Linking surface kinematics to deep structure of the Adriatic indenter near a potential switch in subduction polarity – the Giudicarie Belt (Southern Alps)

PIs: Mark R. Handy[1], Christian Haberland[2], Eline Le Breton[1]
Postdoc: Emanuel Kästle[1]
PhDs: Azam Jozi Najafabadi[2], Vincent Verwater[1]
Close collaboration: Vincenzo Picotti[3]

1 – FU-Berlin; 2 - GFZ-Potsdam; 3 - ETH-Zürich

Goals: This is a seismotectonic study of the eastern Southern Alps, including the Giudicarie Belt (GB), a transverse zone that subdivides the Alps into an eastern part marked by orogen-parallel extrusion of orogenic crust and a western part with well-developed pro-and retro-wedges (**Fig. 1**).

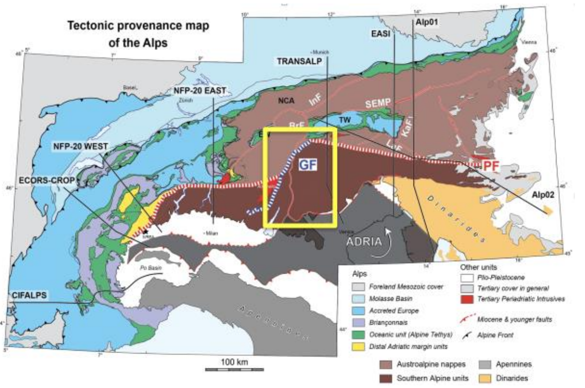

***Figure 1**: Tectonic map of the Alps with target area (yellow box) containing Giudicarie Belt (GB)*

Our project tests the idea that Miocene kinematics at the leading edge of the Adriatic indenter is related to a proposed switch in subduction polarity along the Alpine chain as imaged in body-wave tomography, from a SE-dipping slab anomaly in the west to a subvertical to north-dipping anomaly in the east.

The object is to trace both active and inactive faults associated with the GB down to lithological, structural and seismological discontinuities in the crust and upper mantle. Prime targets include (1) a potential lithospheric tear in the vicinity of the GB, (2) a purported crustal wedge in the Tauern Window area, and (3) thrusts extending from the GB and the eastern Southern Alps into the Veneto-Friuli foreland basin. To map the 3D geometry of faults, we're combining surface structural data (**Fig. 2**) with seismological data from Swath D and the AlpArray station network (**Figs. 3, 4**) to pinpoint low-magnitude events and to delineate offsets of rock-physical domains (Vp, Vp/Vs, Qp, Qs) by using local earthquake tomography. This is complimented by structural and kinematic (fault-slip) analyses of thrusts and folds along profiles crossing key parts of the GB and adjacent units of the Southern and Eastern Alps (**Fig. 5**). The results are being integrated with data along the TRANSALP section as well as with existing thermo-chronological data at the surface.

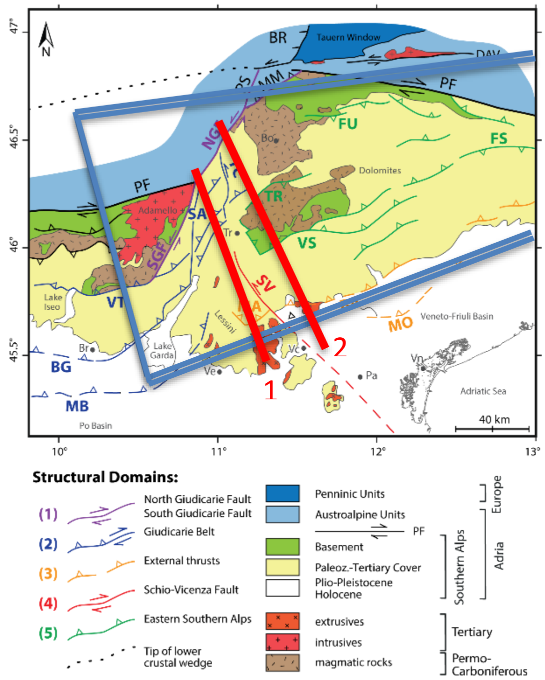

***Figure 2**: Tectonic map of the Giudicarie Belt and 5 structural domains in the Southern Alps; Blue lines – outline dense seismic station network (Swath D) used in this study. Red lines – cross sections in Fig. 5.*

Two PhDs in this project are working in the Giudicarie, Veneto and Friuli areas: (1) Azam Jozi Najafabadi (GFZ-Potsdam) is processing data from Swath-D and the AlpArray network to create crustal models extending down to the base of the crust-mantle boundary and possibly upper Moho; (2) Vincent Verwater (FU-Berlin) is gathering fault-slip data and constructing and balancing tectonic cross-sections across the GB, the Southern Alps and the Periadriatic Fault. Their work is closely linked with the aim of generating a series of 3-D reconstructions of crustal and mantle structures reaching back in time.

Results: Monitoring of seismicity between September 2017 and December 2018 (16 months) shows a diffuse distribution of earthquakes (1 ≤ M_L ≤ 4.2) in the target area; they reach a maximum depth of 35 km, but occur mainly within the upper 20 km with distinct clusters in the Trento-Garda and Friuli regions (**Fig. 3**). These indicate active faults in the basement that are potentially traceable to thrust-and-fold belts at the surface.

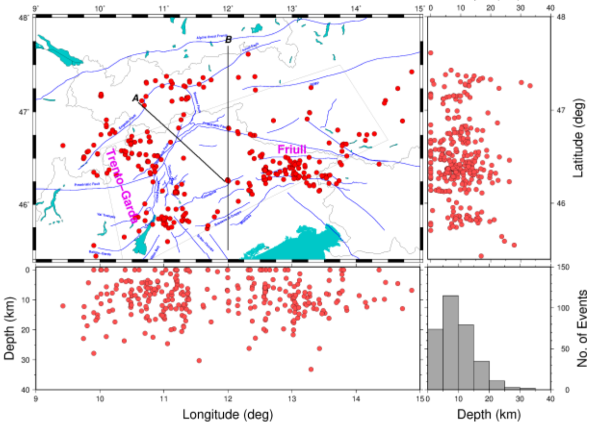

***Figure 3**: Seismicity in the Central, Eastern and Southern Alps recorded by the AlpArray and Swath-D stations.*

The scattered seismicity with high-precision locations (achieved by using the dense stations of Swath-D and AlpArray networks) allows the use of local earthquake tomography to image the Moho and crustal structures with high resolution.

The results of the preliminary 3-D P-wave velocity model based on 320 newly recorded events (11,680 P-picks and 4,225 S-picks) is shown along two cross-sections in **Fig. 4**.

Relevance: There is no obvious offset of the Moho across the Giudicarie Belt evident in the P-wave anomaly section (**Fig. 4a**). Along the TRANSALP section (**Fig. 4b**) the European Moho extends beneath the Adriatic Moho, as already proposed by Kummerow et al. 2004. These preliminary results suggest that the Giudicarie Fault accommodated intra-crustal fragmentation and is not the site of a polarity switch in Neogene subduction. This switch probably occurred further to the east, raising the question of where and how the slab beneath the Eastern Alps is linked to crustal faults in the Southern Alps. Tests with synthetic data will be used to investigate the resolution of the models and the interpreted features.

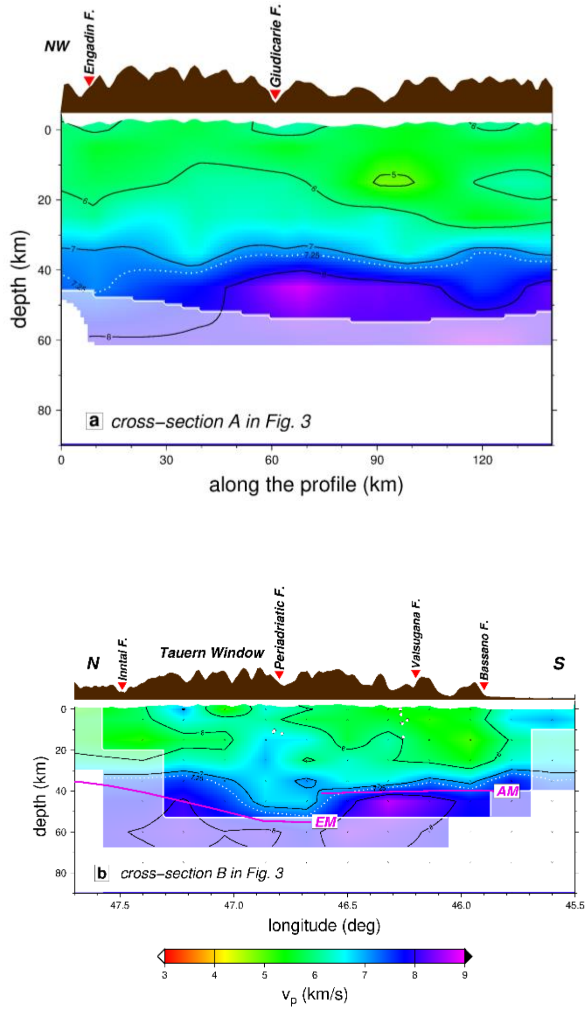

***Figure 4**: Preliminary 3-D P-wave velocity model **(a)** across the Giudicarie Fault and **(b)** along TRANSALP profile at longitude 12°. The pink lines are the European and Adriatic Mohos from Kummerow et al. 2004. The white dashed line is the V_P = 7.25 km s^{-1} contour defined as the "tomography" Moho in Diehl et al. 2009.*

Structural geological work indicates that two Neogene thrust-and-fold belts partition N-S convergence in the eastern part of the Southern Alps (coloured faults in **Fig. 2**): (1) the Giudicarie Belt including the northern and southern Giudicarie Faults (NGF, SGF); and (2) the Valsugana-Montello Belt (VS, MO). The latter is still active along its southern front.

Shortening along the Valsugana-Montello Belt is segmented and generally increases from SW to NE along its southern front (MO, **Fig. 2**). The Schio-Vicenza Fault (SV, **Fig. 2**) accommodated some of this differential shortening as sinistral strike-slip, but also involved later oblique-normal motion.

The geological profiles (**Fig. 5**) provide an initial basis for 3D tectonic balancing. This will be crucial for tracing the faults down to the 20 km depth of most seismicity in the area. The shortening patterns and rates calculated from them will be compared with the Adria-Europe convergence rate through time. This will reveal how faulting has evolved in response to Neogene plate kinematics, i.e., whether it has remained the same through time, or has changed in response to the counterclockwise rotation and possible N-directed subduction of the Adriatic Plate.

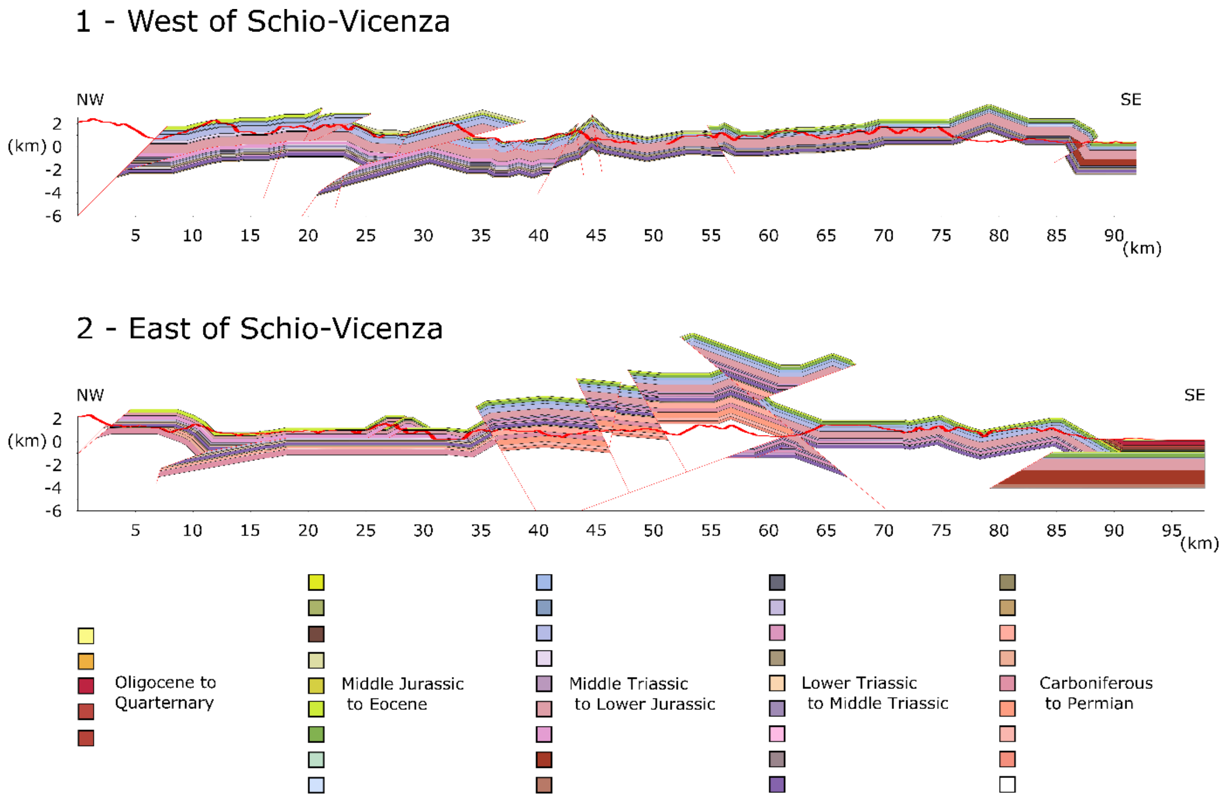

***Figure 5**: 3D-view of profiles 1 and 2 that extend from the Northern Giudicarie Fault to the Southern Alpine front (see **Fig. 2** for section traces).*

<u>Publications</u>:

Jozi-Najafabadi, A., Haberland, C., Weber, M., 2019. Local seismicity pattern and 1-D velocity model in the Southern and Eastern Alps using the temporary SWATH-D network data, Geophysical Research Abstracts Vol. 21, EGU2019-15536, EGU General Assembly (Vienna, Austria 2019).

Jozi-Najafabadi, A., Haberland, C., Verwater, V., Handy, M., Le Breton, E., Michael M., 2019. Crustal Structure of the Southern and Eastern Alps using the Temporary SWATH-D Seismic Network, 27th IUGG General Assembly (Montreal, Canada 2019).

Verwater, V.F., Handy, M.R., Le Breton, E., Picotti, V., Jozi Najafabadi, A., Haberland, C. (2019): Structures and kinematics of Neogene deformation from the Southern Alpine orogenic front to the Northern Giudicarie Belt (eastern Southern Alps, Northern Italy). pp. xx in *Abstract Vol., EGU Series – Emile Argand Conferences*, 14th Workshop on Alpine Geological Studies, September 4-6th, 2019, Sion, Switzerland

Verwater, V., Handy, M.R., Le Breton, E., Picotti, V. (2019): Fault kinematics along the front of the Eastern Southern Alps. *Geophysical Research Abstracts, Vol. 21, EGU2019-15871*, EGU General Assembly 2019