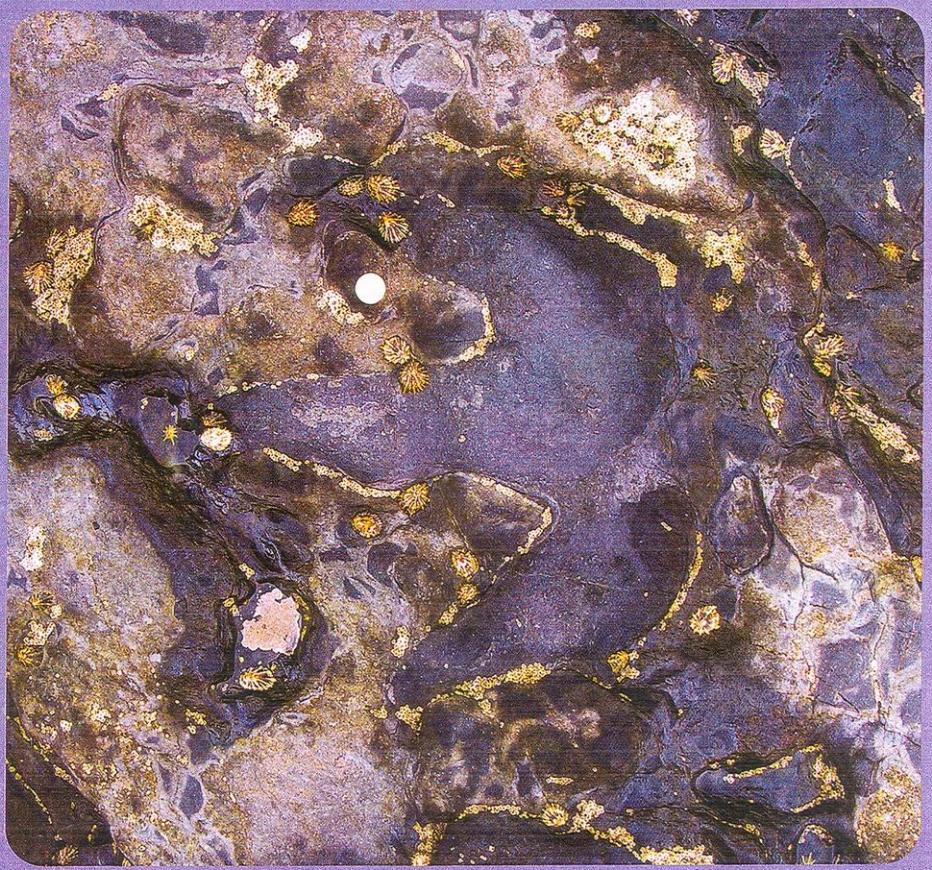
GEOGACETA

Publicada por la Sociedad Geológica de España Nº 36 Septiembre 2004



Editores: M. Segura Redondo, J.M. González Casado y F. Colombo Piñol. ISSN: 0213-683X

Comunicaciones Presentadas en la 36 Sesión Científica

Cathodoluminescence and metamorphism in rudist shells from the Upper Cretaceous marbles of Menderes Massif (Western Turkey)

Catodoluminiscencia y metamorfismo en conchas de rudistas de los mármoles del Cretácico Superior del Macizo de Menderes (W de Turquía)

F. Garcia-Garmilla [1], S. Özer [2] y B. Sari [2]

[1] Dpto. de Mineralogia y Petrologia. Universidad del País Vasco. Ap.644, 48080-Bilbao (Spain)
E-mail: nppgagaf@lg.ehu.es
[2] Dokuz Eylül Üniversitesi. Mühendislik Fakültesi. Jeoloji Mühendisligi Bölümü, 35100 Bornova-Izmir (Turquía). E-mails: sacit.ozer@deu.edu.tr and bilal.sari@deu.edu.tr

ABSTRACT

Radiolitid rudist shells from the Upper Cretaceous marbles in the southern sector of Menderes Massif (Turkey) have been studied under cathodoluminescence microscopy (CL). The background of equant calcite mosaic appears non-luminescent, and only some scarce relicts of growth lines and walls are red and yellow-luminescent. CL observations allow us to think that the Upper Cretaceous marbles of the Menderes Massif were completely homogeneized through high-pressure metamorphism during the Alpine history that led to a strong recrystallization to non-luminescent ferroan calcite. After this process, the "honeycomb" microstructure still remains ill-preserved as some isolated patchs. From our previous observations in bivalve shells from the Middle-to-Upper Cretaceous of the Basque-Cantabrian Region (northern Spain) we think that, in spite of metamorphism, luminiscence survives restricted to the shell parts which originally could host a more dense concentration in organic matter.

Key words: *rudist shells, Upper Cretaceous, Menderes Massif, Turkey, metamorphism, cathodoluminescence.*

RESUMEN

Se han estudiado con microscopía de catodoluminiscencia (CL) varias conchas de rudistas radiolítidos presentes en los mármoles del Cretácico Superior del sector meridional del Macizo de Menderes (Turquía). El mosaico de calcita en cristales equidimensionales carece de luminiscencia, y sólo algunos restos aislados de tabiques y líneas de crecimiento muestran colores rojos y amarillos. Estas observaciones nos llevan a pensar que los mármoles cretácicos del Macizo de Menderes fueron completamente homogeneizados tras el metamorfismo alpino, lo que se tradujo en una fuerte recristalización a calcita férrica no luminiscente. Tras éste proceso, la microestructura "honeycomb" ("en panal de abeja") típica de los radiolítidos sólo se conservó en retazos muy aislados. Por comparación con otros estudios de CL en bivalvos del Cretácico Medio y Superior de la Región Vasco-Cantábrica (norte de España), pensamos que, a pesar del metamorfismo, la luminiscencia aún permanece en las partes de la concha que originalmente pudieron haber sido más ricas en materia orgánica.

Palabras clave: *conchas de rudistas, Cretácico Superior, Macizo de Menderes, Turquía, metamorfismo, catodoluminiscencia.*

Geogaceta, 36 (2004), 167-170
ISSN: 0213683X

Introduction and Geological Setting

The Menderes Massif is located in the Western Turkey between the Izmir-Ankara Zone to the north and Lycian nappes to the south. It is an extentional core complex consisting of an augen gneiss core (Precambrian to Cambrian) and overlying metasedimentary cover (Lower Paleozoic to Lower Paleogene) series (Dürr, 1975; Çaglayan *et al.*, 1980; Sengör *et al.*, 1984; Konak *et al.*, 1987; Dora *et al.*, 1990; Bozkurt & Park, 1994; Hetzel *et al.*, 1995).

The rudist samples of present paper were collected from the southern sector of the Menderes Massif, around Sapliada locality, Akbük (Fig.1a). In this area, the Mesozoic cover series consist mainly of massive platform-type neritic emery and rudist-bearing marbles. Many individual hippuritid species indicating a Santonian-Campanian age, have been determined by Özer (1993, 1998) and Özer *et al.* (2001). The massive rudist-bearing marbles pass gradually upwards (Fig.1b) into the reddish pelagic marbles (Upper

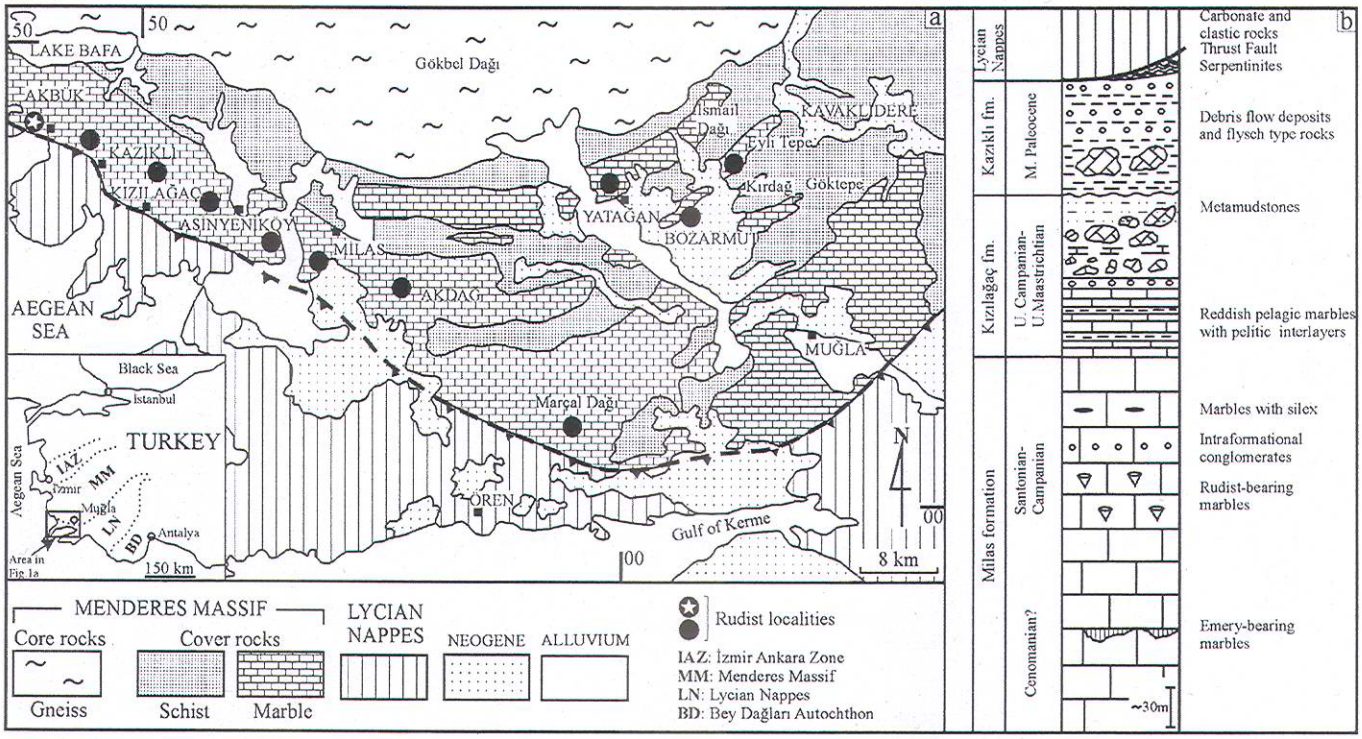


Fig. 1.- a) Geological map of the southern Menderes Massif with indication of rudist localities (modified from Dürr, 1975; Çaglayan *et al.*, 1980 and Konak *et al.*, 1987); b) Generalized stratigraphic section of the Akbük area (after Özer *et al.*, 2001).

Fig. 1.- a) Mapa geológico del sector meridional del Macizo de Menderes con la localización de los yacimientos de rudistas (modificado de Dürr, 1975; Çaglayan* et al., *1980 and Konak* et al., *1987); b) Sección estratigráfica general del sector de Akbük (según Özer* et al., *2001).

Campanian-Upper Maastrichtian) and flysch-type rocks (Middle Paleocene). The cover series of the Menderes Massif were overthrust by the carbonate and clastic rocks of Lycian nappes in this area. The examined marble samples include radiolitid sections belonging to the genus *Sauvagesia* and probably *Durania* (Fig.2).

According to the long established geological concepts, in the southern sector of the Menderes Massif, the uppermost unit of the cover series including rudist-bearing marbles, has been described as slightly metamorphosed at the greenschist-facies conditions (Dürr, 1975; Gutnic *et al.*, 1979; Akkök, 1983; Ashworth & Evirgen, 1984; Sengör *et al.*, 1984; Satir & Friedrichsen, 1986; Konak *et al.*, 1987). However, recently Rimmelé *et al.* (2003) suggest that a high-pressure metamorphism affected the Menderes Massif during the Alpine history when the metasedimentary cover rocks were buried under minimum PT conditions of about 10-12 kbar and 440°C (30 km minimum).

Cathodoluminescence method

Eight thin sections of marbles containing rudists were prepared and polished for observation under cathodoluminescence (CL). A Technosyn Cold Cathode Luminescence system, model 8200 MKII with a vacuum chamber coupled to an Olympus BH-2 research microscope was employed, working under standard operating conditions of

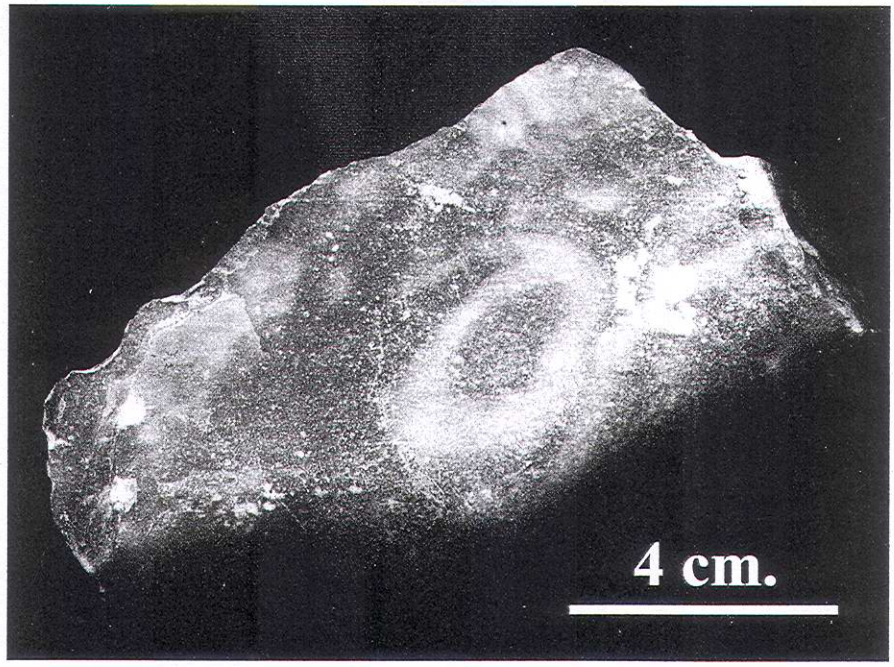


Fig. 2.- A hand-sample of marble (MS 36) containing the radiolitid *Sauvagesia* cf. *tenuicostata* POLSAK. The shell is strongly recrystallized.

Fig. 2.- Muestra de mano (MS 36) de un mármol con* Sauvagesia cf. tenuicostata *POLSAK. La concha está muy recristalizada.

12-15 kV accelerating potential, 0.5-0.6 mA beam current, and a beam diameter of 4.5 mm.

CL is a very useful tool to see diagenetic modifications in bivalve shells. From previous works, we know that CL allows to ellucidate some oblitered microstructures in rudist shells, i.e. some recrystallized growth lines and walls in radiolitids can be recognized by use of this technique (Regidor-Higuera *et al.*, 2002). With the exception of few cases, the recent bivalve shells do not show a luminescent behaviour because of the low content of Mn^{2+} in normal sea water composition (Grossman *et al.*, 1996).

During the last years, our research team in the Basque Country has been concentrated on the recognition of possible ways for diagenetic fluids and studied the distribution of CL in both less-altered shells (Jiménez-Berrocoso & Elorza, 2002; Jiménez-Berrocoso *et al.*, 2003; Regidor-Higuera *et al.*, 2002, 2003), to more intensely affected (Gómez-Alday & Elorza, 2003), to even affected by tectonism and iron mineralizations (Damas *et al.*, 2004). Our experience reveals that CL accurately follows the microstructures in shells (i.e. growth lines) when the diagenetic degree is relatively low. Luminiscence is more intense just in the most obscure parts of the shell, that is to say, those having the highest contents in organic matter. As a result of diagenesis, the original organic matter of the shell suffers from decomposition, and porosity increases allowing the circulation of diagenetic fluids. Diagenesis currently implies the loss of Mg^{2+} and Sr^{2+}, and the entrance of Fe^{2+} and Mn^{2+} (Brand & Morrison, 1987). Nevertheless, we have observed that major diagenetic events like dolomitization may change this geochemical behaviour in a significant manner (Damas *et al.*, 2004). As diagenetic evolution progresses, a major homogeneization of CL in shells is produced. In these cases, luminescence does not coincide with the architectural elements of the shell, suggesting a more active cationic interchange with the host rock with the subsequent modification in the pristine composition of the shell.

Cathodoluminescence in rudist shells

The microfacies of the studied marbles containing rudist shells are very homogeneous and composed of a close homoblastic mosaic of coarse sparry calcite as much as 0.55 mm. in crystal size. Under transmitted light, opaque minerals can be found enclosed into the calcitic groundmass. Scarce relicts of radiolitid rudist shells are shadowed and very difficult to recognize. Nevertheless, some ghosts of both growth lines (horizontal *laminae*, HL) and walls (vertical *muri*, VM) delimiting the original cells of the "honeycomb" microestructure of radiolitids still persist inside the recrystallized mass. These hazy lines appear as discontinuous obscure traces included in the crystalline groundmass. Under CL, the sparry calcite crystals appear non-luminescent, but the growth line remains are marked by more or less densely-condensed, intense-red luminescent calcite minute crystals together with small yellowish rhombic crystals. The Figs.3a and 3b illustrate a recrystallized texture in which a HL can be recognized under CL by a discontinuous cluster of crystals. The VM appear very weakly marked, and outlined by a clearly lesser amount of luminescent crystals. The Figs. 3c and 3d show a similar texture, but in this case both HL and VM are more intensely marked by luminescent crystals. Finally, we have observed in other samples a later system of fractures infilled by strong-red luminescent calcite.

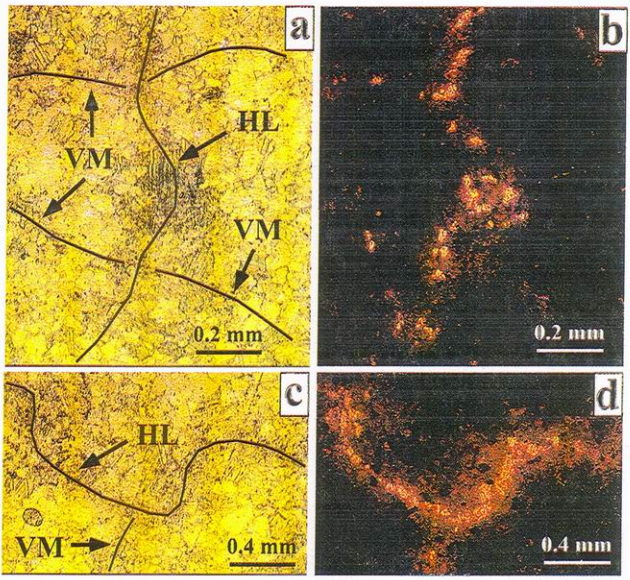


Fig. 3.- Microstructure in *Sauvagesia* cf. *tenuicostata* POLSAK: a, b) a detail of the ghost "honeycomb" structure showing the growth line (HL) marked by a discontinuous line of luminescent crystals, and the walls (VM) even less-marked (PPL and CL); c, d) a similar detail, but showing in this case the growth line (HL) better pictured by luminescent crystals (PPL and CL). In both cases, we have re-drawn the transmitted-light images with a line in order to better visualize the shell microstructure.

Fig. 3.- Microestructura de Sauvagesia cf. tenuicostata *POLSAK: a, b) detalle de la estructura "honeycomb" fantasma con la línea de crecimiento (HL) marcada por una serie discontínua de cristales luminiscentes, y los tabiques (VM), aún menos marcados (PPL y CL); c, d) detalle similar al anterior, pero con la línea de crecimiento (HL) mejor dibujada por los cristales luminiscentes (PPL y CL). En ambos casos, hemos repasado con líneas las imágenes de luz transmitida para una mejor visualización de la microestructura de la concha.*

Discussion and conclusions

Since the Upper Cretaceous marbles of the Menderes Massif seem to have undergone a high-pressure metamorphism reaching to PT conditions of about 10-12 kbar and 440°C, it is logical to suppose, according to Marshall (1988, p.92), that CL should be homogeneous. However, we have already observed important modifications in the luminescent behaviour at the lower pressures and temperatures that

characterize the diagenetic domain. As noted by Regidor-Higuera *et al.* (2002, p.293), the development of cements in cells of radiolitid shells and the recrystallization suffered during middle-to-late diagenetic stages can be responsible for attenuation or even lost of growth lines, in such a manner that only some discontinuous luminescent "patchs" survive. Metamorphism in the Menderes Massif cretaceous sediments was enough high to provoke an extensive recrystallization of the rock, leading to a quasi-complete loss of primary features, such as those related to the shell microstructure of rudists.

Zöldföldi & Satir (2000) and Zöldföldi *et al.* (2002) studied marbles from Greece, Hungary and Slovenia, and saw that those having a high concentration of Mn^{+2} (about 1000 ppm) show an orange luminescence with different colours depending on impurities hosted in the crystal or on lattice defects. Since in carbonates the principal activator of luminescence is Mn^{+2} and the main quencher is Fe^{+2}, we suppose that the balancing between them is responsible for a total quenching of luminescence. Low Mn^{+2} contents implie dull colors or even the lack of luminescence. The Upper Cretaceous marbles of the Menderes Massif have a CL behaviour very similar to those lacking in luminescence described by Zöldföldi *et al.* (2002) in Slovenia Bistrica.

Barbin *et al.*, (1989) studied CL in white marbles from Italy, Greece and Turkey, in order to enlight the historic provenance of dimension stone. A very homogeneous CL behaviour was observed in marbles from Thassos and Carrara (red luminescent) and Paros-Stefani (non-luminescent), but with a particular case recorded in the turkish locality of Usak-Kavacik, where marbles include some porphyroblastic crystals showing zoned luminescence with alternance of yellow and brownish colours. These authors also argued the presence of Fe^{2+} to explain the absence of luminescence in marble samples.

From the comparison to other marble-types of the Mediterranean Domain, we think the Upper Cretaceous marbles of the Menderes Massif were homogeneized through metamorphic processes which led to a strong recrystallization to non-luminescent ferroan calcite, but not in a degree as high as to substantially modify the external shape of the shells or completely destroy the "honeycomb" microstructure of radiolitids. In fact, some "patchs" of this microstructure appear poorly-preserved and marked by a red luminescence together with small yellowish rhombic crystals.

Acknowledgements

This study has been supported by the Research Project 1/MCYT 00130.310-15226/2003 (BTE2003-00733) (Spanish *"Ministerio de Ciencia y Tecnología"*). We thank Francisco de la Cruz and Iván Regidor-Higuera for the accurate preparation and polished of rock thin sections, respectively.

References

Akkök, R. (1983): *Journal of Geology*, 91, 342-350.

Ashworth, J.R. & Evirgen, M.M. (1984): *Geological Magazine*, 121 (4), 323-337.

Barbin, V.; Ramseyer, K.; Decrouez, D. & Herb, R. (1989): *Comptes Rendus Académie des Sciences, Paris*, 308 (2), 861-866.

Bozkurt, E. & Park, R.G. (1994): *J. Geol. Soc. London*, 151, 213-216.

Brand, U. & Morrison, J.O. (1987): *Geoscience Canada*, 14, 85-107.

Çaglayan, A.M.; Öztürk, E.M.; Öztürk, Z.; Sav, H. & Akat, U. (1980): *Jeol. Müh. Derg.*, 10, 9-18.

Damas-Mollá, L.; Aranburu-Artano, A. & García-Garmilla, F. (2004): *Geogaceta*, 36, 159-162

Dora, Ö.O.; Kun, N. & Candan, O. (1990): *International Earth Sciences Congress -on Aegean Regions.* Proceedings II, 102-115

Dürr, S. (1975): Uber alter und geotektonische stellung des Menderes-Kristallins, SW Anatolien und seine Aequivalente in der Mittleren Aegaeis. *PhD Thesis*, 107 pp.

Gómez-Alday, J.J. & Elorza, J. (2003): *Netherlands Journal of Geosciences/ Geologie en Mijnbow*, 82 (3), 289-301.

Grossman, E.L.; Mii, H.-S.; Zhang, C. & Yancey, T.E. (1996): *Jour. Sed. Research*, 66, 1011-1022.

Gutnic, M.; Monod, O.; Poisson, A. & Dumont, J.F. (1979): *Mém. Soc. Géol. Fr.* 137, 1-112.

Hetzel, R.; Passchier, C.W.; Ring, U. & Dora, Ö.O. (1995): *Geology*, 23 (5), 544-458.

Jiménez-Berrocoso, A. & Elorza, J. (2003): *Geogaceta*, 32, 271-274.

Jiménez-Berrocoso, A.; Zuluaga, M.C. & Elorza, J. (2003): *Geogaceta*, 34, 143-146.

Konak, N.; Akdeniz, N. & Öztürk, E.M. (1987): Geology of the south of Menderes Massif: Mineral Research and Exploration Institute of Turkey, *Guide book, IGCP project no. 5, correlation of Variscan and pre-Variscan events of the Alpine-Mediterranean mountain belt.* 42-53.

Marshall, D. J. (1988): *Cathodoluminescence of Geological Materials.* Unwin Hyman, 146 pp.

Özer, S. (1993): *Bull. Geol. Soc. Greece*, 28 (3), 55-73.

Özer, S. (1998): *Geobios Mem. Spec.* 22, 235-249.

Özer, S.; Sözbilir, H.; Özkar, S.; Toker, V. & Sari, B. (2001): *Int. J. Earth Sci.*, 89, 852-866.

Regidor-Higuera, I.; García-Garmilla, F. & Elorza, J. (2002): *Geogaceta*, 32, 291-294.

Regidor Higuera, I.; García-Garmilla, F.; Zuluaga, M.C. & Elorza, J. (2003): *Geogaceta*, 34, 183-186

Rimmelé, G.; Jolivet, L.; Oberhansli, R. & Goffé, B. (2003): *Tectonics*, 22 (2), 1007.

Satir, M. & Friedrichsen, H. (1986): *Geol. Runsch.*, 75, 703-714.

Sengör, A.M.C.; Satir, M. & Akkök, R. (1984): *Tectonics*, 3, 693-707.

Zöldföldi, J. & Satir, M. (2000): *Beihefte zum European Journal of Mineralogy*, 12, H.1, 242.

Zöldföldi, J.; Tóth, M.; Székely, B.; Satir, M. & Árkai, P. (2002): *33rd International Symposium on Archaeometry (Amsterdam, The Netherlands)*