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A seismo-stratigraphic analysis of the relict deposits of the Cilento continental shelf (Southern Italy)†

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Abstract: The relict (palimpsest and lowstand) deposits of the Cilento continental shelf have been analyzed based on the geological interpretation of subsurface Chirp sections, calibrated with core data. A progradational unit, overlying the acoustic basement, is interpreted as the beach deposits of the isotopic stages 4 and 5. This unit is overlain by a seismo-stratigraphic unit, composed of coarse-grained organogenic sands and interpreted as relict sands. This unit consists of sandy ridges, occurring at water depths ranging between 130 and 140 m and has been interpreted as submerged beach deposits, genetically related with the marine isotopic stage 2 (Last Glacial Maximum; starting date 29 ky B.P.) .

Keywords: relict deposits; palimpsest deposits; lowstand deposits; seismo-stratigraphic analysis; Cilento continental shelf; Southern Tyrrhenian Sea.

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1. Introduction

The seismo-stratigraphic analysis of the relict deposits of the Cilento continental shelf (Southern Tyrrhenian Sea, Italy) based on the geological interpretation of Sub-bottom Chirp sections is herein presented [1]. Two types of relict deposits, i.e. the palimpsest deposits and the lowstand deposits, have been identified.

The unconsolidated sedimentary cover of the continental shelf comprises two types of sediments: those that are not in equilibrium with current environmental conditions (i.e., in a broad sense, relict sediments) and those in equilibrium with these conditions. Based on the classical definition of Emery [2] the relict sediments have been deposited long ago, in equilibrium with the depositional environments therefore, while later, these depositional environments are no longer in equilibrium, even though they have not been covered by subsequent sediments. An important feature in recognizing the relict origin of a sediment is the occurrence of coarse-grained sands, located at a greater distance from the coast and at greater depths than fine-grained sands. Another important concept is that of the palimpsest sediments, which have characteristics of two sedimentary environments, one older and one more modern. While the relict sediments represent remnants of previous depositional environments, the palimpsest sediments correspond with relict sediments, which have been subsequently reworked.

The relict deposits of the Mediterranean continental shelves have been investigated in detail. Albarracin et al. [3] have studied the relict sand waves located on the continental shelf of the Gulf of Valencia, located in the Western Mediterranean. The system of sand waves is located in front of the present-day Albufera de Valencia lagoon and is composed of twenty-seven ridges, having a NNE-SSW trending. The seismo-stratigraphic interpretation and the construction of curves of relative sea-level changes have shown that the sand waves were formed during the Younger Dryas (12-10 ky B.P.), allowing for their classification as Holocene sand waves. Bassetti et al. [4] have studied the relict sands offshore the Gulf of Lions (France). The sedimentary succession overlies the major erosional discontinuity related to emersion of the continental shelf during the Last Glacial Maximum (LGM). It consists of basal transgressive deposits, subsequently reworked, on the outer shelf, into dunes and sand ridges, overlying the regressive prograding body. Fernández-Salas et al. [5] have studied the morphology and the characterization of the relict facies on the internal continental shelf in the Gulf of Cadiz (Spain). The analysis of the obtained data has shown that the relict facies beaches and coastal barriers are associated with the coastal spits located in the ancient outlets of the rivers. Pennetta et al. [6] have searched for the relict sands on the Cilento continental shelf aimed at beach nourishments. The sedimentological analyses have allowed for detecting on the continental shelf, at water depths ranging between 20 and 50 m (except the Gulf of Policastro), the occurrence of deposits mainly composed of middle-to-fine-grained sands, overlain by a pelitic drape. These deposits are often associated with *Posidonia Oceanica* meadows and with coarse-grained sands in a maërl facies [7]. The maërl facies is a lithofacies composed of calcareous algae, both whole and fragmented, whose occurrence is controlled by peculiar hydrodynamic and sedimentary conditions.

2. Geologic setting

A sector of the south-eastern Tyrrhenian margin encloses the Cilento continental shelf, constituting the morpho-structural high of the Cilento Promontory, bounded northwestwards by the Gulf of Salerno-Sele Plain basin and southeastwards by the Gulf of Policastro basin, both subsiding. This passive margin, genetically related to the extensional phases of the south-eastern Tyrrhenian sector during the Late Pliocene-Pleistocene, is involved by listric faults, controlling the individuation of lowered areas on the continental shelf [8-10].

The structure of Cilento has been investigated through multichannel seismic data [11-15]. These data have shown the stratigraphic architecture of the Campania margin from the Salerno offshore towards the structural high of the Cilento continental shelf. Early-Middle Pleistocene marine deposits, representing the bulk of the basin filling, strongly deformed by normal faulting and cropping out at the sea bottom in correspondence to main erosional areas represent the first seismo-stratigraphic unit. The second unit consists of Late Pleistocene marine and coastal deposits, relatively undeformed, characterized by progradational geometries in correspondence to the Cilento structural high and by parallel geometries in the Salerno offshore.

The Cilento district, in its emerging portion, is one of the most complex areas of the Southern Apennines. In particular, the outcropping successions consist of a set of terrigenous units, composed of basin turbidites (Flysch del Cilento *Auct.*) and a carbonate platform unit (Alburno Cervati carbonate unit) [10; 16-18] (Figure 1). Plio-Pleistocene and Holocene deposits of the Cilento continental shelf overlie an acoustic substratum, genetically related to the Cilento Flysch (ssi unit in seismic profiles) [6; 19-22].

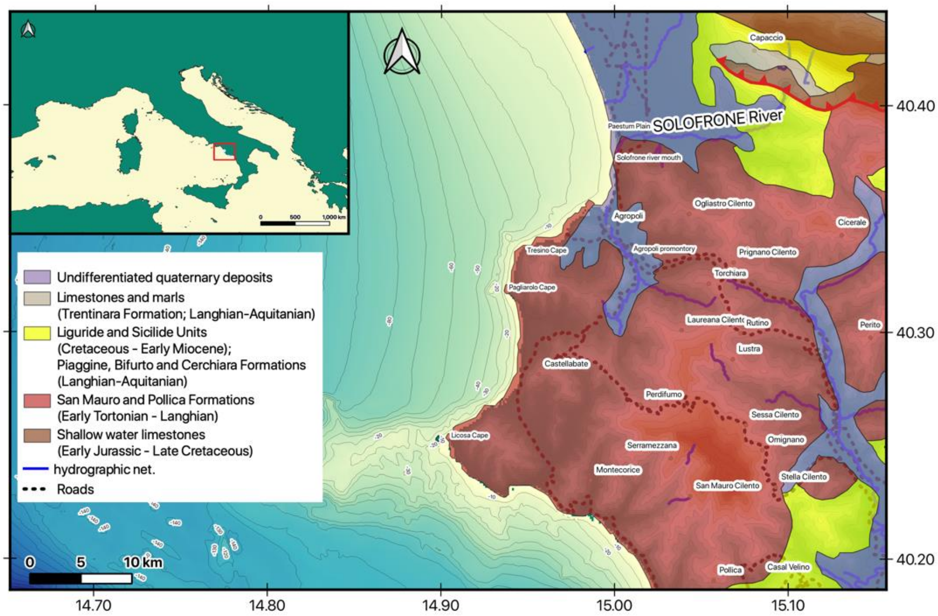

Figure 1. Geological sketch map of the Cilento Promontory.

At the sea bottom the rocky acoustic basement, recognized on seismo-acoustic data, crops out in the area surrounding the structural high of the Licosa Cape and is characterized by erosional morphologies, mainly consisting of terraced surfaces [21; 23] (Figure 2). Aiello [21] has resumed the depths of the marine terraces in the Cilento offshore based on the geological interpretation of Sub-bottom Chirp data. Savini et al. [23] have detected the offshore terraced landforms by using geomorphometric techniques and then have grouped them properly to the depth range of occurrence. The distribution of both onshore and offshore terraced landforms has been reconstructed accordingly to the geological units [23].

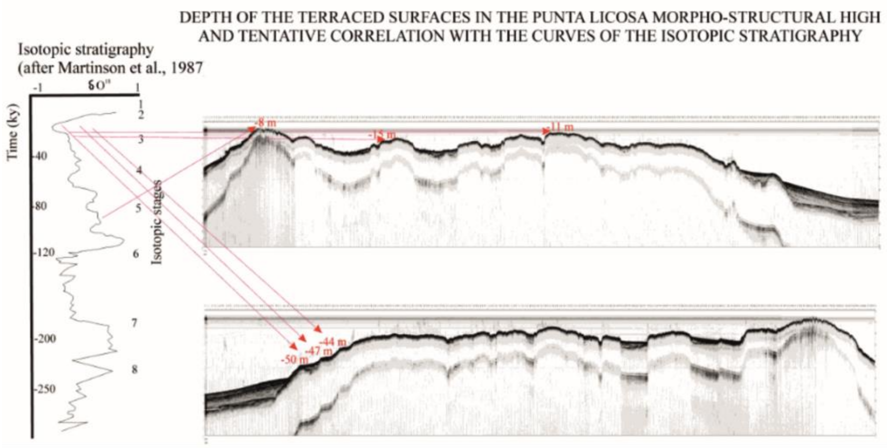

Figure 2. Sketch diagram showing the depth of the terraced surfaces in the Licosa Cape structural high based on Sub-bottom Chirp geological interpretation and tentative correlation with the curves of the isotopic stratigraphy [24].

3. Materials and Methods

The research has been carried out based on the geological interpretation of selected seismic sections (Sub-bottom Chirp; Figure 3) [21-22]. The seismic data, recorded onboard with a SEG Y format, have been processed by using the software Seismic Unix

[25]. A simple processing has been applied to the seismic sections of the Cilento offshore, consisting of the application of a linear vertical gain along the section, which has allowed for a significant improvement of the quality of the processed data. The processing flux consisted of several steps, including the conversion of the traces from SEG Y to SU; the spectral analysis of the frequencies of the seismograms, in order to reconstruct the distribution of the frequencies; the application of the Fast Fourier Transform (FFT) for the visualization and the analysis of the frequencies of the signal; the application of a high-pass filter with a low-cut frequency at 150 Hz in order to eliminate the noise and the dark signal; the application of an uniform gain on each trace; the application of a Time Variant Gain (TVG) in order to improve both the signal of the deeper reflectors and the whole visualization of all the profile; the output of the seismic profiles with Seismic Unix in order to obtain the final files, whose cartographic restitution realizes using a graphic interface.

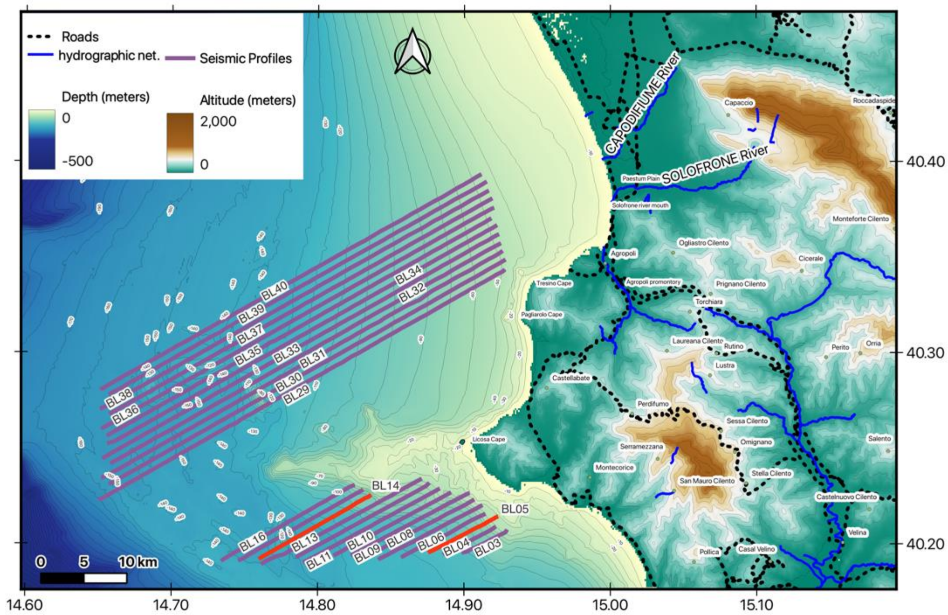

Figure 3. Location map of Sub-bottom Chirp profiles (Red lines indicate the studies profiles).

Seismic data interpretation adopted seismo-stratigraphic criteria [26-27]. The basic principle of the seismic stratigraphy is that the seismic reflectors, determined by contrasts of acoustic impedance, correspond to the strata plains. Perhaps, the geometry of the seismic reflectors corresponds to the depositional geometry (onlap,offlap, toplap, downlap), and also depends on faults density and depositional features. The bedding planes represent the palaeo depositional surfaces and can be heritage structures to contemporary structural settings. The unconformities are palaeo erosional or non-depositional surfaces, corresponding with significant stratigraphic gaps. Catuneanu [28] has deeply revised the sequence stratigraphic methods and concepts, proposing a workflow starting from the tectonic setting, going through the interpretation of palaeo-depositional environments and ending with the determination of the sequence stratigraphic framework (stratal terminations, stratigraphic surfaces, system tracts and sequences). The sequence models have been outlined (depositional sequences; genetic stratigraphic sequences; transgressive-regressive sequences, parasequences).

4. Results

The geomorphologic map has been constructed in a GIS environment (Qgis: http://www.qgis.org) (Figure 4) The study area represents a wide continental shelf, whose outer margin is located at water depths of 250 m. While the continental shelf northwards of the Licosa Cape has uniform gradient, the marine area surrounding the Licosa Cape represents an E-W trending structural high, characterized by remnants of terraced surfaces, carving the rocky acoustic basement and particularly abundant in the bathymetric interval ranging between 10 and 20 m, but occurring up to water depths of 60 m. An abrupt break in slope, located at water depths ranging between 60 and 80 m marks the passage from the structural high of the Licosa Cape, to the outer shelf, through a steep slope. Towards the Gulf of Policastro the continental shelf is characterized by an articulated morphology and high gradients and shows water depths ranging between 10 m and 110 m.

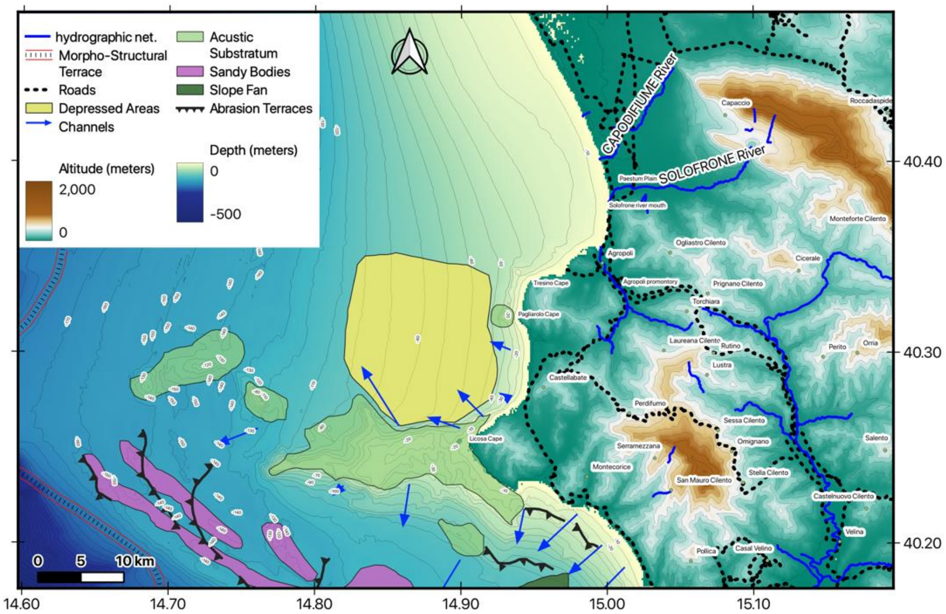

Figure 4. Geomorphologic map of the Cilento offshore, constructed in a GIS environment. The location of the sandy ridges corresponding with the relict deposits has also been reported.

The geological interpretation of the Sub-bottom profile BL14 is herein described in order to summarize the obtained results [22]. The rocky acoustic basement (ssi unit) has been noticed, coupled with three main seismo-stratigraphic units, representing the stratigraphic bulk of the Cilento platform. The ssi unit is overlain by a progradational seismic unit interpreted as the beach deposits of the isotopic stages 4 and 3. It exhibits the remnants of old beach systems, genetically related with the isotopic stages 4 and 3. The core calibration and the seismo-stratigraphic interpretation have shown that this unit is overlaid by the Sg unit, composed of organogenic sands. Due to its location at water depths higher than the usual ones in the bioclastic sedimentary model, the Sg unit has been interpreted as relict sands. This unit has the of shape sandy ridges (Figure 4), interpreted as a part of the submerged beach, genetically related with the last lowstand phase (isotopic stage 2).

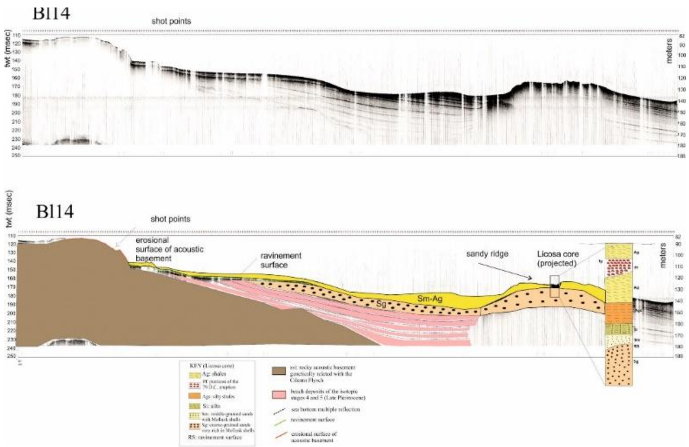

Figure 5. Sub-bottom Chirp profile BL14 and corresponding geological interpretation (modified after Aiello and Caccavale) [22].

In the Cilento offshore significant stratigraphic surfaces are represented by the erosional surface of the acoustic basement and by the ravinement surface (Figure 6). The erosional surface of the acoustic basement is a polyciclic erosional surface located at the top of the acoustic basement, genetically related with the Cilento Flysch (ssi unit; Figures 4 and 5). The ravinement surface is a time transgressive or diachronous subaqueous erosional surface resulting from nearshore marine and shoreline erosion associated with a sea-level rise [29] (http://www.sepmstrata.org/Terminology.aspx?id=ravinement). This erosional surface parallels the migration of the shoreface across previously deposited coastal deposits. The ravinement surface is commonly ascribed to the transgressive movement of the landward margin of the transgressive systems tract. These erosional surfaces will tend to occur wherever the landward edge of the sea rises over an underlying sedimentary surface. Thus if the late lowstand systems tract has a subaerial landward margin it will have an updip ravinement surface associated with it.

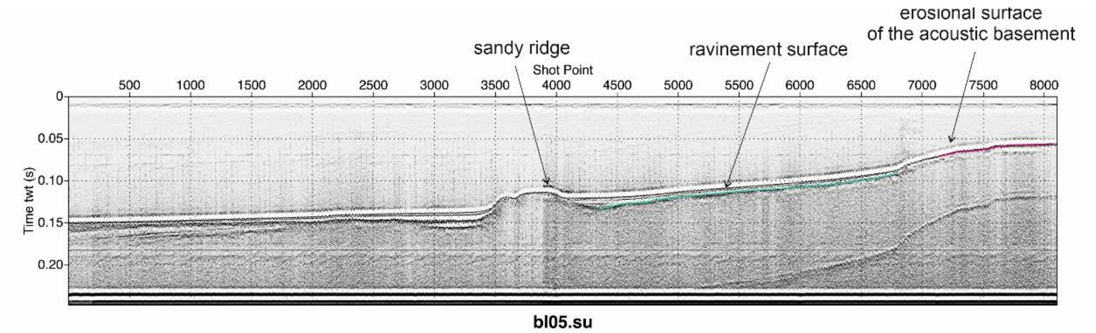

Figure 6. Stratigraphic surfaces in the Cilento offshore, as recognized based on the geological interpretation on the Sub-bottom Chirp profile BL05.

The stratigraphic context of the ravinement surface in the study area is here in highlighted. It represents an erosional surface, marking the sudden boundary between the coarse-grained organogenic sands (Sg unit; Figures 5 and 7), interpreted as relict deposits and the overlying fine-grained deposits (Sm-Ag unit; Figures 5 and 7). It develops progressively landwards during shoreface retreatment, eroding the acoustic basement, genetically related with the Cilento Flysch and leading to sediment bypass towards offshore (Figure 6).

The geological interpretation of the BL05 Sub-bottom Chirp profile has been carried out. Three main seismo-stratigraphic units occur, overlying the rocky acoustic basement (ssi unit), respectively represented by the Late Pleistocene beach deposits, representing the remnants of old beach systems, by the Sg unit and by the Sm-Ag unit. The obtained results are in overall agreement with the seismo-stratigraphic results summarized by the geological interpretation of the BL14 seismic profile (Figure 5).

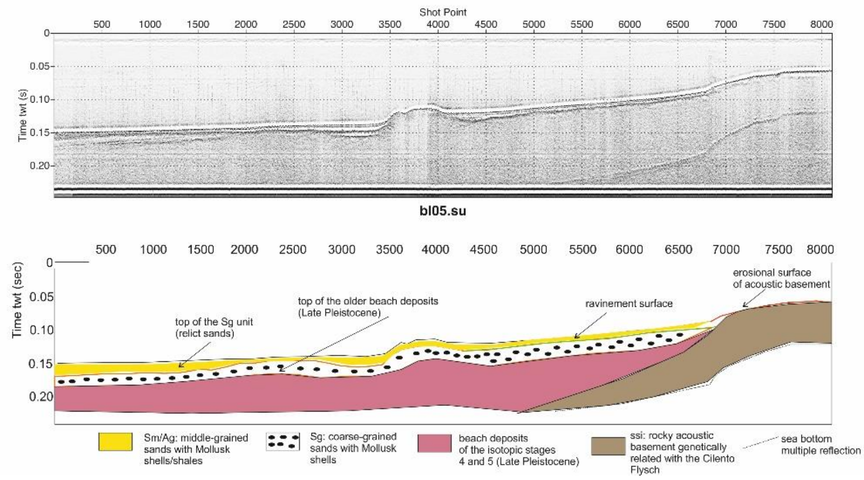

Figure 7. Sub-bottom Chirp profile BL05 and corresponding geological interpretation.

5. Discussion

The relict deposits of the Cilento offshore have been analyzed based on seismo-stratigraphic approach. The deposits of relict sands, often well preserved, can be ascribed to ancient beaches, or to ancient coastal environments, which have been deposited before or during the last sea level lowstand (Pleistocene), referring in particular to the lowstand of the last glacial period (18 ky B.P.), or alternatively, they are genetically related to the subsequent sea level rise, during which these deposits may have been reworked. These deposits well fit in the geological framework of the Quaternary marine deposits of the Cilento offshore, already described [22] and belong to the Early Pleistocene.

A geomorphologic map of the Cilento offshore has been constructed in a GIS environment (Figure 4). In this map, the main morphological lineaments have been reported, including the sandy ridges composed of relict deposits. The Sg unit forms sandy ridges, located at water depths ranging between 130 and 140 m. These sandy ridges, identified also in seismic profiles, have been interpreted as a part of the submerged beach (shoreface) and could be related to the last lowstand phase, corresponding to the isotopic stage 2.

The role of important stratigraphic surfaces (erosional surface of the acoustic basement and ravinement surface) in controlling the stratigraphic architecture of the Cilento offshore has been summarized. The first stratigraphic surface is the erosional surface located at the top of the acoustic basement. This surface is characterized by the occurrence of terrace rims, summarized based on previous seismo-stratigraphic results. The second stratigraphic surface is the ravinement surface, representing an erosional truncation involving the upper part of the progradational sequence.

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