148	97-UKT-193	95-UKT-152	97-UKT-210	97-UKT-211	97-UKT-212	97-UKT-213	97-UKT-214	97-UKT-215	95-54/97-216	97-UKT-218	97-UKT-220	95-UKT-155
Pararuesticyrtium mediofassanicum Kozur and Mostler	+	+													
***Pararuesticyrtium* sp. A**	+	+													
Muelleritortis firma globosa Tekin subsp. nov.	+	+		+	+										
Muelleritortis firma equispinosa Tekin subsp. nov.	+	+	+		+	+									
Muelleritortis firma firma (Gorican)	+	+	+	+		+									
Muelleritortis elegans Tekin sp. nov.	+	+	+	+	+			+	+						
Paurinella latispinosa Kozur and Mostler	+						+	+	+			+			
Staurolonche trispinosa Kozur and Mostler	+	+									+	+			
Triassospongosphaera multispinosa (Kozur and Mostler)	+							+	+				+		
Heliosoma ? mocki (Kozur and Mostler)	+	+	+	+	+		+	+	+	+		+		+	
P. symmetricus Dumitrica, Kozur and Mostler	+				+		+			+				+	
Pseudostylosphaera helicata (Nakaseko and Nishimura)		+	+												
Vinassaspongus erendili Tekin		+					+	+	+						
Karnospongella bispinosa Kozur and Mostler		+						+			+				
Triassocampe deweveri (Nakaseko and Nishimura)		+			+			+				+			
Pseudostylosphaera gracilis Kozur and Mock		+					+					+			
Silicarmiger latus latus Kozur and Mostler		+								+					
Annulotriassocampe sulovensis (Kozur and Mock)		+			+				+	+	+				+
Pentactinocarpus tetracanthus Dumitrica			+		+		+		+			+			
Pseudostylosphaera inaequata (Bragin)			+						+				+		+
Muelleritortis cochleata (Nakaseko and Nishimura) sl			+	+	+	+	+	+	+	+	+	+	+	+	+
Spongostylus koppi (Lahm)					+										
Spongostylus* aff. *koppi (Lahm)					+										
Spongoserrula rarauana trinodosa Kozur and Mostler					+		+								
Hexacatoma nobleae Tekin and Mostler					+		+								
Pentaspongodiscus similediscus Tekin and Mostler					+		+								
Spongoserrula rarauana rarauana Dumitrica					+		+								
Z. latispinosa latispinosa Kozur and Mostler					+							+			
Carterella* aff. *transita Kozur and Mostler					+							+			
Zhamojdasphaera subovalis Kozur and Mostler					+	+								+	
Steigerispongus symmetricus Kozur and Mostler							+								
Paurinella acutispinosa Kozur and Mostler							+								
Veghicyclia krystyni Tekin and Mostler							+								
Paurinella triangularis Kozur and Mostler							+				+				
Vinassaspongus subsphaericus Kozur and Mostler								+	+	+		+			
Pseudostylosphaera longispinosa Kozur and Mostler								+					+		
Pentaspongodiscus discoides Tekin								+			+			+	
Eptingium ? tortile Kozur and Mostler									+			+			
Dumitricasphaera trialata Tekin and Mostler										+					
Scutispongus latus Kozur and Mostler										+					
Entactinosphaera ? simoni Kozur and Mostler										+					
Hozmadia pinnapedisKozur and Mostler										+					
***Praedivatella* sp.**										+		+			
Zhamojdasphaera elegans Kozur and Mostler										+	+	+			
Scutispongus bogdani bogdani (Kolar-Jurkovesk)											+				
***Muelleritortis ?* sp. A**											+				
Pseudostylosphaera nazarovi (Kozur and Mostler)											+				+
***Pentatortis* sp. A**												+			
***Vinassaspongus* sp. A**												+			
Spongoserrula goricanae Kozur and Mostler												+			
S. asymmetricus triangulodentatus Kozur and Mostler												+			
***Tetrapaurinella* sp. A**												+			
Carterella* aff. *subrotunda Kozur and Mostler												+			
***Eptingium* sp. A**												+			
***Pseudostylosphaera* sp. A**												+			
Scutispongus ploechingeri ploechingeri Kozur and Mostler													+		
Spinopaurinella pugioformis Kozur and Mostler													+		
Muelleritortis expansa Kozur and Mostler															+
Whalenella* aff. *kraineri (Tekin)															+

Table 1. Occurrence of Late Ladinian radiolarian taxa in the Egregindere section

Scutispongus latus Kozur and Mostler first appears in sample 97UKT214, accompanied by *Hozmadia pinnapedis* Kozur and Mostler and *Zhamojdasphaera elegans* Kozur and Mostler, the other characteristic taxa of the *Spongoserrula fluegeli* Subzone of the *M. cochleata* Zone (Kozur and Mostler 1996b, 2006). The other taxa of this subzone, such as *Scutispongus bogdani bogdani* (Kolar-Jurkovesk), *S. ploechingeri ploechingeri* Kozur and Mostler, *Spongoserrula goricanae* Kozur and Mostler and *Spinopaurinella pugioformis* Kozur and Mostler, first appear in higher levels, up to sample 95UKT155 (see Text-fig. 5 and Table 1). The subspecies *Tritortis kretaensis dispiralis* (Bragin), the radiolarian index of the highest, eponymous subzone of the *Muelleritortis cochleata* Zone (see Kozur and Mostler 1994 and Kozur 2003), was not found in the Egregindere section, and consequently; this subzone may be missing here (Text-fig. 5).

The three subzones of the *M. cochleata* Zone correlate with the TR 4.A *Muelleritortis cochleata* Zone of Sugiyama (1997), and with the *Yeharaia elegans* Subzone of the *Sarla dispiralis* Zone of Bragin (1991). This interval also correlates with the *Budurovignathus mungoensis* conodont Zone and the *Protrachyceras archelaus* ammonoid Zone (Kozur and Mostler 1994, 1996b; Kozur 2003; Text-fig. 5).

DISCUSSION AND CONCLUSIONS

The Late Anisian–Ladinian dating of the rifting event in the southern branch of the Neotethys (e. g. Özgul 1984; Senel *et al*. 1996; Varol *et al*. 2007) was based originally on the sequence of olistoliths and debris flows of Anisian age followed by Ladinian radiolarites, shales and volcanic rocks, as recognized in the Alakircay (middle) Nappe, SE of the town of Alanya by Özgul (1983, 1984). Analogous sequences were recognized in the Tahtalidag (upper) Nappe of the Antalya nappes, where the Dutdibi structural units contain limestone olistolith blocks, of mainly Late Permian origin, overlying the late Anisian sediments (Senel *et al*. 1992, 1996). In the Egregindere section, the Dutdibi units of the Tahtalidag Nappe likewise contain an alternation of grey to beige conglomeratic limestones with pebbles of Permian limestones and grey to green shale at the base. The overlying pelagic sediments (limestones and radiolarian cherts) are dated as Late Ladinian. The radiolarian cherts first appear in the section in the *M. cochleata* Zone of the middle to late Late Ladinian. The radiolarian cherts are generally thought to represent deep marine sediments (O'Dogherty *et al*. 2001), and thus their occurrence in the succession dates the main deepening event well. Higher up the section, the radiolarian-bearing pelagic sediments become rare and the succession is characterized mainly by thick-bedded neritic limestones, marking an upward-shallowing sequences (Flugel 2004) of the Late Triassic.

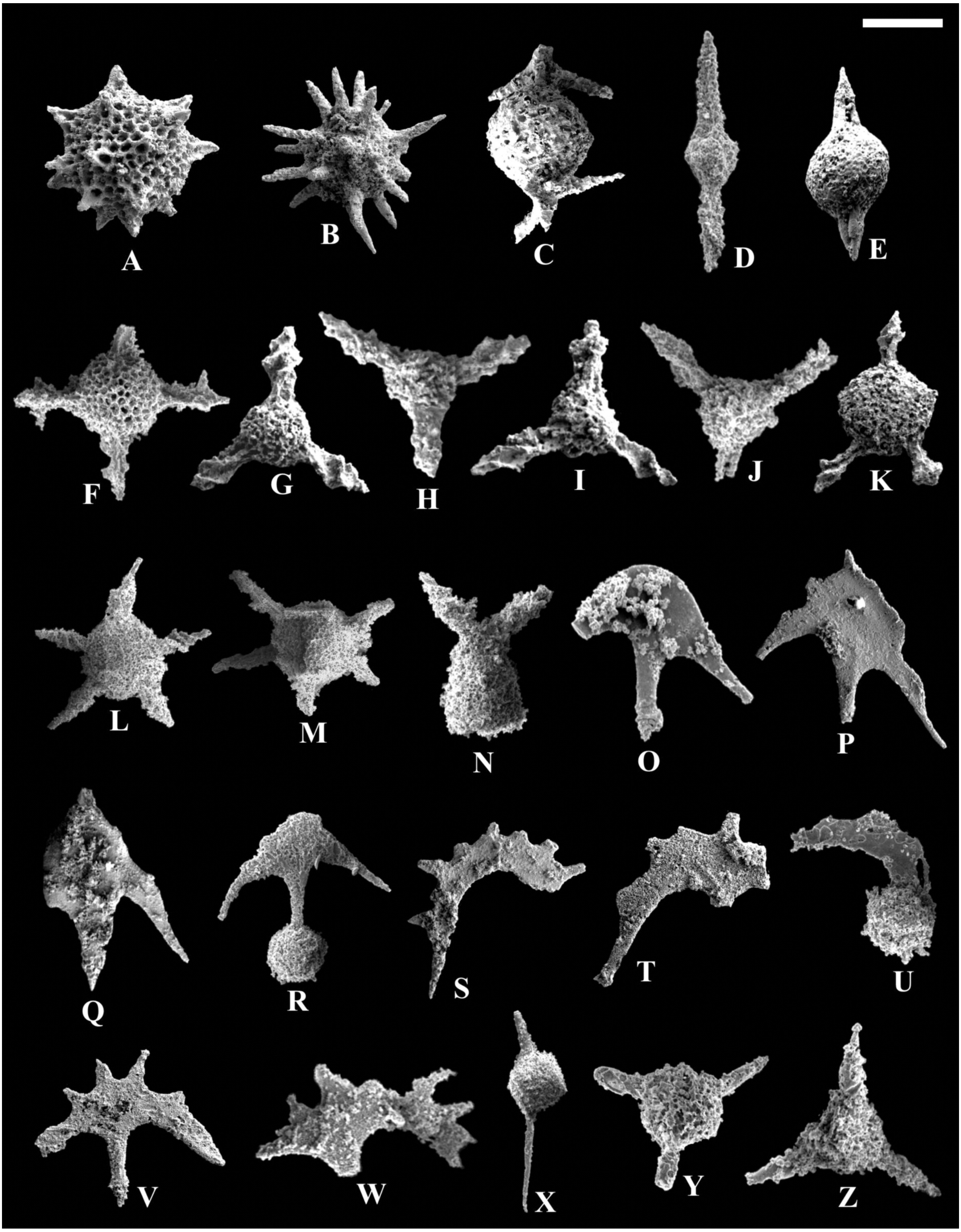
This sequence of events recognized in the succession studied can be interpreted as a result of the appearance of the horst and graben system due to rifting in the Pamphilian (Antalya) basin during the Middle and Late Triassic (Senel *et al*. 1992). The radiolarites, cherts and pelagic limestones, associated with late Middle to Late Triassic basic volcanics, were deposited mainly in grabens (Alakircay nappe of the Antalya nappes), as suggested by Senel *et al*. (1992, 1996) and subsequently confirmed by Tekin (1999) and Varol *et al*. (2007). The upward-shallowing sequences of the Late Triassic were deposited mainly on horsts (Tahtalidag Nappe) (Senel *et al*. 1992; 1996). The same interpretation may be applied to the Egregindere section; after the late Ladinian deposition of radiolarian cherts the Tahtalidag Nappe rose as a horst system, similarly to Jurassic rifting in the Ligurian Basin according to the model by Folk and Mc Bride (1978).

Text-fig. 6. SEM images of the Late Ladinian radiolarians from the Egregindere section. **A** – *Heliosoma* ? *mocki* (Kozur and Mostler, 1979). Sample 97UKT216, scale bar= 115µm. **B** – *Triassospongosphaera multispinosa* (Kozur and Mostler, 1979). Sample 95UKT145, scale bar= 125µm. **C** – *Dumitricasphaera trialata* Tekin and Mostler, 2005b. Sample 97UKT214, scale bar= 150µm. **D** – *Spongostylus koppi* (Lahm, 1984). Sample 95UKT152, scale bar= 120µm. **E** – *Spongostylus* aff. *koppi* (Lahm, 1984). Sample 95UKT152, scale bar = 115 µm. **F** – *Staurolonche trispinosa* Kozur and Mostler, 1979. Sample 97UKT216, scale bar = 120 µm. **G** – *Vinassaspongus erendili* Tekin, 1999. Sample 97UKT212, scale bar = 100 µm. **H-I** – *Vinassaspongus subsphaericus* Kozur and Mostler, 1979. Sample 97UKT214 and 97UKT212, scale bar = 100 and 80 µm, respectively. **J** – *Vinassaspongus* sp. A. Sample 97UKT216, scale bar = 90 µm. **K** – *Pentaspongodiscus discoides* Tekin, 1999. Sample 97UKT212, scale bar = 135 µm. **L** – *Pentaspongodiscus similediscus* Tekin and Mostler, 2005b. Sample 97UKT211, scale bar = 200 µm. **M** – *Pentaspongodiscus symmetricus* Dumitrica, Kozur and Mostler, 1980. Sample 97UKT211, scale bar = 140 µm. **N** – *Karnospongella bispinosa* Kozur and Mostler, 1981. Sample 97UKT215, scale bar = 140 µm. **O** – *Scutispongus bogdani bogdani* (Kolar-Jurkovesk, 1989). sample no. 97UKT215, scale bar = 160 µm. **P-Q** – *Scutispongus latus* Kozur and Mostler, 1996. Both specimens from sample 97UKT214, scale bar = 135 and 145 µm, respectively. **R** – *Scutispongus ploechingeri ploechingeri* Kozur and Mostler, 1996. Sample 97UKT218, scale bar = 135 µm. **S** – *Spongoserrula goricanae* Kozur and Mostler, 1996. Sample 97UKT216, scale bar = 130 µm. **T** – *Spongoserrula rarauana rarauana* Dumitrica, 1982a. Sample 97UKT211, scale bar = 130 µm. **U** – *Spongoserrula rarauana trinodosa* Kozur and Mostler, 1996. Sample 95UKT152, scale bar= 135µm. **V** – *Steigerispongus symmetricus* Kozur and Mostler, 1996. Sample 97UKT211, scale bar = 135 µm. **W** – *Steigerispongus asymmetricus triangulodentatus* Kozur and Mostler, 1996. Sample 95UKT154, scale bar = 100 µm. **X** – *Paurinella acutispinosa* Kozur and Mostler, 1994. Sample 97UKT211, scale bar = 230 µm. **Y** – *Paurinella latispinosa* Kozur and Mostler, 1994. Sample 97UKT216, scale bar = 100 µm. **Z** – *Paurinella triangularis* Kozur and Mostler, 2006. Sample 97UKT215, scale bar = 135 µm

TAXONOMIC NOTES

Following measurements and abbreviations are applied; HT: Holotype, Min.: Minimum, Max.: Maximum, Av.: Average.

Phylum Protozoa
Subclass Radiolaria Müller, 1858
Order Polycystina Ehrenberg, 1875
Suborder Spumellaria Ehrenberg, 1838



Superfamily Actinommacea Haeckel, 1862
Family Stylosphaeridae Haeckel, 1882 emend. Kozur and Mostler, 1979
Genus *Spongostylus* Haeckel, 1882

TYPE SPECIES: *Spongostylus hastatus* Haeckel, 1887.

Spongostylus aff. *koppi* (Lahm, 1984)
(Text-fig. 6E)

Compare:
1984. *Cromyostylus*? *koppi* Lahm, p. 68, pl. 12, figs 1, 2.
1999. *Spongostylus koppi* (Lahm); Sashida *et al*., p. 771, fig. 8–12.
2005b. *Spongostylus koppi* (Lahm); Tekin and Mostler, p. 28, pl. 1, fig. 10

REMARKS: It differs from *Spongostylus koppi* in having shorter and thicker polar spines.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis cochleata* radiolarian Zone. In the study area it occurs in the Günlük Formation.

Genus *Vinassaspongus* Kozur and Mostler, 1979

TYPE SPECIES: *Vinassaspongus subsphaericus* Kozur and Mostler, 1979.

Vinassaspongus sp. A
(Text-fig. 6J)

DESCRIPTION: The shell is subspherical with small pores. Three main spines are triradiate with wide ridges and deep grooves. The main spines are loosely twisted sinistrally and taper distally.

REMARKS: It differs from *Vinassaspongus subsphaericus* Kozur and Mostler (1979, p. 66, pl. 3, figs 5–7; pl. 5, fig. 5) in having loosely twisted main spines.

OCCURRENCE: Middle Triassic, late Ladinian, *Muelleritortis cochleata* radiolarian Zone. In the study area it occurs in the Günlük Formation.

Superfamily Sponguracea Haeckel, 1862 emend. Kozur and Mostler, 1981
Family Pyramispongiidae Kozur and Mostler, 1978 emend. De Wever *et al*., 2001

Genus *Tetrapaurinella* Kozur and Mostler, 1994

TYPE SPECIES: *Tetrapaurinella discoidalis* Kozur and Mostler, 1994.

Tetrapaurinella sp. A
(Text-fig. 7B)

DESCRIPTION: The spongy shell is discoidal with four needle-like spines. Three of them are in the same plane while the fourth is perpendicular to the others. The spines are needle-like, long, slightly tapering distally, pointed.

REMARKS: It differs from *Tetrapaurinella brevispina* Kozur and Mostler (2006, p. 35, pl. 12, fig. 8) in having a discoidal shell and needle-like spines with pointed ends instead of a subtetrahedral shell and needle-like spines with splitting ends.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis cochleata* radiolarian Zone. In the study area it occurs in the Günlük Formation.

Suborder Entactinaria Kozur and Mostler, 1982
Family Divatellidae Kozur and Mostler, 2006
Genus *Carterella* Kozur and Mostler, 2006

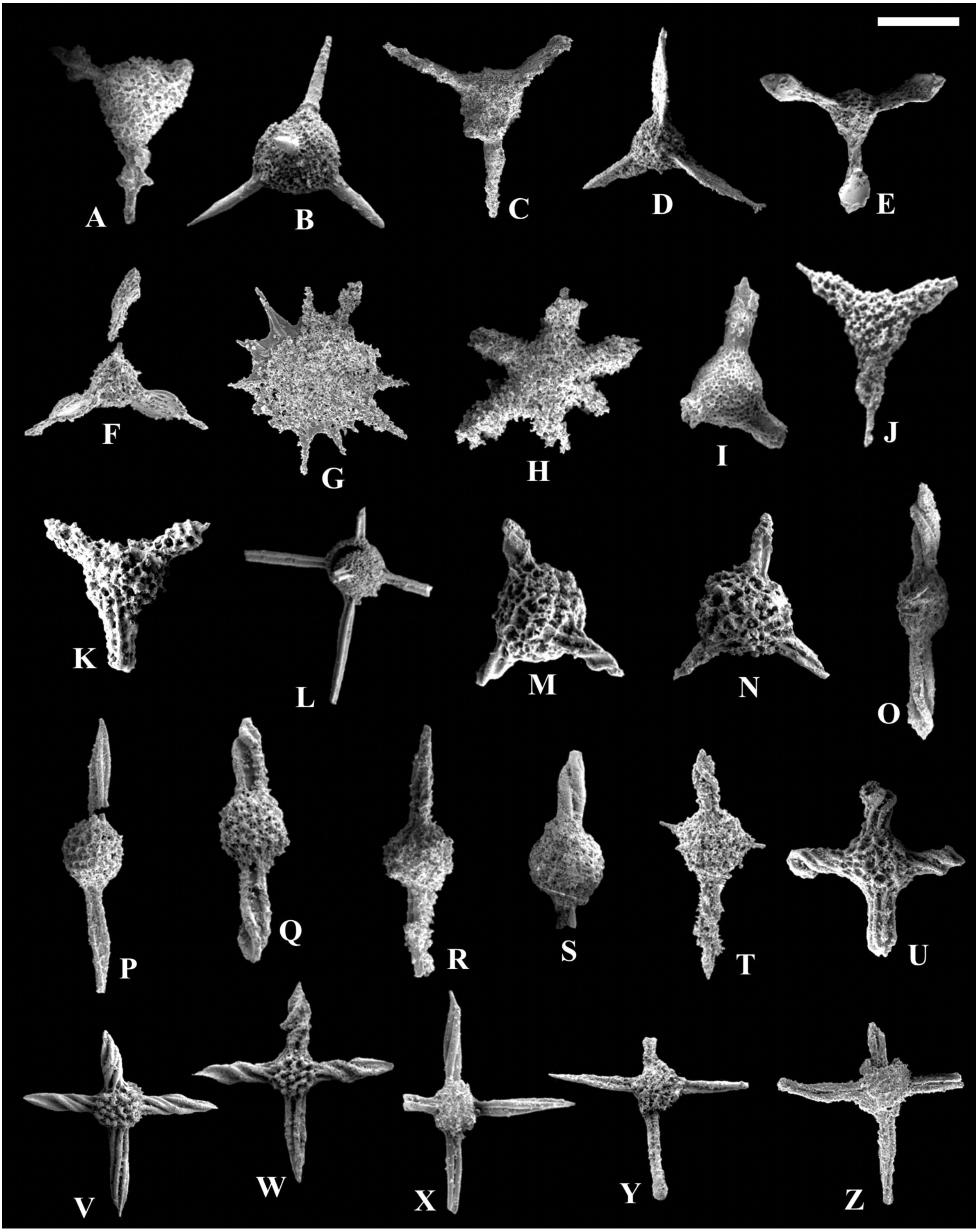
Text-fig. 7. SEM images of the Late Ladinian radiolarians from the Egregindere section. **A** – *Spinopaurinella pugioformis* Kozur and Mostler, 2006. Sample 97UKT218, scale bar = 95 µm. **B** – *Tetrapaurinella* sp. A. Sample 97UKT216, scale bar = 130 µm. **C-D** – *Zhamojdasphaera elegans* Kozur and Mostler, 2006. Sample 95UKT154 and 97UKT214, scale bar = 130 and 150 µm, respectively. **E** – *Zhamojdasphaera latispinosa latispinosa* Kozur and Mostler, 1979. Sample 95UKT152, scale bar = 120 µm. **F** – *Zhamojdasphaera subovalis* Kozur and Mostler, 2006. Sample 97UKT211, scale bar = 150 µm. **G** – *Veghicyclia krystyni* Tekin and Mostler, 2005b. Sample 97UKT211, scale bar = 190 µm. **H** – *Hexacatoma nobleae* Tekin and Mostler, 2005b. Sample 95UKT152, scale bar = 130 µm. **I** – *Praedivatella* sp., sample no. 97UKT216, scale bar = 140 µm. **J** – *Carterella* aff. *subrotunda* Kozur and Mostler, 2006. Sample 97UKT216, scale bar = 180 µm. **K** – *Carterella* aff. *transita* Kozur and Mostler, 2006. Sample 97UKT216, scale bar = 130 µm. **L** – *Entactinosphaera* ? *simoni* Kozur and Mostler, 1979. Sample 97UKT214, scale bar = 120 µm. **M** – *Eptingium* ? *tortile* Kozur and Mostler, 2006. Sample 97UKT216, scale bar = 150 µm. **N** – *Eptingium* sp. A. Sample 97UKT216, scale bar = 130 µm. **O** – *Pseudostylosphaera gracilis* Kozur and Mock, 1981. Sample 97UKT211, scale bar = 190 µm. **P** – *Pseudostylosphaera helicata* (Nakaseko and Nishimura, 1979). Sample 95UKT148, scale bar = 200 µm. **Q** – *Pseudostylosphaera inaequata* (Bragin, 1991). Sample 95UKT148, scale bar = 145 µm. **R** – *Pseudostylosphaera longispinosa* Kozur and Mostler, 1981. Sample 97UKT212, scale bar = 170 µm. **S** – *Pseudostylosphaera nazarovi* (Kozur and Mostler, 1979). Sample 95UKT155, scale bar = 200 µm. **T** – *Pseudostylosphaera* sp. A. Sample 95UKT154, scale bar = 240 µm. **U-W** – *Muelleritortis cochleata* (Nakaseko and Nishimura, 1979) s. l. Sample 95UKT155, 97UKT214 and 97UKT216, scale bar = 200, 250 and 270 µm, respectively. **X-Z** – *Muelleritortis elegans* sp. nov. **X** – Holotype, sample 95UKT145, scale bar = 240 µm. **Y-Z** – Paratypes, Sample 95UKT148 and 97UKT193, scale bar = 280 and 260 µm, respectively

TYPE SPECIES: *Carterella longispinosa* Kozur and Mostler, 2006.

Carterella aff. *subrotunda* Kozur and Mostler, 2006
(Text-fig. 7J)

Compare:
2006 *Carterella subrotunda* Kozur and Mostler, p. 50, pl. 6, fig. 16; pl. 7, fig. 20.

REMARKS: It differs from *Carterella subrotunda* in



having long, needle-like spines at the end of tube-shaped spines.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis cochleata* radiolarian Zone. In the study area it occurs in the Günlük Formation.

Carterella aff. *transita* Kozur and Mostler, 2006
(Text-fig. 7K)

Compare:
2006 *Carterella transita* Kozur and Mostler, p. 50–51, pl. 7, fig 6.

REMARKS: It differs from *Carterella transita* in having a larger shell and two longer spines and a tubopyle.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis cochleata* radiolarian Zone. In the study area it occurs in the Günlük Formation.

Family Eptingidae Dumitrica, 1978
Genus *Eptingium* Dumitrica, 1978

TYPE SPECIES: *Eptingium manfredi* Dumitrica, 1978.

Eptingium sp. A
(Text-fig. 7N)

DESCRIPTION: The shell is subspherical with big pores on the surface. The three spines are situated in the same plane, and are triradiate with wide ridges and thin, narrow and deep grooves. The spines are slightly twisted sinistrally with pointed ends.

REMARKS: From *Eptingium*? *tortile* Kozur and Mostler (2006, pp. 43–44, pl. 7, fig. 8) it differs in having less twisted spines.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis cochleata* radiolarian Zone. In the study area it occurs in the Günlük Formation.

Family Hindeosphaeridae Kozur and Mostler, 1981
Genus *Pseudostylosphaera* Kozur and Mostler, 1981

TYPE SPECIES: *Pseudostylosphaera gracilis* Kozur and Mostler, 1981.

Pseudostylosphaera sp. A
(Text-fig. 7T)

DESCRIPTION: The cortical shell is large, subspherical with long, pointed, needle-like spines. Polar spines are long, unequal, strongly twisted sinistrally. They are tricarinate with thin ridges and deep, wide grooves tapering at the end with pointed termination.

REMARKS: It differs from *Pseudostylosphaera multispinata* Tekin and Mostler (2005a, pp. 2–3, figs 4.4–6) in having a shell with fewer spines and sinistrally twisted polar spines.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis cochleata* radiolarian Zone. In the study area it occurs in the Günlük Formation.

Genus *Muelleritortis* Kozur, 1988a

TYPE SPECIES: *Emiluvia* ? *cochleata* Nakaseko and Nishimura, 1979.

Muelleritortis elegans Tekin sp. nov.
(Text-fig. 7X–Z)

HOLOTYPE: The specimen illustrated in text-fig. 7X.

TYPE LOCALITY: The Egregindere section, chert bands in the Günlük Formation, Tahtalidag Nappe, Antalya nappes, north of the city of Antalya, southern Turkey.

TYPE HORIZON: Chert bands of both the *Muelleritortis firma* and *Muelleritortis cochleata* radiolarian zones, samples 95UKT145, 95UKT147, 95UKT148, 97UKT193, 95UKT152, 97UKT212 and 97UKT213 (Text-figs 2 and 3B). The holotype comes from sample 95UKT145 (*firma* Zone) and the two paratypes come from samples 95UKT148 and 97UKT193 (basal part of the *cochleata* Zone).

ETYMOLOGY: From the Latin (adj.), *elegans*: refined, elegant.

MATERIAL: Ten specimens.

DIAGNOSIS: Cortical shell small with different outlines (subspherical to lenticular etc.). Cortical shell with indistinct outer pore frames and inner pore frames with smaller pores. Four main spines approximately of same width until mid-length then gradually decreasing in width distally, with pointed end. Main spines tricarinate with wide ridges and deep, narrow grooves. Three of the main spines slightly to very slightly twisted dextrally; one main spine untwisted and slightly longer than the others.

MEASUREMENTS (µm): Based on four specimens.

	HT	Min.	Max.	Av.
Max. diameter of the cortical shell	150	150	180	165
Length of the twisted main spines	266	266	300	278
Length of the untwisted spine	266	266	340	302

REMARKS: It can be differentiated from *Muelleritortis longispinosa* Kozur (1988a, p. 54, pl. 3, fig. 4) in having a cortical shell with indistinct pore frames, very much less twisted, slightly shorter main spines. It differs from *Muelleritortis cochleata cochleata* (Nakaseko and Nishimura, 1979, p. 70, pl. 3, figs 2–4, 6) in having a smaller cortical shell, and longer and less twisted main spines.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis firma* and *Muelleritortis cochleata* radiolarian zones. In the study area it occurs in the Günlük Formation.

Muelleritortis firma (Gorican, 1990)
Muelleritortis firma firma (Gorican, 1990)
(Text-fig. 8E–G)

1990. *Plafkerium ? firmum* Gorican in Gorican and Buser, pp. 152–153, pl. 6, figs 3–6.
1995. *Muelleritortis firma* (Gorican); Halamic and Gorican, pl. 1, fig. 15.
1996a. *Muelleritortis firma* (Gorican); Kozur and Mostler, p. 85.
2003. *Muelleritortis firma* (Gorican); Feng and Liang, p. 225, pl. 2, figs 18–20.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis firma* and *Muelleritortis cochleata* radiolarian zones. In the study area it occurs in the Günlük Formation.

Muelleritortis firma equispinosa Tekin subsp. nov.
(Text-fig. 8B–D)

HOLOTYPE: The specimen illustrated in text-fig. 8B.

TYPE LOCALITY: The Egregindere section, chert bands in the Günlük formation, Tahtalidag nappe, Antalya nappes, north of Antalya city, southern Turkey.

TYPE HORIZON: Chert bands of both the *Muelleritortis firma* and *Muelleritortis cochleata* radiolarian zones, samples 95UKT145, 95UKT147, 95UKT148, 95UKT152and 97UKT210 (text-figs 2 and 3B). The holotype and one of the paratypes come from sample 95UKT148 (basal part of the *cochleata* Zone); the other paratype comes from 95UKT145 (*firma* Zone).

ETYMOLOGY: Named for the approximately equal main spines.

MATERIAL: Seven specimens.

DIAGNOSIS: Cortical shell subspherical to square in outline with double-layered pore frames. Outer layer includes irregular polygonal pore frames and nodes at pore frame vertices. Four main spines long, approximately equal, tricarinate with wide ridges and deep and narrow ridges, decreasing in width gradually towards the end of spine and terminating in pointed end.

MEASUREMENTS (µm): Based on five specimens.

	HT	Min.	Max.	Av.
Max. diameter of the cortical shell	105	105	140	121
Length of the main spines	200	180	240	108

REMARKS: It is differentiated from *Muelleritortis firma firma* (Gorican in Gorican and Buser, 1990, pp. 152–153, pl. 6, figs 3–6) in having much longer, approximately equal, slightly tapering main spines with invariably pointed ends. Specimens belonging to *Muelleritortis firma firma* (Gorican) figured by Gorican and Buser 1990) and figured in this study always have unequal, medially expanded main spines generally with blunt ends.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis firma* and *Muelleritortis cochleata* Radiolarian Zones. In the study area it occurs in the Günlük Formation.

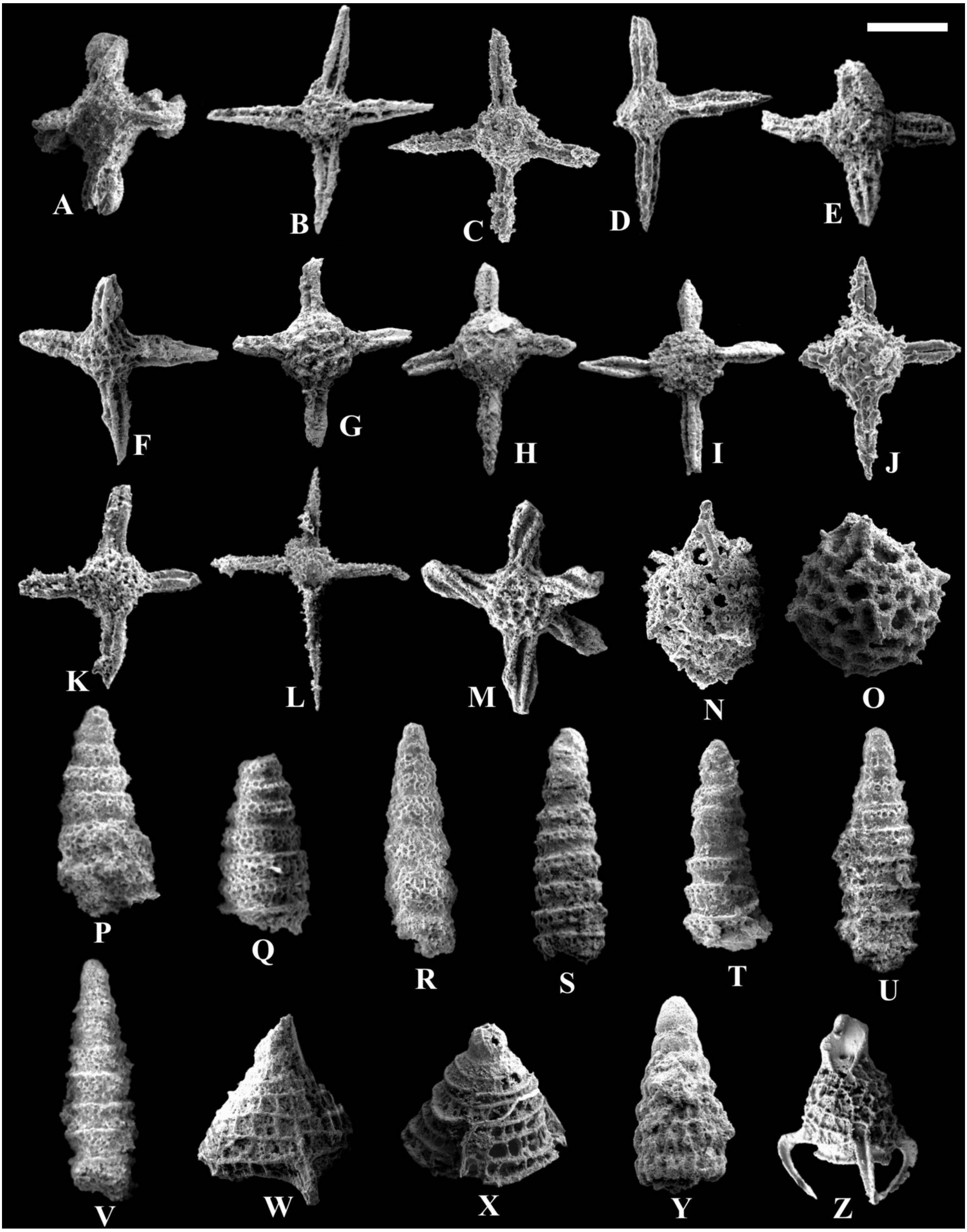
Muelleritortis firma globosa Tekin subsp. nov.
(Text-fig. 8H–K)

Holotype, sample 95UKT145, scale bar = 150 µm; Paratypes, sample 95UKT145, 95UKT152 and 97UKT193, scale bar = 180, 150 and 180 µm, respectively.

HOLOTYPE: The specimen illustrated in text-fig. 8H.

TYPE LOCALITY: The Egregindere section, chert bands in the Günlük formation, Tahtalidag nappe, Antalya nappes, north of Antalya city, southern Turkey.

TYPE HORIZON: Chert bands of the both *Muelleritortis firma* and *Muelleritortis cochleata* Radiolaria zones, samples 95UKT145, 95UKT147, 97UKT193 and 95UKT152 (text-figs 2 and 3B). The holotype and one of the paratypes comes from sample 95UKT145 (*firma* Zone); the other paratypes come from samples 95UKT152 and 97UKT193 (*cochleata* Zone).



ETYMOLOGY: From the Latin (adj.), *globosa*: spherical.

MATERIAL: Six specimens.

DIAGNOSIS: Cortical shell large, spherical to subspherical with elevated outer layer. Four main spines situated mainly in right angle, tricarinate with ridges and relatively wide grooves. Main spines expanding medially then tapering distally, pointed; one of the main spines longer than the others.

MEASUREMENTS (µm): Based on five specimens.

	HT	Min.	Max.	Av.
Max. diameter of the cortical shell	150	130	150	145
Length of the short main spines	150	100	150	118
Length of the long main spine	175	120	180	160

REMARKS: It can be differentiated from *Muelleritortis firma firma* (Gorican in Gorican and Buser, 1990, pp. 152–153, pl. 6, figs 3–6) by having a larger and globular cortical shell and thinner, slightly longer main spines.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis firma* and *Muelleritortis cochleata* radiolarian zones. In the study area it occurs in the Günlük Formation.

Muelleritortis ? sp. A
(Text-fig. 8L)

DESCRIPTION: The cortical shell is globular with four main spines in a cruciform arrangement. Main spines are tricarinate, deep and wide, with wide ridges. Spines taper gradually distally with pointed ends. Three of the main spines are slightly twisted sinistrally; the remaining spine is longest and untwisted.

REMARKS: It can be differentiated from *Muelleritortis elegans* sp. nov. in having three main spines that are slightly twisted sinistrally instead of dextrally. It is only tentatively assigned to the genus *Muelleritortis,* because the shell structure characters are not clear.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis cochleata* radiolarian Zone. In the study area it occurs in the Günlük Formation.

Genus *Pentatortis* Kozur, 1988b

TYPE SPECIES: *Pentatortis longobardica* Kozur, 1988b.

Pentatortis sp. A
(Text-fig. 8M)

DESCRIPTION: The cortical shell is subglobular, with cortical elevated pore frames and nodes at the vertices. The five main spines are carinated with wide ridges and wide, deep grooves situated in the same plane. Four of the main spines are slightly to moderately twisted dextrally, with blunt ends. The untwisted main spine is slightly longer than the twisted ones.

REMARKS: From *Pentatortis hexaspina* Kozur and Mostler (1996a, p. 91, pl. 3, figs 4–5) it differs in possessing five main spines in the same plane.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis cochleata* radiolarian Zone. In the study area it occurs in the Günlük Formation.

Suborder Nassellariina Ehrenberg, 1875
Superfamily Acanthodesmiacea Hertwig, 1879
Family Ruesticyrtiidae Kozur and Mostler, 1979
Genus *Pararuesticyrtium* Kozur and Mock in Kozur and Mostler, 1981

Text-fig. 8. SEM images of the Late Ladinian radiolarians from the Egregindere section. **A** – *Muelleritortis expansa* Kozur and Mostler, 1996. Sample 95UKT155, scale bar = 230 µm. **B-D** – *Muelleritortis firma equispinosa* subsp. nov. **B** – Holotype, Sample 95UKT148, scale bar = 150 µm, **C-D** – Paratypes, Sample 95UKT145 and 95UKT148, scale bar = 160 and 180 µm, respectively. **E-G** – *Muelleritortis firma firma* (Gorican, 1990). Sample 97UKT193, 95UKT147 and 95UKT145, scale bar = 150, 130 and 130 µm, respectively. **H-K** – *Muelleritortis firma globosa* subsp. nov. **H** – Holotype, sample 95UKT145, scale bar = 150 µm, **I-K** – Paratypes, sample 95UKT145, 95UKT152 and 97UKT193, scale bar = 180, 150 and 180 µm, respectively. **L** – *Muelleritortis* ? sp. A. Sample. 97UKT215, scale bar = 350 µm. **M** – *Pentatortis* sp. A. Sample 97UKT216, scale bar = 140 µm. **N-O** – *Pentactinocarpus tetracanthus* Dumitrica, 1978. Sample 95UKT152 and 97UKT216, scale bar = 180 and 140 µm, respectively. **P-Q** – *Pararuesticyrtium mediofassanicum* Kozur and Mostler, 1994. Both specimens are from sample 95UKT147, scale bar = 90 and 105 µm, respectively. **R** – *Pararuesticyrtium* sp. A. Sample 95UKT147, scale bar = 90 µm. **S-T** – *Annulotriassocampe sulovensis* (Kozur and Mock, 1981). Sample 95UKT147 and 95UKT155, scale bar = 90 and 80 µm, respectively. **U-V** – *Triassocampe deweveri* (Nakaseko and Nishimura, 1979). Sample 95UKT154 and 95UKT147, scale bar = 100 and 110 µm, respectively. **W-X** – *Silicarmiger latus latus* Kozur and Mostler, 1994. Sample 95UKT147 and 97UKT214, scale bar = 120 and 130 µm, respectively. **Y** – *Whalenella* aff. *kraineri* (Tekin, 1999). Sample 95UKT155, scale bar = 80 µm. **Z** – *Hozmadia pinnapedis* Kozur and Mostler, 2006. Sample 97UKT214, scale bar = 180 µm

TYPE SPECIES: *Pararuesticyrtium densiporatum* Kozur and Mock in Kozur and Mostler, 1981.

Pararuesticyrtium sp. A
(Text-fig. 8R)

DESCRIPTION: The test is slender, conical, with five post-abdominal segments. It increases in width gradually until the last segment. The cephalo-thorax is dome-shaped, the rest of the segments are hoop-like with polygonal pore frames.

REMARKS: From *Pararuesticyrtium mediofassanicum* Kozur and Mostler (1994, pp. 109–110, pl. 28, figs 1–4, 9, 11) it differs in a more slender test and in fewer segments without a distal skirt.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis firma* radiolarian Zone. In the study area it occurs in the Günlük Formation.

Superfamily Eucyrtidiacea Ehrenberg, 1847
Family Pseudodictyomitridae Pessagno, 1977
Genus *Whalenella* Kozur, 1984

TYPE SPECIES: *Dictyomitra arrecta* Hinde, 1908.

Whalenella aff. *kraineri* (Tekin, 1999)
(Text-fig. 8Y)

Compare:
1999. *Corum kraineri* Tekin, pp. 152–153, pl. 35, figs 7–9.
2005. *Whalenella* sp. cf. *W. kraineri* (Tekin); Bertinelli, Chiari and Marcucci, figs 4–3.

REMARKS: It differs from *Whalenella kraineri* in having a shorter test with more irregular costae on the segments and a more pronounced, bulbous cephalo-thorax.

OCCURRENCE: Middle Triassic; late Ladinian, *Muelleritortis cochleata* radiolarian Zone. In the study area it occurs in the Günlük Formation.

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