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3D Quaternary deformation pattern in the central Po Plain (Northern Italy)

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The Po Plain is a foredeep basin flanked by the two major and active orogens of the Italian Peninsula, the Alps to the North and the Apennines to the South. The basin has a quasi - triangular shape and grades longitudinally to the East in the Adriatic Sea.

We used petroleum industry seismic reflection data acquired by ENI E&P in the Central Po Plain, over an area spanning about 6800 km2 from Lake Como to the W to Lake Garda to the E, and from the Lombardian Southern Alps to the N and the Emilia Apennines to the S, in order to analyze and interpret selected seismic reflectors and to define the evolution in space and time of the local active tectonic structures. Folds associated with underlying thrusts were recognized based on deformation recorded by two regional sequence boundary horizons, i.e. the ‘A’ Surface (1.6 Myr) and the ‘R’ Surface (0. 9 Myr; e.g., Carcano & Piccin, 2002; Muttoni et al., 2003), characterized by good stratigraphic and age bracketing, and marking significant changes in the sedimentary architecture of the Po Basin. Age controls are based on stratigraphic, paleontological and magnetostratigraphic analysis by ENI E&P and Regione Lombardia (Carcano & Piccin, 2002; Scardia et al., 2006). The analysis of strain recorded by these horizons allowed us to: A) recognize a belt of active fold and thrust structures, each 10 to 20 km long, arranged with an en-echelon pattern across the whole Po Basin, and B) analyze their evolution over the Quaternary.

’A’ surface (1.6 Myr)

The ‘A’ surface has been mapped over about 7800 Km2. From North to South four major morphobathymetric domains can be defined in the Pleistocene marine Po Basin: an Alpine platform domain, a slope that links it with the wider central basin domain, a smaller and steeper slope and an Apennine platform domain. The basin shape has an asymmetric transversal profile and is ca. 40 km wide. Several tectonic structures affect this surface. On the Alpine platform domain two small structures have been identified. We interpreted them as N-verging fault propagation folds with low angle ramps that detach the Gonfolite Lombarda clastics (Oligo – Miocene; Bernoulli et al., 1989; Gelati et al., 1991) from the underlying Upper Cretaceous carbonates. The present-day geomorphic evidence of these two structures are represented by the Pievedizio, Capriano, Castenedolo and Ciliverghe Hills South of Brescia (Livio et al, 2008; Michetti et al., 2008).

On the basin floor domain nine structures have been identified. Six of them belong to the Southern Alps and we interpreted them as S-verging fault propagation folds. All these structures have a double plunging termination (Burbank & Anderson, 2001) that mark the endpoints of actively slipping blind thrusts. These structures range from 11 to 16 km long with an average strike of N 110° E. The remaining three structures record shortening at the leading edge of the Apennines; their axial lengths range from 8 to 28 km and the average axial strike is 110°. These structures thus define the 3D architecture of blind thrusts hidden beneath the basin floor; these collectively define the two active, facing fronts of the Apennines and Southern Alps thrust belts (Fantoni et al. 2004).

‘R’ Surface

The second analyzed surface is the ‘R’ surface (0.9 Myr.); strain measured across this sequence stratigraphic boundary confirmed and further defines the magnitude and timing of shortening accommodated by fault propagation folds described on the ‘A’ surface. Differences between the basin between “A” and “R” surface time include the arrangement of the structures on the basin floor and by the number of the identified structures. The Alpine platform domain in “R” time is in fact more extended than on the ‘A’ surface, and a less steep

slope links it with a wider but less deep basin domain; the Apennines platform is smaller, because it has been involved in the deformation of the more internal Apennines structures. The basin floor is ca. 30 km wide with a progressive westward narrowing, and still displays an asymmetric transversal profile. Sedimentation rates are considerably higher than uplift rates of the structures, resulting in a paleobathymetry gentler than the 'A' surface The measurement of the folds axial length becomes consequently more difficult.
In order to filter the tectonic signal we conducted a profile curvature analysis perpendicular to the mean axial direction of the structures. We recognized six structures with an average length of 18 - 20 km and an average axial strike of N 110° E. The comparison of these structures with those recognized on the 'A' surface clearly shows a decreasing number of folds, suggesting some thrusts shut off between "A" and "R" surface time. The similar geometry of folded "R" and "A" surfaces suggest consistent fault geometry and stress orientation during this time. This kinematic pattern is consistent with a spatially – varying shortening rate model (e.g., Salvini & Storti, 2002). The folds appear to grow with constant fault geometry and the displacement varies along strike since the tip of the faults migrates laterally in a direction perpendicular to the regional horizontal stress (Mueller & Talling, 1997, Keller et al., 1999; Champel et al, 2002; Burbank & Anderson, 2001).
In summary, the analysis of the two described Quaternary seismic surfaces allowed us to understand the evolution of active folds within the Po Plain and their growth mechanism and evolution both in space and time. These folds are the modern loci of compressive strain that links the Southern Alps with the Northern Apennines. Comparing the two surfaces we can observe a significant shift in the localization of the tectonic deformation, consisting A) in the reactivation of N-verging backthrusts and associated folds in the Southern Alps instead of the main forethrusts, and B) in a similar backward skip of the activity from the outermost Apennines fronts, with the reactivation of the Pedeappenninic Thrust Fault (e.g. Boccaletti & Martelli, 2004). This might be related to a differential sedimentary load between proximal and distal portions of the basin related to increased erosion, especially in the Alps in hinterland areas and corresponding sedimentation in the foreland, both triggered by climate change in the Mid-Pleistocene (e.g. Muttoni et al., 2002).

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