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Geological model of the central Periadriatic basin (Apennines, Italy)

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ABSTRACT

3D geological models from multi-source data (cross-sections, geological maps, borehole logs and outcrops) are a critical tool to improve the interpretation of the spatial organization of subsurface structures that are not directly accessible. In this paper, we reconstruct the main geological structures and surfaces in three dimensions through the interpolation of closely and regularly spaced 2D seismic sections, constrained by wells data and surface geology. The methodology was applied in the Marche–Abruzzi sector of the Periadriatic basin, where the more external part of the Apennines fold-and-thrust belt is mostly buried under a syn- and post-orogenic, Plio–Pleistocene, siliciclastic sequence. The 3D model allowed us to correlate the main thrust fronts and related anticlines along strike, revealing a general ramp – flat – ramp trajectory characterizing the main structural trends. This geometric organization influences the sequence of thrust-system propagation and characterizes the evolution of syntectonic basins. The obtained 3D model points out several variation occurring along strike: i) main trends geometric relationships; ii) deformation chronology and iii) displacement distribution. In the northern sector, higher displacement and structural elevation are reached out by the Nereto–Bellante structure, whereas in the southern sector the Villadegna–Costiera Structure is the prevalent. All structures show a diachronic thrusts activity along strike, younger toward the north.

1. Introduction

The development of software for 3D modeling (gOcad, Earth Vision, Move, Petrel among many others) has opened a new frontier in the Earth Sciences, leading to a more accurate spatial analysis of geological structure and to 3D models. Numerous papers deal with the integration of different kind of data for a 3D reconstruction of subsurface structures at a regional scale (Ledru, 2001 and references therein; Courrioux et al., 2001; Galera et al., 2003; Wu et al., 2005; Zanchi et al., 2009; Salvi et al., 2010). The subsurface data generally used for 3D reconstruction are the seismic data, integrated with well data log, techniques that has its maximum development in the hydrocarbon research (Fonnesu, 2000; Zampetti et al., 2004; Gee et al., 2007; among many others). Integrating geophysical and geological data, from seismic available database and by geological maps, is possible to define geometrical and geological constraints in order to create 3D surfaces, closed volumes and grids from the constructed objects.

In this work, we integrated 2D reflection seismic dataset, geological maps and borehole data to reconstruct the buried structures; this procedure provided the generation of 3D surfaces taking into account any geometrical constraint derived from the dataset.

The workflow followed three main steps. The first one was the construction of a digital database in a GIS environment, followed by the 2D interpretation of each seismic line; finally we built the main 3D stratigraphic and tectonic surfaces, working in a 3D space where the depth is expressed in TWT time. The depth conversion and restoration has been performed in 2D, along the most representative section derived from the 3D model. Most of the work was carried out with Kingdom 8.4 (Seismic Micro-Technology) for the seismic interpretation and Move 2011 (Midland Valley) for the reconstruction of the 3D model. We applied this approach to a wide sector of the Periadriatic Basin, between Ascoli Piceno to the north and Pescara to the south, at the front of the Apennines thrust belt system (Fig. 1). In this area, which has an extension of about 8000 kmq, an extensive oil exploration activity has been carried out since '70–'80, and, as a consequence, the related seismic dataset is wide and mostly available, although not always of high quality (Videpi Project, 2009) (Fig. 2).

The structural setting of this area is the combination of extremely superficial thrust-related anticlines and their respective

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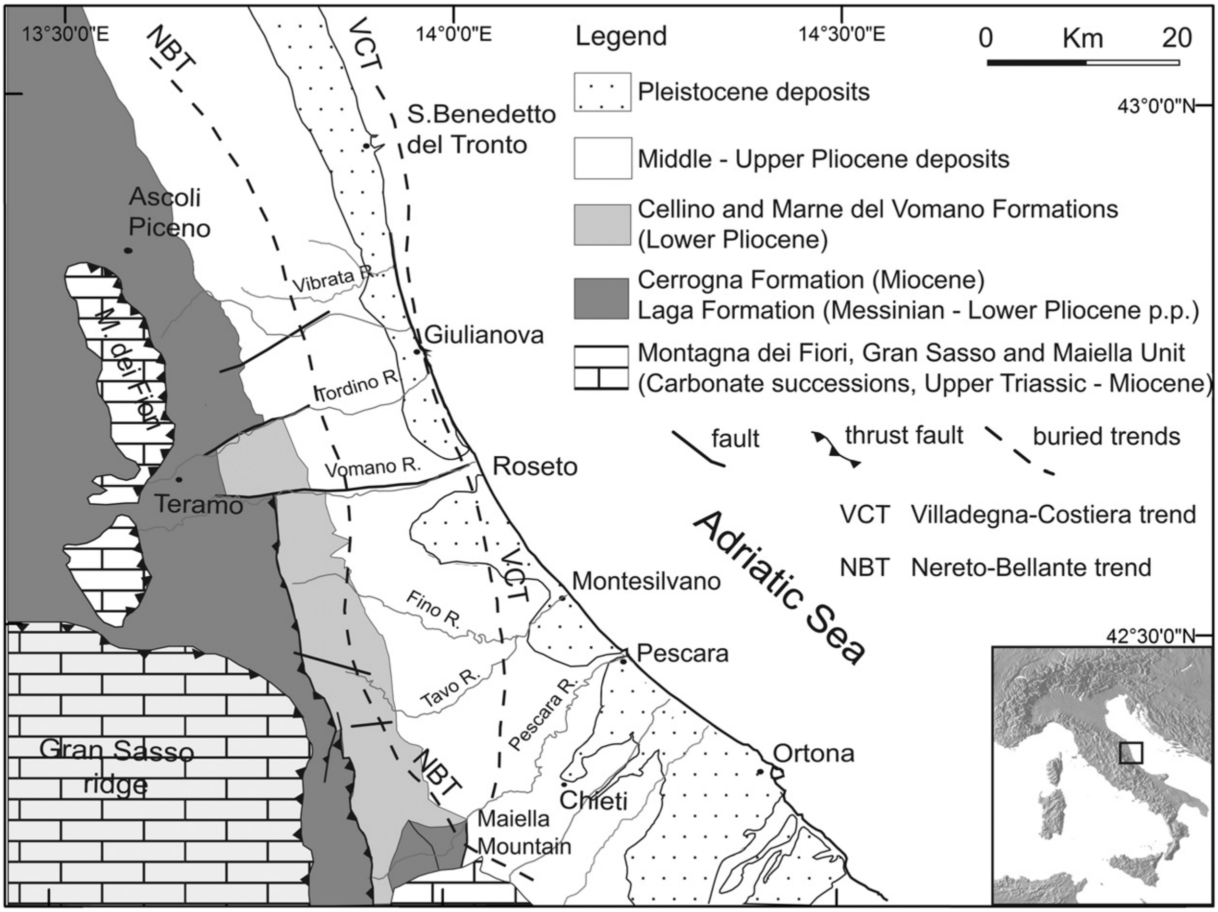

Figure 1. Geological map of the Central Periadriatic basin. The buried trends are the ones generally mapped in this area (from Structural Model of Italy, 1:1,000,000, modified).

deeper ramps, buried under syn- and post-orogenic, Plio-Pleistocene, siliciclastic sequences (Artoni and Casero, 1997; Argnani and Frugoni, 1997; Bigi et al., 2004; Carruba et al., 2006; Tozer et al., 2006).

A general evolution of the Periadriatic basin has been proposed, among many others, by Ori et al. (1991), Crescenti et al. (2004), Artoni (2007). Following Ori et al. (1991), the complex evolution of the Adriatic foredeep can be resumed in four stages: during the Messinian stage, the first one, the area was a typical foredeep basin (sensu DeCelles and Giles, 1996) where a single basin lie parallel to the structural axes of the mountain chain; the same basin was affected during the Early Pliocene by thrusting and a more internal and uplifted zone, still connected to the main basin, called "open piggy back basins" was defined. The third stage, in the Middle–Upper Pliocene, was characterized by an increase of tectonic activity; the fold-related fault grew up until they formed closed piggy back basins. In the last stage, no longer turbiditic deposition occurred and the area became a shallow water to continental depositional plane.

Although the described evolution has been recognized as a general trend by most of the Authors, a synthesis of the relationships among each single thrust related-fold throughout the basin is still a matter of debate. Most of the papers infact analyzed just a single sector of the basin whereas few or no works deal with the correlation of each thrust fronts along strike. There are infact unsolved aspect in terms of geometry, displacements and deformation chronology that can be highlighted by taking into account a bigger area of investigation and by the 3D reconstruction. Our 3D model showed that the two main N–S buried tectonic trends (named Nereto–Bellante Trend and Villadegna–Costiera Trend) are characterized by deeper ramps in the carbonate sequence, long flats developed at their top, and shallower ramps and related anticlines involving the Plio–Pleistocene siliciclastic sequences. These trends are not cylindrical along strike and show different displacement distribution and chronology of deformation from north to south. The Nereto–Bellante Trend reaches the maximum offset and structural elevation in the northern sector, whereas the Villadegna–Costiera Trend progressively becomes the main structure moving to south; in addition, this latter has a very small displacement to the North, in contrast with the former that shows maximum displacement in the same sector. The thrusts activity results diachronic along strike and younger toward the north.

The reconstructed 3D model allowed to better define several features (displacement, chronology, plunging of the main trends) of the structural setting of the Periadriatic basin, hard to detect and visualize only with 2D seismic dataset. Moreover, the 3D approach improves our understanding of geological structures from the integration of multi-source data.

2. Geological setting

The Apennines are an E–NE verging fold-and-thrust belt developed since Late Oligocene and connected to the westward subduction of the continental Adria plate underneath the European plate (Malinverno and Ryan, 1986; Ricci Lucchi, 1986; Doglioni, 1991). Thrusts and related folds affected the Mesozoic–Tertiary carbonate sequence of the Adria continental margin; the over thrusting and uplifting of the Apennines was accompanied by