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Tectonic and climatic inferences from the terrace staircase in the Meduna valley, eastern Southern Alps, NE Italy

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ABSTRACT

Results of stratigraphic and morphotectonic analyses on fluvial terraces at the outlet of the Meduna valley in the eastern Southern Alps are used to investigate on the tectonics and paleoclimate. The Meduna valley, prone to destructive earthquakes, belongs to the front of the eastern Southern Alps, a south-verging fold and thrust belt in evolution from the Middle Miocene to the present, constructed by ENE–WSW striking, SSE-verging medium to low-angle thrusts, gradually propagating in the Venetian–Friulian plain. In the study area, located south of the Periadriatic thrust, the main structural element is the ENE–WSW striking Maniago–M. Jouf thrust system. Seven depositional units, ranging in age from Pliocene to Holocene, and a hierarchy of four numbered terrace complexes were identified. Stratigraphic and geometric relationships between sedimentary units, basal surfaces and terraces allow the reconstruction of the chronology of the depositional events. The study shows that the valley configuration has been shaped during the Pliocene–Quaternary with long-lasting steady intervals, interspaced with periodic tectonic pulses of the thrust front of the eastern Southern Alps. The most recent pulse related to the Maniago thrust shows an upper Pleistocene–Holocene slip rate of about 0.6 mm/yr.

Introduction

The preservation of flights of river terraces in a valley is considered to be an indicator of ongoing geomorphological modifications driven by tectonics (e.g., Holbrook and Schumm, 1999; Burbank and Anderson, 2001; Bull, 2007; Caputo et al., 2008; Harkins and Kirby, 2008; Wegmann and Pazzaglia, 2009; Ponza et al., 2010) and/or climate (e.g., Antoine et al., 2007; Bridgland and Westaway, 2008). However, valley terraces typically display irregular distributions, both in longitudinal and cross sections, while the associated sedimentary stacks are often discontinuous. For these reasons, their correlation in tectonically active areas requires detailed analyses for assessing their meaning as a record of thrust deformation, and not the result of epeirogenic uplift driven by climate (e.g., Westaway et al., 2002; Antoine et al., 2007; Westaway et al., 2009; Westaway and Bridgland, 2014), as estimated for the central–western Alps (e.g., Champagnac et al., 2009; Scardia et al., 2012; Sternai et al., 2012). In this perspective, a preliminary distinction is due between “strath terraces” and “fill terraces” (sensu Bull, 1991, 2007), where the former are characterized by thin deposits (<3 m) above an erosion surface cut into the bedrock and the latter are characterized by thicker preserved deposits. This subdivision is a key aspect for discussing the genesis of the terrace staircase in areas affected by tectonic deformation (e.g., Wegmann and Pazzaglia, 2009), also taking into consideration that a setting dominated by carbonate bedrock is normally suitable for the preservation of fill terraces.

Along the fringe of the eastern Southern Alps, the presence of river terraces at the valley outlets, in correspondence with active thrusts, is common (Venzo, 1977; Benedetti et al., 2000; Mozzi, 2005; Monegato et al., 2010a). But, if the lowermost terraces can be easily correlated to the megafan evolution during the late Pleistocene glaciation and interpreted as the spread of outwash systems and their subsequent incision (at ca. 19–26.5 cal ka BP; Fontana et al., 2014a), the occurrence of ancient surfaces, whose topography clearly rules out a late Pleistocene age, has been long debated.

The present study is based on detailed field surveys and describes for the first time the terraced succession at the lower reach of the Meduna valley (Carnic Prealps, NE Italy) and the related sedimentary units, in order to unravel: 1) the relationships with the evolution of the Meduna alluvial fan (Avigliano et al., 2002) since the onset of the Last Glacial Maximum (LGM); 2) the role of the tectonic activity in the shape of terrace flights along the most active seismic area of the Alps (Galadini et al., 2005); and 3) the fault activity affecting the younger Quaternary units.

Geological setting

The study area belongs to the Southern Alps, a major structural subdivision of the Alpine Chain limited to the north by the Periadriatic

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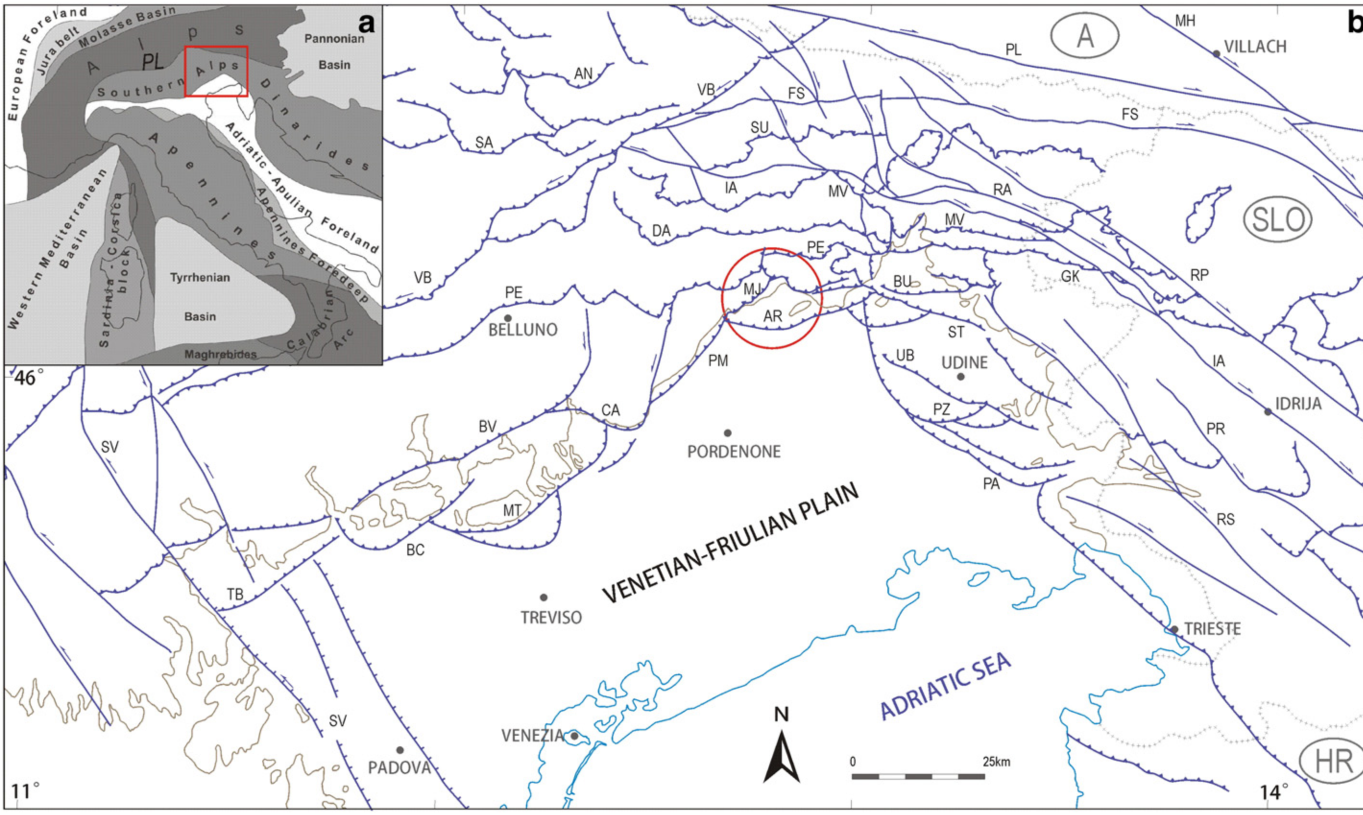

Figure 1. a) The Italian geodynamic framework within the Europe–Africa convergent system (modified from Bigi et al., 1990). Red square shows the eastern Southern Alps; PL: Periadriatic Lineament. b) Structural map of the eastern Southern Alps (modified from Zanferrari et al., 2013). Red circle indicates the investigated area. Main thrust and strike slip faults: AN: Ansiei thrust; AR: Arba–Ragogna thrust; BC: Bassano–Cornuda thrust; BU: Buia thrust; BV: Bassano–Valdobbiadene thrust; CA: Cansiglio thrust; DA: Dof–Auda thrust; FS: Fella–Sava fault; GK: Gemona–Kobarid thrust; MH: Mölltal–Hochsthul fault; IA: Idrija–Ampezzo line; MJ: Maniago–M. Jouf thrust; MT: Montello thrust; MV: Musi–Verzegnis thrust; PA: Palmanova thrust; PE: Periadriatic thrust; PL: Periadriatic Lineament; PM: Polcenigo–Maniago thrust; PR: Predjama fault; PZ: Pozzuolo thrust; RP: Ravne–Paularo fault; RS: Raša fault; SA: Antelao thrust; ST: Susans–Tricesimo thrust; SU: Sauris thrust; SV: Schio–Vicenza line; TB: Thiene–Bassano thrust; UB: Udine–Buttrio thrust; VB: Valsugana–Val Bordaglia thrust system.

Lineament (Fig. 1a). The south-verging fold-and-thrust belt was generated during the complex collision and indentation of the Adria promontory underneath the Alpine chain (Castellarin et al., 2006 and references therein). The development of the eastern portion of the Southern Alps (i.e. the eastern Southern Alps: ESA) occurred during the Neogene–Quaternary time as a result of some major tectonic events (Doglioni and Bosellini, 1987; Doglioni, 1992; Castellarin and Cantelli, 2000; Castellarin et al., 2006). At present, Adria moves northward about 2–3 mm/yr (D'Agostino et al., 2005; Bechtold et al., 2009) and its indentation is accommodated by the activity of the ENE–WSW striking, S-verging thrusts of the ESA frontal chain and by the strike–slip movement of its tectonic boundaries located in the East (Schio–Vicenza strike–slip fault) and in the West (Idrija strike–slip fault system) respectively (Fig. 1b).

The Meduna valley is developed within the Carnic Prealps (Fig. 2, inset), which belong to the outer range of the ESA. The geological setting of this part of the ESA has been strongly influenced by the relationships between the Mesozoic paleogeographic units (basins and carbonate platforms) and by the complex tectonic evolution of the area. Three deformational events were recognized in the Carnic Prealps (Zanferrari et al., 2008a and references therein): the Mesozoic extensional event with the formation of a set of ~N–S extensional faults, and two Cenozoic compressive events. The first, Paleogene in age, was linked to the westward propagation of the External Dinarides chain-front, and the second, Neogene in age, characterized the southward propagation of the ESA thrusts (Zanferrari et al., 2008a).

The Periadriatic thrust (PE in Fig. 1b), is the main structural element of the area. It separates the Carnic Prealps in two sectors: the northern that extends as far as the Tagliamento valley, and the southern, which strikes on the Friulian piedmont plain. North of the Periadriatic thrust, carbonate rocks prevail; here the Upper Triassic carbonate Platform (Dolomia Principale Fm. with its Monticello lower member; Zanferrari et al., 2013) and the Dolomia di Forni Fm. (Carulli et al., 1997) extensively crop out, as well as the lower Jurassic carbonate platform (Calcari Grigi Fm.) and the Jurassic–lower Cretaceous basin formations. In contrast, south of the Periadriatic thrust (Fig. 2) the stratigraphic succession starts with the Upper Jurassic–Upper Cretaceous Friulian Carbonate Platform (Cellina Limestone and M. Cavallo Limestone), drowned during the Paleogene and buried by the Scaglia Rossa Friulana emipelagic unit and by the thick turbiditic sequence of the Clauzetto Flysch (Lower Eocene). Starting from the Aquitanian, the Cretaceous and Paleogene formations were unconformably covered by the sedimentary Miocene clastic wedge of the ESA (Stefani, 1982; Massari et al., 1986; Zanferrari et al., 2008a and references therein); this relationship has been clearly pinpointed in the Carnic Prealps (Cavallin and Pirini Radrizzani, 1980; Ponton, 1989; Grandesso and Stefani, 1998). The Miocene clastic wedge shows its maximum thickness (about 3000 m) in the Carnic piedmont area, becoming thinner toward the present coastline (Fantoni et al., 2002). This is classically subdivided into two portions: a) the lower one, i.e. the "Cavanella group" (sensu ENI-AGIP) Aquitanian to Langhian, formed by a succession of prevailing sandstones and marls sealed at the top by a thick calcarenite unit (M. Baldo Fm.); and b) the upper portion (Serravallian to Lower Messinian) formed by marls (Tarzo Marl), sandstones (Vittorio Veneto Sandstone) and predominant conglomerates (Montello Conglomerate).

South of the Periadriatic thrust, the dextral transpressive Mt. Ciaurlec thrust (Fig. 2), probably linked to the inherited Paleogene (Dinaric) tectonic setting, lets the Neogene south-verging thrusting of the Carbonate platform on the terrigenous Cenozoic units.