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Unraveling polyphase brittle tectonics through fault-slip analysis in the Voltri Massif, Western Alps (Italy)

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We investigated a system of faults in the northwestern Voltri Massif (Ligurian Alps, northern Italy) usually mapped as a km-scale fault, but actually made up of different fault segments. The Ligurian Alps represent the evolving linkage area between the Western Alps and Northern Apennines: here the two orogenic systems interfered since Oligocene times.
Our aim is to characterise kinematics and evolution of this fault system, coupling structural analysis with photointerpretation and paleo-stress/strain determinations, through inversion of fault-slip data.
The high-pressure Voltri Massif belongs to the Internal Pennine Units of the Alps; it is composed mainly of metaophiolites and slices of subcontinental lithospheric mantle. The bedrock is overlain by upper Eocene-lower Oligocene clastic sediments of the Tertiary Piemontese Basin.
The late-orogenic structural evolution (i.e. since Oligocene) of the area is complex, with superposition of several tectonic events, in the framework of the Adria-Europe convergence and the opening of the Liguro-Provençal basin (with associated rotation of the Corsica-Sardinia block).
On the basis of both fieldwork and photointerpretation, we selected 13 structural stations divided into two groups (north-eastern and western): we have measured more than 500 faults in the field and identified more than 400 lineaments from photointerpretation. Both low-angle thrust faults and high-angle (dominantly strike-slip) faults occur. In the NE sector high-angle faults show a clear NE-SW maximum in strike, whereas in the western sector main sets are WNW-ESE and ENE-WSW striking.
Among the collected faults, more than 100 are complete fault-slip data to be analysed by inversion techniques with two different open-source programs (F.s.a. by B. Célérier, 1999 and Tensor by D. Delvaux, 2011).
We detected several incompatible stress/strain fields in each structural station, thus implying that the fault population was heterogeneous. On the basis of crosscutting relationships we reconstructed the following sequence of stress/strain tensors:
T1: strike-slip, with NNW-SSE to NW-SE striking $\sigma 1$/Z axis;
T2: strike-slip (locally oblique), with E-W to NE-SW striking $\sigma 1$/Z axis;
T3: extensional/transtensional, with NW-SE or NE-SW striking $\sigma 3$/X axis in the different fault segments.
As all faults with a complete fault-slip datum have been measured in bedrock lithologies, no age constraints are available. We therefore used the results of the paleostress investigations, the orientation and kinematics of the faults and the studies in adjacent areas with dated structures to unravel the sequence of events.
The T1 tensor fits the orientation of structures described by Maino et al. (Tectonics, 32, 1–27, 2013) related to a Rupelian-lower Chattian tectonic event: it is possibly linked to the far-field incipient rifting in the future Liguro-Provençal basin.
The $\sigma 1$/Z axis of T2 tensor fits the NE-SW shortening of Oligo-Miocene thrusts well-known in this area: the studied faults thus may belong to a left-hand strike-slip zone that accomodated the oblique component of deformation during the rotation of Corsica-Sardinia block. Late-stage extension/transtension (T3) can be referred to a Pliocene or neotectonic stage of activity of these faults.
Therefore this fault system had a prolonged activity in different tectonic settings, linked to changing geodynamic constraints.