QUATRIÈME CONGRÈS INTERNATIONAL SUR LES RUDISTES

Dédie à Henri DOUVILLETÉ (1846-1937)

Marseille 9-15 septembre 1996

J.-P. MASSE & P.W. SKELTON Coordonnateurs

GEOBIOS - Mémoire spécial n° 22 - 1998

Édition de l'Université Claude-Bernard, Lyon 1
Avec le concours du Centre National de la Recherche Scientifique
RUDIST BEARING UPPER CRETACEOUS METAMORPHIC SEQUENCES OF THE MENDERES MASSIF (WESTERN TURKEY)

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ABSTRACT - The Menderes Metamorphic Massif is located between the Izmir-Ankara zone to the north, and the Lycian nappes and Bey Daglari platform to the south in the western part of Turkey. The massif consists of core rocks of Precambrian to Cambrian gneisses, schists, metagranites, and core rocks of Paleozoic micaschists and marbles, Mesozoic thick bedded platform-type metacarbonates, and Lower Tertiary pelagic metacarbonates and flysch type rocks. Rudists were discovered locally from the southern sector of the Menderes Massif, around Milas area, and they were accepted as a very important paleontologic data indicating however only a Late Cretaceous age in the previous studies. The presence of several new localities showing a wide geographic distribution of the rudists in the southern and northern sectors of the massif is revealed, and presented in this study. The rudist-bearing metamorphic sequences are mainly represented by platform-type carbonates. However, sequences consisting of clastics and carbonates are also present. The Upper Cretaceous metamorphic sequences consist of, from base to top, emery-bearing marbles and marbles with rudists (Cenomanian), rudist-bearing marbles (Santonian-Campanian), and red-pinkish pelagic marbles (late Campanian-Maastrichtian). Flysch type rocks (Early Tertiary) overlie these sequences. Two rudist associations allowing precisely to establish the Upper Cretaceous stratigraphy in the massif, are distinguished. The first association is characterized by the abundance of rudists with canals such as Neocaprina gigantea, Caprina schioensis, Schiosia cf. schioensis, Sphaevacaprina cf. forojuilienis, Ichthyosarcolithes poljaki, Ichthyosarcolithes rotundus, Ichthyosarcolithes bicarinatus, Ichthyosarcolithes cf. tricarinatus indicating a middle-late Cenomanian age. This association also consists of Eoradiolites cf. liratus, Durania sp., Apricardia sp., Chondrodonta sp., and Distefanella close to Distefanella bossani and Distefanella cf. montagnei which are found for the first time in Turkey. The second association is represented mainly by hippuritids and radiolitids such as Vaccinites taburni, Vaccinites cf. sulcatus, Hippurites nabresinensis, Hippurites colliciliatus, Sauvagesia cf. tenuicostata, and Durania sp., indicating a Santonian-Campanian age.

KEYWORDS: UPPER CRETACEOUS, TURKEY, RUDISTS, BIVALVIA, MARBRES


MOT-CLÉS: CRÉTACÉ SUPÉRIEUR, RUDISTES, BIVALVES, TURQUIE, MARBRES
INTRODUCTION

The Menderes metamorphic massif is located between the Izmir-Ankara Zone to the north and Lycian nappes to the south, in the western part of Turkey (Fig. 1). According to the long-established geological concepts, the massif consists of, in ascending order, the core series of Precambrian to Cambrian gneisses, schists, metagranites, migmatites and metagabbros, and cover series (or envelope association) of Lower Paleozoic micaschists, Permo-Carboniferous metaquartzites and meta-

The main mass of the massif crops out mainly over a large area in the Western Anatolia, however one of the sliver is also observed in the area extending from Kale-Tavas to the south of Denizli (Fig. 1). The Mesozoic rock cover extends regularly and presents good outcrops in the southern sector of the massif (Fig. 4), while it shows a less regular extension in the northern part of the massif (Fig. 11).

Due to the metamorphism, the fossils are very sparse, and badly preserved in the Paleozoic and Mesozoic sequences. Previous studies suggested some foraminifers such as fusulinids for the Permo-Carboniferous, involutinids for the Triassic, and rare rudist fragments with a Late Cretaceous age (Dürr 1975; Çağlayan et al. 1980; Konak et al. 1987). The occurrence of Upper Cretaceous marbles in the massif, has been known since the first report of rudists from the Akbuk-Milas area (Fig. 1, 4) by Dürr (1975). The rudists of this area have been recently reexamined and many species determined (Ozer 1993).

The aim of this study is to provide an up to date overview on the Upper Cretaceous sequences with rudists from the southern and northern sector of the Menderes massif, and from the Kale-Tavas adjacent area.

**STRATIGRAPHY**

The Upper Cretaceous sequences with rudists were studied in four areas as follows.

**KALE-TAVAS AREA**

The metamorphosed sedimentary rocks belonging to the cover series of the Menderes Massif crop out over a large area extending from southeast of Kale to Tavas and southeast of Denizli (Poisson 1977; Poisson & Sarp 1977; Poisson 1985; Okay 1989; Özkaya 1990). The relationship of these rocks with the main mass of the massif cannot be observed due to the Neogene sedimentary rocks (Fig. 1). In this area, the Paleozoic consists of slightly metamorphosed clastics and carbonate lenses with fusulinids (Okay 1989) and crops out to the south of Tavas, while the Mesozoic neritic, monotonous, platform-type marbles are observed in a major NE-SW striking mountain chain extending over a large area from southeast of Tavas to Denizli. This sequence has an imbricated internal structure (Poisson & Sarp 1977; Poisson 1985; Okay 1989; Özkaya 1990, 1991). Serinhasar (formerly Kızılıshisar) was known from the previous studies as the single rudist locality in Tavas area, indicating a Late Cretaceous age (Çaglayan et al. 1980; Poisson & Sarp 1977; Okay 1989; Özkaya 1990, 1991), which is precisely described in this
study. In the Serinhisar locality, two formations named by Okay (1989) will be described (Fig. 2). Yilanli Formation. This formation is made up of mainly grey, massive, fine grained rudist-bearing platform-type marbles. Over the massive dolomitic marbles, intercalation of bioclastic and rudistid


FIGURE 3 - 1. Transverse sections of a cluster of lower valves of Vaccinites taburni Guiscardi. Sample n° S 92 02/ P, Serinhisar-Tavas, x 1.2. Ligamental ridge (L) is inclined towards the anterior side and cut at the end. The first pillar (S) is pedunculate and the second pillar (E) is reniform. 2. Neocaprina gigantea PleinCar. Transverse section of the lower valve. Sample n° S 92 01/M, Serinhisar-Tavas, x 0.6. Note the accessory cavities and canals (oma, omp and arrow). b, h, tooth sockets, ma, mp, myophores. CV: Central cavity, Vi: external carina. 3. Sphaerocaprina cf. forojulienisis Boeilm. Transverse section of the upper valve. Sample n° S 92 01/B, Serinhisar-Tavas, x 1.7. Note the rectangular canals (big arrow) and fusiform canals (small arrow) separated by thin lamellae. CV: Central cavity, oma, omp: accessory cavities. 4. Small build-ups constructed by Boradilites cf. liratus (Conrad) associated with Durania sp. (D, above). Field photograph from Serinhisar-Tavas, x 0.8. 5. Durania sp. Transverse sections of lower valves. Sample n° S 92 02/M, Serinhisar-Tavas, x 0.8. The outer shell layer is thick (arrows) and shows the characteristic prismatic structure. 6. Fragment of Caprina sp. Note the fusiform canals arranged in a single row (arrow). Sample n° S 92 01/D, Serinhisar-Tavas, x 1.5. 1. Section transversale des valves inférieures d’un groupement de Vaccinites taburni Guiscardi. L’arête ligamentaire (L) est courbée von le côté antérieur et tronquée à son extrémité. Le premier pilier S est pédonculé et le second pilier E est reniforme. 2. Neocaprina gigantea PleinCar. Section transversale de la valve inférieure. Notez les cavités accessoires et les canaux (oma, omp et flèche). b, h, fosses des dents, ma, mp, myophores. CV: cavité centrale, Vi: carène externe. 3. Sphaerocaprina cf. forojulienisis Boeilm. Section transversale de la valve supérieure. Noter les canaux rectangulaires (grande flèche) et les canaux fusiformes (petite flèche) séparés par de minces cloisons. CV: cavité centrale, oma, omp: cavités accessoires. 4. Petit récif construit par Boradilites cf. liratus (Conrad) associé à Durania sp. (D). Photographie de terrain, Serinhisar-Tavas. 5. Durania sp. Sections transversales de valves inférieures. La couche externe est épaisse (flèche) et présente la structure prismatique caractéristique. 6. Fragment de Caprina sp. Noter les canaux fusiformes disposés en une seule rangée (flèche).
marbles are observed. These levels are approximately 25-30 m thick, and mainly composed of rudists with canals: Neocaprina gigantea PLENIAR, Caprina schiosensis BOEHM, Schiosia cf. schiosensis BOEHM, Ichthyosarcolites rotundus POLS, I. tricarinatus PARONA, I. bicarinatus (GEMMELLARO), I. poljaki POLSK, Sphaerocaprina cf. forojulienis BOEHM with a middle-late Cenomanian age (Figs 3, 2, 3; 1, 6, 1, 2, 4, 5, 6, 7, 11, 11). The genus Distefanella PARONA, documented for the first time in Turkey, is also

FIGURE 6 - 1. Schiosia cf. schiosensis BOEHM. Transverse section of the upper valve. Sample n° S 92 02/I, Serinhisar-Tavas, x 1.3. B.B': teeth, ma, mp: myophores, n: socket of the N tooth, n': secondary cavity, CV: Central cavity. 2. Sphaerocaprina cf. forojulienis BOEHM. Transverse section of the upper valve. Sample n° S 92 02/L, Serinhisar-Tavas, x 1.3. Note the rectangular, polygonal and fusiform canals (arrows). 3. Apricaria sp. Sample n° S 92 01/L, Serinhisar-Tavas, x 1.4. Ichthyosarcolites poljaki POLSK. Transverse section of the lower valve, field photo from the area of Serinhisar-Tavas, x 0.6. The ridges (1, 2, and 3) are well-developed. Note the small round or oval canals (arrows). 5. Ichthyosarcolites bicarinatus (GEMMELLARO). Transverse section of the lower valve. Sample n° S 92 02/I, Serinhisar-Tavas, x 1.8. Note two ridges (1 and 2) and the canal (arrow). 6. Ichthyosarcolites cf. tricarinatus PARONA. Transverse section of the lower valve. Sample n° S 92 01/H, Serinhisar-Tavas, x 1.2. The central cavity (CV) is subquadrangular. 7. Ichthyosarcolites rotundus POLSK. Transverse section of the lower valve. Sample n° S 92 02/K, Serinhisar-Tavas, x 0.5. 8. Distefanella cf. montagnei SLFERCIVIC. Transverse section of the lower valve. Sample n° S 92 01/G, Serinhisar-Tavas, x 0.6. Siphonal bands (S, E) are strongly convexe. Note the very convex interband (1). 9, 10. Distefanella bassani PARONA. Transverse sections of lower valves. Field photo taken from the area of Serinhisar-Tavas, x 0.5. Siphonal bands (S, E) are flat. 11. Schiosia cf. schiosensis BOEHM. Transverse section of the upper valve. Sample n° S 92 02/D, Serinhisar-Tavas, x 1.6. Note the rounded or fusiform small canals (arrows). 1. Schiosia cf. schiosensis BOEHM. Section transversale de la valve supérieure. B.B': dents ena, mp: apophyse myophores, n: fossette de la dent N, n': cavité secondaire, CV: cavité viscérale. 2. Sphaerocaprina cf. forojulienis BOEHM. Section transversale de la valve supérieure. Noter les canaux rectangulaires, polygonaux et fusiformes (flèches). 3. Apricaria sp. Echantillon n° S9201L, Serinhisar-Tavas, x 1. 4. Ichthyosarcolites poljaki POLSK. Section transversale de la valve inférieure. Photographie de terrain. Les arêtes (1, 2 et 3) sont bien développées. Noter les petits canaux ronds ou ovales (flèches). 5. Section transversale de la valve inférieure. Noter deux arêtes (1 et 2) et aussi les canaux (flèche). 6. Section transversale de la valve inférieure. La cavité centrale (CV) est subquadrangulaire. 7. Section transversale de la valve inférieure. 8. Section transversale de la valve inférieure. Les bandes siphonales (S, E) sont fortement convexe. Noter l' interbande (I) fortement convexe. 9, 10. Section transversale de la valve inférieure. Photographie de terrain. Noter les petits canaux ronds ou fusiformes (flèches). 11. Section transversale de la valve supérieure. Noter les petits canaux ronds ou fusiformes (flèches).
found in these levels Distefanella bassani Parona and Distefanella cf. montagnei Sliskovic are also present (Fig. 6.8-10). Durania sp., Eoradiolites cf. liratus (Conrad), Chondrodonta sp. and Apricardia sp., are also associated to this fauna (Figs 3.4.5; 6.3). These levels pass upward to 30-35 m thick, grey, massive marbles, and then to rudist-bearing, 10-15 m thick, grey marbles. The rudistid marbles are mainly composed of Vaccinites taburni Guiscardi with a Santonian-Campanian age. Some small build-ups of this species are observed (Fig.

3.1). The uppermost part of the formation is made up of massive, grey marbles. Zeybekölen tepe Formation. This formation consists of breccias, and red-pinkish shales and mudstones. According to Poisson and Sarp (1977), Okay (1989) and Özakaya (1990), the age of the formation is Paleocene-Early Eocene.

MILAS AREA

The region is located between the Bafa Lake and Mugla, where the main features of the cover rocks
are well exposed (Fig. 4). Three formations are distinguished (Fig. 5).

Milas formation. This formation is characterized by platform-type carbonates. The massive, grey, emery-bearing marbles are probably of Cenomanian age, then grade upwards to massive marbles and 30 to 40 m thick rudist-bearing marbles. The rudist fauna consists of *Hippurites nabresinensis Futterer*, *Hippurites collticatius Woodward*, *Vaccinites taburni Guiscard*, *Vaccinites cf. sulcatus Defrance*, *Sauvagesia cf. tenuicostata Polsak*, *Durania sp.*, and Radiolitidae fragments (Fig. 7.1-5) indicative of a Santonian-Campanian age (Ozer 1993). The rudist horizon is clearly visible between Akbük-Kazikli-Kızilagaç and Asinyeniköy (Fig. 4). Rudist sections are also observed around Akdag and Marçaldağ. In Akbük and Asinyeniköy localities, small rudist build-ups constructed by *Hippurites nabresinensis Futterer* are found (Fig. 7.1). The rudist beds grade laterally and vertically to intraformational carbonate breccias. The uppermost part of the Milas formation is made up of grey, massive marbles, with some silex nodules, and passes gradually upwards to the pelagic marbles of the Kızilagaç Formation.

Kızilagaç Formation. This formation (25 to 30 m thick) is characterized by thin to medium bedded, reddish, greenish and light grey pelagic marbles with marly-pelitic interlayers. Upwards appear debris flows with coarsening upward clasts. The formation crops out around Kazikli and Kızilagaç village together with the overlying Kazikli formation.

Nannofossils like *Micula staurophora* (Garted), *Watznauera barnesae* (Black) and *Praediscosphaera cretacea* (Arkhangelsky) and planktonic foraminifers such as *Globotruncana lapparenti Brotzen*, *G. cf. arca* (Cushman), *G. bulboides Vogler*, *G. ventricosa White*, *G. linneiana (DoBrugny)*, *G. falsostuartii Sigal*, *Globotruncanita stuarti* (de Lapparent), *Glb. stuartiformis* (Dalbierz), *Glb. subspinosa* (Pessagno), *Rosita contusa* (Cushman),
Gansserina gansseri (BOLL), Abathomphalus mayaroensis (BOLL), Globotruncanella sp., Racemigumelina sp., Archaeoglobigerina sp. and Globigerinoides sp. have been identified and documented a late Campanian-late Maastrichtian age (Fig. 5). According to Dürre (1975) and Çağlayan et al. (1980), the age of the formation extends to the Early Paleocene.

Kazikli Formation. The formation is made up of flysch type rocks consisting of schists, phylites with carbonate lenses and carbonate blocks. Some foraminifers such as Morozovella angulata (WHITE), Morozovella cf. pseudobulloides (PLUMMER), Morozovella sp. and Globigerina sp. indicating a middle Paleocene age are present; however Dürre (1975) and Çağlayan et al. (1980) suggest only an Early Eocene age for the formation.

The Lycian nappes consisting of siliciclastics, dolomites, and limestones of Upper Triassic-Liassic thrust over the cover rocks. In some areas, the serpentine lenses marking the basal thrust plane of the Lycian nappes (de Graciansky 1966; Dürre 1975; Çağlayan et al. 1980) are observed (Fig. 5).

YATAGAN AREA

The Yatagan-Kavaklidere area (Fig. 4) was known as a reference section showing a clear stratigraphic organization, such as an unconformity between the Paleozoic micaschists and the Mesozoic emery-bearing platform type marbles (Dürre 1975; Çağlayan et al. 1980; Konak et al. 1987; Konak 1994). However, Özer (in Dürre et al. 1995) first demonstrated the presence of a Cretaceous sequence ascribed to the Milas and Kızılağaç formations in the Yatagan-Kavaklidere area suggesting important new data when compared with the previous studies.

Milas Formation. The best sections of the formation were examined in the Bozarmut village-SE of Yatagan and between Söben and Magara villages-SW of Eyli Hill (Fig. 4). The formation comprises,
from bottom to top, micaschists with marble lenses, emery-bearing marbles, dolomitic marbles and rudist-bearing marbles showing a nearly vertical bedding (Figs 8, 9). A gradational transition between the micaschists and the emery-bearing marbles are clearly observed in the lowermost section. Micaschist lenses and intraformational metaconglomerates are present in the formation.

Rudists are abundant upsection. The rudist fauna consist of hippuritid and radiolitid species with a Santonian-Campanian age: Hippurites naboriensiensis Futterer, Hippurites colliciatus Woodward, Vaccinities cf. sulcatus Defrance and Sauvagesia cf. tenuicostata Polsak (Fig. 7.6-7; 10.1,2). Some corals are also observed in the rudist beds.
The marble successions in the north of Yatagan and around Kirdag locality (Fig. 4), display also rudist sections. The rudist bearing marbles grade upward to thick, grey marbles, and pass to the Kizilagac formation.

Kizilagac Formation. This formation is observed only around Kertil Hill-SW of Eyli Hill, Kavaklydere (Fig. 4,9), and is made up of reddish-pinkish pelagic metacarbonates down section and phyllites with carbonate lenses upsection. The pelagic carbonates yield planktonic foraminifers such as Globotruncanana lapparenti BROTEZEN, Globotruncanita cf. stuarti (DE LAPPARENT), Globotruncanita sp., Globotruncanana sp. and Globotruncanella sp., and also nannoplanktons like Micula staurophora (GARTEDEL), Watznaueria barnesae (BLACK) and Prediscosphaera cretacea (ARKHANGELESKY) indicative of a late Campanian-Maastrichtian age.

Yatagan Formation. This formation overlies the units of the Menderes Massif with an angular unconformity and consists of, from bottom to top, conglomerates composed mainly by marble clasts and lacustrine type carbonates (Fig. 4,8). According to the ostracods, vertebrates (Perissodactyla) and palynologic determinations a Middle-Late Miocene age have been suggested for the formation (Goekcen 1982; Gemici et al. 1990; Kaya 1991).

**SELCUK AREA**

In the northern sector of the Menderes Massif, the Mesozoic sequences crop out only around Selcuk (Fig. 11), where two formations were distinguished by Erdogan and Gungor (1992).

Kayaalty Formation. This formation is represented by micaschists and platform-type marbles. In the eastern part of Selcuk, around the village of Kurgak a gradational transition characterises the marble lenses between the micaschist and emery-bearing massive marbles (Fig. 12). Upsection are found grey, rudist-bearing massive marbles. Fragments of rudists are not well preserved; however, some sections of radiolitids belonging probably to genus Sauvagesia and/or Durania have been determined (Fig. 10.3). The rudist sections are also found south of Selcuk and in the western part of Sokke (around Tuzburgaz and Gulbahce) (Fig. 10.4, 5, 11). The uppermost
part of the formation consists of laminated, grey marbles. The top of the Kayaalti formation is capped by the Selçuk formation.

Selçuk Formation. The formation is composed of dark green-gray micaschists with mafic metavolcanics. Blocks of metaserpentinite, metagabbro, and marble with emery lenses are also observed. Due to its stratigraphic position, the age of the formation has been accepted as Maastrichtian by Erdogan and Gündoğ (1992).

CONCLUSION

The main stratigraphic features of the Upper Cretaceous sequences with rudists of the Menderes Massif are listed below.

Two types of Cretaceous sequences are distinguished. The first sequence is characterized by plat-}

form-type neritic carbonates (Kale-Tavas and Milas area). The second is represented by clastics and carbonates (Yatagan-Selçuk areas). These sequences present three levels which are important for the Cretaceous stratigraphy, from base to top:

- emery-bearing marbles and/or marbles with rudists having canals of Cenomanian age,
- hippuritids dominant rudist-bearing marbles of Santonian-Campanian age,
- finally red-pinkish pelagic marbles for the late Campanian-Maastrichtian.

The Upper Cretaceous sequence of the massif is dominated by platform-type rocks; however, the development of pelagic carbonates in the latest Campanian-Maastrichtian indicate the drowning of the platform.

Despite the metamorphism effects, two rudist associations can be distinguished. The first association represented mainly by rudists with canals (middle-late Cenomanian) is typical of the Apulian platform (Plenicer 1963; Polsak 1967; Carbone et al. 1971; Sirna 1982; Camoin 1983), and is also found in the Bey Daglari carbonates of Turkey (Ozer 1988). The second association is characterized by hippuritids described from the Santonian-Campanian of the Mediterranean province (Douville 1910, Parona 1926, Polsak 1967, Lupp 1976), and limestone blocks of the Izmir-Ankara zone, around Izmir (Ozer 1989).

The Upper Cretaceous sequence of the Kale-Tavas area, which is precisely described for the first time in this study, comprises both Cenomanian and Santonian-Campanian rudist faunas. The Cenomanian of this area is characterized by rudists with canals, and the first mention of the genus Distefanella in Turkey. The species of this genus are generally described from late Turonian (Polsak & Mamuzic 1969; Sliskovic 1971; Accordi et al. 1982). However, the presence of Distefanella in the late Cenomanian of the Domaine Prébétique (Spain) has been reported by Martin-Chivelet et al. (1990). The discovery of this genus in the Cenomanian beds in western Turkey, reveals a wide geographic and stratigraphic distribution of Distefanella in the Mediterranean province.

Acknowledgements - The author would like to thank Dr. J.P. Platel (BRGM-Aquitaine), Dr. M. Plenicer (Univ. of Ljubljana), Dr. J.P. Masse (Univ. of Provence) for reviewing the manuscript and Prof. Dr. V. Toker (Univ. of Ankara) for determination of nanoplanktons, Prof. Dr. I. Tansel (Univ. of Istanbul) for foraminifers, and Prof. Dr. A. Poisson (Univ. of Sud-Oursy) for his valuable help in the studies of the Kale-Tavas area. The author also thank M. Gürle (DEU-Izmir) for drawing of the figures, E. Sanli (DEU-Izmir) for the photos and M. Fenereci (DEU-Izmir) for typo of manuscript.
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