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FACIES CHARACTERISTICS AND GEOGRAPHIC DISTRIBUTION OF RHODOLITHS AND MAERLS (RED ALGAE) IN SOUTHERN SHELF OF THE SEA OF MARMARA

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ABSTRACT.- Irregular crusts, rhodolith and maerl facies of crustose coralline red algaes were determined in the recent sediments of southern shelf of Marmara sea. Rhodoliths are found in western off shore of the Kapıdağ peninsula at a depth of 27-52.5 m. They have a diameter of 1-8 cm and are composed of *Lithothamnion corallioides* Crouan and Crouan (1867). They exhibit different growth shapes depending on the environmental conditions and may be found as laminated, nodular, and ball shapes in high-energy, shallow (0-30 m) aerated waters. Maerls are also composed of *Lithothamnion corallioides.* In between Kapıdağ and Bozburun peninsulas and a depth of 27-52.5 m, they are observed as free, open branch, spheroidal, ellipsoidal, and discoidal shapes. *Phymatolithon calcareum* Adey and McKibbin (1970) is another species of red algae. It forms irregular crusts coiling around the rock fragments, pebbles, and corals. Rhodolith-bearing sandy and large pebbled, maerl-bearing sandy and coarse pebbled, and skeletal sandy facies were described in these rhodolith and maerl-bearing deposits. In addition to these facies, two other facies of bryzoa and serpulites were also determined. Crustose coralline red algaes and their depositional environments in the southern shelf of Marmara sea indicate that Mediterranean conditions have prevailed in the sea of Marmara during the interglacial periods along Quaternary and even in the recent time.

Key words: Rhodolith, Maerl, Quaternary, southern Marmara sea.

INTRODUCTION

Rhodoliths are described as clay-originated nodules, nodular clay accumulations, clay associations, and clayey nodules. Bossellini and Ginsburg (1971) and Bates and Jackson (1983) used the term of "rhodolithes" as the accumulation formed by talus of encrusting red algae together with other preserved fauna assemblage. Adey and Macintyre (1973) evaluated the rhodoliths to be a grain enclosure type that shows a bedded internal structure depending on the growth of red algaes and as the synonymous of oncoids. Their structure is shaped by intense layering around the nucleus, repetition of enclosing and algae growth (Prager and Ginsburg, 1989). It is also known that this term is used as "rhodoliths" in some studies (Barnes et al., 1970; Ginsburg and Bosellini, 1973). In addition, branches of dead or actual encrusting red algae may develop growth forms so called maerl on algal banks (Alexanderson, 1977; Bosence, 1977; Ginsburg and Bosellini, 1973). In this study, both terms are used as "rhodolitb" and "maerl". Facies characteristics and geographic distribution of rhodoliths and maerls in the southern shelf of the sea of Marmara were investigated.

MATERIAL AND METHOD

This study was carried out in the frame of TÜBİTAK (Turkish Scientific and Technical Research Council) National Program on Sea Geology and Geophysics using the bottom samples collected by the MTA Sismik-1 research vessel from the sea of Marmara. A total of 182 stations was sampled at depths between 20-134 m. Of these, 77 were examined and encrusting red algae was determined at 22 stations. Rhodoliths were at station no 160 and a depth of 35 m (Table 1 and Fig. 1). Spheroidal maerls were found station nos. 38, 53, 100, 102, 103, 106, 119, 120, and 144 at a depth of 29-50 m, discoidal maerls were at station nos. 52, 66, 67, 69, 82, 85, 144, 166, and 177 at a depth of 27-36.5 m, and ellipsoidal maerls were at station nos. 35, 99, and 144 at a depth of 29-51 .5 m (Table 1 and Fig. 1). Those developed as irregular encrustings were determined at station nos. 35, 38, 39, 52, 53, and 55 (Table 1 and Fig. 1). Bryozoas were found at station no. 139 while serpulites at station no. 40 (Table 1 and Fig. 1). Description of encrusting red algae that display some growth forms, such as rhodolith, maerl, and irregular crusts were carried out with macro and micropa-

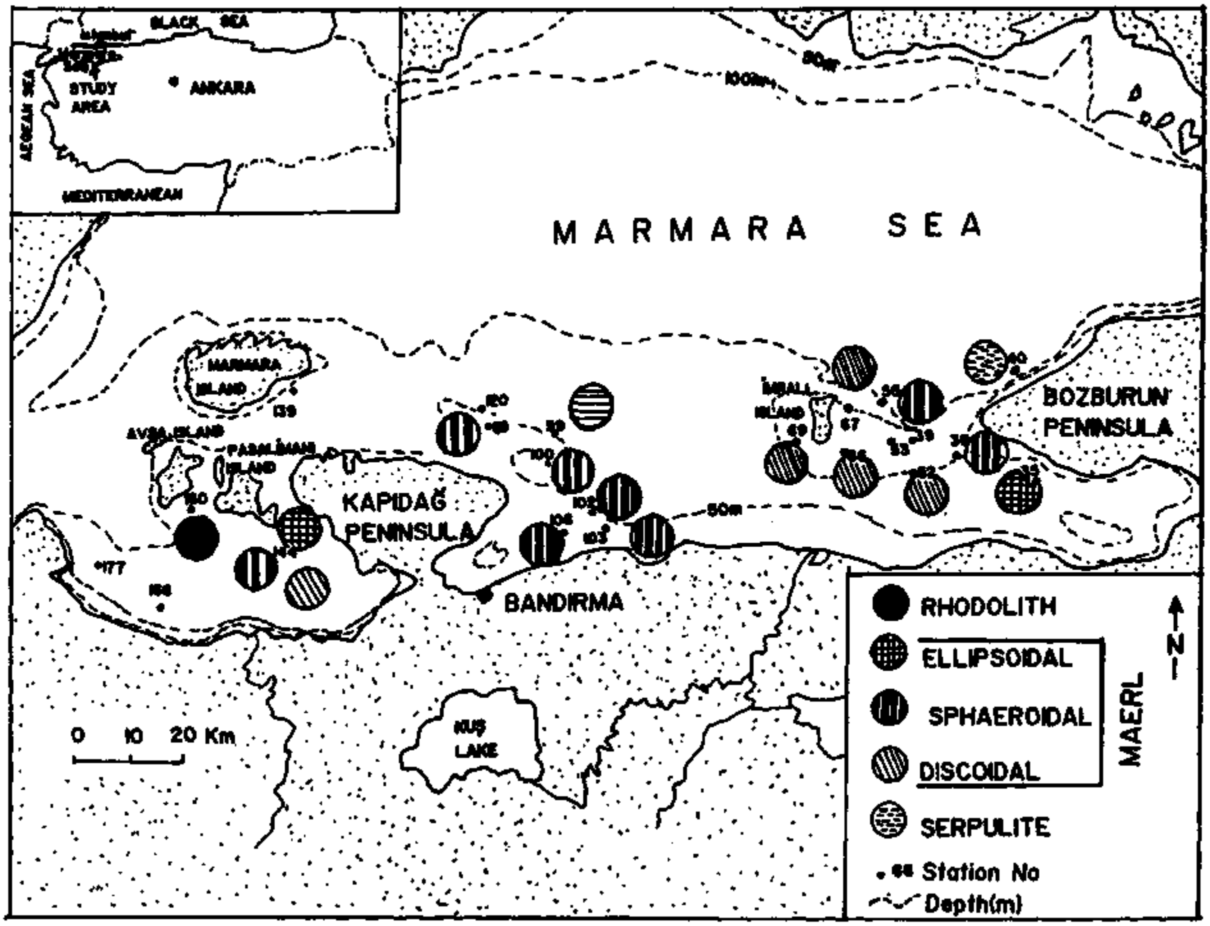

Fig. 1- Distribution of rhodoliths and maerls in southern sea of Marmara.

leontologic studies. For micropaleontologic studies, a number of 30 thin sections was prepared from two rhodolith (with a radius of 8 cm) and four maerl (with a radius of 3-5 cm) samples. Thin sections of rhodoliths and maerls were examined by an ocular microscope and photographed. In order to obtain thin sections, thallus of red algae comprising rhodoliths and maerls were frozen within the Canada balsam. Microtextural features of the samples were determined by scanning electron microscope (SEM). As a result of all these examinations, *Lithothamnion corallioides* and *Phymattolithon calcareum* species were determined. Shape (spheroidal, ellipsoidal, discoidal), size (1-8 cm in radius), and growth forms (rhodolith, maerl, crusts) of rhodolith, maerl, and irregular crusting were determined by macropaleontologic studies.

FORMATION OF RHODOLITHS AND MAERLS AND THEIR BIOLOGIC CHARACTERISTICS

Rhodoliths are characteristic in the sediments in southern shelf of southern part of the sea of Marmara at a depth of 27-52.7 m. *Lithothamnion corallioides* of encrusting red algae forms a laminated structure coiling around a nucleus consisting of small pebble, rock fragment, mollusk, and serpulite type grains under the effect of strong currents and waves (Prager and Ginsburg, 1989). This type of rhodoliths were met at south of the Avsa island at a depth of 35 m (Fig. 1 and Table 1). Internal parts of rhodoliths are generally destroyed by activities of several organisms, such as serpulite worms, some echinoid species, and endolithic bluegreen algae *(Ostreobuim queckettii* Bornet and Flaha-

Table 1- Percent distribution of rhodolith, maerl, irregular encrustings, bryozoa, and serpulites.

Station No:	Depth (m)	Sphaeroidal	Discoidal	Ellipsoidal	Irregular Crusts	Rhodolith	Serpulit	Bryozoa
35	45.3			3	0.51			
38	52.7	7			0.8			
39	71.5				2			
40	50						75	
52	36.5	-	7		0.51			
53	50.4	0.62			4			
55	134				1.8			
66	30.5		8.24					
67	30.2		2.66					
69	27.2		18.24					
82	94.5		1					
85	90.5		1					
99	51.2			10.5				
100	45.5	5.6						
102	40	3.5						
103	43.7	9						
106	34.8	22.5						
119	41.9	9.52						
120	60.4	15						
139	50							75
144	29	16	10	8				
160	35					60		
166	28.1		1					
177	28.5		1					

ult, 1889; *Gomontia polyrhiza* (Lagerh) Bornet and Flahault, 1889; *Hyella caespitosa* Bornet and Flahault, 1889) and emptied. Using the epithallus providing its growth, rhodolith-forming algae hinders the destruction of these organisms (Plate I, figs. 1, 2, 3, 4). Epithallus contains the meristem which facilitates the growth of plant. This part of plant that is in contact with oxygen and light provides the organism to be alive. As a result of development of algae, laminated and ball-shaped forms are existed. In southern coasts of the sea of Marmara governed by warm climate conditions, rhodoliths with radius of 1-8 cm are commonly found (Plate-II,. fig. 1). Strong currents and waves are the most important factors in formation of such structures. Open and freely branching rhodoliths so called maerl formed by branching species of *Lithothamnion corallioides* are found in southern sea of Marmara at a depth, of 27-52.5 m. Maerls display different shapes depending on water depth, light, temperature, and energy of the water (Bosence, 1977). As a result of examinations, spheroidal, ellipsoidal, and discoidal maerls were described. Spheroidal maerls were found west of Erdek gulf at a depth of 29 m, east of Bandırma gulf at a depth of 34-52.5 m and around the Bozburun peninsula at a depth of 50 m (Table 1 and Fig. 1 and Plate II, fig 2A). In general, they are formed in shallow (0-30 m) and high-energy environments. Abundant light and heat cause the branches be thick and intense. In this way, they become resistant to strong current and waves. Ellipsoidal forms were determined at west of Erdek gulf at a depth of 29 m, west of Gemlik gulf at a depth of 45.5 m, and northeast of Kapıdağ peninsula at a depth of 51.5 m. Due to decreasing of light, temperature, and the energy of the environment, they are less intense and have thinner branches (Table 1 and Fig. 1 and Plate II, fig. 2B). Discoidal maerls are found at west of Erdek gulf at a depth of 29 m, north of Imrali island at a depth of 30.2 m and southwest and east of

Imralı island at a depth of 30 m (Table 1 and Fig. 1 and Plate II, fig. 2C). Open and thin-branched, discoidal maerls are developed in low- temperature, scarce of light, durable, and low-energy environments. In order to utilize from the light, branches are opened. Insufficiency of light and oxygen cause branches to open. However, since the environment is durable, there is no breaking and disintegration in the branches. They are more stable in comparison to intensely branching forms. Transportation is insignificant (Bosence, 1977). In addition, since spheroidal forms form more strong structures with thicker and intense branches to adapt to high-energy environments, they seem to be more durable in comparison to spheroidal forms. This type of structure gives rise to them transported in less amounts in the water. Broken branches of maerls are shown in (Plate II fig. 3). Transportation by deep currents causes branches of maerls to be broken.

FACIES CHARACTERISTICS

Three different facies types were differentiated in the sediments of encrusting red algae in southern sea of Marmara. These are rhodolith-bearing sandy and coarse-pebbled facies, maerl-bearing sandy and coarse-pebbled facies, and coarse-pebbled together with crust-bearing sandy facies.

Rhodolith-bearing sandy and coarse-pebbled facies

This facies generally covering rhodoliths of 1-8 cm is observed at south of Avşa island at a depth of 35 m (Plate II, fig 1). It is found together with the fauna assemblage containing mollusk-, bryozoa-, echinoid-, and serpulite-forming worm tubes, benthic foraminifera, and lesser amounts of planktonic foraminifera. The environment has abundant amount of light, free water circulation, and high-energy.

Maerl-bearing sandy and coarse-pebbled facies

Maerls cover a wide area on the sea bottom at a depth of 27-52.5 m. (Plate II, figs. 2A, B, C). Very coarse sand and pebble size material is dominant. Maerls are distributed over the sand as groups or individually. Considering the shape of the maerl reflecting the energy of environment, 3 different zones distinguished. Those in spheroidal shapes (Plate II, figs. 2A-3a) are the products of high-energy, abundant-light, and shallow environments, those in ellipsoidal shapes are characteristic of intermediate-light (Plate II, figs. 2B, 3b) and low-energy environments, and finally the ones with discoidal shapes (Plate II, figs. 2C, 3c) reflect durable, low- energy environments with lesser amounts of light. Fauna assemblage consisting of mollusk- coral- and serpulite-forming worm tubes is rarely observed.

Crusts-bearing sandy facies

This facies comprising intense crust forms at a depth.of 36.5-134 m (Fig. 2) is commonly found covering *Phymattolithon calcareum* of encrusting red algae, rock fragments, pebble; mollusk, and coral pieces as thin layers (>1 cm). It is accompanied by also other encrusting organisms, bryozoa, mollusk, and serpulite.

In addition to encrusting red algae facies, serpulite bioherms formed by vermes tubes are observed at west of Bozburun peninsula at a depth of 50 m. They are associated with broken, disintegrated mollusk shells (Plate III, fig. 1). Due to carving and hollowing activities of vermes, they are composed of sediments with micro structures and very fine-grained material (Fig. 2). Moreover, a facies with vast amount of bryozoa was detected at south of the Marmara island. In general, algae form oncolite or rhodolith surrounding the bryozoas (Plate III, figs. 2, 3).

GEOGRAPHIC DISTRIBUTION

Lithothamnion corallioides forming rhodoliths and maerls in southern shelf of the sea of Marmara and *Phymattolithon calcareum* developing as irregular crusts are the indicator of a cold, warm, subtropical climate belt. This type of occurrences are observed in Atlantic Ocean, along the northern coasts of Norway, and northeast Pacific (Leclaire, 1971 ; Bosellini and Ginsburg, 1971; Adey and Macintyre, 1973; Alexanderson, 1977; Basso, 1995).

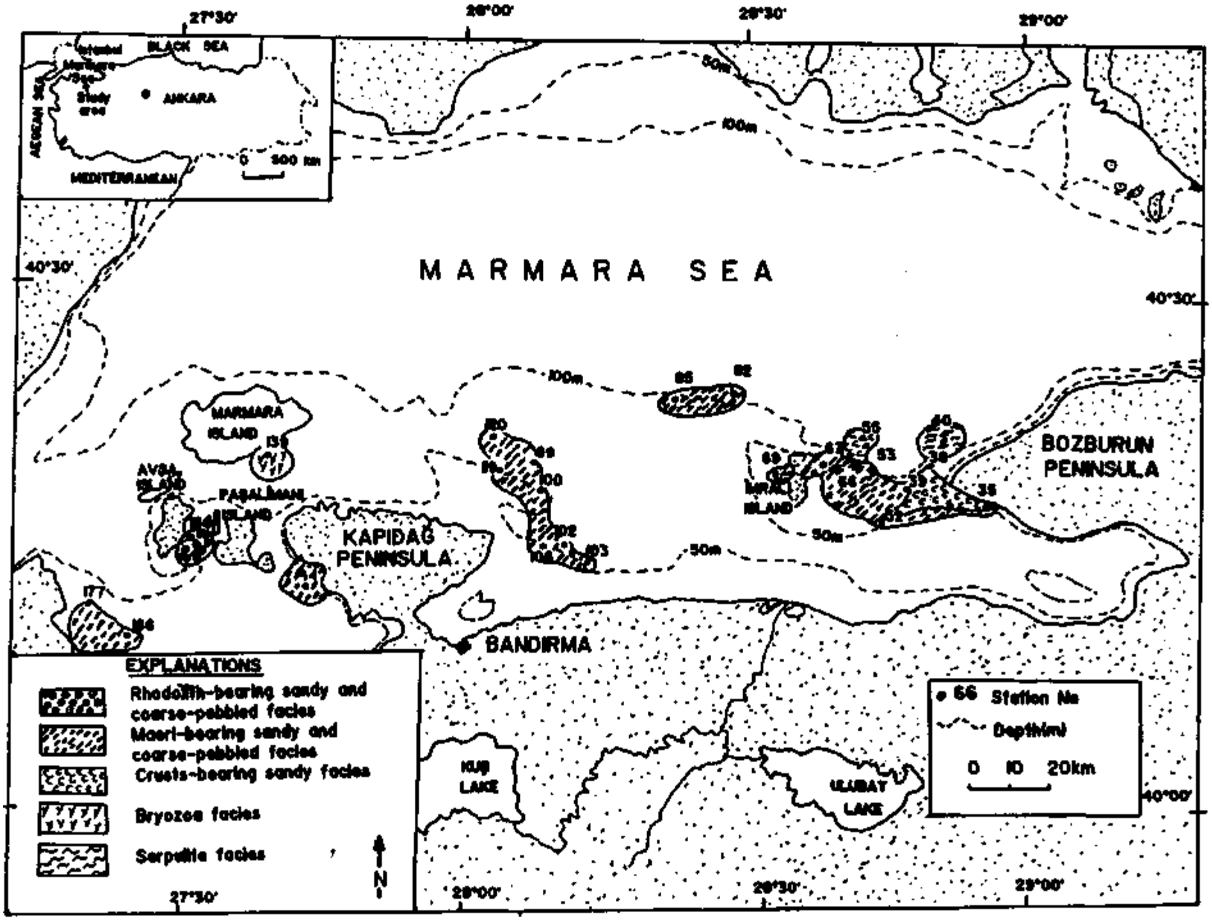

Fig. 2- Distribution of rhodolith, maerl, irregular encrustings, bryozoa, and serpulite facies.

DISCUSSION AND RESULTS

Marine transgressions originated from the Atlantic Ocean were effective in the sea of Marmara along the interglacial periods in Quaternary time. Following the late Walday (Wurm) glacial period at the beginning of Holocene (9-7 thousands years ago), waters of the Mediterranean sea reached to the sea of Marmara via Dardanelles and Bosphorus and then to the Black sea (Ross, 1978; Muratov et al., 1978; Tchepaliga, 1995). Thus, since Holocene the sea of Marmara has resembled the Mediterranean sea with respect to its salinity and fauna and flora content. This was confirmed by paleontologic studies conducted in southern shelf of the sea of Marmara. For example, *Emiliana huxleyi* of calcareous type of nannofossils (V. Toker pers. communication), *Turboella parva, Bittium spira, Ringicula conformis,* and *Ostrea edulis* of the mollusk species in Mediterranean origin (İslamoğlu and Tchepaliga, 1997), *Aurila onvexa, Bosquetina* sp., and *Loxoconca* sp. of theostracod species (Duru, 1996), *Globigerina bulloides, Globigerina quinqueloba, Globigerina bermudezi,* and *Orboulina universa* of the planktonic foraminiferas (V. Toker and A. Hakyemez: pers. communication) together with *Lithothamnion corallioides* and *Phymattolithon calcareum* species of encrustipg red algae were determined in Pleistocene to Recent sediments. Encrusting red algae forming rhodoliths and maerls can stand for a temperature of 5-24°C and a salinity of 25-35‰. In general, rhodoliths and maerls developing at a depth of 50-150 m are observed at depths 40 to 50 m in the Atlantic Ocean which has a cold climate regime

(Vanney, 1965; Adey and McKibbin, 1970). Lithothamnion genus that is found at a depth of 50-150 m in the Mediterranean sea is generally observed in more deeper parts in the Atlantic Ocean (Milliman and Emery, 1971; Ladd, 1961; Bosellini and Ginsburg, 1971). This is due to the fact that as the depth increases temperature also is decreased, hence in turn providing development of Lithothamnion that favors cold waters. Although development of rhodoliths is controlled by biologic, physical, and chemical factors, the primary factor is actions of water that are currents and waves (Adey and Macintyre, 1973). Their morphology depends on the energy regime of the environment in which they are formed. For example, laminated, ball-like coiled rhodoliths characterizing a high-energy environment and spheroidal, ellipsoidal, and discoidal maerls forming at different depths (Bosellini and Ginsburg, 1971; Bosence, 1977). Very strong waves inhibit the light and cause fragile rhodoliths to be broken and disintegrated. Similarly, weak waves and currents inhibits rhodolith development. Fine-grained sediments give rise to welding and burying of shells (Adey and Macintyre, 1973). As a result, it is thought that above mentioned physical, chemical, and biologic conditions necessary for the formation of rhodoliths have been prevailed since interglacial periods of the Quaternary time.

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PLATES

PLATE-I

Fig. 1- Vertical section of *Lithothamnion corallioides.* (C) Conceptacle (Pe), perithallus. x 63 Ocular microscope.

Fig. 2- Oblique section of *Lithothamnion corallioides.* (C) multi pores, sexual conceptacles. x 63 Ocular microscope.

Fig. 3 Perithallus and epithallus in a longitudinal section, x 63 Ocular microscope.

Fig 1 Scanning electron microscope (SEM) image of opithallus cells Spaces among the cells are filled with early diagenetic high magnesian calcite (ç) Black parts (b) non-tilled areas.

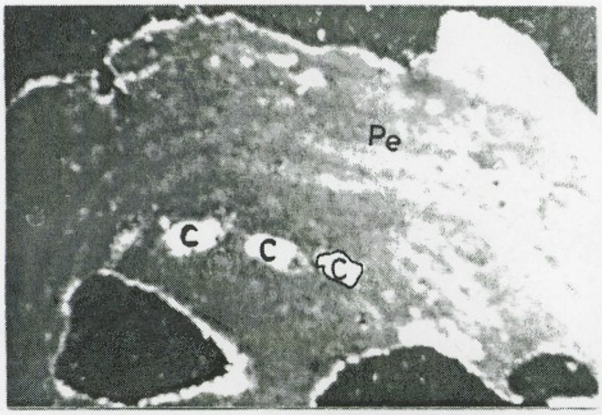

Fig. 1

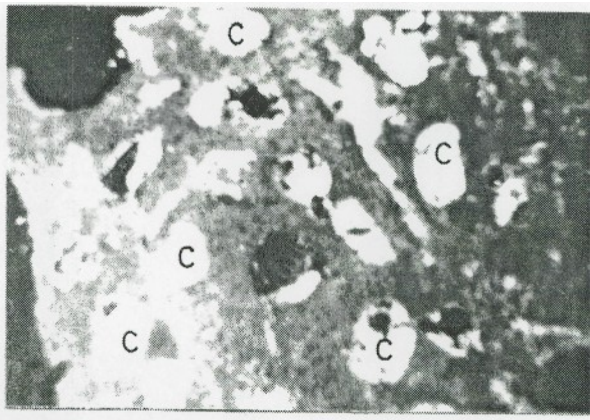

Fig. 2

Fig.3

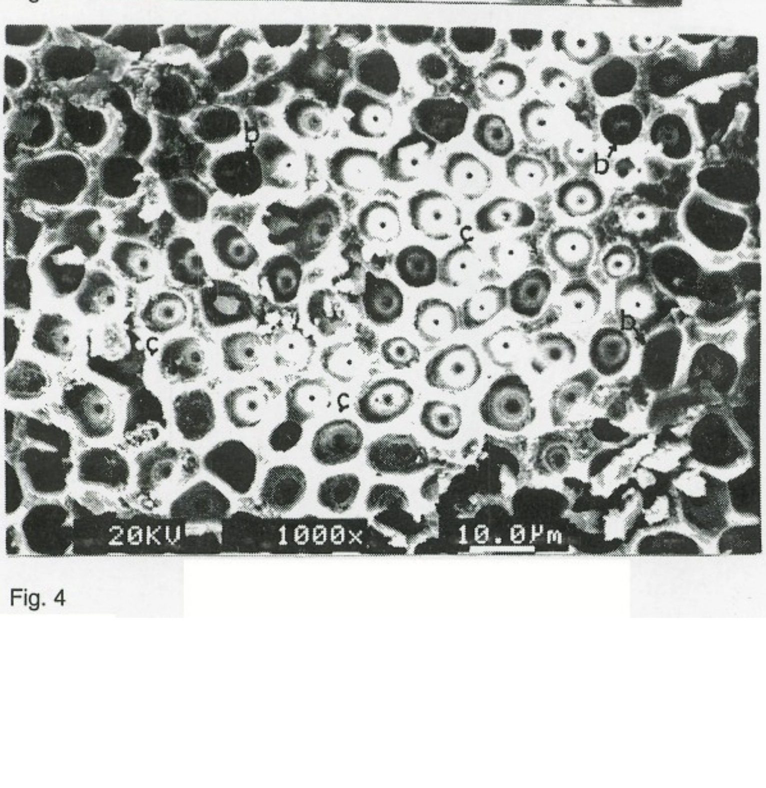

Fig. 4

PLATE-II

Fig. 1- Rhodoliths. Nodules with a radius of 1-8 cm at south of Avşa island. Station no. Southern Marmara 95/07-160.

Fig. *2*- Maerls. A-Spheroidal, B- Ellipsoidal, C-Discoidal forms. Station no. Southern Marmara 95/07-144.

Fig. 3- Broken tallus of *Lithothamnion corallioides.* a-Spheroidal, b- Ellipsoidal, c- Discoidal maerls.

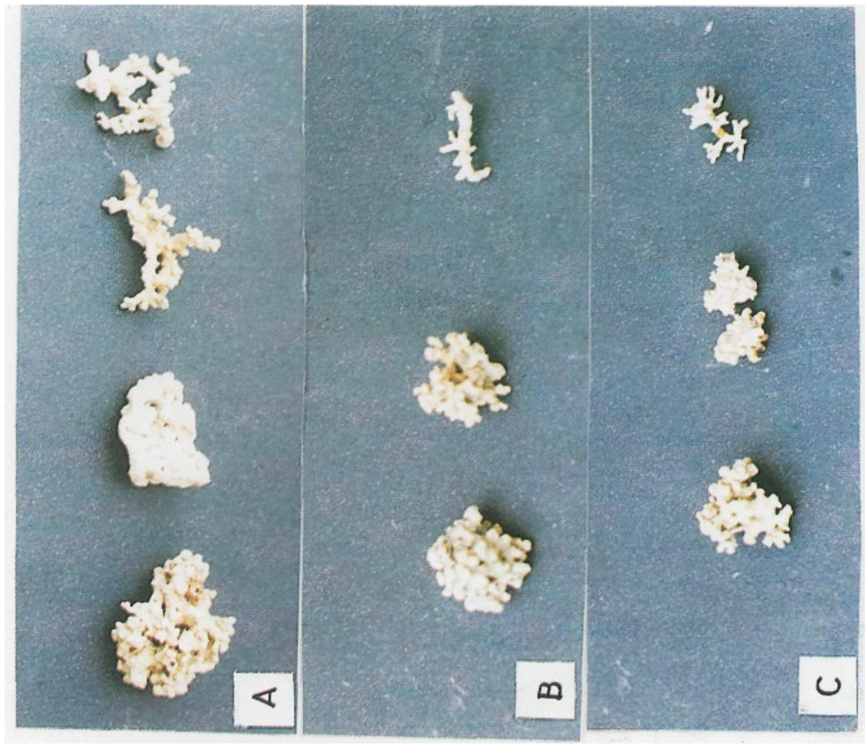

Fig. 2

Fig. 1

Fig. 3

PLATE-III

Fig. 1 - Serpulites formed by vermes tubes.

Fig. 2- Bryozoa.

Fig. 3- Lithothamnion (L.c.) and Bryozoa (B).

Fig. 1

Fig. 2

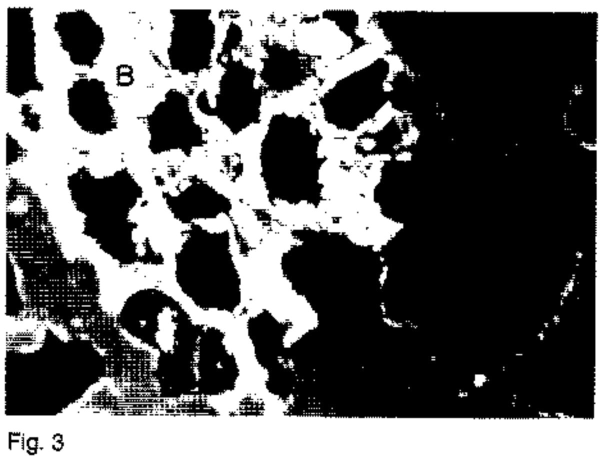

Fig. 3