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DETECTING AND MODELING ACTIVE STRUCTURES IN NORTHERN CALABRIA: NEW INSIGHTS FROM DRAINAGE NETWORK MORPHOMETRIC ANALYSIS.

Enrico Santoro[1], Luigi Ferranti[2], Carmelo Monaco[1], Frank J. Pazzaglia[3] & Pierfrancesco Burrato[4]
[1]Dipartimento di Scienze Geologiche, Università di Catania, Catania
[2]Dipartimento di Scienze della Terra, Università "Federico II", Napoli
[3]Department of Earth and Environmental Science, Lehigh University, Bethlehem (PA)
[4]Sezione di Sismologia e Tettonofisica, I.N.G.V., Roma
Corresponding author: E. Santoro <enrico.santoro@hotmail.it>

ABSTRACT: Santoro E. *et al., Detecting and modeling active structures in northern Calabria: new insights from drainage network morphometric analysis.*(IT ISSN 0394-3356, 2011).
A detailed morphometric analysis of the drainage network on the eastern side of the Pollino mountain range (north-eastern Calabria) was performed in order to gain new insights on the active tectonic frame, the landscape evolution state and the response time of the hydrographic network to the tectonic deformations.

RIASSUNTO: Santoro E. *et al.,* Individuazione e modellazione di strutture attive in Calabria settentrionale: nuove evidenze dall'analisi morfometrica del reticolo idrografico. (IT ISSN 0394-3356, 2011).
Un'analisi morfometrica di dettaglio delle principali fiumare che drenano il versante orientale del Pollino (Calabria nord-orientale) ha consentito di acquisire nuove conoscenze riguardo il quadro tettonico attivo, lo stato evolutivo del paesaggio e i tempi di risposta del sistema idrografico alle deformazioni imposte dalla tettonica.

Key words: morphometric analysis, knickpoints, active transpression, North-eastern Calabria.

Parole chiave: analisi morfometrica, convessità, transpressione attiva, Calabria Nord-orientale.

The longitudinal profile of bedrock channels may yield valuable information about the landscape vertical deformation processes, the rock mass erosional strength, the eustatic cycles and the climatic factors controlling the landforms. A number of studies have been successful in the evaluation of recent deformation features using quantitative analysis of longitudinal profiles (e.g., MERRITTS & VINCENT, 1989); the realization of this goal, however, remain limited to the areas were local calibration of model parameters is possible (KIRBY & WHIPPLE, 2001).

In this study, inspired by previous results obtained through the mapping of the marine terraces and the reconstruction of the relative paleo-shorelines, we have performed a detailed morphometric analysis of the drainage network on the eastern side of the Pollino mountain range (north-eastern Calabria; Fig. 1). The uniform coastal lithology and climate allow us to isolate the tectonic signal from the fluvial morphometric analysis.

This region is located on the north-eastern tip of the Calabrian arc, which lies above the westerly-plunging Ionian slab, and a combination of lithospheric and crustal processes concurred to rapid Late Quaternary uplift. FERRANTI *et al*. (2009) and SANTORO *et al*. (2009) mapped ten terrace orders up to 663 m a.s.l., correlated between the coastal slopes of Pollino range across the Sibari Plain, facing the Ionian Sea side of north-eastern Calabria and eastern Basilicata. Based on the terrace chronology, uplift along the Pollino coastal range, in the last ~600 ka, occurred at an average rate of 1 mm/a, but was characterized by the alternation of more rapid (~2.2 mm/a) and slower (~0.7 mm/a) periods of displacement. Besides, spatial variability in uplift rates is recorded by the deformation profile of terraces parallel to the coast, which document small-wavelength (~20 km) and amplitude (up to ~100 m) local undulations superposed to the regional uplift pattern, which is the dominant tectonic signal (SANTORO *et al*., 2009). Based on the structural, geodetic, geophysical and seismic data the paleo-shorelines undulations were interpreted as fault-propagation folds linked to the transpressive shear zones, NO-SE directed, that affected the region since the Early Pleistocene. This hypothesis is confirmed by the results of the numeric modelling of the shear zones cutting the coastal area where the major deformations were identified. The good match between the modelled vertical co-seismic deformation and the paleo-shorelines deformation profiles testifies that the transpressional regime was active during the Middle-Upper Pleistocene. Through an iterative comparison between the paleo-shoreline profiles and the vertical co-seismic deformation it was possible to define the geometric and kinematic fault parameters that best explain the marine terraces deformation. The final deformation model predicts the active uplift of two anticlines along the south-eastern flank of the Pollino range and the Valsinni

Ridge (hereafter named Pollino and Valsinni anticlines, respectively; Fig. 1).
The morphometric analysis was performed to test and improve the above mentioned deformation model. Linear regressions of the logarithms of channel gradient and drainage area data was used to find convexities (knickpoints) and to determine, the concavity index (θ) and the steepness index (k_s). The method is based on the shear-stress incision model, predicated on the hypothesis that the bedrock-channel-erosion rate (*E*), in volume per unit channel area, is a power-law function of basal shear stress (τ_b):

$$E = k_b \tau_b^{a}, \quad (1)$$

where k_b is a dimensional coefficient dependent on dominant erosion process, rock resistance and sediment load and *a* is a positive, process-dependent constant. Combining the shear-stress incision model with a statement of conservation of mass, assuming that uplift and erosion are uniform in a drainage basin and solving for the river longitudinal slope is possible to write:

$$S = k_s A^{-\theta}. \quad (2)$$

The coefficient k_s (steepness index) and the exponent θ (concavity index) are, respectively, the gradient-axis-intercept and the slope of the linear regressions through the logarithms of channel gradient and drainage area data. We limited our analysis to the bedrock channel region; the results obtained from area controlled by hillslope/colluvial or alluvial processes are, indeed, not reliable. The rivers longitudinal profiles, extracted from DEM 10x10 m, were corrected averaging the elevation through a mobile 200 m window, in order to reduce the gradient data dispersion derived by DEM errors. Following SNYDER *et al*. (2000) and WHIPPLE (2004) we used a fixed reference concavity (θ = 0.45) in order to calculate a normalized steepness index (k_{sn}); this permitted the comparison between channels characterized by different drainage areas (e.g., KIRBY et *al*., 2003). The k_{sn} values increase regularly toward the Pollino and Valsinni anticlines; in other words, the rivers flowing through the areas that are affected by the higher uplift rates tend to establish a steeper longitudinal profile in order to have the energy sufficient to erode the uplifting tectonic barrier.
Several knickpoints (steeper channel segments characterized by convex-upward shapes and θ<0) were detected along the longitudinal profiles of the trunk streams. Being the analyzed rivers adjusted to the sea level (drainage network base level), it is reasonable to hypothesize that some of the knickpoints are related to the glacial-interglacial Quaternary cycles. To test this idea, for each knickpoint the reconstruction of the interglacial profile was performed through the k_s and the θ values calculated for the respective river. An eustatic origin was considered valid if: 1. the paleo-longitudinal profile crosses a marine terrace; 2. at least three knickpoints are related to the same marine terrace (same eustatic regression); 3. the knickpoints correlated to the same eustatic cycle are characterized by migration rates and positions that are in direct relationship with the landward drainage area. For some of the knickpoints the eustatic origin is confirmed by the presence of fluvial terraces aligned with the relative paleo-longitudinal profiles; the terraces are, reasonably, the consequence of the erosive wave triggered by the eustatic regression and progressively transmitted to the entire drainage basin through the knickpoint landward migration. Generally, the elevation of a knickpoint genetically related to an eustatic sea level regression is influenced by the drainage

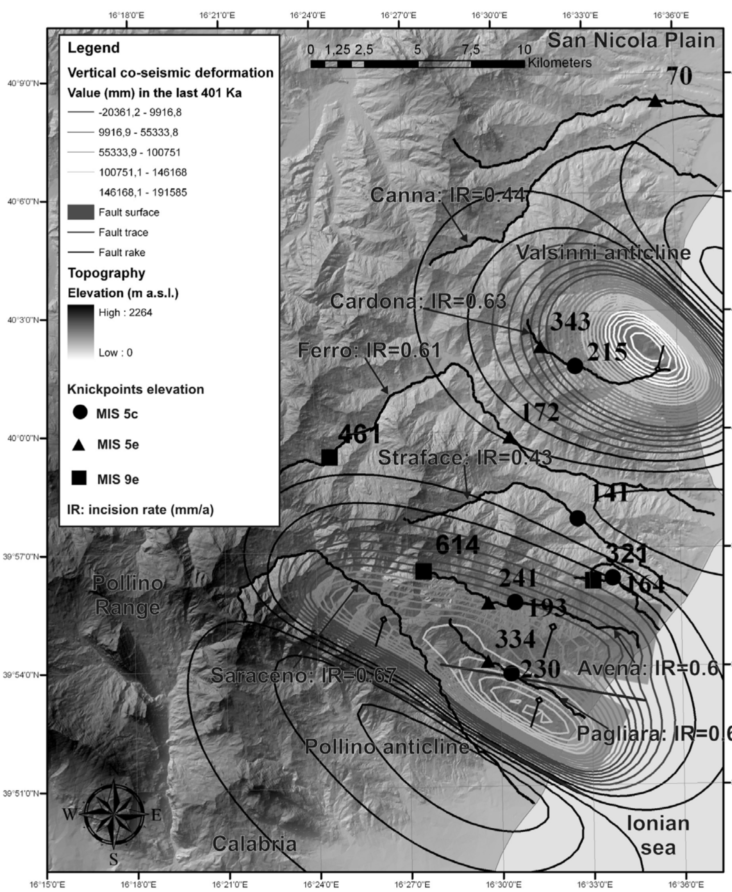

Fig. 1, knickpoints elevation and incision rates compared with the deformation model.
Altezze dei knickpoints e tassi di incisione fluviali comparati con il modello di deformazione.

area (migration rate) and the trunk stream longitudinal gradient. As a consequence, holding constant the drainage area the knickpoint elevation can be influenced by gradient changes determined .by differential uplift rates; the higher the uplift rate the higher the gradient and the knickpoint elevation. In the study area this theoretical prediction is perfectly confirmed: all the knickpoints related to the same marine terrace are always characterized by an increase of the elevations toward the Pollino and Valsinni anticlines (Fig. 1) where the higher uplift rates determine a rise of the river gradients.

The maximum difference in elevation between the paleo-longitudinal profiles and the present riverbed was evaluated in order to determine the mean fluvial incision rates. As forecasted by the deformation model, the rivers flowing through the Pollino and Valsinni anticlines are characterized by the higher incision rates (Fig. 1). These streams, in order to adjust their equilibrium profile disturbed by the tectonic deformation, increase their gradient and vertically incise through their valley.

Finally, based on the migration rates, it was possible to determine the drainage network response time considered to be the time necessary for a convexity to migrate through the entire drainage basin. All the analyzed rivers show a low response time (~10^5 yr) that highlights the youthfulness of the tectonic deformation; indeed, all the tectonic signals older than 10^5 yr can be considered completely erased by the fluvial erosive processes.

The longitudinal profile analysis have permitted to confirm the results independently reached with the marine terraces, the structural and geophysical analysis and the fault modelling, evidencing that compressional regime is still active in this sector of the Southern Apennines.

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