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VERTICAL MOBILITY OF THE CONTINENTAL MARGIN BETWEEN LATIUM AND TUSCANY DEFINED BY MEANS OF EUSTATIC MINIMUM INDICATORS

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ABSTRACT: Chiocci F. L. *et al.*, *Vertical mobility of the continental margin between Latium and Tuscany, defined by means of eustatic minimum indicators* (IT ISSN 0349-3356, 2011)
A number of earlier coastal tectonic studies used marine terraces and their correlation with the eustatic curve in order to define vertical movements (uplift or subsidence) of coastal areas. ANALOGAMENTE, in this study the paleo-shelfbreak formed at the sea level lowstand of MIS 12 (450 kyr) and two submerged terraced related to it were characterized by analyzing high resolution reflection seismic profiles. Their current depth below the present day sea level were measured and compared to the sea level of MIS 12, as know from literature. These features are currently located at different depths along the continental margin, due to the interaction between load subsidence of the margin (at a rate of 0.20 mm yr^{-1} in the last 450 kyr) and tectonic uplift (at a rate up to 0.20-0.24 mm yr^{-1}, varying along the margin).

RIASSUNTO. Chiocci F. L. *et al.*, Mobilità verticale del margine continentale al confine tra Lazio e Toscana, definite attraverso indicatori di minimo eustatico (IT ISSN 0349-3356, 2011)
Molti studi di tettonica costiera utilizzano i terrazzi marini e la loro correlazione con la curva eustatica per definire le variazioni verticali (sollevamento o subsidenza) delle aree costiere. Analogamente, in questo studio il paleociglio di scarpata formatosi in corrispondenza del basso stazionamento del livello marino del MIS 12 (450 ka) e due terrazzi sommersi ad esso correlati sono stati caratterizzati attraverso l'analisi di profili di sismica a riflessione ad alta risoluzione e le loro profondità al di sotto del livello del mare attuale sono state confrontate con il livello marino del MIS 12 noto in letteratura. Tali elementi si trovano attualmente a profondità variabili lungo il margine continentale, a causa dell'interazione di subsidenza del margine, con un tasso di circa 0.20 mm a^{-1} negli ultimi 450 ka, e sollevamento tettonico, con un tasso variabile lungo il margine e fino a 0.20-0.24 mm a^{-1}.

Key words: neotectonics, last glacial maximum, seismic stratigrafy

Parole Chiave: neotettonica, ultimo pleniglaciale, stratigrafia sismica

Global sea level has changed several times during the geological history. During Quaternary, glacio-eustatic sea level changes have been characterized by high amplitude and high frequency (~100 m in 100 kyr) and by a nearly constant range between 120 m depth and the present sea level. In the course of these oscillations, at still-stand stages, terrace-shaped depositional bodies may be formed below the wave base level, resulting from sediment remobilization due to littoral erosion during high-energy storm events (CHIOCCI & ORLANDO, 1996; CHIOCCI *et al.*, 2004). The highstand features are the so-called marine terraces (at the present time occurring along the coasts), whilst lowstand features are wedged-bodies addressed as submerged or lowstand terraces that currently can be found at shelf breaks or, less frequently, in continental shelves (cf. fig. 2 in CHIOCCI *et al.*, 2004).
If deposits building up a continental margin are preserved, a sharp change in slope in stratigraphic units can be usually recognised in seismic profiles, which is commonly interpreted as paleo-shelfbreak. As the current shelfbreak is thought to be related to the minimum sea level reached during the last eustatic cycle, paleo-shelfbreaks can be assumed as paleo-sea level indicators at glacial maximum stages. A paleo-shelfbreak usually matches a limit between an erosional unconformity landward and a correlative conformity basinward, which can be used to define the position of eustatic minimum. When sea level changes occur, the aforementioned features may be preserved at their original position, thus becoming sea level proxies. When a coastal region is affected by tectonics, however, the position of marine and submerged terraces can be shifted either upward or downward, if respectively tectonic uplift or subsidence occurs.
On land and onshore, the use of marine terraces as proxy of sea level highstand is a well established methodology, with worldwide applications in coastal tectonic studies, in order to assess the vertical mobility of a continental margin (amongst many others, CAMPBELL, 1986; MARQUARDT *et al.*, 2004; LITCHFIELD *et al.*, 2010). For instance, when dating is not possible, a constant uplift rate is commonly assumed and different terrace orders are correlated to different highstand events from lower younger terraces to higher older ones (e.g. MCNEILL & COLLIER, 2004). Offshore, however, submerged terraces are not as much exploited. High resolution reflection seismics allows a very good depiction of the shallow features and overall stratigraphic architecture of a continental margin, providing a much higher resolution and spatial continuity than geological surveys on land. Nevertheless, to the knowledge of the authors, earlier studies dealing with submerged terraces focused on the reconstruction of local sea level lowstands (e.g. SHIPP *et al.*, 1991, LERICOLAIS *et al.*, 2009), while only LEBESBYE & VORREN (1996) investigated these features in order to assess vertical movements due to tectonic subsidence in the Barents Sea.

Here, the paleo-shelfbreak and two submerged terraces created during a Middle-Upper Pleistocene glacial maximum were characterized, in order to define the vertical motions of the continental margin between Latium and Tuscany. In fact, seismic and sequence stratigraphy, integrated with core ground-truthing and biostratigraphic analysis, allowed to date depositional features related to sea level lowstand of different eustatic cycles. Consequently, it was possible to reconstruct uplift/subsidence distribution along the margin.

Along the continental margin between Latium and Tuscany (central eastern Tyrrhenian Sea), about 3000 km of high and very resolution reflection seismic profiles, acquired during the last decades, were analyzed and interpreted by applying principles of seismic and sequence stratigraphy.

Six seismic units were defined, related to the last ~500 kyr and interpreted as 4th-order depositional sequences. Sequence boundaries can be either erosional unconformities or correlative conformities related to unconformities eroded by continental shelf emersion during sea level lowstands. Biostratigraphic constraints provided by borehole-logs and gravity cores and correlation with the eustatic curve allowed to establish the chronostratigraphy of sequence boundaries (CHIOCCI, 2000). Each sequence boundary was named referring to the lowstand marine isotope stage (MIS) when they were thought to be formed. Thus, the depositional sequences described in the area are delimited, from the oldest to the most recent one, by the surfaces U14 (540 kyr), U12 (450 kyr), U10 (350 kyr), U8 (260 kyr), U6 (140 kyr) and U2 (20 kyr). Landwards of paleo -shelfbreak, sequence boundaries are regional high-amplitude reflectors, which erosionally truncate underlying reflectors; basinward, they are high-amplitude high-continuity reflectors conformably lying on underlying strata. Load subsidence usually affecting passive continental margins allowed depositional sequences to be partially preserved even in the inner continental shelf, despite the nearly constant oscillation range of sea level during Quaternary. However, in the study area, the sequence boundaries of MIS 10, 8 and 6 lack unconformities and show only correlative conformities, while more ancient sequences (e.g. resting on U14 and U12) show both unconformities and correlative conformities, like the U2, related to the last glacial maximum (CHIOCCI, 2000).

Two buried wedge-bodies were identified in the offshore between Tarquinia and Ladispoli, the first one ~18 km long and the second one ~27 km long (fig.). They were interpreted as submerged terraces owing to the glacio-eustatic minimum of MIS 12. The paleo-shelfbreak and submerged terraces of MIS 12 were analyzed and their characters and depth were defined along the studied margin. Based on the assumption that both features were generated at the same sub-sea level depth, they were considered as paleo-sea level indicators. The depth of paleo-shelfbreak and submerged terraces (inner edge) below the current sea level gradually changes along the margin, rising from an average of 220 m in the northern sector (Mt. Argentario) to 131 m offshore Civitavecchia and Ladispoli, then decreasing to 202 m athwart Tiber River mouth and rising again to 166 m offshore Lido di Ostia (fig.).

The northern sector of the study area, where metamorphic bedrock arises, was considered to be stable, so that current depth of MIS 12 paleo-sea level indicators is only affected by subsidence. Therefore all paleo-sea level indicators found at lower depth are supposed to have been uplifted. Assuming that during MIS 12 the sea level was about 130 m below the current sea level (PISIAS *et al.*, 1990, cited by CAPUTO, 2007), the overall subsidence of the outer continental shelf was estimated in about 0.20 mm yr^{-1} in the last 450 kyr.

Considerations about the differential preservation of depositional sequences in the study area suggests that the regional uplift occurring in the continental margin began between 450 and 350 kyr, when the surfaces U12 and U10 developed, respectively. The depth of MIS12 paleo-shelfbreak and related depositional terrace gradually decreases south-eastward, moving along the margin, implying a relative uplift of about 89 m with respect to expected depth of 220 m (fig. 1). Taking the latter as a reference value, a differential uplift rate up to 0.20 or 0.25 mm yr^{-1} can be estimated for the Civitavecchia-Ladispoli offshore, respectively in the last 450 kyr or 350 kyr. In agreement with this result, the lack of unconformity of MIS 6, 8 and 10 and the preservation only in outer shelf of the older ones, indicates that uplift must have surmounted the regional subsidence that characterizes the Tyrrhenian margin.

The minimum depth observed offshore Civitavecchia-Ladispoli matches with the maximum regional uplift recognized along the coast of Latium by on land studies, based on the altitude of uplifted marine terraces related to MIS 9, 7 and 5e (340, 250 and 125 kyr respectively) (DE RITA *et al.,* 2002; NISI *et al.,* 2003; FERRANTI *et al.,* 2006). Studies of coastal terraces reveal that uplift rate increases southeastward and started between 400 and 200 kyr; both this fact point out that uplift may be due to the volcanic activity that affected the margin since 500 kyr (e.g. CAVINATO *et al.,* 1992; KARNER *et al.,* 2001; GIORDANO *et al.,* 2003; FERRANTI *et al.,* 2006).

The result of our analysis and their comparison with data derived from the present day elevation of marine terraces suggest that the areal distribution of this uplift is not homogeneous along the continental margin. The overall licture highlight the likely presence of a bulge likely centered on the Sabatini Mounts volcanic complex, perfectly aligned with the main measured peak. However, seismostratigraphic analysis made by BARTOLE (1995) highlighted the presence of a magmatic intrusion beneath the shelf in this area, independent from the volcanic complexes on land, which may be responsible for the observed uplift.

The secondary peak in the MIS 12 paleo-sea level elevation (centered to Lido di Ostia) can be attributed to a local uplift caused by three anticlines whose end of activity is unknown, because the erosion unconformity formed during the last glacial sea-level lowstand eroded most of the depositional sequences more recent than 450 kyr ago. Very high-resolution seismic reflection data in this area reveal deformation evidences at least up to 350 kyr.

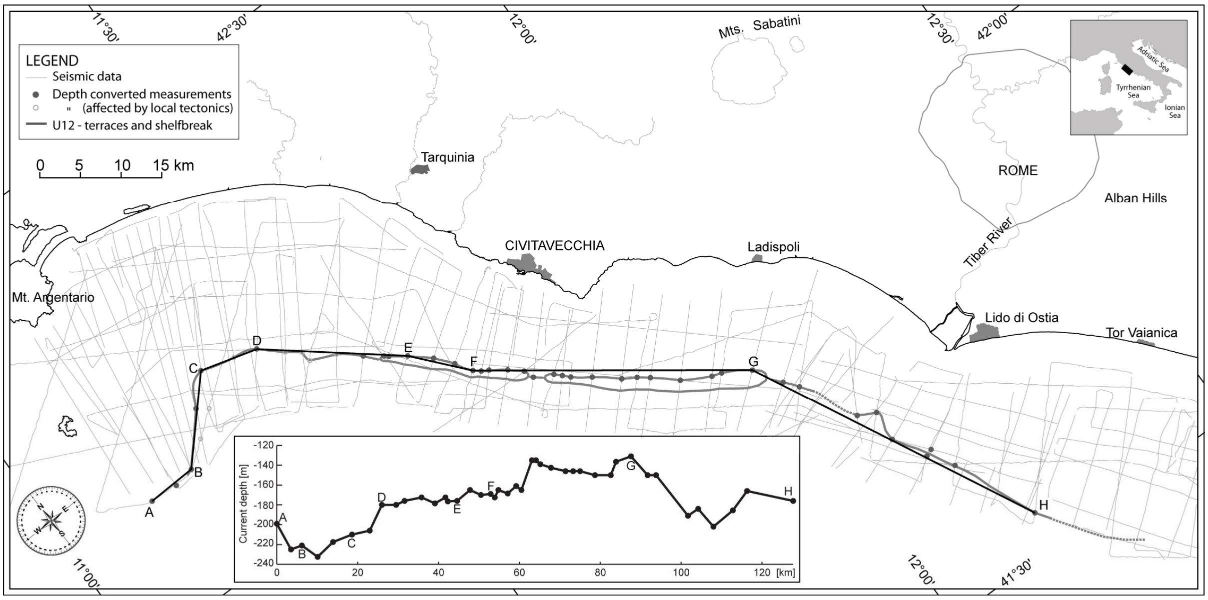

Fig. 1, Study area and data location. The plot shows the elevation of MIS 12 paleo-sea level indicators below current sea level along the transect A-H.
Area di studio. Il diagramma mostra le quote attuali degli indicatori del paleolivello del mare durante il MIS 12 lungo il profilo A-H.

REFERENCES

Bartole R. (1995) - *The North Tyrrhenian - Northern Apennines Postcollisional System* - Constraints for a Geodynamic Model. Terra Nova, **7**, 7-30.

Campbell J.F. (1986) - *Subsidence Rates for the Southeastern Hawaiian-Islands Determined from Submerged Terraces*. Geo-Marine Letters, **6**, 139-146.

Caputo R. (2007) - *Sea-level curves: Perplexities of an end-user in morphotectonic applications*. Global and Planetary Change, **57**, 417-423.

Cavinato G.P., De Rita D., Milli S., & Zarlenga F. (1992) - *Correlazione tra i principali eventi tettonici, sedimentari, vulcanici ed eustatici che hanno interessato l'entroterra (conche appenniniche) e il margine costiero tirrenico laziale durante il Pliocene superiore ed il Pleistocene*. Studi Geologici Camerti, **1992/1**, 109-114.

Chiocci F.L. (2000) - *Depositional response to Quaternary fourth-order sea-level fluctuations on the Latium margin (Tyrrhenian Sea, Italy).* In Hunt, D., and Gawthorpe, R.L., eds., Sedimentary Responses to Forced Regressions: Special Publications: London, Geological Society, 271-289.

Chiocci F.L., D'Angelo S., Romagnoli C., Ricci Lucchi F., & Group S.W. (2004) - *Submerged depositional terraces along the Italian coasts - conclusion*. In Chiocci F.L., D'Angelo S., & Romagnoli C., eds., ATLAS of Submerged Depositional Terraces along the Italian coasts: Memorie Descrittive della Carta Geologica d'Italia: Roma, APAT - Dipartimento Difesa del Suolo, Servizio Geologico d'Italia, 111-116.

Chiocci F.L. & Orlando L. (1996) - *Lowstand terraces on Tyrrhenian Sea steep continental slopes*. Marine Geology, **134**, 127-143.

De Rita D. et al. (2002) - *Volcaniclastic sedimentation in coastal environments: the interplay between volcanism and Quaternary sea level changes* (*central Italy):* Quaternary International, **95**-6, 141-154.

Ferranti L. et al. (2006) - *Markers of the last interglacial sea-level high stand along the coast of Italy*. Tectonic implications: Quaternary International, **145**, 30-54.

Giordano G. et al. (2003) - *The sedimentation along the roman coast between middle and upper Pleistocene: the interplay of eustatism, tectonics and volcanism - New data and review.* Il Quaternario, **16**, 121-129.

Karner D.B., Marra F., Florindo F. & Boschi E. (2001) - *Pulsed uplift estimated from terrace elevations in the coast of Rome: evidence for a new phase of volcanic activity?.* Earth and Planetary Science Letters, **188**, 135-148.

Lebesbye E., & Vorren T.O. (1996) - *Submerged terraces in the southwestern Barents Sea: Origin and implications for the Late Cenozoic geological history*. Marine Geology, **130**, 265-280.

Lericolais, G., Bulois, C., Gillet, H., & Guichard, F. (2009) - *High frequency sea level fluctuations recorded in the Black Sea since the LGM*: Global and Planetary Change, **66**, 65-75.

Litchfield N., Wilson, K., Berryman K. & Wallace L. (2010) - *Coastal uplift mechanisms at Pakarae River mouth: Constraints from a combined Holocene fluvial and marine terrace dataset*. Marine Geology, **270**, 72-83.

Marquardt C., Lavenu A., Ortlieb L., Godoy E. & Comte D. (2004) - *Coastal neotectonics in Southern Central Andes: uplift and deformation of marine terraces in Northern Chile (27° S).* Tectonophysics, **394**, 193-219.

McNeill L.C. & Collier R.E.L. (2004) - *Uplift and slip rates of the eastern Eliki fault segment, Gulf of Corinth, Greece, inferred from Holocene and Pleistocene terraces:* Journal of the Geological Society, **161**, 81-92.

Nisi M.F., Antonioli F., Pra G.D., Leon G. & Silenzi S. (2003) - *Coastal deformation between the Versilia and the Garigliano plains (Italy) since the last interglacial stage.* Journal of Quaternary Science, **18**, 709-721.

Pisias N.G., Mix A.C. & Zahn R. (1990) - *Nonlinear response in the global climate system: Evidence from benthic oxygen isotopic record in core RC13-110.* Paleoceanography, **5**, 147–160.

Shipp R.C., Belknap D.F. & Kelley J.T. (1991) - *Seismic-Stratigraphic and Geomorphic Evidence for a Postglacial Sea-Level Lowstand in the Northern Gulf of Maine:* Journal of Coastal Research, **7**, 341-364.

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