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STEFANO FURLANI, FABRIZIO ANTONIOLI, GIANFRANCO SCICCHITANO & MARTINA BUSETTI

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THALASSIA GIACCONE [1*], GIUSEPPE GIACCONE [2] & ANNA MARIA MANNINO [3]

DEEP RHODOLITH BEDS IN THE USTICA ISLAND (SICILY, SOUTHERN TYRRHENIAN SEA): A SEDIMENTARY AND PALEOECOLOGICAL APPROACH

ABSTRACT: GIACCONE T., GIACCONE G. & MANNINO A.M., *Deep rhodolith beds in the Ustica island (Sicily, Southern Tyrrhenian Sea): a sedimentary and paleoecological approach.* (IT ISSN 0391-9838, 2018).

The results of a multidisciplinary study conducted on the circalittoral soft bottom assemblages at Secchitello (*Sicchiteddu*) and in the neighbouring areas along the southern coast of Ustica Island (Sicily, Southern Tyrrhenian Sea) are presented. In particular, the study provided useful data for a taxonomic, ecological and paleoecological revision of the Coastal Detritic *facies* with free-living calcareous algae and for a critical analysis of their relationship with the sedimentary dynamics. During a survey, carried out by the University of Catania (1991) with a R.O.V. (remotely operated vehicle), the presence of the Coastal Detritic (DC) biocoenosis, characterized by a surprisingly high biodiversity, and of the Platform Coralligenous (C) biocoenosis, dominated by rhodolith bio-concretions with large and branched *Bryozoa* was recorded.

The DC of Secchitello, situated at a depth of between 50 and 90 m, was mainly characterized by: *prâlines*, *boxwork, branches and coated grains* growth forms; the dominance of the *Lithothamnion minervae facies;* coarse sediments belonging to the sand and gravel classes, with the last one mainly of biogenic nature. Where the hydrodynamism is reduced (at a depth of between 80 and 90 m), an ecotone community between the DC and the C biocoenoses, growing on *boxworks*, was found. The density and biodiversity of the free-living calcareous algae and of epiflora found at Secchitello are high, and the extension of the rhodolith beds are comparable to that of the C assemblage.

The rough morphology of the bottom, increasing the current activity, together with the presence of biodisturbance phenomena mainly due to echinoderms such as *Cidaris cidaris*, *Echinaster sepositus* and "sail" epiphytes, such as *Cystoseira spinosa* v. *compressa* and *Phyllophora crispa*, were responsible for the increase of the rhodolith overturning. The analysis of thin sections of non-geniculate coralline red algae allowed to reconstruct the paleoenvironmental evolution of the Secchitello, pointing out three different phases of colonization: initial, intermediate and recent. The transition from one phase to another is probably due to the changes in intensity and direction of the currents in the last millennium.

KEY WORDS: Circalittoral zone, Coastal Detritic Bottom Biocoenosis, Rhodolith beds, Sediments, Southern Tyrrhenian Sea, Ustica Island.

RIASSUNTO: GIACCONE T., GIACCONE G. & MANNINO A.M., *Letti a rodoliti di profondita' nell'Isola di Ustica (Sicilia, Mare Tirreno meridionale): un approccio sedimentologico e paleoecologico.* (IT ISSN 0391-9838, 2018).

Vengono presentati i risultati di uno studio multidisciplinare condotto sulle comunità dei fondi mobili circalitorali del Secchitello (*Sicchiteddu*) e di aree limitrofe della costa meridionale dell'Isola di Ustica (Sicilia, Tirreno meridionale). In particolare, lo studio ha fornito dati utili ai fini di una revisione tassonomica, ecologica e paleoecologica delle *facies* ad Alghe Calcaree libere del Detritico Costiero e di una analisi critica dei loro rapporti con la dinamica sedimentaria.

Durante una campagna di ricerca, condotta nel 1991 dall'Università di Catania utilizzando un R.O.V. (veicolo a controllo remoto), è stata rilevata la presenza della Biocenosi del Detritico Costiero (DC), caratterizzata da una sorprendente biodiversità, e della Biocenosi del Coralligeno di Piattaforma (C), dominata da formazioni organogene a rodoliti con grandi Briozoi ramificati.

Il DC di Secchitello, presente tra 50 e 90 m, è principalmente caratterizzato da: *prâlines*, *boxworks*, *branches* and *coated grains* come forme di crescita; una prevalenza della *facies* a *Lithothamnion minervae*; da sedimenti grossolani appartenenti alle classi granulometriche delle sabbie e delle ghiaie, queste ultime di natura prevalentemente biogenica. Lì dove l'idrodinamismo si riduce (tra 80 e 90 m), si trova l'ecotono di transizione tra il DC ad alghe calcaree libere e la Biocenosi del C, impiantata su *boxworks*. La densità e la biodiversità delle alghe calcaree libere e delle specie epifite trovate nel Secchitello sono davvero elevati e l'estensione dei letti a rodoliti è paragonabile a quella della Biocenosi del C.

La morfologia accidentata di questi fondali, che incrementa l'attività delle correnti, unitamente alla presenza di fenomeni di bioturbazione ad opera di echinodermi quali *Cidaris cidaris* ed *Echinaster sepositus* e di alghe denominate epifiti "vela", come *Cystoseira spinosa* v. *compressa* e *Phyllophora crispa*, aumenta il movimento delle rodoliti.

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Thalassia Giaccone, one of the co-author, wish to thank Salvatore Giacobbe and Daniela Basso for their precious help and suggestions during her Phd on non-geniculate Corallinales (2009, University of Messina), Marcello Catra for his technical help and the Mancuso family for the help during the phases of sampling.

L'analisi delle sezioni sottili di *Corallinales* non geniculate, ha permesso di ricostruire l'evoluzione paleoambientale del Secchitello, evidenziando tre fasi di colonizzazione: iniziale, intermedia e recente. Il passaggio da una fase all'altra è probabilmente dovuto alla variazione temporanea di intensità e direzione delle correnti causate dai cambiamenti verificatisi in questo ultimo millennio.

Termini Chiave: Circalitorale, Biocenosi del Detritico Costiero, Letti a Rodoliti, Sedimenti, Tirreno Meridionale, Isola di Ustica.

INTRODUCTION

Calcareous non-geniculate coralline algae (*Rhodophyta*) constitute one of the most widespread and successful groups of marine macrophytes. They are distributed from the mediolittoral zone to the infralittoral and circalittoral zones, and occur as crusts, laminar thalli, or structures freely rolling on the substrate with an inner nucleus or without it, the last one called rhodoliths (Aguirre & *alii*, 2017). The formal definition of "rhodolith" is due to Bosellini & Ginsburg (1971) and since then, rhodoliths are intended as unattached nodules formed by coralline red algae and their fragments, as part of a continuous spectrum of forms, with size spanning from 2 to 250 mm of mean diameter (Bosellini & Ginsburg, 1971; Basso & *alii*, 2016). They often form rhodolith beds, composed of live and dead thalli of coralline red algae (as unattached branches and/or nodules) and their fragments.

On the basis of the definition mentioned before, the term rhodolith beds also includes *maërl* and fully calcified *Peyssonnelia* beds (Lanfranco & *alii*, 1999; Steller & *alii*, 2003; Foster & *alii*, 2013). The term "*maërl*" coming from the Breton language ("marga" = calcareous land or deposits of calcified algae), was created by Pérès & Picard (1964).

The terms "rhodolith" and "*maërl*" have been often used as synonyms, with a consequent misleading use of the term "*maërl*" (Basso & *alii*, 2016).

Mediterranean rhodolith beds have been considered as "facies" of infralittoral and circalittoral biocoenoses (Pérès & Picard, 1964; Relini & Giaccone, 2009; Basso & *alii*, 2016). Rhodoliths are frequent in the Coastal Detritic Biocoenosis (DC), one of the most widely distributed biocoenosis on the soft bottoms of the circalittoral zone in the Mediterranean Sea. The coralligenous (C) biocoenosis may develop from rhodolith beds and the two biocoenoses can transform one into the other due to the progressive cementation by coralline algae (Laborel, 1961).

The codes and names of the C and DC biocoenoses have been reviewed by UNEP / (OCA) / MED WG: 149/5 CAR / ASP Tunis, 1998 as follows: Habitat IV. 2. 2 (Coastal Detritic Bottom Assemblage) and Habitat IV. 3. 1 (Coralligenous Assemblage).

Rhodoliths are long-lived (often >100 years) and slow growing seaweeds (typically <1 mm y-1) and have a remarkable ability to recolonize the sea bottoms (Bosence, 1983; Frantz & Kashgarian, 2000; Blake & Maggs, 2003; Bosence & Wilson, 2003; Steller & *alii*, 2003; Rivera & *alii*, 2004).

Intra- and interspecific variations in rhodolith growth forms and shapes are extremely high (Riosmena-Rodriguez & *alii*, 1999; Perry, 2005; Basso & *alii*, 2009). Rhodoliths commonly occur on sediment, often of biogenic origin, and form beds (with a > 10% cover of living corallines, according to Steller & *alii*, 2003), mainly in environments where water motion is strong enough to prevent burial by sediments or overgrowth by other organisms (Marrack, 1999; Ballantine & *alii*, 2000; Ryan & *alii*, 2007). In the Mediterranean Sea, rhodolith and *maërl* beds are reported from 9 to 150 m, with the majority occurring from 30 to 75 m. About 18 % extends deeper than 75 m and only a few occur from the depth of 25 m to the surface (Basso & *alii*, 2017).

They are often considered intermediate sea bottoms, between hard and mobile sea bottoms, and also a non-renewable resource threatened by human activities (Biomaerl Team, 1998; Foster, 2001; Aguado-Giménez & Ruiz-Fernández, 2012; Basso, 2012).

Among pressures threatening Mediterranean rhodolith beds, we may include dredging, fishing gear, bottom trawling, pollution changes in sedimentation rates, ocean warming and acidification, invasive alien species (Grall & Hall-Spencer, 2003; Bordehore & *alii*, 2000, 2003; Sanz-Lázaro & *alii*, 2011; Martin & Gattuso, 2009; Aguado-Giménez & Ruiz-Fernández, 2012; Basso, 2012; McCoy & Ragazzola, 2014).

Free living calcareous algae provide manifold services such as microhabitats for invertebrates, algae and fishes (Steller & *alii*, 2003; Littler & Littler, 2008) and food for many animal species. Thus, they are recognized as foundation species (Amado-Filho & *alii*, 2007; Foster & *alii*, 2007; Steller & *alii*, 2007). Rhodolith beds may also provide useful information on climate change (Martin & Gattuso, 2009; Barberá & *alii*, 2003, 2012; Nelson, 2009; Basso, 2012). They are also used for beach nourishment by dredging, in agriculture to stabilize acidic soils or to neutralize acidic waters in the production of drinking water, as additives for animal fodders or organic gravel for aquariums, in pharmaceutical, cosmetic and medical industries as they are rich in calcium and magnesium carbonates (Barberà & *alii*, 2003).

Mediterranean rhodolith beds are considered habitat of high conservation interest for different reasons, such as the high level of biodiversity they host (Basso & *alii*, 2016).

The ecological importance and vulnerability of this habitat has been recognized in various European and international frameworks, leading to several international initiatives, aimed at their conservation (European Parliament and Council of the European Union, 2008; UNEP-MAP-RAC/SPA, 2008, 2010; UNEP-MAP, 2011). Rhodolith beds have been considered habitat of special scientific and biodiversity interest (Commission Directive of EU, 2017) and have been included in the national initial assessment process by several European countries, including France, Spain, Italy, Malta and Greece (EIONET, 2015).

Within the framework of the United Nations Programme's Mediterranean Action Plan, a plan for the protection of the Mediterranean rhodolith beds is present (UNEP-MAP-RAC/ SPA, 2008; Agnesi & *alii*, 2009). In this plan the Eolian Islands and the Island of Ustica (Sicily, Southern Tyrrhenian Sea) are indicated as particularly suitable sites for the study of the complex "*Corallingenous/ Maërl* assemblages" in the Mediterranean Sea.

The Island of Ustica is a Marine Protected Area (MPA, since 1986) and since 1997 a Site of Community Importance (SIC ITA020046, Fondali dell'Isola di Ustica). Even though several studies have been carried out on geological and biological characteristics of the Island (e.g. Martelli, 1912; Ruggeri & Buccheri, 1968; AA.VV., 1989-1990-1991-1997; Giaccone & Riggio, 1983; Giaccone & *alii*, 1985, 1994, 2009a-h; Di Geronimo & *alii*, 1988; Giaccone & *alii*, 2009; Mannino, 2003; Castriota & *alii*, 1998; Mannino & *alii*, 2003; Catra & *alii*, 2006), multidisciplinary studies on the circalittoral soft bottoms of Ustica Island were lacking. A research campaign, carried out by the University of Catania in 1991, provided the opportunity to carry out a multidisciplinary study on the circalittoral soft bottoms of Ustica Island, with particular attention to the bottoms at Secchitello (*Sicchiteddu*) and in the neighbouring areas. During a survey, carried out for the first time in this area with a R.O.V. (remotely operated vehicle), the presence of DC (with high biodiversity) and C (dominated by rhodolith bio-concretions) assemblages was recorded. In 2006, after a re-examination of the images provided by the R.O.V., an intensive sampling campaign of coralline red algae was carried out. Since coralline red algae biocoenosis results from the synergy of biotic and abiotic factors of the environment, it can help to identify the *facies* of the DC and also to follow the evolution of the environment through space and time. Indeed, paleoecological and ecological analyses may allow to reconstruct the sedimentological, biocoenotic and hydrodynamic conditions of paleoenvironments, and also to highlight possible paleoecological and paleoclimatic markers (Basso & Tomaselli, 1994).

Thus, the aim of this study was to analyse the rhodolith beds characterizing the circalittoral soft bottoms at Secchitello and in the neighbouring areas, and their relationship with environmental conditions such as hydrodynamism and substrate, in order to highlight their role as ecological indicators and paleo-ecological markers.

GEOLOGICAL SETTING

The Island of Ustica is located in the southern Tyrrhenian Sea, about 60 km N-NW of the Sicily coast, on the southern edge of the oceanic domain (Rehault & *alii*, 1987) of the Magnaghi-Vavilov and Marsili basins. It is the emerged top of a large volcanic complex, which rises more than 2000 m above sea floor (Calanchi & *alii*, 1984). It is morphologically characterized by a range of peaks ringed by flat surfaces at various heights. The origin of Ustica Island is related to crustal deep transtensional faults, generated during the opening of the Tyrrhenian basin, as consequence of complex interactions between the African and Eurasian plates. This mechanism allowed magma to reach the surface directly from the mantle, making Ustica the only volcano of anorogenic origin that emerged from the Southern Tyrrhenian Sea.

Ustica is included in the Tyrrhenian Basin of the Hinterland Domain, characterized by a triangular shape that suggests a progressive increase in the southward distension, emphasizing the ongoing oceanization process. Tectonic and volcano-tectonic activities led to the formation of the Scoglio del Medico (north-west), the Secca della Colombaia (north) and likely the Banco Apollo, at about 3 km west from the Ustica Island.

Mt. Guardia dei Turchi and Mt. Costa del Fallo, the second highest peak on the Island, are the two oldest crateric cones. Other crateric centers EW oriented, the Falconiera hill, the northern coast of Tramontana and the Spalmatore coast, also exist.

According to Romano & Sturiale (1971), Ustica magmas originated in the upper mantle. A typical gravitational differentiation of a primary alkaline-basaltic magma (hawaiiti → mugeariti → trachiti), was clearly highlithed by the petrographic analysis and by the values of the $^{87}Sr/^{86}Sr$ ratio. The affinity of the rocks of Ustica with the Na-alkaline series, ranging from basalts to Trachytes, was also reported in Floresta Martin & *alii* (2015).

The Ustica's volcanic history was characterized by several overlapping cycles of marine transgression, particularly occurring during the Quaternary period, that generated typical sedimentary terraces with 3 orders of level surfaces at heights ranging from about 90-115 m u.s.l. (upper sea medium level) for the oldest to 25-35 m u.s.l. for the most recent. There are also two small sedimentary terraces along the Tramontana coast and in the northern side of the Falconiera hill, which belong to the cycles of the Quaternary marine transgression. The coasts of Ustica Island are still affected by the erosive action of the waves and of the atmospheric agents, which have produced characteristics sea caves and niches.

MATERIAL AND METHODS

Survey

The circalittoral soft bottoms of Secchitello and neighbouring sites, located along the southern coast of Ustica Island MPA, were surveyed for the first time in 1991 thanks to a R.O.V. (remotely operated vehicle).

During this survey, the presence of DC (with high biodiversity) and C (dominated by rhodolith bio-concretions) assemblages was recorded. A SCUBA diver explored the bottoms at a depth of about 50 m and images were take with a Canon Power Shot 630 provided of a waterproof case Canon WP-DC 8.

Sampling

The bottoms of Secchitello were then explored by using a triangular dredge (side=51cm) in order to identify the areas mainly colonized by free-living calcareous algae. Two stations were selected to carry out a quantitative sampling at different depth (table 1).

Then, nineteen more stations were chosen both at Secchitello and in the neighbouring areas, by using the GPS-Ecobathometer GP-1650 WF, C-MAP NT, FURUNO (table 2), to collect samples at different depth, by using a Van Veen grab, 30 l in volume (fig. 1).

TABLE 1 - Stations sampled by using the dredge (USD: Ustica dredge sample; am: ante meridian; lat: latitude; long: longitude).

Sampling date	Sample code	Station	Time, Latitude, Longitude and Depth		
20/09/06	*USD1*	*Secchitello Levante*	11:12 am lat: 38° 40'.98 N long: 13° 10.09 E depth: 87 m	11:15 am lat: 38° 40'.99 N long: 13° 10'.14 E depth: 76.4 m	11:25 am lat: 38° 41'.01 N long: 13° 10'.24 E depth: 91.4 m
20/09/06	*USD2*	*Secchitello Levante*	12:05 am lat: 38° 41'.05 N long: 13° 10'.08 E depth: 71.6 m	12:10 am lat: 38° 41'.11 N long: 13° 10'.23 E depth: 56.5 m	12:20 am lat: 38° 41'.16 N long: 13° 10'.35 E depth: 66 m

TABLE 2 - Stations sampled by using the Van Veen grab (USB: Ustica grab sample).

Date (Time)	Sample code	Station	Latitude	Longitude	Depth (m)
19/09/06 (9:30)	USB1	Secchitello	38° 41'.08 N	13° 10'.19 E	61.7
19/09/06 (9:45)	USB2	Punta dell'Arpa	38° 41'.51 N	13° 10'.64 E	58
19/09/06 (10:05)	USB3	Grotta Verde	38° 41'.46 N	13° 10'.66 E	70
19/09/06 (10:50)	USB4	Punta Galera Ponente	38° 41'.59 N	13° 10'.85 E	67
19/09/06 (11:10)	USB5	Punta Galera Ponente	38° 41'.53 N	13° 10'.80 E	90.6
19/09/06 (12:05)	USB6	Punta Galera Levante	38° 41'.64 N	13° 11'.18 E	88
19/09/06 (13:40)	USB7	Secchitello	38° 41'.08 N	13° 10'.12 E	61.7
19/09/06 (14:30)	USB8	Secchitello	38° 40'.91 N	13° 10'.16 E	80
19/09/06 (15:10)	USB9	Punta Galera Levante	38° 41'.65 N	13° 11'.14 E	75
19/09/06 (15:30)	USB10	Punta Galera Levante	38° 41'.61 N	13° 11'.12 E	70
19/09/06 (15:45)	USB11	Punta San Paolo	38° 41'.85 N	13° 11'.26 E	56.5
20/09/06 (9:05)	USB12	Secchitello	38° 41'.08 N	13° 10'.16 E	64
20/09/06 (9:20)	USB13	Secchitello	38° 41'.02 N	13° 10'.09 E	83.7
20/09/06 (9:38)	USB14	Secchitello	38° 41'.21 N	13° 09'.97 E	72
20/09/06 (10:00)	USB15	Secchitello Ponente	38° 41'.13 N	13° 09'.86 E	96
20/09/06 (14:45)	USB17	Secchitello-Punta dell'Arpa	38° 41'.14 N	13° 10'.45 E	86
20/09/06 (15:00)	USB18	Secchitello-Punta dell'Arpa	38° 41'.19 N	13° 10'.21 E	47
20/09/06 (15:50)	USB19	Punta Omo Morto	38° 42'.59 N	13° 12'.15 E	56.4

The sampling surface of the benthic grab, comparable to a rectangular surface, was of 1313.5 cm^2 (37 x 35.5 cm). It is estimated that the penetration of the jaws of the benthic grab within the soft bottom (with coarse biogenic sediments) was of about 5 cm.

Samples were fixed in 5% formalin solution and kept in the freezer until subsequent analyses.

Sedimentological analysis

Sixteen samples, used for sedimentological analysis, were dried at 100 °C, repeatedly washed, dried again and weighted. Then, the samples were sieved in a sieve sets from 32 mm to 0.063 mm mesh size, and an aliquot was used for the densimetric analysis. Sixteen samples were also used for mechanical granulometric analysis whereas densimetric analysis were performed on 11 samples because in 5 samples (USB2, USB4, USB7, USB11, USB14) the fraction <0.063 was < 5%.

At the fraction <0.063 a deflocculant was added and the samples were shacken, then a saline solution (1%) was added and the samples were analysed with a densimeter (Elzone 282 PC). Data were processed to estimate texture characteristics and statistical parameters, by using the Folk

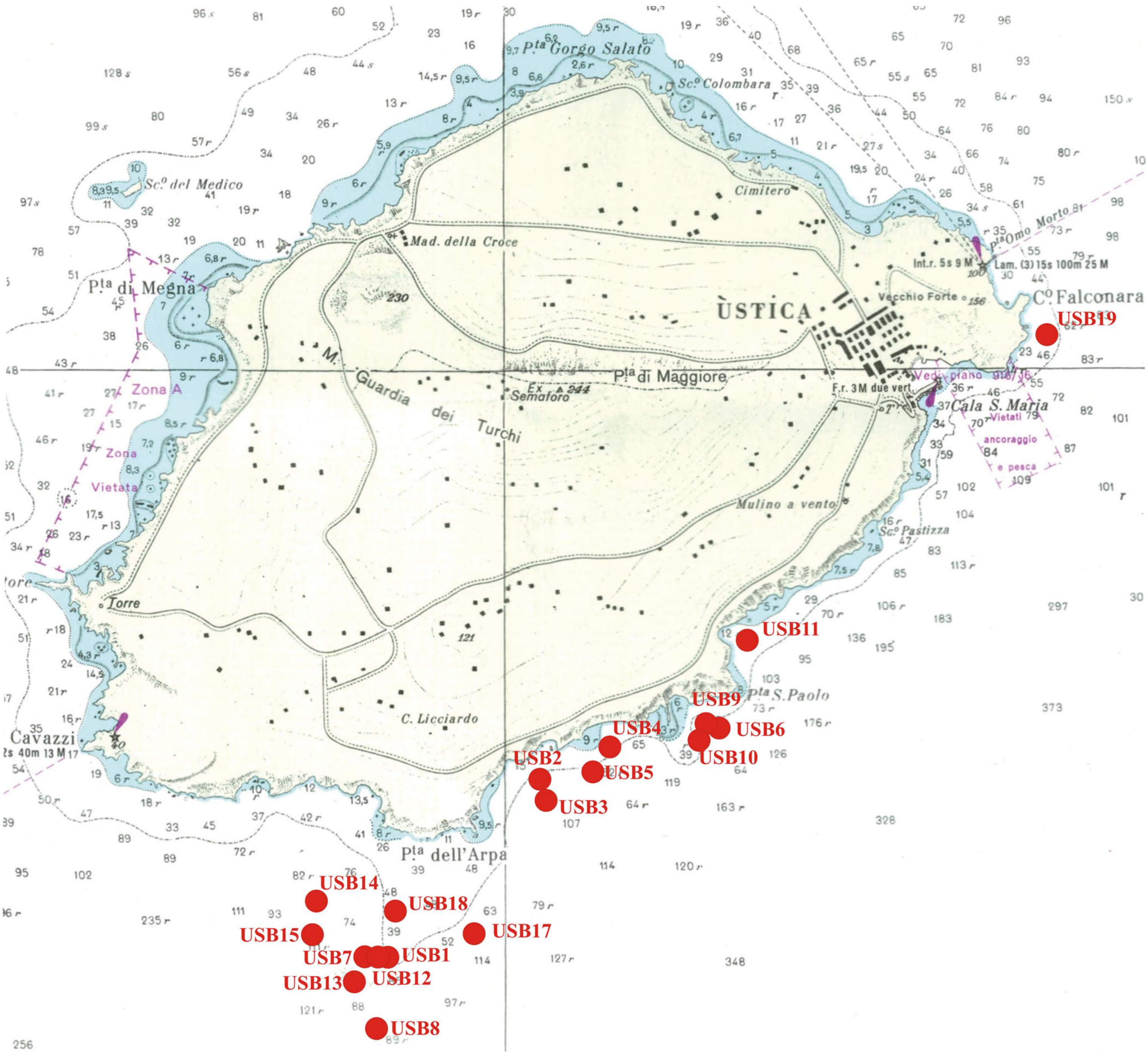

FIG. 1 - A georeferenced map of Ustica Island showing the stations sampled by using the Van Veen grab.

& Ward (1957) method. The relationship between the texture of the sediment and the characteristics of a depositional agent, is particularly evident if the texture is represented by two parameters of the grain size distribution, the 1° percentile (C) and the median diameter or 50° percentile (M). Indeed, CM patterns formed by sample points of a deposit are characteristic of the depositional agent (Passega, 1964). Therefore, a CM diagram was drawn, according to Passega (1964), to determine the grain size patterns as a geological tool. Ternary diagrams for the textural classification of sediments (Folk, 1954 modified by Tortora, 1999), histograms, cumulative curves and grain-size frequency curves were also considered.

Carbonate-content analysis

Calcimetric analysis was always performed on 16 samples by using a Calcimeter De Astis. Samples were dried at 100 °C, sieved by using a sieve of a 0.5 mm mesh size. For each sample, a sub sample, weighing about 1gr, was treated with HCl 37% and processed with the Calcimeter to estimate the carbonate content.

The obtained carbonate contents were corrected in relation to the temperature reported in the tables correlated to the calcimetric data and processed by using specific softwares.

Rhodolith analysis

A phycological analysis was carried out on 16 samples (both fossil and living algae). All samples were photographed with a digital camera, Canon Power Shot 630. Subsequently, samples were dried in an oven at 70 °C and examined either under a SEM (scanning electron microscope VEGA TS 5136XM at variable pressure) and a LM (light microscope). For LM thin sections were prepared whereas for SEM analysis samples were mounted onto aluminum stubs and coated with gold.

Some rhodoliths were examined under a stereo-microscope in order to check algal epiphytes. For the species identification we follow: Giaccone G. (1973 and subsequent updates), Boudouresque & Denizot (1975), Woelkerling (1988), Basso (1990, 1995a, b, 1996a, b, 1998), Woelkerling & Campbell (1992), Basso & Tomaselli (1994), Basso & *alii* (1997), Bressan & Babbini (2003).

The samples analysed under the SEM are housed at the Department of Geological Sciences and Geotechnology of the University of Milan-Bicocca whereas the thin sections are kept by Prof. Giuseppe Giaccone, emeritus professor of Phycologia of the University of Catania.

TABLE 3 - Dried weights of the sediment samples.

Sample code	Weight (gr)
USB2	406.4
USB3	420.9
USB4	116.2
USB5	431.1
USB6	310.8
USB7	428.8
USB9	170.3
USB10	79.1
USB11	145
USB12	481.4
USB13	510.3
USB14	380.4
USB15	665.3
USB17	67.5
USB18	675.3
USB19	695.3

RESULTS AND DISCUSSION

Sedimentological analysis

Dried weights of the sediment samples are reported in table 3. The granulometric analysis showed the presence of different types of sediment texture and values of the Folk & Ward (1957) statistical parameters (see tables 4 and 5).

The soft bottom of the analysed area was mainly characterised by coarse sediments included in the granulometric classes of sands and gravels. The biogenic component of these sediments was very high (about 95%) whereas the volcano-clastic component was particularly low (about 5%). The volcanic clasts were irregular and measured no more than 10-15 cm. Due to the sediment composition, it has been possible to rename the lithologies listed in the table 6, adding the prefix "bio" to the different classes: USB2-USB4-USB9-USB11-USB18 (*biocalcirudite sabbiosa*), USB3-USB5-USB6-USB7-USB14-USB15-USB17 (*biocalcarenite ghiaiosa*), USB10-USB12-USB19 (*biocalcarenite ghiaioso-fangosa*), USB13 (*biocalcirudite sabbioso-fangosa*).

Biogenic sediments have a low level of size-sorting (table 6) and the values of 50° percentile (see table 7) highlight the medium capacity of the current they are subjected to. Moreover, the sediments have polimodal grain size with a mode mainly distributed within the classes of sands and gravels.

TABLE 4 - Textures of the analysed sediments.

Sample code	Lithology (Folk, 1954)	Stations	Depth (m)
USB2	Sandy gravel	*Grotta Verde*	58
USB3	Gravelly sand	*Grotta Verde*	70
USB4	Sandy gravel	*Punta Galera Ponente*	67
USB5	Gravelly sand	*Punta Galera Ponente*	90.6
USB6	Gravelly sand	*Punta Galera Levante*	88
USB7	Gravelly sand	*Secchitello*	61.7
USB9	Sandy gravel	*Punta Galera Levante*	75
USB10	Gravelly-muddy sand	*Punta Galera Levante*	70
USB11	Sandy gravel	*Punta San Paolo*	56.5
USB12	Gravelly-muddy sand	*Secchitello*	64
USB13	Sandy-muddy gravel	*Secchitello*	83.7
USB14	Gravelly sand	*Secchitello*	72
USB15	Gravelly sand	*Secchitello Ponente*	96
USB17	Gravelly sand	*Secchitello-Punta dell'Arpa*	86
USB18	Sandy gravel	*Secchitello-Punta dell'Arpa*	47
USB19	Gravelly-muddy sand	*Punta Omo Morto*	56.4

TABLE 5 - Statistical parameters of Folk & Ward (1957).

Sample code	Mean diameter (mz)	Standard deviation (σ_φ)	Asymmetry (s_k)	Kurtosis (k_g)	Median (md_φ)	Mode (m)
USB2	- 1.126	2.854	-0.018	0.674	-0.834	-0.500
USB3	1.312	2.239	0.168	1.468	1.387	2.000
USB4	- 1.566	1.116	-0.311	0.961	-1.277	- 0.500
USB5	0.826	1.998	0.173	1.093	0.766	- 0.500
USB6	0.765	2.547	0.237	1.740	0.641	0.500
USB7	0.062	2.009	-0.174	1.127	0.177	0.500
USB9	- 0.600	2.155	0.266	1.548	- 0.869	- 1.000
USB10	0.999	2.289	0.136	1.410	1.066	2.000
USB11	- 1.304	0.547	-0.210	1.820	-1.267	-1.000
USB12	0.904	2.362	0.100	1.948	1.098	2.000
USB13	- 0.332	2.572	0.492	1.755	- 0.749	- 1.500
USB14	-0.740	0.804	0.150	1.901	-0.752	-0.500
USB15	0.991	2.178	0.332	1.907	0.837	0.500
USB17	1.138	1.860	0.020	1.100	1.255	2.000
USB18	- 0.290	2.075	0.169	1.791	- 0.212	0.500
USB19	1.080	2.504	-0.058	1.710	1.574	2.000

TABLE 6 - Size-sorting, simmetry and Kurtosis according to Folk & Ward (1957).

Sample code	Size-sorting	Simmetry	Kurtosis
USB2	Very little	Symmetric	Platykurtic
USB3	Very little	Asymmetric positive	Leptokurtic
USB4	Little	Asymmetric high negative	Mesokurtic
USB5	Little	Asymmetric positive	Mesokurtic
USB6	Very little	Asymmetric positive	High Leptokurtic
USB7	Very little	Asymmetric negative	Leptokurtic
USB9	Very little	Asymmetric positive	High Leptokurtic
USB10	Very little	Asymmetric positive	Leptokurtic
USB11	Moderately	Asymmetric negative	High Leptokurtic
USB12	Very little	Symmetric	High Leptokurtic
USB13	Very little	Asymmetric high positive	High Leptokurtic
USB14	Moderately	Asymmetric positive	High Leptokurtic
USB15	Very little	Asymmetric high positive	High Leptokurtic
USB17	Little	Symmetric	Mesokurtic
USB18	Very little	Asymmetric positive	High Leptokurtic
USB19	Very little	Symmetric	High Leptokurtic

According to Flügel (1982), the variously sandy and gravelly *bioareniti* and *bioruditi* of the circalittoral soft bottom at Secchitello can be included within the sublittoral carbonatic sedimentation (at a depth of between 20 and 200 m), characterized by different typologies of sediments: "Sediments on the inner shelf" (biogenic thin sediments); "Sediments on the outer shelf" (biogenic coarse sediments located until a depth of 100 m), corresponding to the DC described by Pérès & Picard (1964); "Algal ridges" or Formation of biogenic frameworks built by encrusting calcareous algae (banks until a 5 m thickness located from 40 to 180 m) corresponding to the Platform C described by Pérès & Picard (1964); "Shelf oolites" (sands with oolites located until a depth of 160 m).

Carbonate-content analysis

In table 8 are reported the calcium carbonate values corrected according to temperature. Calcimetric data represent a quantitative measure of the biomass produced by

TABLE 7 - 50° percentile of the sediment samples (Passega, 1964).

Sample code	50° percentile mm
USB2	-0.834
USB3	1.387
USB4	-1.277
USB5	0.766
USB6	0.641
USB7	0.177
USB9	- 0.869
USB10	1.066
USB11	-1.267
USB12	1.098
USB13	- 0.749
USB14	-0.752
USB15	0.837
USB17	1.255
USB18	- 0.212
USB19	1.574

the calcareous organisms such as foraminifers, molluscs, gasteropods, calcareous algae, etc.

The biogenic detritus of the analysed samples showed a mean percentage of $CaCO_3$ of about 77.70 %, except for two stations where we found lower percentages, precisely at Punta San Paolo (56.5 m) we found a percentage of 38.5% and at Punta Omo Morto (56.4 m) we found a percentage of 29.8% (table 9). In these two stations the reduced hydrodinamism and a huge quantities of leaves of *Posidonia oceanica* (L.) Delile and of other plants and algae cause a reduction of the pH which does not allow the deposition of $CaCO_3$.

RHODOLITH ANALYSIS OF DC

Species composition

In table 10 are reported the presence of fossil and living rhodoliths in the analysed samples. Overall, 19 *Corallinales* (table 11) have been identified at a specific level. *Peyssonnelia inamoena* Pilger, a fleshy alga found as epiphyte on rhodoliths, has been included in the list reported in table 11 due to the importance of its hypobasal calcification, which testify the presence of the DC bottom assemblage between 50 and 90 m. Moreover, the coralline red alga *Hydrolithon boreale* (Foslie) Y.M. Chamberlain has been found as epiphyte on fleshy seaweeds.

With respect to *Neogoniolithon brassica-florida* (Harvey) Setchell & L.R. Mason and *Spongites fruticulosus* Kützing, the absence of carposporophytes and male gametophytes in the analysed samples and the great variability of the diacritical characters, made it difficult to distinguish the two species. Therefore, all the analysed samples were labelled as follow: *Neogoniolithon brassica-florida/Spongites fruticulosus* or *vice - versa*. Some samples were identified as *Mesophyllum alternans* (Foslie) Cabioch & M.L. Mendoza and *Mesophyllum lichenoides* (J. Ellis) M.me Lemoine following Bressan & Babbini (2003), species widely reported for the Mediterranean Sea. But recent studies, using a molecular approach, have questioned the taxonomic *status* of samples collected in the Mediterranean basin (Athanasiadis & Neto, 2010; Peña & *alii*, 2015).

Lithothamnion minervae Basso, *Mesophyllum alternans* (Foslie) Cabioch & M.L. Mendoza and *Peyssonnelia inamoena* represent the first record for the Island of Ustica (Giaccone, 2009). The presence of *Lithothamnion minervae* also represents the first record for Sicily (Giaccone, 2009).

The analysis of rhodolith epiphytes has shown the presence of two alien invasive species, *Acrothamnion preissii* (Sonder) E.M. Wollaston and *Womersleyella setacea* (Hollenberg) R.E. Norris. Moreover, *Cystoseira brachycarpa*

TABLE 8 - Calcium carbonate values corrected according to temperature.

Sample code	Temperature measured during the analysis (°C)	$CaCO_3$ value (%)	$CaCO_3$ values (%) corrected according to the temperature
USB2	24	82	78.9
USB3	24	88	84.6
USB4	24	81	77.9
USB5	24	88	84.6
USB6	24	91	87.5
USB7	24	86	82.7
USB9	24	86	82.7
USB10	24	90	86.5
USB11	24	40	38.5
USB12	24	94	90.4
USB13	24	91	87.5
USB14	24	96	92.3
USB15	24	73	70.2
USB17	24	86	82.7
USB18	24	90	86.5
USB19	24	31	29.8

TABLE 9 - Lithology, percentages of $CaCO_3$ and depths in the analysed samples.

Sample code	Lithology (Folk, 1954)	$CaCO_3$ (%)	Depth (m)
USB2	Sandy gravel	78.9	-58
USB3	Gravelly sand	84.6	-70
USB4	Sandy gravel	77.9	-67
USB5	Gravelly sand	84.6	-90.6
USB6	Gravelly sand	87.5	-88
USB7	Gravelly sand	82.7	-61.7
USB9	Sandy gravel	82.7	-75
USB10	Gravelly-muddy sand	86.5	-70
USB11	Sandy gravel	38.5	-56.5
USB12	Gravelly-muddy sand	90.4	-64
USB13	Sandy-muddy gravel	87.5	-83.7
USB14	Gravelly sand	92.3	-72
USB15	Gravelly sand	70.2	-96
USB17	Gravelly sand	82.7	-86
USB18	Sandy gravel	86.5	-47
USB19	Gravelly-muddy sand	29.8	-56.4

TABLE 10 - Fossil and living rhodoliths in the analysed samples (+ = presence; 0 = absence).

Sample code	Fossil algae	Living algae
USB1	+	+
USB2	+	+
USB3	0	+
USB4	+	+
USB5	+	0
USB6	+	+
USB7	+	+
USB8	0	+
USB9	+	+
USB10	+	+
USB11	+	+
USB12	+	+
USB13	+	+
USB17	0	+
USB18	+	+
USB19	+	+

J. Agardh *emend.* Giaccone v. *claudiae* (Giaccone) Giaccone (indicator of environmental instability caused by hydrodynamic variations), *Cystoseira spinosa* Sauvageau v. *compressa* (Ercegovic) Cormaci & *alii* (indicator of environmental stability), and *Arthrocladia villosa* (Hudson) Duby (indicator of significant hydrodynamism) were also recorded.

The most common epiphytes are characteristic of the following benthic assemblages (according to the Convention of Barcellona (CB) of UNEP/PAM/RAC/SPA): III.6.1 (Biocoenosis of infralittoral seaweeds), IV.2.2. (Biocoenosis of the DC) and IV.3.1 (C biocoenosis). Since these algae are preferential and not exclusive species of the listed biocoenoses, their presence does not necessarily imply that all associations of these biocoenoses are present.

By comparing our list with the epiflora of a "rhodolith bed" reported by Mannino & *alii* (2003), 27 taxa resulted new records (Giaccone, 2009) for the Island of Ustica (see table 12). The presence of *Cystoseira dubia* Valiante, found on different dredged rhodoliths in the ecotone between the DC bottoms assemblage and the platform C assemblage, was the first record as epiphyte on rhodoliths. Moreover, a rich community of colonial Diatoms was found.

Growth-Form

Rhodoliths identified at Secchitello, formed by non-geniculate coralline red algae and *Peyssonneliceae*, have been classified into three main morphological groups: boxwork, coated grains and unattached branches. The multispecific rhodolits, with a vacuolar boxwork structure of several centimeters, found between 61.7 m and 90.6 m, were composed of different species as already documented in Basso & Tomaselli (1994): *Lithothamnion minervae*, *Lithothamnion valens, Mesophyllum alternans, M. lichenoides, Neogoniolithon brassica-florida*, *Spongites fruticulosus, Titanoderma (Lithophyllum) pustulatum,* together with other species belonging to the genera *Lithophyllum* (e.g. *L. stictaeforme*), *Lithothamnion* (e.g. *L. philippii*) and *Peyssonnelia* (e.g. *P. rosa-marina, P. inamoena*, etc.), mainly occurring on the rocky substrate of the Circalittoral and the sciaphilous Infralittoral zones. Coated grains, with a lithic nucleus (volcanic pebbles) making up > 50% of the total thickness of the nodule, were found between 56.5 m and 80 m. The branches, mainly including branched specimens with different classes of branches (I-II-III-IV-V), were found at 56.4 and 70 m and were composed of *Lithothamnion corallioides* and *Phymatolithon calcareum*.

Prâlines (sugared sweets), forming spheroidal warty nodules with a diameter of a few centimeters, were also found and were composed of *Lithophyllum racemus* (often associated to *Lithothamnion valens* and other rarer calcareous Rhodophyta). These morphologies were always found between 47 m and 88 m together with boxwork or coated grains or both morphological groups (see table 13).

Chorology and biogeography

The results of the chorological and biogeographic analysis of the rhodolith bed biodiversity (Babbini & Bressan, 1997; Bressan & Babbini, 2003) are reported in table 14. Notwithstanding the prevalence of the Atlantic bio-geographical element (48%), we observed a considerable presence of the Mediterranean bio-geographical element (21%) whereas the Indo-Pacific bio-geographical element was scarcely represented (11%). The presence of Cosmopolitan, Subcosmopolitan, Circumboreal and Pantropical bio-geographical elements was very low (each of them 5%). The prevalence of the Atlantic elements, consistent with the chorological spectrum of the Island of Ustica (Catra & *alii*, 2006), is a consequence of its location along the northern branch of the ingression Atlantic current.

TABLE 11 - Records of coralline red algae at Ustica (Secchitello, this work), in Sicily and in the Mediterranean Sea (+= presence; N= new record in Giaccone, 2009).

Taxa	Ustica	Sicily	Mediterranean Sea
Lithophyllum incrustans Philippi	+	+	+
Lithophyllum racemus (Lamarck) Foslie	+	+	+
Lithophyllum stictaeforme (Areschoug) Hauck	+	+	+
Lithothamnion cfr *philippii* Foslie	+	+	+
Lithothamnion corallioides (P. & H. Crouan) P. & H. Crouan	+	+	+
Lithothamnion minervae Basso	N	N	+
Lithothamnion sonderi Hauck	+	+	+
Lithothamnion valens Foslie	+	+	+
Mesophyllum alternans (Foslie) Cabioch & Mendoza	N	+	+
Mesophyllum lichenoides (J. Ellis) Me. Lemoine	+	+	+
Neogoniolithon brassica-florida (Harvey) Setchell & L.R. Mason	+	+	+
Peyssonnelia inamoena Pilger	N	+	+
Peyssonnelia rosa-marina Boudouresque & Denizot	+	+	+
Phymatolithon calcareum (Pallas) W.H. Adey & D.L. McKibbin	+	+	+
Pneophyllum confervicolum (Kützing) Y.M. Chamberlain	+	+	+
Pneophyllum fragile Kützing	+	+	+
Spongites fruticulosus Kützing (as *L. fruticulosum f. clavulatum* e *f. crassiusculum*)	+	+	+
Titanoderma mediterraneum (Foslie) Woelkerling	+	+	+
Titanoderma pustulatum (Lamouroux) Näegeli	+	+	+

Benthic bionomy

According to Pérès & Picard (1964), the DC is tipically distributed in the Circalittoral zone even if it can be found in a poorer form in the low infralittoral zone.

The DC is extremely variable in relation to the nature of the coast and, according to the dominance of animal or vegetal species, it may present a suite of *zoofacies* or *phytofacies*. Pérès & Picard (1964) recognized 7 *phytofacies* in the DC: *prâlines facies*; *Lithothamnion valens facies; Maërl facies*; *Lithothamnion fruticulosum facies;* free-living *Squamariaceae facies; Osmundaria volubilis facies; Halarachnion spathulathum facies.* We propose here a new model, consisting of 4 *phytofacies*: *prâlines facies*; *Maërl facies*; *Lithothamnion minervae facies;* free-living *Peyssonneliaceae facies.*

The *Osmundaria volubilis* and *Halarachnion spathulathum facies* were eliminated because epiphyte algae cannot characterize a *facies*. The *Lithothamnion valens facies* has been included in the *prâlines facies.* The free-living *Squamariaceae facies* has been updated into the free-living *Peyssonneliaceae facies.* We first describe the *Lithothamnion minervae facies,* which partially substitutes the "*Lithothamnium fruticulosum" facies* described by Pérès & Picard (1964).

The "*Lithothamnion minervae*" *facies,* widespread in the Mediterranean Sea, is dominated by free coralline red algae, characterized by spheroidal or elliptical breast shapes, i.e. with short cylindrical branches radially arranged. "*Lithothamnium fruticulosum*", often reported as a preferencial species of the DC *facies*, is in fact a group of species.

TABLE 12 - New records for the Island of Ustica (Giaccone, 2009).

Epiphytic taxa
Acrodiscus vidovichii (Meneghini) Zanardini
Acrothamnion preissi (Sonder) E.M. Wollaston
Bonnemaisonia asparagoides (Woodward) C. Agardh
Botryocladia botryoides (Wulfen) Feldmann
Ceramium comptum Bøergesen
Cladophora pellucida (Hudson) Kützing
Cystoseira brachycarpa J. Agardh *emend.* Giaccone v. *claudiae* (Giaccone) Giaccone
Cystoseira dubia Valiante
Cystoseira spinosa Sauvageau *v. compressa* (Ercegovi) Cormaci *& alii*
Dictyota dichotoma (Hudson) J.V. Lamouroux *v. dichotoma*
Dictyota dichotoma (Hudson) J.V. Lamouroux *v. intricata* (C. Agardh) Greville
Ectocarpus siliculosus (Dillwyn) Lyngbye *v. dasycarpus* (Kuckuck) Gallardo
Feldmannophycus rayssiae (Feldmann *et* Feldmann-Mazoyer) H. Augier *et* Boudouresque
Gelidium spinosum (S.G. Gmelin) P.C. Silva
Hydrolithon boreale (Foslie) Y.M. Chamberlain
Jania adherens J.V. Lamouroux
Laurencia chondrioides Bøergesen
Myrionema strangulans Greville
Neurocaulon foliosum (Meneghini) Zanardini
Palmophyllum crassum (Naccari) Rabenhorst
Peyssonnelia armorica (P. *et* H. Crouan) Weber Bosse
Peyssonnelia inamoena Pilger
Phyllophora crispa (Hudson) P.S. Dixon
Pneophyllum confervicolum (Kützing) Y.M. Chamberlain
Polysiphonia elongata (Hudson) Sprengel
Rhodymenia delicatula P.J.L. Dangeard
Rhodymenia ligulata Zanardini
Womersleyella setacea (Hollenberg) R.E. Norris

TABLE 13 - Depth, morphotypes, shapes and branching classes of analysed samples.

Sample code	Depth (m)	Morphotype	Shape	Branching class
USB1	-61.7	BOXWORK	COMPACT-BLADED	---
USB2	-58	COATED GRAINS	BLADED	---
USB3	-70	COATED GRAINS	PLATY	---
USB4	-67	COATED GRAINS	PLATY	---
USB5	-90.6	DIED BOXWORK	COMPACT-BLADED	---
USB6	-88	BOXWORK	BLADED	---
USB7	-61.7	BOXWORK	BLADED	---
USB8	-80.5	COATED GRAINS	PLATY	---
USB9	-75	DIED BOXWORK	BLADED	---
USB10	-70	BOXWORK-BRANCHES	COMPACT	I-II
USB11	-56.5	COATED GRAINS	BLADED	---
USB12	-64	BOXWORK	COMPACT-ELONGATED	---
USB13	-83.7	BOXWORK	ELONGATED	---
USB17	-86	BOXWORK	COMPACT-BLADED	---
USB18	-47	BOXWORK	COMPACT-PLATY	---
USB19	-56.4	BRANCHES	---	II-III-IV

When the hydrodinamism is reduced, it is possible to find multispecific boxwork (diameter of 10-15 cm), composed of the previously listed coralline red algae. A symplified form of this *facies* can be found in the infralittoral channels of the *Posidonia oceanica intermatte*s or in the lagunar mouth communicating with the sea and oriented according to the direction of the dominant winds and of the tidal currents. According to the different hydrodynamic conditions, spheroidal shapes (pumping currents) or elliptical shapes (fluctuating currents) can be found. Sediments are characterized by coarse sands and fine muddy gravel, but in transition zone (ecotons) with a low hydrodinamism and a high turbidity we also found rhodoliths composed of calcareous Peyssonneliaceae. On the boxwork a rich epiphytic assemblage can develop. In clear waters a reofil epiflora can be found, mainly composed of fleshy algae dominated by *Arthrocladia villosa* (Hudson) Duby*, Cryptonemia lomation* (Bertoloni) J. Agardh*, Kallymenia patens* (J. Agardh) Codomier ex P.G. Parkinson*, K. spathulata* (J. Agardh) Codomier ex P.G. Parkinson*, Laminaria rodriguezii* Bornet*, Osmundaria volubilis* (Linnaeus) R.E. Norris*, Phyllophora crispa* (Hudson) P.S. Dixon*, Rytiphloea tinctoria* (Clemente) C. Agardh*, Sporochnus pedunculatus* (Hudson) C. Agardh.

The DC of the studied area is characterized by species belonging to different *facies* even if the morphological groups and the species of the *Lithothamnion minervae facies* are dominant. This omogeneity is consistent with the typology of the sediments (mainly biogenic sandy gravels or gravelly sands) and with the regular hydrodinamism.

Ecology

In the Mediterranean Sea the phytosociological association *Phymatolitho-Lithothamnietum corallioidis* Giaccone 1965, recorded in the Circalittoral soft bottoms at Secchitello, corresponds to the *Melobesie libere facies*, term

TABLE 14 - Chorological groups of the rhodolith beds present in the studied area.

Taxa	Chorological group
Lithophyllum incrustans Philippi	ATLANTIC BOREAL
Lithophyllum racemus (Lamarck) Foslie	INDO-PACIFIC
Lithophyllum stictaeforme (Areschoug) Hauck	INDO-ATLANTIC
Lithothamnion cfr *philippii* Foslie	ATLANTIC -TROPICAL
Lithothamnion corallioides (P. & H. Crouan) P. & H. Crouan	ATLANTIC BOREAL
Lithothamnion minervae Basso	MEDITERRANEAN
Lithothamnion sonderi Hauck	ATLANTIC BOREAL
Lithothamnion valens Foslie	MEDITERRANEAN
Mesophyllum alternans (Foslie) Cabioch & Mendoza	ATLANTIC
Mesophyllum lichenoides (J. Ellis) Me. Lemoine	ATLANTIC BOREO-TROPICAL
Neogoniolithon brassica-florida (Harvey) Setchell & L.R. Mason	SUB-COSMOPOLITAN
Peyssonnelia inamoena Pilger	PANTROPICAL
Peyssonnelia rosa-marina Boudouresque & Denizot	MEDITERRANEAN
Phymatolithon calcareum (Pallas) W.H. Adey & D.L. McKibbin	ATLANTIC BOREAL
Pneophyllum confervicolum (Kützing) Y.M. Chamberlain	CIRCUMBOREAL
Pneophyllum fragile Kützing	COSMOPOLITAN
Spongites fruticulosus Kützing	INDO-PACIFIC
Titanoderma mediterraneum (Foslie) Woelkerling	MEDITERRANEAN
Titanoderma pustulatum (Lamouroux) Näegeli	INDO-ATLANTIC

created by Pérès & Picard (1964) and currently used to generically indicate the non-geniculate *Corallinales* and the free *Peyssonneliaceae* assemblages occurring in the DC.

The bottoms at Secchitello, due to the presence of volcanic pinnacles which can be considered reefs with laminar and regular currents, are certainly a favourable environment for the DC development (Pérès & Picard, 1964). Changes in the hydrodynamic, light intensity and sediment conditions can determine the development of the poorerly structured subassociation *Laminarietosum rodriguezii* Giaccone 1973, belonging to the association *Cystoseiretum zosteroidis* Giaccone 1973, as observed in the circalittoral soft bottoms at Banco Apollo (Island of Ustica; Giaccone, 1967) in substitution of the *Phymatolitho-Lithothamnietum corallioidis* Giaccone 1965 association.

The rhodolith growth forms recorded at Secchitello confirm the presence of a regular hydrodinamism. A reduced hydrodinamism is found at a depth of between 80 and 90 m, where an ecotone between the DC with free coralline red algae and the presence of C growing on boxwork was observed. Between 50 and 90 m, the movement of rhodoliths (DC and ecotone) is also due to the echinoderm *Cidaris cidaris* (Linnaeus, 1758) which is able to overturn them, but also to the so called "sail" epiphytes, i.e. algae such as *Cystoseira spinosa* v. *compressa* and *Phyllophora crispa* in the DC and *Cystoseira dubia* in the ecotone, which act as a sail in presence of laminar currents. It has also hypothesized that the branches of the starfish *Echinaster sepositus* (Retzius, 1783), frequently found at Secchitello, may be responsible of the overturning of the rhodoliths.

The evolution from the DC Biocoenosis to the C Biocoenosis may be observed at the stations USB5, USB6, USB8 e USB13, USB17 and in the dredged line, linking these stations at 80 m and 90 m, which rapresent an ecotone of transition. The area located between Secchitello and Punta Galera is a transition zone between the two circalittoral biocoenosis. In the station USB6 the red alga *Womersleyella setacea*, considered one of the most dangerous invasive species for the C biocoenosis, was recorded. The coverage of this alga is responsible of a consistent reduction of the light and then of the photosintetic activity of coralline red algae growing below (Ballesteros, 2006). At Secchitello, the DC biocoenosis formed by *Mesophyllum lichenoides, Mesophyllum alternans*, *Lithophyllum stictaeforme* and *Spongites fruticulosus / Neogoniolithon brassica-florida* along an abandoned trammel, correspond to the C biocoenosis recorded by the R.O.V. In the Mediterranean Sea, the C is represented by the association *Lithophyllo-Halimedetum tunae* Giaccone 1965, but its aspect may change as consequence of the presence of bioconstructor animals, i.e. the "Big branched *Briozoa*" *facies* observed at Secchitello. As the depth increases, the red coralline algae *Lithophyllum stictaeforme, Spongites fruticulosus / Neogoniolithon brassica-florida* and *Peyssonnelia rosa-marina* dominate the assemblage instead of *Halimeda tuna.*

Paleoecological analysis

The analysed rhodoliths showed a multispecific structure. According to Basso & Tomaselli (1994), the analysis of the rhodolith growth, from the inner nucleus towards the outer surface, allow us to make a paleoreconstruction of underwater environment but also to describe the actual underwater environment. The results of the analysis of the thin sections of the rhodolith recorded at Secchitello (table 15) show as the evolution from the paleoenvironment to the actual environment is beated by the regular alternation in the time of bottoms with free coralline red algae (DC) and transitional bottoms (ecotone between the DC Biocoenosis and the C Biocoenosis).

TABLE 15 - Phases of colonization of the circalittoral soft bottoms at Secchitello and in the neighbouring areas (Punta dell'Arpa, Punta San Paolo, Punta Galera Ponente, Punta Galera Levante, Grotta Verde).

Actual environment	Paleoenvironment		
Free coralline red algae *facies* and Ecotone	Free coralline red algae paleo*facies*	Free coralline red algae paleo*facies* and paleoecotone	Free coralline red algae paleo*facies*
Actual colonization	Recent colonization	Intermediate colonization	Initial colonization
Lithophyllum racemus	*Lithothamnion* cfr *minervae*	*Lithophyllum incrustans*	*Lithophyllum incrustans*
Lithophyllum stictaeforme	*Lithothamnion minervae*	*Lithophyllum racemus*	*Lithophyllum racemus*
Lithothamnion cfr *philippii*	*Mesophyllum alternans*	*Lithophyllum stictaeforme*	*Lithothamnion minervae*
Lithothamnion corallioides	*Phymatolithon calcareum*	*Lithothamnion* cfr *sonderi*	*Lithothamnion* sp.
Lithothamnion minervae	*Titanoderma* sp.	*Lithothamnion minervae*	*Lithothamnion valens*
Lithothamnion sonderi		*Lithothamnion valens*	*Mesophyllum alternans*
Lithothamnion sp.		*Mesophyllum alternans*	*Mesophyllum lichenoides*
Lithothamnion valens		*Mesophyllum lichenoides*	*Phymatolithon calcareum*
Mesophyllum alternans		*Spongites fruticulosus / Neogoniolithon brassica-florida*	*Spongites fruticulosus / Neogoniolithon brassica-florida*
Mesophyllum lichenoides		*Titanoderma pustulatum*	*Titanoderma mediterraneum*
Peyssonnelia inamoena		*Titanoderma* sp.	*Titanoderma pustulatum*
Peyssonnelia rosa-marina			*Titanoderma* sp.
Phymatolithon calcareum			
Pneophyllum confervicolum			
Pneophyllum fragile			
Spongites fruticulosus / Neogoniolithon brassica-florida			
Titanoderma pustulatum			
Titanoderma sp.			

CONCLUSIONS

The DC *facies* characterizing the circalittoral soft bottoms at Secchitello and in the neighbouring areas were presented and interpreted in an evolutionary key. Useful data for a taxonomic, ecological and paleoecological revision of the Mediterranean associations with calcareous free-living *Rhodophyceae* together with information on their relations with the sedimentary dynamic were provided.

Within the bathymetric range of the investigated circalittoral soft bottoms three main growth forms of living rhodoliths have been identified: the unattached branches, the vacuolar boxwork rhodoliths and the coated grains, which develop under different environmental conditions. Since the succession of different species inside multispecific boxwork rhodoliths reflects changing in the environmental conditions (Bosence, 1983; Basso & Tomaselli, 1994), boxworks allow to accurately reconstruct the environmental conditions (e.g. water movement, sedimentation, light penetration).

The traditional model of Pérès & Picard (1964) about the DC *phytofacies* has been updated as follow: *prâlines facies*, *Maërl facies*, *Lithothamnion minervae facies* and free-living Peyssonneliaceae *facies*. We describe the new *Lithothamnion minervae facies*, which partially replaced the "*Lithothamnion fruticulosum*" (a taxon with a controversial nomenclatural and systematic status) *facies*, described by Pérès & Picard (1964).

The DC biocoenosis at Secchitello does not belong to a specific *facies* even if a prevalence of *Lithothamnion min-*

ervae was observed. The presence of an ecotone of transition, between the DC and the C communities has also been recorded.

The analysis of various sections of non-geniculate *Corallinales* allowed to reconstruct the paleoenvironmental evolution of the Secchitello, pointing out three phases (initial, intermediate and recent colonization) and to characterize the actual colonization. The transition from one phase to another is probably due to the temporary changes of intensity and direction of the currents which took place in the last millennium. The coverage and biodiversity of the free-living calcareous algae and of epibionts found at Secchitello are quite comparable to those described for the C assemblage.

The soft-bottoms are characterized by coarse sediments included in the granulometric classes of sands and gravels, the last one mainly of biogenic nature (about 95%). The rough morphology of these bottoms, characterized by the alternation of pinnacles and gorges with soft bottoms, increases the current activity (wave motion currents and Ingression Atlantic Current). According to Basso & Tomaselli (1994) the rhodolits should begin to overturn with an average current speed of 1.30 m/s. Their overturn is also ensured by the presence of biodisturbance phenomena and of "sail" epiphytes.

Among the anthropogenic activities, the trawler fishing, responsible of physical and biological destruction, has the greatest impact on the rhodolith beds (Steller & *alii*, 2003), therefore this habitat as a whole should be protected, in order to prevent disturbance and/or destruction. Luckely, trawler fishing is forbidden in the MPAs such as the Island of Ustica, therefore the circalittoral rhodolith assemblages are not in danger. Instead, the superficial rhodoliths, which do not form rich assemblages from a depth of 50 m to the surface, may be caught in the fishermen's gill nets.

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