Deformed Pleistocene marine terraces along the Ionian sea margin of southern Italy: Unveiling blind fault-related folds contribution to coastal uplift.

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Key words: marine terraces, regional uplift, fault propagation folds, fault modeling.

Morphotectonic analysis and fault numeric modeling of uplifted marine terraces along the southern half of the Taranto Gulf, between the Sibari and San Nicola plains (Fig. 1), allow us to place quantitative constraints on Middle Pleistocene-Holocene deformation in the Southern Apennines.

At the end of the Early Pleistocene, a tectonic change occurred in southern Italy (HIPPOLYTE et alii, 1994). At this time, NW-SE striking transpressional faults in the frontal part of the Apennines (Fig. 1a) were activated, related to involvement of the foreland continental lithosphere in the collision (CATALANO et alii, 1993). Based on seismic reflection profiles and borehole data, DEL BEN et alii (2007) and FERRANTI et alii (2009) demonstrated that the strike-slip fault zones continue in the offshore and deform up to the Middle-Upper Pleistocene sequences (Fig. 1a). FERRANTI et alii (2009), through morphometric, structural and seismic data (Fig. 1a), proposed that a compression phase, under a ~NE to ENE-trending shortening axis, was active since Early Middle-Pleistocene and, probably, is still ongoing. Previous works proposed the existence of paleo-shorelines deformations induced by local thrust and transpressional faults (FERRANTI et alii, 2009; CAPUTO et alii, 2010).

The observations discussed here build on, and refine, the works published by FERRANTI et alii (2009) and SANTORO et alii (2009), by slightly adjusting their marine terrace positions and by extending their terrace map to the southern sector of the San Nicola Plain (Fig. 1a). Terraced surfaces have been identified through aereophotography analysis (1:17.000 scale) and morphological and sedimentological field surveys (1:10.000 and 1:5.000 scale topo maps and orthophotos, respectively).

Ten terrace orders uplifted up to +660 m were mapped along ~80 km of the Taranto Gulf coastline (Fig. 1a). Terrace chronology (Fig. 1a) was established through a critical review of all the available dating in the Taranto Gulf [Brükner, 1980; DAI PRA & HEARTY, 1988; AMATO et alii, 1997; CUCI, 2004; ZANDER et alii, 2006; SANTORO et alii, 2009; CAPUTO et alii, 2010]. The lack of an agreement among authors dealing with this problem hampers a correct estimate of the local and regional uplift rates. We are confident that the application of Optical Stimulated Luminescence and Cosmogenic Radionuclides exposure ages methods will pose further constraints about terrace chronology (RISTUCCIA et alii, this volume).

The shorelines, projected along section A-B (Fig. 1a) document both a regional and a local, fault-induced contribution to uplift (Fig. 1c). Two major undulations, hereafter named Valsimini and Pollino antelines (labeled as 1 and 2 in Figs. 1a and 2c, respectively) were found along the Pollino coast. The undulations spatially coincide with the trace of NW-SE striking transpressional faults that affected the coastal mountain range during the Early Pleistocene, but display scarce evidence of more recent activity. To test whether fault activity continued to the present, we modeled the differential uplift of marine terraces as progressive elastic displacement above blind oblique-thrust ramps seated beneath the coast.

A first step toward determining the fault-induced signal and derive fault parameters from the paleo-shorelines record requires splitting the total uplift of individual terraces in its regional and local tectonic component. The two components, local and regional, are characterized by different wavelength, which varies from the few 10s to the several 10s to 100 km, respectively, and their understanding requires assessment of different spatial distribution of markers. The large wavelength geomorphological signature of the regional uplift was reconstructed by using the elevation of the MIS 5.5 terrace along a ~300 km long coastal sector of the Taranto Gulf (Fig. 2). Specifically, we used MIS 5.5 elevation data from sectors where the terrace chronology is well constrained and the paleo-shorelines are not appreciably deformed by local thrust and transpressional faults. The linear regression (R²=0.979) through the MIS 5.5 elevation data highlights a northeastward tilt of the coast with a mean regional gradient of 0.4 m km⁻¹ and a tilt rate (gradient of the coastline divided by the MIS 5.5 age) of 3×10⁻³ m km⁻¹ ka⁻¹ (Fig. 2a). The accuracy of our regional uplift trend was verified by plotting it against the observed
Indeed, if we force the regional curve to pass close to the tilted (but not folded) terraces of San Nicola Plain, it apparently runs very close by the inflection point between uplift and subsidence for the Pollino and Valsinni anticlines (Fig. 2c). The inflection point position for the two anticlines was derived using the elastic deformation models of Okada (1985) that predict, for a blind thrust with a geometry similar to that of the northern Calabria faults, a co-seismic surface deformation partitioned on the average between an ~84% uplift and ~16% subsidence. It is evident from Fig. 2c that the model condition is closely matched by the combined terrace observation data and computed regional trend. Finally, relying on the simplistic assumption that the regional uplift is steady and uniform, we derived regional and local uplift signals for lower and higher terraces (Fig. 2b).

Through an iterative and mathematically based
procedure we defined the best geometric and kinematic fault parameters as well as the number and position of fault segments. Only the local vertical displacement (elevation difference between paleo-shoreline and regional uplift curve) was modeled (Fig. 2c).

Kinematic parameters (rake) of the modeled transpressive faults rely on structural analysis carried out in Early-Middle Pleistocene sequences and on strain tensor data derived from available focal mechanisms (ERRANTI et alii., 2009). In light of the small scatter in both the finite and incremental shortening trend estimates, we determined the preferred orientation (N30°E) carrying out a set of fault models with different shortening axis trend changing from NNE-SSW to E-W, tested against the MIS 5.5 terrace.

Regarding to the geometric parameters, we started from strike, dip direction, minimum depth and dip derived from geological maps, geological cross sections and geophysical data. Because the fold wavelength is controlled by dip and width of the fault plane, we used our deformed paleo-shorelines (geographic position and distance between anticline and syncline axis) to calibrate the width, maximum depth and dip of the fault surfaces by moving in the value ranges derived from seismic sections, with steps of 1 km and 1°, respectively. The width we obtained following this procedure can be assumed as the subsurface rupture width of WELLS & COPPERSMITH (1994). Once this parameter was fixed, we were able to evaluate the moment magnitude and, hence, the length (subsurface rupture length) trough the empirical relationships of WELLS & COPPERSMITH (1994).

We found that only the Satanaso and Valsinni faults (STF and VF, respectively; Fig. 1a) are involved in warping of the marine terraces. Indeed, the surface deformatonal areas predicted by the numeric models for CF, PF, SRF and CNNF (Fig. 1a) are not geographically coincident with paleo-shorelines dislocation. Therefore, we regard these latter faults as inactive and discard them from further modeling.

Fault numerical models predict two fault-propagation folds cored by blind thrusts (STF1 and VF1 in Fig. 2c) with slip rates ranging from 0.5 to 0.7 mm/a and capable of generating an earthquake with a maximum moment magnitude of 5.9-6.3. The modeled slip on the thrust faults reproduces with fair accuracy not only the MIS 5.5 paleo-shoreline shape, through which the model itself was tested, but also the elevation trend of terraces from T2 to T8.

In the time period investigated, local, fault-induced, vertical deformation was not constant but occurred as an alternation of more rapid (up to ~1.9 mm/a) and slower or null periods of vertical displacement rates. Remarkably, we found that not only the fault segments activity was not constant at the 400-ka scale, but also that deformation shifted during time between the two modeled fault segments.

It is not clear if the active deformation is seismogenic or dominated by aseismic creep; however, the modeled faults are embedded in an offshore transpressional belt that may have sourced historical earthquakes. Thus, acknowledging that the elastic fault model can overestimate the maximum expected magnitudes, we propose that the modeled fault zones can be responsible of moderate-high intensity earthquakes, probably not registered in the historical record due to recurrence time interval exceeding the record length.

REFERENCES


