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Occurrence of submerged depositional terraces off Sorrento Peninsula (Campania - Southern Italy)

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INTRODUCTION

The Sorrento Peninsula is situated transversally to the Apennines Chain and is mainly constituted by mesozoic carbonatic units and in the western sector by transgressive siliciclastic units, Miocene in age (PERRONE, 1988).

Since as early as the Pliocene the Peninsula probably appeared as a promontory extended ortogonally to the chain and raised about one hundred meters above sea level, while the adiacent structural depressions (Napoli and Salerno Gulf) were originally scarcely outlined and poorly prolonged to the east (BRANCACCIO *et alii*, 1981, CINQUE, 1986).

During the Lower Pleistocene the splitting of the carbonatic units started, with considerable uplifting of the blocks in correspondence to the peninsula and lowering in the Sele and Campania Plains, which were subsequently filled up by clastic deposits. An erosive surface, the so called "Paleosuperficie", formed during the Pliocene, was dislocated in Peninsula to a height of 1400 m.

As a consequence of the enlargement of the Sele and Campana Plains, the coastal sectors of the Peninsula were dissected and submerged. A promontory with decreasing altitude and wideness towards the west was outlined, bounded by faults escarpement and on its cliffs remain traces of recent sea level changes.

Several ancient shoreline traces have been identified and interpreted (CINQUE & ROMANO, 1990): the occurrence of paleoshoreline features on the structural cliffs and relative to sealevel stillstand former to the last interglacial period should prove that the last phases of tectonic fragmentation occurred no later than the Middle Pleistocene; moreover a general stability seems to have characterized the whole Peninsula for the last 125.000 years, since the Eutyrrhenian paleoshorelines have the same elevation above sea-level (+7.4 m).

On the contrary, vertical movements have been affecting the adiacent structural depressions, the Sele and Campana Plains: in the first, strand units relative to the isotopic stage 5e and 5c, are found respectively at 25 and 13 meters above sea level (AMATO *et alii*, 1991), while in the second and exactly in the Sarno Plain, similar units have been identified in borehole about 20 meters below sea level (BRANCACCIO *et alii*, 1991).

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The two margins of the Sorrento Peninsula are noticeably different even in the submarine domain: in fact the northern continental shelf is wide, mostly horizontal and its edge is located at 150 m bsl (PESCATORE & SENATORE, 1988); the shelf on the southern side is generally steep, narrow (no more than 4 km wide), and practically disappears in correspondence of Punta Campanella and Capo Sottile. In this sector the shelf edge is structurally defined by a fault cliff, in correspondence of a tectonical regional feature, which exposes Mesozoic carbonate units (SACCHI *et alii*, 1994).

Several orders of submerged terraces have been recognized all around the shelf by CINQUE & PUTIGNANO, 1992, through ecosounder survey and through geomorphological observations down to 35 m bsl. They identified erosional features often policiclic in origin and depositional features occurring in correspondence to small depocentres.

The submerged depositional terraces (TDS) reported in this paper, were identified south-west of Capo di Massa, west of Punta Campanella and in the proximity of Li Galli Islands (Figs.2 and 5) and are found between 35/40 m and 125 m below sea level.

It is generally observed that they rest on erosive surfaces cut into the acoustic substratum, composed of carbonatic Mesozoic units, while those located around Li Galli develop on a sedimentary unit probably Pleistocene in age.

Fig. 1 - *Location of the study area. Isobath are in metres.*

DATA COLLECTION AND ANALYSIS

We base this note on data collected during two oceanographic cruises organized by the Istituto di Ricerca Geomare sud and the Dipartimento di Geologia e Geodesia of Palermo University. During the 1995 cruise, Sparker 1kJ and Subbottom 3.5 kHz were recorded; during 1996 cruise, 60 nm of multichannel seismic profiles were acquired between Bocca Piccola and Positano. The configuration system consisted of a watergun source SSI 15 by 10 c.i. and a 12 channel Teledyne seismic streamer with idrophones spaced at 6.250 m. The acquisition was carried out with a shot interval of 3 sec and a recording time variable between 0.5 and 2 seconds. Part of the system has been provided by OGS, Trieste and IGM, Bologna.

Ship positioning was controlled by GPS system, provided by R/V Urania and a WGS '84 datum was utilized; bathymetric data, acquired by bi-frequency scientific ecosounder have been filtered and processed by applying triangolation algorithm.

Seismic data however are still in the course of being processed: watergun seismic lines, here shown in Figs. 3, 4 and 6, refer to digital signals recorded on the first channel.

Fig. 2 - *Bathymetric map and areal distribution of Submerged Depositional Terraces in the sector off Capo di Massa- Punta Campanella. Bold lines represent parts of watergun seismic profiles BP42 and BP2, shown in Figs. 3 and 4.*

In this area two groups of composit TDS have been identified. The northernmost, the Vervece terrace, is formed by two partially overlapping depositional bodies in backstepping. The lower unit is expansive and develops for an overall length of 4 km with a variable wideness between 0.6 and 1.3 km. In plan the unit shows a concavo-convex trend, which is wider on the outskirts of the inlet and narrower on the convex tract, which curves around the Vervece rock (outcropping of acoustic substratum). The edge of the unit gently dips towards south-west and passes from a depth of 78 to 85 m where it gently closes; it probaby proceeds towards north-east in a sector where no data have been acquired. The upper unit lies in proximity of an inlet south of Capo di Massa and continues around the Vervece for 2.5 km, dipping toward south-west as well (the offlap-break of the unit passes from -40 m to -60 m). Towards the north-east it becomes narrower on the outskirts of Capo di Massa promontory and at 35 m of depth is cutted by an erosive surface; towards south-west it closes probably because of the deepening of its downlap surface to depths not compatible with its formation.

Proceeding southward, at 60-70 m of depth, a wide erosional surface extends, incised in the acoustic substratum and represents a threshold, structurally controlled, between the Sorrento and the Amalfi coast.

On the southern side of the erosional surface, westward of Punta Campanella a second composit TDS has been

identified, consisting of three partially overlapping bodies and showing a retrogradational architecture.

Likewise the Vervece terrace, from the lower to the upper body, length, width and thickness decrease; their orientation in space changes as well, trending along the isobaths untill they are subparallel to the present-day coastline. Respective offlap-breaks occur at -95, -85 and -60 m of depht.

The lower and the middle bodies overlap and both open in correspondence of -80 meters isobath. Their irregular trending seems to be the expression of the rough morphology of the basement they lie on. The west closure has not been identified while eastward it closes over the Punta Campanella promontory. The upper body, small in size, develops in a bathymetric range of -50 and -70 m and takes up a concave area between the Bocca Piccola erosional surface and Punta Campanella promontory; it is situated slightly to the rear of the lower bodies and, only close to the coast, it directly laps over the more ancient body (see Fig.4).

Fig. 3 - *The watergun seismic line BP42, recorded south-west of Capo di Massa (for location see Fig.2): the Vervece terrace consists of two bodies partially overlapping, with a retrogradational pattern; both open on an erosive surface incised in the acoustic substratum.*

The lower body progrades with oblique reflectors, which then become sigmoidal outwards and close at 95 m of depth in downlap. A thin layer of sub-horizontal retrograding reflectors bounds the lower body at the top and onlaps the acoustic substratum. This layer represents the base on which the upper body downlaps. The internal geometries of the upper body are similar to the lower and consist in reflectors which close at 50-65 m. The toplap surface shows a gradient of about 3% , but its relation with the seafloor is not clear, due to the masking effect of the seafloor ringing.

Fig. 4 - *The watergun BP2 seismic line shows the depositional terrace located westward of Punta Campanella. Close to the coast the terrace consists of two depositional units in backstepping, which lie on an erosive and irregular surface, cut in the acoustic substratum. The lower unit is rather wide and thick (30 msec) and is composed of oblique reflections which become sigmoidal outwards and close in downlap at approximately 100/110 m. The upper unit, which shows a max thickness of 15 msec, opens on the acoustic substratum and develops on the toplap surface of the underlyng body. The prograding reflectors are initially obliquous and not continuous and become stronger but less pending reflections upwards. The offlap break is located at 60 m of depth (this section is not morphologically clear, because of the tracking of the line in respect to the body). The unit closes in downlap over the lower body and presents an aggradation whose thickness is not measurable because of the ringing of the bottom.*

Fig. 5 - *Bathymetric map of the southern sector off Sorrento Peninsula and areal distribution of the submerged depositional terraces: note the shape of the small semicircular basin facing Positano. Isobaths initially subparallel to the coastline, below -50 m become perpendicular, due to the presence of many structural highs, cropping out of the bottom or above the sea level (Li Galli) and whose southern flank is a fault scarp that borders the continental slope.*

Bold lines represent tracts of G13 and C4 seismic lines of Figs.6 and 7.

North of Li Galli Islands a submerged depositional terrace is formed by two juxtaposed prograding units (Fig.6): the upper body develops in a bathymetric range of 50-95 m with an offlap break located at - 65/70 m and trends perpendicularly to the coast line. Laterally it closes over the acoustic substratum, while it probably proceeds towards north-east following the bathymetry, but there does not seem to be a corresponding depositional terrace on the opposite side of the basin.

A second TDS has been identified east of Li Galli Islands, in a small area within the bathymetric range of 90-125 m. It abruptly ends in corrispondence to the shelf break due to the sudden sea floor deepening; northwestward it seems to gently close with a blander and more regular slope.

Fig. 6 - *Seismic line Watergun G13, (see location in Fig.5), showing the terrace located north of Li Galli. It is composed of two juxtaposed depositional units, the more ancient of which progrades with sigmoidal reflectors and is clearly eroded on the top (W surface, identified on the Subbottom 3.5 kHz). The younger unit lays on the morphological step created by the foreset of the underlying body* (Trincardi & Field, 1991) *and progrades down to 65/70 m of depht with caothic and discontinuous reflections and closes at about 90 m of depth. The W surface, which deeply erodes the ancient body, bounds the top of the younger one as well,with a quite steep dip.*

The terrace as a whole has a component of aggradation in the bottomset and downlaps on a sedimentary unit whose stratigraphic position is uncertain.

The distinctive seismic facies of the youngest body can be related to the high percentage of bio- and litoclasts avai-

lable even far off the coast, from the many calcareous outcrops and biogenic sediments (AA.VV., 1995).

Fig. 7 - *Sparker line 1 kJ C4 trends east-west and shows the shape of the small basin and the stratigraphic relations among sedimentary units inside. A submerged depositional terrace develops on the western side of the teather-shaped basin, level with the islands of Li Galli (Fig.5). The seismic line has been processed with graphic software in order to reduce vertical exageration: in this case the shape of the terrace and the steepness of the prograding reflectors is exagerated by a factor two.*

In the section a mesozoic substratum (unit M) is topped at intervals by strips of a Pliocene unconformity (PS); unit P is relative to a phase of infilling (probably Lower - Middle Pleistocene in age) interrupted by periods of relative falling of sea level (channels incision); W surface, which has an erosive character by the basin margin but becomes concordant at the depht of 125-130 m at its center, forms the base of the T unit (Eastern Li Galli terrace) and bounds at the top the Northern Li Galli terrace. The W surface, which is often covered by the acoustic ringing of the sea floor, has been recognized on the Subbottom profiler 3.5 kHz records.

The Eastern Li Galli terrace develops between 80 and 125 m of depth and reaches a thickness of 30 msec; it could represent the sedimentation wedge relative to the last sea level lowstand (18 ka).

CONCLUSIONS

Submerged Depositional Terraces in the Sorrento Peninsula generally present short lateral continuity; their areal distribution seems to be related to the acoustic substratum pattern.

The TDS of the northern and southern margins of the Sorrento Peninsula are significantly different.

The terraces of Vervece and Punta Campanella lie on the acoustic substratum and are organized in backstepping. Their lowermost unit is wider and thicker compared to the uppermost which are generally smaller, well preserved and develop parallel to the present-day coastline.

These indications strongly suggest that in correspondence of morphological and stable sectors (as Bocca Piccola morpho-structural high), terraces develop only when accomodation is available (together with availability of sediment), i.e. when relative sea level is increasing. This is probably the case of Vervece and Punta Campanella terraces and their bathymetric range could confirm this hypothesis. In particular they could have formed during the last sea level rise, post 18 ka, explaining the good preservation. During the previous phase of falling sea level, formation of erosive features prevailed, with abrasion of the acoustic substratum and removal of older depositional bodies (infact neither buried terraces nor reworked ones has been recognized in the stratigraphic record of this area).

Both northern and eastern Li Galli terraces occur on the border of a small epicontinental basin and overlie a Pleistocene sedimentary unit. They are respectively overlied and underlied by an unconformity (W surface), which probably represents the last period of epicontinental morphoevolution and from a sequence stratigraphic point of view corresponds to the boundary of the Late Quaternary sequence. The northern terrace is partially eroded at the top, while the eastern terrace appears to be well preserved.

Considering their stacking patterns, the scarce preservation of the northern Li Galli terrace and its stratigraphic and bathymetric position, the northern and eastern Li Galli terraces could have been formed during the last sealevel drop and the last lowstand respectively . In this case they could represent forced regression deposits.

The acoustic substratum and its roughness determine a control on the areal distribution of the TDS and on their lateral continuity; relative sea level change (i.e. accomodation space) control the bathymetric range of the TDS formation. The possibility of their preservation, as many authors have already pointed out, is aided during increasing relative sea level.