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Submerged depositional terraces in the Southern S. Eufemia Gulf (Calabria)

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GEOLOGICAL FRAMEWORK AND SURVEY RESULTS

The area studied is the stretch of coast between the mouth of the Angitola River and Cape Cozzo in the southern part of the S. Eufemia Gulf (Fig. 1). The geology of southern-central Calabria is dominated by phillitic and gneiss schist formations. The continuity of the metamorphic formations is interrupted by Cantanzaro and Mesima grabens that are mainly filled with post-orogenic Pleistocene sediments (OGNIBEN, 1973).

Up until the Late Miocene, the whole Calabrian area was affected by a strong uplift associated with the opening of the Tyrrhenian basin that began in Tortonian time (BOSQUET, 1973; PATACCA *et alii*, 1990).

The uplift rate and the extent of the phenomenon are demonstrated by both of the Plio-Calabrian marine terraces, lying up to 600 m above sea level (DAMIANI & PANNUZZI, 1978), and the Late Pleistocene terraces, lying 20-40 m above sea level (COSENTINO & GILOZZI, 1988). The terraces are broken by faults normal to the coast that lift them to different heights along the coast. The uplifting Calabrian Arc and the subsidence of the Tyrrhenian basin generated a high-sedimentation rate and a rather immature morphology of the Calabrian continental margin. In the Paola basin, more than 4500 m of sediments are found above the Messinian (BARONE *et alii*, 1982; TRINCARDI *et alii*, 1995). In the study area, the large structural feature making up the southern boundary of the Catanzaro graben (FINETTI & MORELLI, 1972) hindered the formation of a real continental shelf and the development of a well-defined shelf-break (CHIOCCI *et alii*, 1989). In fact, in the southern part of the S. Eufemia Gulf, the sea floor is very steep, reaching a depth of 200 m at less than 4 km from the coast.

The area was surveyed with high-resolution seismics using the EG&G Uniboom source and analogic data acquisition. In the acquisition phase, the data were filtered using a 400-4000 Hz pass-band filter and amplified with an automatic gain control (AGC). The Loran C system was used for location. Due to the close proximity to the Catanzaro Master Station, notable problems were found in correctly locating the profiles. These problems were partially resolved by an accurate check at the intersection between the profiles.

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A 250 twtt ms time sweep was generally used in analog recording; 500 ms twtt sweep was used only for brief sectors in the outer shelf areas. The area was investigated by 12 profiles shot in dip direction with about 1500m distance between them, and some perpendicular profiles for control. In total, about 100 km of seismic profiles were acquired in an area of 90 km^2.

Two submerged depositional terraces were found in the area. The first one has an edge 40-50 m deep and the second, around 150-170 m deep. While the shallower SDT is poorly preserved and only found in two profiles, the deeper one is well preserved and has a good lateral continuity of more than 15 km Similarly the terraces are only visible in the area between Cape Cozzo and the mouth of the Angitola River, that is, until the morphology of the sea floor becomes extremely steep (more than 2°). The terraces are not present in the rest of the S. Eufemia Gulf where a wide continental shelf (reaching 7 km in width) develops north of the Angitola Canyon, and the gradient of the sea floor smoothes out. Other submerged depositional terraces have been shown by MONGARDI *et alii* (same volume) further north of the S. Eufemia Gulf.

Fig. 1 - *Location of the study area.*

Fig. 2 - *Uniboom seismic profile offshore Pizzo (for location, see Fig. 5). One can observe a submerged depositional terrace on the upper continental slope near a sharp slope break. The sedimentary base on which the SDT rests shows weakly deformed reflectors of high amplitude and high continuity. Within the terrace, numerous foresets, sloping up to 8-10°, concave-up geometry and tangential bases are observed. The topsets are not very visible due to the strong ringing produced by sea floor reflection. The bottomsets gently join the continental slope. The internal reflectors become convex-up only towards the last progradational phases. In every case, the internal structure of the depositional terrace indicates continuity in sedimentation and the entire body seems to have been deposited in one single sedimentary cycle. The slope break above the terrace, although quite sharp, does not seem to be structural in nature as shown by the continuity of the reflectors within the sedimentary substrate. The upper surface has a maximum apparent slope of 2° and a barely defined edge.*

Fig. 3 - *Seismic profile in dip direction, about 4.5 km west of the previous one (see Fig. 5). The right part of the section was acquired with a time sweep of 500 ms to give a more complete picture of the continental margin and of its relationship with the submerged depositional terrace. The terrace seems to be located exactly on a slope break of the sedimentary substrate.*

The latter is characterised by transparent acoustic facies and a notable deformation of the reflectors in its lower part. Instead, in the upper part, there are relatively undeformed reflectors of greater amplitude and continuity. The top of the depositional terrace, however, continues the morphology of the continental shelf, which has a slope of 2° in this zone. In this case, contrary to the previous and the following cases, the edge of the depositional terrace coincides with a pseudo-edge of the continental shelf. The frontal slope of the terrace has an apparent slope of about 20° and its edge abruptly joins the underlying sedimentary substrate. The seismic unit on which the STD rests, which is weakly deformed and represents the last outbuilding phase of the continental margin, is made up of a well-stratified unit off-lapping towards the basin. In this sedimentary substrate, the degree of deformation increases downward and landward, thus suggesting a slow and constant deformation on which the glacio-eustatic Pleistocene oscillations are superimposed, as has been broadly discussed by CHIOCCI & ORLANDO (1995).

It is important to observe that the terrace is absolutely undeformed and that no other depositional bodies similar to the terrace exist either within the margin or on the sea floor at greater depths. The inner structure of the terrace is not visible due to the strong ringing effect of the sea floor reflection.

Fig. 4 - *Seismic profile offshore Vibo Valentina, positioned in between the previous two profiles (see Fig. 5 for location). Here one can see (as in Fig. 2) how the position and the geometry of the depositional terrace are not conditioned at all by the morphology of the pre-existing sea floor due to the fact that the STD is located at a depth greater than the shelf break. One can see how different the morphology and the acoustic facies of the terrace are with respect to the sedimentary basement on which the STD rests. In fact, the basement is well stratified with weakly undulating, high-continuity reflectors dipping basinwards at 7°. The deposits making up the sedimentary substrate were interpreted as sedimented on the continental slope during different phases of sea level lowstand* (CHIOCCI, 1993: CHIOCCI & ORLANDO, 1995).

The terrace deposit has a flat base and a convex top with an acoustically transparent internal facies. A compa-

rison with the contiguous profile of Fig. 2 suggests that actually, reflectors inside the terrace are present but are not seismically depicted because of the great steepness. In fact, the apparent dip of the terrace's frontal slope averages 20°, and the actual dip should be as much as 25° (see CHIOCCI, *this volume). It is possible that the slope of the foresets is similar, and therefore, much greater than the apparent slope of the internal reflectors of the profile in Fig.2 (max. 10°), which probably was not shot exactly in dip direction of the layers. The terrace top has an apparent slope of little more than one degree, comparable with that of the continental shelf in this area, while the frontal slope dips more than the continental slope.*

Note that the profile in the figure was used as an example for the application of the seismic migration procedure in the article "Distortions in STD shape, as depicted in high-resolution profiles, and re-establishment of the correct geometry (seismic migration)" (CHIOCCI, *this volume*).

Fig. 5 - *Distribution of the submerged depositional terrace in the southern S. Eufemia Gulf. The width of the terrace normal to the coast varies from 300 to 800 m (the top alone varies from 100 to 500m). Parallel to the coast, the depositional terrace develops for 10 km between Cape Cozzo and Point Safo and 5 km between Bivona and the southern flank of the Angitola Canyon. Between Point Safo and Bivona the terrace was not seen due to the following: a) a very sharp change in depth of all of the depositional parameters; b) a significant variation in the distance from the shoreline and in the orientation of the SDT; c) a difference within the SDT structure that shows a more developed and homogeneous structure to the east, while to the west, is thinner and more irregular. On the contrary, west of Bivona the trend of the depositional parameters seems to be rather constant.*

Thick lines indicate the location of the seismic profiles reported in figures 2, 3 and 4.

Fig. 6 - *Depth diagram of the submerged depositional terrace in the southern S. Eufemia Gulf.*

The deposit is found in a narrow bathymetric range between 135-150 m and 180-200 m. In particular, the terrace edge is found at a depth between 125 and 160 m. From Cape Cozzo eastwards, there is a gradual diminishing of the terrace depth reaching almost Point Safo. As previously stated, between Point Safo and Bivona there is an abrupt increase in depth of all the depositional parameters and a variation in the characteristics of the SDT (see previous caption) and therefore the two areas were not correlated each other.

CONCLUSIONS

In the southern S. Eufemia Gulf, along a section of coast more than 15 k long, a submerged depositional terrace is present, with rather constant geometry and acoustic facies in the entire area. The terrace rests on a sedimentary basement made up of weakly deformed stratified deposits, probably emplaced during the glacial periods in Late Pleistocene (CHIOCCI & ORLANDO, 1996).

The terrace is found at a depth between 100 and 230 m (the depositional edge, between 125 and 160 m). Such depths are slightly greater than those reached during the last minimum in the eustatic Würm. The terrace is found on the continental slope, at times exactly at the shelf edge, but more often at the foot of a slope-break defining the external limits of the outer shelf. The acoustic facies of the SDT differs significantly from that of the sedimentary substrate on which it rests. It is only sometimes possible to depict the prograding reflectors inside the terrace, as they are poorly resolved seismically, most likely because of their steep slope.

The thickness and bathymetric distribution of the SDT is quite constant in the entire area. It is possible to hypothesize a structural discontinuity offshore Point Safo on the basis of a change in the westward deepening trend that is constantly observed in the western part of the study area. Such a change coincides with a shift of the SDT position more than 1000m offshore. The depth (even if variable) of the SDT is compatible with the minimum eustatic level reached at the end of the last Pleniglacial time. Instead, there is lacking evidence of terraces older and/or deeper created at lowstands older than the last one. This is demonstrated by the fact that the SDT seems to have been emplaced in a single depositional phase and that other SDTs have never been observed. The peculiar setting of the Calabrian arch could justify the above-described features In fact, the constant uplift to which the area was subjected during the entire Pleistocene should have raised the terraces (which were eventually formed during other eustatic minimum) to shallower depths. Thus the cyclical emersion and erosion of the shelf (always as a result of the glacio-eustatic sea level fluctuations) would have forseen a complete removal of the SDTs older than the one formed in the latest cycle.