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An updated reporting of rhodolith deposits in the offshore of Ischia (Gulf of Naples, Italy)

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***Abstract* – In this work, the occurrence of rhodolith deposits on the sea bottom of the Ischia offshore is highlighted on the base of sedimentological data coming from samples collected during the marine geological mapping of the Ischia Island coupled with seismo-stratigraphic data derived from the geological interpretation of Sparker seismic profiles. The sea bottom samples are rich in bioclasts, mainly gravelly sands. These deposits prevail in the eastern Ischia offshore, on the relict volcanic edifice of the Ischia Bank and on the genetically related parasitic vent and in the Ischia Channel. Subordinately, these deposits occur also in the northern Ischia offshore (Casamicciola) and on the top of the Forio Bank. The ternary plots of the sedimentological data have shown that the main lithologies are represented by silty sands and gravelly sands, sands and gravelly sands and subordinately, by sandy silts. The seismo-stratigraphic data have suggested that these deposits are mainly inter-layered in the highstand deposits. Further studies are required in order to collect new ecological data from the studied samples.**

I. INTRODUCTION

Rhodolith or maërl deposits are represented by either alive or dead aggregations of coralline algae, which cover large coastal areas in the present-day oceans [1-3]. These deposits represent common facies in carbonate platform environments, in some cases indicating the transition from bioclastic-to-rocky sea bottoms [4-5]. The rhodoliths are the main components of the rhodalgal skeletal assemblage, that characterizes the carbonate production in the oligophotic zone of Cenozoic and modern carbonate platforms [5-10]. Since Early Cretaceous calcareous red algae (*Rhodophyta*, *Corallinales*) live in the photic zone [11-13] from warm, tropical and temperate regions, to cold, polar and subpolar ones [5; 14-18]. The colonization of red calcareous algae occurs both on the rocky substratum and on the mobile sea bottoms. Their growth-form varies from encrusting forms to erect, articulated or free forms [12; 19-25]. Red coral algae play an important ecological role in the marine ecosystems as habitat builders and produce important biodiversity peaks [3; 26-29]. The mäerl / rhodolite layers [30-33] and the coralligenous [34-36] represent important examples. Furthermore, these algae significantly contribute to the carbonate production, playing a major role in the carbon cycle [18; 25; 33]. This work provides an updated report on the rhodolith deposits offshore of the island of Ischia (Gulf of Naples, Italy); it is based on data coming from sea bottom samples collected during the CARG project aimed at the realization and informatization of the marine geological cartography of the geological sheet No. 464 [38]. The island of Ischia represents the emerged part of a large volcanic field, which extends from the island of Procida to the submerged volcanoes of the western offshore of Ischia [38-40]. The sedimentological analysis of the sea bottom samples, together with the realization of geological cartography at the 1: 10.000 scale has allowed to give an updated report on the rhodolith deposits occurring in the Ischia offshore and representing both relict deposits and zones of active carbonate sediment production. Although qualitatively, the seismo-stratigraphic data have allowed for the calibration of the rhodalgal deposits on previously interpreted seismic Sparker profiles [40]. The aim of this work is to improve the knowledge on the rhodolith deposits offshore of Ischia based on sedimentological, geological and cartographic data, integrating the previous data, which mainly concern the ecology of these deposits, with a little attention paid to their location and classification within the Quaternary geological structure of the offshore of Ischia. Ternary plots of the sedimentological data have been constructed for a better evaluation of different grain sizes, considering as variables respectively clay-sand-silt and gravel-sand-silt. The samples have been plotted into ternary diagrams subdividing them with respect to the oceanographic cruises GMS02_01 and GMS06_03, carried out by CNR-IAMC of Naples (now ISMAR of Naples) respectively in 2002 and 2006.

II. MATERIALS AND METHODS

The geological and geophysical data were acquired in the framework of the realization of the geological map n. 464 "Ischia Island" at the 1:10.000 scale [38]. Detailed geological maps, showing the distribution of sea bottom

sediments, were built on the basis of the previous geological survey. Furthermore, the new sedimentological analyses of sea bottom samples have allowed to reconstruct the facies distribution on the sea bottom. The stratigraphic framework of the investigated area is based on both high-resolution seismic profiles calibrated by cores and on high-resolution sequence stratigraphy. Geological and geomorphological data collected at the 1: 10.000 and 1: 5000 scales have been reported on the 1:10.000 geological maps of Campania in order to later produce national geological maps at the 1: 50.000 scale. A new detailed interpretation of the previously interpreted Sparker seismic profiles available around Ischia [40] has been carried out, focusing on the Ischia Bank, on the Ischia Channel and on the Casamicciola offshore. The aims of this interpretation are the identification of the bioclastic deposits and the definition of their stratigraphic relationships with the volcanic and sedimentary units recognized offshore of Ischia [40]. An integrated diagram has been constructed, reporting the location map (Fig. 1, inset A), the Ischia Digital Elevation Model (DEM) with the location of the samples (Fig. 1, inset B), the geologic interpretation of the seismic profile L27 (Casamicciola offshore; Fig. 1, inset C), the geologic interpretation of the seismic profile L57 (Ischia Channel; Fig. 1, inset D) and the ternary plots of the sedimentological data (Fig. 1, inset E). Ecological data have not been yet analyzed and will require further studies. In the north-western Ischia offshore the taxonomic analysis of the macro-phyto-benthic component of the red coral algae has shown well-pigmented thalli, with a various growth-form, consisting of alive and dead thalli belonging to the species *Lithothamnion corallioides* and *Phymatolithon calcareum* [41]. The identified zoo-benthic species are typical of the "détritique còtier" [42] and of muddy sea bottoms, and the rhodolith deposits of the Ischia offshore have shown a rich and diverse benthic flora and fauna, especially in a maërl facies [41]. The delivery and the discovery of the rhodolith beds offshore of Campania have been recently studied [43]. In the Naples Bay four sites (Capri, Punta Campanella, Secchitiello and Ischia) have been described. Around Ischia, the new ecological data have been correlated with the previous ecological data [41] and have suggested three morpho-types of rhodoliths, with a prevalence of unattached branches of *Phymatolithon calcareum* and *Lithothamnion corallioides* [43]. A high percentage of dead thalli of red algae, together with the alive rhodoliths, has been suggested. A high fraction of fine-grained sediments, triggering the burial of the rhodolith deposits was probably the main control factor of a so high percentage of dead thalli [43].

III. RESULTS AND DISCUSSION

The sedimentological analyses were performed with the aim of showing the main compositional and textural characters of sediments sampled at the sea bottom in Ischia (Fig. 1, inset B). The sediment fractions recognized at the sea bottom based on particle size analyses include gravel sands, sands, silty sands, muddy sands, sandy silts and silts. Ternary plots have been assembled (Fig. 1, inset E), respectively taking into account clay-sand-silt and gravel-sand-silt. The samples have been splitted in the samples collected in the oceanographic cruise GMS02_01 (diagrams in the upper part of Fig.1, inset E) and in the oceanographic cruise GMS06_03 (diagrams in the lower part of Fig. 1, inset E). The ternary plot located in the upper left corner of Fig. 1 (inset E) considers as variables: clay, sand and silt. This plot has shown that the main lithologies are the clayey silts and the sandy silts (Fig. 1, inset E). The ternary diagram located in the upper right corner of Fig. 1 (inset E) considers as variables: gravel, sand and silt. This plot has shown that the main lithologies are represented by the silty sands and by the gravelly sands. The ternary plot located in the lower left corner of Fig. 1(inset E) considers as variables: clay, sand and silt. This plot has suggested that the main lithologies are represented by the sands and by the silty sands (Fig. 1, inset E). The ternary plot located in the lower right corner of Fig. 1(inset E) considers as variables: gravel, sand and silt. This plot has suggested that the main lithologies are represented by the sands and by the gravelly sands and subordinately, by the sandy silts. Based on the field data description of the sea bottom samples the bioclasts are mainly composed of *Posidonia oceanica* leaves, *Posidonia oceanica* rhizomes, fragments and valves of lamellibranchs, fragments of gastropods, fragments of calcareous algae, fragments of echinoids, whole irregular echinoids, corals, fragments of bryozoans, red algae. The concretions of red algae reach dimensions in the order of 7-10 cm. The volcaniclasts are mainly composed of volcanic lithics and small pumices. The sampling data on rhodolith deposits have allowed to review previous interpretations of seismic lines in the offshore of Ischia [41]. In the Casamicciola offshore, the rhodolith deposits are probably inter-layered in a wide seismic unit, characterized by parallel and continuous seismic reflectors and interpreted as highstand deposits (Fig. 1, inset C). The Late Quaternary depositional sequence consist of both highstand deposits and forced regression prograding wedges (Fig. 1, inset C). Several volcanic seismic units have been recognized (V1, V2, V3; Fig. 1, inset C). The V1 unit is characterized by an acoustically-transparent seismic facies and has been interpreted as an undetermined volcanic acoustic basement, whose top is eroded by an erosional unconformity (Fig. 1, inset C). The V2 unit is characterized by an acoustically-transparent seismic facies and by a mounded-shaped external geometry and has been interpreted as buried volcanic edifices, which appear to be partly tectonically-controlled by normal faults, having a little vertical throw (Fig. 1, inset C). The

V3 unit, interpreted as an undetermined pyroclastic unit, locally filling depressions, is characterized by discontinuous seismic reflectors and forms a mounded-shaped pyroclastic edifice (Fig. 1, inset C). The Quaternary marine deposits of northern Ischia (Casamicciola) consist of two seismic units (M1 and M2; Fig. 1, inset C). Both the M1 unit and the M2 unit are characterized by parallel to sub-parallel seismic reflectors (Fig. 1, inset C). In the Ischia Channel the rhodalgal facies are probably inter-stratified in the highstand deposits, which unconformably overlie the volcanic unit of the Ischia Channel. This unit has been identified on the north-eastern section of the L57 seismic line, reaching the continental shelf of the Procida island and crossing, in the Ischia Channel, the relict volcanic edifice of "Il Pertuso" (Fig. 1, inset D). The volcanic unit of the Ischia Channel has been correlated with pyroclastites and lavas genetically related with the relict volcanic edifices of the Ischia Channel [40].The obtained results are in agreement with the previous data on rhodolith deposits in the Mediterranean area, referring to the southern Tyrrhenian Sea (Pontine Islands) [4; 7; 14], and to the Naples Bay [41]. The rhodolith layers have been found in the eastern and western Mediterranean sub-basins at water depths ranging between - 30 m to - 75 m. They have been reported in the most of the coastal sections of the Mediterranean sea, while they are missing in the eastern Adriatic sea, Egypt, Syria, Lebanon and in the Black Sea. In the Mediterranean sea these deposits have shown a high spatial and bathymetric extension, also if the biocostructions of coralline algae virtually occur in all the seas. On the Tyrrhenian continental shelf (Pontine Islands) the occurrence of calcareous algae has been discussed through two different carbonate facies, namely the coralline algae facies and the carbonate matrix facies [4]. The Pontine Islands represent a mobile sea bottom of the littoral zone. The corresponding biocenosis is the "Détritique Cotier""and is constituted by a mixture of sands, gravels and muds. Furthermore, a moderate variability of sedimentary facies, in particular of sands dominated by biogenic carbonates, has been suggested in this area [14]. The coralline algae are the most important control factor on the carbonate production and occur at depths ranging between - 40 m to - 70 m. These water depths are coherent with the depths of the rhodolith deposits found in the Ischia offshore and discussed in this paper. The bioclastic deposits of Ischia, referring to the rhodolith layers, in particular, can be compared with similar successions, which have been detected in other sectors of the Naples Bay (island of Capri, Gulf of Pozzuoli, offshore of Naples town) [42]. They correspond to detrital facies, whose deposition has been controlled by an *in situ* reworking of organogenic material on rocky sea bottoms. These deposits are composed of medium-coarse-grained sands and bioclastic gravels in a scarce pelitic matrix and crop out at the sea bottom in a portion of the inner shelf located at water depths between - 20 m and - 50 m, characterized by a prevalent carbonate sedimentation. Other significant outcrops are found on the morphological thresholds (Ischia Channel) and at the top of relict volcanic edifices, both in Ischia (Ischia and Forio Banks) and in Procida (La Catena, Il Pertuso and Vivara ants). Below water depths of - 30 m the bioclastic deposits are rhodolith, characterized by gravels and lithoclastic sands. Offshore of Naples town (Nisida Bank; La Cavallara saddle) the pyroclastic gravels are often mixed with rhodolith deposits characterized by living red algae. The rhodalgal facies is constituted by dead, fallen or transported thalli from submerged rocky outcrops, which have been colonized in different ways. The biogenic fraction is composed of sandy skeletal assemblages, forming variable types of deposits, which have undergone an intense mechanical degradation. Various types of rhodalgal facies have been found on the Miseno Bank (Gulf of Pozzuoli). In correspondence with the rocky outcrops, alive thalli have been found. On the surrounding sea bottom, characterized by gravels and bioclastic sands, palimpsest deposits were sampled, formed by bioclastic sands.

IV. CONCLUDING REMARKS

In the Ischia offshore the rhodolith deposits have shown that in variable geomorphological and hydrological settings the carbonate facies composed of red coralline algae have different structures. The topography of the sea bottom has controlled the stratigraphic architecture of these deposits (relict volcanic edifices, morphological tresholds, rough topographies controlled by the development of debris avalanche deposits). The sedimentological data have shown that the main lithologies are represented by clayey sands and sandy silts; silty sands and gravelly sands; sands and silty sands and subordinately sandy silts. Fine-grained lithologies are often associated with coarser lithologies. Although qualitatively, the correlation between the sampling data and the interpretation of seismic profiles, previously interpreted and reviewed here, has suggested that the rhodolith deposits are inter-stratified within large seismic units, cropping out at the sea bottom or sub-surficial. In the Casamicciola offshore the rhodolith deposits are presumably inter-layered with the highstand deposits, represented by a thick seismic unit cropping out at the sea bottom. This unit is adjacent to a thick seismic unit interpreted as debris avalanche deposits.

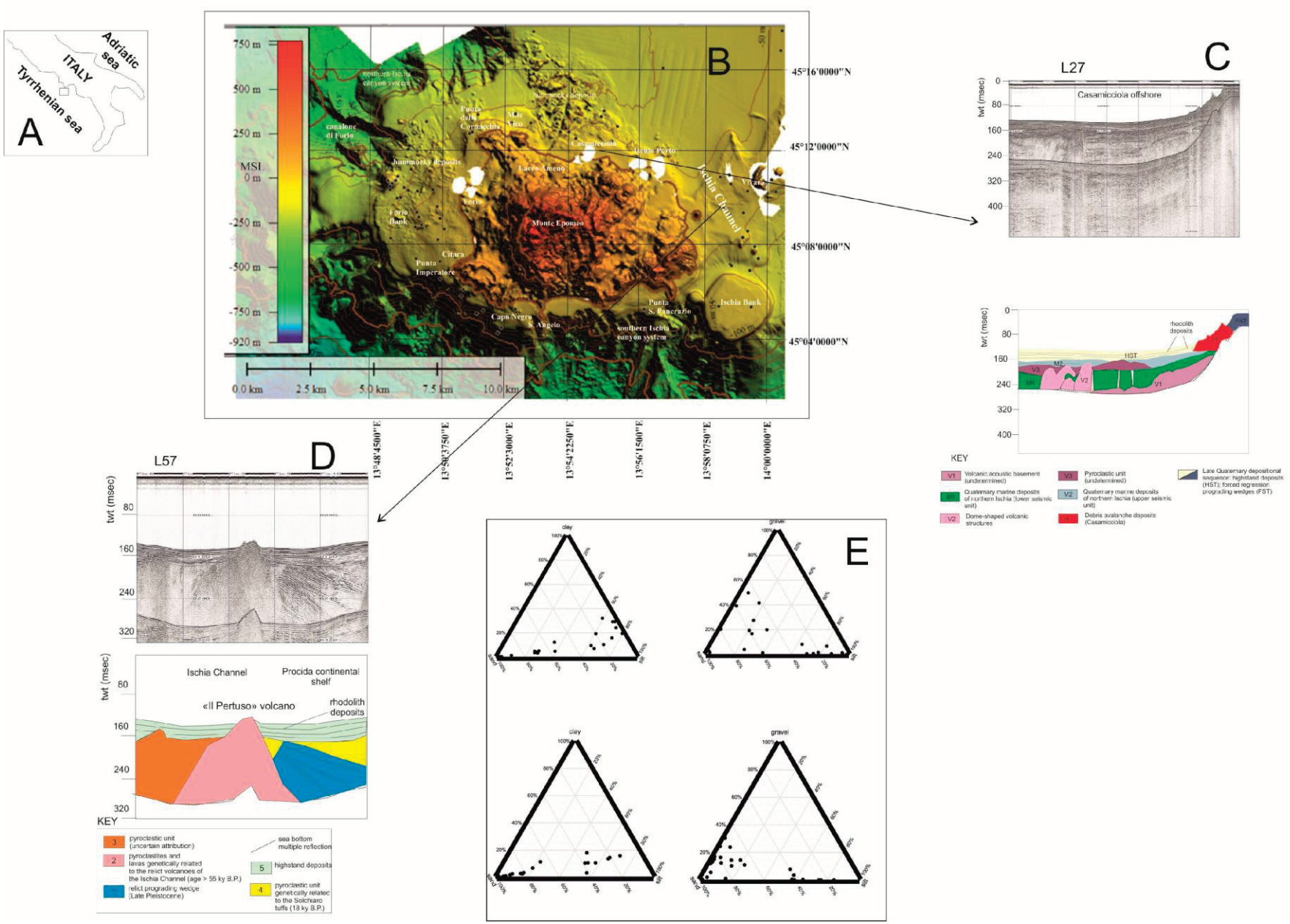
A
Adriatic sea
ITALY
Tyrrhenian sea
B
750 m
500 m
250 m
MSL
0 m
-250 m
-500 m
-750 m
-920 m
0.0 km
2.5 km
5.0 km
7.5 km
10.0 km
45°16'0000"N
45°12'0000"N
45°08'0000"N
45°04'0000"N
13°48'4500"E
13°50'3750"E
13°52'3000"E
13°54'2250"E
13°56'1500"E
13°58'0750"E
14°00'0000"E
southern Ischia canyon system
Punta della Cornacchia
Mte Vico
Casamicciola
Ischia Channel
Lacco Ameno
Forio
Forio Bank
hummocky deposits
Monte Epomeo
Citara
Punta Imperatore
Capo Negro
S. Angelo
Punta S. Pancrazio
Ischia Bank
Vivara
C
L27
Casamicciola offshore
twt (msec)
0
80
160
240
320
400
rhodolith deposits
HST
M2
V3
V2
V1
M1
KEY
Volcanic acoustic basement (undetermined)
Quaternary marine deposits of northern Ischia (lower seismic unit)
Dome-shaped volcanic structures
Pyroclastic unit (undetermined)
Quaternary marine deposits of northern Ischia (upper seismic unit)
Debris avalanche deposits (Casamicciola)
Late Quaternary depositional sequence: highstand deposits (HST); forced regression prograding wedges (FST)
D
L57
twt (msec)
80
160
240
320
Ischia Channel
Procida continental shelf
«Il Pertuso» volcano
rhodolith deposits
KEY
pyroclastic unit (uncertain attribution)
pyroclastites and lavas genetically related to the relict volcanoes of the Ischia Channel (age > 55 ky B.P.)
relict prograding wedge (Late Pleistocene)
sea bottom multiple reflection
highstand deposits
pyroclastic unit genetically related to the Solchiaro tuffs (18 ky B.P.)
E
clay
gravel
sand
silt

Fig. 1: Integrated sketch diagram of the analyzed data, respectively showing the location map (inset A), the Ischia DEM with the location of samples (inset B), the geological interpretation of the seismic profile L27 (inset C), the geological interpretation of the seismic profile L57 (inset D) and the ternary plots of the sedimentological data (oceanographic cruise GMS02_01; upper part of the figure; oceanographic cruise GMS06_03; lower part of the figure).

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