A NEW SEISMOTECTONIC MODEL FOR THE FRIULI AREA

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Structural framework and seismicity. The Friuli region belongs to the NE edge of the Adria microplate that includes the thrust-belt of the eastern Southern Alps (ESA) with its foreland basin (i.e. the Veneto-Friuli Plain) at present sheared with the Northern Apennines, and the right lateral strike slip system of the western Slovenia (Fig. 1).

Starting from the Mesozoic, the Friuli upper crust have been subjected to multiple tectonic phases, leading to the development of structures with variable orientations and kinematic histories and therefore variable potential for reactivation under the present stress conditions. The region is therefore affected by a complex fault-pattern, made up by the S-verging, about E–W trending imbricated thrusts of the Middle Miocene to Present eastern Southern Alps (that deformed and

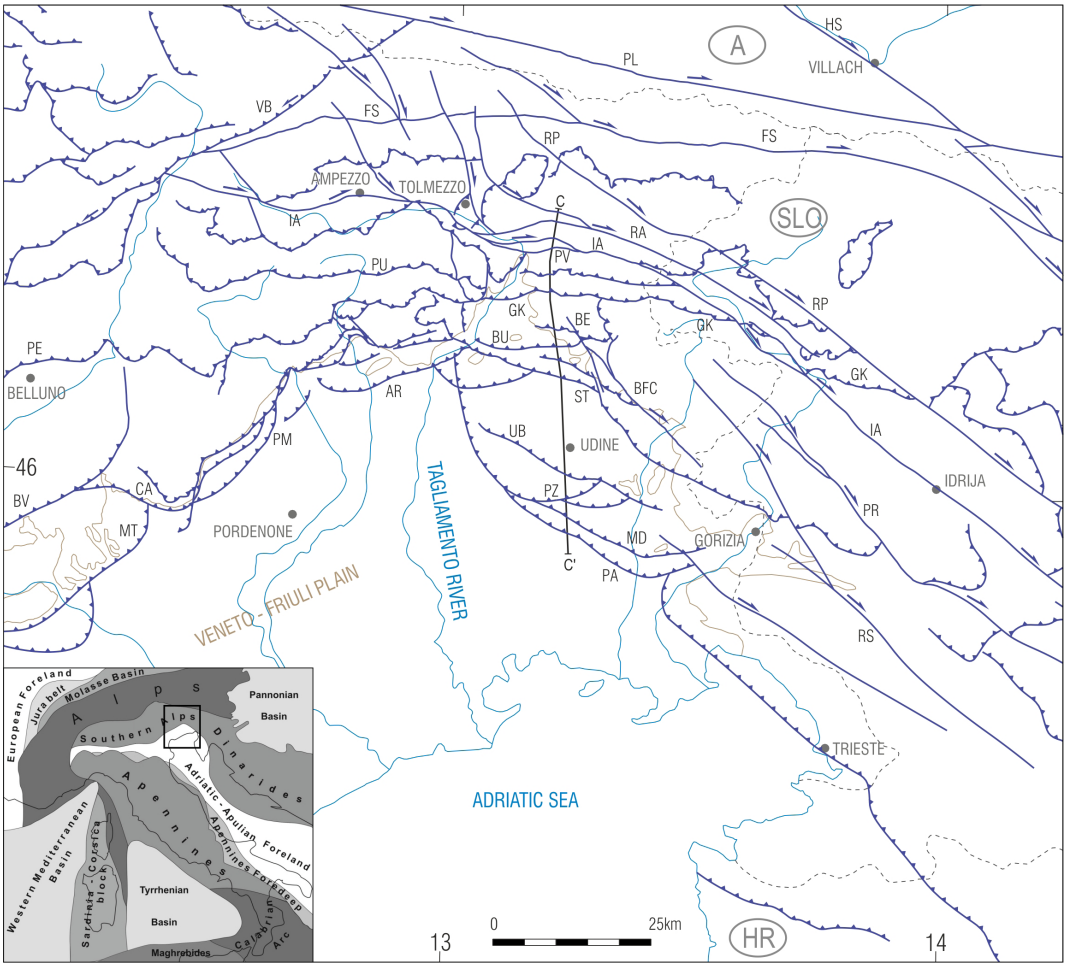

Fig. 1 - Tectonic sketch of the eastern Southern Alps in NE-Italy and W-Slovenia. CC' trace of geological cross section of Fig. 2. Legend: AR: Arba-Ragogna thrust; BE: Bernadia th.; BU: Buia th.; BV: Bassano–Valdobbiadene th.; BFC: Borgo Faris–Cividale fault.; CA: Cansiglio th.; FS: Fella–Sava fault; GK: Gemona–Kobarid th.; HS: Hochstuhl fault; IA: Idrija–Ampezzo fault; MD: Medea th.; MT: Montello th.; PA: Palmanova th.; PE: Periadriatic th.; PL: Periadriatic Lineament; PM: Polcenigo-Montereale th.; PR: Predijama fault; PV: Pioverno fault; PZ: Pozzuolo th.; RA: Resiutta-Ponte Avons fault; RP: Raune–Paularo fault; RS: Raša fault; ST: Susans-Tricesimo th.; UB: Udine–Buttrio th.; VB: Valsugana-Val Bordaglia th.

partially re-used the inherited NW–SE trending thrusts of the Paleogene External Dinarides), and by the active right lateral strike slip systems of the western Slovenia and eastern Friuli.

At present GPS data show 2-3 mm/yr. northward movement of Adria relative to Eurasia. This is absorbed by WSW-ENE trending, SSE-verging thrust front of the eastern Southern Alps and by NW-SE trending, right-lateral strike-slip fault systems in western Slovenia (Vrabec e Fodor, 2006). The external sector of the ESA in Veneto and Friuli is still in evolution, as confirm both historical and instrumental seismicity (Rovida *et al*., 2016) and the widespread deformations of the Upper Pleistocene-Holocene deposits cropping out in the piedmont plain (Galadini *et al*., 2005; Poli *et al*., 2009, 2015; Monegato and Poli, 2015).

The Friuli and the western Slovenia are two of the most seismically active areas in the western Mediterranean region (Tab. 1). The seismicity in the eastern Southern Alps shows that both the south-verging Southalpine thrusts and the NW–SE trending Dinaric strike-slip faults are active within the same stress field, but fault plane solutions for western Slovenia typically show dextral strike slip kinematics on steep NE-dipping fault planes (Poljak *et al*., 2000) while the eastern southern Alps generally show NNW-dipping reverse faults planes, with local strike slip component (Bressan and Bragato, 2009).

Tab. 1 - Historical and instrumental major seismic events in the Friuli and western Slovenia (Rovida *et al*., 2016).

Y/M/D	I_o	M_w	Epicentre area
1348/01/25	9	6.63	Julian Alps
1511/03/26	9	6.32	Friuli-Slovenia
1794/06/07	8-9	5.96	Carnic Alps
1873/06/29	9-10	6.32	Alpago-Cansiglio
1928/03/27	9	6.02	Verzegnis
1936/10/18	9	6.06	Alpago
1976/05/06	9-10	6.45	Friuli
1976/09/15	8-9	5.95	Friuli

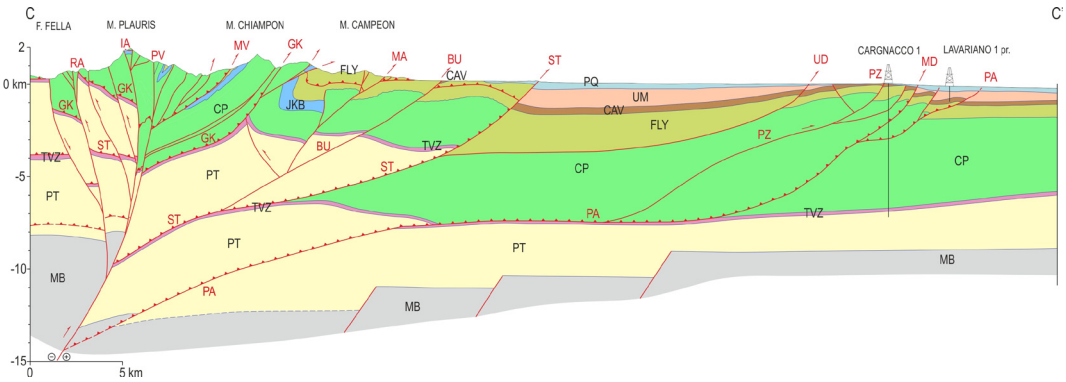

Fig. 2 - N-S regional geological cross-section across the ESA thrust belt and its foreland in Friuli. The section highlights the relationships between the active S-verging thrusts of the ESA and the Idrija-Ampezzo dextral strike slip system. W-verging Dinaric thrust: capped lines. Modified from Zanferrari et al. (2013). For location see Fig. 1. Legend: MB) Magnetic basement (Cati *et al*., 1987); PT) undifferentiated Permo-Triassic succession; TVZ) Upper Carnian mostly terrigenous-evaporitic succession; CP) undifferentiated Upper Triassic - Upper Cretaceous/Paleocene carbonate platforms; JKB) Jurassic-Cretaceous basin successions; FLY) Upper Cretaceous-Lower Eocene turbiditic succession; CAV) Lower-Middle Miocene Cavanella Group; UM) Middle-Upper Miocene Molassa succession; PQ) Pliocene-Quaternary succession. Legend: BU: Buia th.; GK: Gemona-Kobarid th.; IA: Idrija-Ampezzo fault; MA: Magnano th.; MD: Medea th.; MV: Musi – Verzegnis th.; PA: Palmanova thrust; PV: Pioverno fault; PZ: Pozzuolo th.; RA: Resiutta –Ponte Avons fault; ST: Susans-Tricesimo th.; UD: Udine-Buttrio th.

The upper crust in Friuli: a new seismotectonic model. Matching interpretation of seismic profiles of the Friuli prealpine area and the outward data carried out by means the new detailed geological survey (CARG – FVG project: 066 – Udine and 049-Gemona del Friuli sheets: Zanferrari *et al*., 2008a, 2013), we propose and discuss a new geological section crossing the upper crust of the eastern Southern Alps from the Fella valley to the piedmont plain south of Udine (Fig. 2).

We can underline two main features:

1. the Paleogene External Dinarides thrust-belt represents a pervasive framework inside the eastern Southalpine chain in Friuli. On the bases of the geological and structural surveys we propose that the upper crust in Friuli is arranged in a stack of Paleogene tectonic units (among which the Gemona-Kobarid, the Susans-Tricesimo, and the Palmanova one, progressively incorporated and merged in the eastern Southalpine chain by means the polyphase Neogene-Quaternary compressive tectonics. The Paleogene Dinaric thrusts frequently show evidence of S-verging Neogene-Quaternary reactivation;
2. the identification of a wide, steeply N-dipping, right lateral strike slip fault-system along the Resia and Tagliamento valleys. It deals with a broad and anastomosed right lateral N 110°-115° strike slip fault system, coupled with synthetic (N135° striking) and antithetic (N30° striking) faults, NW- or SE- verging reverse faults, en echelon fold systems, strike slip duplexes, contractional and releasing bends, positive or negative flower structures (Zanferrari *et al*., 2013). This strike slip system is the prosecution in the Friuli region of the Idrija system in the W-Slovenia and therefore it was named Idrjia-Ampezzo strike-slip system (IA in Figs. 1 and 2).

Neotectonic activity of the Idrija-Ampezzo strike slip system is demonstrated by:

1) widespread deformation of Pliocene - Middle Pleistocene continental successions (Monegato and Stefani, 2011);
2) medium to high historical and instrumental seismicity that hit the Tolmezzo area (see for example the Verzegnis earthquake (1928/3/26; Mw: 6.0) that shows strike-slip FPS congruent with the average striking of the Idrija-Ampezzo strike slip system;
3) the coseismic deformations recorded by the topographic high precision survey performed after the M=6.45 and M=5.95, 1976 Friuli earthquakes (Talamo *et al*., 1978) , which now may be linked to the present activity of the Idrija fault system in the Tolmezzo-Venzone area.

Discussion. On the bases of the discussed data, we propose a relationship between the set of low angle SSW-verging thrust of the Julian Prealps (i.e. Gemona-Kobarid, Susans-Tricesimo and Buia thrusts) and the Idrija-Ampezzo strike-slip fault system.

On the bases of the evidence of active deformation along the Idrjia-Ampezzo strike slip fault and the available knowledge on the kinematics of the region, we suggest that the transpressive slip is probably splits between the Idrjia-Ampezzo strike slip fault-system and the compressive thrust-belt developing along the Julian prealpine area (Fig. 1). Slip partitioning on splays of oblique structures has been observed in many cases from across the world, both as for the coseismic and long-term displacements (e.g., Bemis *et al*., 2015; Henyey *et al*., 1999; Walker *et al*., 2003). This new seismotectonic model may have crucial consequences for the assessment of the seismic hazard in Friuli.

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