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Bioerosion Structures on the *Crassostrea gryphoides* (Schlotheim, 1813) Shells from the Salyan Formation (Upper Burdigalian-Lower Langhian), K. Maraş, Southeastern Turkey

Salyan Formasyonu'undaki (Üst Burdigaliyen-Alt Langiyen) Crassostrea gryphoides (Schlotheim, 1813) Kavkıları Üzerinde Biyoerozyon Yapıları, K. Maraş, Güneydoğu Türkiye

İzzet HOŞGÖR [1] and Yavuz OKAN [2]

[1] *Transatlantic Petroleum (Turkey) corp., Ankara, Turkey*

[2] *Ankara University, Faculty of Engineering, Dept. of Geological Engineering, Tandoğan, 06100, Ankara, Turkey*

ABSTRACT

The Salyan Formation (Upper Burdigalian-Lower Langhian) of K. Maraş, Turkey contains thick-bedded deposits of oysters. Bioerosion structures found on the Early-Middle Miocene oyster specimens *Crassostrea gyrphoides* (Schlotheim, 1813) from the Northwestern K. Maraş Basin area are much affected by the boring of micro-organisms. The borings, represented by three ichnogenera, are assigned to *Renichnus* isp., *Caulostrepsis* isp., and *Entobia* isp. The activity of Clionid sponges, Polychaete worms and vermetid gastropods have also been observed.

Key Words: bioerosion, *Crassostrea gryphoides*, Salyan Formation, Upper Burdigalian-Lower Langhian, K. Maraş, Turkey

ÖZ

K. Maraş'da Salyan Formasyonu (Üst Burdigaliyen-Alt Langiyen) kalın oyster depoları içermektedir. Kahramanmaraş Miyosen Havza'sının kuzeybatısında, oyucu/delici mikro-organizmalar tarafından oluşturulan biyoerozyon yapıları Crassostrea gryphoides (Schlotheim, 1813) oyster türü üzerinde bulunmuştur. Bu oyuk/delikler üç iz fosil cinsini; Renichnus isp., Caulostrepsis isp., ve Entobia isp., işaret etmektedir. Bu yapılar Klionid süngerler, Polychaete kurtlar ve vermetid gastropodların aktiviteleri olarak gözlemlenmşitir.

Anahtar Sözcükler: *biyoerozyon, Crassostrea gryphoides, Salyan Formasyonu, Üst Burdigaliyen-Alt Langiyen, K. Maraş, Türkiye*

INTRODUCTION

Bioerosion structures found on *Crassostrea gryphoides* (Schlotheim, 1813) shells of the Salyan Formation (Early-Middle Miocene) of K. Maraş are described, and the main paleoenvironmental conditions and taphonomic processes are analyzed. The term bioerosion was introduced by Neumann in 1966 as an abbreviated form of the phrase biologic erosion. It has been used to identify the processes by which animals, plants and microbes penetrate into hard substrates (Bromley, 1992).

The Miocene rocks exposed in the North of the K. Maraş Basin in Southeastern Turkey (Figure 1) contain a rich macroinvertebrate fauna dominated by bivalves, gastropods, scophids and echinoids (Hoşgör, 2008). With their large size and distinct shape, representatives of the bivalve genus *Crassostrea* form a conspicuous element of the fauna, and are particularly well represented in Miocene beds. The most dominant element of the benthic community in the Late Paleogene-Neogene areas of southern Turkey are oysters, which are particularly well represented in the Oligocene to Miocene (Hoşgör, 2008; Hoşgör and Okan, 2009). Morphologically, Miocene oyster shells are strongly influenced by ecological factors. In addition, they display interesting traces of boring predation and many signs of post-mortem processes (bioerosion), and other taphonomical features that give important indications of the post-mortem processes acting on their shells. The borings refer to the activities of Clionid sponges, Polychaete worms and vermetid gastropods that have been observed.

GEOLOGICAL SETTING

A number of sedimentary basins were formed within the Tauride-Anatolide Platform of Anatolia during the Late Cretaceous-Tertiary period. In southeastern Turkey, the most complete Miocene rock sequence of the East Taurus Belt is exposed in the K.Maraş area (Figure 1). The Miocene stratigraphic record in the North of the K. Maraş area, in the Salyan Formation, is characterized by a thin marine and coastal plain interval interfingered within terrestrial conglomerates (Hoşgör, 2008). The typical locations of the unit in the area are around Salyan, Saraycık and Ahmetcik Valley (Figure 1). The Salyan Formation (SW Çardak) is represented by conglomerate, sandstone, marl, shale and limestone, all belonging to the molasse facies (Figure 2). The outcrops of the limestone member are observed around Salyan Valley. The limestone, which is sandy, bioclastic and with abundant macro and micro fossils, is laterally wedged. It contains Early-Middle Miocene fauna (Hoşgör, 2008). The Salyan Formation lies over the Berit group and the Malatya Metamorphics units. The Malatya Metamorphics and the melange units are thrust over the formation, which are overlain unconformably by the Miocene sequences. The geological evolution and the development of the marine Miocene of the K. Maraş area have been discussed at length by several authors (Gözübol and Gürpınar, 1980; Perinçek and Kozlu, 1984; Tarhan, 1984; Önalan, 1988; Yılmaz *et al.,* 1993; Derman *et al.*, 1996; Yılmaz and Gürer, 1996; Robertson *et al.*, 2005; Hoşgör, 2008).

BIOEROSION AND TAPHONOMIC PROCESSES

Bioerosion is known to be a major process driving the degradation of carbonate skelatel material and rocky limestone coasts in all marine and some freshwater environments, in concert with physicochemical dissolution and mechanical abrasion. A wide range of mechanical and/or chemical boring organisms are known to infest calcareous substrates, comprising macroborers (such as sponges, bryozoans, worms, molluscs, etc.) and microborers (mainly bacteria, fungi and algae) (Golubic *et al.,* 1975; Taylor and Wilson, 2003). In intertidal and shallow sublittoral environments, boring marine organisms are the primary agent of shell destruction (Cutler and Flessa, 1995; El-Hedeny, 2005); their importance increases with productivity and decreases with higher sedimentation. Besides, bioerosion is an important factor making differences in the preservation of fossil fauna. Considering the fossil record, oysters constitute one of the most ubiquitous groups in marine deposits due to a high preservation potential shown by their shells. Moreover, borings appear to be widely distributed in their shells.

The Late Burdigalian-Early Langhian species of *Crassostrea gryphoides* (Schlotheim, 1813) of the Salyan Formation are much affected by the boring of micro-organisms. It is observed that 22 (88%) out of 25 of the Early-Middle Miocene oyster species of K. Maraş are affected by bioerosion. Among them the number of left valves as 12, while the number of right valves was 10. A number of bioerosion traces refer to the activity of Clionid sponges. *Entobia* isp. is a product of borings by clionid sponges (Bromley and D'Alessandro 1984). Activities of polychaete worms and vermetid gastropods are also recorded.

During the life of oysters, the influence of biological and environmental factors upon their valve morphology can be pronounced. After their death, they do not enter the fossil record without taphonomic modification on the sediment surface or within the sediment. The following paragraphs will provide some important information relating to the paleoecological influences and taphonomic processes (Kidwell, 2002) that had an effect on the Early-Middle Miocene oyster species *Crassostrea gryphoides* (Schlotheim, 1813) assemblage of northwest K. Maraş area (Salyan Formation). Howover, paleoecologically the Miocene oyster shells in the studied area are characterized by large and massive valves as compared to their recent representatives (Figure 3).

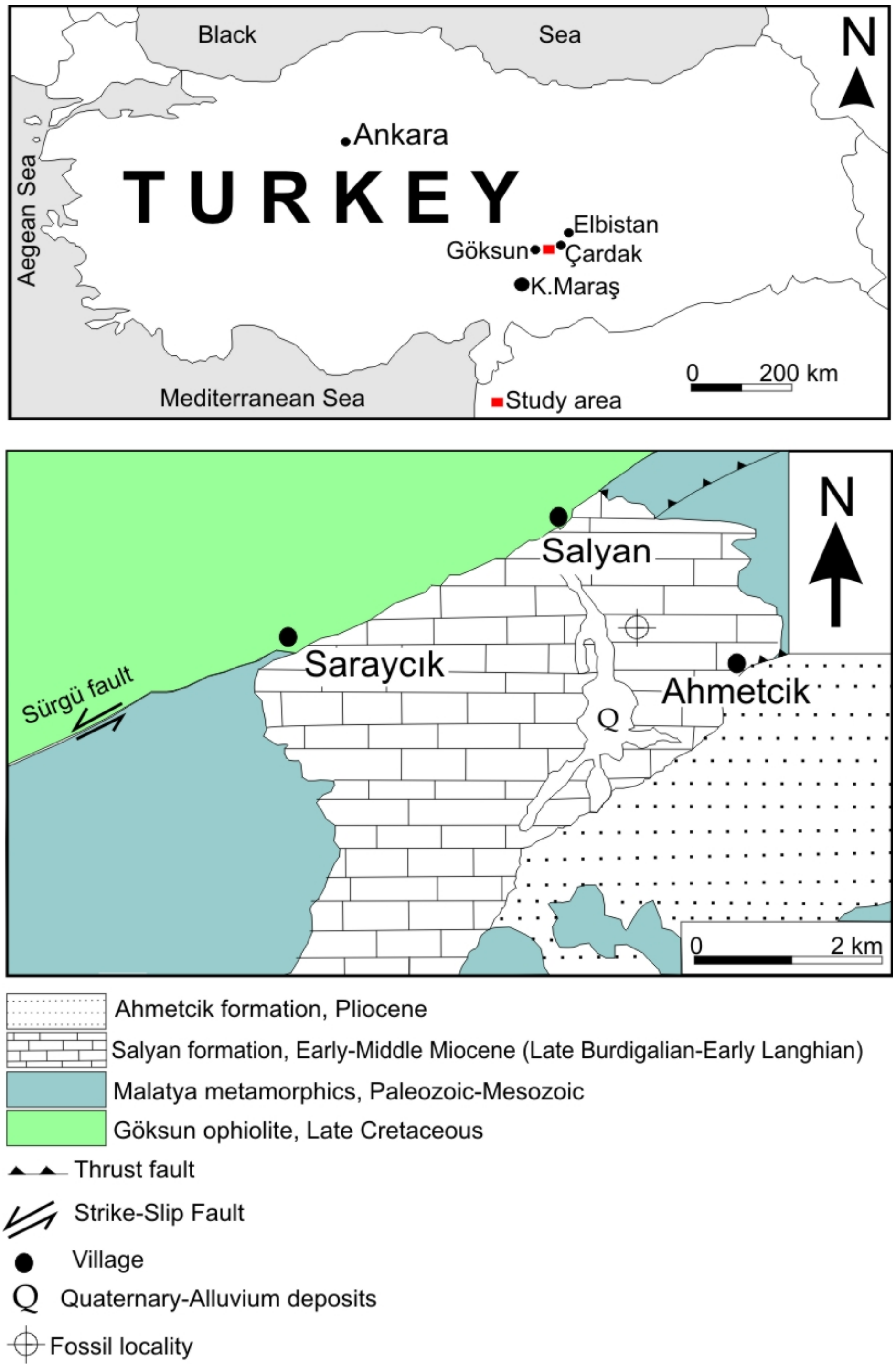

Figure 1. Location and regional geological map of the studied area (Hoşgör, 2008).

Şekil 1. *Çalışma alanının yer bulduru ve jeoloji haritası (Hoşgör, 2008)*

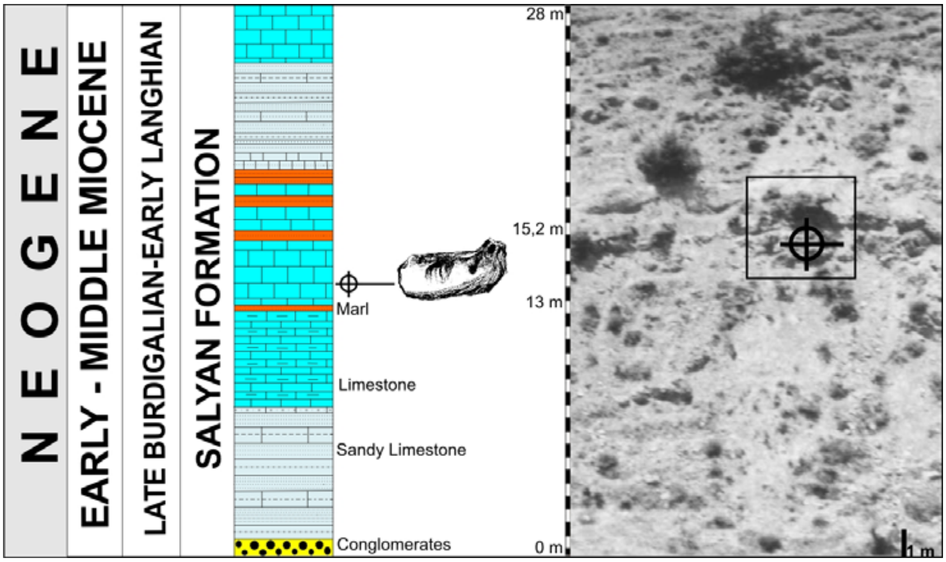

Figure 2. Measured stratigraphic section from Salyan Formation (Hoşgör, 2008).

Şekil. 2. *Salyan Formasyonunda ölçülen stratigrafi kesiti (Hoşgör, 2008).*

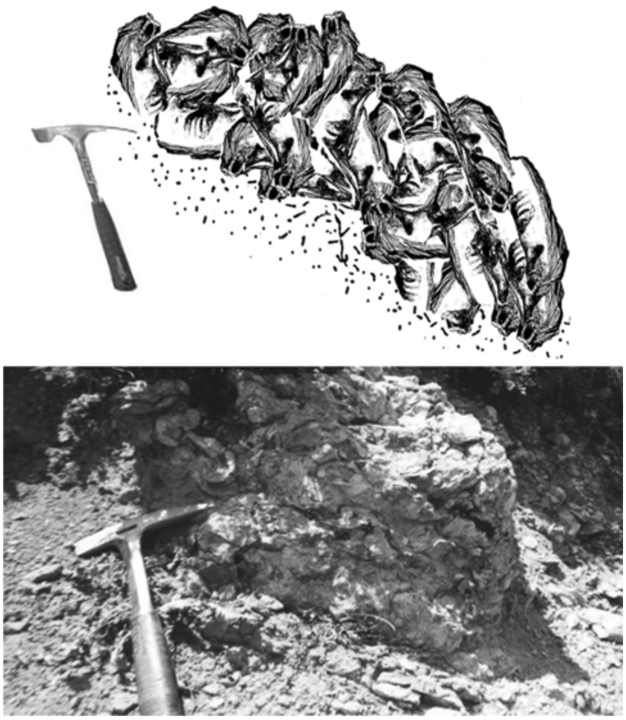

Figure 3. Large and massive valves from *Crassostrea gryphoides* (Schlotheim) and simplified sketch to illustrate the oysters assemblage.

***Şekil 3.** Geniş ve büyük yapılı Crassostrea gryphoides (Schlotheim) kavkıları, arazi ve şekilsel görünüşü.*

It is remarkable that some of the studied Miocene oyster shells are stacked as densely packed shells. This phenomenon strongly reflects deposition in storm-generated waves and indicates deposition above the storm wave-base (Aigner, 1984; El-Hedeny, 2005). That this deposition occurred after their death is indicated by some post-mortem processes on their shells. These processes tend to alter shell material from its original state at the time of death until its final burial and ultimate preservation as part of fossil shell assemblages. They include biostratinomic processes, which occur between the death of an organism and its final burial, and diagenetic processes, which occur subsequent to final burial (Brett and Baird, 1986). Certain pre-biostratinomic processes, notably the feeding activities of predators, extend into the pre-diagenetic processes by influencing the initial state of shell material as it enters the upper sediment layer of the taphonomically active zone (Davies *et al*., 1989) where rates of dissolution, abrasion and bioerosion are most intense. Taphonomic processes commonly described include decomposition, dissolution, abrasion, bioerosion, fragmentation and the biological and hydraulic reworking of skeletal remains. Disarticulation, bioerosion and encrustation, respectively, are considered as the most predominant taphonomic features recorded in the Early-Middle Miocene *Crassostrea gryphoides* (Schlotheim, 1813) of the Salyan Formation.

Specimens of *Crassostrea gryphoides* (Schlotheim, 1813) founded a colony-forming in the shell beds. The form of colonies of oysters show the shells attached to other oyster shells and consitıtuting radially arranged, bouquet-like aggregates (Figure 3) (Komatsu *et al.,* 2002; Hoşgör, 2008). These aggregates are usually found in the upper part of dense shell beds, are about 0-3 m or less in diameter, and are composed of several tens of individuals, many being articulated and embedded in a sandstone matrix. The shells in the basal part of the colony are attached to other flatlying shells. Large individuals near the centre of the colony are usually encrusted with juveniles of later generations. Some oyster forms lie parallel to the bedding, but the individuals appear to have maintained their original relative positions within the colonies.

BIOEROSION

Bioerosion is the process by which organisms sculpt or penetrate hard substrates. The resultant biogenous structures qualify as trace fossils and are named ichnotaxa (Ekdale *et al.,* 1984; Bromley, 1994). As reviewed by Pleydell and Jones (1988), such ichnotaxa are characteristic of, but not exclusively limited to, rocky shorelines, hardgrounds and reefs. Moreover, Ekdale *et al.* (1984) proposed a classification of bioerosion structures based on their morphology and ethology. This classification has been of common use among ichnologists (Martinell, 1989; Bromley, 1992) and some groups of structures have been discussed.

Recently, Taylor and Wilson (2002) proposed a new, more informative terminology for marine organisms inhabiting hard substrates. Besides, trace fossils nomenclature is a discipline distinct from the traditional biological systematic one. This is due, in part, to the intimate relationship between trace fossils and the taphonomic processes (Macnaughton and Pickerill, 2003).

SYSTEMATIC PALEOICHNOLOGY

Ichnogenus *Renichnus* Mayoral 1987

Renichnus isp.

Pl. 1, Figs.1-2

Figured Specimens. SETKS 04. 01S. 02

Horizons and Localities. NE Göksun, Salyan Valley, 13-15.2 m.

Description and Discussion. Kidney-shaped depressions in the form of a half moon, disposed in a crude row or coarsely coiled. There is a straight to gently curved succession of closely associated, progressively broader, kidney-shaped depressions with smooth walls. Up to 3 depressions are found per specimen. Walls between the depressions are either perpendicular to the surface or slightly oblique. The lining apparent in some depressions is presumably a remnant of the original gastropod shell. Some vermetid gastropods, however, deeply etch the carbonate substrates, attaching the shell directly to the skeletal substrate or limestone. The corresponding structures have the ichnogenus *Renichnus* (Savazzi, 1996; Bromley and Heinberg, 2006).

Radwanski (1977, p. 247, pl. 9, pl. 10, figs. a-c) discussed the cementation and embedment of modern vermetid gastropods, and their implications for ichnology (Savazzi, 1996; Donovan, 2003). Bromley and Martinell (1991) discussed the similarities between *Renichnus* and *Centrichnus* Bromley and Martinell 1991, and the latter was interpreted as the etching traces of anomiid bivalves and verrucid cirripedes. Moreover, *Radulichnus* Voight 1977 (Jagt, 2003, p.177, pl. 2, fig.3),is a very similiar ichnogenus, described from the Maastrichtian of the Netherlands and Belgium (Jagt, 2003) and from the Middle Miocene of Egypt on the oysters shells (El-Hedeny, 2005, p.724, pl. 1, fig.E). It is differentiated from *Renichnus* isp., by a number of specimens showing parallel sets of straight to slightly curved scrape marks forming scoop-like depressions. The ichnogenus *Renichnus* was redefined by Mayoral (1987) for borings, generally from Mesozoic and Cenozoic, that closely resemble the work of living vermetid gastropods.

This is the first record of *Renichnus* isp., from the fossil record of Turkey. The other trace fossils, *Entobia* isp., and *Caulostrepsis* isp., were found in the Miocene Mut Basin, but the trace fossils were recorded on the sedimentary sequence (Uchman *et al*., 2002). It is generally accepted that *Renichnus* isp., represents the cementation and embedment trace produced by attachment of a vermetid gastropod. Four vermetid species are found in the Miocene shallow-water environments of South Turkey, attached to rocks, dead corals and bivalves (Erünal-Erentöz, 1958). Most of these species have been identified from the Salyan Formation.

In this formation, the macroinvertebrate fauna consist of bivalves. The abundant and generally well-preserved bivalves are dominated by *Crassostrea gryphoides* (68%). These lithologic units contain abundant veneroid, arcoid bivalves and vermetid gastropods (Hoşgör, 2008). Moreover, the description and paleontologically identified vermetid gastropod species of *Petaloconchus intortus* (Lamarck, 1818) (Pl. 1, fig. 4) are from the Salyan Formation (Erünal-Erentöz, 1958; Baluk, 2006). In conclusion, the oyster and vermetid gastropod association refers to *Renichnus* traces. Similarly, four of the extant Antillean species are attributed to *Petaloconchus* Lea 1843, a genus known to have produced *Renichnus* traces in the Miocene southern Poland (Radwanski, 1977).

The *Renichnus* isp., must have been produced after the oyster was dead (Figure 4) as it is on an interior valve surface, but the other ichnogenera may have been excavated in living hosts (Paul.D. Taylor, pers. comm., 2006).

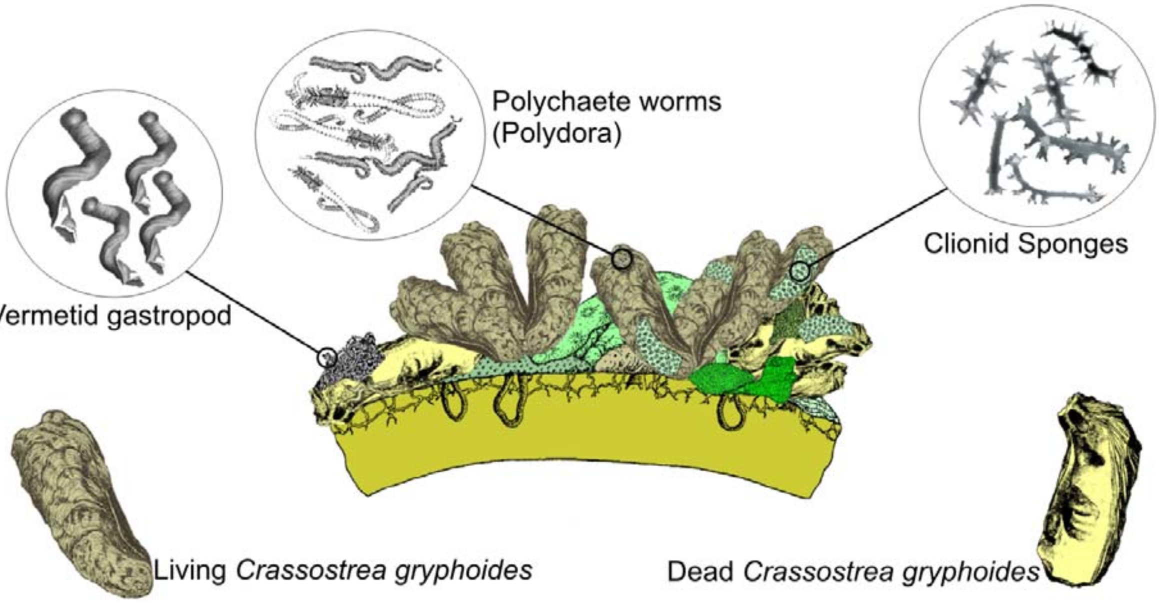

Figure 4. Distribution of a microcommunity structure on a typical heavily encrusted, Early-Middle Miocene *Crassostrea gryphoides* from K. Maraş. This is the maximum development of endo/epibiont habitation observed on oysters shells from the study area, suggesting a sequence of microcomunities or associations from clionid sponge borings, boring U-shaped polychaete worms and vermetid gastropods.

Şekil 4. *Erken-Orta Miyosen K.Maraş, Crassostrea gryphoides kavkıları üzerinde ağrlıklı olarak gözlenen mikrobirlikteliklerin dağılımı. İstifde çoğunlukla oyster kavkıları üzerinde veya iç bölgesinde gelişmiş olan yapılar klionid süngerler, U-şekilli oyucu polychaete kurtlar ve vermetid gastropodlar tarafından oluşturulmuştur.*

Ichnogenus *Entobia* Bronn 1837

Entobia isp.

Pl.1, Figs. 3, 7

Figured Specimens. SETKS 04. 01S. 03 and 04.

Horizon and Localities. NE Göksun, Salyan Valley, 13-15.2 m.

Description and Discussion. Entobia isp., several examples were found (SETKS 04. 01S. 03, 04, 05, 06, 07, 08 and 09). A detailed description and ichnospecific assignment is unwarranted for several reasons: Specimens are intensely weathered or poorly preserved, the latter a common consequence of secondary recrystallization and associated dissolution; several are fragmentary and incomplete segments of borings; and some examples are preserved on shell interiors or exteriors only, precluding the three-dimensional analysis necessary for ichnospecific assignment (Bromley and D'Alessandro, 1984; Pickerill *et.al.,*2002). The many and varied morphological parameters used to distinguish the numerous ichnospecies of Entobia have been discussed by Bromley and D'Alessandro (1984). Of these criteria, size, arrangement and fusion/non-fusion of chambers, and the presence and dimensions of the various canal systems were considered the most significant.

The material may exhibit essentially only apertural canals or, alternatively, multiple boxwork chambers interconnected by intercameral canals, but never in mutual association. Camerate entobian are composed of net-works of chambers arranged parallel to the external oyster shell.

The ichnogenus *Entobia* was redefined by Bromley (1970) for borings from the Mesozoic and Cenozoic that closely resemble the work of living clionid sponges. Living clionid sponges occur widely in reefs today, and did so during the Mesozoic and Cenozoic (Johnson and Baarli, 1999). *Entobia* is a product of borings by clionid sponges (Figure 4) (Bromley and D'Alessandro, 1984). Historically, the terminology applied to the anatomical parts of the clionid sponge boring *Entobia*, and its synonyms and numerous ichnospecies, has proven convoluted. Sponges that produce *Entobia* are also known to thrive in clear waters with very low sedimentation (Görög and Somody, 1987; Domenech *et. al.,* 2001; Farinati and Zavala, 2002).

Bores also appeared as small, rounded and closely spaced chambers that are mainly related to ichnogenus *Entobia* Bronn, 1837 (the depth of its penetration did not exceed 3 mm). In these cases yjr bore diameters varied from 0.5 to 1.0 mm . The walls of the bores are sharply vertical and rarely degraded.

The Domichnial structures (*Entobia* isp.) of macroborings were produced on either live or dead hosts (Figure 3) (Pickerill *et. al*., 2002). It is observed that borings are concentrated in some specific sites, in both the inner and outer surfaces of the oyster shells. They occur mainly very close to the ligamental area (pl. 1, fig. c) and to the external view of the left valve (pl. 1, fig. g). In addition, the presence of microborings in the inner surface of the dorsal margin of shells indicates the rapid activity of the sponge directly after the death of the oyster when the two valves starting gaping.

Boring sponges predominantly belong to the family Clionidae, Class Demospongiae. They bore into calcareous substrates by chemically etching chips (10 to 100 μm) with specialized archeocyte cells (Cobb, 1969). The chips are expelled through the exhalent water currents. The resulting borings are roughly spherical chambers, one to a few milimeters in diameter, connected by smaller canals (0.10 mm diameter). If the calcareous substrate is homogenous and spacious, colonizing sponges may produce the idiomorphic (species characteristic) borings of the ichnogenus *Entobia*, which contains several ichnospecies (Bromley and D'Alessandro, 1984-1989; Stearly and Ekdale, 1989).

Ichnogenus *Caulostrepsis* Clarke 1908

Caulostrepsis isp.

Pl.1, Figs. 5-6

Figured Specimens. SETKS 04. 03S. 04 and 05.

Horizons and Localities. NE Göksun, Salyan Valley, 13-15.2 m.

Description and Discussion. Smooth, elongate, U-shaped galleries with fused limbs and no central vane, a central axial depression that extends from the distal U-bend along the entire exposed length. Galleries are variably oriented, straight to curved, but never tortuous. Length, mostly incomplete up to 15 mm; width 1,5-3 mm.

Caulostrepsis is generally considered to result from the euendolithic or paraendolithic activities of polychaete annelids (*Polydora* sp.) (Figure 4) of various families (Bromley, 1978-1994; Bromley and D'Alessandro, 1983), most probably spionids (Barrier and D'Alessandro, 1985; Bromley and D'Alessandro, 1989; Paul Taylor, pers. comm. 2006). Polychaetes of the family Spionidae bore chemically as well as mechanically. Members of the genus *Polydora* create simple to meandering U-shaped borings whereby the tunnels (with a diameter of 1-2 mm) are separated by a spreite (Feige and Fürsich, 1991). Boring traces of the polychaete *Polydora,* the ichnogenus *Caulostrepsis* isp., were found in shallow water conditions. *Polydora* resembling the ichnospecies *Caulostrepsis cretacea* Voigt 1971 were recently very common in the shallowest station, especially in the lagoonal setting, and were also rarely found at water depths of 7 and 15 m (Wisshak *et al*., 2005).

CONCLUSIONS

The Early-Middle Miocene oysters, *Crassostrea gryphoides* (Schlotheim, 1813) of the Salyan Formation are characterized by large and massive valves. Their shells exhibit significant information about paleoecology and the post mortem processes. Paleoecologically, they were living in nearshore shallow, low-energy marine environments. After their death, they were deposited by storm-generated waves above the storm wave-base.

The Late Burdigalian-Early Langhian oysters of East Göksun area are much affected by post-mortem boring of organisms (activity of a variety of organisms including gastropods, sponges and polychaetes). The borings can be regarded as relatively diverse, being represented by ichnotaxa *Renichnus* isp., *Caulostrepsis* isp., and *Entobia* isp. They are concentrated in some specific sites, both in the inner and outer surfaces of the oyster shells.

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GENİŞLETİLMİŞ ÖZET

Bu çalışmada K. Maraş'da Salyan Formasyonu (Üst Burdigaliyen-Alt Langiyen)'da Crassostrea gryphoides oyster kavkıları üzerindeki biyoerozyon yapıları incelenmeye çalışılarak, paleoortam ve tafonomik gelişimi analiz edilmiştir. Terim olarak Neumann (1966) tarafından ortaya atılan biyoerozyon, daha sonra Bromley (1992) tarafından detaylı bir şekilde sınıflandırılmıştır. Güneydoğu Anadolu'da GeçPaleojen-Neojen istiflerinde oyster türleri belirleyici bir rol oynar. Özellikle Crassostrea türlerinin, bu bölgelerde son yapılan çalışmalar ile Oligosen-Miyosen yaş aralıklarında yaygınlığı belirtilmiştir (Hoşgör, 2008; Hoşgör ve Okan, 2009). Kalın ve yer yer buket şeklinde gelişmiş koloni yapıları ile çevresel etkilere herzaman açık olan bu kavkı yığınları üzerinde biyoerozyon yapıları gelişebilmiştir. Kahramanmaraş Miyosen Havza'sının kuzeybatısında, oyucu/delici mikro-organizmalar tarafından oluşturulan biyoerozyon yapıları Crassostrea gryphoides oyster türü üzerinde bulunmuştur. Bu oyuk/delikler üç iz fosil cinsini; Renichnus isp., Caulostrepsis isp., ve Entobia isp., işaret etmektedir. Bu yapılar Klionid süngerler, Polychaete kurtlar ve vermetid gastropodların aktiviteleri olarak gözlemlenmşitir.

PLATE 1

All specimens are from the limestone member at the Salyan Formation (Salyan Valley).

1-3, 5-7. *Crassostrea gryphoides* (Schlotheim, 1813);

Figure 1. Internal view of the left valve showing borings reflecting activity of vermetid gastropod and clionid sponges,

Figure 2. ***Renichnus* isp.,** SETKS 04. 01S. 02;

Figure 3. ***Entobia* isp.,** SETKS 04. 01S. 03;

Figure 4. Species of vermetid gastropod, ***Petaloconchus intortus*** (Lamarck, 1818);

Figure 5. *Crassostrea gryphoides* (Schlotheim, 1813); internal showing elongate U-shaped galleries related to ***Caulostrepsis* isp.**, SETKS 04. 03S. 04;

Figure 6. external view of the left valve showing the U-shaped galleries related to ***Caulostrepsis* isp.,** SETKS 04. 03S. 05;

Figure 7. *Crassostrea gryphoides* (Schlotheim, 1813); external view of the left valve showing small borings related to ichnogenus ***Entobia* isp.,** SETKS 04. 01S. 04.

(Scale bars represents 10 mm).

LEVHA 1

Tanımlanan türler Salyan Formasyonu (Salyan Köyü) kireçtaşı üyesindendir.

1-3, 5-7. *Crassostrea gryphoides* (Schlotheim, 1813);

Şekil 1. Vermetid gastropod ve klionid süngerlerin delici aktivitelerinin iç-sol kapaktan görünümü.

Şekil 2. ***Renichnus* isp.,** SETKS 04. 01S. 02;

Şekil 3. ***Entobia* isp.,** SETKS 04. 01S. 03;

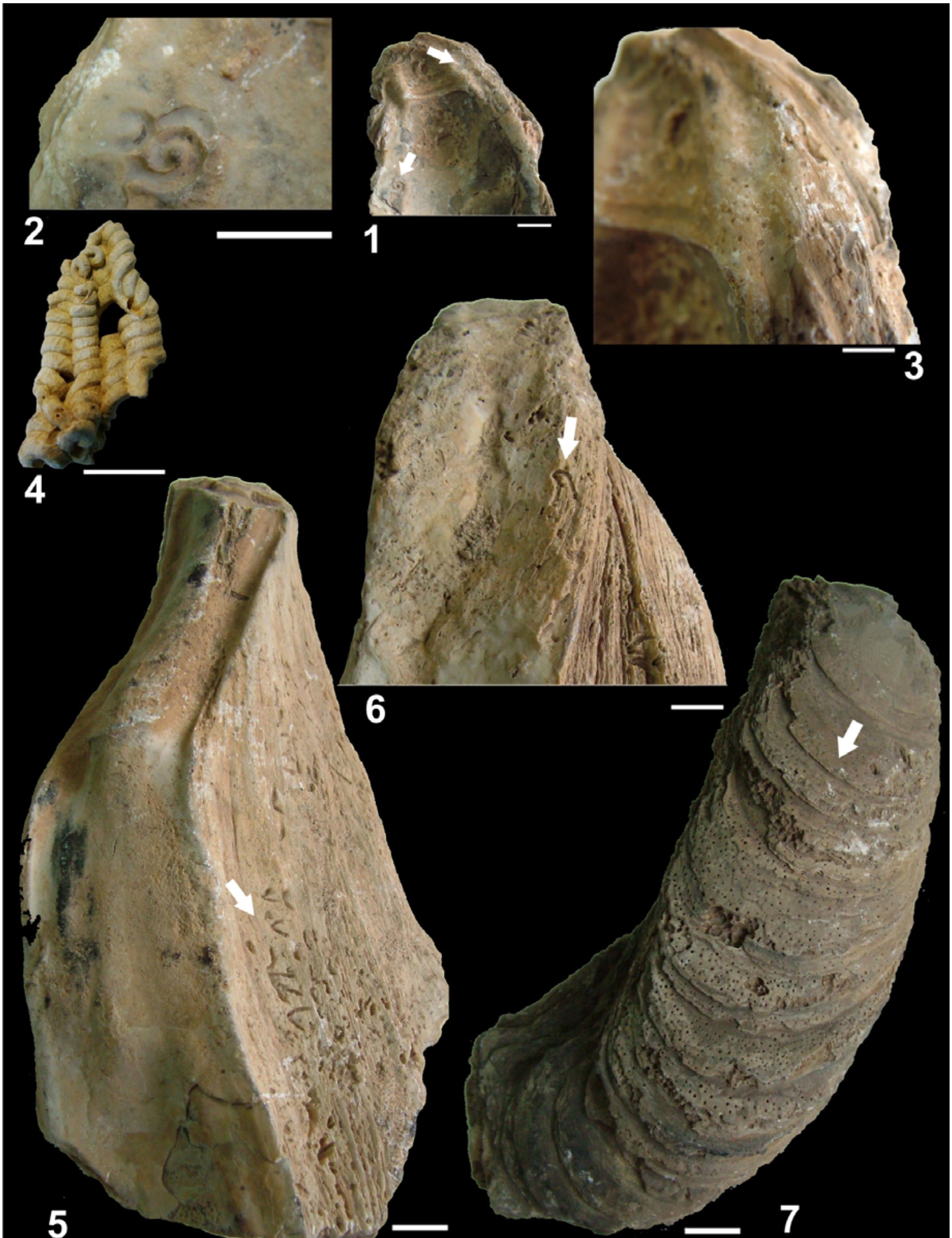
Şekil 4. Vermetid gastropod türü, ***Petaloconchus intortus*** (Lamarck, 1818);

Şekil 5. *Crassostrea gryphoides* (Schlotheim, 1813) kavkısının iç kısmında U-şeklinde galeri açan ***Caulostrepsis* isp.**, SETKS 04. 03S. 04;

Şekil 6. Sol kapak dışında U-Şeklinde galeri açan ***Caulostrepsis* isp.,** SETKS 04. 03S. 05;

Şekil 7. *Crassostrea gryphoides* (Schlotheim, 1813) kavkısının dış kısmında kavkı üzerinde küçük oyucuların oluşturduğu yapı, ***Entobia* isp.,** SETKS 04. 01S. 04.

(Ölçek 10 mm).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