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Quantitative Assessment of Post Tyrrhenian Differential Crustal Movements in a Mediterranean Coastal Area (S. Vito–Sicily–Italy)

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Abstract. Aim of the present study, which is part of the E.U. Commission SELF II Research Project, is the reconstruction of the Pleistocene and Holocene tectonic trends in a Mediterranean coastal area. The study is focused on the upper Pleistocene to Holocene tectonic history of NW Sicily. The emerged and submerged coastal zone of a selected area (St. Vito lo Capo, NW Sicily) was studied, by using jointly different sectoral approaches and carrying out geological and geomorphological surveys. The studied area shows morphological evidence of a succession of marine terraces, which is uncommon for the Mediterranean region. These evidences of the coastal evolution, which are currently located both above and below the present sea level, were ascribed to the Middle and Upper Pleistocene, by using morphological (notches and terraces) and stratigraphical criteria, supported by radiometric dating. A detailed study of the longitudinal profiles of the most recently emerged marine terraces, ascribed to isotope stage 5e, revealed the presence of six sectors characterized by different rates of crustal uplift during the post Tyrrhenian age. The rates of uplift calculated for each of these post-Tyrrhenian age sectors allowed to recognize that the error related to tectonic uplift, in the reconstruction of eustatic fluctuations relative to the last 10 kyr from submerged speleothems and vermetid reefs, is negligible.

1 Introduction

The main objective of the Research Project SELF II (Sea Level Fluctuations in the Mediterranean: interactions with climate processes and vertical crustal movement) was to outline the sea level rise curve for the last 10 kyr, by studying the present vertical distribution of submerged speleothems and vermetid reefs (now living at the present sea level), the age of which was determined through radiometric dating. This method can be used only in areas with little evidence of vertical tectonic mobility, or where the eustatic component can be precisely discriminated from the tectonic and/or isostatic component, starting from the Upper Pleistocene. The area of the Promontory of St. Vito Lo Capo (North-Western Sicily, Fig. 1) fits this criterion and is a good case-study.

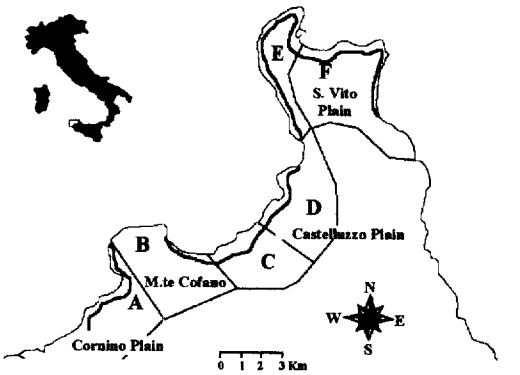

FIG. 1., St.Vito Promontory (Italy). Map of the studied area showing the Sectors (A, B,..) characterized by different tectonic uplift. Black line indicates the location of the Eutyrrhenian marine terrace inner margin, and marks its good lateral continuity.

Geomorphological evidences of marine trangressions were identified, mapped, analysed and subsequently correlated through field surveys and the analysis of aerial photographs. Both notches and inner margins of marine

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terraces, which characterize the studied area, indicate the maximum level reached by the sea at each isotopic stage (Lajoie, 1986), although with different degrees of accuracy. Direct measurements of notches provide a degree of accuracy of ±0.5 m (Carobene & Pasini, 1982; Pirazzoli, 1986). Heights above sea level of Tyrrhenian inner margins have been measured by means of a total station, whereas for the older others a reference map has been used. A total error of ±1.5 m, related to the inaccuracy in the exact location of the position of the Tyrrhenian inner margin was assumed. By taking into consideration this error, the altimetric distribution of the identified forms was carried out by using an appropriate working scale, which required the transformation in digital format (scale 1:10.000) of the local Regional Technical Mapping.

2 Geomorphological and chronostratigraphical considerations

Morphological evidences of seven marine erosional terraced surfaces (one submerged) were identified. The whole succession of inner margins, correlated with the marine erosion surfaces, is currently located from about + 90 to about -18 metres. In the whole area, each terrace order shows a remarkable morphological evidence and lateral continuity.

This very good lateral continuity of inner margins and, to a lesser extent, of notches - which have been found exclusively along the best preserved sections of carbonate paleocliffs – and the morphostratigraphic analysis techniques, allowed to recognize differences in elevation for homologous features along the whole extension of the studied area and, consequently, to reconstruct the different neotectonic deformation.

The lower chronological limit of the raised terraced succession dates back to the Lower Pleistocene, which corresponds to the age of the *Calcareniti Siciliane formation* (Abate et al., 1991; 1993), bioclastic calcarenites that represent the most recent substratum onto which the terraces were cut. Dating through U/Th method on speleothems, which locally coat marine notches, provides the upper chronological limit for each relative sea level permanence at different stages. Table 1 shows that the speleothem sampled at + 42 m a. s. l, yielded an age > 300 kyr BP. Consequently, Terrace III formed before 300 kyr BP. On the contrary, the lower terrace (terrace VI, Fig 2), developed before 19695±5300 yr BP. Due to the frequent occurrence of the warm Senegalese fauna (*Strombus bubonius*) in several bioclastic lenses which overlie the VI° marine terrace order, these terraces can be ascribed to the Eutyrrhenian (5e oxygen-isotope sub-stage, 125 kyr BP). On the basis of the aforementioned morphostratigraphic considerations, it is probable that the six emerged terraced morphologies developed between the late Middle Pleistocene and the Upper Pleistocene. The submerged terraces probably developed during oxygen isotope stage 3, as already hypothesized by Antonioli & Ferranti (1996) and confirmed by both radiometric dating of submerged speleothems (Antonioli et al., 1994) and the age interpretation of other marine platforms, located at similar depths in the Mediterranean and extra-Mediterranean regions (De Vita & Orsi, 1994; Cann et al., 1988; Aharon and Chappel, 1986).

3 Neotectonic considerations

In order to evaluate the vertical tectonic component as well as the related vertical movement rates, the inner margins ascribed to Eutyrrhenian sub-stage were considered, on the assumption that the eustatic maximum reached 7±1 metres above the present mean sea level (Ku et al., 1974; Harmon et al., 1983).

By comparing the heights of the eustatic level reached during the Eutyrrhenian sub-stage, six different sectors were identified (Fig. 1, 2 and 3), showing different vertical displacements, from 6 to 16 m s.l.m., which are related with the N-S and NE-SW aligned tectonic regional trend (Abate et al., 1991; 1993) :

1. **Sectors A and C (Cornino Plain, West side of Castelluzzo Plain):** the inner margin related to the Eutyrrhenian transgression is located between + 14 and + 16 m a.s.l.
2. **Sectors B, D, F (M. Cofano area, East side of Castelluzzo Plain and S. Vito Plain):** inner margin and notch related to the Eutyrrhenian transgression occur between + 9 and + 11 m a.s.l;
3. **Sector E (Piana di Sopra area) :** the evidences of inner margin and notch of the Eutyrrhenian terrace are located between + 6 and + 8 m a.s.l.

The vertical displacements of the geomorphological features which mark the Eutyrrhenian transgression indicate a tectonic uplift of 6-8 m for Sectors A and C, and of 2-3 m for Sectors B, D and F. Sector E shows relatively stable conditions. The changes in inner margins heights seem to be controlled by disgiuntive tectonic activity, with meter-scale differences between the vertical displacements for each sector. The data relative to F sector are similar to those reported by Mauz et al., (1996) in an adjacent coastal area. Inside the Castelluzzo Plain area, which is characterized by a significant uplift of terrace VI inner margin, some fractures which cross-cut vermetid reefs seem to indicate very recent tectonic activity. In fact, the fossil part of the reef yielded a calendar age of about 450 yrs cal BP (Tab. 1).

4 Conclusions

The studied area shows a very high degree of morphological preservation of the middle an upper

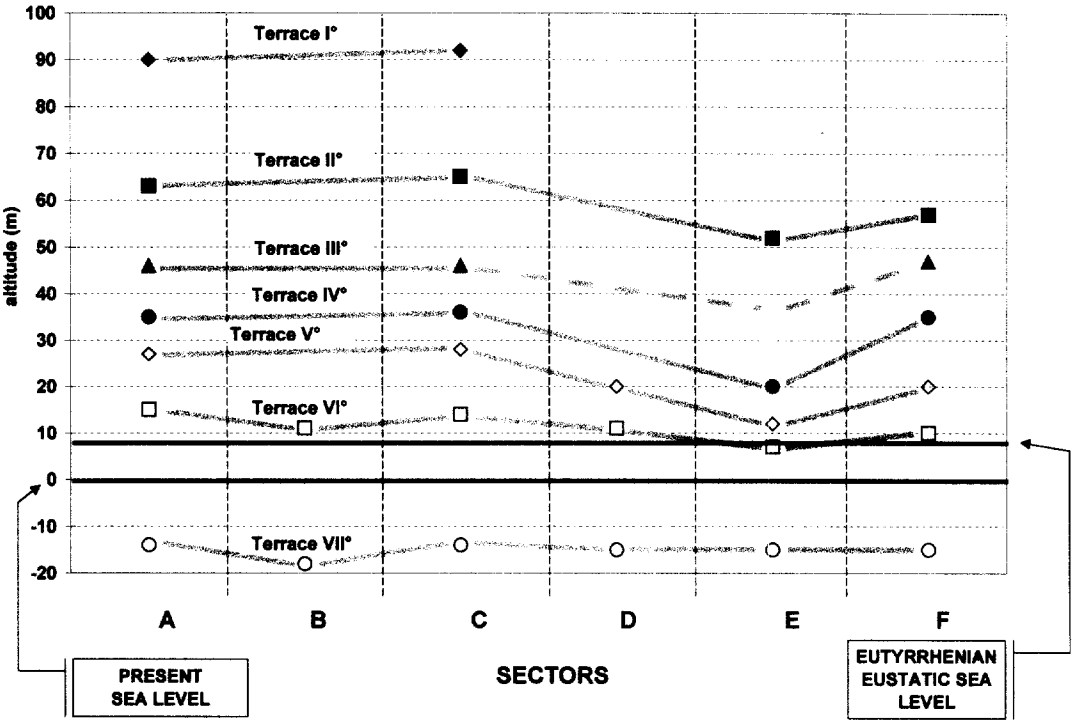

FIG. 2., Outline of the whole succession of marine terraces in Sectors A through F (see Fig. 1). The Present and the 5e eustatic sea level stage are put to evidence.

Metres on m.s.l	Sector	Material	Age yr BP	Dating method
+62	E	speleothemes	78000±1950	Th/U
+42	E	speleothemes	> 300000	Th/U
+8	E	speleothemes	19695±5300	Th/U
+2	F	speleothemes	48964± 6000	Th/U
-0.3	F	speleothemes	7816±96	cal ^{14}C 1σ
-1.3	F	speleothemes	16531± 200	cal ^{14}C 1σ
-0.4	D	vermetid reef	461 - 400	cal ^{14}C 1σ
-0.3	D	vermetid reef	251-127	cal ^{14}C 1σ
-0.3	E	vermetid reef	232-106	cal ^{14}C 1σ
-0.3	E	vermetid reef	232-94	cal ^{14}C 1σ
on the beach	E	broken vermetid reef	923-876	cal ^{14}C 1σ
on the beach	D	broken vermetid reef	2350-2293	cal ^{14}C 1σ
on the beach	D	broken vermetid reef	1695-1586	cal ^{14}C 1σ
on the beach	C	broken vermetid reef	1156-1055	cal ^{14}C 1σ

Table 1., Radiometric dating results. Radiometric dating was carried out through the Th/U method for speleothems (Gascoyne et al., 1978) and ^{14}C method for vermetid reefs (Alessio et al., 1976).

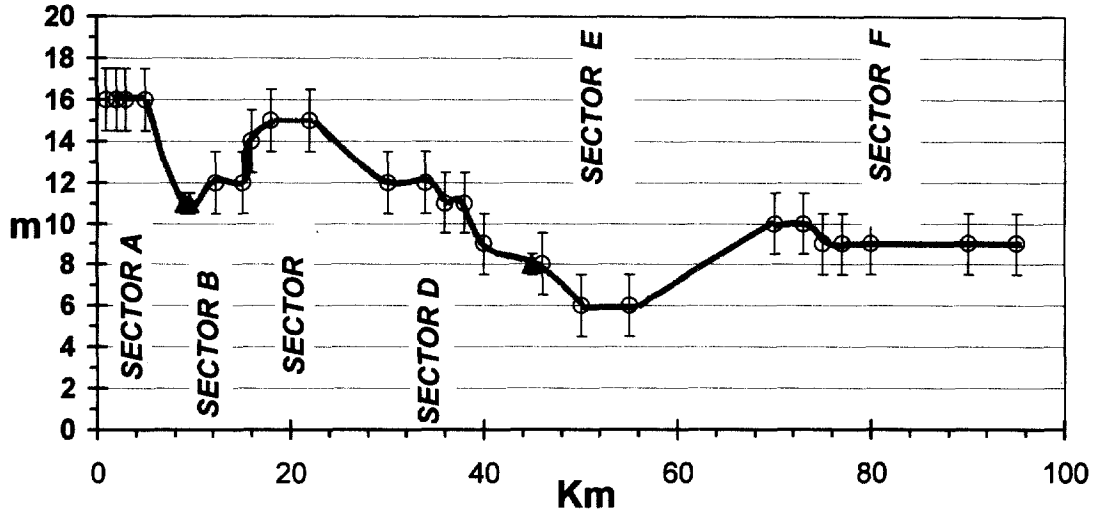

FIG. 3., Vertical trend of Eutyrrhenian paleo-sea level morphological evidences for each sectors. Open circles indicate the inner margin, triangle indicate notches. The bars indicate the error (±0.5 m for notches and ± 1.5 m for inner margin).

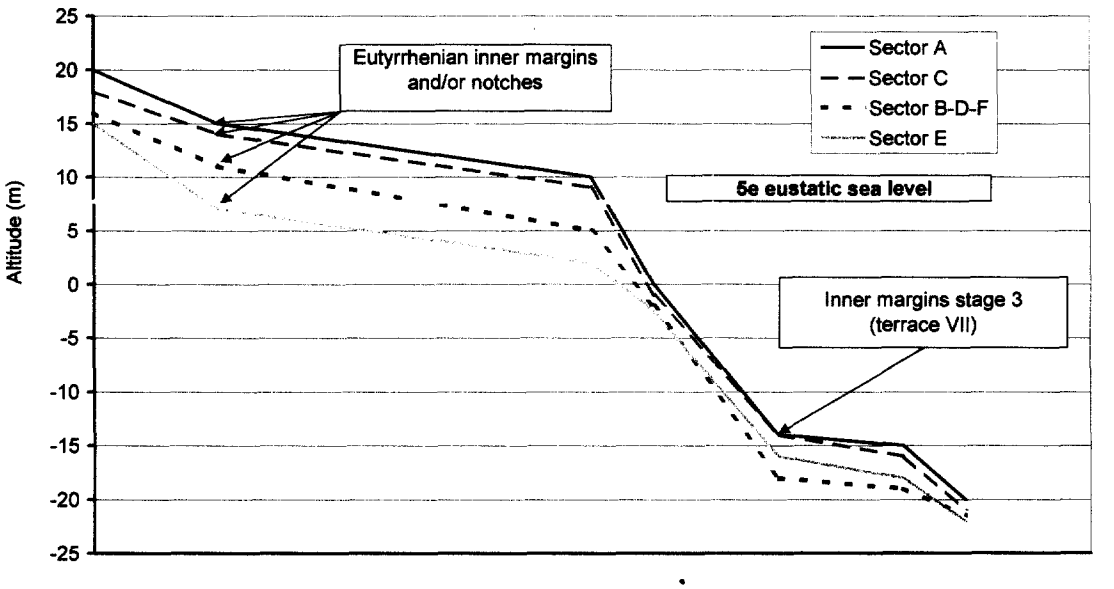

FIG. 4., Vertical distribution of the Upper Pleistocenec marine terraces inner margins and notches for each sectors.

Pleistocene inner margins and notches, up to heights greater than 90 m, which is definitely unusual for the Mediterranen coastal area.

When considering the magnitude of the differential uplift of the Eutyrrhenian inner margins and notches, the uplift rate related to the time interval following 125 kyr, varies from 0.072 mm/year to 0.056 mm/yr for Sectors A e C, and between 0.032 and 0.016 mm/yr for Sectors B, D and F. Sector E was relatively stable.

For each sector, the middle Pleistocene terraces seem to be tectonically deformed. The polarity and intensity of these tectonic dislocations are comparable with those measured for the Eutyrrhenian morphologies. For example, in Sectors A and C the Eutyrrhenian inner margins and notches are located at the highest elevations. This is true also for the inner margins and notches which can be ascribed to middle Pleistocene transgressions. In fact, they are at higher elevations with respect to the same morphologies in other Sectors (Fig. 2).

Providing that the submerged terrace (VII) shows a gait similar to that of the Eutyrrhenian forms, it is likely that it has been subjected to uniform tectonic displacement since the Upper Pleistocene (Fig. 4).

Table 1 shows the results of ^{14}C and U/Th radiometric datings. The age of the Holocene speleothem, sampled at a depth of -0.3 m on the eastern side of the S. Vito Promontory (Sector F), is about 7800 years BP. The age of the most ancient specimen of vermetid reef, sampled at the greater depth (Sector D), is 450 yrs cal BP.

Consequently, by assuming that the crustal movements have been constant from the Upper Pleistocene to the Present, the palaeoeustatic elevation which can be reconstructed from the Holocene submerged speleothem and the vermetid reef should be diminished of about 0.25 m and 0.01 m respectively. These corrections are negligible, because they are small compared to errors stemming from dating and sampling inaccuracy.

In conclusion, submerged karst deposits and vermetid reefs provide a tool for dating Holocene sea level fluctuations recognized through terraces and notches, for the Pleistocene and Holocene, following the methodology by Alessio et al., 1994.

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